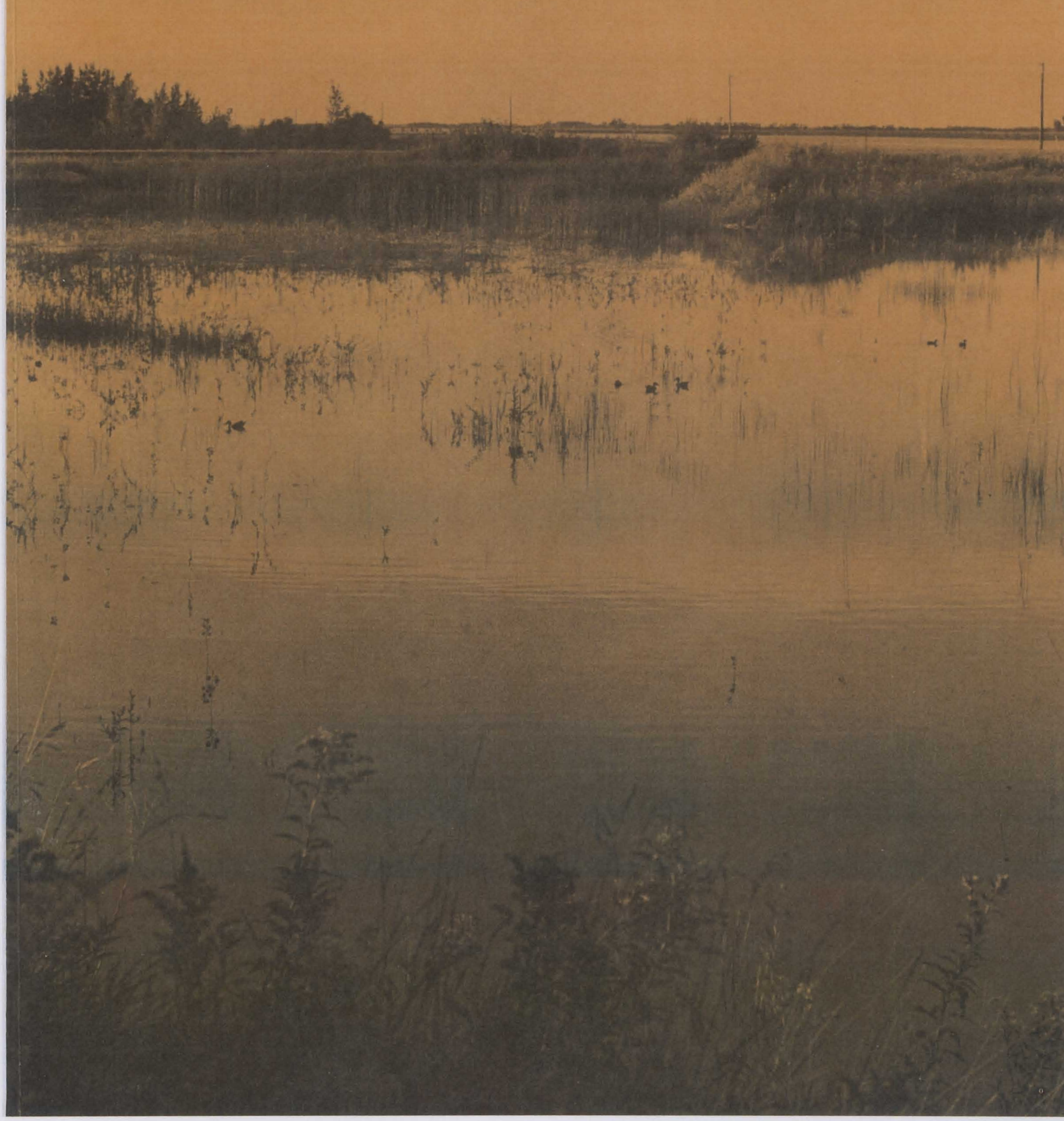
Miscellaneous Publication 17—1982
Agricultural Experiment Station
University of Minnesota

Wildlife Values of Gravel Pits



Wildlife Values of Gravel Pits

Symposium Proceedings

June 24-26, 1982
University of Minnesota
Crookston, Minnesota

Editors:
W. Daniel Svedarsky and
Richard D. Crawford

Miscellaneous Publication 17 - 1982
Agricultural Experiment Station
University of Minnesota
St. Paul, Minnesota 55108

Available for $10.00 prepaid from:
Northwest Agricultural Experiment Station
University of Minnesota
Crookston, Minnesota 56716

Acknowledgments

The development and carrying out of this symposium was a joint effort of several people and organizations. A key individual was Bernie Youngquist, Superintendent of the Northwest Agricultural Experiment Station, who, in 1971, helped establish a wildlife management demonstration area in an abandoned gravel pit as a Station project and was a constant source of encouragement to me during the one and one-half years of symposium planning. Also key was Gus Swanson, who, when asked about the concept of such a meeting, not only responded affirmatively, but charted out an action plan and later identified five speakers. A major portion of the symposium planning was carried out during a single quarter leave made possible by the University of Minnesota Technical College and, in particular, Agriculture Division Chairman, Gary McVey and Natural Resources Head, Philip Buckley. All members of the planning committee provided assistance with logistical challenges, fund-raising ideas, program organization and, in some cases, presented papers as well. The planning committee was made up of: Rich Crawford, Morris Eng, Carrol Henderson, Doug Keran, John Mathisen, Larry Pollard, Gus Swanson, Ralph Town, Milt Weller, Terry Wolfe and Bernie Youngquist. Dan Leedy, while not an."official" member of the planning committee, assisted greatly in identifying fund raising possibilities, ways of getting the word out to participants, and generally helping to keep the enthusiasm up. Gus Swanson, Rich Crawford and Carrol Henderson also served as session chairmen.

The symposium was held at the Crookston Campus of the University of Minnesota with the Technical College providing meeting facilities. Provost Stanley Sahlstrom welcomed symposium participants to the campus and the excellent dining and lodging facilities coordinated by Keith Ramberg and Gary Willhite, respectively, made for a pleasant three days.

A special thanks to my assistant, Tom Feiro, and two student interns, Wendy Hogan and Kevin Walz. They were indispensible in attending to a multitude of details that go into making a symposium run smoothly. Some of these included: coordinating airport transportation, providing general information and assistance to attendees, seeing that refreshments arrived on time at breaks, and manning visual aid equipment.

Terry Wolfe organized and led an interesting field tip to view local gravel pit habitats at the start of the symposium. Ray Mair, owner of a large gravel pit, kindly permitted access to his operation and spoke to the tour group about his concerns as a land owner.

Vicki Svedarsky coordinated the spouse's program for the symposium, prepared a delightful post-symposium dinner for attendees with later flight schedules, and displayed her usual tolerance and support for her husband when he gets involved in projects like a symposium.

Station secretaries, Patti Malme, Jan Solheim, Julie Hamre, Yvonne Hanson, and Sady Newell and Sue Dwyer, Agriculture Division secretary,deserve special recognition for coordinating registration details, typing four notebooks of symposium correspondence and assisting with preparation of the proceedings. John Zak and Jeff Sinks of the Technical College and Sam Brungardt with the Agricultural Experiment Station at St. Paul assisted with layout and production aspects of the proceedings.

W. Daniel Svedarsky, Chairman
Symposium Planning Committee

SPONSORING ORGANIZATIONS

University of Minnesota -
Northwest Agr. Exp. Sta., Crookston
Agricultural Experiment Station, St. Paul
Technical College, Crookston

Caterpillar Foundation

Norman Pankratz Conservation Fund

J. L. Shiely Company

American Petroleum Institute

Aggregate Ready-Mix of Minnesota

Agassiz Audubon Society

Minnesota Chapter, The Wildlife Society

Minnesota Department of Natural Resources -
Division of Fish and Wildlife

Minnesota Department of Transportation

Minnesota Chapter, Soil Conservation of America

U. S. Fish and Wildlife Service

Max McGraw Wildlife Foundation

Wildlife Management Institute

Crookston Conservation Club

Preface

Although reclaimed and abandoned gravel pits have served as fish and wildlife habitat in the United States for many years, few studies or publications have focused on the topic. Literature searches would turn up primarily British publications. Such was the state of information when the idea of a symposium took shape in the winter of 1980.

In the face of declining habitats, gravel pits were seen as a developing opportunity and one with significant potentials in view of their extensiveness and proximity to population centers. Demonstration projects and preliminary research studies in such areas have commenced mostly in the last 10 years, but the results generally have not been widely disseminated. This symposium was planned to bring together people and ideas relating in some way to fish and wildlife values, and environmental education uses of gravel and borrow pits. The intent was to involve as many disciplines as possible so as to examine the subject from all points of view.

The Northwest Agricultural Experiment Station of the University of Minnesota agreed to be the lead sponsor with the Agricultural Experiment Station at St. Paul publishing the proceedings and assisting with the initial mailing. Proposals were made for co-sponsorship by other organizations and agencies, and these are listed in the "Acknowledgments" section. Carrol Henderson, president of the Minnesota Chapter of The Wildlife Society, and the Board, accepted the proposal that this meeting serve as the annual Chapter symposium. A Symposium announcement and call for papers was circulated in mid-summer of 1981 and notices were placed in professional journals, newsletters, magazines, and at various conferences relating to wildlife or land reclamation in the Upper Midwest.

Initially, the symposium was to focus on the Upper Midwest, but as the "Table of Contents" indicates, it took on somewhat of a national or, perhaps, international dimension with reports coming from 14 states plus Canada and Great Britain. Registrants totaled 109 and represented a broad diversity of backgrounds including: zoning administrators, planners, foresters, wildlife biologists, gravel company operators, trade organization representatives, landscape architects, highway engineers, and naturalists. A productive atmosphere of sharing ideas towards the common goal of enhancing post-mining environments for fish and wildlife prevailed throughout the symposium.

Most papers were presented orally with poster presentations made of papers for which abstracts were received after the program had become finalized in early January. All papers appear in the proceedings. Authors were provided format guidelines and they prepared camera-ready manuscripts ahead of the symposium date. Gus Swanson and Dan Leedy were then provided advance copies from which they developed their papers. With a few minor alterations, papers appear as they were submitted by the authors, who then assume editorial responsibility. Overall, manuscripts were promptly submitted and conscientiously prepared. To adapt writing styles appropriate to different disciplines to a common format, was somewhat of a challenge, especially since the content of papers varied widely in many cases. We feel, however, that the authors did very well in this regard as well as "keeping it close to the ground" as requested.

Authors were also requested to include a list of references that they felt to be relevant to our topic. These are presented in the "Selected Bibliography" with as much information as we were provided. A few are incomplete, but we felt it better to include incomplete references rather than to omit them considering that this is the first round for this sort of bibliography.

Already, the dialogue that has occurred and is ongoing amongst participants has been productive. Many requests for proceedings have been received from those unable to attend the symposium. Thus, the fact that the symposium was held should contribute to enhanced habitat in areas previously overlooked or not developed to their greatest fish and wildlife potential. The creative approaches to gravel pit environments described in these proceedings have hopefully laid the ground work for the development of refined information where needed, additional end-use alternatives with a fish and wildlife orientation that can be incorporated into reclamation plans, and perhaps an up-dating symposium in the future in a different setting.

W. Daniel Svedarsky, and
Richard D. Crawford, Editors.

Table of Contents

Page

Preface i

Summary of Wildlife Values of Gravel Pits Symposium 1
Gustav A. Swanson

Keynote Address: Gravel Pits as Wildlife Habitat in Great Britain 6
Christopher L. Tydeman

Land Reclamation After Gravel Mining in Great Britain and Possible Applications in the Upper Midwest 13
Bernard E. Youngquist

Regulatory and Land Use Aspects of Sand and Gravel Mining as They Affect Reclamation for Wildlife Habitat and Open Space--A National Perspective 16
Richard A. Morris

Economics of Gravel Pit Reclamation for Wildlife 24
Jay A. Leitch

Industry Perspectives on Gravel Mining and Post-mining Uses 31
Ray Lappegaard

The Nature of Gravel Deposits in Minnesota and Extraction Procedures 34
Morris T. Eng

Manipulating Mining Operations to Create Wildlife Habitats: A Pre-mining Planning Process 41
Anthony M. Bauer

General Design Considerations in Creating Artificial Wetlands for Wildlife 44
Richard D. Crawford and Judith A. Rossiter

Creating Small Islands for Wildlife and Visual Enhancement 48
Robert E. Stoecker

Principles of Revegetating Mined Lands 51
Darrel G. Morrison

Wildlife Considerations in the Development of Riparian Communities 59
Robert E. Szafoni

The Formulation of Lowland Sand and Gravel Excavation Regulations: Wisconsin Administrative Code NR-340 67
Mitchell J. Zmuda

Public Rights to Scenic Resources: Infringement is Sufficient Cause for Denial of Lowland Sand and Gravel Operations in Wisconsin 73
Richard E. Chenoweth, Wayne G. Tlusty, and Bernard J. Niemann

An Overview of Gravel Mining in Missouri and Fish and Wildlife Implications 80
Ronald Crunkilton

Conservation, Recreation, Mining, and Rehabilitation in Story County, Iowa 89
James M. Patchett

Citizen Involvement in Gravel Pit Reclamation: A Case Study 95
Howard R. Alden

Page

A Study for Vegetation and Wildlife Habitat on Lower Grey Cloud Island 102
William D. Sanders, Jon B. Burley and Craig A. Churchward

Sand and Gravel Pit Reclamation in Louisiana: Creating of Wetlands Habitats and its Integration into Adjacent Undisturbed Bayou 109
William Ettinger and Charles Yuill

Wildlife Use of Mineral Extraction Industry Sites in the Coastal Plains of New Jersey 115
Joseph L. Lomax

Eugene's Urban Wildlife Area: Delta Ponds 122
Thomas J. Gallagher

Pits, Ponds and People: Reclamation and Public Use 127
Richard W. Koopman

The Red River Valley Natural History Area: Wildlife Management and Environmental Education in an Abandoned Gravel Pit in Northwest Minnesota 132
W. Daniel Svedarsky

Gravel Pit Reclamation in Ontario: The Crieff Case Study 141
Paul F. J. Eagles

The Effects of Aggregate Extraction on Deer Habitat Preferences in Southern Ontario 148
Harry N. Chabwela and Fredrick F. Gilbert

Wildlife Values and Management of Gravel Pits in Forest Ecosystems 155
John E. Mathisen

Principal Flora and Wildlife Use of a 35-40 Year Old Gravel Pit in North Dakota 159
Kenneth F. Higgins

Duck Use of Gravel Pits Near Ft. Collins, Colorado 162
Goran E. D. Blomberg

The Great Linford Project: Waterfowl Research in a Gravel Pit Wildlife Reserve 170
Michael Street

The Ecology of Dolomite Quarries in South Central Minnesota 181
Henry W. Quade, Dennis M. Kubly, and Dale E. McMichael

The Ecology of Gravel Pit Lakes in Southwestern Ohio 191
Thomas C. Kane, Michael C. Miller, William H. Hoople, Mary Schonhoft, and Kevina Vulinec

Development of Aquatic Habitat Potential of Gravel Pits 196
Edwin E. Herricks

Fishery Management in Colorado's Gravel Pit Lakes 208
Robin F. Knox

The Chain of Lakes Project Along Interstate 80 in Nebraska 211
Harold K. Edwards

Gravel Pits as Fish and Wildlife Habitat at the Max McGraw Wildlife Foundation 215
R. C. Oldenburg, R. A. Montgomery, T. M. Harder, and G. V. Burger

Research Needs and Priorities of Gravel Pits. 221
Daniel L. Leedy

Selected Bibliography 237

List of Attendees 246

Summary of Wildlife Values of Gravel Pits Symposium

GUSTAV A. SWANSON, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

This symposium, the first of its kind as far as we know, has brought together a remarkable variety of information and ideas which should be useful to professionals in several areas. In addition to the obvious audience of fishery and wildlife biologists and managers, the information presented here should be helpful to such disciplines as developers, city and regional planners, engineers, landscape architects, public relations specialists, ecologists, students, educators, land managers, outdoor recreation planners and, of course, those directly involved in the business of mining sand and gravel.

I sincerely hope that the printed proceedings will be available and brought to the attention of workers in these many areas by way of their professional and trade journals and newsletters so that maximum educational impact results.

I have organized my summary into several subject categories beginning with Perspective. I will not cite sources, but they are from papers presented at the symposium.

PERSPECTIVE

Sand and gravel are essential to our economic growth and development. They are so important that their use provides one of the most accurate indices of economic activity that we have. In the U. S. we use an average of 5 tons annually for every man, woman and child in our population.

Every one of our states produces sand and gravel. In a recent 40-year period nearly one million acres in the U. S. was disturbed for sand and gravel mining, and less than a third of these acres were "reclaimed."

Sand and gravel have a low unit cost, estimated in 1980 as averaging about $2.50 per ton. Since transportation costs are high, trucking for 20 to 25 miles doubles the cost. Aggregate is, therefore, usually mined close to the point where it will be used. Most of it is mined near urban centers where construction activity is highest, so the mining activity is highly visible to urban populations. Much gravel mining occurs in rural areas also, as for road construction, so the activity is very widespread. For example, Minnesota, the land of 10,000 lakes, also has 10,000 gravel pits.

Because the aggregate is found primarily along present or past stream beds, its extraction disturbs a riparian habitat, a type which is exceptionally productive of wildlife, and also exceptionally subject to destruction by many of man's activities. An estimated 70% of the riparian habitat once found in the U. S. has already been destroyed.

Sand and gravel mining is a temporary land use. When the aggregate has been mined, the area will be simply abandoned or put to some other use. The abandonment, so usual in earlier days, occurs much less often today because so many states and local governments have reclamation requirements. Our interest at this meeting is that the potential for fish and wildlife, being the "other use," shall be recognized and considered.

Because gravel extraction at any one site usually continues for a number of years, sometimes even 20 to 30 years, and because so much of it occurs near cities, gravel producers are members of the urban communities, and are increasingly aware of the need for good relations with their neighbors. They have become accustomed to regulations of their activities, and recognize the need for regulations, and the value of planning for socially acceptable land uses of the spent gravel pits. One of these desirable uses is production of fish and wildlife.

The account by an industry representative of introducing a thriving population of Canada Geese to an area still being mined was an interesting example, especially when he reported that now it is not uncommon to see a 70-ton Euclid bottom-dump-truck stopped while a mother goose hustles her goslings across the road. Some of you may recall the classic children's book by Robert McCloskey entitled "Make Way For The Ducklings" which came out over 40 years ago and is still in print. Its locale was the Boston Commons with its pond and Mallard population. One of the heros is the Irish policeman who halts traffic while a mother Mallard herds her brood across the busy street. I am expecting an imaginative writer to produce a book entitled, "Make Way For The Goslings" which should be just as interesting as McCloskey's, and which could also contribute to good public relations for the aggregate extraction industry.

HISTORY

For a bit of historical perspective we go to Britain where they have accurate information on the sand and gravel industry as early as the last century. The wildlife values of gravel pits were widely recognized rather suddenly in 1931 when a nationwide census of the rare and spectacular Great Crested Grebe revealed that many of them were using gravel pits. Later that same decade the first nesting record for Britain of the Little Ringed Plover was at a gravel pit. The latest census of these two exceptionally interesting species showed 22% of the Great Crested Grebes and 70% of the Little Ringed Plover inhabiting gravel pits. It is clear that the availability of the gravel pits has contributed substantially to the increase of these two species.

The discoveries of rare birds using gravel pits led to serious studies in Britain of their value for other birds soon after World War II, and also active management of some pits for waterfowl. If you will excuse a personal note, I'd like to mention my first two trips to Great Britain in 1955 and 1960 when I served as a consultant to the Nature Conservancy at the invitation of their Director-General Max Nicholson to review their waterfowl research and management programs. Among the waterfowl habitats I visited on those tours was a series of gravel pits near Larne in Northern Ireland where the Larne Lough Wildfowler's Association had made local reserves, and the two famous pits at Seven Oaks in Kent where Jeffery Harrison pioneered in management for waterbirds. Here is a 1961 quote from Jeffery Harrison: "With the number of new ballast waters steadily increasing, their importance as possible wildlife reserves cannot be overstressed." (Note his use of the term "ballast waters" for what we could call a flooded gravel pit).

Thus, the British experience with gravel pits as wildlife habitat, both managed and unmanaged, is much longer than ours here in the States, so it is fortunate for us that Dr. Tydeman could be here to describe it to us. His description of the sequence of events in Britain is helpful, because we, a few decades later, will be going through the same general sequence and we should be able to learn from their experiences. Unfortunately, I don't know of any of our American endangered species of birds which have selected gravel pits as their favorite habitat.

The four phases which Tydeman recognized in Britain's historical sequence are just as applicable here: First is ignorance of the value of pits to wildlife, then awareness, then conflict, and finally cooperation. We are still largely in the ignorance phase, and we hope that this symposium will help bring us along to the awareness phase so that progress can be accelerated. Some of the case histories described during the past two days show, however, that here and there we have moved on into the cooperation phase leading to gratifying accomplishments.

Conflict, which Tydeman suggests as a third phase, before cooperation, may involve public objections to gravel mining because it creates an eyesore, or because it destroys an environment. The conflict may also be between competing end uses of the areas after mining has ceased.

General historical developments relevant to our topic are the increasing population, increasing urbanization, and increasing interest in non-consumptive recreation involving nature and especially wildlife. These trends will make gravel pits as wildlife habitat increasingly valuable. Many of them, for example are too small, and too close to cities, to be of any value for hunting, but they may be very valuable to bird watchers, hikers, and nature photographers.

LAWS AND REGULATIONS

With the era of environmental awareness and litigation which exploded in the 1960s, a great deal of legislation to protect the environment was passed at federal, state, and local levels. Some of it was aimed at gravel mining in an effort to find a balance between what is economically profitable, and what is socially acceptable or desirable. Many other laws and regulations also affect the gravel miner because of their broad application, like the health and safety and the workmen's compensation requirements of the U. S. Department of Labor.

We confine ourselves here to those laws and regulations which apply specifically to sand and gravel mining. Thirty states have surface mining laws which apply to sand and gravel, and in 13 other states there are county or local laws which apply, so an estimated 80% of the sand and gravel used in the U. S. is extracted under state or local regulations. The surface mining of sand and gravel and that for coal are so very different in the environmental and social problems they involve that it is truly unfortunate that several of the state laws on surface mining do not distinquish between the types. The Council on Environmental Quality, in a 1981 special report on the subject, recognized this and recommended that sand and gravel mining be regulated at the state and local level, not federal.

These would appear to be the characteristics of regulations appropriate for the aggregate mining industry:

1. A permit should be required from either the state or local government, but not both.

2. The application for a permit must include a detailed plan of the area to be mined, the amounts of aggregate to be removed, the period over which the mining will continue, and a proposal for the type of reclamation and the pro-

posed use of the area after termination of the mining, and completion of the reclamation.

3. Approval of the application should automatically require the permittee to implement the plan which was a part of the application, but modifications may be considered as conditions change over the years. The regulations should be flexible enough to accommodate creative proposals. (The rigidity of some current laws which require restoration to the original condition should be avoided!)

There have been cases where a local government has purchased a proposed gravel mining site and leased the mining rights on a royalty basis, a favorable situation where possible because it avoids the adversary relationship which sometimes develops between the applicant and the permit-granting unit.

In brief, regulations are necessary to protect the public interest, and to discourage the irresponsible operator. To this the industry agrees, but the regulations should be as simple as possible, and flexible enough to accommodate local needs and conditions, and the changes which can occur over the very long time that mining may take place at a site.

The State of Wisconsin, which has a tradition of progressive laws relating to natural resources, provides us with some valuable models. Its Supreme Court in 1972 upheld as a public right the enjoyment of scenic beauty from navigable waters, and any water is considered navigable if it will float a canoe during the spring high water period. This ruling, of course, has a bearing upon gravel mining along streams. Permission to mine may be conditional upon minimizing the adverse effects of all kinds, including aesthetics, and expediting rehabilitation to an approved end-use.

One Wisconsin feature which is unique as far as I know, is the Office of Public Intervenor in the State Department of Justice. This was created in 1967 when the State DNR was formed as a resource development agency, as well as the conservation agency it had previously been. The DNR was not in the business of granting development permits and some were concerned that the DNR, as well as other state agencies, might not be responsive enough to the public interest when resource controversies occurred. The Public Intervenor is available to intercede on behalf of interested citizen(s).

States which are looking for model laws for gravel mining could well look at Wisconsin's Administrative Code NR 340, developed in 1979 in the light of concerns of the Public Intervenor.

WILDLIFE USE

So many of the papers we have heard and seen report on the incidence of wildlife in gravel pits that a thorough summary is not possible, at least by me. I'll, therefore, mention only samples, leaving it to the published papers to provide you with details.

Our British contributors, as expected, have particularly good information on wildlife use. We have already mentioned the serendipitous discovery of gravel pit use by the rare Little Ringed Plover and the spectacular Great Crested Grebe. A summary of British studies on birds found in gravel pits, covering a total of 70 site-years, revealed 97 breeding species, nearly half of all the breeding birds in Great Britain. A study of 11 sites in the Thames Valley for 2 years found 65 species of birds nesting, 10 of them at all 11 sites, 17 species at 9 of the 11 sites. This is an impressive proof of the value of gravel pits as wildlife habitat, and of their value also to those who enjoy bird watching.

We have some evidence also here at home. A one-year study of 15 gravel pits near Ft. Collins, Colorado revealed that they were used by a large variety of ducks, both dabblers and divers. The three pits with the greatest duck use had 10, 13, and 15 species, respectively.

On the Chippewa National Forest the ecological significance of gravel pits is based upon the fact that they are responsible for about 10% of the permanent openings in the forest, and a large number of the birds, mammals, and herps of the forest make extensive use of openings. The bare areas and the mounds of excavated material characteristic of abandoned gravel pits are attractive to many species, including the threatened timber wolf.

Changes in the wildlife use with plant succession have been reported both in Britain and the U. S. At one semi-dry British area studied over 10 years, the progression was traced in detail as plant succession changed the nature of the habitat from the initial bare ground stage used by the Little Ringed Plover to a mature vegetated stage where 7 species of birds were still found. The Bank Swallow (Sand Martin) adopted the vertical bare banks in the first year and quickly built up a colony of nearly 800 pairs by year 5, only to drop to zero 3 years later when the bank was no longer suitable.

Here at the site of our symposium our hosts have studied intensively the flora and fauna, especially the birds, of an abandoned 35-acre gravel pit area for 5 years and found 40 species of birds nesting, 17 of them every year. We need't go any further to agree that gravel pits are an important type of wildlife habitat, meriting more attention than they have been given here in the U. S.

LESSONS FROM SOME CASE STUDIES

Individual case studies from around the country, and in Britain and Canada, have revealed many lessons which have wide applicability. I shall mention only a few. The serious student will want to dig into the papers actively. He or she is sure to find accomplishments relevant to his or her local situation.

One case from Colorado showed how negotiations including citizen conservation organizations, the Chamber of Commerce, and sand and gravel companies resulted in gifts of gravel pits to the city park system which, if purchased, would have cost hundreds of thousands of dollars.

Another showed how, by creative thinking and long range planning, the city and county have developed from spent gravel pits a natural history area so valuable they felt it appropriate to name it Walden Ponds. Colorado has also shown the way to management of gravel pit areas for intensive fishing near cities.

Several cases showed us how deeply interested the industry is in making the end-use of their gravel extraction areas socially acceptable and desirable. They have demonstrated that they are interested in much more than the immediate profit, and that they recognize the value of basic research to attain optimum end results.

In North Dakota and Nebraska the desire of departments of transportation to produce areas valuable to wildlife as by-products of highway construction were impressively demonstrated.

For further examples of accomplishments applicable to your own locality read carefully the individual papers.

MANAGEMENT RECOMMENDATIONS

My final topic is the management recommendations which have been offered and discussed during the Symposium. Although they relate to the rather specialized type of habitat, gravel pits, they embrace practically all the practices one would find in a wildlife management handbook for any type of habitat.

A refreshing overall attitude of the discussions was that the usual game/nongame cleavage was not evident at all.

Perhaps the most persistent thrust was that diversity of habitat and of wildlife were a goal. To achieve diversity many management practices were recommended:

1. Large rather than small areas.

2. Maximum shoreline lengths by use of irregular, undulating edges, and use of islands, even C-shaped and "hollow" islands.

3. Retain variety in topography, but avoid high banks on all sides of a pond, because ducks avoid the high-sides.

4. Manage the vegetation for both horizontal and vertical heterogeneity.

5. Retain some bare areas--don't permit everything to become vegetated.

6. Use some dead vegetation--snags, logs, leaf litter.

7. Have some parts of a pond or lake shallow, some deep, bottom uneven.

8. Mine below the groundwater level so some open water will be permanent.

9. Accelerating plant succession may be desirable in some situations and can be accomplished by: (a) planting, (b) seeding and fertilizing some areas, (c) grading some lake edges with shallow slopes which encourage rapid vegetation, (d) moving in the muck from other areas, with its seeds, propagules, and fertility which hasten plant growth.

10. Sometimes slowing plant succession is desirable and can be accomplished by: (a) not reforesting, (b) locating ponds where they will not be flooded out, (c) the use of fire, herbicides, or mowing to set back succession, (d) making sure a pond has a good clay seal so that it will hold permanent open water.

11. Increasing primary productivity may be important to produce the rich invertebrate crop so essential to some wildlife, especially growing young. Adding hay, straw, top-soil, mulch, or other organic matter can help; temporary flooding is sometimes useful.

12. To avoid excessive predator losses the use of brush piles under water or on land may be helpful as escape cover. Islands as nesting sites may reduce predator loss. Be sure that waterfowl nesting sites are not too far from the brood rearing areas or duckling losses en route may be excessive.

13. Some management measures are for particular species, such as the raw vertical banks for nesting Bank and Rough-winged Swallows, and Kingfishers.

14. Perches and loafing sites are important for many species and include: snags, floating rafts, and rocks or small islands.

15. Mounds are used by canids such as wolves, in forest openings.

16. Several recommendations were mentioned to encourage nesting: leaving dead trees with their woodpecker cavities, adding nest boxes, and providing seclusion from human disturbances.

It was generally agreed that advance planning was desirable, to create change rather than to react to it but there was mild disagreement over one interesting point; that of reclamation, rehabilitation, or restoration of the gravel pit at the termination of the mining process. Some felt that the best practice was to leave it as it, essentially abandoning the site, and that this not only provided good diversity, but it was also least expensive. Others maintained that "Yes, calling it a wildlife area is cheapest, but making it a wildlife area is not cheap."

EPILOGUE

So much for the plethora of possible management measures. We should not close the Symposium without giving thought to what comes next. This meeting has had 109 enthusiastic registrants from 14 states plus Canada and Great Britain. Through the leadership of Dan Svedarsky there has developed a momentum in the recognition of the value and the potential of gravel pits as wildlife habitat. It is important that this momentum continues. Some means of communication is needed to facilitate exchanges of experience and to stimulate wider adoption of some of the successful practices we have heard described. Some day we will want another such meeting to bring us up-to-date on further experiences. In the meantime how do we keep the spark of enthusiasm alive? Should there be a gravel pits newsletter? And if so, who will bell the cat?

One possibility which might be much less work, and still might be as effective as a special "Gravel Pits Wildlife Newsletter" would be to work out an arrangement with the Urban Wildlife Research Center to carry, in its newsletter, a section on gravel pit developments. This has a certain attraction, because most gravel mining and reclamation problems do occur near urban centers.

In conclusion, I would like to leave a challenge to the Symposium participants. This Symposium has brought together so much information that could be so very useful to leaders in the many disciplines which I listed in my opening paragraph that it could provide the basis for a handbook or manual on "Management of Gravel Pits for Fish and Wildlife Habitat." The 30 papers we have heard contain the basic information for such a handbook.

Think how useful such a handbook would be to the owner of the gravel mining operation we saw near here on our Thursday field trip, where 200,000 tons a year of gravel are being extracted, but where the owner is looking forward to having a lake for hunting and fishing when the mining is finished. And remember that this situation is duplicated thousands of times around the country right now. Such a handbook is certainly needed. Will someone in this audience accept the challenge and do the job?

Keynote Address:
Gravel Pits as Wildlife Habitat in Great Britain

CHRIS TYDEMAN. World Wildlife Fund, 11-13 Ockford Road, Godalming, Surrey, GU7 1QU.

INTRODUCTION

This symposium is concerned with the values of gravel pits for wildlife, and my task is to tell you about their importance in Britain, where such values have been known for some time, although they have largely been ignored or overlooked elsewhere. This may be a reflection of the relative scarcity of freshwater bodies generally in our crowded landscape, but it may be instructive to consider how gravel pits were discovered to be valuable in Britain and the development of interest that followed. I shall then describe the bird communities and how they change with time and then speculate a little about the future of gravel pits as wildlife habitats.

HISTORY

Sand and gravel deposits have been extracted by a number of means for a considerable number of years, but there are only reasonable accurate figures as far back as 1895. However, gravel pits were not recognised as of any wildlife interest until 1931 when a nationwide census of the great crested grebe (Podiceps cristatus) was organised (Harrison and Hollom 1932). At that time great crested grebes were considered to be relatively scarce, still in the progress of recovery from the plume trade at the turn of the century. Then, the mere fact that great crested grebes were present on gravel pits was thought to be highly significant. The survey was repeated in 1965 (Presst and Mills 1966, 1969) and it was found that 22% of all grebes were to be found on gravel pits.

Following the 1931 survey came perhaps the most crucial step in arousing interest in gravel pits. This was the discovery of the nesting in England of the little ringed plover (Charadrius dubius). It is, and was then, a common breeding bird of stony banked rivers on the continent of Europe, but had only been seen a dozen times in Britain prior to 1939. In that year a pair nested on exposed gravel in a water storage reservoir in south east England. There was a gap until 1944 when they bred on the same site again, and another pair were located at a gravel pit near to where London's Heathrow Airport now stands (England et al 1944). This discovery led to an exhaustive search of all gravel pits in the London area. The London Natural History Society even had a series of aerial photographs taken to pinpoint the most likely breeding localities. Since then the little ringed plover has increased throughout south east England using gravel pits as its main breeding sites, and has now spread to Wales in the west and Scotland in the north (Parrinder and Parrinder 1975). About 70% of all pairs in Britain use gravel pits as their breeding site.

As a result of the original discovery the London Natural History Society decided to carry out a survey of a selection of pits to ascertain their importance for birds in general, and four pits were studied between 1948 and 1951 (Keywood and Melluish 1953). They concluded, "....the digging of the gravel pits with subsequent flooding and attendant growth of vegetation tends to increase the variety of the local bird life, at all seasons of the year.".

It is of particular interest to note that so far 'wildlife' has been synonymous with birds, and that remains true up to the present day. Very little work has been carried out on other groups although assumptions have been made about aquatic invertebrates, like the dragonflies, and plants. Following the Keywood and Melluish survey there was a lull and little serious work was carried out for a decade, although ornithologists had been alerted to the possibilities and records from gravel pits became far more noticeable in the local records. Between the middle 1950's and the early 1960's there was, however, some important pioneering work being carried out at a site at Sevenoaks in Kent, where the local wildfowlers set about improving their stocks by using a gravel pit as a breeding area and refuge (Harrison 1974). This was extremely far sighted and way ahead of its time.

Before progressing, it is important to stop and think about the social history and attitudes of those times. Gravel pits had been 'discovered' and largely thanks to the little ringed plover, had been explored locally in some detail. Naturalists had discovered a new habitat with a selection of different species and one or two rare specialities. Ecology was in its infancy, and conservation only just beginning to be thought about. The first comprehensive legislation along these lines was passed in 1949,

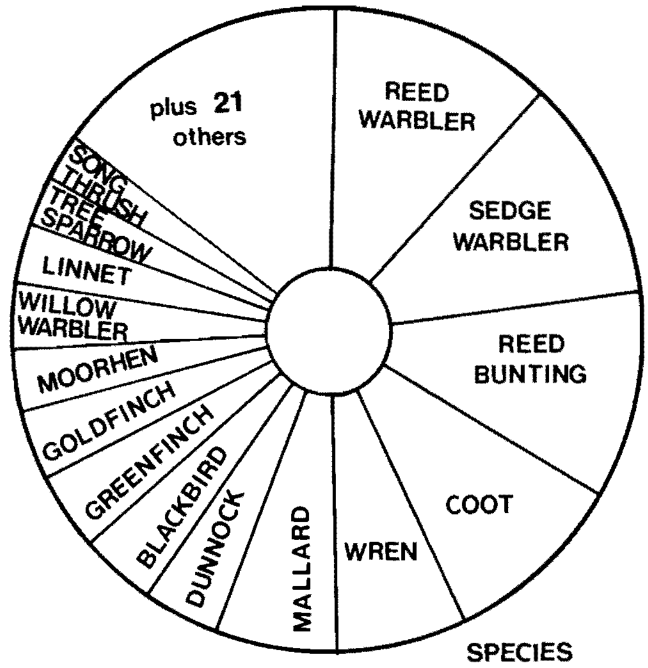
---

This work was supported by a grant from the Natural Environment Research Council.

and the Government's advisory body on conservation formed the same year. Gravel pits were either still functioning in an industrial capacity or else were abandoned and derelict. The pits were generally far enough away from the public gaze, and their only concern was that the dust and noise did not interfere too greatly in their lives. Furthermore, the gravel was being used to provide new homes and roads to replace those destroyed during the Second World War and thus there was some incentive to put up with the inconvenience. However, as more houses were constructed they were built nearer to the quarries and public pressure increased gradually to the extent that planning controls were tightened up. The mixtures of bare gravel, reedswamp, open water and scrub were being filled in, and alarm bells were beginning to sound amongst the naturalists. By now it was the mid-1960's and many once good sites had become playing fields. There was a growing realisation among the naturalists that these bits of waste ground, which had previously been their domain alone, were being altered and destroyed. This led to more studies e.g. Glue (1970), Milne (1974) and the intensification of interest in places like the Sevenoaks Reserve, where by now scientific studies on habitat improvement had been carried out (Olney 1964,1967). This gradual, slow awakening of interest coincided also with the start of the decline in area of more natural wetlands - a decline which subsequently suffered a dramatic increase and which continues to this day. Gravel pits and water storage reservoirs (with all their limitations) were the only new sources of water as replacements.

Also, at about this time there was a considerable increase in interest in leisure activities, particularly water-based ones. The gravel extracting companies realised that there was revenue potential in the greater recreational use of the wet pits, and started to organise fishing, sailing and water skiing activities at a much greater level than hitherto. One company even started a subsidiary called Leisure Sport Ltd..

This sequence of events can be summarised into a series of phases. The first of these was ignorance, followed by awareness (at least on the part of the ornithologists) which brought about the third phase of conflict. These unofficial nature reserves were now to be actively managed for recreational use, with aquatic macrophytes dredged out to provide safer boat passage, and banks cleared and graded for the use of anglers.



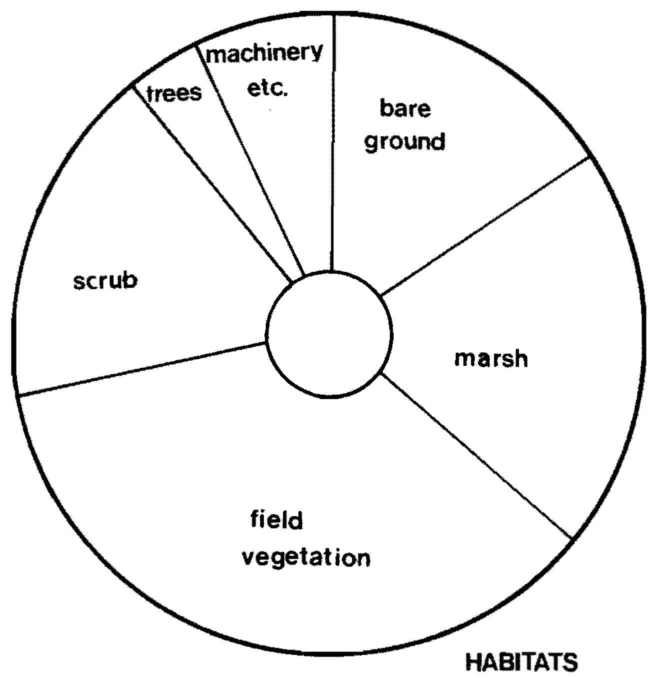


Fig. 1 Percentage distribution of breeding species and habitat types at Stanstead Abbots gravel pit.

THE WILDLIFE ITSELF - THE BIRD COMMUNITIES

Numbers of species

This, then, was the scene at the beginning of the 1970's. Had the wildlife value of gravel pits been destroyed by these changing uses? I attempted to find out. Eleven sites in the Thames Valley were surveyed for breeding birds during the years 1973-75. The sites all varied in physical characteristics and, if worked out, their types of after-use. The number of breeding species varied greatly from site to site (19-44) and also from year to year (19-30 on one site). A representative example of a community is given in Fig. 1. Further information may be found in Catchpole and Tydeman (1975). Breeding densities varied even more widely from 167 prs km^{-2} to 1801 prs km^{-2}.

A total of 65 species were found breeding, of which only ten bred at all eleven sites; a further two bred at ten sites, and a further five at nine sites. Of these 17, six are closely associated with open water or marshland. These figures may be compared with the earlier study of Keywood and Melluish (1953) who found a total of 40 species, of which eleven bred at all four sites studied and another four at three of the sites. Keywood and Melluish concluded that the 15 species were characteristic of the survey areas. A comparison between the two sets of results shows that only eight species are common, including the six associated with water. The species present in the earlier study are more characteristic of open habitats, with a high proportion of ground nesters; those in the later study were more associated with scrub or woodland. This is a reflection of the age of the pits at the time of the survey and also of the management that had been undertaken prior to the later study.

This sort of analysis can be taken further by incorporating more sites from published work. Adding another ten sites gives a total of 70 site/years, which provide a total of 91 breeding species, none of which was recorded as breeding in all site/years. The highest was 68 which was achieved by a marshland passerine, the reed bunting (Emberiza schoeniclus). Since this list was put together in 1978 a further half dozen species have been recorded as breeding, making a total of 97 in all. (This does not account for gravel pits at coastal sites). Thus just under half the total number of species that breed regularly in Britain may be found breeding on gravel pits.

Community structure

It is evident that differences are present in community structure with so many species involved, and relatively few of them breeding together at any one site. One way of looking at this is to use a simple Similarity Index, for example that of Sandars (1960). Of 55 comparisons made in the Thames Valley pits using the author's data, only ten have a value of 70% or over (highest 76%), with the lowest value being 41%. 80% is normally taken to be the level of significant similarity. There is a tendency towards difference in community structure, even on adjacent sites to quite a high degree. This is not due to differences solely in after-use as similar results were obtained using the 1948-51 data.

It is this inherent dissimilarity which is one of the most interesting characteristics of gravel pits. They are constantly changing. During the average 15 years of working time there is a distinct vegetational succession from the colonisation of bare ground and mud, through marsh and scrub, to carr and ultimately woodland. Of course, it is possible at a number of points to maintain the required conditions, through active management. Milne (1974) divided the colonisation process at his site into five stages:

1) excavation
2) sedimentation
3) colonisation
4) inundation
5) maturation

Number 4) will not happen on pits that are worked flooded. The successional stages are given diagramatically in Fig.2.

Succession

Putting together data from several studies, it is possible to look at changes in the bird community with succession. Milne (1974) provides information on the initial stages over the first ten years. His results are presented graphically in Fig. 3. Initial colonisation was made only seven months after the commencement of extraction by sand martins (Riparia riparia) and a pair of little ringed plovers. Only seven species (mallard (Anas platyrhynchos), moorhen (Gallinula chloropus), reed bunting, tufted duck (Aythya fuligula), coot (Fulica atra), sedge warbler (Acrocephalus schoenobaenus) and great crested grebe) were still nesting at the end of the study having done so since their initial colonisation. A summary of the breeding bird colonisation over the ten years is provided in Fig. 4.

Species diversity

Another facet of community structure is diversity. Many authors have suggested that the diversity of a community is fundamentallyconnect-connected with succession and that diversity reflects ecosystem stability. It has further been suggested that diversity initially increases rapidly, reaches a maximum, and then decreases in late stages. Milne's data were submitted to analysis using the Shannon-Wiener function and the results plotted graphically against

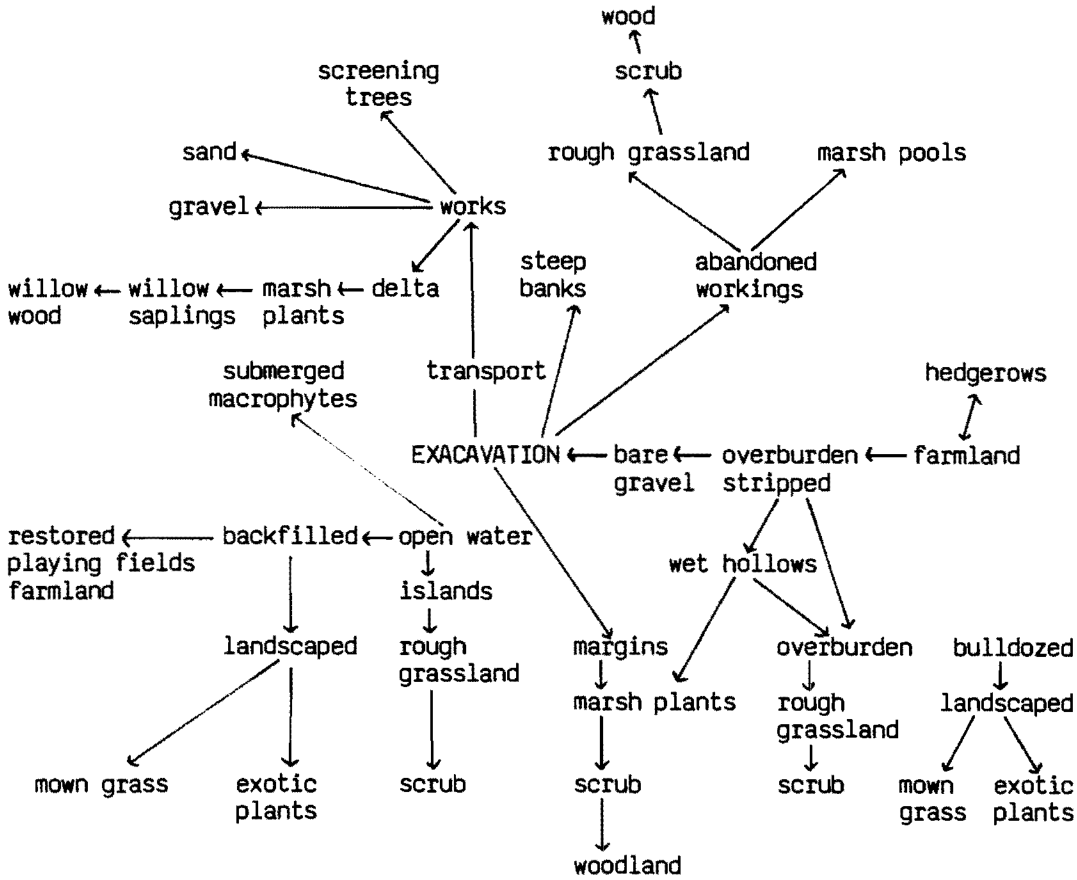


Fig. 2. Succession in the gravel pit habitat.

time (Figure 5). There is an initial rapid increase followed by a levelling off. In 1969 the increase is greater than would have been predictedcoincident with the loss of the colonial nesting sand martin following inundation of the pit.

To go further with this line of thought, other examples need to be brought in. Diversity after ten years at Milne's pit was 2.89 bits per individual. The following examples are from sites that I have studied:

Site	Age	Diversity (bits per individual)
Queensmead	12 yrs	3.62
	13 yrs	3.92
	14 yrs	4.04
Yeoveney	ca.17 yrs	4.48
Stanstead Abbots	ca.17 yrs	4.43
Wraysbury One	ca.30 yrs	4.65-4.80
Old Slade	ca.50 yrs	4.39

These figures may be compared to those of Karr (1968) whose data span a successional period of 70 years for strip-mined land in Illinois.

The figures for ten year periods are: 1.37 - 2.22 - 3.96 - 4.72 - 4.78 - 4.21 - 3.69 bits per individual (Data reworked from original using $\log_2$)

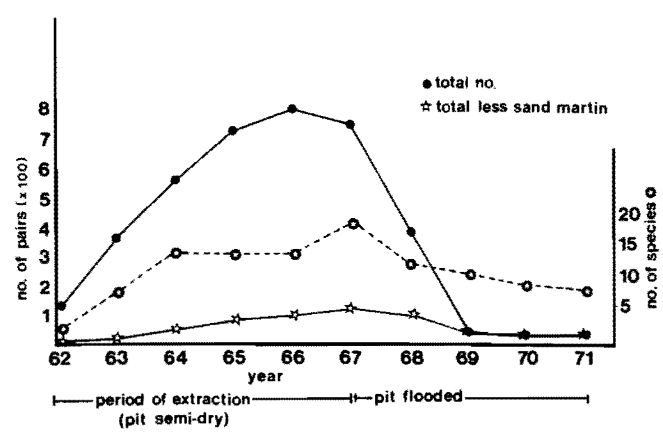


Fig. 3. Summary of results of breeding bird censuses at Parson's Drove gravel pit (after Milne 1974).

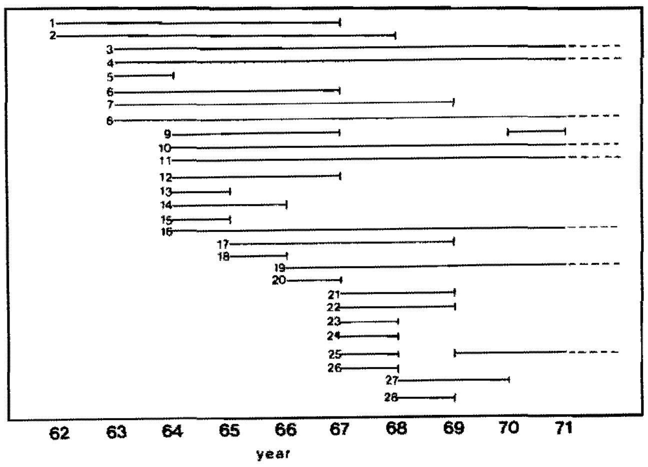


Fig. 4. Summary of breeding bird colonisation at Parson's Drove gravel pit (after Milne 1974).

Key: 1 little ringed plover (Charadrius dubius); 2 sand martin (Riparia riparia); 3 mallard (Anas platyrhynchos); 4 moorhen (Gallinula chloropus); 5 ringed plover (Charadrius hiaticula); 6 skylark (Alauda arvensis); 7 yellow wagtail (Motacilla flava); 8 reed bunting (Emberiza schoeniclus); 9 mute swan (Cygnus olor); 10 tufted duck (Aythya fuligula); 11 coot (Fulica atra); 12 red legged partridge (Alectoris rufa); 13 redshank (Tringa totanus); 14 blackbird (Turdus merula); 15 robin (Erithacus rubecula); 16 sedge warbler (Acrocephalus schoenobaenus); 17 little grebe (Tachybaptus ruficollis); 18 house sparrow (Passer domesticus); 19 great crested grebe (Podiceps cristatus); 20 Canada goose (Branta canadensis); 21 pochard (Aythya ferina); 22 lapwing (Vanellus vanellus); 23 snipe (Gallinago gallinago); 24 black-headed gull (Larus ridibundus); 25 common tern (Sterna hirundo); 26 meadow pipit (Anthus pratensis); 27 kingfisher (Alcedo atthis); 28 reed warbler (Acrocephalus scirpaceus).

Thus it may be assumed that species diversity is varying with the structure of the habitat, which, assuming no management, varies with time. This hypothesis was tested using a Habitat Diversity Index (HDI) since clearly the more usual Foliage Height Diversity is inapplicable to the gravel pit habitat. HDI was calculated using percentage habitat types measured on scale maps. The results are shown graphically in Fig. 6. Thus there would appear to be a good relationship between species diversity and habitat diversity. No relationship could be found between species diversity and area, although there was some relationship between species richness and area.

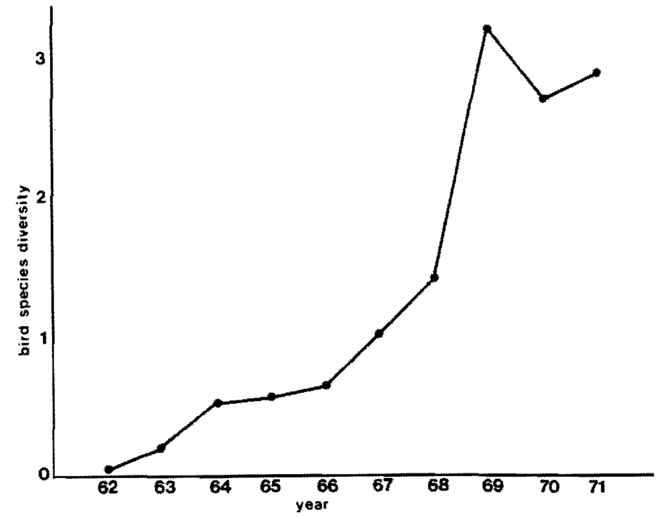


Fig. 5. Species diversity and succession at Parson's Drove gravel pit (after Milne 1974).

THE FUTURE

The analysis above shows that gravel pits, however managed, may hold high densities of common birds; have considerable potential when suitably managed as nature reserves; and, in addition, may be particularly important for individual species e.g. little ringed plover. Let us examine what this means in a British context.

Among their physical features, gravel pits are characterised by their close proximity to man in an urban/agricultural environment. They are typically found in river valleys which are important avenues of communication by river, rail and road, and many pits are bordered by all three. Human populations traditionally settle in river valleys, and, together with existing communications, attract industrial development and continued urbanisation. Many of the areas mentioned in this paper are in the Thames Valley which is one of the most densely populated areas in Britain, and in addition many pits are very close to its largest airport, Heathrow. Indeed, the runways have been constructed with the results of the local extractive industries. This shows that such physical features need not be a problem for even relatively sensitive creatures like birds. As we have seen, in earlier days, the birds and birdwatchers 'had it to themselves', but now pressures have mounted from other quarters. The close association between gravel pits and high human population densities has in turn brought about pressures for their use as a recreational facility. They are good fishing waters, and, if large enough, provide sufficient

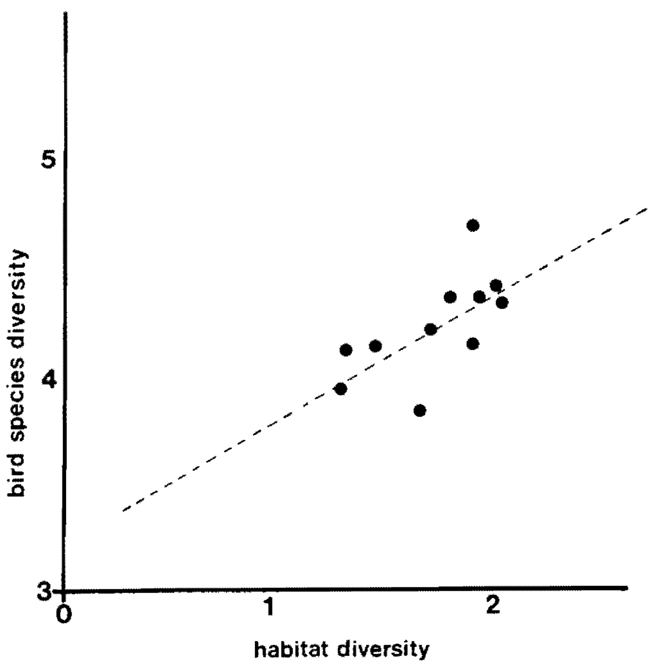


Fig. 6. The graph of bird species diversity against habitat diversity for eleven gravel pit sites.

water for sailing, powerboat racing and water skiing. Some of these may be deleterious (Tydeman 1975) and totally incompatible with any form of conservation. Thus conflict still exists; but many activities are not completely deleterious. The management and landscaping options adopted by the extracting companies have often provided suitable areas for the more terrestrial components. They can, therefore, act as 'generative centres' for these commoner species and, by holding many species (often at high densities) in relatively isolated areas help to buffer local populations against adverse factors operating in the surrounding urban/agricultural environment. While on the subject of agriculture, this provides yet another source of conflict. Much of the remaining aggregate-producing land is under first or second grade agricultural land, or has been made sterile by being built upon. This conflict is not one that will be easy to resolve unless reinstatement of the land to its former quality can be guaranteed.

Also, by their very nature close to man gravel pits can provide extremely good educational or field study facilities. It is possible that such areas could relieve pressure on the existing more natural areas. Interest in the environment has increased, and continues to increase apace, and the desire to get out and look at the 'natural world' has run a parallel course. It is also worth remembering that there is much to be learnt about the gravel pit environment.

In conservation terms this might have benefit for the more natural areas, but what of the conservation importance of gravel pits themselves? Some authors, for example Haslam (1973) suggest that gravel pits have little conservation value and should be used entirely for recreation, thus relieving the pressure on natural wetlands. The evidence would not seem to support that view. Up to now most of the discussion has concerned breeding birds, but wetlands in Britain are more often thought of in terms of their wintering wildfowl. One gravel pit near Heathrow has now assumed national importance for this as it contains more than 1% of the total British wintering population of 3 species of duck. In one case the smew (Mergus albellus) it can hold up to 10% of the population of one species of duck. This, incidentally, is on a site where sailing takes place.

The gravel pit reserve at Sevenoaks has provided wintering grounds for large numbers of snipe (Gallinago gallinago) while the natural flood meadows around have been drained one after the other. This same reserve shows what can be achieved by management; the more so, because if given the option most people would not have chosen the site for conservation purposes. It was originally designed for waterfowl production but the main water body is up to 30 metres deep and therefore seemingly unsuitable. Nonetheless, through the sheer hard work of Dr. Jeffery Harrison and his family, it was transformed into an excellent nature reserve.

This brings in the fourth phase. The first was ignorance, then awareness, the third conflict - now the fourth and most important - cooperation. Sevenoaks reserve was taken over by wildfowling interests on a short term lease with no guarantee, during the working life of the pit. At first the management tasks followed on from the remains of extraction. Then it became apparent that so much more could be done if the extraction was carried out in such a way that it acted almost as a precursor for the management that was to follow. The company, in this case Redland Ltd., were persuaded, as long as efficiency was maintained. Since then, a number of schemes have started with collaboration between nature conservation interests and gravel companies. One of them, between Amey Roadstone Corporation and the Game Conservancy, is the subject of a paper at this symposium. There is another larger and more complicated scheme to integrate all the uses of gravel pits in an area known as the Cotswold Water Park. It is centered in Gloucestershire but impinges on three counties, and involves about half a dozen different gravel companies, at least as many different local government authorities, and as many again conservation bodies. Before each lake has been dug its fate has more or less been decided. Several have been allocated as nature reserves.

In complete contrast, a large complex near London has been given over to leisure activities. It is called Thorpe Water Park. Although of little consequence for nature conservation itself, it does illustrate the 'honey pot principle' rather well, in that has taken attention away from other areas which might otherwise have suffered.

Within the last year, two worked out sites have been handed over to conservation bodies, one in Warwickshire and the other in Buckinghamshire at Milton Keynes New Town. Gravel was extracted in order to build a new link road for the new city designed from scratch as an overspill for London. Now, thanks to the cooperation of the gravel extractors, there is a wetland reserve on the edge of the town, designed to the requirements of the conservation bodies as extraction was carried out, and an important marsh was left to the birds without excavation under the same spirit of cooperation. It is important that such design is incorporated at the start because the fate of a gravel pit does not now wait until gravel is exhausted. The likelihood is that plans have been made for its future before the first excavator arrives. Furthermore, it is easier and cheaper to use existing equipment on site at the time, rather than try to alter structure later.

Mr. T.U. Hartwright of Leisure Sport Ltd. suggested that gravel extraction provided 'a challenge and an opportunity' (Hartwright 1974). This is equally true for wildlife as it is for industry.

REFERENCES

CATCHPOLE, C.K. & TYDEMAN, C.F. (1975). Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8, 47-59.
ENGLAND. M.O., HOHN, E.O., PEDLAR, E.G. & TUCKER B.W. (1944). The breeding of the little ringed plover in England in 1944. Br. Birds, 38, 102-11.
GLUE, D.E. (1970). Changes in the bird community of a Hampshire gravel pit, 1963-68. Bird Study, 17, 15-27.
HARRISON, J.G. (1974). The Sevenoaks Gravel Pit Reserve. A Conservation Publication of WAGBI in co-operation with Redland Ltd. and the Harrison Zoological Museum Trust.
HARRISSON, T.H. & HOLLOM, P.A.D. (1932). The great crested grebe enquiry 1931. Br. Birds, 26, 62-92; 102-131; 142-155; 174-195.
HARTWRIGHT, T.U. (1974). Worked out gravel land - a challenge and an opportunity. Environ. Conserv. 1, 139-143.
HASLAM, S.M. (1973). The management of British wetlands. II. Conservation. J.environ.Mgmt, 1, 345-61.
KARR, J.R. (1968). Habitat and avian diversity on strip mined land in east central Illinois. Condor, 70, 348-357.
KEYWOOD, K.P. & MELLUISH, W.D. (1953). A report on the bird populations of four gravel pits in the London area, 1948-1951. Lond. Bird Rep., 17, 43-72.
MILNE, B. (1974). Ecological succession and birdlife at a newly excavated gravel pit. Bird Study, 21, 263-78.
OLNEY, P.J.S. (1964). Gravel pits as waterfowl reserves. I.U.C.N. Publications New Series No.3. 414-420 Morges.
OLNEY, P.J.S. (1967). The W.A.G.B.I. - Wildfowl Trust Experimental Reserve. Part II. The feeding ecology of local mallard and other wildfowl. Rep. Wildfowl Trust 18, 47-55.
PARRINDER, E.R. & PARRINDER, E.D. (1975). Little ringed plovers in Britain 1968-73. Br. Birds, 68, 359-368.
PRESTT, I. & MILLS, D.H. (1966). A census of the great crested grebe in Britain in 1965. Bird Study, 13, 163-203.
PRESST, I. & MILLS, D.H. (1969), Correction. A census of the great crested grebe in Britain 1965 (Bird Study 13 1966: 163-203) Bird Study, 16, 186.
SANDARS, H.L. (1960). Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr. 5, 138-153.
TYDEMAN, C.F. (1977). The importance of the close fishing season to breeding bird communities. J. environ. Mgmt., 5, 289-296.

Land Reclamation After Gravel Mining in Great Britain and Possible Applications in the Upper Midwest

B. E. YOUNGQUIST, Professor and Superintendent, Northwest Agricultural Experiment Station, University of Minnesota, Crookston, MN 56716

This paper covers the contents of the address of B. E. Youngquist at the opening session of the Wildlife Values of Gravel Pits Symposium, June 24, 1982, Crookston, Minnesota. He is the superintendent of a Branch Agricultural Experiment Station for the University of Minnesota and has worked for 37 years in applied agricultural research and agricultural education related to production agriculture. During that time he has been involved firsthand in land and water resource management whether for agricultural production purposes or for the other needs of society.

The primary role of the Northwest Experiment Station is applied research for agriculture; however, the Station has concerned itself with land use for purposes other than producing food and fiber. A 35-acre gravel pit was set up as a research project investigating wildlife habitat uses of such land. Dr. Dan Svedarsky has headed the project for a period of 9 years.

A search of the literature found that the country of England is generally leading other nations of the world in their concern and activity in the restoration of gravel pits.

The contents, findings, and recommendations of this paper are based on a search of the literature and of a study tour of gravel pit restoration sites in England in the summer of 1981. While in England, the writer visited extensive gravel pit areas in the Thames Valley of the greater London region. Gravel for construction purposes has been mined for centuries in the London area. Deposits of gravel in the Thames River Valley have been and still are extensive, but the removal of gravel has largely been without any kind of joint-agency planning up until recent years. More recently, gravel mining corporations, conservation agencies, agricultural agencies, and the federal government have begun to work together in the establishment of guidelines for future mining of gravel.

The author visited sites now used for water recreational purposes, for wildlife habitat, and for commercial fish farming.

He spent a day visiting Thorpe Park, somewhat like Disneyland in the U. S. A. Thorpe Park was built on worked-out gravel pits by Leisure Sport, Limited, a subsidiary of the Ready Mix Concrete, Ltd., London. A great deal of emphasis is given to creative educational displays depicting the early history of the British Isles. An unusual educational sector is the buildings of a miniature "Wonders of the World" model. The author learned quickly about the Eiffel Tower, Egyptian Pyramids, Greek Parthenon, Roman architecture and also a few modern structures on earth. The models are built 1/36 size scale and placed in reasonable proximity to each other where one could make ready comparisons, read the tableaux provided, and gain a sense of international perspective in a very short time. All of these ideas are established in a rather pleasing setting as part of a profit-making exposition. The author was there on a day when over 4,000 school children from London were bused to the Park, along with several small groups from nursing homes and institutions for the handicapped. Visitors not only learn about their heritage as British people, but gain a perspective of the wonders of the world. Too, there is: water recreation, limited wildlife observations, and a sport fishing opportunity licensed by Leisure Sport, Ltd., among other recreational opportunities.

The fish farms are a commercial venture by gravel companies or by fish farmers leasing land from the gravel companies. At this time most of the fish raised are rainbow trout brought in originally from the United States. The trout, grown to about a pound, are served in the top restaurants in the City of London. This is a growing industry.

Land is a scarce and expensive resource in Britain. Consequently, the utilization of these worked-out gravel pits is coming under increasing use for housing purposes where there is appropriate subgrade fill available. The high water table in the Thames Valley is a problem for utilization of mined-out gravel pits for housing. Considerable rubble and solid waste from old buildings and construction sites and from industry in the city of London is used to replace the gravel and the rubble is covered with the overburden soil left from the gravel removal operations.

Land for food production in England is scarce. The study and deliberation of the Verney Committee of 1972 developed a consensus that, "no more land in the easterly Thames agricultural area can be mined for gravel without restoration for agriculture," among other guidelines for land use in the gravel mining areas. Extensive studies are now in process by appropriate agencies in government and private industry who are working on developing restoration practices which restore the land back to agricultural production.

The author visited the Bush Farm Experiment and viewed the process of restoring the land to agricultural production. He examined wheat crops being raised on restored land. The cost of this experiment is being borne primarily by the private gravel company. The author raised the question, "How can you afford to spend the equivalent of $100,000 U. S. funds per acre to reclaim this land for agricultural production purposes?" The answer was, "We don't know the answer yet; however, we had to put a stop to losing any more prime land for food production. When we have a few more years experience with this expensive reclamation, we intend to assess the findings against the need for food production for hundreds of years ahead."

IMPLICATIONS FOR THE UPPER MIDWEST

Worked-out and operational gravel pits in the Upper Midwest sector of the U. S. A. are numerous. No one really knows how many or how much land is involved. Up to now, little thought has been given by agencies and/or private citizens on the use of these areas once gravel is removed. Most of the worked-out areas have been left rough and scarred. There is a growing awareness that this land has potential use. Already, there are examples of private development of small-sized worked-out gravel pits as well as of the larger pits which are located near population centers. The University of Minnesota, Northwest Experiment Station began pilot studies in 1971 and later launched a more complex study on wildlife habitat and management in a 35-acre gravel pit located on the Experiment Station land.

From reading the literature that is available on the world scene, from the experiences on the tour in England, and from limited research findings and personal observation of gravel pit use in the Upper Midwest, the following uses of worked-out pits in the Upper midwest, U. S. A. are suggested:

1. Wildlife Habitat - Habitat for waterfowl or other birds and wildlife as appropriate is probably the leading use for these gravel pits whether the pits are located on land operated by large or medium-sized gravel companies or located on individual farms. Worked-out pits, if located near a college or school, can be very helpful outdoor laboratories for study of native plants and wildlife. Research now in progress by the Northwest Experiment Station already has developed some understandings for what has happened naturally to a near-century-old gravel pit and what management practices are needed to enhance wildlife habitat and use as an outdoor educational laboratory.

2. Recreation - There would be limited opportunity for water sports development in the worked-out gravel pits of the Midwest as water levels and pit size tend to be insufficient.

3. Home Sites - There are already examples of small worked-out pits where home sites have been established.

4. Park Land - Worked-out pits of considerable size can be allowed to reforest naturally, or plantings can be established by private or governmental agencies, and could provide reforestation, hunting, picnic facilities, or other appropriate park facilities.

5. Fish Farming - Useful only where water table is sufficient for proper habitat. The experience of England and in the U. S. suggests this as a viable option.

6. Agricultural Use - The abundance of relatively good agricultural land in the Upper Midwest is such that except for truck gardening located close to metropolitan centers or a small garden site for family garden production, the economics of restoration would not be feasible for the production of general farm crops.

7. Biomass Production - Should the use of biomass continue to develop as a replaceable energy source, rough mined-out pits might be used with a minimum amount of adjustment to produce biomass for heat energy needs.

DO THE IMPLICATIONS SUGGEST ANY FOLLOW UP?

Yes, needed is more knowledge of the extent of worked-out gravel pits and how to manage the restoration for various purposes.

How many, what sizes, and where are gravel pits located? Such an inventory would be a useful tool for those who are doing research and also for other agencies concerned at the county and state levels.

Research on the use of worked-out pits for wildlife habitat in the Upper Midwest merits public support as the findings may well suggest least-cost techniques for use of worked-out pits for wildlife habitat as well as other techniques of management useful to the public domain.

A follow-up on the symposium of June 1982 might well be joint dialogue among aggregate associations, highway departments, state departments of agriculture, departments of natural resources, and university researchers looking to guidelines for gravel pit restoration during the next half century.

ACKNOWLEDGEMENTS.--The author wishes to acknowledge the following individuals who provided information and tour leadership to him on his trip to Britain: Mr. M. W. Bently, Consultant, Adkins Land & Water Management; Mr. T. U. Hartright, Director, Thorpe Park, Leisure Sport, Ltd., Mr. Brian Davis, Soil Scientist, Ready-Mix Concrete, Ltd. of London; and Dr. C. F. Tydeman, Staff Ecologist, World Wildlife Fund.

Regulatory and Land Use Aspects of Sand and Gravel Mining as They Affect Reclamation for Wildlife Habitat and Open Space: A National Perspective

RICHARD A. MORRIS. National Sand and Gravel Association, 900 Spring Street, Silver Spring, Maryland 20910

Sand and gravel producers are by the nature of their activity involved in land use planning. Through a sometimes painful historical process they are aware that their ability to operate under reasonable and workable controls necessitates participation in the development of land use planning and regulatory policies designed to protect and promote the interests of the public as well as their own private rights in a manner consistent with the protection of the health, safety and welfare of the community in which they operate. The social, political and economic forces that come to play in this process have significant impacts on the use of the land after mining is completed. Certain factors tend to encourage or inhibit the use of sand and gravel mined lands as wildlife habitat or open space. Recognizing significant differences in various parts of the country it is nevertheless useful to explore the sand and gravel industry from the national perspective to get a general idea of the nature of these influences on land use and reclamation. First, a brief description of the industry and its attitudes toward regulation and land use planning is in order.

SAND AND GRAVEL

Sand and gravel are the result of the breakup of pre-existing rock material. Sand and gravel consist of unconsolidated mineral and rock particles resulting from the erosive forces of water, wind and ice. Sand and gravel are distinguished from each other primarily by grain size. Sand, or "fine aggregate" is small enough to pass through a screen with a one-quarter-inch square opening and be retained on a screen with 200 meshes per square inch. Particles that will pass through a screen with openings between one-quarter and two square inches are considered to be gravel or "coarse aggregate." Mixed with other rock particles sand and gravel have little commercial value. Deposits of sand and gravel that prove commercially valuable are generally found in and near valleys, terraces and fans of existing and pre-existing rivers, other water bodies and in formations where they have been deposited by glacial action.

Most sand and gravel are used in Portland cement concrete or asphaltic concrete, as a general fill, as a base course or subgrade material for highways, railroads, runways, road surfacing and for water filtration. Sand and gravel are therefore important in virtually all construction, commercial and residential. Precise specifications for gradation and quality must be met with requirements varying according to the nature of the use and the specifying agency. Specialty industrial sands with high purity silica content are also used for glass making, oil and gas well hydrofracturing, sand blasting, abrasives, light bulbs and fixtures, eyeglass and other optics, television tubes, mirrors, pottery, chinaware, porcelainware, and because of its heat resistance, as a surface lining for iron and steel foundries. Industrial or silica sand's heat resistance made it the material of choice for those heat-resistant tiles which received so much publicity as the critical means for preventing the Columbia Space Shuttle from burning up on re-entry to the earth's atmosphere. If we could only make sure that they stay on during blastoff!

Demand for sand and gravel is so widespread that we annually use an average of five tons per capita. Sand and gravel is so important to the general urban economy that its use is considered one of the most accurate indices of economic activity.

Sand and gravel is currently the second largest of the mining industries in terms of tons produced. While we are talking about almost one billion tons annually in the late 1970's, less than one tenth of one percent of the land area in the United States is devoted to such mining. Sand and gravel mining accounts for only 17 percent of the land used for mining. Due to the impact of the recession on construction activity, production slipped to below 800 million tons in 1980 for the second lowest tonnage in the last 18 years. Sand and gravel mining occurs in every state. According to the latest figures from the U.S. Bureau of Mines there are approximately 4,500 producers of sand and gravel with 6,200 operations. In 1980, the national average value per ton of construction sand and gravel was approximately $2.50.

As a result of low unit cost, construction sand and gravel are generally mined close to the urban or urbanizing centers where they are used. In most cases, transporting sand and gravel 20 miles from the processing plant to the construction site doubles their cost. Of special interest to the creation or preservation of wildlife habitat and "green belts" is the related fact that to a very large degree, sand and gravel mining occurs in areas where open spaces and wildlife habitat are under the most intense development pressures. It is in such a situation where the "problem" of mining holds such promise as an opportunity for preservation and creation of a valuable ecological resource for the community after the initial resource is extracted and utilized.

Sand and gravel extraction is an "interim" land use within the concept of "multiple" or "sequential" land development. Quite simply this means that property containing valuable resources such as sand and gravel have the potential for a sequence of different valuable uses. In some cases, this may mean that the initial land use, agriculture, for example, is restored after the mineral resource is extracted. In other instances, the land may go through a sequence of uses that are all different from each other yet valuable and productive in their own right.

While sand and gravel mining may disrupt fish, game and other wildlife habitats, it has the ability to create new and sometimes better ones. In addition, producers have shown that under strict controls and concerned management, in some circumstances mining concurrent with progressive reclamation may be accomplished in sensitive areas without disturbing wildlife. Even abandoned mined gravel lands have been found to provide highly productive areas, especially for waterfowl, often encouraging species variation beyond what the land sustained prior to mining.

ATTITUDES TOWARD REGULATION

"Regulatory Relief" is a term much in vogue these days. To the regulator it is often perceived as a smokescreen for no regulation at all. But for the "regulatee" (if there is such a word) it often means reasonable, sensible and thoughtfully measured controls that will produce the desired result in as painless a way as possible. The sand and gravel industry, requiring close proximity to its markets, finds a degree of self-interest in assuring that regulations to protect the public interest and discourage the irresponsible businessman are in place. Only with such an accommodation can the industry hope to plan and operate efficiently.

Unlike the surface mining of coal -- to which it is so frequently and unjustly compared -- sand and gravel mining is a local industry, serving local markets and stable in site location for a considerable period of time, often 10, 20 or 30 years and more. As such, it is a member of the community and thus requires for its very existence some form of accommodation with its neighbors and their local representatives. In our society this means some form of regulation. Unlike many larger mining operations located in sparsely settled areas producing a high value per ton commodity and serving worldwide markets, the sand and gravel operator can not hope for an "out of sight, out of mind" public attitude. Continued operations providing construction aggregate at a reasonable cost can only be assured by reasoned local regulation that weeds out the irresponsible operator and rewards the responsible businessman. The public must feel confident that the "public interest" is being protected and the operator must also feel confident that he will be able to carry on his business in an efficient and profitable manner within accepted constraints. The necessity of local regulation and sound land use planning is clear. A combination of the two provide important opportunities for protecting and reserving for future extraction sand and gravel reserves in a manner that would benefit producers and consumers individually, as well as society as a whole. This is of course a goal, if not a dream, but one worth working toward. It has been tried in a number of areas with varying degrees of success. In many cases it is still in the experimental phase.

Since 1955, the National Sand and Gravel Association has aggressively promoted the concept of sound land use planning and emphasized the restoration of mined land to an after-use amenable and suitable to the surrounding environment. The Association has also accepted the concept of mandatory requirements for planning suitable post mining land uses as a prerequisite for obtaining a mining permit. However, as spokesman for the industry, the Association has often argued over what level of government should exercise that control and over other regulations that affect the industry. A A major problem is often the way in which these regulations have been developed and applied.

In any discussion of the industry's attitude toward regulation (and the factors that tend to encourage or inhibit reclamation of mined lands for wildlife habitat or open space) it is important to note one further aspect of the industry because it is intricately intertwined with all of these concerns. This element is the poor public image that the industry inspires. Like many other necessary contributors to our standard of living, people quite naturally want the fruits of our labor without "the pits". People want sewage treatment plants, hazardous waste treatment and disposal sites, etc. -- but not near them, near somebody else.

As surface miners the industry is certainly much unloved. While implementing more environmentally progressive production techniques the sand and gravel producers' image continues to suffer from the damage done by earlier generations and from the unparalleled though not necessarily undeserved negative image of the mining industry as a whole.

In the 1960's and 1970's governmental control was seen as the only solution to many of the problems of society and especially for mitigating the impact of business upon the land and its people that was unrestrained solely by market conditions. Although much good has been accomplished the nation has sadly suffered through regulatory overkill in many areas. Punitive, multi-layered and misdirected regulation has served primarily to increase costs and decrease overall benefits to society.

From the sand and gravel operator's perspective -- and we are often talking about small businessmen with less than 10 employees -- the regulatory maze he confronts is a frightening and frustrating one. At a minimum, dual sets of requirements are often the case as local zoning ordinances and state laws regulate the industry's surface mining activities in most parts of the country. Provisions often involve the necessity of securing permits from two levels of government. These permits are frequently restricted to a limited time period requiring extensive renewal procedures on the part of the producer with no assurance that the permit will be renewed. The operator is also subject to regulation by the federal and state governments under the Clean Air and Clean Water Acts and the Resource Conservation and Recovery Act for the protection of the environment. Numerous other federal and state laws ranging from endangered species to archeologically oriented preservation requirements must also be adhered to. Thus, the substantial investment in considerable time and capital required to gain approval for a modern sand and gravel plant becomes quite an undertaking -- hazardous in economic terms.

In discussing the operator's attitudes toward regulation and the way he perceives his business and his responsibilities it is important to go beyond those regulations that affect his use of the land and to be aware that the operator is also subject to regulation by the U.S. Department of Labor for the health and safety of his employees. Actually, it is this area of regulation that has caused the greatest conflict on a national basis and helped shape the producer's perspective on federal regulation. Such conflict is not without parallel in certain state surface mining laws for in both, one legislative statute is used to regulate activities in both the coal and noncoal industries. The sand and gravel industry's greatest regulatory headaches appear to come about when as a mining industry it is indiscriminately thrown into a regulatory framework designed to deal with safety and health problems of underground coal mines and environmental impacts of surface coal mines.

In accepting mandatory requirements the industry believes that such regulation should rest in the lowest practical level of government and duplicative coverage should be avoided. Hence, while the industry strongly opposed including sand and gravel operations in the federal Surface Mining Control and Reclamation Act, the Association has actively encouraged the industry to take the initiative to see that responsible state surface mining laws covering its operations are in place. Unfortunately, several state laws have not differentiated between coal and sand and gravel mining and have created serious problems in both administration and implementation as it affects the sand and gravel industry.

The basic nature of the surface coal mining industry and the aggregate mining industry are at opposite ends of the spectrum because of geology and economics. In many locations it is economically feasible to remove fifty feet of overburden to recover two feet of coal. Unlike the surface mining of coal, mining for sand and gravel and for stone for that matter, progresses in the downward direction rather than horizontal. In the aggregate mining industry, economics almost always dictate that only deposits that have a few feet of overburden on top of a considerable depth of sand and gravel be worked. There is therefore a high proportion of product, per land area disturbed. This is most unlike the case of coal, wherein relatively vast land areas are disturbed in relation to the recoverable product. Since there is very little unused material with which to return the land to its original contour, the appropriate reclamation goal must be different than that specified for coal in the federal Surface Mining Control and Reclamation Act.

When the Surface Mining Control and Reclamation Act regulating coal was passed by the Congress it specifically directed the Council on Environmental Quality (CEQ) to undertake an in-depth study of the surface mining of non-coal minerals and to submit to the Congress a report with recommendations concerning possible reclamation regulations. CEQ was charged with analyzing the coal legislation to determine its applicability to other minerals. After two years of study and evaluation CEQ issued its report in May, 1981. CEQ aptly cited the many differences among mineral commodities. The Council noted the inapplicability of many aspects of the coal act to the aggregates industry and specifically recommended against federal regulation for the reclamation of mined sand and gravel lands.

CEQ stated in its official report to Congress, "For commodities of primarily local impact, such as sand and gravel, which is increasingly regulated at the state and local levels as well as subject to specific federal environmental controls, further direct federal enforcement programs appear unnecessary." While recognizing that state enforcement of reclamation programs is uneven, the CEQ found encouraging trends and cited as the most productive federal goal the bolstering and nurturing of these efforts.

Thirty states currently have a state surface mining law applicable to sand and gravel. In thirteen states without such state laws sand and gravel operations are regulated under county or local laws. Close to 80% of the tonnage of sand and gravel produced in the United States is therefore regulated at the state or substate level. In nine states accounting for approximately one-third of the nation's tonnage, dual jurisdication requiring separate permits from the state and county or other local entity is widely prevalent.

CEQ's report advised regulatory agencies to consider large mining operations of national significance separately from ubiquitous sand, gravel, and other construction aggregate mining operations because of major differences in economic, environmental and sociological factors.

WILDLIFE VALUES OF GRAVEL MINES

CEQ specifically recommended allowing innovative and creative reclamation approaches, recognizing that it is not always possible to restore mined land to a "natural state." It is possible however, to restore mined lands to a state that is more ecologically productive and useful than its original condition.

Lakes and ponds remaining after mining often become stopping places for migrating birds. Gravel banks are known to provide superb nesting places for such birds as the bank swallow. Even ponds resulting from abandoned gravel pits have proven so productive in increasing an area's species diversity that retired biologist Worth Randle was moved to exclaim that "Gravel Pits are the only thing I know created by man, when left behind, are actually beneficial for wildlife." Sometimes successful varieties of non-native vegetation are introduced during the reclamation process and improve and diversify the ecology of the area in that regard. During rehabilitation shrubs can be introduced that provide valuable food sources for wildlife species at a faster rate and in greater numbers than natural reseeding could achieve.

FACTORS INHIBITING RECLAMATION FOR WILDLIFE HABITAT

While state and local regulations and their administration do in some cases present roadblocks and disincentives to reclamation for wildlife habitat, other factors tend to be more predominant as inhibiting influences. These include the loss in economic terms in urban and suburban areas as opposed to potentially high profits for intensive development of lands with skyrocketing appreciation. The potential loss of a high financial return is understandably a significant factor. However, other discouraging factors in addition to inflexible regulations and low economic return are as follows: 1) the short-lived nature of public relations benefits derived from previous "good performance" 2) difficulties in working closely with local government bodies on long range planning; 3) counterproductive tax policies; 4) concerns over liability; and 5) neighborhood opposition to public places planned for their areas.

First it should be understood that as a general rule the economics of the situation is the reverse in rural as opposed to urban and suburban areas. In the more rural areas where less financial return on the land is feasible and therefore more expensive reclamation and land development work is neither desired nor practical, much of the land is reclaimed for open space purposes -- passive recreation, wildlife habitat and agriculture.

Inflexible state and local regulations requiring time consuming procedures to modify stringent or uniform slope requirements, backfilling and highwall elimination requirements more applicable to coal operations and prohibitions against any mining below water make many types of wildlife habitat development more difficult. In some arid states water laws concerned with pond evaporation necessitate purchase of water rights prior to creating new wetland habitat.

Some regulations are contradictory and ignore the different needs of various wildlife. Birds of course make the best use of shallow water while large fish require deeper depths. Creation of gentle slopes into the water body will promote the growth of aquatic vegetation required for the resting and feeding of fish and waterbirds. Reclamation requirements must be based on the needs of the specific species for which habitat is being provided.

Reclamation statutes that require the very subjective concept of "restoring the land to an equivalent or higher and better use" than existed prior to mining can be red flags to companies that might see wildlife habitat opportunities but shy away from a long drawn out fight with regulatory authorities. They may also not want to risk the negative public image that might result in the minds of those who feared the company was just trying to minimize its reclamation costs or avoid its responsibilities.

In urban and suburban areas where the financial return from intensive commercial or residential development is alluring and an overwhelming personal interest in alternative reclamation is not prevalent, other incentives such as public relations benefits must be present. Unfortunately, the experience of most companies, among them those widely acclaimed for reclamation and land stewardship, is that when it comes to decisions on approving new mine sites, the public relations benefits derived from good past performance tend to be short-lived. Nearby residents and those not so nearby to proposed mines sites tend to vehemently oppose such an operation regardless of all other factors, including the area's need for the aggregate at a reasonable cost and the company's particular record and reputation in being a good neighbor and responsible land steward.

Time and time again, even when planning professionals of local governments recognize the need for such operations, such public pressure is brought to bear on elected officials that gaining new permits is extremely costly and difficult for even the most respected producer. On top of this, locally-based and local chapters of national environmental groups have at times become involved in efforts to prevent mining activities indiscriminately. One would hope that more good would be gained if potential opponents analyzed the record of company actions and in deserving cases supported mining, thus restoring incentive to be derived by those in the construction aggregates mining business who pay close attention to their public and environmental responsibilities. Although this has occurred in several instances many producers feel that there is very little connection between either the presence of well-enforced state reclamation laws or past reclamation practices that generate good public relations and their ability to receive approval on new mining permits. Such a sad state of affairs hurts everyone in the long run for it provides little incentive to encourage good operations that can provide aggregate to consumers at reasonable prices.

Along these same lines lies the question of reserve land held in considerable quantity by mining companies. Increasingly, pressure is brought to bear by local groups against mining companies to preserve trees, farmland and wildlife habitat on company land as soon as an application for a mining permit is made. While special arrangements can and have been made to preserve sensitive or ecologically significant areas and mitigate the impact on wildlife on the mine property, such pressure which threatens the possibility that extreme restrictions may become a condition of the permit may force the company in the future to take drastic action to eliminate such a threat -- exercising the right of any property owner to clear his land upon purchase. Allowing wildlife habitat areas to remain until the land is needed for the production process is a much better way to proceed.

Concern over increasing the assessed tax value of the land and liability exposure for public use of private lands are serious restraints on development of private land for public purposes. Some states have taken concrete steps to overcome these obstacles as will be discussed later.

One unlikely inhibiting factor is neighborhood opposition. Despite the fact that the end use of the reclaimed land would be an attractive one, some residents strenuously object to providing any area within their neighborhood for public use. Neighbors fear increased traffic and noise in their neighborhoods. A number of mining companies have had to shelve plans to donate lands to the public for these reasons.

Another factor inhibiting reclamation of mined lands and their donation to municipalities or counties for recreation, parkland and wildlife habitat arises from the difficulty of engaging in long-range planning with officials in decision-making positions for only short-term tenures. Frequent changes on the part of the elected officials and agency personnel make it difficult to get the necessary long-range commitment when you're talking about planned land use ten or twenty years or more down the road.

Although it is often preferable that mining and reclamation be pre-planned and integrated in a progressive and sequential manner as previously described, reclamation is by its very nature a site-specific activity. The appropriate end use for each site depends on many factors including the physical features of the land; the value and demand for land in the area; local zoning provisions and land-use plans; and other social and political factors. Choosing a very specific final land use many years prior to the completion of mining does not always serve the best interests of the local government, the community or the operator. In some instances it is not easy to predict what land uses and community needs will develop and become priorities ten to twenty years before they come to pass. Since the objective of reclamation strategies should be to restore the mined land to a condition that is suitable to and amenable to existing or prospective uses of surrounding land and no proposed use is clearly the "appropriate" one, another flexible, "interim" use may be desired. In cases where state and local governments may require that the end use be specified before a permit is issued and there is great doubt as to the land's most appropriate use, open space and wildlife habitat provide potential "interim" uses that are both feasible and beneficial.

FACTORS ENCOURAGING RECLAMATION FOR WILDLIFE HABITAT

What are the major factors that tend to encourage the use of mined sand and gravel lands for wildlife habitat or open space? An informal survey of industry leaders reveals several forces which exert a positive effect. It is not really possible to separate out single, independent factors since several are usually present in a different mix in each instance. However, with the tremendous constraints placed upon the producer and his ever-present need for renewal of old and approval of new permits to continue to stay in business, perceived public relations benefits are often a primary factor in decisions to reclaim mined land for wildlife habitat regardless of whether or not such land remains in private hands or is donated or traded for other lands to a public entity. Public relations is a difficult area to discuss since it means many things to many people. Everyone in business has relations of some kind with the public. Good public relations is nothing more nor less than good performance, publicly appreciated. The sand and gravel producer has proven more capable of generating appreciation for good performance from governmental planning bodies than from current or potential neighbors.

In rural areas where reclamation and development of mined land for commercial and residential building is not practical or desired, agricultural, wildlife habitat and recreational uses are more common. In some rural areas it is considerably less costly to reclaim the land for wildlife habitat than it is for other productive but noncommercial and nonresidential uses. In more urban and suburban areas, creating wildlife habitat or public parks is sometimes a financial sacrifice decided upon for the sake of good public relations as defined above or as a precondition in the permit approval process.

In many of the more urban areas the need for open space, "green zones" and wildlife habitat sanctuaries is so great that comprehensive land use planning and cooperation between communities, industry and government have led to everyone's mutual benefit. Innovative efforts in cooperative land use planning like one currently under way in Colorado facilitate the the involvement of sand and gravel producers in managing human growth pressures on wildlife by preserving and creating habitat areas.

In Colorado, the Colorado Rock Products Association and the Colorado Division of Wildlife (DOW) are working together to provide habitat out of gravel pits and rock quarries for wildlife, including fish, waterfowl, and small game and non-game animals and birds. Upon the initiative of the producers, DOW professionals are evaluating the suitability of existing or completed sites as wildlife propagation areas and refuges or public recreation sites. Suitable plans will be supported by direct testimony from DOW personnel before county commissioners determining mining permit and reclamation plan approval.

The DOW offers fish and some wildlife stocking and management services and liability insurance to provide a rearing area or public access for fishing. In addition to being authorized to buy an appropriate site, the DOW can lease a site or work out a wildlife easement. Since the DOW cannot provide or fund such non-game services or facilities such as trash management, fencing, picnic tables, etc. service organizations, recreation districts and cities and counties are encouraged to join in cooperative arrangements.

Another current example of cooperative reclamation is taking place in the province of Ontario, Canada. Aggregate producers have donated a 100 acre site to the province's Conservation Authority for use as wildlife habitat. The Authority has accepted responsibility for management of planting and vegetation with much emphasis placed on natural regeneration.

Tax benefits can be a significant incentive to donating land to public entities or private conservation groups like the Nature Conservancy. However, such tax benefits themselves are rarely large enough for the bigger corporations to be the prominent consideration for donating land. Many of the larger companies, like Dravo, headquartered in Pittsburgh, Pennsylvania, have donated unique lands such as an island in the Allegheny River that serves as a feeding ground for migratory birds. The island was given to the Western Pennsylvania Conservancy and acreage in the Little Miami River Watershed was also given to the Nature Conservancy because of the company's recognition that the land was of unique ecological value and that its most appropriate use was for wildlife habitat. In analyzing the factors that motivate sand and gravel companies to reclaim or donate land for wildlife habitat the recognition that the land in question is most appropriate for such use and the personal commitment to such values are perhaps the most overlooked and underrated.

In many circumstances the land being mined is leased and the decision to create wildlife habitat is made by the private landowner.

In Illinois, a Forest Land Incentives Act encourages putting lands into "conserving areas" by directing the Department of Conservation to rebate 80 percent of the taxes paid on registered forest land. This allows mining companies to plant their reserve land in trees or let it revert to forest naturally while not using the land without being subjected to increased taxes for so doing. Pennsylvania provides a similar incentive to encourage prime agricultural land preservation wherein such land left in agricultural production is assessed at a lesser value for tax purposes.

State and local regulations which distinguish between mineral commodities and allow for flexibility and creativity in reclamation requirements are most conducive to reclamation for wildlife habitat. For example, the ideal slope for any reclamation project is a function of the after use planned. Regulations that take natural conditions into account and allow in some circumstances for fairly steep slopes, etc., provide ample opportunity for innovative wildlife habitat preparation to be undertaken. The Illinois Surface Mined Land Reclamation Act, for example, provides that:

> Exceptions to regulations should allow for interesting and challenging deviations from the more traditional plans for recreation development. For example there may be allowance for non-grading in certain areas so as to permit natural revegetation, development of wilderness type facility, certain scenic or landscaping opportunities, planned sites of isolation or interesting and unusual hiking and riding trails.

REGULATION: PROTECTING DEPOSITS AS WELL THE LAND

Although it is highly unlikely that the supply of sand and gravel will ever be exhausted it has become scarce and costly within certain areas. In a few areas commercial deposits necessary to meet demand do not exist in close proximity. In many others unplanned growth and restrictive zoning have precluded extraction and created "artificial" shortages. With the price of sand and gravel doubling every 20 miles it is hauled to the customer such preemption of existing deposits has a tremendous financial impact on the cost of construction. Ironically, environmental impacts tend to increase in such areas as well, as aggregates are transported mainly by truck over greater and greater distances.

Regional and local land use planning can and in several areas is employed to identify commercially feasible deposits in areas of projected growth and to protect them for future extraction. Such resource plans hold the potential for providing the maximum value from the land while reducing the opportunity for conflicting land uses. Low-cost aggregates and well-planned end uses can also be assured. It is important, however, to preserve a number of sites to promote competition within the industry and avoid giving undue advantage to one operator over another. Protection techniques being used in addition to the more common zoning powers include: special extraction districts where mining is established as the primary land use and other uses are allowed subject to special permit; overlay districts, where resource extraction is allowed while the longer-term existing use designation is preserved; mapping deposits into existing zoning districts whose uses do not conflict with future extraction; and state action to classify, designate and protect extractable resource areas.

In California, under the state's Surface Mining and Reclamation Act of 1975, the state undertakes identification of deposits and assesses the market demand in each area. Deposits are classified into mineral resource zone (MRZs) and deposits of regional or statewide significance are designated for protection. Local governments take part in the designation process and are required by the law to incorporate a conservation element into their general plan and develop their own planning tools to protect identified resources.

The Colorado Mined Land Reclamation Act similarly requires local planning for protection and extraction of sand and gravel deposits. However, neither of these innovative laws are to the point in their implementation where intentions are being realized. An additional resource protection approach is to use transfer of development rights (TDRs) in a fashion similar to the way it is being used in Montgomery County, Maryland to preserve farmland. In exchange for foregoing development on parcels near extraction sites developers can be allowed higher densities for sites away from the mining area.

SUMMARY

Surprising as it may seem, regulation and sound land use planning may be of great benefit to the consumer and producer alike. And for the benefit of wildlife as well. Lands designated as sand and gravel resource areas in which development is not permitted prior to mining can serve as wildlife preserves near urban or suburban centers. Following mining, areas left undeveloped, especially those with wet pits and with some adjoining unmined lands, may serve the same purpose.

Performance oriented requirements recognizing differences between minerals and allowing for local flexibility, innovation and creativity tend to promote responsible and responsive behavior on the part of the regulated community. Such an approach provides the opportunity for real cooperation among industry, local government and the planning community with the possibility that common needs may be served and in this case more mined gravel lands reclaimed for wildlife habitat and open space than might otherwise occur. The increasing acceptance by both government and industry of sound land use planning, including preservation of aggregate deposits for future extraction, will stimulate the use of appropriate mined gravel lands for wildlife habitat and open space.

The industry certainly desires the good public relations benefits that come from such cooperation but we all need to work toward making these benefits more sustainable to increase their influence as a motivating factor. Regulation and land use planning are by their very nature double-edged swords. When wielded recklessly or improperly they can do much damage but when skillfully and evenhandedly applied they can bring about much good. Sand and gravel producers provide not only important materials for construction and other purposes, but a unique opportunity to help shape the communities in which they live and operate. A practical regulatory framework and sound land use planning will help them work with others to create and preserve open space and wildlife habitat in conjunction with the wishes of these communities.

LITERATURE CITED

AHEARN, VINCENT P., JR. 1964. Land use planning and the sand and gravel producers. National Sand and Gravel Association, Silver Spring, MD. 30 pp.

WERTH, JOEL T. 1980. Sand and gravel resources: protection, regulation, and reclamation. American Planning Association, Chicago, IL 33 pp.

NATIONAL ACADEMY OF SCIENCES. 1980. Surface mining of non-coal minerals. appendix I: sand and gravel mining, and quarrying and blasting for crushed stone and other construction minerals. National Academy of Sciences, Washington, D.C. 91 pp.

BUREAU OF MINES. 1982. Land utilization and reclamation in the mining industry, 1930-80. U.S. Dept. Inter. Bureau of Mines Information Circular. 22 pp.

BUREAU OF MINES. 1980. Minerals Yearbook. U.S. Dept. Inter., Washington, D.C. 950 pp.

SCHELLIE, KENNETH L. 1977. Sand & gravel operations: a transitional land use, National Sand and Gravel Association. Silver Spring, MD. 212 pp.

COUNCIL ON ENVIRONMENTAL QUALITY. 1981. Regulation of surface mining and reclamation for minerals other than coal. A report to the President and the Congress, pursuant to Section 709 of the Surface Mining Control and Reclamation Act of 1977. Council on Environmental Quality. Washington, D.C. 46 pp.

NATIONAL ACADEMY OF SCIENCES. 1979. Surface mining of non-coal minerals. A study of mineral mining from the perspective of the Surface Mining Control and Reclamation Act of 1977. National Academy of Sciences. Washington, D.C. 339 pp.

Economics of Gravel Pit Reclamation for Wildlife

JAY A. LEITCH. Department of Agricultural Economics, North Dakota State University, Fargo, ND 58105.

During the settlement of North America, wildlife was a valuable commodity. It was the main food source of early settlers in this area. The importance of wildlife for man's direct livelihood diminished as the country developed. What is wildlife worth to society today? Each person may be able to express in general terms what it is worth to them as individuals and probably what they think it is worth to society. General, subjective arguments, however, do not maintain wildlife habitat.

What better use can you think of for an abandoned gravel pit than wildlife habitat? With a little effort, abandoned mine areas make very good habitat (Holland 1973, Kerr 1977, TVA 1969). The answer depends on your perspective; whether you are a farmer, a public official, an agribusinessman, or a sportsman club member. It also depends on where you reside: next to the site, in a nearby town, or in an urban area far removed from the site. These two sets of characteristics are not totally exclusive. One individual could operate a farm, be a public official, own land next to the site, . . .

Post-mine land use will be determined by default if there are no competing uses for the site or by conscious decision where there are competing uses. A conscious decision can be made by the site owner, whereby the decision is influenced by market forces. Alternatively, the government can mandate via regulation (zoning) what can and cannot be done with post-mine land. The government can make a collective decision after determining the best alternative.

Ignoring the "do nothing alternative," we are left with a private market decision or a government decision. There are problems with both. The government decision is dependent upon jurisdictional size, composition of the constituancy, and politcal influences. An efficient market allocation will usually not be forthcoming when nonmarket goods or services--wildlife habitat in this case--are components in the decision making process.

WILDLIFE AND PROPERTY RIGHTS

The fundamental problem with efficient market allocation of wildlife resources is that wildlife is available on a basis which does not reveal how much we would be willing to pay for the activity. Wildlife is typically not priced in the market (Langford and Cocheba 1978). Everyone owns wildlife, so in effect no one owns wildlife. History and tradition have placed the burden of protecting and managing wildlife resources on the public sector. States have taken the management role for all but migratory wildlife (and threatened and endangered species), where the Federal government has implemented general guidelines. Government assumed those responsibilities because of the common property nature of the resource.

Most of you have heard or read Garret Hardin's "Tragedy of the Commons" parable, where a pasture was held in common by a village. Because no single owner could be identified, each user overused the pasture to his own benefit at the expense of other users. Eventually the pasture was worthless to all. A contemporary paradigm could be the "tragedy of the automobile." Assume that all private ownership rights to cars were abolished at this moment. People would be free to use any car they wished. What would happen? We would each go to the parking lot and select a car to drive home. Someone else would come along tomorrow and take the car from in front of our house. When it came time to fill with gas, the person would take another car with gas in it if that were more convenient than filling the tank. People would put in only enough gas to get to their destination--if you put any more in, someone else could use it. Neither would there be an incentive for maintaining the car. We would just look around for one that ran. An individual would have no incentive to replace the tires, nor fix a crumpled fender. The end of this story would be a nation of run-down automobiles, held together by baling wire, just able to get from point to point. Eventually the stock of usable cars would decline to zero, because there would be no incentive to purchase new cars. Two results may then come about: 1) individuals could enforce their own property rights; or 2) the government could reinstate private property rights in automobiles.

There are no property rights for wildlife, at least not until they have been legally captured by licensed sportsmen. A free flying mallard belongs to all of us. A mallard in my hunting jacket, however, is my personal property. A whitetailed deer standing in a meadow at dawn belongs to everyone and no one. In November, that same deer in the back of a pickup belongs to whomever has legally tagged it.

Wildlife can be both a public good and private property, the distinction being made by the nature of its use. A private good can be consumed by only one person, those not willing to pay can be excluded. An automobile is a private good--only one person can consume a single automobile, once it is purchased no one else can purchase that same auto. A can of beans is a private good, only one person (or consuming unit) consumes the beans. Consumption of private goods is rival (my consumption rivals yours) and exclusive (you can be excluded from consumption if you do not pay).

Public goods on the other hand are not rival; that is, one person's consumption does not affect another's. For example, an individual in Crookston may watch a flock of migrating Canadian geese; that use does not detract from my use as they fly over Moorhead. Another characteristic of a public good is that exclusion is not feasible, once available to one person it becomes available for all. It would not be feasible to exclude potential viewers from watching the flock of Canadian geese. Since exclusion is not feasible, no one can be forced to pay for the privilege of use. Noncontributors can still view the geese, they are called "free riders" by economists.

With some exceptions, the free market works fairly well for the allocation of private goods. However, it does not work at all for public goods because of the free rider effect and other common property characteristics. In addition, wildlife are "mixed" public and private goods making it imperative to develop surrogate market prices or economic values to insure survival in a market economy.

The net result of the common property/public good problem regarding wildlife resources has been enactment of government regulation to prevent overharvest or misuse as in the hypothetical case of the unowned automobiles. Private investment in wildlife production (except for private game farms) is limited to philanthropy and forced contributions (license fees, migratory bird stamps) from sportsmen. There is little incentive for private entrepreneurs to produce common property wildlife resources--they would pay all the costs of production and reap only a portion of the benefits.

WILDLIFE VALUES

Wildlife resources are valued for a variety of reasons ranging from a basis for protective legislation to setting fines for fish kills. Most often a value has been placed on wildlife or wildlife habitat when they have been components in benefit/cost analysis. In many cases there are established guidelines for evaluators when estimating either potential of foregone wildlife benefits from proposed land-use changes (U.S. Water Resources Council 1969). There are relatively few benchmarks for valuing site-specific, marginal changes such as gravel pit reclamation.

Wildlife related activity can be catagorized into three general groups for purposes of economic evaluation: 1) consumptive activity, 2) nonconsumptive or appreciative activity (Hendee 1969), and 3) option or existence values.

Consumptive activites are those where the wildlife may be transferred to possession (private ownership) and physically removed from its environment. Examples would be hunting, trapping, and fishing.

Nonconsumptive activities are those whenever wildlife form a part of the basis of an experience but is not "used up." Birdwatching, watching wildlife programs on television, or viewing wildlife while participating in some form of wilderness or outdoor recreation would be nonconsumptive uses of wildlife. Included in this group could also be potential gene pool values, medicinal values, biological diversity values, and educational (Brainerd 1965) or scientific values of wildlife.

Examples of existence values would be the values some of you hold for blue whales, you value their existence although you may have never seen one. Satisfaction is derived from simply knowing that blue whales exist. More specifically, option values are held by individuals who place value on having the option, for themselves or others, to participate in a wildlife related activity in the future. In the case of blue whales you value the option of one day being able to see a blue whale in its ocean habitat.

Each of these three general types of wildlife value is important and has been reviewed at length in the literature (Leitch and Scott 1977; Daniel, Zube and Driver 1979). This discussion will be limited to consumptive and nonconsumptive activity values. They comprise the majority of habitat reclamation benefits at the margin.[1]

---

[1]We are concerned with the values of reclaimed habitat at the margin. In other words the value of one more or one less habitat parcel and not with the value of either all or no habitat.

Values of Consumptive Activity

Consumptive activity values are the easiest to estimate because participants are licensed and the activity is regulated. There is a host of literature on recreation valuation, most of which is either theoretical or site specific. While there are many methods for evaluation (Brookshire et al. 1978, Coomber and Biswas 1973, Dwyer et al. 1977) which rely on various data bases, only an expenditure based procedure will be discussed herein. Expenditures are not equivalent to value, but as will be shown can be used to compare alternative land-use values.

What people spend during nonmarket, consumptive recreation activity is analogous to the prices paid for marketplace experiences. The last dollar spent for the recreation experience yields a unit of satisfaction equal to the last dollar spent in all other alternatives. If the last dollar spent yielded more than a dollar's worth of satisfaction, they would have spent yet another dollar; conversely, if it had yielded less than a dollar's worth of satisfaction it would not have been spent. Many of the inputs into a recreation experience are unpriced (i.e. public goods), which does not invalidate this marginal value rule, it simply allows consumption beyond what it would be if all inputs were priced.

A factor that complicates placing a value on wildlife or wildlife habitat is that the price paid represents willingness to spend for the entire experience. A recreation experience can have up to five components: 1) planning and anticipation, 2) travel to, 3) on-site activity, 4) travel from, and 5) recollection (Clawsen and Knetsch 1966). Wildlife can play a role in any of the five components, more significant perhaps in some than others. The difficulty is twofold: 1) wildlife is only one part of the overall experience, and furthermore 2) it is the habitat we seek to value. This second factor raises the question of "What portion of the value of wildlife can be attributed to certain habitats?" A mallard, for example, may have been raised on the Saskatchewan prairies, fed on North Dakota durum and Nebraska wheat, rested in Kansas, and wintered in Mississippi. A dollar value for many wildlife species still leaves us one step removed from a value for its habitat.

Our problem with gravel pit habitat is not so complicated as it may seem. We need a method to make a rational, local decision. The wildlife values of a single gravel pit are insignificant at the national or state level. We have shown that a rational private sector decision will not be forthcoming. The decision we seek is based on local or regional values of reclaimed habitat. For the moment, assume a reliable estimate of expenditures made by recreationists in pursuit of wildlife related to reclaimed gravel pit habitat is available. Census takers in the vicinity of the habitat during hunting and trapping seasons could collect this information if necessary.

Values of Nonconsumptive Activity

Valuing nonconsumptive wildlife uses beckons even more problems than does valuing consumptive uses. This is due to the fugitive nature of the resource, the wide variety of users and types of use, the tendency for strategic behavior, and site specific nature of gravel pit habitat. Nonconsumptive activities occur at all times throughout the year, in virtually any location from your breakfast table to Horicon Marsh. It is virtually impossible to identify, much less locate, participants in able to collect expenditure and use data. Even if they could be asked their expenditures or asked to place a value on their use there is a tendency for strategic behavior, not unlike the free rider problem. An individual birdwatcher, for example, has no incentive to pay for the privilege of birdwatching, since one individual's contribution is not significant to whether or not the activity remains available. Rational individuals would be free riders, rather than contributors. If however, the birdwatcher feels he may be charged a fee in the future, there is a tendency to underestimate his value estimate. Alternatively, if there is a feeling that the resource might be threatened by low values, the tendency would be to overstate individual values.

While there exist several alternative methods to value nonconsumptive recreation activity, none is readily applicable to gravel pit reclamation nor easily implemented without rigorous data collection or sophisticated economic models. An estimate of the number of user days may be the best alternative to complex studies.

Estimation of wildlife values in dollar terms remains a formidable problem. There are several characteristics that combine to aggravate the issue. Primary among them is that there are little or no market transactions involved where a common denominator of value--the dollar--is employed. There are no available valuation techniques which are without serious limitations, no matter which is chosen it is not reasonable to expect a high degree of precision (Langford and Cocheba 1978). Nevertheless, defensible approximations of value can be extremely useful for making rational decisions regarding post-mine land use.

Review of Literature

Few studies reported in the literature provide dollar figures for individual animals

(Lonner and House 1977) or acres of habitat, rather, most present aggregate values for geographic areas or user groups. Unfortunately, the values that have been reported are not readily generalizable to other situations, especially not to such site specific cases as reclaimed gravel pits. Some examples are provided for illustrative purposes, however.

The American Fisheries Society (1975) estimated the monetary values of fish using hatchery price as a proxy for value. Largemouth bass had an estimated value of $2.85 per pound; walleye $4.56 per pound; catfish $1.14 per pound; and northern pike $3.99 per pound. Even at those prices most of us would be better off buying our fish than catching them! However, the value of the fish is only one part of the value we place on a day of fishing.

A 1971 outdoor recreation survey of southeast U.S. recreationists (Horvath 1974; Skow 1977) provided data for estimates of the compensation required to induce people to give up recreation days and the value they placed on each day. The average daily value reported for nonconsumptive wildlife enjoyment (animals) was $80.30, while respondents reported $107.06 was necessary to induce them to forgo a day of wildlife enjoyment.[2] Big game hunting, a consumptive activity, was valued at $60.86 per day; with a compensation payment of $81.98 required to reduce activity by one day.

The cost to replace a deer lost due to habitat destruction in Colorado was estimated to be $709 (Norman et al. 1976). Other habitat replacement estimates include $21 for ducks, $169 for geese, and $33 for sharptail grouse. Values such as these can be extremely useful in determining the economic value of reclaimed mineland for wildlife habitat, however much work is required to develop methodologies that will generate universally acceptable estimates.

LAND-USE ALTERNATIVES: THE PROBLEM AT HAND

The problem to be addressed is the allocation of post-mine land use. It was mentioned above that the decision can be left to the market or made by the public sector. We argued that a market decision would not be efficient because of the public good and common property characteristics of wildlife and wildlife habitat. However, in order to make a rational decision in the public sector, alternative uses must be compared on common grounds or using a common denominator. This common denominator is the dollar. We argued that an individual will not make outlays for wildlife since a disproportionate share of the benefits would be lost to free riding users. The only case where a private individual could capture a large percentage of the benefits is if the reclaimed area were converted to a game preserve with admission fees. We must turn instead to the public sector to provide the desired level of public goods. The wildlife benefits of a reclaimed gravel pit are one such public good. If it is a public decision, it is public values that should be considered and not private.

The Issues

Despite the relative insignificance of land taken out of other productive uses by wildlife habitat, local decision makers believe there are several problems that arise, especially if the area is publically owned. Problems include economic effects, land management problems, and threats to the autonomous decision making authority of local public officials and citizens. Potential economic impacts arise from placing land in a use that is typically thought of as nonproductive. The operation of local gravel pits generates local revenues in the form of property taxes, incomes to workers, sales of gravel, purchases of productive inputs (fuel, machinery), and purchases of services (repair and other business services).

Post-mine alternative land-uses may include agricultural, residential, industrial, or abandoned gravel pit. If the gravel pit is left idle when the resource is exhausted, nature generally provides for wildlife habitat within a few years. In this case there is little to be done in the short run to ensure the area is kept as a habitat. However, if there are viable economic alternatives to abandonment, the relative value of the alternatives must be weighed. We will assume the gravel pit does not cover a large expanse of land so its impact is primarily local[3] (one or more contiguous counties).

---

[2]It was not clear from the source whether people were asked to forgo a day at the margin, in other words the last day of participation, or whether this value represented a daily average to forgo all days. The possibility of strategic behavior and other potential shortcomings of this particular study are recognized. Strategic behavior may be suggested in the self valuation of $80 while willingness to sell is $107.

[3]The issue takes on a different set of considerations when viewed from a national perspective. From society's viewpoint, wildlife habitat should be maintained as long as the total net social value is greater than it would be with the next best alternative land use. However, local decision makers are quick to point out that it takes real dollars to buy snowplows and build roads, and not derived measures of society's values.

The onerous economic problem is income foregone due to reduction in business activity. A shift from an active gravel pit to wildlife habitat may result in fewer employment opportunities in both the primary industry and in sectors that service that industry. This is directly related to business income flows and can be assessed after business flows have been estimated. However, we are not comparing operating gravel pits with wildlife habitat, rather the alternatives are post-mine gravel pit uses. Let us assume for the purposes of this discussion that the best alternative use of a gravel pit is agriculture. It then becomes a matter of weighing the local benefits of agriculture against those of wildlife habitat. The choice is to be made by local governments because if left to individuals in the marketplace an inefficient allocation would result.

Methods

Input-output analysis will be used to compare the local economy dollar flows resulting from alternative post-mine land uses. Input-output analysis is a technique for tabluating and describing the linkages or interdependencies between various industrial groups within an economy.[4] The economy considered may be the national economy or an economy as small as that of a multicounty area. Production by any sector requires the use of inputs, or direct requirements. Some of these will be obtained from outside the region, but many will be produced by and purchased from other sectors in the regional economy. Indirect requirements are a result of additional rounds of input requirements of supporting industry. Total direct and indirect input requirements of each sector are called the input-output interdependence coefficients multiplier. Each coefficient represents the total (direct and indirect) input requirement that must be produced per dollar of output for final demand. Final demand is output by a sector that is sold outside the region.

The input-output model is appropriate to evaluate marginal land-use changes in terms of regional impact only if much internal interdependence exists. Direct, indirect, and induced effects can be estimated. Direct effects are those payments from outside the region to sectors inside the region producing export commodities. Indirect impacts are those that occur within the exporting sector as a result of the sale to outside the region. Induced effects are those that ripple through the sectors that support the exporting sector, the residentiary sectors. In addition to effects on the levels of gross output, employment level effects can also be estimated.

Since data were not available for either the costs of reclaiming gravel pits for alternative uses or the dollar flows resulting from post-mine gravel pit wildlife habitat, results from a similar study comparing wetland habitat and cropland are used (Leitch 1980).[5] We can assume *a priori* that similar conclusions would be reached if reliable estimates of these costs and dollar flows were available.

RESULTS

The study to which we will defer investigated the alternative impacts of producing agricultural crops or maintaining wildlife habitat on a 76 acre parcel in west central Minnesota (Leitch 1980). These competing land-use choices are not unlike those faced with post-mine gravel pits in rural areas.

An average sized parcel (76 acres) was found to generate $12,654 in crop sales annually.[6] The sale of this annual agricultural production by an individual farm operator resulted in $27,459 in gross sales in the region, $8,390 of which went to households (a high percentage to the farm operator) in the form of personal income, and provided employment of 0.87 persons. The same parcel managed for wildlife habitat accounted for $10,752 worth of initial round transactions and generated $20,399 in regional gross sales, $12,642 in regional personal income to households (including payments to the former landowner), and provided employment for 0.94 persons.

Looking only at gross sales, one would conclude that cropland was better for the regional economy than wildlife habitat. However, since both personal income and employment are greater for wildlife habitat, that use of land tends to benefit the region more. Wildlife habitat generates more personal income because much of

---

[4]The input-output model was initially developed and explained by Leontief (1951). Maki (1979) discusses the literature in detail.

[5]Dollar flows resulting from farming an acre of land are readily available, however the cost to convert mine land to productive agricultural land is an extremely significant yet unavailable variable. Dollar flows from wildlife habitat can be found in Anderson *et al.* 1976, Leitch and Nelson 1976, or Leitch 1978 but none of these are directly applicable to the case under study.

[6]This analysis assumed initial private ownership was transferred to public ownership to be maintained as wildlife habitat. The significant dollar flows are those in the regional economy and not necessarily private sales, which however are the driving force behind regional dollar flows.

the dollar flow into the local area goes to households which spend it locally, as compared to purchase of productive inputs for agriculture where leakage exists through input purchases from outside the region (e.g. fuel, machinery, fertilizer imports).

The economic impacts on the local economy favor wildlife habitat over agricultural production, given the posited conditions in the study. This is due, firstly to the marginal nature of the change, and secondly, to the fact that wildlife habitat was found to generate higher household income and greater employment than cropland. The local personal income and employment "multipliers" for wildlife related activity were higher than for agricultural activity.

In the examples of estimated wildlife dollar values given above, nonconsumptive uses were seen to be valued more highly than consumptive (Horvath 1974). I-O method presented was limited to dollar flows from expenditures for consumptive recreation. If the value of nonconsumptive recreation were included the resulting estimated local dollar flows due to habitat maintenance could be considerably larger.

SUMMARY AND RECOMMENDATIONS

This type of analysis is sensitive to the income and expenditure flow assumptions, especially on the wildlife habitat side. Significant variables affecting the outcome include the specification of sectors receiving income flows, crop prices, recreation expenditures, land owner equity position, reclamation costs, and the very long-run implications. As long as reclaimed gravel pit habitat constitutes only a very limited portion of overall land use the conclusions reached should hold. However, they are not justification for carte blanche conversion of cropland to wildlife habitat. The conclusions and results can be supported at the margin, and only for marginal changes.

We have discussed the reasons that wildlife habitat allocation cannot be left to the vagaries of the marketplace, leading to an argument for government decisions when public goods allocation is at stake. This did not rescue us from the difficult problem of placing economic values on some aspect of the wildlife resource, however, since rational decision making requires common denominators whether in the public or private sector.

A related case study contrasting wildlife habitat and cropland in west central Minnesota indicated that at the margin, when habitat is only a small proportion of land use, the local community can be made better off with a marginal land use change that increases habitat. This finding is highly sensitive to the structure of the local economy and several underlying assumptions.

Individuals or groups interested in reclaiming a gravel pit for wildlife habitat could use the I-O approach, augmented with site specific data, to aid their local decision makers in making a rational, public decision. Wildlife supporters have little going for them when competing in the private market place, unless they can enter the market and vote with dollars, otherwise they must vote in the political process. Most alternative land uses to wildlife habitat have well established market values, unless similar values are developed for wildlife habitat there is little objective basis for preserving habitat. This paper has shown how the regional economy fares under alternative land uses.

LITERATURE CITED

American Fisheries Society. 1975. Monetary values of fish. Pollution Committee, Southern Division, Nashville, Tennessee. 18 pp.

Anderson, Arlin C., Carroll L. Henderson, and Robert Benson. 1976. Lac qui Parle Wildlife Refuge goose report. Minnesota Department of Natural Resources.

Brainerd, John W. 1965. Natural areas as school conservation education aids. Pages 460-470 in Transactions of the Thirtieth North American Wildlife Conference.

Brookshire, David S., Larry S. Eubanks, and Alan J. Randall. 1978. Valuing wildlife resources: An experiment. REEL Paper #4, University of Wyoming, Laramie. 19 pp.

Clawson, Marion, and Jack L. Knetsch. 1966. Economics of outdoor recreation. Johns Hopkins Press, Baltimore, Maryland. 328 pp.

Coomber, Nicholas H., and Asit K. Biswas. 1973. Evaluation of environmental intangibles. Genera Press, Bronxville, New York. 77 pp.

Daniel, Terry C., Ervin H. Zube, and B. L. Driver, tech. coords. 1979. Assessing amenity resource values. Rocky Mountain Forest and Range Experiment Station General Technical Report RM-68, Forest Service, U.S. Department of Agriuclture. 70 pp.

Dwyer, John F., John R. Kelly, and Michael D. Bowes. 1977. Imporved procedures for valuation of the contribution of recreation to national economic development. Water Resources Center Res. Rpt. No. 128, University of Illinois, Urbana-Champaign. 218 pp.

Hardin, Garrett. 1970. The tragedy of the commons. Pages 31-52 in Garrett de Bell, ed. The Environmental Handbook. Ballantine Books Inc., New York.

Hendee, John C. 1969. Appreciative versus consumptive uses of wildlife refuges: Studies of who gets what and trends in use. Pages 252-262 in Transactions of the Thirty-Fourth North American Wildlife Conference.

Holland, Frank R. 1973. Wildlife benefits from strip-mine reclamation. Pages 377-388 in Russell J. Hutnik and Grant Davis, eds. Ecology and Reclamation of devastated land, Volume 1. Gordon and Breach, New York.

Horvath, Joseph C. 1974. Economic survey of southeastern wildlife and wildlife-oriented recreation. Pages 187-194 in Transactions of the Thirty-Ninth North American Wildlife and Natural Resources Conference.

Langford, William A., and Donald J. Cocheba. 1978. The wildlife valuation problem: A critical review of economic approaches. Canadian Wildlife Service Occasional Paper Number 37. 36 pp.

Kerr, Richard. 1977. Ideas about reclaiming western mined lands for wildlife. Pages 69-73 in Reclamation for wildlife habitat, reclamation workshop II proceedings. Ecology Consultants, Inc.

Leitch, Jay A. 1980. Economic effects of wetland acquisition on rural economies. Department of Agricultural and Applied Economics, P80-18, University of Minnesota, St. Paul. 29 pp.

Leitch, Jay A. 1978. A model to estimate changes in sportsman expenditures due to land use changes in a five-county area of North Dakota. Department of Agricultural Economics AE 78003, North Dakota State University, Fargo. 15 pp.

Leitch, Jay A., and William C. Nelson. 1976. Economic value of wildlife in the Lower Sheyenne River Basin. Department of Agricultural Economics Report No. 114, North Dakota State University, Fargo. 25 pp.

Leitch, Jay A., and Donald F. Scott. 1977. A selected annotated bibliography of economic values of fish and wildlife and their habitats. Department of Agricultural Economics Misc. Rpt. No. 27, North Dakota State University, Fargo. 132 pp.

Leontief, Wassily W. 1951. The structure of American economy. Oxford University Press, New York.

Maki, Wilbur R. 1979. Alternate forecast methods for water and land resources planning in Minnesota. Department of Agricultural and Applied Economics Staff Paper Series P79-29, University of Minnesota, St. Paul.

Norman, Richard L. et al. 1976. Using wildlife values in benefit/cost analysis and mitigation of wildlife losses. Colorado Division of Wildlife. 18 pp.

Skow, John. 1977. Joe Horvath is adding up your dollars of happiness. Outdoor Life 162(3):66-67, 188, 190-192.

Tennessee Valley Authority, 1969. Reclamation brings wildlife back to Paradise Srip Mine. Division of Forestry, Fisheries, and Wildlife Development.

U.S. Water Resources Council. 1969. Procedures for evaluation of water and related land resource projects. Report to the Water Resources Council by the Special Task Force. Washington, D.C.

Lonner, Terry, and Verne House. 1977. How much is wildlife worth? Montana Outdoors 8(7):46-53.

Industry Perspectives on Gravel Mining and Post-mining Uses

RAY LAPPEGAARD. Vice President, J. L. Shiely Co.
St. Paul, Minnesota.

It should come as no surprise that the first perspective of industry, regarding gravel mining, is the economic perspective. Indeed, if the economic evaluation of the proposed project does not show a positive value to the company, there will be no gravel mining and hence, no post-mining use. But since new construction and reconstruction of buildings and roads do contribute to improving the quality of our life, the aggregate producer often finds it possible to justify opening a new gravel mining site to serve these needs and desires for new construction and reconstruction.

At this point, the viewpoint or the perspective with which the industry views the entire subject widens and the potential operator is now concerned with achieving an optimum balance between the economic necessities he or she faces and the social constraints which began in the 60's and continued and became institutionalized to a large extent during the 70's and are now embodied in laws, ordinances, and a plethora of approvals that must be obtained from various governmentally established bodies and agencies.

While many producers would be unable to find any positive values in all these requirements, most of them have now become institutionalized to the point that they are predictable, they can be anticipated and one knows what is required to deal with them. Nevertheless, all producers would state that these constraints should be justified, should be fair, and should be reasonable and should be applied to all producers. Unfortunately, with the amount of regulatory power invested in local communities, the constraints are not always applied fairly and in a reasonable manner.

Stemming from the concern expressed through governmental controls, the industry responds, from its perspective, by wholeheartedly agreeing that reclamation of worked out gravel pits or aggregate resource sites is a desirable objective. One, it is required. Two, because in most instances the operator owns the land and would like to realize additional value from it. He or she recognized the secondary use of the land as an extremely important part of the enterprise.

One of the great attractions of the subject of this symposium - development of wildlife habitat - is that it is almost universally considered socially acceptable and desirable, two considerations which the aggregate producer lists very high on his agenda of desirable qualities.

As is well known the resource, in this instance sand and gravel, is distributed by the dictates of geological history. In other words, it is where nature put it and whenever possible, the producer will try to find the resource as close to the point of use as possible since, as everyone knows, it is a relatively inexpensive product that is expensive to move.

While the locations are fixed in an absolute sense, by geographical history, they are also limited in an economic sense. Transporting sand and gravel any significant distance by truck, for example, does not make good sense. A generally accepted rule of thumb is a twenty-five mile hauling distance equals the initial cost of the product. In addition, other problems are caused by the truck traffic required, again, emphasizing the desirability of the resource being located near the point of use. In many instances, this means near a metropolitan area which is relatively heavily populated.

One of the burning questions that is immediately raised whenever an operator proposes to mine sand and gravel is the question, "After you have finished your operation, how will you restore the land?" At this point we usually get a great number of opinions offered as to what should be done, including denying the permit to the operator to excavate any sand or gravel.

Let us keep in mind that the industry is characterized by small companies, most of them owner-operated, many of them with a background of several years of operation with little or no restraints. Very few employ a staff specialist in public affairs. They are now recognizing that land use problems are of great concern. A concern that has been growing for the last twenty-five years, at least on an organized basis. It's been that long since the National Sand & Gravel Association began publishing its reports on zoning problems and end use problems.

But, in answering this question, "How will you restore the land?" there are a number of pressures on the operator. Generally speaking members of the planning profession are holding those governmental positions of concern to the aggregate producer and, unfortunately, planners are, in most instances, no more adept at predicting the future than others. In this instance, predicting future desires and needs on the part of the local population. As a consequence, most industry members would suggest, as strongly as possible, that an agreement be reached on an end use land form, leaving the details as to what the specific use of the land might be to future members of the governmental body involved and perhaps future members of the company, since in many instances a fairly long time span is anticipated for extraction of the resource from a specific site.

This symposium, however, has raised the possibility of an additional use which has not been usually contemplated, particularly in a metropolitan areas, namely the development of wildlife habitat. Such a use will have to compete with other desired uses such as parks, residential use possibly even industrial or commercial use. This is particularly true near metropolitan areas.

As stated before, the almost automatic response to the suggestion to develop wildlife habitate is positive. Again, to repeat it is socially acceptable and desirable. As you will hear from others, there are a number of instances where the development of wildlife habitat has taken place with considerable success. I would suggest that it should also be considered a possibility, even in a metropolitan area.

Such a use does pose a new problem, I suspect for landscape architects and other professionals who would have to be engaged in the development of wildlife habitat. Biologists, zoologists, specialists in wildlife management, and others representing professions which seem to be developing daily, would have to be involved. In addition, I suspect a fair amount of education would be involved for those planners and representatives of the government agencies involved to achieve understanding that the relatively rough appearance of wildlife habitat in contrast to a metropolitan park area is desirable and should be approved and the operator permitted to let the area develop in that way. This will still require the handling of large quantities of earth materials, grading, planning, screening. Once again, we are talking about land forms and this means that large amounts of material must be bulldozed and molded into the desired land form.

Again, we have the problem that must be faced of how the operator is compensated for the giving over of his land to this purpose. In the case of the operator working on leased land, we have a different problem since the operator would have a hesitancy to invest a sizeable amount in a reclamation program unless it is at least partially subsidized by the landowner as well.

I have been pleased to note in some of the literature describing industry operations that some rather innovative ideas have emerged regarding the governmental bodies' method of compensating the owner of the land who may be the operator, or in some cases may not. In some instances this involves buying the land early on in the beginning stages of the operation by the governmental agency and then leasing back the mining rights to the operator who, in turn, pays a royalty which helps to purchase the land from the operator/owner. Included in these arrangements are fairly explicit plans for reclamation with a harmonious and cooperative arrangement between the governmental body and the operator.

From the industry perspective, one obtains a sense of what can be done over time. To repeat, a number of these operations do involve a long time period and its surprising what changes can occur over a twenty-five year period in the sense of reclamation, development of habitat, of forests, of vegetation, of wildlife. As a personal opinion, it seems to me that governmental agencies have an extremely short time span when it comes to planning usually related, I'm afraid, to the terms of office of elected officials. They feel the pressure of delivering so to speak while they are still occupying the office to which they have been elected. This is not in keeping with the nature of this industry and certainly not in keeping with most reclamation endeavors.

Also, the cries of retaining natural features often times masks a simple antagonism towards the industry and a desire to have the operation moved somewhere else. There is very little natural land near any metropolitan area of consequence today. Natural in the sense that it has not been disturbed by some human activity, usually farming.

We have found in a modest way that the propagation of wildlife is possible within a metropolitan area. In 1975, a lake was formed by mining gravel from Lower Grey Cloud Island (Stearn 1976). As an experiment, a small number of Canadian Geese were introduced to the area with clipped wings. The result was a flock of geese, that today number well over 100, consider the lake and surrounding area their home. It is not an uncommon sight to see a 70 ton Euclid bottom-dump truck stopped while a mother goose hustles her goslings from one side of the road to the other. The interesting conclusion to draw from this is that the operation does not have to be completed before reclamation as wildlife habitat can begin. Fish can be introduced that provide an important link in the food chain for animal life as well as recreation for the fisherman and, with the introduction of one kind of species such as geese, others develop naturally such as raptors and a host of other kinds of animal life which seem to develop almost magically in a symbiotic relationship within a remarkably short time period.

A Florida Highway project was teamed with the development of a wildlife area (Anon. 1978). More than two million yards of sandy material was excavated from a borrow pit about three and a half miles long in a Florida swamp land. When the highway project was completed, the specially shaped borrow pit became a wildlife refuge for the Florida State Game and Fish Commission.

Utilization of worked out gravel pits for wildlife habitat from the industry perspective offers one more opportunity to prove to the public generally, that is can provide a needed resource, and it can do so and make an additional contribution to the quality of life in the area in which the operation is located. While I see some evidence that the industry is winning its struggle to educate others that aggregate resources are a necessary part of needed and desired construction, the opportunity to utilize yet another socially acceptable and desirable end use to aid in the process of education, is heartily welcomed. From my standpoint at least, and I think I speak for the industry, our perspective on gravel mining and post mining use of aggregate resource sites for wildlife habitat, is positive and we welcome the opportunity to be a part of and contribute to this highly desirable objective.

LITERATURE CITED

ANONYMOUS. 1978. Borrow pit shaped for wildlife. Highway and Levee Construction (June), pp. 114-115.

STEARN, E. W. 1976. Two facets of land use: In Minnesota wild beauty is restored at Shiely Company's sand and gravel operations. Rock Products (Oct.), pp. 50-52.

The Nature of Gravel Deposits in Minnesota and Extraction Procedures

MORRIS T. ENG. Minnesota Department of Natural Resources, Division of Minerals, Box 45, Centennial Office Building, St. Paul, Minnesota 55155.

In comparison to other states Minnesota is endowed with a bountiful supply of sand and gravel. This valuable resource has made a significant impact upon the economic development of the state in general construction and the building of roads. Consequently, there are a large number of old abandoned or inactive gravel pits scattered around the state that have provided materials from a wide variety of glacial deposits.

No complete inventory is known to exist for the total number of gravel pit excavations in the state. However, the Minnesota Department of Transportation maintains an ongoing program to locate gravel and has laboratory and drilling records on over 5400 gravel pits which they have tested for road construction materials. It is estimated that at least an equal number of abandoned or unrecorded pits exist associated with mining operations by local government or private interests.

The purpose of this paper is to assist in identifying the many types of gravel deposits scattered across the state and to discuss the mining procedures that are commonly used in mining them. This information in turn should provide an insight as to some of the types of wildlife habitat one might expect in the different types of gravel pits found opened in the various glacial terrains throughout Minnesota.

GLACIATION

A brief introduction to Minnesota's glacial history is essential for obtaining a basic understanding of the wheres and whys of gravel deposition in the state. The surface of Minnesota was severly glaciated during the last Great Ice Age. During this period of time covering the last two million years the state was subjected to at least four major periods of continental glaciation, which are commonly referred to as Ice Stages. Each continental Ice Stage was separated by warm interglacial periods when the ice thinned and retreated back into the arctic regions. A precise picture of the earliest glacial events cannot be fully reconstructed because most of the evidence of this glaciation was destroyed or altered by succeeding glaciers. Consequently, nearly all of the surficial glacial features in Minnesota represent events that occurred during the latest period of glaciation during the Wisconsin Ice Stage, which was active from 10,000 to 1000,000 years ago.

The Wisconsin Stage is subdivided into several phases of glaciation based upon the events associated with individual lobes. Each phase was separated from the next by warm periods of melting which caused the glacial lobes to diminish and retreat. This permitted other lobes to advance from different directions over previously glaciated terrain.

It is not necessary for the purpose of this paper to give a detailed explanation of the names and movements of individual glacial lobes that advanced during the last phase of the Wisconsin Ice Stage. Instead it is more appropriate to simply note the names of the three continental glaciers that invaded the state from the northwest, north, and northeast during this phase.

1. The Des Moine Lobe advanced from southern Manitoba into NW Minnesota traveling south along the Red River Valley and then angled southeast through southern Minnesota into Iowa. This lobe and its St. Louis sublobe is responsible for creating a wide range of gravel deposits in southern, western, and northern Minnesota.

2. The Rainy Lobe advanced from the north around the Rainy Lake and traveled south and southwest extending as far as the Twin Cities Metropolitan Area. This lobe at various times blocked the advance of glaciers from the northwest (St. Louis sublobe) and from the northeast (Superior lobe).

3. The Superior Lobe occupied the Lake Superior basin and advanced from the northeast direction, sometimes in unison with the Rainy lobe, covering large areas in the east, central, and northern part of the state.

The general direction taken by each advancing lobe was controlled by the elevation of the topography over which it traveled, or by deflection caused by other glaciers blocking its path. Figure 1 reflects the movement of these glaciers through Minnesota. The map shown in Figure 1 indicates that multiple glaciers were drawn into the lowland in Central Minnesota and overrode one another.

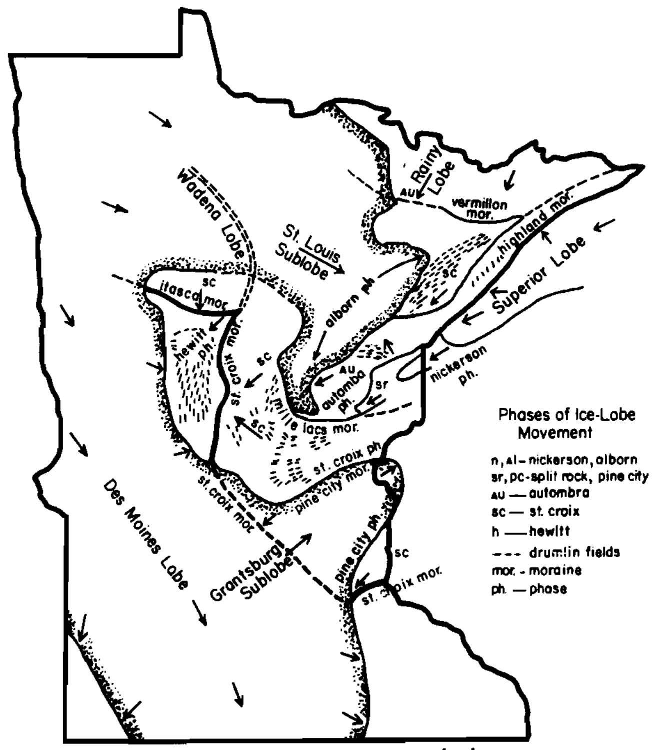


Figure 1. Glaciers in Minnesota during the Wisconsin Ice Stage (modified from Wright 1972)

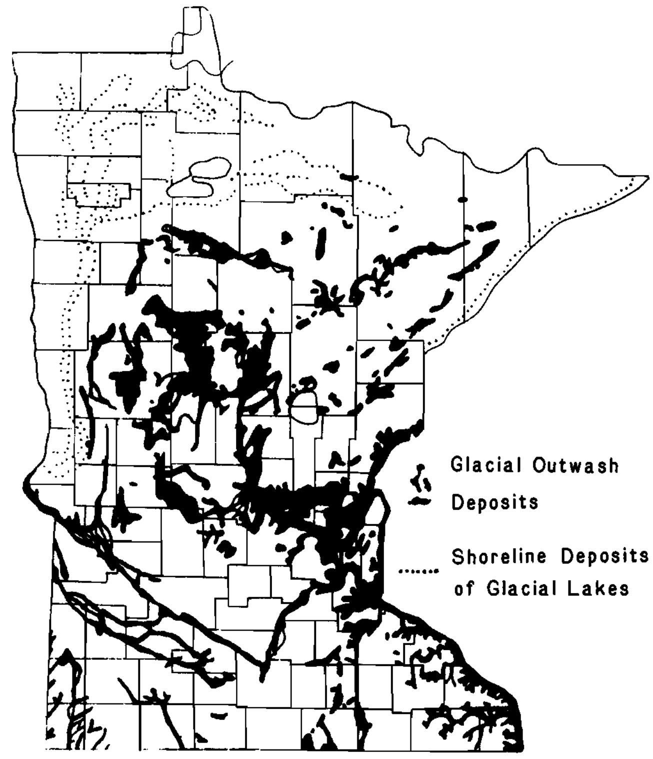


Figure 2. Outwash and Lacustrine gravel deposits in Minnesota (modified from F. Leverett)

The advance retreat of these glaciers resulted in the discharge of enormous amounts of meltwater, which sorted out the glacial debris (till) into stratified deposits of sand and gravel. Consequently gravel potential is directly correlated with the former glacial hydrologic system, which in effect is presently represented as a system of gravel deposits. Gravel sized particles were segregated and placed by the hydraulic sorting of meltwater streams along the margin of glaciers and then transported to the lower level ground beyond the ice front where the large glacial streams deposited their heavy load of sediment. This serves to explain why extensive outwash plains are now presently found concentrated in Central Minnesota (Figure 2)

TYPES OF GRAVEL DEPOSITS AND MINING METHODS

Sand and gravel deposits can be subdivided into glaciofluvial and lacustrine deposits representing those deposited by meltwater far beyond the ice, and ice contact deposits, or those deposited within the glacial ice environment. The schematic drawing in Figure 3 shows the general relationship of the various sand and gravel deposits that might be found along a typical ice front.

Glaciofluvial deposits are deposited for many miles beyond the ice front by meltwater streams along the margin of the glacier. Lacustrine deposits originate from large glacial lakes that were formed by meltwater impounded by moraine dams. Typical fluvial and lacustrine deposits are glacial outwash, valley train, terraces, channel deposits, fans, shoreline bars, deltas, and beaches.

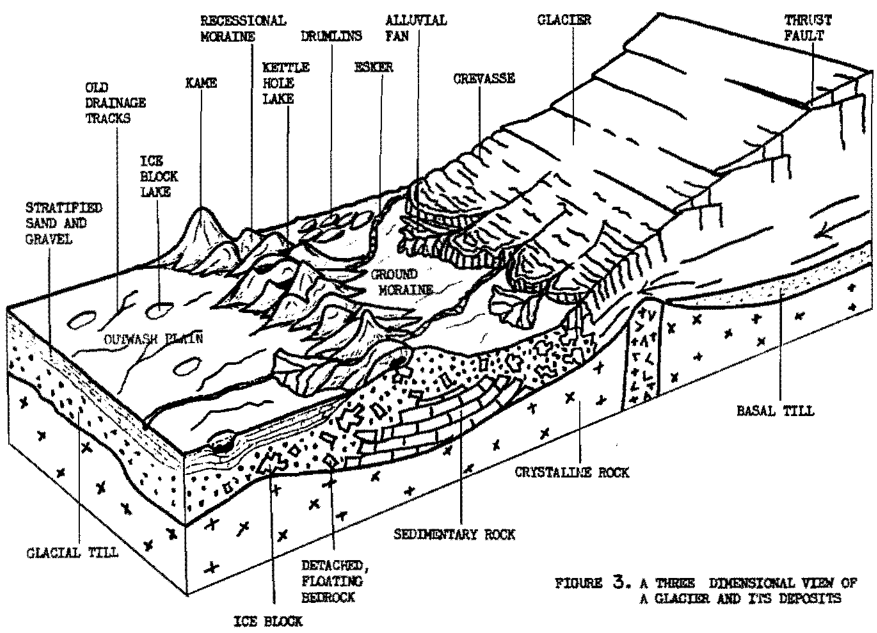


FIGURE 3. A THREE DIMENSIONAL VIEW OF A GLACIER AND ITS DEPOSITS

GLACIOFLUVIAL DEPOSITS

Glacial Outwash. This type of deposit consists ot a broad plain of sand and gravel deposited by overloaded streams. Glacial streams often shifted their channels and merged to fill in large expanses many miles wide with a plain of stratified sand and gravel, usually ranging between 25 to 75 feet deep.

Central Minnesota contains large outwash plains of sand and gravel representing the melt-water drainage deposits of multiple glaciers that were drawn into the central lowlands (Figure 2). In addition to being an important source of gravel, outwash deposits usually contain valuable groundwater resources for irrigation and potable water supplies for farms and municipalities. Valley train, terraces, and channel deposits are forms of outwash that are more closely related to existing streams and are actively mined especially along the Minnesota River, and other streams in Southern Minnesota.

Railroad pits probably represent the largest pit excavations resulting from using conventional dry pit mining operations. Usually these pits are developed in large outwash deposits where large quantities of uniform stratified material is available. Customarily they have a steeply sloping pit face perhaps thousands of feet long.

These pits were excavated by power shovels which loaded pit run material directly into gondola rail cars brought in on a spur rail line. As the mining progressed the spur line was systematically moved closer to the retreating pit face. This type of mining operation created a long, steeply sloping pit face and a large level pit floor sometimes covering up to 20 to 40 acres or more. The large quantities of pit run material mined from these pits was transported long distances to gravel scarcity areas for constructing the road bed of the railroads. Good examples of large railroad pits are located near the town of Muskoda in east central Clay County, and northeast of Appleton in Swift County.

Outwash deposits frequently contain significant amounts of gravel below the groundwater table. Often the gravel below water is of better quality than the material above water, because it has not been broken down by weathering. As a result a higher number of gravel pits in outwash are mined below water than any other type of deposit.

Mining of underwater gravel is accomplished by using one of three methods.

1. The most commonly used method is to temporarily dewater the pit by installing a number of shallow wells or constructing a sump in the pit bottom. The water table is then lowered by pumping so that conventional excavation and loading equipment may be used. This method is limited by the economics of pumping costs related to the amount of water that must be pumped which is determined by the permeability and depth of the gravel deposit. Such dewatering operations usually are temporary and result in relatively shallow ponds less than

10 feet deep in the pit with stable water levels that are representative of the local groundwater table.

Gravel pit dewatering procedures are more frequently used in short term operations to provide a large amount of material that is needed for a specific construction project. This method is most often used in providing material for road construction which utilizes remote gravel deposits that otherwise aren't economical to operate because of their distance from a market.

Some good examples of these type of underwater pits can be found in southwestern Minnesota along glacial outwash channels now occupied by existing rivers and streams. Some of the most important pits are associated with gravel deposits opened along Kanaranzie Creek, in Nobles County, the Rock River in Rock County, the Des Moines and Sioux Rivers in Jackson and Cottonwood counties, the Cottonwood River and Sleepy Eye Creek in Brown and Redwood counties, and the Redwood River in Lyon and Redwood counties. A more precise location of these pits is shown on Minnesota Department of Transportation county gravel pit maps.

2. Another method used for mining underwater gravel involves a nonpumping operation in which a dragline or clam shell is used to remove the material. In this instance the groundwater is allowed to fill in the excavation as the mining progresses. This is the most commonly used method because it requires less equipment, is more economical, and is better suited for mining the deeper deposits which probably cannot be pumped down because of their high permeability. It is also a better method for a long-term commercial mining operation where a steady supply of sand and gravel is produced for processing into various types of aggregate products.

An excellent example of a large mined-out gravel pit resulting from a dragline operation is Lac Lavon, located near Apple Valley in Dakota County. Lac Lavon is situated in a large outwash deposit that trends southeast through Dakota County along the Vermilion River. In this instance draglines were used to excavate an average of 30 feet of coarse gravel below the groundwater table. This lake was stocked with fish and now contains an excellent fish population.

Examples of underwater clamshell or slack line cableway mining operations are uncommon in this state, however one such operation involves a deep sand and gravel pit located about 2½ miles north of Sabin in Clay County. The material from this deposit indicates that it is an ice contact glacial deposit partially covered by lake sediments in the bed of Lake Agassiz.

3. Dredging is another type of wet-pit mining used specifically in deep underwater pits and in mining material found beneath the beds of lakes and streams. Under this procedure the material is mined from a barge by using a suction device, a rotating bucket wheel, or a cutter auger head. The mined material is then pumped through a system of pipes and deposited on shore where it is processed. This type of mining occurs in outwash terraces or valley train deposits found along some of our large rivers.

Many old underwater outwash gravel pits are found scattered throughout the outwash plains in central and southern Minnesota. One of the most important aspects of outwash gravel pits is that their location closely corresponds with the agricultural regions where wildlife habitat is severely limited because of intensive farming practices.

The type of wildlife habitat resulting from underwater gravel mining is dependent upon the depth of the excavation below the water table and the angle of slope around the edges of the pit. If a conventional mining dewatering operation is used, the pit bottom will extend a few feet below the water table and have moderate slopes. The resulting environment in the pit bottom often consists of permanent shallow pools surrounded by moderate slopes, which is ideal for wildlife. Sometimes small islands or long narrow points are created from rejected materials or ridges left by the bulldozer that provide excellent protective habitat.

When a dragline or dredging operation is used a deepwater environment is created. Typical pits are commonly excavated about 25 to 30 feet below the water table resulting in small cold water lakes more suitable for fisheries management. They have a more limited wildlife environmental potential than other types of underwater pits because of their steep slopes and lack of shallow water areas for aquatic plants.

LACUSTRINE DEPOSITS

Lake Agassiz

Valuable gravel deposits are found associated with former shorelines of glacial lakes. Large parts of northwestern and northern Minnesota are representative of a broad lake plain formed by Glacial Lake Agassiz. This lake at various stages covered over 200,000 square miles in North Dakota, South Dakota, Minnesota and Canada (Figure 4). The former shorelines of

Lake Agassiz are clearly marked by a series of long beach ridges composed of sand and gravel, each representing various stages of the lake.

Beach ridge deposits may range up to several hundred feet wide and generally contain shallower deposits of material in comparison to other gravel deposits. Other off-shore deposits such as bars and spits are located on the lakeward side in close proximity to the beach ridges.

Gravel excavations in these deposits are typically long and narrow and often become filled with water because of underwater mining or high water tables that are commonly found in lake plains. These pits have a potential to provide exceptional habitat for wildlife because many of the beach ridges are parallel to one another and are separated by cultivated strips of land in the interbeach area. Numerous gravel pits have been opened in the beach ridges of Lake Agassiz in the northwestern counties because of the high demand for sand and gravel in this region and in North Dakota. Concentrations of beach ridge pits occur trending in a north-south direction from Kittson County

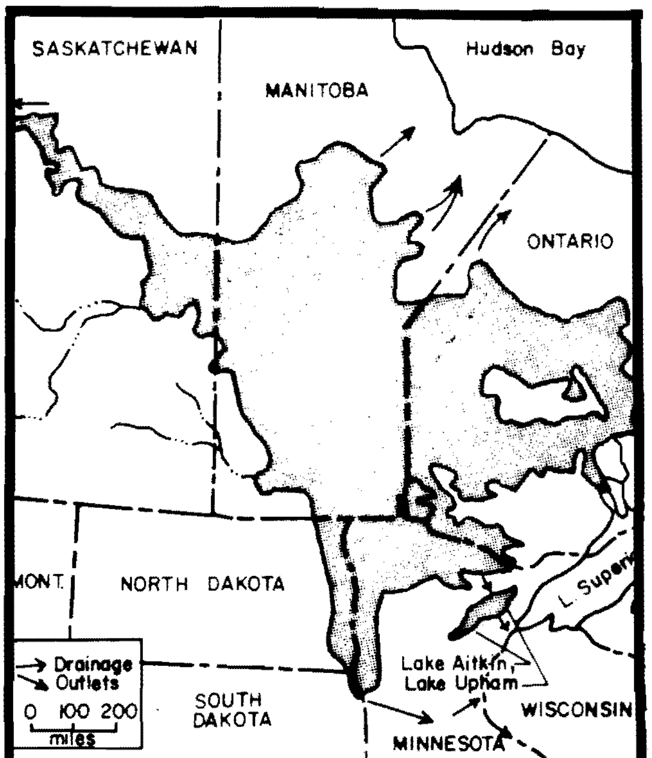


Figure 4. Maximum area covered by Glacial Lake Agassiz. Arrows show major outlets for the lake (modified from Arndt 1977)

to Traverse County. Large beach ridge pit complexes occur in Clay County near Hawley, Barnesville, and Muskoda, and in Polk County near Melvin, Marcoux, and Fertile.

Lake Duluth

The former shoreline of Glacial Lake Duluth in northeastern Minnesota is another area of beach ridge gravel mining. These beach ridge deposits are generally located several miles inland and are about 550 feet above the level of Lake Superior. Lake Duluth had a rocky coastline similar to Lake Superior and the shoreline beach deposits here are usually disconnected by rocky sea cliffs. Very little soil was available for the strong lake currents in Lake Duluth to build extensive beach deposits as in Lake Agassiz. As a result, the area inundated by Lake Duluth contains only scattered deposits of sand and gravel in beaches, bars, and spits. Most of this region is forested. However, most of the pits opened in recessional beaches along the North Shore of Lake Superior still provide important habitat for grouse, gulls, and migrating birds. Nearly all of the abandoned pits in the area close to Highway #61 remain dry due to the natural drainage in the steeply sloping rocky terrain.

ICE CONTACT DEPOSITS

Ice contact deposits are important sources of sand and gravel found associated with glacial moraines. Examples of ice contact deposits are kames, crevasse fillings, and eskers.

1. Kames and Crevasse Fillings represented steep gravelley hills within a moraine complex. Kames are high cone shaped hills of sand and gravel formed by water plunging into a hole in the ice near the front of the glacier (Figure 5). Kames may vary considerably in size but sometimes may rise to over 100 feet in height. "Crevasse filling" is a term applied to those ice contact deposits that cannot be readily identified as kames but probably formed under similar conditions. These deposits usually are poorly sorted and generally are sandy near the top and grade into gravel near the bottom.

Kames and crevasse fillings are mined by conventional methods using the dragline, power shovel bulldozer, backhoe, and front-end loader. These are high upland deposits which seldom are mined below the water table. Typically they contain much waste material such as excess overburden, boulders, silt, and fine sands. This results in a dry irregular pit bottom containing reject materials, stripping piles, and rock screenings surrounded by a steeply sloping pit face. Such pits afford variable habitat depending upon their location, depth, and ease of access to wildlife.

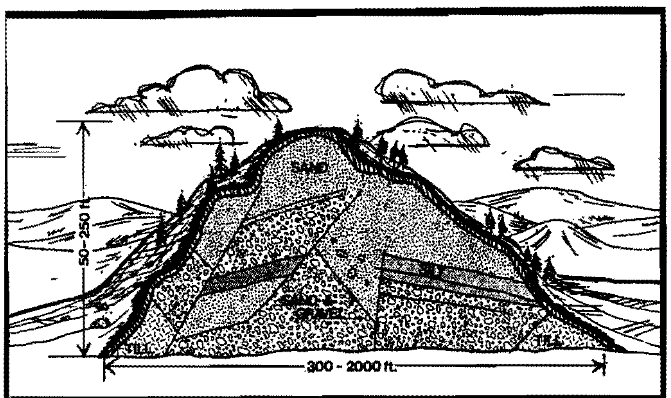


FIGURE 5. A schematic drawing of a kame deposit showing its complex structure of sand and gravel. Pits opened in this type of deposit have steep slopes and dry conditions and offers a more limited Wildlife environment than other gravel deposits.

2. Eskers, sometimes referred to as "hogs-back ridges", are narrow, sinuous ridges often miles in length that were formed in the channels of subglacial streams flowing through tunnels within or at the base of glaciers. The gravel in eskers represents stream bottom sediments. Consequently the material in this deposit is very irregular in composition because the hydraulic effect of ice movement can severely change the rate of streamflow. Eskers are important sources of sand and gravel as they frequently cross areas of ground moraine where other gravel deposits are unavailable. They may range from fifty to several hundred feet wide at their base, and between 25 to 75 feet in height. Eskers seem to occur more often in the northern and central parts of the state where the glaciers such as the Rainy and Superior lobes encountered one another, or where the ice was blocked or restricted by irregularities in the terrain. Some of the better known eskers are located in Pine County near Finlayson, in Carlton County near Cloquet, and in many locations in St. Louis, Itasca, Morrison, Mille Lacs, and Kanabec Counties.

Conventional mining equipment and practices are used for mining gravel from eskers, and they have bouldery characteristics similar to those of kames and crevasse fillings. The long sinuous pits opened in eskers have a different habitat potential for wildlife than other ice contact deposits because they normally meander through low wet terrains in an "esker trough" channel. The trough marks the width of the subglacial drainageway in which the esker was formed, and frequently contains small "esker trough lakes" and wetlands. Gravel pits located in eskers have an excellent potential to provide habitat to a wide variety of wildlife because of their orientation to lakes and wetlands in the trough. A good example of an esker trough lake is located a few miles west of Finlayson in Pine County associated with a large esker. (Fig. 6).

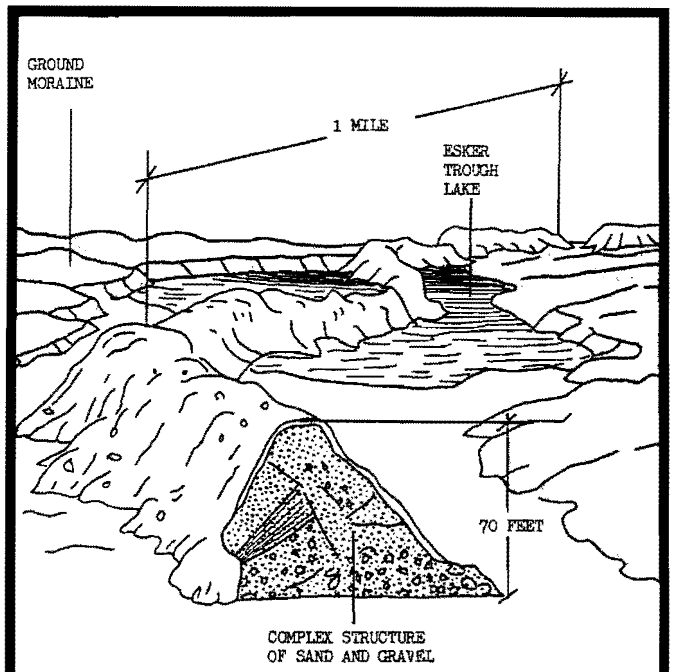


FIGURE 6. A schematic view of an esker near Finlayson, Minnesota showing its complex structure of sand and gravel. The esker trough with esker trough lakes marks the width of the subglacial drainageway. The wetlands in the esker trough indicates gravel pits opened in this type of deposit have a high potential for use by wildlife.

SUMMARY

Minnesota has many valuable wildlife habitats associated with abandoned or inactive gravel pits distributed throughout the state. Those pits having the greatest wildlife value are the water oriented pits associated with glacial outwash and beach ridge deposits found along shorelines of glacial lakes in the agricultural regions. Other water oriented pits located in other forested parts of the state provide important habitat but are situated in areas where habitat is not as crucial and the competition for wildlife environment is considerably less than in the agricultural areas.

Non-water pits associated with ice contact deposits within the moraines have a lower potential for wildlife habitat. Generally the presence of a variety of slopes are beneficial, but severe slopes limits the habitat and generally benefits fewer types of wildlife.

In the writer's opinion old gravel pits have over the years always provided a unique oasis of habitat for wildlife without any specific management programs. Their irregular slopes, ponds, and natural weedy vegetation affords an isolated sanctuary to all types of wildlife for cover, food, sunning, nesting, and protection from predators and storms. However these benefits to wildlife can be greatly enhanced if this potential is recognized by gravel pit owners, contractors, landowners, resource managers, and the general public.

RECOMMENDATIONS

The following recommendations are made to assist in identifying some of the objectives that should be included in planning a gravel pit habitat program.

1. Water oriented gravel pits should be identified and inventoried, with the highest priority given to the agricultural regions in southern and northwestern Minnesota where wildlife habitat is rapidly disappearing.

2. Inactive gravel pits should be protected from undue disturbance from the public. Access to vehicles should be restricted by blocking or removing old haul roads leading to inactive or exhausted pits.

3. Operators of large gravel operations could enhance the compatability of their long-term mining operations for wildlife by adopting an on-going reclamation program that would provide temporary or permanent habitat in unused areas during the operation of the pit.

4. Local volunteer groups should be organized to undertake projects to assist landowners in cleaning up debris, restricting access, and then generally restoring the gravel pit habitat.

5. Wildlife habitat could be greatly enhanced if gravel contractors and gravel pit landowners were advised as to how minor changes in mining practices can improve slopes and water conditions.

LITERATURE CITED

ARNDT, M. B. 1977. Stratigraphy of offshore sediment in Lake Agassiz, North Dakota. Report of Investigation No. 60, North Dakota Geological Survey.

ENG, M. T. AND M. J. COSTELLO, 1979. Industrial Minerals in Minnesota A Status Report on Sand, Gravel, and Crushed Rock. Minnesota Department of Natural Resources.

LEVERETT, F. AND F. W. SARDESON, 1932. Quaternary Geology of Minnesota and Parts of Adjacent States. Professional Paper 161, U. S. Dept. of Interior, Geological Survey.

WRIGHT, H. E., JR. 1972. Quaternary History of Minnesota, Cenozoic, Chapt. VII. Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, University of Minnesota.

Manipulating Mining Operations to Create Wildlife Habitats: A Pre-mining Planning Process

ANTHONY M. BAUER. School of Urban Planning and Landscape Architecture, Michigan State University, East Lansing, MI 48824.

INTRODUCTION

It is in the nature of man to modify the environment to accommodate various human activities. A drainage ditch, subdivision, highway or a park all require various degrees of earth work and earth moving activity in order that it functions properly. Generally these modifications proceed according to a plan prepared before modifications are initiated.

As an earth moving activity, mining also results in the modification of the landscape, but with three basic differences in approach.

1. Extensive quantities of earth materials are removed from the site.
2. The life of this earth moving activity extends over decades rather than months.
3. The purpose of the activity is to extract a resource with the end use incidental to that purpose.

The final landscapes tend to be more a reflection of efficient mining practices than efficient end-use land forms. (Bradshaw & Chadwick 1980). Impressive examples of pits and quarries reclaimed, (after mining has been completed) for housing, recreation and a variety of uses exist throughout the United States. On evaluation of several such sites (Bauer, personal field experiences) it is apparent, the fullest development potential was not achieved, because:

1. During the operation, earth materials were not placed to create efficient land forms.
2. The "reclaimed" sites often contained significant amounts of unusable land and water areas; remnants that were too narrow, too shallow or too steep.
3. Equipment and labor for earth moving, which are available during the mining operation, are available only by contract at a considerably higher cost, after mining.

A RECLAMATION CONCEPT

The fullest and most productive approach to mining and reclamation can be achieved when it is recognized that the mining operation, itself, is the means of shaping new and productive environments. Mining, when planned and integrated with the reclamation objectives can create efficient land forms that satisfy specific end use needs (Schellie, 1977). The two key words are planned and integrated. The most cost effective and productive approach occurs when reclamation plans are developed before mining is initiated, and are combined with the mining operation to make efficient use of materials, equipment and deposit features (Bauer, 1968).

Development of a comprehensive data base is basic to the pre-mine planning of a sequential reclamation program. It includes aesthetic factors, soil, drainage, regulations, traffic, earth moving activities, etc. (Schellie & Rogier 1963). Detailed descriptions of this information and its application is beyond the scope of this paper. Thus, the focus of this paper will be limited to earth moving and earth manipulating aspects of a sequential mining and reclamation program.

DEPOSIT DATA

Materials contained within the deposit will be redistributed in some manner during the course of the mining activity, regardless of the existence of a plan. How, when and where these materials are handled is a prime concern of the planning process. Consequently, a concise picture of the deposit structure, its contents, the composition and distribution of its contents, and the quantity of available earth material is basic to setting up a reclamation planning program.

Deposit Structure

The relevant information about the deposit structure include, area of the commercial material, depth of the material and ground water elevations. This information can be illustrated in the form of an isopac map that shows the deposit floor contour and the deposit floor depths above and/or below ground water. The information is useful in assessing where desired end use landforms can be created most efficiently.

Earth Materials for Land Shaping

A variety of materials exist in the typical deposit that are not processed but must be handled to produce the sand and gravel. This material may vary in volume, from a few thousand cubic yards per acre to more than 30,000 cubic yards per acre. The significance of this factor is that the material is available and must be relocated, with or without an end use in mind. It is therefore important for the reclamation planner to understand the quantity, characteristics and location of these materials.

Four types of materials are typically encountered in a sand and gravel deposit, depending on the type of geologic formation in which the deposit is located.

1. Overburden (topsoil and subsoil) covering the sand and gravel deposit: The depth of this material will range from a few inches to fifteen or more feet. It is the most common source of land shaping and land forming material available. In all cases the topsoil should be handled separately from the subsoil. There are two reasons for this. First, the material is essential for reestablishing good vegetation stands. Second, concentrations of topsoil fill is not a stable base for building. A typical range of the amount of overburden covering of deposit is 4,000 to 15,000 cubic yards per acre.
2. Fines: Residue from the processing plant in the form of fine sand and clay is another potential source of land building material. It typically is flumed from the processing plant as a slurry and expands as a fan-shaped land form relatively near the processing plant. The quantity of this material will vary with the character and quantity of sand and gravel processed. An industry rule of thumb for the creation of fines is that it represents between five and ten percent of the volume of processed sand and gravel. Assuming a five percent factor for a sand and gravel deposit thirty feet deep, approximately 2,420 cubic yards of fines will be created per acre of deposit excavated.
3. Excess Sand: In deposits where the proportion of sand to aggregate exceeds sixty percent, sand above the sixty percent volume may be redeposited into the site as excess sand flumed from the processing plant. These types of deposits are generally located in outwash plains and are common in Ohio, Illinois and Indiana (Bauer, 1963). The volume produced will depend upon the depth and composition of the deposit. For example, a deposit thirty feet deep containing eighty percent sand will produce over 9,500 cubic yards of excess sand per acre of material excavated.
4. Clay Lense: Occasionally lense or veins of clay are contained within the sand and gravel deposit. The decision to remove this lense will depend upon the volume of material to be removed and the quantity of sand and gravel below the lense. In either situation the lense will have an impact on the final configuration of the mine site. The amount of this material in the deposits is unpredictable. In many deposits it is non-existant.

To illustrate the scope and significance of available materials for land forming, the above stated per acre volumes is applied to a 100 acre site. Assume that no clay lense exists in the deposit. Also assume the average overburden depth is nine feet. The total volume of overburden, fines and excess sand would be 2,644,000 cubic yards. This figure translates in opportunities to create:

78 acres of additional land requiring 21 feet of fill or; 55 acres of additional land requiring 30 feet of fill, or; 36 acres of additional land requiring 45 feet of fill.

Thus, in addition to information about the available fill materials, knowledge of the shallow and deep portions of the deposit can be a factor in determining the amount of land created and how the earth material will be redeposited.

Distribution of Overburden

Typically the overburden depth will vary throughout the mine site. When the variation is major, such as depths of fifteen feet on one half the site and three feet on another half, the cost of moving earth becomes a significant factor. Large quantities of overburden in a particular area should suggest, other factors being equal, that the greatest amount of land forming activity be concentrated in close proximity to the overburden source (Design Enterprise, 1979).

OPERATIONS

The mining operation is the tool used to mold and shape a new and useful environment. Because it moves non-commercial material as part of its extraction and processing activity, it is feasible to move this material, without significant cost increase, to create productive landforms. (Design Enterprises, 1979)

Type of Earth Moving Equipment

A variety of earth moving equipment is used in a mining operation to extract and transport both the sand and gravel and the overburden. The most common are the bulldozers, scrappers, draglines and front end loaders. Each piece of equipment offers a range of earth moving and land shaping capabilities that can significantly influence the feasibility of various reclamation proposals (Nichols, 1976). Knowledge about the equipments' availability and capability is essential in coordinating the earth shaping activities of the mining operation.

Mining Procedures

Procedures used by mining companies in handling overburden and excavating sand and gravel varies considerably. Some operations begin near the processing plant and move in a pattern away from the mining, while other operations will mine several parts of the site simultaneously. Whatever procedure is used, it is important to understand the rationale behind the procedure and how it can be used or modified to benefit the land shaping effort.

END USE CRITERIA

The extensive nature of earth moving activities in mining operations permits considerable flexibility in adapting the site to a wide range of end uses. Given the requirements of an end use such as a specific wildlife habitat, the information would be used to influence and determine the pattern and direction of mining, the distribution of overburden and the reclamation phasing. The final plan would then be an accommodation of the deposit, operations and wildlife habitat needs.

While each type of wildlife area would have specific and detailed requirements, the following general information is useful in initiating the sequential mining and reclamation planning process.

1. Desired water depths and the percentage of each area of depth to the total lake.
2. Lake bottom configuration requirements.
3. Lake edge configuration requirements.
4. Materials for specific environments, i.e. areas requiring a gravel bed, areas needing a rich nutrient base, or areas requiring large boulders and debris.
5. Special landforms, i.e. islands, wetlands.

Most of these elements could be created as an integral part of the mining operation as it proceeds with the excavation process. A key factor in setting up the type of end use environment is that the environment will be an outgrowth of the deposit (Humphries, 1980). Both the assets and constraints of the deposit must be considered in setting up the criteria.

CONCLUSION

Preparing a plan for the development of an end use as an integral part of a mining process is similar to preparing a plan for any type of land development; with one exception. The prime objective of the mine operation is the efficient extraction of a mineral resource. In that process it has the potential for achieving a second objective, which is the creation of a new and productive landscape. This cannot be accomplished by chance. It involves a systematic process that integrates the elements of the deposit, operation and end use needs. With a plan for reclamation, mining can be a constructive and positive means of creating new environments.

LITERATURE CITED

BAUER, A.M. 1968.(ed.) Mining In An Urban Environment, Conference Proceedings, Univ. of Guelph, Ontario. 86pp.

BRADSHAW, A.D. and CHADWICK, M.J. 1980. The Restoration of Land. Univ. of California Press, Los Angelos, CA 317pp.

DESIGN ENTERPRISES, LTD. 1979. Earlham College Mining and Reclamation Study. Unpublished 48pp.

HUMPHRIES, R.N. 1980. The Development of Wildlife Interest In Limestone Quarries. Recl. Rev., Vol. 3 No. 4.

NICHOLS, H.L., 1980, 3rd Ed. Moving the Earth. New Castle Books, Greenwich, CN

SCHELLIE, K.L. Ed. 1977. Sand and Gravel Operations: A Transitional Land Use. National Sand and Gravel Association, Silver Spring, MD 211pp.

SCHELLIE, K.L. and ROGIER, D.A. 1963. Site Utilization and Rehabilitation Practices for Sand and Gravel Operations. National Sand and Gravel Association, Silver Springs, MD 80pp.

General Design Considerations in Creating Artificial Wetlands for Wildlife

RICHARD D. CRAWFORD and JUDITH A. ROSSITER,[1]
Department of Biology, University of North Dakota, Grand Forks, ND 58202.

Wetlands are widely recognized as being valuable natural resources throughout the world. In North America, inland wetlands alone are known to provide wildlife habitat, for both game and nongame species, and aid in flood control, ground water recharge, and sediment and pollution control (Council on Environmental Quality 1978, U.S. General Accounting Office 1979, Davis et al. 1981, Jahn 1981, Larson 1981, Oberts 1981). They supply recreational opportunities and, recently, have been used for sewage treatment and energy production (Kadlec 1981).

Natural basin wetlands in the Prairie Pothole Region, from northwest Iowa to Alberta, are widely known for their capacity to produce wildlife. This region covers approximately 10% of the continental area, but produces 50% or more of the North American duck population annually. Plants, nongame animals, and other game species also abound in these areas (Smith et al. 1964).

Despite their prime importance, however, wetlands are being destroyed at an alarming rate. In some areas, such as northwest Iowa, western Minnesota, and eastern North Dakota, most natural basin wetlands have been drained or otherwise destroyed, and those in most states and provinces have been severely degraded (Harmon 1981, Weller 1981). This loss prompted the Committee on North American Wildlife Policy to recommend that ways "should be explored for creating or restoring water areas along rights of way of federal and state highway systems and on public lands generally" (Allen 1973:83).

Our work with constructed wetlands began in 1975, when recommendations for pond design were given to the North Dakota Highway Department for wetlands to be placed along highway rights-of-way within the state. The intent of this paper is to briefly describe our past studies and to make recommendations for constructing wetlands in the Midwest.

[1]Present address: 700 Warren Road, Apt. 23-2F, Ithaca, NY 14850.

PREVIOUS STUDY

We began a monitoring and study program for constructed basins in 1979. The first phase of the study was designed to assess waterfowl and wetland bird use of the basins, but included work on plant species diversity, invertebrate abundance, water quality, and soil ions (Rossiter and Crawford 1981). Phase II of the study began in 1981 and will continue through 1983; during this phase, more intense effort will be directed toward plant and invertebrate abundance.

During Phase I of the study, 13 basins in Pembina County, North Dakota, 3 in Pierce County, and 2 in Barnes County were investigated. Four natural basin wetlands also were studied for comparative purposes. Constructed basins ranged in size from 0.6 to 12.6 acres and in age from 3 to 5 years at the onset of fieldwork. More detailed descriptions of the artificial wetlands can be found in Rossiter and Crawford (1981).

In designing artificial basins, we attempted to build ponds that would resemble a natural basin wetland as closely as possible. Our goal was to build a relatively small wetland (about 4 acres) that would provide diversity and would develop into a productive water area as rapidly as possible. Before describing design features that were built into these wetlands, we will briefly describe our findings for the first 2 years of study.

It is difficult and often misleading to discuss waterfowl and wetland bird densities found in marsh habitat without also discussing the many variables combining to produce this dynamic ecosystem, but essentially we found breeding pair densities for waterfowl of about 1.5 pairs per acre (Rossiter and Crawford 1981). This value is slightly lower, but comparable to, average densities found on the natural basins and in other studies (Farmes 1946, Jahn and Hunt 1964, Bellrose 1979). Among the Pembina County wetlands, pair density was higher on hexagonal wetlands than on rectangular or triangular ones. Density of Class III ducklings (Bellrose 1979) also was comparable between natural and artificial wetlands (Rossiter and Crawford 1981). Numerous species of other wetland birds used the constructed basins as well.

Invertebrate diversity and abundance were lower on constructed ponds than on natural basins; plant species diversity and percent coverage also were lower on artificial basins. Percent organic content and levels of most ions were generally lower in bottom soils of constructed wetlands (Rossiter and Crawford 1981).

As stated earlier, our intent here is to give only a brief overview of the first 2 years of study. The reader is referred to Rossiter and Crawford (1981) for more detailed information and discussion.

DESIGN RECOMMENDATIONS FOR CONSTRUCTED BASINS

Considering that our wetlands were young (3-5 years old) and were not always built to design specifications by the contractors, we believe that overall they were effective in waterfowl and wetland bird production. On the basis of our findings and pertinent literature, we offer the following recommendations for features that should be considered in constructing wetlands. These recommendations are for constructing a wetland that is relatively small and would resemble a natural basin as closely as is possible. For wetlands in other geographic areas, in urban areas, or for purposes other than wildlife production, the design may necessarily have to be changed.

1) An uneven, rolling bottom contour is probably the best. This will produce a variable water depth and allow for emergent vegetation growth on shallow areas throughout the basin. Water depth in the shallow areas should be about 12-18 inches and about 3-4 feet in the deepest areas. Vegetation (principally Typha spp. or Scirpus spp. in North Dakota) growing on the shallower sites should produce vegetative "islands" and thereby increase interspersion or "edge" habitat. Including emergent vegetation around the shoreline, we recommend about 50:50 vegetation:open water coverage of the wetland for greatest species richness and diversity (Weller and Fredrickson 1974).

2) The wetland should have a good clay seal to prevent leakage. We also recommend that topsoil be placed on the bottom of the basin to provide a more suitable substrate for aquatic vegetation growth. This ideally will more quickly establish a detritus food chain and increase invertebrate abundance. In our study, wetlands lined with clay only produced less vegetation, fewer invertebrates, and lower numbers of waterfowl than those lined with topsoil also.

3) After construction, we recommend placing a layer of natural or domestic hay on the wetland substrate. This should act to establish a detritus food chain more rapidly (Linde and Morehouse 1966).

4) In areas where feasible, such as during highway construction, muck from existing wetlands could be placed in the bottom of newly built ones. This soil would have the advantage of carrying a naturally occurring seed bank and other material with it, as well as being high in organic content.

5) In most wetlands, earthen islands could be constructed to add diversity and provide nesting space. Wetlands with islands have now been built as part of our study in North Dakota, but they are too new to properly evaluate.

6) For the shoreline, a gentle slope will provide for adequate vegetative coverage. We recommend a 10:1 to 20:1 slope, which also could be variable to provide for small vegetative "fingers" and open water "bays," and thus more edge. A variable shoreline, rather than even-sided, will increase the amount of shoreline per unit area. However achieved, a variable shoreline ideally will increase waterfowl usuage by providing isolated areas for feeding and loafing.

7) Little attention was given to upland vegetation management in our study because of the close proximity of highway rights-of-way. In other areas, however, providing upland areas for nesting may be necessary for optimum wildlife production.

Again, for more specific construction designs that we used and further elaboration of these recommendations, the reader is referred to Rossiter and Crawford (1981).

RECOMMENDATIONS FOR FURTHER WORK

Despite our belief that artificial wetlands, if properly constructed, can be effective as wildlife habitat, a number of questions still remain. For example, what type of wetland complex is necessary for optimum wildlife production? Natural basin wetlands in undisturbed areas occur in a complex array of sizes, shapes, and types. Some of these are small and shallow, whereas others are larger and deeper. Many also have distinct vegetative coverage. How much of what kind of wetland is necessary before the area becomes a functional marsh unit? Unfortunately, we do not yet know. We now believe that it is best to have several wetland types, as well as upland areas, present (Weller 1978), but the exact proportion of each for various purposes needs further study.

Methods for propagating wetland vegetation should be undertaken, such as the study by Pederson (1981). Use of fertilizers and other wetland substrates also should be investigated.

Artificial wetlands offer tremendous opportunity for research on the marsh ecosystem in general. They can be designed to investigator specification in any size or spatial complex desired. Long term research on these areas should yield valuable experimental data on marsh ecosystems not available by other means.

CONCLUSIONS

Obviously, the best solution to maintaining adequate wetland resources is to prevent drainage or disturbance to existing natural basins. When this is impossible, however, loss of natural basins can be at least partially offset by construction of artificial basins.

Our work to date has dealt mainly with constructing small wetlands for wildlife production. Waterfowl and other wetland bird use of these areas has been comparable to natural basins, but plant and animal species diversity and abundance have been generally lower, probably because of the age of the ponds. Although most of our work has been in relation to wetlands along highway systems, we believe our designs should have wide applicability throughout the upper midwest and possibly to other areas as well.

ACKNOWLEDGMENTS.—We thank the North Dakota Highway Department, U.S. Federal Highway Administration, and University of North Dakota for financial support. David Nilson and Terry Messmer contributed many of the original wetland designs while they were employed by the North Dakota Highway Department. Terry Brokke, Karen Kreil, Randy Kreil, and Sarah Wharton provided many helpful ideas and hours of field assistance.

LITERATURE CITED

Allen, D. L. 1973. Report of the Committee on North American Wildlife Policy. Wildl. Soc. Bull. 1:73-92.

Bellrose, F. C. 1979. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pa. 540pp.

Council on Environmental Quality. 1978. Our nation's wetlands - an interagency task force report. U.S. Govt. Printing Off., Washington, D.C. 70pp.

Davis, C. B., J. L. Baker, A. G. van der Valk, and C. E. Beer. 1981. Prairie pothole marshes as traps for nitrogen and phosphorous in agricultural runoff. Pages 153-164 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Farmes, R. E. 1956. Potholes of Mahnomen County. Flicker 28:24-30.

Harmon, K. W. 1981. Impacts of wetland losses on wildlife. Pages 347-354 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Jahn, L. R. 1981. Conference summary. Pages 3-14 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Jahn, L. R., and R. A. Hunt. 1964. Duck and coot ecology and management in Wisconsin. Wisc. Dept. Conserv., Tech. Bull. No. 33. 212pp.

Kadlec, R. H. 1981. How natural wetlands treat wastewater. Pages 241-254 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Larson, C. L. 1981. Effects of drainage on surface runoff. Pages 117-120 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Linde, A. F., and M. Morehouse. 1966. To feed wildlife, fertilize game foods? Wisc. Conserv. Dept. Bull. 31:16-17.

Oberts, G. L. 1981. Impact of wetlands on watershed water quality. Pages 213-226 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Pederson, R. L. 1981. Seed bank characteristics of the Delta Marsh, Manitoba: applications for wetland management. Pages 61-70 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Rossiter, J. A., and R. D. Crawford. 1981. Evaluation of constructed ponds as a means of replacing natural wetland habitat affected by highway projects in North Dakota. U.S. Dept. of Transportation, Washington, D.C. 171pp. (Available from National Technical Information Service, Springfield, Va. 22161).

Smith, A. G., J. H. Stoudt, and J. B. Gollop. 1964. Prairie potholes and marshes. Pages 39-50 in J. P. Linduska, ed. Waterfowl tomorrow. U.S. Govt. Printing Off., Washington, D.C.

U.S. General Accounting Office. 1979. Better understanding of wetland benefits will help water bank and other federal programs achieve wetland preservation objectives. U.S. Govt. Printing Office, Washington, D.C. 58pp.

Weller, M. W. 1978. Management of freshwater marshes for wildlife. Pages 267-284 in R. E. Good, D. F. Whigham, and R. L. Simpson, eds. Freshwater wetlands - ecological processes and management potential. Academic Press, N.Y.

Weller, M. W. 1981. Estimating wildlife and wetland losses due to drainage and other perturbations. Pages 337-346 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, Minneapolis.

Weller, M. W., and L. H. Fredrickson. 1974. Avian ecology of a managed glacial marsh. Living Bird 12:269-291.

Creating Small Islands for Wildlife and Visual Enhancement

ROBERT E. STOECKER, Stoecker-Keammerer & Assoc. Ecological Consultants. 329 Forest Lane, JSR, Boulder, CO. 80302.

Maximizing non-hunting wildlife values in addition to developing a natural landscape have been primary reclamation objectives at the White Rocks Sand and Gravel Pit in central Colorado. To meet these objectives the reclamation plan has emphasized the development of small islands, undulating shorelines, and diversity of plant communities. Wildlife monitoring has been ongoing for 10 years to document changes in animal populations. Modifications in the original reclamation plan have been made to increase wildlife species diversity and enhance scenic quality.

HISTORY OF GRAVEL MINING AT WHITE ROCKS

Gravel extraction at the White Rocks Sand and Gravel Pit, located 5 miles east of Boulder, Colorado, began in 1973. Mining and reclamation have been in progress since that time under the management of Flatiron Companies. The property consists of 150 acres adjacent to Boulder Creek, and is part of an area known locally as the White Rocks. An attractive outcrop of white sandstone is responsible for the area's name, and this feature dominates a landscape otherwise consisting of grassland, cropland, pasture, and a riparian zone of scattered cottonwood trees and willow shrub. Past years have seen the encroachment of subdivisions, and together with gravel mining and other potential disturbances there soon developed among the local citizenry a concern for preservation of existing scenic and wildlife qualities.

In 1972, prior to obtaining permits to mine, a reclamation plan was developed which emphasized plant community diversity, and lakes with several large islands and undulating shorelines. Two main lakes (18 and 22 acres each) and six smaller lakes were planned. Final construction of the second of these lakes will be completed in 1982 or 1983.

BIOLOGICAL MONITORING

Vegetation and wildlife monitoring have been a major part of the reclamation program at White Rocks since 1972. The wildlife component of the monitoring program has emphasized studies of bird populations and small mammal prey species. Objectives of wildlife monitoring were to 1) document major changes in the fauna as the area undergoes change from pasture to wetland habitat, and 2) to evaluate the efficacy of various reclamation schemes.

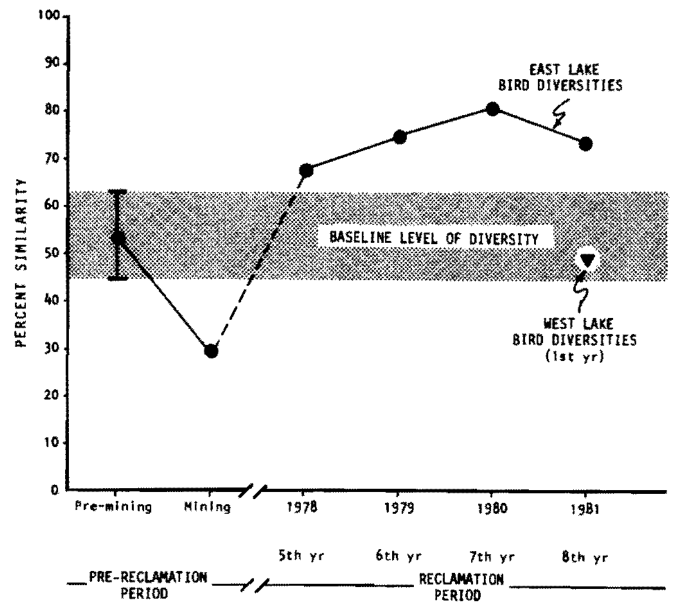


Fig. 1 Trends in bird diversities. The points plotted are bird diversities relative to a reference area (undisturbed riparian habitat). Percent similarity = experimental area / reference area x 100. Baseline level of diversity is expressed as the mean and standard deviation of bird diversities obtained in nearby pasture habitat (sample size = 5 yrs.).

Methods used to sample bird and small mammal populations were as follows: spring breeding bird counts were conducted in 1972 and from 1978 through 1982. Sampling occurred in three habitat types: nearby pasture habitat (representative of pre-mining conditions), reclaimed areas around newly established lakes (experimental area), and in unmodified riparian habitat near Boulder Creek (control area). Replicated counts were performed during mornings by recording, within a 1-hour period, numbers of birds of each species observed along transects 328 feet wide by 2625 feet long (100m x 800m). The estimator used for bird diversity was average richness (mean number of species observed during 1-hour counts). Small mammal populations were sampled in these same habitats using live traps. A moving transect method was employed wherein transects of 10 traps each were

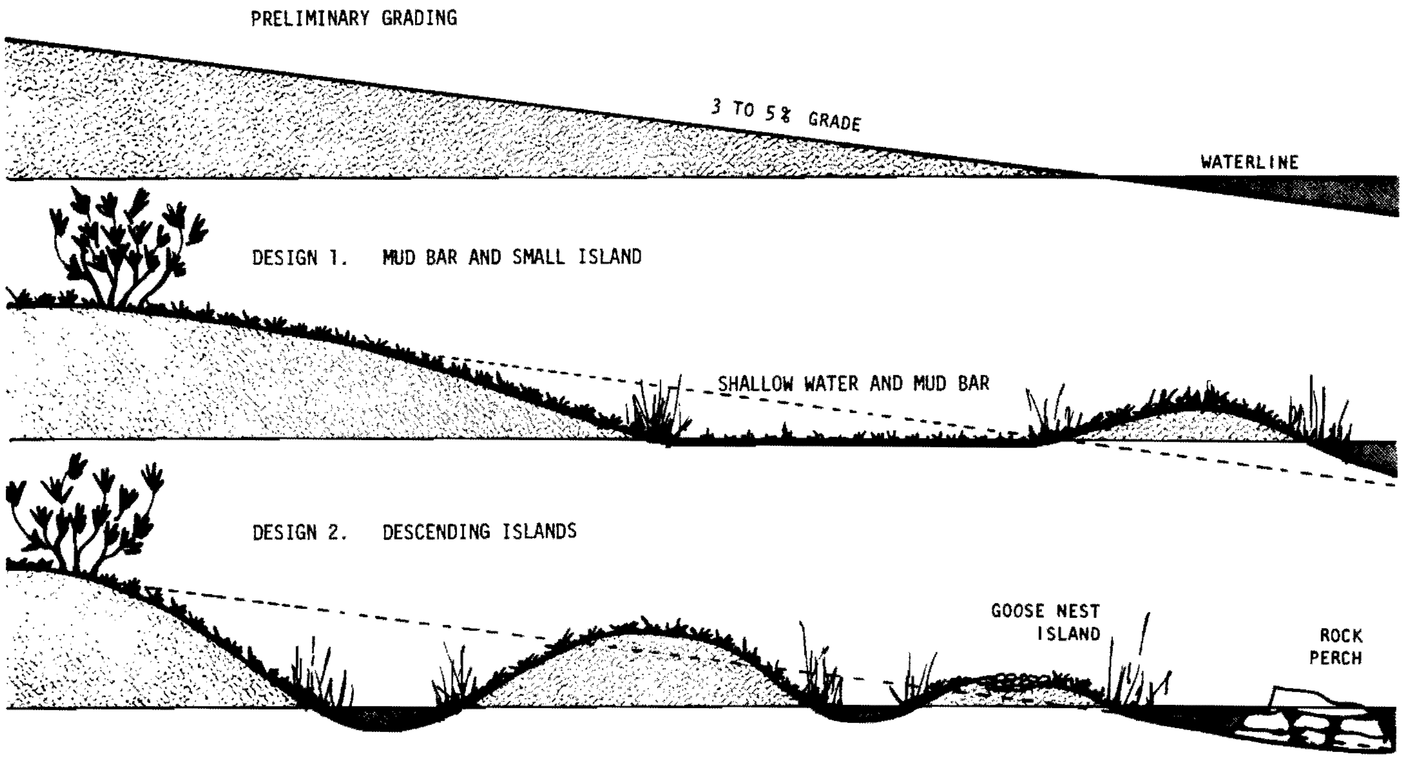


Fig. 2. Wildlife habitat design for arms of cove islands and shoreline peninsulas.

randomly repositioned each day. This method achieved statistical independence of samples and minimized recaptures.

RESULTS OF MONITORING

Results of spring bird counts have shown that over the past 5 years bird diversities in reclaimed habitats surrounding the oldest lake, East Lake (now 9 years old), have remained higher than in areas characteristic of pre-mining conditions (Fig. 1). Furthermore, an upward trend in bird diversities compared with the riparian control area is suggested. Documentation of an enhanced wildlife resource resulting from reclamation has been valuable in demonstrating to the general public that mining can be accomplished in an environmentally acceptable manner. Studies of the responses of birds to the first few years of gravel pit reclamation are presently underway. A first-year estimate of bird diversities for West Lake (prior to seeding shorelines) is shown in Figure 1.

The importance of islands to birds was realized largely through qualitative observations at White Rocks, and from literature sources (Hammond and Mann 1956, Kaminski and Prince 1977, Johnson et al. 1978, Giroux 1981, and others). However, results of small mammal studies gave quantitative support to the view that wildlife productivity in general might be substantially increased if more islands were developed than had been called for in the original reclamation plan. Early in the reclamation process, the desire to increase the abundance of predatory birds, particularly hawks and owls, resulted in habitat affinity studies of the small mammal prey base. It was found that the most important prey species, voles (*Microtus pennsylvanicus* and *M. ochrogaster*) are most abundant immediately next to the water's edge. More than twice as many voles were captured 3 feet from the shoreline than were captured 30 feet from the shoreline ($P = 0.015$), and approximately three times as many were captured next to the shoreline as were captured in the original pasture habitat ($P = 0.002$). These results are consistent with the view that the water's edge is a biologically productive zone and, being an interface between distinct habitats (in this case aquatic and terrestrial), it contributes as well to the total edge-effect so desirable to wildlife habitat quality.

ISLAND DEVELOPMENT

In keeping with the objective of creating a natural and attractive landscape, island designs were sought that would not only optimize wildlife habitat, but also enhance the appearance of final lake configuration.

The original reclamation plan for West Lake (22 acres) called for one large island. This plan was recently changed to include 50 small islands (ranging from 10 to 80 square feet each) and two larger cove islands (approximately 0.2 and 0.5 acres each). The increase in shoreline length over the original plan is 40 percent, or a difference of 1800 feet.

The longer shoreline, and the increased spatial complexity due to various shapes and locations of islands, are expected to increase both nongame and waterfowl nesting habitat. To maximize this potential, three distinct island types were developed: circular islands (from 4 to 10 feet in diameter); island perches made of rock; and cove islands with mud bars, exposed cobles and snags, and shallow water feeding areas (Fig. 2).

Shelter from wind was an important part of island design. Most coves face downwind, and islands tend to occur in clusters on the upwind side of the lake. A number of small islands were also placed in protected coves of larger islands or within coves of the lake itself.

During the first years of reclamation, it was recognized that establishing vegetation on islands 4 feet or more above the water was difficult because of desiccation and no convenient way to irrigate. Seed mixtures consisting mainly of tall wheatgrass (*Agropyron elongatum*), slender wheatgrass (*A. trachycaulum*) and alkali sacaton (*Sporobolus airoides*) have worked well at White Rocks for islands that are not planned to receive additional attention following initial seeding. Plans presently call for transplanting clumps of sedges, rushes, and willows on at least several of the smaller islands.

Island construction in West Lake was comparatively inexpensive because maximum lake depth was only 4 feet. Costs for the smaller islands (5 to 10 feet in diameter) were approximately $100.00 per island. Small islands were constructed with a front-end loader; cove islands were constructed by using an earth mover. Islands were seeded just prior to filling the lake.

In summary, small islands can be a highly effective landscape design feature, while at the same time contributing the following values to wildlife: 1) the additional shoreline length provides increased food and ecotonal habitat; 2) nongame bird and waterfowl nesting habitat is increased; 3) greater protection from predators, and from harassment by people and dogs, is achieved; and 4) islands permit the development of mud bars, perches, and shallow water feeding areas out in the lake itself where birds can be more readily observed.

Acknowledgements.—Appreciation is extended to Flatiron Companies of Boulder, Colorado for support and assistance. Thanks is also extended to Jill A. Stoecker for fieldwork and review of the manuscript, and to Paula Hansley and Nancy Lederer for additional field support.

LITERATURE CITED

Giroux, J.-F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. J. Wildl. Manage. 45:669-679.

Hammond, M.C., and G.E. Mann. 1956. Waterfowl nesting islands. J. Wildl. Manage. 20:345-352.

Johnson, R.F. Jr, R.O. Woodward, and L.M. Kirsch. 1978. Waterfowl nesting on small man-made islands in prairie wetlands. Wildl. Soc. Bull. 6:240-243.

Kaminski, R.M., and H.H. Prince. 1977. Nesting habitat of Canada geese in southeastern Michigan. Wilson Bull. 89:523-531.

Principles of Revegetating Mined Lands

DARREL G. MORRISON. Department of Landscape Architecture, University of Wisconsin-Madison, Madison, Wisconsin 53706.

Revegetation of lands disturbed by mining activity is generally acknowledged to be a desirable practice, and is in many cases a legislated requirement. For example, Public Law 95-87, the Surface Mining Control and Reclamation Act of 1977 (S.M.C.R.), passed by the U.S. Congress on August 3, 1977 requires mine operators to "establish on the regraded areas, and all other lands affected, a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area." (S.M.C.R. 1977, Sec. 515.(6) 19).

Three often-cited objectives for the revegetation of disturbed sites are: (1) prevention or reduction of wind and water erosion (Sec. 515(6)(4), S.M.C.R. 1977); (2) provision of food and cover for a variety of animal species (Plummer 1977); and (3) improvement of the visual or aesthetic quality of such sites (Bureau of Land Management 1981).

The purpose of this paper is to present:

1. Criteria for meeting the objectives of erosion control, wildlife habitat provision, and aesthetic quality improvement of disturbed sites through revegetation.
2. Concepts relating to naturally-evolved plant communities and successional processes as a basis for developing revegetation strategies.
3. A brief summary of environmental conditions which may prevail on a mined site.
4. Alternate strategies for revegetation of disturbed sites to concurrently meet the three major objectives listed above.
5. Tentative results of a specific revegetation experiment on an iron ore tailings deposit in Wisconsin, utilizing a natural successional theme.

Since revegetation techniques need to be specific not only to the region but also to the site, I will not attempt to enumerate specific techniques for ameliorating different site conditions nor provide recommended species lists. The case study will, however, suggest how certain principles can be applied to a specific revegetation project.

CRITERIA FOR CONCURRENTLY MEETING THE OBJECTIVES OF REVEGETATION

The objectives of erosion control, wildlife habitat provision, and visual quality improvement are not mutually exclusive. However, many revegetation practices in the past have emphasized one of these aspects at the expense of the others. In the following discussion, we will first examine criteria of successful revegetation to meet general performance standards in each of the three areas. Next, we will consider how the three objectives interrelate, and how they might be met concurrently.

Erosion and Sediment Control

Collier, et al. (1964) noted that the average annual sediment production from a surface-mined watershed was 42 T/acre, or more than one thousand times that of an unmined watershed. Curtis (1974) found in a study of three mined watersheds in Kentucky that the highest sediment yields occurred during the first six months after mining. Such findings emphasize the importance of providing a vegetative cover as soon as possible after mining activity occurs.

Two key characteristics of vegetation for controlling erosion and sedimentation are: (1) above-ground foliage which intercepts rainfall, thereby reducing the likelihood of its displacing and transporting soil particles; and, (2) a dense, fibrous network of roots to hold soil in place. Hill and Grim (1977) observed that erosion-controlling capability increases as the percentage of ground cover and canopy cover increase, and as the height of the canopy decreases. This suggests that high-level forest canopy--especially if it inhibits the growth of ground covering vegetation--is less valuable than lower-growing cover, e.g., shrubs and small trees.

Weaver (1968) extensively explored the erosion- and runoff-controlling capability of native prairie vegetation in the Midwest. He found the combination of above-ground parts of the plants (predominantly grasses), and the extensive network of rhizomes and fibrous roots to minimize both runoff and sedimentation. He compared the runoff and soil loss in test plots of prairie vegetation and alfalfa on a five-degree slope. At the time alfalfa had reached a height of five inches, four inches of "rainfall" were applied in each plot. Runoff in the alfalfa plot was measured at 40.8%, with a loss of 0.72 tons of soil per acre; runoff in the prairie plot was measured at 5.9% with no soil loss (Weaver, 1968).

Wildlife Habitat Provision

A diverse plant cover providing a variety of food and cover, logically enough, is likely to facilitate the presence of a variety of animal species (U.S. Department of the Interior, Fish and Wildlife Service 1978). In addition to plant species diversity, per se, growth form variation is likely to meet the needs of a greater diversity of animal species, e.g., herbaceous vegetation, shrubs and vines, and trees of varying size and density. If the vegetation occurs in community-like groupings that are interspersed, benefits to wildlife are increased because of the potential for overlapping utilization by species from adjoining habitats (Illinois Department of Conservation 1981).

Conveniently for wildlife habitat provision, a wide range of micro-habitats are likely to exist on a reclaimed gravel pit site (e.g., dry upland conditions to aquatic sites), facilitating the development of a "mosaic" of plant community types.

Aesthetic Quality Improvement

In situations where a mine site is adjacent to, or visible from, transportation corridors, recreational or residential sites, the aesthetic quality represents an additional objective of revegetation. It is not the point of this paper to discuss aesthetic theory or the controversies related to the possible quantification of aesthetic quality. However, it is appropriate to consider some characteristics of natural landscapes that have been identified as contributing to beauty in the environment.

Kates (1967), in an effort to determine those characteristics which provide the elusive quality of beauty, came to the conclusion that environmental beauty exists in the absence of discordant elements. Most people would find barren, excavated areas within an otherwise vegetated area to be discordant.

Dasmann (1964) identified four characteristics contributing to beauty in the natural environment as order, diversity, health, and function. Order is demonstrated in the presence of many individuals of a plant species, with a resultant repetition of forms, colors and texture. Yet this order is not carried to the point of monotony, due to the diversity of sizes, the different species' occurrence in different micro-habitats, and spatial contrasts. Health is evidenced by green and growing plants producing flowers and seeds. Function is apparent when the vegetation is seen to stabilize soil or to provide food and cover for wildlife (Dasmann,1964).

Jones (1979) characterized beauty in the environment as having three essential components. These are unity, or a sense of one-ness, similar to the concept of order; intactness, or a quality of being unimpaired or undamaged; and vividness, which may result from contrasts, or outstanding form, color, or texture, for example (Jones 1979).

From these preliminary criteria for accomplishing the three earlier-stated objectives of revegetation, it is clear that performance standards for erosion control, wildlife habitat provision, and aesthetic quality improvement may not only be compatible, but complementary.

The characteristics of species diversity as well as growth form diversity are appropriate to all three objectives, as is a spatial organization which leads to interspersion of different associations of vegetation in a mosaic of subunits with varying spatial characteristics.

CONCEPTS OF PLANT COMMUNITIES AND VEGETATIONAL SUCCESSION

The pre-settlement landscape typically possessed these various characteristics, being a series of associations of plants adapted to the prevailing edaphic, topographic, climatic, hydrologic, and biotic conditions. These aggregations, for convenience referred to as plant communities, usually graded gradually one into the next, creating a vegetational "continuum" (Curtis 1959) that provided for the food and cover requirements of a variety of native animal species. Plant communities are rarely completely stable entities, even in the absence of human-induced changes. Instead, they are dynamic, with the process of species change that occurs therein typically referred to as plant succession (Clements 1916). In the following discussion, theories of plant succession and of the role of early invaders in the successional process will be presented, insofar as they appear to be useful in establishing principles for revegetation.

In "classical" successional theory, as set forth by Clements (1916), the process is called primary succession if it originates on a site where a layer of soil has not yet developed, as on bare rock or sand. The sequence of plants on such sites, beginning with mosses and lichens, plays a soil-building role in this process. Secondary succession refers to the process in which a series of plant species invades and colonizes a site where there is soil developed, but from which the vegetation has been removed.

The first plants to invade a site in either of these successional sequences are commonly referred to as pioneer species (Clements 1916). In Clements' classical concept of succession, these "pioneers" modify the environment to make it more amenable to plants which invade and colonize later. Those species which are the last to invade and which may ultimately perpetuate themselves in a relatively stable community are called climax species.

These views and even these terms have undergone re-examination and refinement in the years since Clements originally advanced them (McCormick 1968, Connell 1972, Connell and Slatyer 1977, Drury and Nisbet 1978). Some of these later refinements are particularly relevant to our discussion of a successional approach to revegetation. For example, Connell and Slatyer (1977) submit that there are three different models of succession relative to the mechanisms to which vegetational change occurs and the roles played by the first species to invade a site.

Typical characteristics of early-successional species cited by Connell and Slatyer include their ability to:
(1) Produce large numbers of propagules.
(2) Be widely dispersed.
(3) Survive in a dormant state for a long period of time.
(4) Germinate and become established on unoccupied places.
(5) Grow quickly to maturity, e.g. annuals and biennials which mature and produce seed in one or two years.

In contrast, these early-successional colonizers are typically not able to:
(1) Germinate, grow and survive on already-occupied sites.
(2) Grow and survive where there is heavy shade or deep litter.

In all three models of succession, the early occupants of a site modify it so that it is unsuitable for further recruitment of more individuals of these same early-successional species. But they differ in their relationship to later-successional species and their effect on the way in which new species may enter the site. The three models of succession may be identified as:
(1) The facilitation model. This model in essence accepts Clements' view that the early-successional plant species modify the environment, making it more suitable for later successional species to invade and grow to maturity, i.e., "facilitating" their entry.
(2) The tolerance model. In this, the late succession species are thought to be those which are simply dispersed later and/or grow more slowly than the earlier invaders. They do not depend on the presence of those early colonizers to create a suitable environment and would develop whether or not the early-successional plants were present.
(3) The inhibition model. This departs most dramatically from classical successional concepts, in that it states that the first invaders, once colonized, actually inhibit the invasion of subsequent colonists and/or suppress the growth of those already present. The later species can only invade or grow when the early colonizers are damaged or killed. Connell and Slatyer cite evidence of "mid-successional" species forming dense stands through vegetative spreading, e.g. shrubs and perennial sod-forming grasses which appear to effectively stop a successional sequence.

The facilitation model, i.e., the traditional, classical sequence, commonly applies to primary successional sites, i.e., where the substrate is exposed by disturbance, or rock and rock-like materials are deposited on the surface.

The tolerance and inhibition models apply in most secondary successions. Whether the tolerance model or the inhibition model is in effect in a specific situation will be determined in large part by the actual species which are introduced first. For example, if the first plants are annuals, they are unlikely to greatly inhibit later introductions or slower-growing species. On the other hand, if the first plants on the site are sod-forming perennial grasses, they may inhibit the germination and growth of slower-growing species that may have been introduced simultaneously; or they may prevent the growth of other species whose propagules arrive later, either through natural invasion or human introduction.

In vegetation of mined sites, both primary and secondary successional situations may exist. From the above discussion, it is apparent that the strategy for revegetation should be geared to the specific situation. Further, if successional change is a part of the strategy for revegetation, it seems obvious that the first species introduced should behave in the "facilitative" or "tolerant" manner, as opposed to inhibiting later succession species.

ENVIRONMENTAL CONDITIONS ON MINED LANDS

The effects of open pit or surface mining on a site are many and varied, depending on the material to be removed, the depth of the deposit, the mining method(s), and processing techniques. Common to most such activities are the following effects:
(1) Removal of the vegetational cover.
(2) Changes in the hydrologic environment;

i.e., modification of surface drainage patterns and/or changes in subsurface water table.

(3) Creation of new topographic forms; for example:
    a) the pit, from which material is removed during the mining process,
    b) sheer cliffs,
    c) new above-grade deposits of overburden (spoils), removed to gain access to the mineral that is being mined; and sometimes deposits of waste products resulting from processing of the material.

(4) "Unnatural" compaction of surfaces, as a result of the movement of trucks and heavy equipment over them.

There are a variety of other chemical and physical changes specific to individual minerals and specific sites. Further, there may be extremes of pH and a shortage of available nutrients, both of which affect revegetation potential and/or approaches. There is no attempt in this paper to enumerate the various specific conditions which might occur on a variety of mine sites, nor to provide amelioration techniques for them. It is important to recognize, however, that these conditions need to be monitored on a specific site, and need to be considered in reclamation and revegetation planning.

ALTERNATIVE STRATEGIES FOR REVEGETATION OF MINED SITES

Having considered general requirements for erosion control, wildlife habitat provision, and aesthetic improvement of mined sites through vegetation, as well as the concepts of natural succession in plant communities and some of the typical characteristics of mined sites, we are now ready to consider alternative strategies for revegetation.

"Hands off" (No Intervention) Revegetation Strategy

This theoretical strategy for revegetating a disturbed site entails the same "natural succession" process which occurs on sites that are laid bare by natural disturbances (e.g., fire, flood, or glacial action). The "hands off" strategy would simply permit agents such as birds, mammals, wind and water to carry propagules of a wide variety of plants to the site. These, along with those already present on the site, would germinate and grow on the portions of the site that are favorable for them. These first colonizers might persist or be replaced by others, depending on which of the successional models is operating and/or the combination of plant species and environmental conditions that prevail. Under certain conditions, this technique could be quite effective in meeting the three objectives under discussion. These conditions would include: a) a ready supply of propagules (e.g., seeds and/or rhizomes) of a variety of plant species that meet criteria for providing erosion control, wildlife habitat, and aesthetic quality; b) the presence of a variety of site conditions with the capacity to support a diversity of plant community types.

Drawbacks or impediments to this "hands off" strategy for revegetation include: a) the potential for erosion on part or all of the site prior to the invasion and establishment of a vegetative cover; b) the improbability of a sufficiently diverse mix of species being readily available on or near the site to meet the variety of site conditions; c) invasion and colonization by species which, once they become established, act as inhibitors of successional processes; and, d) parts or all of the site may not be capable of supporting the invading species without soil amendments or other ameliorative techniques.

"Active" Revegetation Strategies

If any or all of these impediments to "natural" succession exist, conscious decisions must be made to overcome them, through a program of active revegetation efforts. Among the concerns to be considered in the development of such a program are these:

(1) Selection of plant species, both for the initial planting and those which will be encouraged in the long run.

(2) Selection of site modification and soil amendment techniques to facilitate the establishment of the vegetation.

Species selection. For the revegetation objectives being discussed in this paper, there is strong support for a diversity of plant species, of a variety of growth forms and spatial distribution patterns. Other criteria in selecting plant species for revegetation in this context are the following:

a) They should not include strong invasive plants that may create problems either on or off-site by developing "monocultures" which eliminate diversity.
b) They should be capable of surviving on the site without extensive or continued irrigation.
c) They should be capable of surviving with minimal inputs of fertilizers and/or other soil amendments.

There is a long-standing argument relative to the comparative value of native plant species versus introduced species for revegetation of disturbed areas. In practice, there has probably been greater use of introduced species, often in single-species plantings with heavy fertilization programs, than there has been of native species in groupings resembling naturally-evolved plant communities. Arguments against the use of natives have included the following:

a) Seed is not readily available in the quantities needed.
b) Native species are slower to establish than certain highly reliable introduced species.
c) Productivity of native species may be less than that of non-native.

The non-availability factor is certainly a detriment to the exclusive use of native species in some areas. However, if more experimental work with natives were conducted which could demonstrate their usefulness in revegetation work and people in the field created a demand, the supply could be developed. Even now, it is often possible to obtain many species as seed. The Soil Conservation Society of America at Ankeny, Iowa publishes a state-by-state directory of sources of native seeds and plants. The Illinois Department of Conservation's Mining Program has recently published Illinois Plants for Habitat Restoration, with information not only on the plants' characteristics and their utilization by fish and wildlife, but also their commercial availability (Illinois Department of Conservation, 1981).

Regarding b) and c) above, Wiener (1980) argues as follows:

> "Most experts agree that introduced plant species will grow faster and produce higher yields sooner than native species. However, native plant species have become adapted over the years to the area's climate and topography. Adaptation to the environment changes the genetic makeup of plant species through years of natural selection. Introduced species do not have these advantages, although they may serve to establish a ground cover to minimize erosion. Reclamation is incomplete if the area is dominated by introduced species whose ability to withstand the environmental pressures of a given region is not proven." (Wiener, 1980: 80).

In recent reclamation work at Colstrip, Montana, Depuit et al. (1980) have found that native species can achieve an excellent rate of establishment and site stabilization. They suggest that problems that have been associated with establishment of native species result from a complex of factors, including incompatability of the plant species with the soil conditions, inadequate consideration of seed germination requirements, poor seedbed preparation, inappropriate planting time or inferior seed quality. They further contend that the difficulty in establishing natives is often strong competition from aggressive introduced species (DePuit, et al., 1980).

These strongly aggressive introduced species, then, might often act as "inhibitors" of succession on the revegetation site, and might even become "pest" plants on adjacent lands. Long-term studies need to be made in a variety of revegetation situations, in order to determine which species--native or introduced--act as facilitators, or as inhibitors, of successional processes on a site. It would seem likely that perennial sod-forming species would constitute an inhibitory element to subsequent invasion; and that annuals would act more in the "facilitation" and/or "tolerance" models of succession on such sites.

Regardless of whether native or introduced species are utilized in the intial revegetation efforts, a long-term goal of a complex of native community-like groupings is capable of accomplishing the three goals of erosion control, wildlife habitat provision, and aesthetic improvement of a disturbed site.

Site modifications/soil amendments. To facilitate a successional process leading to natural community-like groupings, thorough analyses of soil chemistry and texture may suggest a variety of amelioration techniques. For our purposes here, suffice it to say that revegetation planning must be done to make the site amenable to the species selected. This may mean the addition of fertilizers to provide essential nutrients; "furrowing" or roughening of the surface to create micro-environments conducive to the germination and growth of some species; and mulching to retain moisture and reduce erosion potential during the initial period.

For surface mining such as gravel extraction, grading during and after the mining operation can facilitate the development of naturally-evolving plant community types. For example, by creating gentle slopes at edges of post-mining bodies of water, and then providing propagules of emergent aquatic plant species, a "natural transition" between land and water can be accomplished. This will help in meeting all three objectives under discussion here.

A CASE STUDY IN REVEGETATION

As an example of a revegetation strategy with the goal of initiating a natural successional process, a description of a case study dealing with the revegetation of an iron ore tailing deposit in Jackson County, Wisconsin is provided.

Initiated in 1979, and funded by USDA Hatch funding administered by the College of Agricultural and Life Sciences at the University of Wisconsin-Madison, the project supplies three years' data at this time. Hence, it cannot be considered a long-term study, but does provide useful information about the early establishment and successional tendencies on a difficult site (Morrison, 1981).

After doing preliminary greenhouse studies, graduate student Julie Hardell planted field plots in early June 1979, utilizing nine native prairie species and one non-native annual grass as an initial companion crop.

Species that were selected for the initial planting were:

Grasses:
<u>Andropogon gerardii</u> (Big Bluestem)
<u>Andropogon scoparius</u> (Little Bluestem)
<u>Bouteloua curtipendula</u> (Sideoats Grama Grass)
<u>Elymus canadensis</u> (Canada Wildrye)
<u>Panicum virgatum</u> (Switchgrass)
<u>Setaria spp.</u> (Foxtail) (Annual)

Forbs:
<u>Amorpha canescens</u> (Leadplant)
<u>Lespedeza capitata</u> (Roundheaded Bush-clover)
<u>Monarda fistulosa</u> (Bergamot)
<u>Rudbeckia hirta</u> (Black-eyed Susan)

These species were selected because a) they are indigenous to the area; b) they are tolerant of wind and sun exposure, limited water supply and high temperature--all properties of the tailings environment; c) many are able to tolerate relatively low-nutrient soils; d) they have the capacity to control erosion because of their above-ground foliage in combination with deep and fibrous root systems. (Hardell, 1980).

The grasses include a cool-season species (<u>Elymus canadensis</u>) for early growth. The other native species are warm-season species and include both clump-forming and sod-forming species. The annual non-native, Foxtail (<u>Setaria spp.</u>) was selected because of its observed ability to germinate and grow on disturbed sites without seeming to persist or inhibit the development of perennials.

The forbs include two species of leguminous plants (Leadplant and Bush-clover), for their nitrogen-fixing capabilities. The other two forbs were included because of their ability to thrive in "pioneer" sites without inhibiting later species.

Iron ore tailings are not typically invaded naturally by adjacent vegetation. High surface temperatures, combined with low nutrient availability and essentially no organic matter create a hostile environment. The experimental site tailings analysis revealed low phosphorous, very low nitrogen, marginal potassium and magnesium, and sufficient calcium. The average pH is 8.5.

In order to determine amounts of supplementary nutrients needed to achieve an erosion-controlling cover of predominantly native species, three rates of nitrogen and phosphorous fertilizers were added to the plots in various combinations; two levels of sewage sludge were applied. See Table 1 for rate of fertilizer applied. Including the control plots with no additives, a total of eleven different treatments were applied, with four replications of each in four square-meter plots. No supplemental watering or weeding has been done in the plots since they were planted. Nitrogen was added at the beginning of the 1980 and 1981 growing season at the same rates which were applied to each plot initially. Careful monitoring of plant growth and cover were carried out by Julie Hardell and Gretel Hengst during the 1979, 1980 and 1981 growing seasons.

In summarizing the results to date, it is significant that foliage cover on the N_1P_2 and N_2P_2 plots has exceeded 90 per cent during the second and third growing seasons. While foxtail was visually dominant the first year, and provided both organic matter and some erosion protection during the first year, it has become almost non-existent in the third year plots. Canada Wild Rye and Sideoats Grama Grass accounted for the largest percentage of cover in the second and third years. Forb response has been slow, although the Black-eyed Susan (a biennial) bloomed abundantly during the second year.

TABLE 1. FERTILIZER RATES APPLIED

Fertilizer	Symbol	Rate	
Ammonium nitrate (NH_4NO_3)	N_2	175 Kg/ha	156 lbs/ac
	N_1	88 Kg/ha	79 lbs/ac
	N_0	0 Kg/ha	0 lbs/ac
Triple super phosphate ($CA(H_2PO_4)_2$)	P_2	112 Kg/ha	100 lbs/ac
	P_1	28 Kg/ha	25 lbs/ac
	P_0	0 Kg/ha	0 lbs/ac
Sewage sludge (dry weight)	SS_2	85 mt/ha	38 t/a
	SS_1	42 mt/ha	19 t/a

A small number of Trembling Aspen (<u>Populus tremuloides</u>) invaded the experimental plot area during 1980 and 1981, suggesting that there will be additional successional changes occurring; and that the initial planting has facilitated succession rather than inhibiting it. The Foxtail (<u>Setaria</u> spp.) did provide some competition to the native species during the first growing season. But it also demonstrated erosion-controlling potential, provided some protection from dessication and tailings abrasion to the young native seedlings, and certainly contributed to organic matter deposition in the plots. That role has been taken over by the cool-season Canada Wild Rye (Elymus canadensis) in the second and third years. It is likely to be assumed by Sideoats Grama Grass (Bouteloua curtipendula) and other warm season species in later years. Because of the tendency of many of those species to be clump-formers, as opposed to solid sod-formers, they will likely permit continued invasion by woody species (trees and shrubs) from adjacent areas. If there were not a ready supply of seed of the woody species available, the site could have been "innoculated" with a mix of these seeds as well.

By contrast, if the first generation of planting on a site such as this were an aggressive sod-forming species (e.g., Smooth Brome (Bromus inermis)), it is likely that it would have inhibited any changes in species composition over time.

SUMMARY AND CONCLUSIONS

It has been the intent in this paper to present information and/or concepts in the following areas as a basis for establishing some principles for revegetating land disturbed by surface mining activity:

(1) Requirements of revegetation to meet three concurrent objectives:
 a) erosion and sedimentation control;
 b) provision of wildlife habitat; and,
 c) improvement of aesthetic quality on such land.

There is evidence supporting the principle that a diversity of plant species, growth forms, and spatial distribution patterns will enhance each of these three objectives.

(2) Concepts relating to natural plant communities and successional models that have been identified as being at work in them; i.e.,
 a) the facilitation model;
 b) the tolerance model; and,
 c) the inhibition model.

To accomplish a "successful" successional revegetation, it is important to determine whether the species that are initially introduced will function in one or another of these manners on the site being revegetated. To achieve desirable diversity levels, it is reasonable to avoid utilizing species which tend to inhibit other species by developing dense, "impenetrable" stands themselves.

(3) A summary of physical characteristics of sites that have been modified by surface mining.

In many cases, the changes which occur create conditions which actually permit a greater variety of environmental conditions than existed previously. Grading which occurs during and after the extraction process can be planned to maximize opportunities for a variety of natural community-like groupings.

(4) A discussion of two alternative strategies for revegetation; i.e.,
 a) the non-intevention approach, versus
 b) active revegetation approaches.

It is suggested that in order to concurrently meet the three objectives, some "hands-on" activity must be carried out, and decisions regarding species selection and site modification need to be based on specific site conditions.

(5) A presentation of one specific experimental study, in which a successional approach has been taken on iron ore tailings in Wisconsin, as an example.

The experience there--while it needs to be monitored for much more than three years--suggests that planning for successional change and for a diverse vegetational cover is a practical possibility.

ACKNOWLEDGEMENTS. The author wishes to acknowledge the assistance of several individuals whose work and consultation has proven vital to the ideas presented herein. These include: Dr. Richard Corey of the Soil Science Department at the University of Wisconsin-Madison, for advice on soil amendments for the iron ore tailings revegetation study; Dr. Evelyn Howell, plant ecologist in the Department of Landscape Architecture, University of Wisconsin-Madison; also graduate students Julie Hardell, Peter Lindquist, Gretel Hengst, and John Harrington. Support by the Jackson County Iron Company and the College of Agricultural and Life Sciences, University of Wisconsin-Madison is also gratefully acknowledged.

LITERATURE CITED

Bureau of Land Management, 1981. Powder River, Draft Environmental Impact Statement, Coal. U.S. Dept. of the Interior, September.

Clements, F.E. 1916. Plant succession: an analysis of the development of vegetation. Carnegie Inst. Pub. 242, 512 pp.

Collier, C.R., R.J. Pickering and J.J. Musser, 1964. Influence of strip mining on hydrologic environment of Beaver Creek Basin, Kentucky, 1955-1959. Dept. of the Interior USGS Professional Paper 427-B. Washington, D.C.

Connell, J.H. 1972. Community interactions on marine rocky intertidal shores. Ann. Rev. Ecol. Syst. 3: 169-192.

Connell, J.H. and R.O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. Amer. Naturalist 3: 1119-1144.

Curtis, J.T. 1959. The vegetation of Wisconsin. The University of Wisconsin Press, Madison.

Curtis, W.R. 1972. Sediment yield from strip-mine watersheds in eastern Kentucky, in: Second research and applied technology symposium on mined land reclamation. National Coal Association, Washington, D.C.

Dasmann, Raymond F. 1964. Aesthetics of the natural environment. Paper presented to meeting of The Conservation Foundation.

DePuit, E.J. 1980. Establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding method, mixture and rate. Montana Agricultural Experiment Station. Research Report No. 163. Montana State University, Bozeman, Montana.

Drury, W.H. and I.C.T. Nisbet. 1973. Succession. Journ. Arnold Arboretum 54: 331-368.

Hardell, Julie. 1980. Response of prairie species planted on iron ore tailings under different fertilization levels. M.S. thesis, Department of Landscape Architecture, University of Wisconsin-Madison.

Hill, R.D. and E.C. Grim. 1974. Environmental protection in surface mining of coal. National Environmental Research Center. Environmental Protection Technology Series EPA-670/2-74-093. Cinncinnati.

Illinois Department of Conservation. 1981. Illinois plants for habitat restoration: commercial availability, characteristics and fish and wildlife utilization, Springfield. 61 pp.

Jones, G.R. 1979. Landscape assessment: where logic and feelings meet. Landscape Architecture 68(2): 113-121.

Kates, R. 1967. The pursuit of beauty in the environment. Landscape 16: 21-25.

McCormick, J. 1968. Succession. VIA I (Student publication, Graduate School of Fine Arts, University of Pennsylvania), Philadelphia, pp. 22-35, 131-132.

Morrison, D.G. 1981. Vegetation and iron ore tailings: short-term conclusions. Landscape Architecture 71(4): 480-481.

Plummer, A.P. 1977. Revegetation of disturbed intermountain sites. In: Reclamation and use of disturbed land in the Southwest, John L. Thames, editor. The University of Arizona Press, Tucson, pp. 302-339.

Surface Mining Control and Reclamation Act of 1977. Public Law 95-87, 95th United States Congress.

U.S. Department of the Interior, Fish and Wildlife Service. 1978. Mined land reclamation for fish and wildlife. Government Printing Office, Washington, D.C.

Weaver, J.E. 1968. Prairie plants and their environment. University of Nebraska Press, Lincoln.

Wiener, D.P. 1980. Reclaiming the West. INFORM, Inc., New York.

Wildlife Considerations in the Development of Riparian Communities

ROBERT E. SZAFONI. Department of Civil Engineering, University of Illinois, Urbana, IL 61801.

INTRODUCTION

In any mining operation, especially those which have the potential for formation of lakes and ponds, the development of wildlife habitat must consider the riparian zone. A riparian zone as generally defined is the vegetation occuring in or adjacent to a water body, including but not restricted to flood plain areas which have the ability to persist under saturated conditions and/or frequent inundation. In the use applied in this paper, the borders of lakes and ponds which grade from moist through mesic to dry conditions will be considered a riparian zone. With careful development the intrinsic value of the area for wildlife as well as recreation will be improved. A carefully developed zone of vegetation will serve to provide habitat to wildlife and protect and improve water quality. All of these benefits can be provided at relatively low cost if proper planning is implemented early in the mining operation.

The quality and quantity of riparian vegetation has significant influence on the physical, chemical, and biological properties of the associated terrestrial and aquatic ecosystems. Vegetation cover slows overland water runoff, increases percolation and reduces sheet erosion. Riparian vegetation also stabilizes banks and functions as a trap for nutrients, sediments and pesticides. It, therefore, maintains water quality and biological integrity of associated aquatic systems (Karr & Dudley, 1980).

Riparian vegetation plays an equally important role in the maintenance of biological communities. Numerous wildlife species utilize these areas to meet some or all of their requirements for food, cover, and reproduction. Avian breeding densities in riparian habitats are greater than in associated upland areas (Johnson, 1978). Rappole and Warner (1976) and Stevens, et al. (1977) found that censuses of riparian areas commonly resulted in several times the number of avian migrants when compared to adjacent habitats. Emmerich and Vohs (1982) in a study of four woodland habitats found the riparian community possessed not only the most diverse bird populations during the breeding season but also during the winter and during spring migration. Several mammals, particularly furbears (e.g. mink, muskrat), are closely associated with the land/water interface. Other mammals will visit these areas regularly in search of food or water (Odum,1978). Many reptiles and amphibians, especially frogs and turtles, are dependent on shoreline areas. Riparian habitats, per unit area, support greater numbers and diversity of wildlife species and sustain higher productivity than many other terrestrial or aquatic systems (Odum, 1978).

Table 1. Fur and game species associated with the riparian zone.

Species	Habitat Use[a]
Mallard	r,f,c
Wood Duck	R,F,C
American Woodcock	R,F,C
Canada Goose	r,f,c
Raccoon	r,F,c
Red Fox	f,c
Gray Fox	f,c
Striped Skunk	R,F,C
Mink	R,F,C
Muskrat	R,F,C
Eastern Cottontail	r,f,c
White-tailed Deer	f,c

[a] R = reproduction, F = food, C = cover. Upper case letter indicates riparian zone primary area of activity.

In spite of their ecological significance, more than 70% of North American riparian areas may have already been destroyed (Council of Environmental Quality, 1978). What remains is continually being infringed upon by agriculture, flood control, residential development, channelization, and other projects.

Tremendous potential exists for the development of newly created riparian areas for the benefit of wildlife. Gravel mining and quarrying present excellent opportunities to design natural habitats. All too often, however, these 'reclamation' attempts consist of seeding grass or a

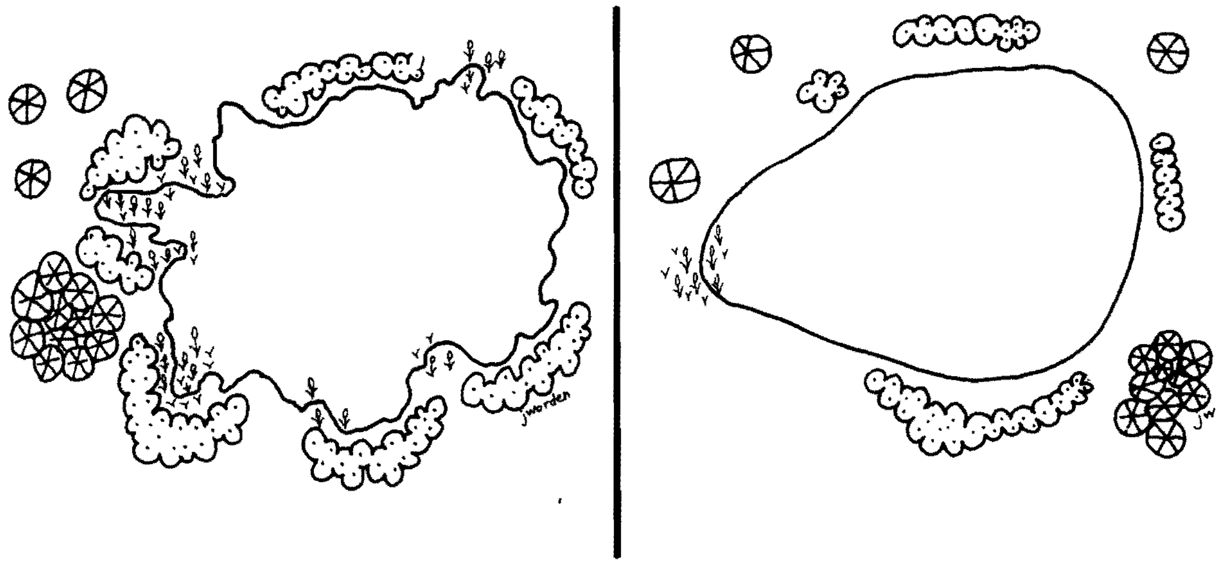


Figure 1. Though of similar areas, the lake illustrated on the left provides greater potential for wildlife populations due to increased shoreline development.

grass/legume mixture over the entire area. These efforts result in a dense, low-lying vegetation cover which is effective in erosion control but affords poor wildlife habitat. Additionally, the density of vegetation can impair colonization, germination, or growth of invading plant species and slow successional development (Vogel, 1980).

This paper reviews management techniques and strategies for the development of the riparian communities of gravel pit lakes specifically addressing wildlife needs. Several fur and game species occur in riparian areas (Table 1). Management for one or more of these may provide recreational or economics returns while producing a habitat useful to many non-game species.

Although aspects such as habitat size and shoreline development are discussed, the greatest benefits will be accrued from the judicious selection and establishment of vegetation. As such, vegetational development will be the major emphasis of this paper.

The success of any reclamation program is dependent on the extent of pre-operational planning. Several questions will need to be answered before the initiation of any work.

1)What species or groups of species are desired (i.e. target species) and, what are its (their) habitat requirements?

2)What are the economic limits of the project?

3)Can any required monitoring or maintenance be performed?

After dealing with these issues and working out conflicts, one can proceed in the design and implementation of a reclamation scheme.

MANAGEMENT STRATEGIES

Shoreline Development

Shoreline development refers to the degree of irregularity exhibited by a lake shore. Circular and rectangular lakes have relatively low shoreline development while lakes with several bays, inlets, coves, and point bars have much greater development (Wetzel & Likens, 1977).

Lakes with a high degree of shoreline development offer a greater potential for attracting and maintaining wildlife populations. As noted above, many reptiles and amphibians are intimately associated with the land/water interface. Shorebirds, waterfowl, songbirds, large mammals, and furbearers also utilize lake shores extensively.

Gravel mining frequently produces final pit lakes that are very regular in shape with poor shoreline development. Grading and developing points, coves, and bays will increase the length of shoreline and provide for increased abundance and diversity of these wildlife species (Figure 1).

Fisheries will also benefit from shallow water areas created as a result of shoreline development, since these areas provide spawning and feeding grounds. Coves and point bars can also offer protection during periods of bad weather or high winds.

Area Size

Investigations of the relationship between species richness (# of species) and size of habitat islands have indicated that the number of species on a habitat island increases with island size. Here, the term island refers to any area of habitat surrounded by areas of dissimiliar habitat. Some familiar examples are woodlots surrounded by agricultural fields, clearings within mature forests, and parklands in urban areas.

In their investigations of breeding bird use of riparian habitats, Stauffer and Best (1980) observed bird species richness to increase with habitat width. This trend was recorded for both herbaceous and wooded strips though the effects of width on wooded strips was much greater. Species specific data indicate that 7 species used wooded plots less than 20m wide. As width increased to 50m, 4 species were added while 9 more were present in plots less than 200m. Forman, et al. (1976) recorded a similiar trend for New Jersey forests. The richness and abundance of spring migrants is also related to habitat patch size (Martin,1980).

While the response of mammals to increaing 'island' size has not been documented, it will be true that larger habitat patches offer greater potential for colonization and continued use than smaller areas.

When planning and designing gravel pit lakes and ponds, riparian areas revegetated for wildlife should be as large as possible (200m or more). This is especially important in areas where the surrounding land use is of little or no value to wildlife (e.g. agricultural lands, pasture). These large patches will be vital in attracting and maintaining wildlife populations in these areas. If the adjacent habitats presently support abundant and diverse wildlife populations, patch width will be less critical. In these situations, it will be important to develop high quality habitat immediately along the shoreline.

Table 2. Ground cover plant species useful to wildlife and their applications.

Species	Wildlife Use[a]		Situation[b]
Reed canarygrass	F(s,b)	C(b)	W,D
Redtop	F(s,b)	C(b)	W,D
Deertongue	F(s,b)	C(b)	W
Timothy	F(b)	C(b)	W,D
Alsike clover	F(s,b)	C(b)	W
Birdsfoot trefoil	F(b)	C(b)	W,D
Switchgrass	F(s,b)	C(b)	D
Korean lespedeza	F(s,b)	C(o)	D
Kobe lespedeza	F(s,b)	C(o)	D
Clover	F(s,b)	C(b)	D
Smartweeds	F(s,b)		W
Wildmillets	F(s,b)		W
Weeping lovegrass	F(s,b)	C(o)	D

[a] F = food (m = mast, s = seeds, f = fruit, b = browse).
C = cover (n = nest/den, 0 = other (e.g. escape), b = both).

[b] W = wet to moist areas near water's edge.
D = drier, upland areas.

Vegetation Plantings

The development of riparian vegetation is performed in two phases. The initial phase requires the establishment of a quick-growing, erosion controlling ground cover. If shorelines are already in permanent cover such a procedure may not be required. However, the creation of ponds and lakes through mining and quarrying operations frequently destroys much, if not all, of the surrounding plant community.

The second phase of vegetation development involves the establishment of herbaceous and woody plantings to increase spatial heterogeneity, create edges, and provide wildlife food, cover, and nest sites. These factors increase the potential wildlife value of the area.

In either phase, a critical item is the judicious selection of plant species. There are several criteria used in this process. These can be broadly classified under site compatibility and wildlife benefits. Species selection should be made with respect to site specific parameters such as soil type, moisture relationships, and shade tolerance as well as local climate (temperature range, rainfall patterns,

Table 3. Shrub species useful to wildlife and their applications.

Species	Wildlife Use[a]		Situation[a]
Alder	F(s,b)	C(n)	W
Arrowwood	F(f,b)	C(n)	W
Red osier dogwood	F(f,b)	C(n)	W
Silky dogwood	F(f,b)	C(n)	W
Gray dogwood	F(f,b)	C(n)	W,D
Rough leaf dogwood	F(f,b)	C(n)	W
Blackberry/raspberry	F(f)	C(o)	D
Cherry	F(f)	C(n)	D
Crabapple	F(f,b)	C(n)	D
Hawthorn	F(f,b)	C(n)	D
Persimmon	F(f,b)	C(n)	D
Sumac	F(f,b)		D
Autumn olive	F(f,b)	C(n)	D
Russian olive	F(f,b)	C(n)	D

[a] Codes same as Table 2.

Table 4. Tree species useful to wildlife and their applications.

Species	Wildlife Use[a]		Situation[a]
Cottonwood		C(n)	W
Sycamore		C(n)	W
Silver maple	F(s)	C(n)	W
Birches	F(b)	C(b)	W
Willows		C(b)	W
Green Ash	F(s)	C(n)	W
Hackberry	F(f)	C(n)	W
Pin oak	F(m)	C(n)	W
Swamp white oak	F(m)	C(n)	W
White oak	F(m)	C(n)	D
Red oak	F(m)	C(n)	D
Hickories	F(m)	C(n)	D
Black walnut	F(m)	C(n)	D
White ash	F(s)	C(n)	D

[a] Codes same as Table 2.

etc.). Species which can survive in wetter areas at the water's edge may not do well in areas farther upland. The season of planting must also be considered as it affects the establishment of many grasses, legumes, and herbaceous plants.

The second consideration is the ability of the planting to meet wildlife requirements. Herbaceous species should be evaluated on their potential as cover (e.g. dense grass patches), nesting sites, and food (good seed crop, superior forage). Woody species are also selected on the basis of cover (e.g. low-lying shrubs), nest/den sites, and food (fruit, mast, browse).

Specific plant species referred to in this paper are those I have observed or literature has indicated as beneficial to wildlife and are suitable for use in central and southern Illinois (Tables 2,3,4). Though these species can exist over a wide geographic area, some may not be compatible with particular local conditions. In these situations, alternative species, especially a closely related one, may perform equally well. In many instances, it is preferable to plant native species. Wildlife are more familiar with these species and may avoid novel plantings. Some exotics, however, have proven quite useful in wildlife management and their value should not be overlooked (e.g. autumn olive, Russian olive).

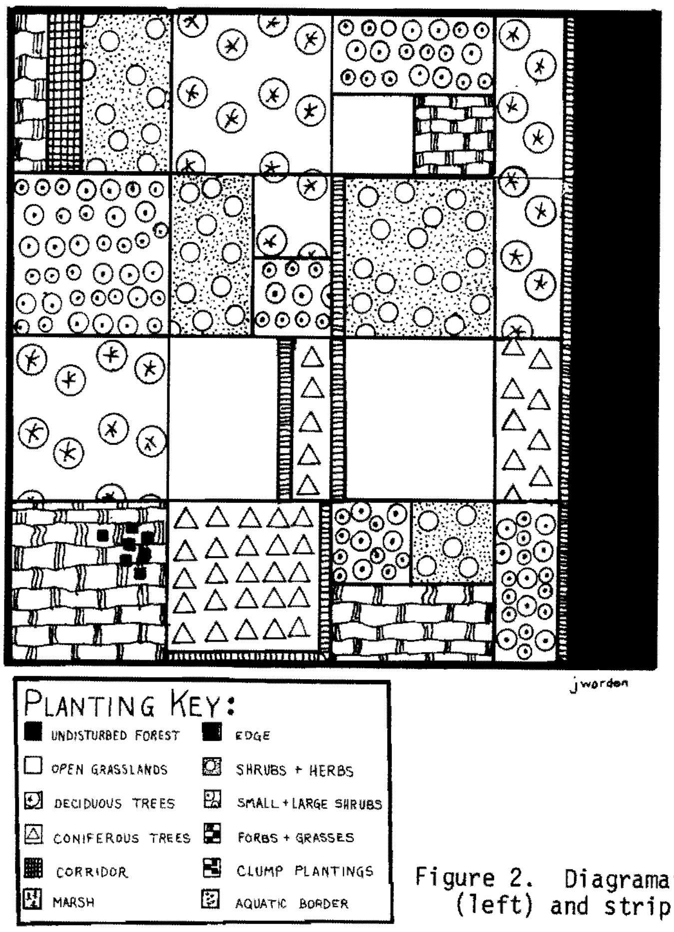
Initial efforts

Initial planting efforts should provide rapid and persistent erosion control, wildlife food, cover, and nest sites and a source of litter, nutrients and organic matter to enrich the soil. This requires the planting of some combination of quick-growing grasses, legumes and forbs.

The area at the water's edge frequently exhibits great variation in moisture availibility, ranging from semi-moist to seasonally flooded. Reed canarygrass (scientific names in appendix) has proven effective in tolerating these extremes and maintaining erosion control (USDA,1969). Other species which can be seeded in these wet areas are redtop, deertongue, timothy, alsike clover, and birdsfoot trefoil. This mixture provides rapid erosion control and tolerates a wide variety of riparian site conditions (Krzysik, et al.,1981).

Moist mud flats which are flooded during early spring can be planted with a mixture of wildmillet and smartweeds. These plants grow well in these areas, occur over a wide geographic range and provide excellent wildlife food particularly attractive to waterfowl.

In drier upland areas, it is desirable to establish a grass/legume mixture containing annual and perennial species. The annuals provide rapid cover while the perennials grow more slowly but provide erosion control for a longer period. Timothy is established rapidly, but is relatively short-lived. It can be seeded in conjunction with switchgrass, a slower



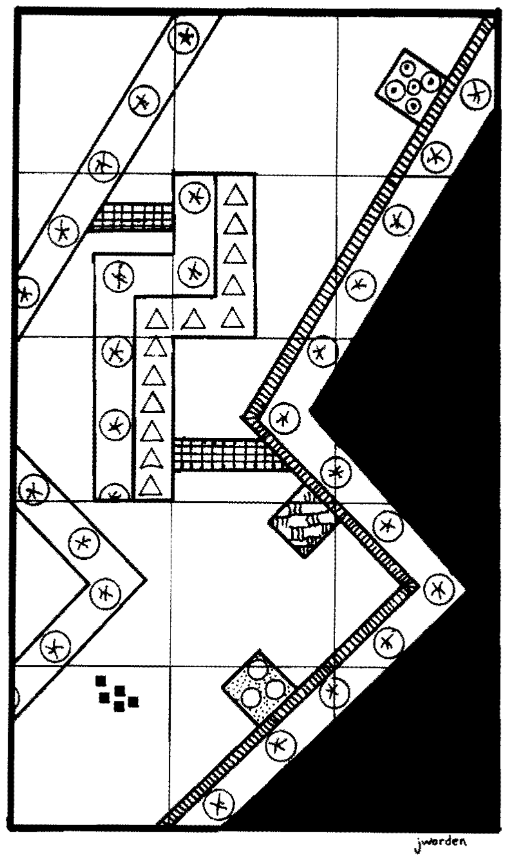


Figure 2. Diagramatic representation of block (left) and strip plantings of vegetation

growing but persistent species. Both possess excellent wildlife food value and can be grown under a variety of site and soil conditions (Krzysik, et al.,1981). In addition, legumes such as Korean and Kobe lespedeza, clovers and birdsfoot trefoil will add to vegetational heterogeneity and provide food and cover. Korean and Kobe lespedeza and weeping lovegrass do not compete strongly with woody plantings and should be established in areas where trees and shrubs will be planted (Vogel,1980; Krzysik, et al.,1981).

Secondary efforts

After successful development of a ground cover, woody plants can be established. These plantings increase vertical and horizontal heterogeneity and create edges which are known to increase wildlife species richness and population numbers. Their presence is vital in attracting and maintaining wildlife.

Woody vegetation can be planted in two types of spatial patterns (Figure 2). The first, strip planting, is the development of a long, relatively narrow area or row which usually consists of a single species. Field borders and hedgerows are two common examples of strip plantings. The second scheme, block planting, is the establishment of vegetation in clumps or patches which have less edge but create more interior area. These schemes are not mutually exclusive and are frequently used in conjunction with each other.

When establishing trees and shrubs along the water's edge, moisture conditions or seasonal flooding will restrict selection to moisture/flood tolerant species. I have found the following shrubs important in this regard: alders, arrowwood, and dogwoods such as red osier, silky, gray, and roughleaved. These species also possess excellent wildlife food and cover values and provide fine nesting sites. They can be planted in strips along the shoreline supplying shrubby habitat at the water's edge.

Trees should also be planted along the shoreline. Important species include cottonwood, sycamore, silver maple, birches, willows, green ash, hackberry and bottomland oaks such as pin and swamp white oak. These should be established in single species clumps of 6-15 individuals. Clumps can be situated next to one another to create larger, multi-species stands. Cottonwood and sycamore are important components of this area. Due to their rapid growth rates, they form the first trees in the developing system. Later, they will provide the tallest canopy cover, excellent denning sites, food, and cavities for birds such as wood ducks and woodpeckers. Other species are important in supplying wildlife food (hackberry, birch, silver maple, oaks) or additional diversity (green ash, willows). In their early life stages, all of these species (esp. birch and willow) will provide a shrub-like habitat attractive to many species of wildlife.

If conditions permit, woody plantings should be established on drier, upland sites. Shrub species appropriate for these sites include blackberries and raspberries, cherries, gray dogwood, crabapples, hawthorns, persimmons, and sumac. These can be planted individually, in small blocks or as strip plantings along a tree line or fence border. Several different species should be utilized in any given project.

Trees plantings on these drier sites should include one or more species each from the white and red oak group, hickories, walnuts, and white ash. Trees are planted in plots of 6-15 with proper spacing between individuals. The planting of oaks, hickories, and walnuts is critical since their large seeds make them poor colonizers.

The use of coniferous trees and shrubs should be restricted to one or two small (<.5 ha) patches and exterior borders. They support few wildlife species and serve primarily as windbreaks and protection from harsh weather.

Additional Habitat Components

Wildlife use of gravel pit lake riparian zones can be further enhanced by providing critical habitat components. These techniques are especially important in the early stages of habitat development when these components are not available on the site. The following practices are designed to supply food, cover, or other habitat component and have been proven successful in management schemes.

Nest structures

Nest boxes provide nesting sites for many birds that would otherwise require natural cavities. They can be very important additions to early successional stages which lack adequately sized or decadent trees for cavity production and construction.

Nest boxes must be properly designed, located, and erected for beneficial results. Success, in terms of number of boxes used, is variable and dependent on design and implementation. Since nest box construction varies with species, specific guides must be consulted. Kalmbach et al. (1969), Hassinger et al. (1979) and Schemnitz (1980) provide specifications for many species.

Nest platforms situated in or near lakes and ponds provide nesting sites for waterfowl. These platforms are readily accepted by ducks and geese and are effective in increasing nest success where ground nests undergo severe predation. As with nest boxes, proper design and placement are vital to adequate performance. Schemnitz (1980) provides detailed information on their construction and placement.

Brush piles

Brush piles supply wildlife cover in areas where shrubby growth and/or dense cover is sparse or non-existant. They can be very effective as supplemental cover on areas in early successional stages. Their values include concealment from predators, escape cover and protection in harsh weather.

A mound or lane of woody limbs/vegetation will make an adequate brush pile. Limbs should be loosely piled, not compressed into impermeable mounds. Larger logs and stumps can be used at the base of the pile for stabilization (Figure 3).

Brush piles can be established in many sizes and shapes. Piles 1.5-2.0m in diameter and 1m high are recommended for quail cover. Distribution rate should be approximately 1/hectare. Piles 8-15m in diameter can enhance pheasant and rabbit populations. Larger brush piles should be established at lower densities than smaller ones (e.g. 1/2-5 hectares).

Logs and stumps

Logs and stumps can fulfill a number of objectives: provide areas of invertebrate colonization, supply cover/sunning spots for reptiles and amphibians, provide denning and nesting sites for furbearers and small mammals, and supply loafing sites for waterfowl and marshbirds. They can be

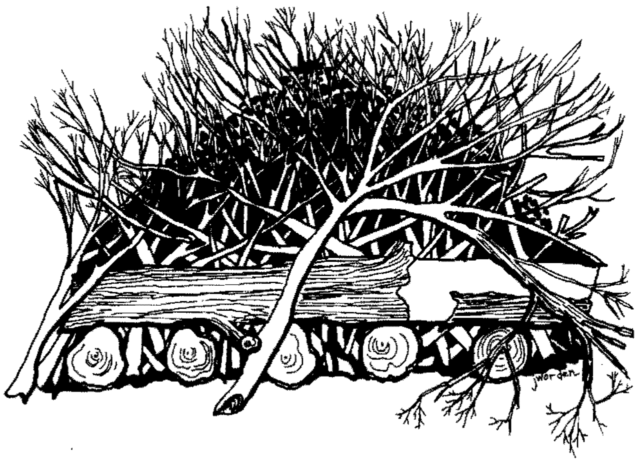


Figure 3. Example of a brush pile used to enhance wildlife populations. The larger logs at the base provide for stability.

randomly distributed about the area including in shallow water. Densities are unimportant as in many cases the supply of logs will be limiting.

Rocks and boulders

If possible, a few areas of rocks and boulders can be situated along the shoreline and in nearby upland areas. These provide food, cover and hibernacula for reptiles, amphibians and mammals. Rock patches should be less than 10 square meters in area and, therefore, do not provide support for wholesale riprapping of shorelines.

SUMMARY

The goal has been to provide specific but flexible guidelines for the development of riparian zones and local upland areas of gravel pit lakes in the interest of wildlife. The two objectives have been to 1) to increase habitat area through shoreline development and habitat width, and 2) to increase habitat quality for wildlife by implementing planting schemes and growth forms that increase spatial heterogeneity and develop edges as well as selecting plant species that supply known wildlife requirements. The addition of other habitat components can also enhance wildlife populations. This goal can be obtained without sacrificing erosion control, water quality, recreational access, or aesthetics.

The flexibility of the system permits modifications that will improve restoration techniques within a regional area. Such modification and experimentation is encouraged so that the rapid loss of these valuable wildilfe habitats can, in part, be mitigated.

ACKNOWLEDGMENTS

I would like to thank T. Krzysik and E. Herricks for their encouragement and critical review of the manuscript.

LITERATURE CITED

Council on Environmental Quality. 1978. Environmental quality - 1978. The 9th Annual Report of the Council of Environmental Quality. US Gov't. Printing Office, Wash., D. C. 599p.

Emmerich, J. M. and P. A. Vohs. 1982. Comparative use of four woodland habitats by birds. J. Wildl. Manage. 46:43-49.

Forman, R. T., A. C. Galli, and C. F. Leck. 1976. Forest size and avian diversity in New Jersey woodlots with some management implications. Oecologia 26:1-8.

Hassinger, J., L. Hoffman, M. J. Puglisi, T. D. Rader, and R. G. Wingard. 1979. Woodlands and Wildlife. Penn State University, University Park, PA. 68p.

Johnson, R. R. 1978. The lower Colorado River: a western system. pp. 41-55 in Johnson, R. R. and J. F. McCormick (eds.) Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. USDA-Forest Service, Gen. Tech. Rep. WO-12.

Kalmbach, E. R., W. L. McAtee, F. R. Courtsal, and R. E. Ivers. 1969. Homes for Birds. USDI Fish and Wildlife Service Conserv. Bull. no. 14. 18p.

Karr, J. R. and D. R. Dudley. 1980. Biological perspectives on water quality goals. USEPA. Chicago, IL.

Krzysik, A. J., E. E. Herricks, D. J. Tazik, and R. E. Szafoni. 1981. A primer of successional ecology. Landscape Arcitecture 71:482-487, 510.

Martin, T. E. 1980. Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. Condor 82:430-439.

Odum, E. P. 1978. Ecological importance of the riparian zone. pp. 2-4 in Johnson, R. R. and J. F. McCormick (eds.) Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. USDA-Forest Service, Gen. Tech. Rep. WO-12.

Rappole, J. H. and D. W. Warner. 1976. Relationships between behavior, physiology and weather in avian transients at a migratory stopover site. Oecologia 26:193-212.

Schemnitz, S. D. 1980. Wildlife Management Techniques Manual. The Wildlife Society. Wash., D. C. 686p.

Stauffer, D. F. and L. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alteration. J. Wildl. Manage. 44:1-15.

Stevens, L. E., B. T. Brown, J. M. Simpson, and R. R. Johnson. 1977. The importance of riparian habitat to migrating birds. pp. 156-164 in Johnson, R. R. and D. A Jones (eds.) Importance, Perservation, and Management of Riparian Habitat: a Symposium. USDA-Forest Service, Gen. Tech. Rep. RM-43.

USDA-Forest Service. 1969. Wildlife Habitat Improvement Handbook. Forest Service Handbook FSH 2609.11.

Vogel, W. G. 1980. Revegetating surface mined land with herbaceous and woody species together. in Trees for Reclamation. USDA-Forest Service, Gen. Tech. Rep. NC-61.

Wetzel, R. G. and G. E. Likens. 1979. Limnological Analyses. W. B. Saunders Co., Philadelphia, PA. 357p.

Appendix A. Scientific names of plant species mentioned in text.

Common Name	Scientific Name
Reed canarygrass	*Phalaris arundinacea*
Redtop	*Agrostis alba*
Deertongue	*Panicum clandestinum*
Timothy	*Phleum pratense*
Alsike clover	*Trifolium hybridum*
Bridsfoot trefoil	*Lotus corniculatus*
Switchgrass	*Panicum virgatum*
Korean lespedeza	*Lespedeza stipulacea*
Kobe lespedeza	*Lespedeza striata*
Clover	*Trifolium sp.*
Smartweeds	*Polygonum*
Wildmillet	*Echinochloa sp.*
Weeping lovegrass	*Eragrostis curvula*
Arrowwood	*Viburnum dentatum*
Alders	*Alnus sp.*
Red osier dogwood	*Cornus stolonifera*
Rough leaf dogwood	*Cornus drummondi*
Gray dogwood	*Cornus racemosa*
Silky dogwood	*Cornus amomum*
Blackberries/Raspberries	*Rubus sp.*
Cherries	*Prunus sp.*
Autumn olive	*Elaeagnus umbellata*
Russian olive	*Elaeagnus angustifolia*
Crabapples	*Malus sp.*
Hawthorns	*Crataegus sp.*
Persimmon	*Diospyros virginiana*
Sumac	*Rhus sp.*
Cottonwood	*Populus deltoides*
Sycamore	*Platanus occidentalis*
Silver maple	*Acer saccharinum*
Birch	*Betula sp.*
Willow	*Salix sp.*
Green ash	*Fraxinus pennsylvanica*
White ash	*Fraxinus americana*
Hackberry	*Celtis occidentalis*
Oak	*Quercus sp.*
Hickory	*Carya sp.*
Black walnut	*Juglans nigra*
Pin oak	*Quercus palustris*
Swamp white oak	*Quercus bicolor*

The Formulation of Lowland Sand and Gravel Excavation Regulations: Wisconsin Administrative Code NR-340

MITCHELL J. ZMUDA
Area Water Management Specialist,
Wisconsin Department of Natural Resources,
P.O. Box 310
Antigo, WI 54409

INTRODUCTION

The excavation of sand, gravel or rock, in or adjacent to navigable waters in Wisconsin has been regulated under Chapter 30, Wisconsin Statutes since 1961. Excavations requiring permits are those which result in removal of material from the bed of a natural waterway, relocation of a stream, creation of an artificial waterway within 500 feet of navigable water, and/or grading on the bank in excess of 10,000 square feet. (See Figures 1 and 2). The bank is defined as any land surface abutting the bed of navigable water which also slopes or drains, without complete interruption, into the water either before or after excavation. (See Figure 2, Examples A and B).

The Big Rib River which runs through Marathon County in Central Wisconsin, has had a long history of extensive sand and gravel removal. Many of the gravel pits excavated during the late 1960's and early 1970's did not have Chapter 30 permits, and those that did have a permit were not subject to the levels of rehabilitation established by NR 340 in 1979.

Due to an increase in demand for sand and gravel during the mid 1970's, numerous permits to excavate new areas in or adjacent to the Big Rib River were applied for under Chapter 30 of the Wisconsin Statutes. With the increased requests for excavation permits and the apparent condition of old excavation sites, the Public Intervenor's office of the Wisconsin Department of Justice filed objections to the new Chapter 30 permit applications and petitioned the Wisconsin Department of Natural Resources to develop statewide guidelines for lowland sand and gravel excavations under Sections 30.19, 30.195, and 30.20 of Chapter 30, Wisconsin Statutes. Through the administrative procedure, the State of Wisconsin then promulgated Chapter NR 340, Wisconsin Administrative Code, regulating dredging, grading or excavating for sand and gravel in or adjacent to navigable water.

LIMITATIONS OF CHAPTER 30

While working in Marathon County with permits issued in the late 1960's and early 1970's, under Sections 30.19, 30.195 and 30.20, of Chapter 30, Wisconsin Statutes it was found that the specific details needed to obtain complete reclamation of gravel pits were lacking. Therefore, gravel pits had little, if any, topsoil and vegetative cover. This condition existed because of different permit interpretations by permittees, as well as the lack of specific requirements.

The permittee, in essence, could comply with a permit without reclaiming the depleted gravel pit. Therefore, further legal action to obtain reclamation was not possible because the permit was never violated. The letter of the law was met, but not the intent.

PROBLEMS SPECIFIC TO BIG RIB RIVER

During 1976, the demand for gravel increased dramatically. Eleven applications were received by our agency for permits to excavate gravel along a ten mile section of the Big Rib River.

As a whole, the gravel industry in Marathon County experienced a substantial growth between 1972 and 1978. The value of Marathon County stone, sand, and gravel increased from $407,000 in 1972 to $8,341,000 in 1978 (Reuss, Latour, and Evans, 1977, Hill and Evans 1978-79, Briggs and Ostrom 1975). Excavation activities for sand and gravel were centered upon the Big Rib River corridor due to the geology of the area. Downstream from Rib Falls, the Big Rib River generally follows a one-fourth mile wide bedrock channel containing well sorted outwash deposits. Outwash deposits extend away from the bedrock channel in broad, flat plains providing a local source of commercial sand and gravel. The sand and gravel deposit at Marathon City has been estimated to be 80 feet thick, and is intermixed with silt and clay. Deposits in the valley below Marathon City are thicker with a greater percentage of sand and gravel (Bell and Sherrill, 1974). This deposit has been a commercially valuable resource for the local excavators for more than 40 years, as is evident by the 27 old gravel pits which are within 500 feet of the Big Rib River and numerous gravel pits outside the 500 foot fringe. In addition, the area is a major source of groundwater in an area of Wisconsin that is generally groundwater deficient because of varying depth to underlying

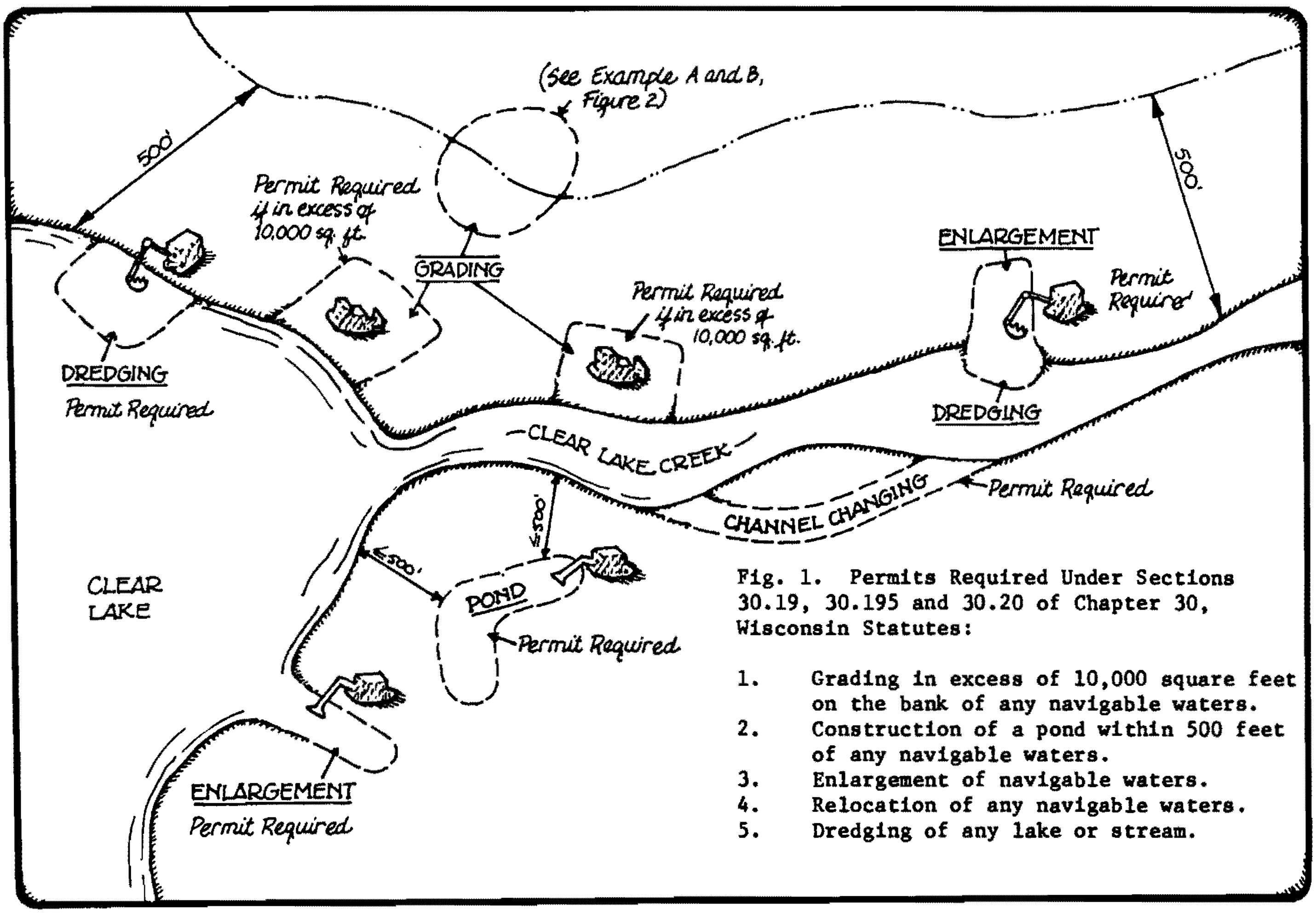


Fig. 1. Permits Required Under Sections 30.19, 30.195 and 30.20 of Chapter 30, Wisconsin Statutes:

1. **Grading in excess of 10,000 square feet on the bank of any navigable waters.**
2. **Construction of a pond within 500 feet of any navigable waters.**
3. **Enlargement of navigable waters.**
4. **Relocation of any navigable waters.**
5. **Dredging of any lake or stream.**

crystalline rock (Bell and Sherrill, 1974).

In general, the higher quality sand and gravel deposit is quite narrow, with some scattered deposits being intermixed with lower quality deposits in the adjacent uplands. These upland deposits have a greater silt and clay content with underlying weathered crystalline bedrock, which lowers their desirability.

PUBLIC INTERVENOR'S CONCERNS

The Wisconsin Public Intervenor's office was created in 1967 when the old Wisconsin Conservation Department merged with the Department of Resource Development to form the Wisconsin Department of Natural Resources. At that time, the old-line conservationists feared no one would be left to act as an adversary to protect the resources if everything were placed in one agency. In a compromise, the State Legislature created the Public Intervenor's office under Chapter 165.07 of the Wisconsin Statutes. The statute ordered that the Attorney General designate an Assistant Attorney General on his staff as Public Intervenor. The Public Intervenor may formally intervene in all such proceedings where such intervention is needed for protection of public rights in water and other natural resources, as provided in Chapter 30, 31 and defined by the Supreme Court.

Upon the receipt of 11 applications in 1976 for Chapter 30 permits to excavate gravel in and adjacent to the Big Rib River, the Department sent notices to Peter Peshek, the Public Intervenor as required in Section 165.07 of the Wisconsin Statutes. With the increased requests for excavation permits and the apparent condition of old gravel pits, the Public Intervenor filed objections to all new Chapter 30 permit applications for gravel extraction in or adjacent to the Big Rib River.

In addition, the Public Intervenor argued that the Department of Natural Resources (DNR) failed to fulfill the requirements of Section 1.11 of the Wisconsin Statutes (Wisconsin Environmental Policy Act). The Public Intervenor maintained that the Environmental Impact

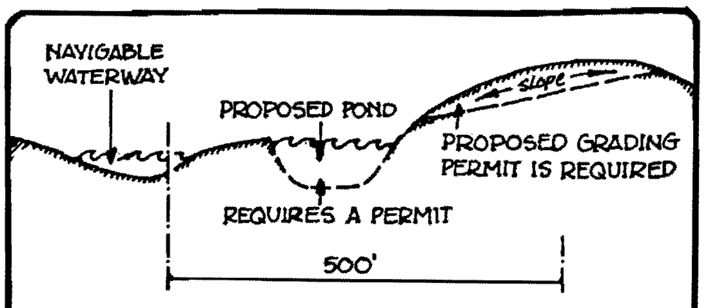


Figure 2, Example A

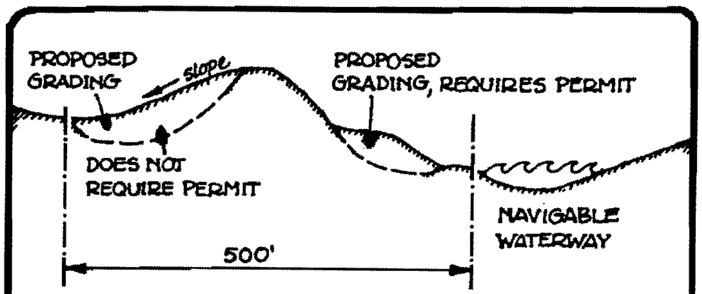


Figure 2, Example B

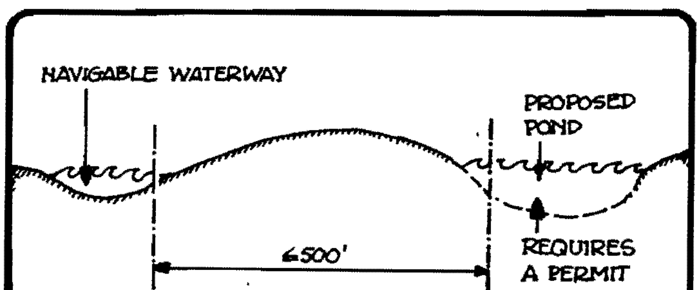


Figure 2, Example C

Assessments (EIA) prepared for pending projects failed to address the long range ramifications of gravel extraction on the Big Rib River (Peter Peshek, pers. commun.). EIA's are environmental documents prepared by the DNR to determine whether a project is a major action that will significantly affect the quality of the human environment, thus requiring a full Environmental Impact Statement. In response to the Public Intervenor's ojections, DNR withdrew, and subsequently modified, pending EIA's addressing in detail primary, secondary and cumulative impacts of the pending projects.

To eliminate the lack of specific guidelines for sand, gravel and rock excavation, the Public Intervenor petitioned the Wisconsin Department of Natural Resources to develop statewide guidelines that would promote consistency in the application of Chapter 30 (Peter Peshek, pers. commun.). Through the administrative process, NR 340 was drafted with input from staff of the Department of Natural Resources, Department of Justice, and representatives from the Wisconsin sand and gravel industry.

NR 340 GUIDELINES

The statewide adoption of Chapter NR 340, Wisconsin Administrative Codes became official in January of 1979. This Chapter applies to all sand, gravel or rock excavation projects requiring approvals under Chapter 30, Wisconsin Statutes. The promulgation of NR 340 was to accomplish consistency in the application of Sections 30.19, 30.195 and 30.20 of Chapter 30, Wisconsin Statutes to the excavation of sand, gravel or rock. Without guidelines, it is recognized that serious degradation of water quality, fish and wildlife habitat and public interest in recreation and scenic beauty may occur both during and after excavation, dredging and grading.

The main purpose of NR 340 is to minimize adverse effects, expedite rehabilitation of affected lands, restrict excavation where the adverse effects cannot be minimized or avoided, and codify the definitions of certain terms set forth in Section 30.19 of Wisconsin Statutes. The definitions provide the basis for determining whether or not Sections 30.19, 30.195, and 30.20 would be applicable to a specific excavation project (See Figure 2, Examples A, B and C), (Wisconsin Department of Natural Resources, 1979).

Application for a permit under Chapter 30, Wisconsin Statutes, to dredge, grade or excavate a pond for sand and gravel must have detailed plans as outlined under NR 340, Wisconsin Administrative Codes. The plan must contain the location (legal description), extent, depth, estimated volume and quality of material to be extracted and manner of project operations. In addition, very specific site plans as are outlined in NR 340.05(4), must accompany an application. A description of the existing natural and physical conditions of the project site, including necessary maps and cross sections acceptable to the department concerning the following details:

(a) Soil and geologic composition of the project area;
(b) Location and dimensions of surface waters;
(c) Location of ground water;
(d) Hydraulic cross sections of the floodplains of any streams;
(e) Location of manmade features in the project site;
(f) Detailed map and description of the nature and extent of existing excavations,

stockpiled materials, topsoil and refuse in the project site;

(g) Historical and archaeological features, if known; and

(h) Existing drainage patterns.

The applicant must also have a timetable for commencement, duration and cessation, with the project site being operated for the minimum period of time. The type of equipment used for loading and transporting material must also be included in the application along with a reclamation plan that provides the nature, extent, side slopes, screening, grading, stabilization and final configuration of the project site. In addition, the progressive and final reclamation plans must include the nature, depth, location and extent of stockpiled materials, disposal of waste or overburden and diversion of ground and surface waters to avoid their pollution (Wisconsin Department of Natural Resources, 1979).

If excavation creates a pond that entraps fish, the pond must be designed to provide adequate public access, sufficient size, depth and water quality to sustain aquatic life (Wisconsin Department of Natural Resources, 1979).

To accomplish erosion control, the applicant is required to obtain guidelines from the Soil Conservation Service or use the Wisconsin Department of Transportation minimum seeding requirements for final reclamation. In either case the applicant must acknowledge continuing responsibility for restoration and revegetation of the project site until stabilization has been determined to be adequate by the Wisconsin Department of Natural Resources (Wisconsin Department of Natural Resources, 1979).

Upon receipt of a completed application and drawings, the Department reviews the project, and compiles data for an Environmental Impact Assessment (EIA) to determine if an Environmental Impact Statement is needed (Gregory Edtvedt, pers. commun.).

ENVIRONMENTAL IMPACT ASSESSMENTS DEVELOPED SINCE ENACTMENT OF NR 340

The scope and details required in Environmental Impact Assessments (EIA's) for sand and gravel excavations have increased significantly since the enactment of NR 340.

The basic subjects addressed in an Environmental Impact Assessment include:

a) A detailed description of the proposed project

b) The existing environment of the area affected by the proposed project.

c) Potential beneficial and adverse environmental impacts resulting from the proposed project.

d) Feasible alternatives to the proposed project.

Included in the discussion of the EIA subject areas is a review to determine if adverse effects of the excavation project can be minimized, expeditious rehabilitation of the affected land will be carried out, or if the proposed excavation, dredging or grading should be restricted where adverse effects cannot be avoided or minimized. Every possible aspect of the excavation proposal is addressed, with a total review of the entire water body and past actions. This review includes assessing biological, socio-economic, beneficial and cumulative impacts to determine the overall impact of a specifically proposed extraction project (Gregory Egtvedt, pers. commun.). Establishment of a data base for writing of an EIA involves the disciplines of: fish management, wildlife management, hydrology, water regulation and zoning.

During the assessment process, the proposal is reviewed to determine what, if any, adverse effects the project will have on the existing environment. The project site is also inspected to determine the existing vegetative cover, terrain, fish and wildlife habitat. Proposals including excavations that create a pond must provide adequate water depths to carry fish populations through stress periods and sufficient sloping both above and below water to provide a growing surface for upland and aquatic vegetation. Should the artificial water body be located in an area which is periodically flooded, thus causing the entrapment of fish, it is a condition of NR 340 that the applicant provide public access to the pond (Wisconsin Department of Natural Resources, 1979).

All dredging, grading or excavating must have a minimum sloping of 3:1. Proposed ponds must have minimum sloping of 3:1 along the edge. However, most wildlife managers will require that 20% of the edge have 5:1 to 10:1 slopes above and below water. This encourages duck use and growth of aquatic vegetation. In some situations, to provide the maximum amount of edge, a meandered shore and islands are required. The minimum slopes of the island, both above and below the water, are 5:1 slopes, but 10:1 slopes are preferred to satisfy wildlife concerns. (Carl McIlquham, pers. commun.).

The creation of meandering edges and islands is generally conducive to most excavation plans for the disposal of excess amounts of overburden and waste sands. This provides an area for placement of material that was usually left in large unsightly piles with no productive use.

The Environmental Impact Assessment also includes review of the project site's existing screening and hydrological effects upon the waterway and flood flows. A review of existing screening is done in order to determine if the project site is visible from the waterway and what effects the project will have upon the public's right to scenic beauty in navigable waters (Wisconsin Department of Natural Resources, 1979).

To adequately satisfy all concerns raised during an interdisciplinary review, it has usually been necessary to propose a modification of the original application. Upon completion of the EIA preparation process, the document is made available to the general public for review and comment. After the completion of the public review period, all public comments are taken into consideration by the Department of Natural Resources; then necessary modifications to the EIA are made. The determination on the need for an EIS is finalized and the EIA is then certified to be in compliance with the Wisconsin Environmental Policy Act (Gregory Egtvedt, pers. commun.).

As a result of the requirement for a more comprehensive Environmental Impact Assessment, NR 340 and negotiations with the applicants, Environmental Impact Statements were not required for the projects. However, all eleven proposals were either revised or dropped because of the adverse environmental effects. The EIA process also helped in directing some applicants to old partially excavated gravel pits for which they subsequently obtained permits per NR 340 guidelines. Once the project has been determined acceptable and the EIA process has been completed, the granting of a permit is conditioned upon the relevant standards of Chapter 30, Wisconsin Statutes, provisions of NR 340, and the findings in the EIA. These conditions limit the project to dimension and depth as approved by the Department. The applicant is required to submit a performance bond to the Wisconsin Department of Natural Resources to equal the estimated cost to the State for fulfilling the reclamation plan. When the project is satisfactorily completed, the bond is released (Wisconsin Department of Natural Resources, 1979).

The reclamation of old excavated gravel pits eliminates existing steep side slopes and shallow fish entrapment ponds. The long-term benefit of reworking the old gravel pits will be the reclamation of over 100 acres, creation of two 40-acre lakes, one 11-acre lake and public access for fishing to the new water bodies. The gravel industry is being given the opportunity to prove that gravel pit ponds may be built to the benefit of all parties concerned.

NR 340 BROCHURE

In an effort to help individual excavators with applications, a brochure containing required details in NR 340 is being developed. Illustrations of plans detailing the proposed excavation in phases will help the applicant in the early stages of planning. Due to the difference of topography at every excavation, site examples of using natural screening, planting vegetation, and constructing earth berms or use of natural terrain for screening are being developed.

With the informational brochure and through cooperation with the Department of Natural Resources, the sand and gravel industry can comply with the application specifications, project and reclamation plans.

SUMMARY

This report has described briefly the problems specific to the Big Rib River in Marathon County, Wisconsin, and the creation of NR 340 through interaction of the public and state agencies. Through the promulgation of NR 340, both the gravel industry and the Wisconsin Department of Natural Resources have been given statewide guidelines needed when addressing gravel extraction proposals in Wisconsin's shoreline areas (See Figure 1).

One of the resources that was recognized in NR 340 and of concern to the Public Intervenor is scenic beauty. This resource is becoming increasingly recognized as important to the State of Wisconsin (Chenoweth et al. 1981). The Department is working towards developing methods to incorporate scenic beauty criteria along with other more traditional resource concerns as a part of the EIA review. The creation of NR 340 has provided the details needed to develop specific plans for the writing of an Environmental Impact Assessment. Besides providing a comprehensive environmental impact analysis of a project, the development of an EIA can assist in determining if adverse effects will be minimized, expeditious rehabilitation of affected land will be accomplished and if excavations should be restricted where adverse effects cannot be avoided or minimized. With the development of more environmentally sound projects, fish, wildlife, scenic beauty, water quality and public interest in recreation are protected for the long term to the benefit of all.

ACKNOWLEDGMENTS

Egtvedt, Gregory W., North Central District Assistant Environmental Impact Coordinator, Wisconsin Department of Natural Resources, Rhinelander, Wisconsin

Johnson, Max, Antigo Area Fish Manager, Wisconsin Department of Natural Resources, Antigo, Wisconsin

McIlquham, Carl, Antigo Area Wildlife Manager, Wisconsin Department of Natural Resources, Antigo, Wisconsin

Peshek, Peter, Assistant Attorney General, Public Intervenor, Wisconsin Department of Justice, Madison, Wisconsin

Tlusty, Wayne, Department of Landscape Architecture, University of Wisconsin Extension, University of Wisconsin, Madison, Wisconsin

LITERATURE CITED

Bell, E.A., and M.G. Sherrill, 1974. Water Availability in Central Wisconsin, An Area of Near-Surface Crystalline Rock, Geological Survey Water Supply Paper 2022, University Extension - The University of Wisconsin Geological and Natural History Survey, Madison, Wisconsin

Reuss, J.L., P. Latour, and T.J. Evans, 1977. The Mineral Industry of Wisconsin, Bureau of Mines, United States Department of Interior, Washington, D.C., and the Wisconsin Geological and Natural History Survey, Madison, Wisconsin

Hill, J.J., and T.J. Evans, 1978-79. The Mineral Industry of Wisconsin, Bureau of Mines, United States Department of Interior, Washington, D.C., and the Wisconsin Geological and Natural History Survey, Madison, Wisconsin

Briggs, R.C., and M.E. Ostrom, 1975. The Mineral Industry of Wisconsin, Bureau of Mines, U.S. Department of the Interior and the Wisconsin Geological and Natural History Survey, Madison, Wisconsin

Wisconsin Department of Natural Resources, 1979. Sand, Gravel or Rock Excavation and Reclamation Associated with Navigable Waterways and Adjacent Areas, Chapter NR 340, Wisconsin Administrative Codes.

Chenoweth, R.E., B.J. Niemann, and W. Tlusty, 1981. Scenic Beauty as a Requirement of NR 340: Compliance Requires More Than a Reclamation Plan, Reclamation News, Vol. 1, No. 4, University of Wisconsin, Madison, Wisconsin

Public Rights to Scenic Resources: Infringement is Sufficient Cause for Denial of Lowland Sand and Gravel Operations in Wisconsin

RICHARD E. CHENOWETH, WAYNE G. TLUSTY, and BERNARD J. NIEMANN, JR., Department of Landscape Architecture, College of Agriculture and Life Sciences, University of Wisconsin, Madison, Wisc. 53706.

INTRODUCTION

The major point to be addressed in this paper is that the granting of permits to excavate gravel is not, according to Wisconsin law, supposed to be a foregone conclusion and that the denial of permits is a legitimate decision in instances where public rights to scenic beauty would be significantly damaged, even if no other adverse impacts could be demonstrated.

With this in mind, we shall (1) briefly enumerate public rights to enjoy scenic beauty from navigable waters, (2) discuss an administrative rule in Wisconsin which is used to regulate the lowland sand and gravel industry, (3) describe a case study on the Rib River, (4) set forth recommendations for information to be included in all permit applications with respect to the protection of Wisconsin's scenic resources and finally, (5) to provide some topics for future discussion.

Before enumerating public rights to scenic beauty, it is important to recognize the extent to which the sand and gravel industry could potentially infringe upon those rights. While any given mining operation may be relatively small in geographic area, such operations nevertheless cover the Wisconsin landscape. In doing so, they must be considered as potentially conflicting with the objective of protecting, enhancing and restoring the scenic resources of the state. Indeed, 53 of Wisconsin's 72 counties contain landscapes disturbed by the mining of sand and gravel (Soil Conservation Service, 1977). In all of these counties, reclamation is required by law.

A recent study of nine Wisconsin counties (River County Resource Conservation and Development Council, 1981) was conducted, in part, due to the recognition that inactive surface mines are unsightly. The study identified 1,024 sites in nine counties. Of these, 258 sites (25%) were judged as ugly or unpleasing to the eye and therefore were considered to be a problem.

The research was supported in part by funds from the Public Intervenor's Office, Department of Justice, State of Wisconsin.

Although scenic beauty may be regarded as an important amenity, the sand and gravel industry would be expected to argue that their resource contributes significantly to the economy of the state. A 1978 U.S. Bureau of Mines study estimated the value of sand, gravel, and crushed stone to the economy of Wisconsin at approximately 100 million dollars.

What is frequently overlooked, however, is that although scenic beauty may be considered an amenity, it is also a resource which contributes to the economy of Wisconsin. Indeed, an entire state agency encourages both residents and visitors to experience Wisconsin's scenic beauty - "Escape to Wisconsin." In the same year that Wisconsin's sand and gravel industry was valued at 100 million dollars, the recreation and tourism industry was reported to have grossed 4.9 billion dollars (Recreation Resources Center, 1978). In a series of studies conducted by the Wisconsin Division of Tourism, looking at scenery was found to be the number one attraction in all four seasons when compared with the many leisure activities one could pursue in Wisconsin.

PUBLIC RIGHTS TO SCENIC BEAUTY FROM NAVIGABLE WATERS

The State Supreme Court has ruled that title to navigable waters of Wisconsin is held in trust for the public by the state, and such trust extends to the uses of navigable waters for fishing, hunting, swimming, skiing, boating and bathing. More recently, the Court stated, "the active public trust duty of the State of Wisconsin in respect to navigable waters requires the state not only to promote navigation but also to protect and preserve those waters for fishing, recreation, and <u>scenic beauty</u>." (Just v. Marinette County, 1972) (emphasis added)

Thus the publics' right to enjoy scenic beauty along its navigable waters is protected by constitutional law. While no rights are absolute, the important point is that rights to excavate sand and gravel, even on one's own shoreland, carry no more legal weight than the public's right to scenic beauty. These rights extend to all navigable waters and the test for navigability is whether or not the shallowest draft boat available for recreation can float at high water during spring. The upshot of all of this is that gravel mining adjacent to navigable waters must be responsive to issues of scenic beauty as well as fish, wildlife, soil erosion, water turbidity, etc., and must be addressed on its own merits.

SCENIC BEAUTY AS A REQUIREMENT OF NR 340

It has been demonstrated that scenic beauty is not only a proven asset to the economy of the state, but also the enjoyment of it along navigable waters is a constitutional right. Therefore, the question of how best to protect, preserve, restore, and manage its potential becomes important. One such effort is NR 340: "Sand, Gravel or Rock Excavation and Reclamation Associated With Navigable Waterways and Adjacent Areas." As an administrative rule, it has the effect of law and its purpose is to guide the actions of the Wisconsin Department of Natural Resources (WDNR) with respect to the regulation of the sand and gravel excavation industry. More specifically, the intent of the rule is to:

(a) "Minimize the adverse effects caused during and after such (excavation, dredging, or grading) activities."

(b) "To provide for the expeditious rehabilitation of effected land."

(c) "To restrict excavation, dredging and grading where the adverse effects cannot be minimized or avoided." (emphasis added)

In addition to the more typical values of wildlife, fisheries, water quality and soil erosion control, one of the adverse effects explicitly recognized in NR 340 is damage to scenic beauty. The magnitude of the potential impact of this administrative rule is especially large when one realized that Wisconsin has over 60,000 miles of lakes and streams that are classified as shoreland, as well as thousands of additional miles that meet the navigability test and are therefore subject to provisions and intent of the rule including the restriction of mining where adverse effects on scenic beauty cannot be minimized or avoided. While the intent of NR 340 is relatively clear, until recently most sand and gravel operators have generally ignored negative impacts on scenic beauty as an issue during permit application and compliance with the rule has usually been limited to post excavation grading and seeding of mining sites. Simply stated, when values other than scenic beauty are not threatened, the granting of a permit has typically been *fait accompli* followed by minimal regard for the protection preservation, restoration or management of the scenic resource. Such a sequence of actions violates the purpose of NR 340.

In order to be in full compliance with the rule, a permit application should first be reviewed to determine potential adverse effects which cannot be minimized or avoided including impacts on scenic beauty. At this stage the adverse impacts are critical to the decision making and the reclamation plan is therefore relevant only to the degree that it cannot minimize adverse effects on scenic beauty. In any case, the decision to be made is whether or not to restrict the mining operation in the first place. This is clearly a decision which is intended to precede any decision regarding the relative merits of a post excavation reclamation plan as we typically think of one. Actually the reclamation plan is intended to serve two purposes: (1) as an indicator of the extent to which adverse impacts might be minimized, and (2) as a plan for action which would follow the mining operation should it be permitted. If it cannot be clearly demonstrated that adverse impacts on scenic beauty can be avoided or significantly minimized, no permit should be issued. In this instance, the reclamation plan serves only the first purpose and does not serve as a plan for action which will follow mining since no mining will occur. Alternately, should a permit be granted, NR 340 still requires the expeditious reclamation of effected land including the rehabilitation of scenic beauty.

RIB RIVER CASE STUDY

Objectives

The objective of the research was to provide both an aesthetic and an empirical basis for a decision involving the granting of a permit to extract gravel from areas on or near the Rib River which is located in central Wisconsin. An aesthetic basis was required because in this particular instance the issue was solely an aesthetic one in which a permit issuance potentially conflicted with the legal right of Wisconsin citizens to enjoy scenic beauty on navigable waters of the state (Muench v. Public Service Commission, 1952). Fish and wildlife values were not an issue here since no negative impacts on these values could be demonstrated nor were any projected for the proposed mining site.

An empirical basis was required because opinions about permit issuance had to share a factual foundation and not rest on the biases of the individual investigators or WDNR personnel. This is a paramount concern since the denial of a permit based on scenic beauty considerations is very likely to be questioned by gravel operators as being a highly subjective judgement - indeed most would argue that scenic beauty is in the eye of the beholder.

Bufford (1973), in discussing court reluctance to address aesthetic issues, translated the notion that "beauty is in the eye of the beholder" into two requirements the fulfillment of which would satisfy the legal concern that beauty is a matter of personal taste, hence decisions regarding such matters would be arbitrary and capricious and a violation of the fourteenth amendment. The first requirement is that consensus be demonstrated. He further added that concensus need not be perfect. The second requirement for satisfying legal concerns is that opinions regarding aesthetic matters must rest on publicly ascertainable facts.

The Situation

The Rib River originates in Northcentral Wisconsin, is more than 34 miles in length and has about 3.2 miles in public ownership. The major land uses in the 460 square mile drainage are about evenly divided between agriculture and areas that are primarily wooded and wild in character. Several small communities are adjacent to the river. Outwash deposits are a major source of commercial sand and gravel and are found within the bedrock channel and in the broad, flat, adjacent plains.

Participants in the Permit Review Process

Several prominent participants are involved in the review process of sand and gravel permits. The gravel operators have used the river and adjacent areas for over 40 years (Zmuda, 1978) as a source of commercial gravel. They generally own or have a lease option to the better sites. Gravel operators bring a long history of supplying the area consumers with low cost material. Prior to NR 340 they operated without a significant permit review process and generally did not rehabilitate excavated areas. The operators have always represented a strong position for the "absolute rights" of riparian landowners.

The WDNR area water management specialist has responsibilities in assessing environmental impacts, establishing reclamation criteria and inspecting for compliance with Department of Natural Resource Administrative Code Chapter NR 340. The WDNR area specialist must consolidate resource reports from several agency reviews into an environmental assessment. This process determines compliance with administrative codes. If the permit is denied the applicant can request a public hearing, conducted by a hearing examiner.

A more recent participant to the sand and gravel permit process is the Public Intervenor. This position is within the Department of Justice and is charged with intervening on citizens' behalf when state agencies are deemed unresponsive to environmental matters. The Public Intervenor is concerned with all environmental impacts, but in the Rib River Study was specifically interested both in protecting the "public's right to the enjoyment of scenic beauty on navigable waters" vis a vis gravel mining and in evaluating the WDNR's compliance with NR 340 specifically regarding the protection of the scenic resource.

Recreationists have 3.2 miles of river frontage in public ownership, including three county parks. But most river access is across private lands. No camping facilities are available in public lands, but fishing, hunting, trapping and swimming are water-based activities. Canoeing is dependent on the fluctuating water levels. The best opportunities are early in the season. The local river users are without effective recreation resource representation by state agencies or local officials.

In summary, gravel operators desire voluntary controls and see themselves as providing the "greatest public good." The WDNR tries to institutionalize recent administrative codes without severely disrupting or limiting gravel operations, but in a manner which will satisfy all participants. The Public Intervenor represents a threat because of the many legal options and is therefore considered an obstructionist by the operators while attempting to influence statewide policies related to the environment. Recreationists have an interest in enjoying scenic beauty and other rights, yet do not have an organized voice.

Client Needs

The public intervenor, as our client in the case of the Rib River, had a number of needs which were not immediately apparent, either to the client or to us as investigators. However, as these needs became evident, the extent to which a traditional descriptive visual inventory approach (e.g., Jones and Jones, 1978; Litton 1978) or a site specific visual reclamation approach to problem solving would fail to adequately address these needs becomes obvious. At the risk of oversimplification, five needs of the client can be distinguished as follows:

(1) The client needed to make a decision about whether to contest the granting of a permit.

(2) Secondly, the client desired a solution that would have a range of applicability extending beyond just one gravel mining permit request.

(3) Thirdly, the public had to be represented in some fashion since the client was charged with the responsibility of protecting the public's rights, in

this instance the right to scenic beauty.

(4) Fourth, whatever was to be done had to be a step towards addressing the larger issue of public rights to scenic beauty since the protection of rights solely on a case-by-case basis is, and will remain, impossible.

(5) Finally, a complete record had to be kept of the observations, rationales, and actions which gave rise to the solution. Furthermore, those observations, rationales, and actions could potentially constitute legal evidence and, therefore, had to be legally defensible against the charge that the solution reflected the personal biases of the investigators rather than objective appraisal.

A final comment on what the client's needs were not is in order here. The client had not decided prior to the Rib River case study that the granting of a permit to mine gravel violated public rights to scenic beauty and therefore was not simply seeking someone to generate evidence in support of a foregone conclusion that a permit should be denied. Rather the problem solving approach had to generate information bearing on public consensus and provide publicly ascertainable facts which would be useful to the decision about whether to allow the mining impact to occur at all.

Questions and Problem Solving Approach

The identification of empirical questions which would address the clients needs was in many respects more difficult and important than creating a research methodology which would begin to answer the questions. After a substantial amount of struggling and consultation with the client, four sets of questions were developed which seemed appropriate for meeting the aesthetic and legal objectives. Each set of questions is posed below and the problem solving approach is briefly described. Specific results are not described since it is the questions and approach which should have general applicability to many situations. This is in contrast to the results, which may not generalize to rivers differing substantially in environmental characteristics from the Rib River.

How scenically beautiful is the Rib River perceived to be by selected representatives of various publics? Are some sections of the Rib River perceived as more scenically beautiful than others? What is the spatial distribution of perceived scenic beauty in relation to previous or current gravel extraction operations?

To what extent are measurable features, chosen by the investigators on a priori basis, perceived by selected publics as adding to or detracting from the scenic beauty of the Rib River? What is the spatial distribution of these features along the Rib River? Are features identified by selected publics as contributing to the scenic beauty similar to those features chosen on an a priori basis by the investigators.

To what extent are features along the Rib River sensitive to various types and intensities of gravel and reclamation operations? What is the spatial distribution of particularly sensitive features along the Rib River?

Should gravel extraction occur, what parts of reclamation efforts are perceived by selected publics as relatively more acceptable than others in terms of manipulation characteristics of the land (e.g., type of vegetation, shoreline configuration of ponds)?

In general, the problem solving approach used to answer these questions conformed to the following requirements: (1) free from the biases of the investigators, (2) demonstrate some degree of public consensus, (3) straightforward and easily reproduced, and (4) results easily communicated in a format understandable to the lay public.

Several different types of tools were developed to answer the questions posed above while also conforming to the requirements. Only a highly abbreviated idea of the tools can be presented here.

Aerial photographs of the Rib River were marked at quarter-mile intervals using a random start. The investigators then canoed the river taking three photographs (forward and each side) every quarter mile in order to obtain an unbiased representative sample of scenes. This sample was later used as: (a) illustrative material, and (b) stimulus material to which subjects responded on a scenic beauty scale which ranged from one through ten (Daniel and Boster, 1976). In addition, the investigators prepared a list of 30 specific landscape features (e.g., rock outcroppings, white pine stand, rapids, etc.) and photographed striking examples. This photographic sample was later used (a) as illustrative material, and

(b) stimulus material which subjects rated for the degree to which the specific features added to or detracted from the area depicted in the scene.

Low altitude aerial photographs were analyzed in order to portray the spatial distributions of those specific landscape features which could be reliably interpreted from aerial photographs.

Having acquired the necessary materials, studies were conducted in which aesthetic judgements were elicited from representatives of various public groups.

In the first study, slides randomly selected from the representative photographic sample were used to simulate a trip down the river. Subjects were asked to rate each scene on the scenic rating scale used by Daniel and Boster (1976). Later the means and standard deviations of the raw scores constituted the extent of the data analysis. Together with information on mining sites, differing degrees of perceived scenic beauty in different segments of the river could be spatially portrayed in relation to previous or current gravel extraction operations.

The second study provided information most directly related to projecting scenic beauty impacts of proposed gravel mining operations. Subjects, who represented many groups including gravel mining equipment operators, garden club members, canoeing clubs, and high school students, were asked to view slides and to rate the degree to which specific landscape features added to or detracted from scenes along the Rib River. The ratings were made on a plus three to minus three scale. By calculating the mean scores and standard deviations it was possible to determine both the degree to which different features contributed to scenic beauty along the river as well as the extent to which consensus existed regarding their judgements. Together with interpretations of low altitude aerial photography it was possible to map the features along the riverway and to include information on the "scenic value" of these features. Obviously, from the clients point of view, permit applications for gravel mining in areas containing large concentrations of high scenically valued features, as determined from the public might be more likely candidates for denial than applications in other situations. As would be expected from the bulk of studies in landscape aesthetic assessment which employ user analysis techniques, there was substantial consensus among the different publics regarding what was scenically beautiful (e.g., Daniel and Boster, 1976; Zube, Sell, and Taylor, 1982).

The next question addressed was the extent to which different areas along the Rib River might be differentially sensitive to potential gravel mining operations. Conceptually, the approach was simple. First, areas containing features which were judged to contribute relatively highly to scenic beauty might plausibly be considered more sensitive to mining than other areas. Second, areas containing relatively unique features as determined from aerial photography, would plausibly make those areas relatively more sensitive, given that the features had been rated positively. Third, areas containing positively rated features appearing in concentrations would hypothetically make these areas more sensitive. Fourth, some biological and geological literature was examined in order to estimate the average time which would be required for the naturally-occurring features to reach or return to a mature stage under optimal conditions. Thus, the longer the replacement time of a feature, the less likely that adverse impacts could be avoided.

The final question of perceived acceptability of different reclamation efforts was examined using slides of alternative treatments within each of four categories: water, vegetation, earth forms, and mining artifacts. Each slide was rated by different publics on the degree of scenic beauty perceived and also rated for the degree to which the treatment was considered scenically acceptable. Here again, there was substantial consensus and, not unexpectedly, rectilinear shaped ponds with standard slopes and typical seeding applications did not fair well aesthetically relative to other possible alternative treatments.

In summary, although the case study was limited to the Rib River, it does contain impli-ations for the protection of public rights to enjoy scenic beauty from navigable waters. First, techniques and procedures are available which can be used to assess the scenic beauty of navigable waterways. Second, specific features can be identified, the degree to which they contribute to scenic beauty can be determined, and the extent of public consensus on these judgements can be ascertained. Third, the sensitivity to potential sand and gravel operations of areas adjacent to waterways can be estimated. Fourth, the visual acceptability of various mining reclamation proposals can be established.

Recommendations Based on the Rib River Case Study

We have recommended to the Public Intervenor that a proper interpretation of NR 340 would require that the following assessment information be established by the WDNR in the review process for all excavation, dredging, or grading activities:

(1) The scenic beauty of floodplain areas visible from the navigable waterway,

the scenic beauty of areas germane to the permit application, and the effects the mining operations will have on both.

(2) The features which (a) add to the scenic beauty of the area germane to the permit application, (b) are relatively unique considering the navigable waterway, and (c) require substantial periods of time for natural processes to replace.

(3) A description of the reclamation activities which would maintain, restore, or enhance the scenic beauty of the area germane to the permit application relative to pre-mining conditions.

In addition, we also recommended that the information described above be used to determine whether or not a mining permit application ought to be denied or restricted.

Finally, we have recommended that, as a condition for granting a permit, reclamation plans required by NR 340 must ensure that the scenic beauty of the mining site will be maintained, restored, or enhanced.

FUTURE DISCUSSION TOPICS

The methods that have been described for scenic beauty assessment may transfer to evaluations of other natural resources which require permit restriction or specific rehabilitation measures. While permit applications currently require site specific approval, large area evaluations of scenic beauty may show especially sensitive areas which should perhaps be off limits to permit applications since it is determined in advance that it is highly unlikely that adverse impacts could adequately be minimized or avoided. Another potential use of a large area evaluations would be to create an information base by which an established level of scenic beauty could be maintained or managed for throughout the length of a river. This is, of course, analogous to the forestry concept of sustained yield for timber management.

Another idea which will need to be addressed, in the future, is the notion of scenic beauty as a recognized land use classification which may contain several categories such as a developed park, pastoral rural character, or a natural appearing landscape. Each of these categories implies different criteria would be appropriate for judging the merits of a reclamation plan. Without detailing such criteria, it is obvious that the quality of a reclamation plan cannot be judged unless one specifies the use to which the reclaimed land will be put.

Finally, although minimizing adverse impacts on wildlife and fisheries may simultaneously minimize impacts on scenic beauty it is not always the case and it should not be assumed that appropriate wildlife management will necessarily insure adequate scenic beauty resources management. This would appear to be especially true in determining where to restrict mining operations. For instance, preserving several miles of old-growth forests may not be significant for wildlife use, but would protect or preserve the area for scenic beauty. A waterfall may impede fish movement and its removal may be beneficial to fish management, but just the opposite may be true of scenic beauty management.

Often rehabilitation plans with dual objective measures are compatible. An irregularly shaped pond would be of benefit to both wildlife and scenic beauty. But shrubs and trees could be located in a manner that would be very beneficial to wildlife and not meet visual rehabilitation needs.

These and other ideas related to the scenic resource need to be explored cooperatively in future symposia to the forum.

ACKNOWLEDGEMENTS

Students in a workshop offered by the investigators, contributed many of the ideas for data collection tools, and collected and analyzed all of the data with guidance from the investigators. Much of the credit for the research, in contrast to this report of the research, should be shared with the following people: Sue Cedarleaf, Jim China, Terry Iliff, Alan Kastelic, Charles Law, Angela Les, Claudia Mielke, James Mills, Jim Pardee, Allison Rein, Robert Ribe, Tony Sticha, Sue Weller, and Jim Whitliff.

In addition, special thanks go to Peter Peshek and Tom Dawson, Public Intervenors, State of Wisconsin, for their insightful commentary on the research as it developed and was completed. Special thanks go to Mitch Zmuda, Area Water Management Specialist, North Central District, Department of natural Resources. Mr. Zmuda served as an educator and guide during field collection of data, provided slides of types of reclamation efforts, and gave excellent feedback regarding the potential usefulness of research such as this to the problems of agents in-the-field.

LITERATURE CITED

Soil Conservation Service. 1977. The status of land disturbed by surface mining in the United States - basic statistics by State and County as of July 1, 1977. U.S. Department of Agriculture. SCS-TP-158.

River County Resource Conservation and Development Council. 1981. A study of surface-mined areas in west central Wisconsin. U.S. Department of Agriculture, Soil Conservation Service, Madison, Wisconsin.

Recreation Resources Center. 1978. Gross sales of Wisconsin's H-R-T, University of Wisconsin-Extension, Madison, Wisconsin.

Jones, G. and I. Jones. 1978. Esthetics and visual resource management for highways. Training course workbook for the Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

Bufford. 1973. Beyond the eye of the beholder: aesthetics and objectivity. Michigan Law Review, Vol. 71, Pages 1438-62.

Muench v. Public Service Commission. 1952. Wisconsin Reports, Vol. 261, Pages 492-515.

Daniel, T.C., and R.S. Boster. 1976. Measuring landscape esthetics: the scenic beauty estimation method, U.S. Department of Agriculture - Forest Service Research Paper RM-167. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

Zube, E.H., J.L. Sell and J.G. Taylor. 1981. Landscape perception: research, application and theory. Draft Manuscript. School of Natural Resources, University of Arizona, Tuscon, Arizona. 57 pp.

Litton, R.B., Jr. 1968. Forest Landscape description and inventories -- a basis for land planning and design. U.S. Department of Agriculture - Forest Service Research Paper PSW-49. Pacific Southwest Forest and Range Experiment Station, Berkeley, California. 64 pp.

Litton, R.B., Jr. 1979. Descriptive approaches to landscape analysis. Pages 77-87 in G.H. Elsner and R.C. Smardon, Technical Coordinators. Proceedings from our national landscape: a conference on applied techniques for analysis and management of the visual resource. U.S. Department of Agriculture - Forest Service PSW-35. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Zmuda, M. 1978. Environmental impact asessment screening worksheet. 3-NC-78-518 (draft) Wisconsin Department of Natural Resources, Antigo, Wisconsin. 40 pp.

Just v. Marinette County. 1972. Wisconsin Reports, Vol. 56.

An Overview of Gravel Mining in Missouri and Fish and Wildlife Implications

RONALD L. CRUNKILTON. Fisheries Research, Missouri Department of Conservation, 1110 College Avenue, Columbia, Missouri 65201.

Sand, gravel and stone is the largest non-mineral industry in the United States. Its principal use is as aggregate for concrete, bituminous paving, road bases and coverings, cement production, lime production and fill. Missouri is ranked 20th nationally in production of sand and gravel and 5th in stone, and it is the state's 2nd largest non-mineral industry. Abandoned quarries in the state represent a new resource which if properly developed and managed can result in additional habitat for wildlife. Since the mining industry typically operates in the expanding fringe areas of cities or near associated recreation areas, multiple use conflicts are likely to result. Certain segments of the industry have a direct impact on fish and wildlife or indirectly affect the recreational use of those resources. This paper presents an overview of gravel mining in the state and discusses two case histories that typify several of the most significant environmental conflicts associated with the industry in Missouri.

THE INDUSTRY IN MISSOURI

Sand and Gravel

In 1980, eight million tons of sand and gravel were mined in Missouri (Fig. 1). The principal sources of sand and gravel are the alluvial deposits associated with streams and floodplains. Floodplain and inchannel deposits of the Mississippi and Missouri rivers are the source of about 75% of the sand and 15% of the gravel produced annually (Martin 1967). The most important source of gravel is from alluvial deposits associated with smaller streams in the unglaciated Ozark province (Fig. 2). Glacial outwash and upland terrace deposits are important in the Dissected Till Plains in northwest Missouri. Upland terrace deposits are the principal resource in the southeastern Lowland province. Gravels are rare in the Osage Plains province.

Low unit value, high bulk density, and high transportation costs cause major production sites to be located near large metropolitan areas. More than 50% of the state's total production is centered in the four county area near metropolitan St. Louis in eastern Missouri. The potential sand and gravel production from the Mississippi and Missouri rivers and the Ozark region is virtually unlimited and supplies will remain far into the future.

The two basic types of sand and gravel mining employed in the state are open pit excavation and dredging. Open pit excavation and processing has four major steps: (1) site clearing - involving the removal of vegetation and trees along with overburden and topsoil; (2) mining - removing the product from the deposit; (3) processing - crushing, screening, washing and stockpiling mined materials to specifications; (4) reclamation.

Open pit extraction is not as harmful to the stream environment as river dredging because most operations are located off-river. However, mining sites located near a stream channel or on the floodplain are of great concern and can produce some adverse effects on the riverine community even if the river channel is not physically altered. Site clearing on the floodplain and removal of riparian vegetation may lead to alteration of the runoff pattern, increased erosion, bank destabilization, sedimentation and turbidity. However, these direct effects of off-river excavation may not be as damaging to the environment as the methods of processing mined materials. Construction specifications require essentially all sand and gravel to undergo washing to remove silt. Discharges from washing operations are a predominant source of environmental problems associated with the gravel industry.

The practice of instream gravel removal or dredging is quite different from open pit extraction and varies greatly with the size of the operation and the composition of the material to be removed. Larger operations utilize a suction or bucket-type dredge mounted on boats or barges. Equipment used in smaller operations range in size from a crane and dragline dredge bucket to a front loading or track earth mover that can operate in shallow streams.

A significant number of environmental alterations have been attributed to instream gravel dredging. Some are hypothetical, however sufficient evidence exists in the literature to list a number of the adverse effects of dredging. They are categorized and listed below:

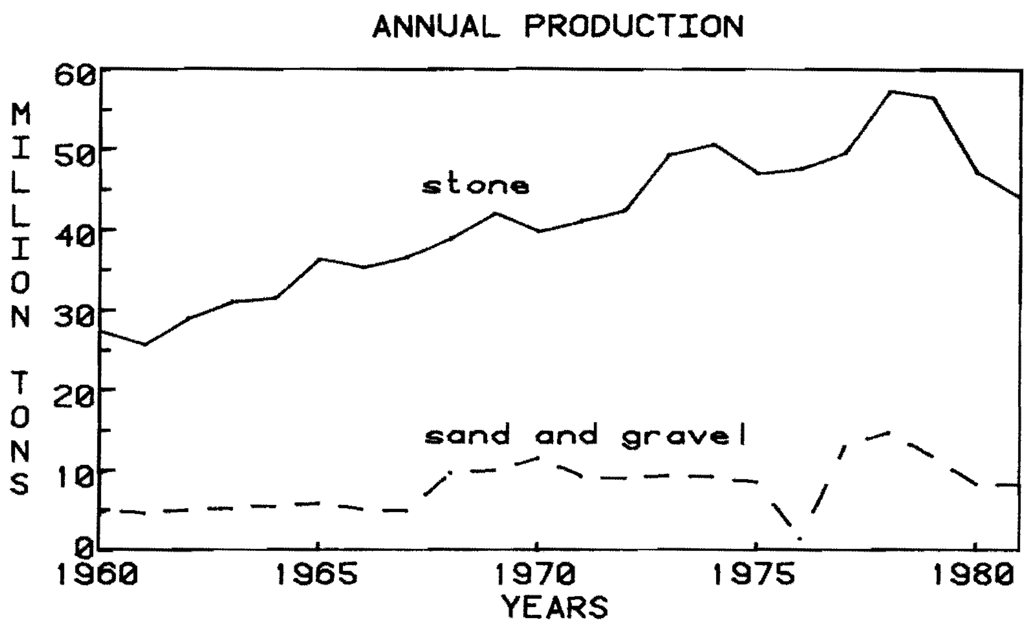


Figure 1. Annual production (short tons) of sand, gravel, and stone in Missouri since 1960. Redrawn from Rueff (1982).

Modifications of the Stream Channel

1. Alteration of habitat
   a. creation of deep pools
   b. loss of riffle habitat
2. Alteration of bed load transport
3. Increased head cutting
4. Alteration of channel flow
5. Bank destabilization

Modifications of Water Quality

1. Increased turbidity
2. Reduced light penetration
3. Reduced photosynthesis (primary production)
4. Increased stream temperature due to ponding and removal of riparian vegetation
5. Resuspension of organic material resulting in increased oxygen demand
6. Resuspension of toxic materials associated with sediment such as pesticides or metals.

Modifications of Aquatic Populations
(Naiades or mussels, benthic macroinvertebrates and fish)

1. Physical elimination of naiades, and other benthic macroinvertebrate life
2. Destruction of spawning beds, and nursery habitat
3. Reduction and/or elimination of silt intolerant organisms
4. Enhancement of silt tolerant organisms
5. Alteration of food web

Modification of Recreation

1. Change in fish species composition
2. Reduced fishing success
3. Aesthetics

Continued excavation of an open pit mine on the floodplain can result in many of the same environmental problems as dredging. Many operations that originate on the floodplain progressively enlarge, encroach upon and eventually capture the adjacent stream channel. Thus, the open pit becomes contiguous with the stream and can result in a compounding of the adverse consequences of both open pit and dredging practices. One of the most serious outcomes is the subsequent ponding resulting from the excavated pit. This in association with the removal of riparian streamside vegetation can result in abnormal thermal increases which can have far reaching environmental effects on downstream aquatic communities. This has been

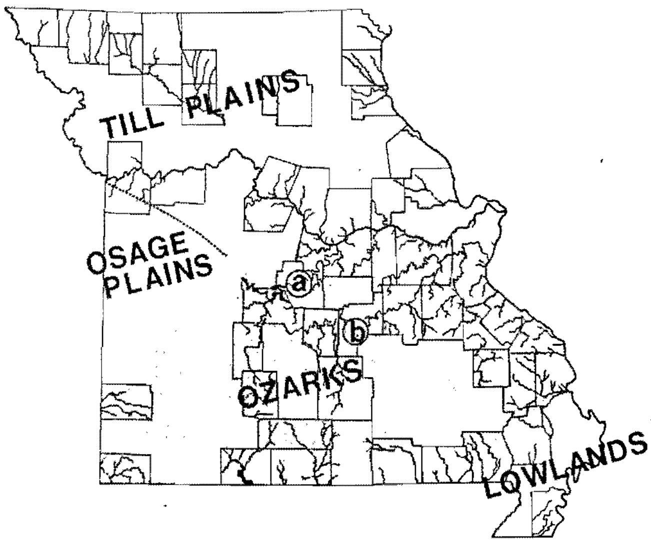


Figure 2. Physiographic regions of Missouri showing major sites of sand and gravel production. Counties outlined with major streams shown reported sand and gravel production for 1980. Production data from Rueff (1982). Areas designated as "a" and "b" are locations of case history study sites.

particularly damaging in Missouri streams that normally support a coldwater fauna.

Stone

Missouri is ranked 5th in the nation in production of crushed stone (Singleton 1980). Total production since 1960 is presented in Fig. 1. Quarrying in the state is by hillside cut, open pit and in drive-in underground rooms in limestone and dolomite formations. The quarrying method depends on the thickness of overburden, topography, and thickness of rock extracted. Open-cut hillside quarries are most common along the Missouri and Mississippi rivers and in the Ozarks. Open pits are most common in the St. Louis area, southwestern and northern parts of the state. Underground rooms are most common in the Kansas City area.

In addition to the uses in aggregate mixtures similar to sand and gravel, crushed stone is used in cement and lime manufacturing, riprap and agricultural liming. Alluvial gravel deposits in the Osage Plains (Fig. 2) are rare and crushed stone is used for most aggregate applications in that region. Although construction standards dictate the type of aggregate used, alluvial gravel and crushed stone are interchangeable for many applications. Market competition is an important factor in setting specifications.

Fewer environmental problems are associated with stone quarries than sand and gravel operations. Quarry operations require more capital outlay, are generally more methodical, and operate in a more clearly defined area. Stone quarries are infrequently associated with streams, generally do not have a washer discharge, and when abandoned most often result in the net addition of aquatic habitat. Since quarries are generally isolated from stream channels they do not compromise stream integrity.

INDUSTRY REGULATION

Regulation of the industry in Missouri is based on the Missouri Land Reclamation Act, the Missouri Clean Water Law, and Section 404 of the Federal Clean Water Act. The Missouri Land Reclamation Act requires registration of all active mining sites. The act has no provisions for setting guidelines for extraction procedures, but does require reclamation of worked sites. In part, the purpose of the act is to "encourage the planting of forests, to advance seeding of grasses and legumes for grazing purposes and crops for harvest, to aid in the protection of wildlife and aquatic resources, and to establish recreational, home and industrial sites." All ridges and peaks of overburden must be reduced to a minimum of 20 feet at the top or the affected land must be graded in a manner that the area can be traversed with farm machinery. Consolidated stone quarry highwalls are exempt from this provision. Lakes may be constructed from mined pits to meet reclamation requirements.

A serious weakness of this law is that mining sites in the river or floodplain are exempt from the reclamation requirements. This has resulted in an economic advantage and has effectively kept the industry in or near the river channel where reclamation costs are not a factor. It also places the industry in a position that maximizes the potential for environmental conflict.

The Missouri Clean Water Law contains provisions that regulate washer discharges and protect water quality. Regulations fall under two categories, effluent standards and water quality criteria. Effluent standards pertain to point source discharges such as any discernable, confined or discrete conveyance where pollutants may be discharged. Point source discharges require NPDES (National Pollution Discharge Elimination System) permits which set maximum allowable levels of pollutants that can be discharged. Non-point or discharges from diffuse sources cannot be regulated under existing state law. Limitations for gravel washer effluents include settleable solids not to exceed .2ml/l and a pH of 6-9. Water quality criteria are defined as "chemical, physical and biological properties of water such as are found instream that are necessary to protect beneficial uses." Water quality criteria apply to stream measurements and in relation to mining operations specifically to turbidity and temperature changes caused by their activities. Unlike effluent standards which are enforceable, water quality criteria are guidelines only. They are not directly enforceable unless a violation can be traced to a point source discharge where limitations have been exceeded. Furthermore, all pollution generated by instream dredging operations by virtue of definition is non-point. Thus, turbidity or sedimentation originating from dredging does not fall under the jurisdiction of the Missouri Clean Water Law. Pollution caused by gravel washing is also often classified as non-point, especially where permanent settling basins are not constructed, therefore much of this activity is also not regulated.

Regulation of gravel dredging also falls under Section 404 of the Federal Clean Water Act. This section requires a permit on any action that would result in "fill" in any waters or wetland in the United States. The U. S. Corps of Engineers administers this program. Interpretation of the law has been as varied as the activities this law regulates. "Fill" has been interpreted in a number of ways. In the most conservative sense, it has been applied to any material stockpiled within the high water mark such as sand or gravel removed from the river. At the other end of the spectrum, any structure placed within the high water mark to remove such material (deadman or cable dredge, crane and bucket or even a bulldozer) has, at times, been designated as fill and necessitated a permit. The real regulatory power of this law is that before a Section 404 permit can be issued the projected action must be certified by the state as not causing a violation of the state's water quality criteria. The full ramification of the state's regulatory power under this law is not entirely known, but the law has been useful in controlling a number of other environmental alterations such as stream channelization and draining or filling of wetlands.

The full potential of Section 404 may never be realized because of recent efforts by the presential task force on regulatory relief. This committee has been reviewing a number of regulations in an effort to reduce the jurisdictional extent of the federal government. This law has been identified as one area where regulations could be streamlined or eliminated altogether, although stiff opposition has been encountered from the U. S. Fish and Wildlife Service and other resource protection oriented groups.

CASE HISTORIES

Two recent studies will be reviewed which involve the effects of gravel dredging on stream biota. The first is a Missouri Department of Conservation study done by Grace and Buchanan (1981) on the naiades (mussels) of the lower Osage River, Missouri. It is an in-depth study of potential impacts of commercial gravel dredging on endangered naiades in a large Missouri stream. The second case history by Tryon (1980) discusses the effects of ponding and subsequent thermal encroachment upon the coldwater fish population in a small Ozark stream.

Osage River

This study was initiated in 1980 to determine the effects of commercial dredging on the pink pearly mussel (*Lampsilis orbiculata*) presently listed as endangered in the United States List of Endangered and Threatened Wildlife (U. S. Department of Interior, Fish and Wildlife Service, 1976), and the spectacle case (*Cumberlandia monodonta*) under review for inclusion in the above list. A secondary objective was to gather similar data on other species of naiades.

The study area was located on the lower Osage River in central Missouri downstream from Bagnell Dam on Lake of the Ozarks (Fig. 2; area a). The Osage River originates in west central Missouri at the confluence of the Marais des Cygnes and the Marmaton rivers and flows to the east about 250 miles to join the Missouri River. The Osage basin has a drainage area of over 16,000 square miles making it the largest stream that flows entirely within the borders of the state. The lower Osage is low gradient (average .5 ft./mile) moderately clear, with long pools usually less than 10 feet in depth and has poorly defined riffles. Gravel and cobble are the principal bottom types with silt covering the riverbed in many of the deeper, sluggish pools.

Three large commercial sand and gravel operations, Ozark Sand Company, Osage Sand and Gravel Company and Roweth Sand and Gravel Company are located on the lower Osage River. Each operation is separated by 10 or more miles. Ozark Sand Company mines in the river with a crane dragline dredge and a crane with bucket.

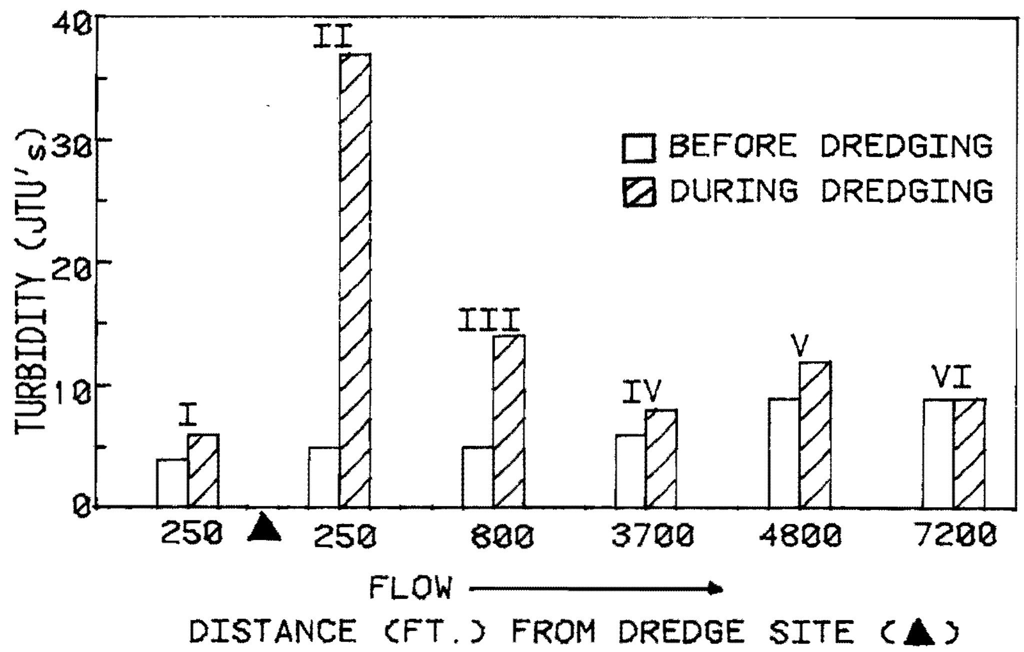


Figure 3. Turbidity (JTU's) upstream (1 site) and downstream (5 sites) from Ozark Sand Company before and after dredging on the lower Osage River. Redrawn from Grace and Buchanan (1981).

Sand and gravel is processed with river water with a discharge through a settling pond back to the river. Osage Sand and Gravel Company hydraulically mines from the river with a cutterhead dredge mounted on floating pontoons. Roweth Sand and Gravel Company mines from the river with a Sauerman dragline dredge. The latter two companies process the sand and gravel with river water and return it directly to the river without settling. The large excavation in the stream channel left by these mining operations may exceed 60 feet in depth.

Naiades were collected at 23 sites on the Osage River at 3-5 mile intervals. Shells were collected by hand along shore, from muskrat and raccoon piles, and from the stream bottom. Live naiades were collected by hand while wading with a benthoscope (viewing box) snorkeling and by scuba diving. Physical and chemical site characteristics recorded included bottom type, water velocity, depth, temperature, turbidity, alkalinity, hardness, pH, and dissolved oxygen. Turbidity was monitored 250 feet above and 250 below each dredging operation over a 3-4 day period. Four additional stations were selected between 800 and 7,200 feet downstream from the dredging site. Water samples were taken each day before dredging and washing operations began and throughout the day at 2-hour intervals.

The results of the naiad survey showed 34 species from over 18,000 living specimens examined. Ten species comprised 92% of the living naiades. The three most abundant were the washboard (Megalonaias nervosa) 51%, three ridge (Amblema plicata plicata) 9.1%, and pimple back (Quadrula pustulosa) 8.1%. The pink pearly mussel and the spectacle case, under review for endangered status, comprised .3% of all living naiades found.

No living naiades were found in dredged areas of all three gravel operations based on qualitative and quantitative sampling. Some of the dredged areas sampled had not been worked for as long as 15 years. Few living naiades were found in the undredged river immediately adjacent to each operation. However, well developed naiad beds were found downstream from gravel operations where the bottom substrate had not been disturbed.

The study showed turbidity was significantly higher ($p \leq .05$) during operation at Ozark Sand Company than before operation at stations 250 feet upstream and 250 feet, 800 feet, and 3,700 feet downstream (Fig. 3). No significant differences were found at stations 4,800 feet and 7,200 feet downstream. Turbidity averaged 5,700 Jackson Turbidity Units in wash water returned to the river and turbidity was significantly greater in samples taken near the bottom than at the surface. Turbidity measurements taken at the other two commercial operations showed similar patterns; average turbidity was greater downstream during operation than before and decreased in a downstream direction. Turbidity also appeared to be slightly greater below the operations than above even after dredging had ceased because of the permanent disruption of the stream bottom.

A literature review showed a number of studies related to the impact of suspended silt, silt and sand sedimentation on naiades, but only one study dealt specifically with these adverse effects as they related to gravel dredging. Ellis (1931a, 1931b) contended that the outstanding factor producing changes in the Mississippi River fauna was erosion silt. Van der Schalie (1938, 1941) and Ellis (1936) believed that siltation resulting from land clearing and farm cultivation have adversely affected naiades in the eastern United States. Additional studies by Starrett (1971) and Stansbery (1970) supported these observations and concluded naiades are less widely distributed today because of siltation. Feeding efficiency may also be altered by suspended particulate matter (Loosanoff and Tommers 1948; Loosanoff 1962). They found the addition of silt lowered pumping and therefore feeding rate. They concluded bivalve mollusks feed most effectively in relatively clear water. More recent laboratory studies by Marking and Bills (1980) have confirmed early expectations by other authors and showed direct mortality in naiades covered with sand and silt. In addition to the direct smothering effects of siltation, Yokley and Gooch (1976) in the only study that dealt with specific effects of gravel dredging showed slower growth rates in naiad species downstream from turbid gravel dredging sites. They also believed at least 10 years would be required for a dredged area to recover depending on stabilization of substrate and its attractiveness to fish hosts carrying larval naiades.

Dredging activities may also indirectly impact naiades by altering fish populations. Since naiades must depend on fish as larval hosts and for dispersal, any activity that altered the species composition or movement of the fish population would also alter naiad distribution. Some host relationships are species specific and therefore directly affect their survival.

The authors of this study concluded the Osage River generally provided favorable habitat for 34 species of naiades. Marked effects on naiades were observed in dredged areas and areas immediately adjacent to the dredge site due to physical destruction of habitat. In addition to the physical destruction of habitat, other factors preventing recolonization appeared to be the destabilization of bottom substrate and deepening of pools. The adverse effects of dredging on naiades are long lasting and reestablishment in dredged areas appears to take many years. Continued dredging within the existing operation zone at all three commercial sites would be unlikely to have additional serious impact on the population of the pink pearly mussel and the spectacle case. However, any expansion of dredging at existing sites or any new dredging should not be permitted without first conducting a survey to determine the presence of endangered species. The authors also stated that floodplain dredging at all sites would be unlikely to have adverse affects on the naiad fauna if the river configuration were not altered. Although turbidity was significantly increased downstream from dredging activities, the direct impact of turbidity could not be determined and additional research was recommended.

Little Piney River

The second case history by Tryon (1980) discusses the effects of ponding and subsequent thermal increases caused downstream from a gravel mining plant on the Little Piney River. The Little Piney River originates in the central Ozark region and flows about 35 miles north to its confluence with the Gasconade River (Fig. 2; area b). The basin drains approximately 250 square miles, classifying it as a small to intermediate stream. The study area is located in the headwaters near the uppermost point of permanent spring-fed stream flow. The gradient is moderate (10 ft./mile) and the water is normally clear, with long runs separated by well defined riffles and pools. Pools are generally less than 5 feet in depth. Gravel and sand are the principal bottom types.

Havin Materials Company removes sand and gravel from a large floodplain excavation ($\sim$ 20 acres) which has captured the adjacent stream channel. The lake subsequently formed on the Little Piney River is shallow, generally less than 10 feet in depth, and in contrast to the cool spring-fed stream, supports a warmwater fish fauna dominated by largemouth bass. The Missouri Department of Conservation maintains a trout management area beginning 1,000 feet below the Havin Lake. Catchable sized trout have been stocked on a put and take basis during the recreation season for a number of years. Natural trout reproduction does occur on a limited basis in this area.

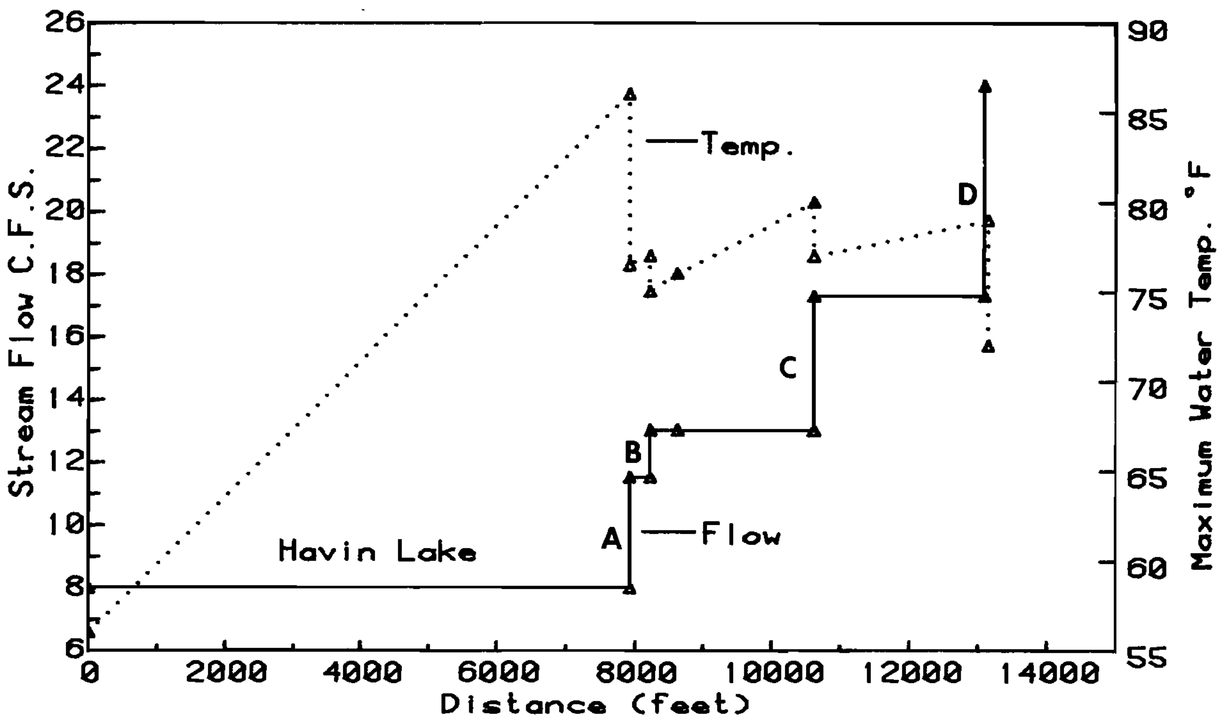


Figure 4. Stream flow and temperature profiles upstream and downstream from the 20-acre Havin gravel pit excavation on the Little Piney River. Distance is measured from the uppermost permanent flowing springs on the river. Triangular data points (Δ) represent sites of spring flow input. A, B, C, and D correspond to Table Rock, Twin, Yancy Mills and Lane Springs, respectively. Redrawn from Tryon (1980).

The major source of flow in the study area, except during periods of precipitation, is from 7 surface springs, three above the gravel plant and four below. During low flow the uppermost three springs contribute 8 cfs of 57°F water which passes through the Havin Lake. An additional 16 cfs of spring water at the same temperature is added by the four springs downstream from the lake over the course of about 1 mile. Approximately 1/4 mile of stream on either side of the lake has been channelized by previous dredging. Consequently, all canopy vegetation has been removed and the stream is open to direct solar radiation.

An intensive study was undertaken on July 7, 1980 due to an extended period of 100°+F air temperatures when solar intensity on the stream bottom was near maximum. Flow and temperatures were measured above and below the mouth of every spring tributary branch on the stream. These measurements were used to calcuate a stream temperature profile and to model temperature throughout the study area.

The results showed a temperature increase of 30°F between the spring discharge above the Havin Pond where the permanent stream flow originates and a point 8,000 feet downstream where flow from the first downstream spring (Table Rock) enters (Fig. 4). The addition of 4 cfs at this point lowers the temperature 9°F to 77°F. Stream temperature was further characterized by gradual increases between points of additional entry of spring flow due to high ambient temperatures. However, the steepest point on the temperature curve or the zone of greatest observed temperature increase corresponded to the ponded water on the Little Piney River at the Havin Lake. The channelized portion of the stream also undoubtedly added to the thermal increase which was never completely overcome by further additions of spring flow.

The author of this study concluded the 86°F temperature measured upstream from Table Rock Spring was lethal to any trout present. Downstream from Table Rock Spring where temperatures were cooler (75-80°F) it was inferred there were no surviving young-of-the-year which are more sensitive to thermal increases. The juvenile and adult trout in this same area were believed to be under considerable stress. Downstream from Lane Spring the water cooled further to nearly 70°F and the trout were probably unaffected. Unfortunately, almost all of the natural trout spawning had historically been upstream from Lane Spring where the thermal stress had been greatest. In addition to the projected trout losses, the put-and-take trout stocking program had to be cancelled until temperatures cooled later in the season.

In addition to the thermal increases, Havin Materials Company processes gravel, returns wash water to the stream, and substantially increases turbidity downstream in the trout management area. The Little Piney River is normally a clear stream with visibility extending to the stream bottom which may reach 5-6 feet in pools. Any increase in turbidity in this type of stream is aesthetically damaging and can restrict recreational uses. Some of the serious complaints have come from fishermen, especially fly fishermen who rely on trout to spot surface laid patterns through several feet of water.

In addition to a turbid washer effuent, turbidity generated from the actual dredging within the onstream lake or within the stream is sufficient to warrant complaints in downstream areas on the river. This problem is not unique to the Little Piney, but is virtually characteristic of almost any free-flowing stream in the Ozarks where gravel mining takes place. The streams in this physiographic region are noted for unusual water clarity and are in high demand for recreational use. Turbidity in these streams is aesthetically damaging to recreational users expecting a high quality experience. Certain aspects of fishing and canoeing are adversely affected for many miles below problem sources of turbidity.

CONCLUSIONS

The quantity of sand, gravel, and stone is the second largest non-fuel mineral mined in Missouri. Because of its low value and high transportation costs, sand, gravel, and stone are produced near the point of use; therefore, the industry is concentrated in large rapidly expanding areas or where other large-scale projects are under construction. This places the industry in direct competition with other land use and in some instances alternative stream use for fish, wildlife and recreation.

The industry faces the problem of any mining practices which can affect the environment. From a fisheries and wildlife viewpoint the few positive aspects that instream dredging might afford such as deepening of pools are far outweighed by the detrimental aspects of the mining process. Off-stream mining should be encouraged wherever feasible and would have very few adverse effects if the channel integrity and a buffer of riparian vegetation remained intact.

The two case histories discussed pointed out significant problems that need to be addressed in further regulation of the industry. Present guidelines are largely ineffective and in some instances promote the location of sand and gravel mines in or near river channels. This maximizes the potential for environmental conflict. An effective effort must be made to reduce water pollution, reclaim areas, and improve the overall operation of facilities. The industry and users of the product must recognize the time and costs required to protect the environment. Overregulation is a concern, but historically and in perspective with many other states, the industry has operated freely in Missouri. Concern for development of the resource needs to be properly balanced with available technology that will also protect fish, wildlife and recreational use.

LITERATURE CITED

ELLIS, M. M. 1931a. A survey of conditions affecting fisheries in the Upper Mississippi River. Fish. Circ. 5:1-18.

ELLIS, M. M. 1931b. Some factors affecting the replacement of the commercial freshwater mussels. U.S. Bur. Fish. Circ. 7:1-10.

ELLIS, M. M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1): 29-42.

GRACE, T. B., and A. C. BUCHANAN. 1981. Naiades (mussels) of the Lower Osage River, Tavern Creek, and Maries River, Missouri. Mo. Dept. Conser., Project funded by the U.S. Army Corps of Engi. 147 pp.

LOOSANOFF, V. L. 1962. Effects of turbidity on some larval and adult bivalves. Proc. 14th Ann. Sess., Gulf and Caribb. Fish. Inst. 14:80-95.

LOOSANOFF, V. L., and F. D. TOMMERS. 1948. Effect of suspended silt and other substances on rate of feeding of oysters. Science 107(2768):69-70.

MARKING, L. L. and T. D. BILLS. 1980. Acute effects of silt and sand sedimentation on freshwater mussels. pp. 204-211 in J. L. Rasmussen, ed. Proc. of the UMRCC symposium on Upper Mississippi River bivalve mollusks, Upp. Miss. River Conser. Comm., Rock Island, Illinois.

MARTIN, J. A. 1967. Sand and gravel chapter in Water Resour. of Missouri. Mo. Geol. Sur. and Water Resour. 43:196-203.
RUEFF, A. W. 1982. Personal communication, Mo. Dept. of Nat. Resour., Div. Geol. and Land Surv., Rolla, Missouri 65401.
SINGLETON, R. H. 1980. Stone chapter in Mineral Facts and Problems. U.S. Dept. of Inter., Bur. of Mines. Bulletin 671:853-868.
STANSBERY, D. H. 1970. 2. Eastern freshwater mollusks (1). The Mississippi and St. Lawrence River systems. Malacologia 10(1):9-22.
STARRETT, W. C. 1971. A survey of the mussles (Unionidae) of the Illinois River: A polluted stream. Ill. Nat. Hist. Suv. Bull. 30(5):266-403.
TRYON, C. P. 1980. A study of extreme water temperatures at the Lane Spring Trout Management Area. In-service report. Mark Twain Natl. Forest Superv's Off., Rolla, Missouri. 9 pp.
UNITED STATES DEPARTMENT OF THE INTERIOR, FISH AND WILDLIFE SERVICE. 1976. Federal Register. Part IV: Endangered and threatened wildlife and plants. Fed. Regis. 41(208):47,181-47,198.
VAN DER SCHALIE, H. 1938. Contributing factors in the depletion of naiades in eastern United States. Basteria 3(4): 51-57.
VAN DER SCHALIE, H. 1941. Zoogeography of naiades in the Grand and Muskegon rivers of Michigan as related to glacial history. Pap. of the Mich. Acad. of Sci., Arts and Lett. 26:297-310.
YOKLEY, P., JR., AND C. H. GOOCH. 1976. The effect of gravel dredging on reservoir primary production, invertebrate production, and mussel production. Tenn. Wildl. Res. Agency, Nashville. Pro. No. 2-245-R. 32 pp.

Conservation, Recreation, Mining, and Rehabilitation in Story County, Iowa

JAMES M. PATCHETT, Story County Conservation Board, Hickory Grove Park, Colo, Iowa 50056.

In June, 1978, the Story County Board of Supervisors adopted an amendment to the County's "Land Use Policies, Zoning Ordinance, and Subdivision Regulations", creating a Greenbelt/Conservation District zoning classification. The Greenbelt/Conservation District zoning ordinance is intended to protect and enhance critical natural resources in Story County. The ordinance established special regulations for the use of land under both private and public ownership. These regulations are designed to permit reasonable economic use of property, while at the same time, protecting the natural and recreational resources of the area.

Mineral extraction is a conditional use in a Greenbelt/Conservation zoning district. Upon reviewing and compiling prior research dealing with progressive rehabilitation in sand and gravel operations, Story County has adopted a set of procedural guidelines for planning and implementing the orderly extraction and rehabilitation of sand and gravel sites. This was achieved through the cooperation of state and local governmental agencies, local citizens, and representatives of the sand and gravel industry. These procedural guidelines were established to insure that natural, recreational and wildlife values are carefully considered and safeguarded throughout the excavation and development process.

Additionally, the Story County Conservation Board, the County Board of Supervisors, the County Engineer and officials of the City of Ames have cooperated in the purchase of a 200 acre tract of land within the Greenbelt. Known as Peterson Pits, the area has been intermittently mined for sand and gravel for over 50 years. Plans call for the continued excavation of sand and gravel from the site. Mining will be coordinated towards the eventual development of a multi-purpose recreational/wildlife park and preserve.

THE GREENBELT CONCEPT

The Greenbelt concept arose in the early 1970's when the U.S. Army Corps of Engineers proposed the construction of a reservoir to be located in the Skunk River Valley from Ames north to Story City. The Skunk River flows roughly north to south through the western half of Story County in central Iowa.

The reservoir was originally conceived as a multi-purpose water resources project. It's primary objectives were to insure high water quality and quantity for the City of Ames, flood control for the lower Skunk River Valley, outdoor water recreation for a nine (9) county central Iowa region, and incidental fish and wildlife propagation.

The reservoir project would have required the acquisition of 8,065 total acres, innundating a 12 mile stretch of river valley with a conservation pool of 2,150 acres and a maximum pool of 7,500 acres. This area included 55 households and would have required the displacement of up to one hundred seventy (170) individuals.

There was a great deal of local opposition to the reservoir concept, not only from those citizens being displaced, but from groups and individuals who were concerned about the destruction of the areas' unique natural and cultural resources, as well as the expense of the proposed reservoir construction and upkeep.

The Skunk River corridor, with its meandering ing stream and wooded valley, is rich in natural resources.

During preparation of the Reservoir Environmental Impact Statement, the forest inventory revealed that twenty-five (25%) of the woodland cover in Story County is contained within this 12 mile stretch of the Skunk River valley.

The overstory vegetation in this area was found to be among the highest quality existing in the county.

Mineral extraction is important to the region. Sand, gravel and limestone rock are extracted at several locations for construction materials. Geologic features such as rock outcroppings and artesian springs are not uncommon in the river valley.

Wildlife census data has revealed a quantity and quality level of fair to good in species densities and adequacy of suitable habitat. The importance of preserving the river corridor for wildlife habitat is magnified when you consider that most land in the county is intensively row cropped.

Archealogical sites were inventoried during a reconnaissance study in 1973 and periods of occupancy identified were the historic Euro-American, native American "Indian", post-woodland tradition, and possible archaic tradition. These sites were identified throughout the river valley corridor. One area known as Soper's Mill, is listed in the National Register of Historic Places. Soper's Mill was the site of the first grist mill in Story County. An arch span bridge constructed across the Skunk River in 1867, linking the valley stage coach trail, remains intact today.

As required in the preparation of an environmental impact statement, several alternatives to the major reservoir concept were examined. After analyzing the various alternatives, the research team concluded that the major reservoir alternative would have a greater impact on the natural resources of the river valley than the Greenbelt, open space, or minor reservoir alternatives. A suggested "do nothing" alternative, with no reservoir or greenbelt open space plan, appeared to pose a threat to the natural resources of the river corridor due to urban encroachments and other intensive land use patterns.

The final environmental evaluation recommended that the maximum greenbelt proposal calling for public ownership and management of a 5000 acre tract, appeared to be the most favorable alternative in terms of lessening environmental impact. However, at the time these recommendations were released in late 1973, the study team expressed great concern that adoption and implementation of the greenbelt alternative would fail due to a lack of public concern and funding, or inadequate local and state initiative.

THE GREENBELT/CONSERVATION DISTRICT ZONING ORDINANCE

The Ames Reservoir environmental impact statement identified many of the significant natural and cultural resources of the Skunk River valley, and pointed out the need of establishing a means for their protection. From a financial standpoint, outright acquisition of such a large area would be extremely difficult for a local agency. At least half of the 5000 acre tract is comprised of agricultural land. Most rural families were not interested in selling their property, nor were local governmental agencies interested in purchasing agricultural land surrounding the river corridor.

An alternative method of protecting the county's major stream corridors became possible with the adoption of a county land use plan in 1977. Story County's "Land Use Policies, Zoning Ordinance, and Subdivision Regulations", required the county to recognize and develop programs to preserve and protect our unique natural resources. The County Conservation Board and the County Planning and Zoning Commission introduced the concept of a Greenbelt/Conservation Zoning District, primarily as a method for achieving these objectives.

The maximum greenbelt alternatives proposed in the impact statement required total public ownership of the land. The Greenbelt/Conservation District, however, provides special regulations for the use of lands under private and public ownership in the form of a zoning ordinance.

The basic intent of a Greenbelt/Conservation Zoning District, as adopted by the Story County Board of Supervisors in December, 1978, is " . . . to promote water quality and conservation to protect aquifers, alluvial soils and slopes, and to protect areas which possess outstanding scenic, vegetation, wildlife habitat, travel corridors, geological, historic or recreational values". These regulations permit reasonable economic use of property and at the same time protect the natural and cultural resources and recreational assets of the area.

A Greenbelt/Conservation District is a specifically zoned, officially recognized area with definite boundaries. The boundaries are established using the following principal criteria: floodplain, alluvial soils in conjunction with steep slopes (18-40%), vegetative cover and its effect on visual periphery from within the river valley, wildlife habitat, and historical/archaeological sites. The planning permiters are used in conjunction with legally defined boundaries based on property lines, section lines, and existing road right-of-ways which closely border the specified resources. In cases where the boundary lines could not be described in these terms, a 100' buffer zone was established from the center line of the river.

The principal permitted uses within a Greenbelt/Conservation District zone include crop production, truck gardening, nurseries, orchards, tree farms, livestock grazing, sustained yield forestry, wildlife preserves, soil and water conservation projects, recreational uses and cultural/historic restoration.

Conditional use permits may be issued for the installation of temporary facilities for music events, religious meetings and similar activities. Mineral extraction is also listed as a conditional use, subject to receiving a mineral extraction overlay zoning classification, and obtaining a special use permit. Once mineral extraction and rehabilitation have been properly completed, the overlay zoning classification reverts to a Greenbelt/Conservation zoning classification.

Specific uses which are not permitted include feedlots, poultry farms, clear cutting of timber, and rural residences.

The afore mentioned portion of the Skunk River represents the first area to be designated a Greenbelt/Conservation Zoning District. The area encompasses 2,100 acres, stretching about 10 river miles from Ames to Story City. Approximately 925 acres are either publically owned or managed at the present time, with the remainder in private ownership. Tracts of land which provide public access to the river and areas which link existing public property have the highest priority for acquisition. The County Conservation Board is using both fee title purchase and 10-20 year easements to acquire land and provide for public access and enjoyment of the river valley.

Total public acquisition of the greenbelt, however, is neither desired, nor necessary as the zoning system provides a means for protecting and enhancing the natural resources of the area, while retaining private property in the public tax role and agricultural land in production.

MINERAL EXTRACTION AND REHABILITATION IN THE GREENBELT

As previously mentioned, mineral extraction is allowed as a conditional use in a Greenbelt/Conservation District. A two step process is involved before mining operations can begin.

Initially, the operator or landowner must request a mineral extraction district overlay classification for the proposed extraction site. The County Conservation Board and the County Planning and Zoning Commission review the proposed extraction and rehabilitation plans and provide the opportunity for public input. After receiving recommendations from the Conservation Board and the Planning and Zoning Commission, the County Board of Supervisors hold an open hearing and are ultimately responsible for approving or denying the mineral extraction overlay request.

If the overlay zoning classification is approved, the operator may then apply for a conditional use permit, which is issued by the County Zoning Board of Adjustment.

In the spring of 1981, the county was faced with the first request for sand and gravel extraction within the Skunk River Greenbelt. As required by the Greenbelt/Conservation District and the A-M Mineral Extraction District ordinances, the operator is required to submit information concerning the proposed extraction and rehabilitation plans. The required information includes evidence concerning the feasibility of the proposed extraction and its effect on surrounding property, a site plan including location of parking, driveways, points of ingress and egress, access roads, and an overall extraction, restoration, and re-use plan.

Although operations are required to submit extraction and restoration plans, the ordinance requirements were somewhat ambiguous as to the scale, detail, and specific types of information to be provided.

The Conservation Board and the Planning and Zoning Commission held several open hearings to discuss the proposed plans. It quickly became apparent that more detailed information concerning the extraction and rehabilitation plans was necessary to insure that the potential impact of the operation and the long range effect of the rehabilitated land use could be adequately analyzed.

This case was controversial for a number of reasons. Since it represented the first request for mining in the Greenbelt, the specific criteria required for submitting mineral extraction requests, plus the operational requirements placed on the conditional use permit, would set a precedent for future mineral extraction and rehabilitation in Greenbelt/Conservation districts.

In addition, the proposed extraction site is located on a twelve acre field adjacent to Soper's Mill County Park. The park is located along the river in an area where surrounding agricultural land uses have left a very thin vegetation buffer and wildlife travel corridor. Many local citizens were concerned about the possible adverse short and long range impact on wildlife, wildlife habitat, the surrounding environment, and the recreational values of the area.

As a result, the Conservation Board staff and the County Planning and Zoning Administrator began to develop a list of specific criteria to be addressed in extraction and rehabilitation plans. Literature pertaining to progressive rehabilitation and operational procedures associated with the sand and gravel industry was researched.

Initially, the staff identified six general goals for establishing an effective set of mining and rehabilitation guidelines.

1. To develop specific criteria for the submittal of petitions to establish <u>A-M Mineral Extraction District</u> Zoning.

2. To develop guidelines and performance standards which may be incorporated into mining and rehabilitation plans.

3. To develop mining and reclamation guidelines

and operational performance standards which represent a combined effort of the government, the sand and gravel industry, and the local citizens.

4. To develop specific guidelines and standards that would provide a means of rehabilitation within reasonable industry practice standards.

5. To develop guidelines and standards that are compatible with State and Federal regulations including Chapter 83A, of the Code of Iowa which regulated surface mining operations.

6. To ensure that proposed rehabilitation land uses are consistent with the intent and spirit of the Story County Zoning Ordinance.

Once goals were established, the staff prepared a draft set of mining and rehabilitation guidelines. These guidelines were presented and discussed with local and state governmental agencies, citizen groups, and representatives of the sand and gravel industry.

Further research into progressive rehabilitation, or the simultaneous extraction and rehabilitation of sand and gravel sites, according to a preconceived plan, provided additional information pertaining to methods for planning and implementing cost effective, yet environmentally sound, sand and gravel extraction operations.

The properly planned extraction and rehabilitation of sand and gravel sites can provide excellent opportunities for recreational, residential, commercial, wildlife and natural resource developments.

The heavy excavating and transporting equipment used for the excavation of sand and gravel can also be used in creating functional land forms and achieving site development objectives. Operating patterns can be organized efficiently into a rehabilitation cycle accomplished within the framework of normal extraction operations.

In March, 1982, after a great deal of research and review, the County Planning and Zoning Commission adopted a comprehensive set of procedural guidelines for obtaining an A-M Mineral Extraction District zoning classification and a conditional use permit. These procedural guidelines will be observed, not only for mining which occurs within Greenbelt/Conservation Districts, but for all future proposed mineral extraction throughout the county.

The required information is broken down into a two stage format. The first stage requires evidence concerning the feasibility of the proposed operation and a site and operational analysis in a conceptual form. Stage one plans are required for obtaining an A-M Mineral Extraction District zoning classification.

Once the zoning is approved, stage two requires the operator to provide a more detailed set of mining and rehabilitation plans.

Specific operational conditions or performance standards are assigned on a case by case basis.

The following flow chart explains the procedures for obtaining an A-M Mineral Extraction District zoning classification and a conditional use permit. Following the flow chart is the list of specific criteria required in the two stage mineral extraction request process.

Upon notice by landowner or mineral extraction operator of interest in mining a specific area in a Greenbelt/Conservation district, the Conservation Board staff will prepare an analysis of environmental conditions and constraints, which, in turn, may be addressed in the extraction/rehabilitation plan.
↓
Preparation of Analysis of Environmental Conditions and Constraints by Conservation Board staff.
↓
Preparation by Sand and Gravel Producer of Stage I--Conceptual Extraction Rehabilitation Plan for Rezoning to A-M Mineral Extraction Overlay District.
↓
Review and comment on Conceptual Plan by Conservation Board and Planning and Zoning Commission. Public hearings.
↓
Board of Supervisors Open Hearing. Decision on Rezoning.
If Rezoning approved, ↓
Preparation by Producer of State II--Detailed Extraction and Rehabilitation Plan.
↓
Review and comment on detailed plan by Conservation Board and Planning and Zoning Commission.
↓
Board of Adjustment Review. Decision on Conditional Use Permit.

STAGE ONE - Required for Rezoning to A-M Overlay Classification

I. Evidence Concerning Feasibility
   A. Description of the character and thickness of the mineral deposit.
   B. Boring logs - composition of sand and gravel.
   C. Average depth of overburden to be redis-

tributed.

II. Site & Operational Analysis
  A. Site
    1. Location of site - county, section, & township.
    2. Property line survey.
    3. Easements and rights-of-way.
    4. Aerial photo (Story County Conservation Board has aerial photos of entire Greenbelt/Conservation area on file.)
    5. Zoning and land use maps.
    6. Existing land use (adjacent and in general area of the site).
    7. Access and transportation arteries (indicate types of surface).
    8. Development trends (patterns of expansion) of adjacent land uses.
  B. Description of Environment
    1. Contour maps (2 or 5" contour interval preferred).
    2. Soils data.
    3. Existing ground cover and location of any wooded area.
    4. Relationship of site to surrounding terrain.
    5. Special surface or subsurface geologic features such as streams, rock out croppings, etc.
    6. Views into site.
    7. Areas of most probable visual conflict
  C. The Deposit
    1. Depth of topsoil and overburden.
    2. Deposit depth and outline.
    3. Percentage of waste sand.
    4. Depth, outline, and type of unmineable material.
    5. Ground water elevation (normal).
    6. Ground water flow and character.
  D. Equipment and Operational Procedures
    1. Type of excavating equipment.
    2. Type of transporting equipment.
    3. Processing plant layout, including stockpiles (diagrammatic).
    4. Anticipating general excavation patterns.
    5. Location of settling ponds (if any).
  E. Review of Historical/Archaeological features on site.
  F. Assessment of wildlife and possible impacts from proposed operation.

III. Extraction/Rehabilitation Plan (Conceptual)
  A. Conceptual Sketch Plan
    1. Layout major excavation and rehabilitation pattern (to include)
      a. Establish high and low points.
      b. Stockpiling method.
      c. Handling of topsoil (preservation and respreading of topsoil) and possible effects on change in soil composition.
      d. Staged method of restoration.
      e. Proposed land features.
      f. Drives, access and traffic generation.
      g. Set backs.
      h. Fences.
      i. Outline measures to be taken for hoise, dust, and erosion control.
      j. Permanent man-made features to be left on-site.
      k. Estimated length of operation.
      l. Determine essential screening to reduce inherent conflicts.
      m. Future land use alternatives.
    2. Brief discussion considering impact of proposed operations on surrounding land areas.

STAGE TWO - Required to obtain Mineral Extraction Conditional Use Permit

I. Detailed Site and Operational Analysis
  A. Prepare detailed outline of sand and gravel deposits.
  B. Determine the volume of material unsuitable for processing.
    1. Outline areas where these volumes are located.
  C. Outline area required for processing plant (including stockpiles and handling of topsoil).
  D. Coordinate excavation and development functions.
    1. Review equipment in respect to land forming capabilities.
    2. Manipulate the excavation equipment within the scope of its operating patterns.
    3. Minimize hauling distance of land forming material.
    4. Taking both site and operational characteristics into consideration, develop the specific pattern of excavation that will implement the development of the proposed land forms.

II. Detailed Excavation/Rehabilitation Plan
  A. Handling and placement of overburden.
  B. Handling and placement of topsoil.
  C. Detailed planting and screening plans.
  D. Detailed grading plan including topography (1 or 2" contour interval), drainage and land form grading.
  E. Master plan - illustrates proposed land forms, land uses, and basic site features.

THE PETERSON PIT AREA

In December, 1979, the Story County Conservation Board, the County Board of Supervisors, the County Engineer and the City of Ames cooperated in the purchase of a 200 acre tract of land in the Skunk River Greenbelt. Known as Peterson Pits, the area has been mined for sand and gravel intermittently for 50 years.

The Skunk River bisects the property. Five existing gravel pits presently comprise approximately 26 acres of surface water on the site. Test borings reveal approximately 2 million tons of sand and gravel remain in the site, which are economically reasonable to mine.

The County Engineer and officials of the City of Ames are interested in the potential sand and gravel resources from the area. The City of Ames is also interested in water rights in case of periods of water shortage or drought. A permanent pump system can be installed in the pits which would pump water into the Skunk River. The water would flow downstream and infiltrate into the ground water aquifer, replinishing Ames well fields.

The County Conservation Board is interested in the eventual development of a multi-purpose recreational/wildlife park and preserve.

Short and longe range conceptual mining, reclamation and development plans have been drafted. Land on the east side of the river, which comprises approximately one-third of the 200 acres, will be developed primarily as a natural wildlife management area. Much of the existing tree cover occurs on this side of the river, and no future mining is planned. Grading and revegetation work has commenced in areas which were previously mined or disturbed. This section provides an important link in the wildlife travel corridor throughout the river valley. Wildlife habitat and habitat diversity are the prime development considerations in this area.

Further mineral extraction will take place on the west side of the river. Plans call for this area to be developed as a multi-purpose recreational park. Extraction and rehabilitation plans will be drafted in accordance with the mining ordinance requirements. Additional boring tests and detailed topographic information will be necessary before developing a comprehensive extraction and rehabilitation plan. It is estimated that an eventual water cell of 50 to 70 acres could be developed. Mining in the Peterson Pits area is not scheduled to commence prior to 1985.

SUMMARY

Story County residents have taken steps to protect existing limited natural and cultural resources.

Although other alternatives may exist, the use of zoning as a means of protecting and enhancing Story County's natural resources, has been effective and well received.

The extraction of sand and gravel resources is necessary for continued growth and expansion.

Yet, to insure the protection of surrounding resources, forethought into the planning and implementation of sand and gravel operations is imperative.

In many situations, proper rehabilitation can actually enhance and improve upon the quality of existing wildlife habitat and recreational resources.

The sand and gravel industry has the opportunity to play an important role in the future development of functional land uses and a quality environment.

LITERATURE CITED

IOWA STATE WATER RESOURCES RESEARCH INSTITUTE. 1973. Outdoor Recreation and Open Space. Ames Reservoir Environmental Study. Appendix 3. Iowa State University, Ames, Iowa.

BAUER, ANTHONY M. 1965. Simultaneous Excavation and Rehabilitation of Sand and Gravel Sites. Department of Urban Planning and Landscape Architecture, University of Illinois, Urbana, Illinois, National Sand and Gravel Association, Silver Spring, Maryland.

JOHNSON, CRAIG. 1966. Practical Operating Procedures for Progressive Rehabilitation of Sand and Gravel sites. Department of Landscape Architecture, University of Illinois, Urbana, Illinois, and National Sand and Gravel Association, Silver Spring, Maryland.

LANDERMAN, NORMAN J., AND S. SCHUARTZ. 1972. Community Resource the Development-Rehabilitation of Sand and Gravel Lands. Deptment of Landscape Architecture, School of Environmental Design, California State Polytechnic University, Pomona, California.

Citizen Involvement in Gravel Pit Reclamation: A Case Study

HOWARD R. ALDEN,[1] Professor, Recreation Resources Department, College of Forestry and Natural Resources, Colorado State University, Fort Collins, Colorado 80524

INTRODUCTION/BACKGROUND

Fort Collins is not unlike other small but rapidly growing communities that are both in awe of and perplexed by growth. In this "one sentence scenario" we need to add a delightful river replete with historic significance but modified with some traditional development up to its banks, abuse in terms of pollution, and extensive water diversion. When we combine these factors with limited public access, gravel mining to accommodate growth and citizens seeking leisure time opportunities in or adjacent to areas previously mined, we have a public constituency that starts to focus in on a very basic problem. Specifically, how do we reclaim these mined areas and make them available to the community?

This focusing takes several forms:

1. What is the cultural and ecological value of a "Cache la Poudre River" to our community?
2. Who is going to take the leadership in value clarification, setting an appropriate agenda to reclaim mined areas adjacent to the river?
3. Who is going to assume the responsibility to carry out the agenda?
4. Who can put their finger on dollar resources to recapture lost values? and
5. Who has knowledge of and the ability to wade through the bureaucratic maze of regulations and incentives to insure action can be successfully completed?

While none of these questions may be new to any of us, we all probably ask ourselves, "how do we get a community to recognize the value of areas mined for gravel, go through the focusing process, and then take appropriate action so citizens can enjoy these areas?" Given the assumption that there are no absolute answers to our questions, I want to share with you the Fort Collins experience.

[1]Past President, Poudre Valley Greenbelt Association and Member of the Board of Directors, Fort Collins Area Chamber of Commerce.

RECENT HISTORY

With the simplified scenario in mind, the citizens of Fort Collins (in 1973) voted for an increase in the City sales tax to fund a capital improvements program (CIP) including open space acquisition and development. A significant portion of this open space acquisition and development was to occur along the Cache la Poudre River (Figure 1). The value of the river to the community and reclamation and development for public use was a major selling point of the CIP program. The vote was a clear statement of both concern and desired action.

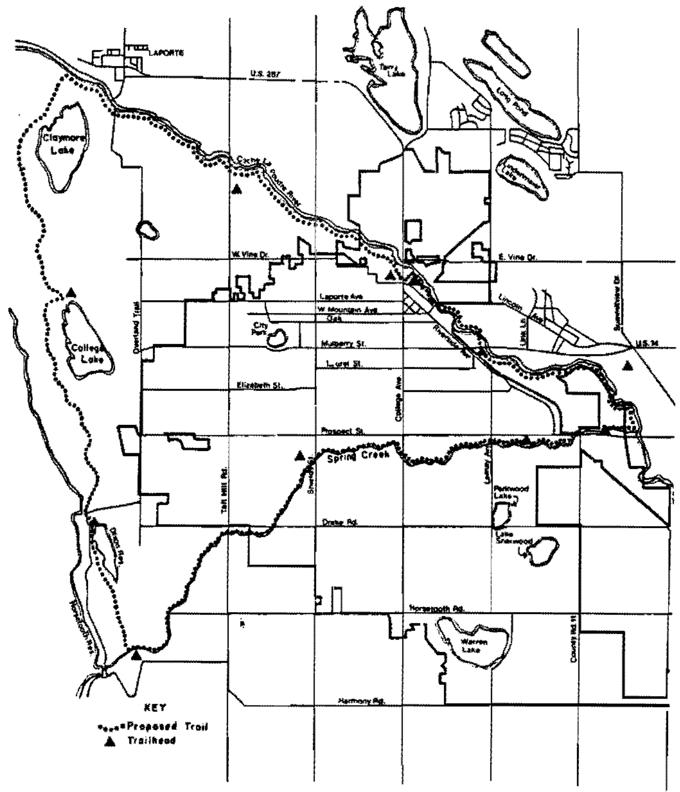


Fig. 1. Proposed Fort Collins trail system.

The citizens turned over the planning and implementation of acquisition and development of open space to the City. The year 1973 went by, then 1974 and then 1975. With rapid growth, changes in land use along the river and inaction by the City, citizens who were responsible for formulating the CIP program and its support became restless. In 1976 the City officials made public their position that CIP funds were inadequate to fund the open space program, particularly since cost of land acquisition and development had significantly escalated. The community, for all practical purposes, was asked to choose between a city hall, a performing arts center and the open space program.

Enter citizens, conservation and performing arts groups, the Chamber of Commerce, and the formulators of the original program. They conducted their own audit of the City's cash flow situation and made a compelling case to Council to get on with the entire CIP program. This was in the fall of 1976. As an outgrowth of the controversy, these participants rightly concluded that citizen involvement cannot end with the exercising of voting rights.

Getting back to open space acquisition and development, both the legal and financial framework were back in place. It didn't take a great deal of wisdom, however, to know that there was a loss of purchasing power due to the incredible time lag in program implementation. With this added dilemma, the setting was ripe for further citizen involvement to implement the program.

An interesting informal coalition was formed. It was made up of the Poudre Valley Greenbelt Association, the Fort Collins Chapter of the Audubon Society and the Fort Collins Area Chamber of Commerce. This coalition not only agreed to hold the City's "feet to the fire" to implement the open space portion of the CIP program but also established its own strategy to deal with both the problem and basic questions previously posed.

THE AGENDA AND IMPLEMENTATION STRATEGY

The coalition no longer considered it valid to debate the relative merits of implementing an open space program for public access to and use of the river corridor. Gravel pits were and are a significant portion of this corridor. From your interest and ours, they chose the following agenda and implied implementation strategy:

1. Keep the pressure on the City to be accountable to the community for completing the priority elements of the CIP program.
2. Work with the City to insure completion of these elements as soon as possible (within existing financial constraints but not sacrificing the quality of the projects or long-term value to the community).
3. Identify and work with private landowners to seek alternative ways to finance land acquisition and development.
4. Utilize an existing non-governmental entity in the community to facilitate land acquisition.
5. Bank land for the community in the event government grant-in-aid programs are available for land development or further acquisition.
6. Utilize a 501 (c)(3) organization as a recipient of land donations from private landowners and gravel companies in conjunction with tax incentives associated with such donations.
7. Participate in the private land reclamation planning and subsequent governmental reclamation requirements to insure wildlife and recreational values are a part of reclamation prior to land acquisition negotiations.
8. Agree to be responsible for insuring that items are carried out and then monitor implementation for reclaiming gravel pits as well as other aspects of the open space program.

While this coalition represented a mechanism to achieve this agenda, its accomplishment still rested squarely on the shoulders of some key people.

Leadership

Several individuals within the three groups met and agreed to what many citizens have said for years, "the Poudre River has values that are essential to the character of our community." These individuals then agreed to give "up front" and "behind-the-scenes" leadership to provide leverage for completion of the open space program. The Poudre River Area was given first priority.

Land Negotiations

Representatives of the Poudre Valley Greenbelt Association approached Flatiron Gravel Companies to determine their long-range plans regarding significant areas of mined land adjacent to the river. The intentions behind this particular approach were: (1) that there had to be a successful example of alternative ways to acquire open space lands along the river; (2) that a company such as Flatiron had the community at heart and was willing to explore ways of getting land back to public use; (3) that there were tax incentives available to private individuals and companies who exercised alternative land sale methods; (4) taxpayers and City officials could be shown that some of these methods would significantly reduce capital expenditures by the City and probably preclude the necessity of raising taxes; and (5) given the availability of governmental grant-in-aid programs, donated land could be "banked" and then used as the community's matching resources to qualify for these grants.

It should be fairly obvious that the coalition representatives must have a degree of respect from both private land owners and city officials. These citizens should be very knowledgeable about the concept and application of alternative methods to acquire land. They also need to have enough common sense to know when to involve lawyers and accountants at the point actual negotiations are going to be initiated. It should be noted that the coalition exhibited considerable awareness in selecting individuals who would make preliminary contacts and then work with the private companies and City officials.

Land negotiations took several months. They were initiated through personal contacts with top level management of the companies. Once all parties agreed to explore alternative methods for land acquisition, the economic tradeoffs for each alternative were compared. These alternatives with tradeoffs were arrayed for both the private individual and the community.

Some examples of alternatives considered were:

* outright conveyances (donations)
* bargain sales
* conservation easements
* leases

Potential benefits to the landowner and community naturally would vary depending upon the alternative exercised in any given situation. Some of those considered in the negotiations were:

<u>Benefits to the Landowner</u>

* Retains ownership (lease and easements only
* Retains original land use and open space character
* Generates income tax deduction for charitable contribution in amount of difference between the fair market value of their property and the sale price
* Eliminates property tax

<u>Benefits to the Community</u>

* Retains open space character and values
* Provides for public access where appropriate
* Reduces the cost of land acquisition
* Provides local matching share for grant from Land and Water Conservation Fund or other sources in the amount of the charitable contribution.

In this particular case, land donation was considered the preferred alternative.

Transfer of Land Ownership

Prior to final transfer of land ownership three items concerning the future management and use of the land were considered necessary. The first was a management plan to be completed by the City in response to the letter of intent from the private company. The second was a lease agreement between the tax-exempt foundation and the City. The third item was to execute the land transfers simultaneously.

<u>The first item</u>, while a rather straightforward requirement, represented a formal public commitment by the City to guarantee reclamation. In addition, City officials had to engage experts in wildlife and fisheries, reclamation and recreation land use. To insure reclamation was responsive to people concerns and needs, a public survey was conducted (Maas, 1975). Table 1 shows the citizen groupings that were interviewed. This was done by stratified sampling. User preferences (needs and concerns) were solicited for the river and adjacent gravel ponds. The results are presented in Tables 2 and 3. It is interesting to note that the wide range of groups interviewed selected activities that were primarily passive and with an environmental value orientation. Least preferred activities were the group activities and hunting. These results represented a key input into the reclamation and management plans by the private companies and the City.

The <u>second item</u> was negotiated between the 501 (c)(3) organization and the City. The private company participated in these negotiations to insure that the intent of the land donation was being carried out. The lease agreement included such items as land use limitations, maintenance, liability insurance and further changes in ownership. The legal property description and land management plan were attached as exhibits to the lease. The lease was as follows:

This lease agreement is made and entered into this 27th day of December, 1977, by and between THE CITY OF FORT COLLINS, Colorado, a municipal corporation, hereinafter referred to as "Lessee" and THE POUDRE VALLEY GREENBELT FOUNDATION, INC., a Colorado corporation, hereinafter referred to as "Lessor";

WITNESSETH:

1. <u>Premises</u>. Lessor hereby leases unto Lessee and Lessee hereby leases from Lessor property situate in the County of Larimer, State of Colorado, the legal description of which is set forth on Exhibit A, attached hereto and by this reference made a part hereof.
2. <u>Term</u>. The term of the within lease shall be <u>five</u> (5) years commencing on the 27th day of December, 1977, and shall thereafter be automatically renewed from year to year subject

Table 1. List of citizen groups surveyed, Fort Collins Open Space Study, 1975.

Groups	General Characteristics
1. Neighbor to Neighbor	Lower Income, Chicano/ Anglo Mix
2. Good Samaritan Retirement Home	Elderly, Retired
3. Statistics class, Colorado State Univ.	Middle to Upper Income, Students
4. Natural Resources Class, Colorado State Univ.	Middle to Upper Income, Students
5. Recreation Center	Lower Income, Chicano/ Anglo Mix
6. Trailer Park	Middle Income, Middle Age and Retired
7. Youth Services Bureau	Lower to Middle Income, Youth
8. League of Women Voters	Middle to Upper Income, Women

Table 2. Public preference for recreation activities in the River Zone, Fort Collins Open Space Study, 1975.

Activity	Percent Response
Most Preferred	
Boat Travel (Canoe)	65.4
Seeing Natural Scenery	65.2
Fishing	60.2
Least Preferred	
Group Nature Study	26.5
Hunting	
Small Game	22.6
Waterfowl	21.2

to the right of either party hereto to terminate this Agreement as hereinafter set forth.

Table 3. Public preference for recreation activities in the Pond Zone, Fort Collins Open Space Study, 1975.

Activity	Percent Response
Most Preferred	
Seeing Natural Scenery	72.2
Casual Hiking	72.0
Fishing	63.6
Bird Watching	57.1
Least Preferred	
Group Nature Study	26.3
Hunting	
Small Game	23.3
Waterfowl	20.5

3. Rent. Lessee agrees to pay Lessor as rental for the above premises the sum of One Dollar ($1.00) per year, in advance, such amount to be payable on or before the 7th day of January each year hereunder.

4. Use. Lessee understands and agrees that the use of the rental property shall be restricted primarily to use by the public for recreational and open space purposes.

5. Maintenance. It shall be the responsibility of the Lessee to provide any maintenance of the rental premises which Lessee may desire in connection with the above-stated use of said rental premises.

6. Insurance. Lessee shall further be responsible for obtaining such liability insurance as it may desire in connection with the use of the rental premises, it being understood and agreed upon by the parties hereto that Lessor shall not be liable for the use made of said rental premises.

7. Acquisition of Property. In the event that Lessee secures Federal matching funds for parkland acquisition and development of said rental premises, Lessor agrees to immediately transfer ownership of said premises to Lessee at no cost to Lessee.

8. Termination of Lease. This lease may be terminated by either party hereto at any time after expiration of the five-year term by giving to the other party not less than sixty (60) days written notice of the decision to so terminate this lease.

9. Notice. Any notice which either party desires to give hereunder shall be deemed delivered if set forth in writing and mailed to the other party at the following address:

LESSOR: Poudre Valley Greenbelt Foundation, Inc.
P. O. Box 26
Fort Collins, Colorado 80521

LESSEE: City of Fort Collins
Attention: City Attorney
P. O. Box 580
Fort Collins, Colorado 80522

10. Assignment and Sublease. Lessee shall not have the right to assign this lease or to sublease any part of the premises except with the written consent of the Lessor.

11. This agreement shall be binding upon and inure to the benefit of the parties hereto, their respective heirs, personal representatives, successors and assigns.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be signed the day and year first hereinabove written.

The third item, executing the land transfer from the private company to the Poudre Valley Greenbelt Foundation and then the leasing of the land to the City was a simple matter of timing.

Similar to the land negotiations, members of the informal coalition met with key participants from the private company and the City to insure that the transfer of land ownership took place. Further, these same individuals participated in the generating of citizen inputs and then the preparation of the management plan.

The Reclamation and Management Plan

At this point of the Fort Collins experience, it is important to emphasize that the City more openly recognized the merits of the role of the informal coalition. As a result of the City's new "position," both the private company and the City provided financial resources to conduct baseline resource inventories, and reclamation and management planning. These were carried out within the context of existing state mined land reclamation regulations. In addition, they took into consideration the results of citizen surveys regarding preferred and compatible recreation and land use activities.

As the Fort Collins experience progressed, the commitment by all parties was strengthened. There was open communication and mutual acceptance among the various participants. The culmination of this "openness" takes us to another essential element of our experience--participant recognition.

Participant Recognition

Several individuals within the coalition felt it was absolutely necessary to have participant recognition. Without recognition, it was felt that the community would once again become complacent, the private sector would become less likely to participate in the future and that City officials would not have a sufficient "imprinting" of the significance of the process and its results.

With the City firmly "on board," the following news release amply illustrates the outcome of the experience and the fact that a lot of folks wanted to join in the recognition party.

January 14, 1977

CITY NEWS RELEASE

"The Flatiron Companies, City and two community foundations show the way in the cooperative community program.

After considerable cooperative effort, the Flatiron Companies have donated 65 acres of reclaimed gravel land to the Fort Collins Community Foundation. The Foundation in turn has leased the land to the City for its open space program. The Poudre Valley Greenbelt Association, City of Fort Collins and Flatiron Companies have worked on planning for surface restoration to insure the donated land would be compatible with the open space needs of Fort Collins citizens.

The Fort Collins Community Foundation has played a key role in the receiving and holding of land for the City. The unique aspect of their role is that by holding the land for the City, the City at a later date can use the value of this donated land for federal matching monies/funds for additional open space acquisition and development. This represents a new approach in increasing the capabilities of limited community funds. This approach also provides private individuals and companies with a tax break incentive as well as the opportunity to contribute to a better Fort Collins.

The initial land gift, located along the Poudre River, includes both pond and marsh area making it valuable for wildlife habitat. The area also fits into the City's existing Poudre River Trail system. The City and Flatiron are still engaged in land grooming, planting and removal of safety hazards. Since this work will not be completed until late spring-early summer, it will not be open for use until the latter part of the summer.

In recognition of their cooperative efforts and contribution to the City's open space program, Flatiron is receiving the Keep Colorado Beautiful Environmental Achievement Award and the Bureau of Outdoor Recreation Achievement Award."

Figure 2 shows a very pleased vice-president of the private company receiving the achievement award signed by the President of the United States and the Secretary of the Interior.

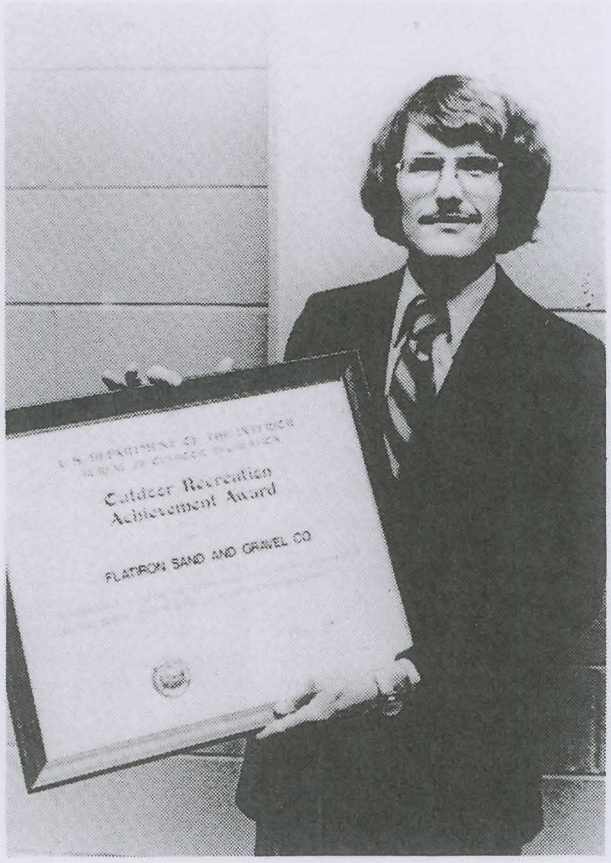


Fig. 2. Outdoor Recreation achievement award presented to the company that donated land for public use.

SUMMARY COMMENTS

Every time I recount the Fort Collins Experience I get a warm inner glow. Regrettably, I have to come back to reality because once this type of a task is begun it is never ended. On the surface, it appears that a problem was clearly identified and rational publics formed a coalition to scope in on an agenda and implementation strategy to conserve resources (wise use) for a community. The community (through the coalition), the City and the private landowner sought some common objectives and collectively worked to achieve these objectives. They achieved some of what they set out to do.

Individuals within the informal coalition, however, have differing views on the degree of accomplishment of objectives. These views are well founded for some of the following reasons:

* The community continues to grow at a substantial rate (one of the ten fastest in the country).
* Due to rapid growth it is difficult to have a sense of community cohesiveness.
* New citizens coming from communities with a less desirable environmental setting, have the general attitude that Fort Collins doesn't have any real community conservation issues.
* The "players" or participants from the City, private landowners and the coalition tend to change more frequently now than in past years.
* The new players often have a new agenda with different or revised priorities.

The challenge then becomes one of maintaining a high or reasonable level of community interest in our initial objective of reclaiming gravel ponds for their environmental and recreational values. The informal coalition must consciously seek long-term stability, educate the new players and continue to work with all parties to insure that objectives are pursued to a successful end.

By way of conclusions, the initial problem of "how to get a community to recognize the value of areas mined for gravel, go through the focusing process, and then take appropriate action so citizens can enjoy these area?" remains. Members of the coalition are currently wrestling with the problem of maintaining community awareness, program implementation strategies and orienting future leaders to insure that the open space program can be achieved along with associated mined land reclamation.

The informal coalition is still working with key City officials and private land owners. In spite of the complexity of modern day conservation problems motivated people in Fort Collins as in other communities are achieving success.

REFERENCES

Land Conservation Techniques

Colorado Open Land Foundation. 1979. How to donate land in Colorado. Denver, Colorado. 13pp.

Tiedt, Glenn F. 1976. Conservation easements in Colorado. The Colorado Lawyer 5:1265-1272.

U.S. Department of the Interior. 1979. Land conservation and preservation techniques. Heritage Conservation and Recreation Service, Washington, D.C. 75pp.

Establishing Foundations

U.S. Department of the Interior. 1979. Foundations, a handbook. The "whys," "wherefores," and "how-tos" of 501(c)(3) organizations. Heritage Conservation and Recreation Service, Washington, D.C. 38pp.

Management Planning, Cache La Poudre River, Fort Collins, Colorado

Flatiron Companies. 1976. Correspondence outlining Flatiron Company's commitment to rehabilitation. 2pp.

Fort Collins, City of. 1976. Development and management cost estimates, Flatiron gravel pits. 3pp.

Fort Collins, City of. 1977. Management plan objectives for Flatiron gravel pits. 2pp.

Kemmerer, J. D. 1976. Recreation potentials of gravel mine rehabilitation. M.S. Professional Paper. Colorado State University, Fort Collins. 127pp.

Koirtoyohann, J. C. 1975. Cache La Poudre trail interpretive plan. M.S. Professional Paper. Colorado State University, Fort Collins. 121pp.

Maas, J. W. 1975. Scenic and recreation preferences, the southeast greenbelt/open space study. M.S. Professional Paper. Colorado State University, Fort Collins. 70pp.

A Study for Vegetation and Wildlife Habitat on Lower Grey Cloud Island

WILLIAM D. SANDERS, JON BRYAN BURLEY
CRAIG ALLAN CHURCHWARD: Sanders and
Associates, Inc., 307 McColl Building
Saint Paul, Minnesota 55101

INTRODUCTION

The following paper was developed from a case study of mining and reclamation activities on Lower Grey Cloud Island in Washington County, Minnesota. The site is located beside the Mississippi River in the southeast portion of the Twin Cities (Minneapolis/St. Paul) Metropolitan Region and is currently being mined for sand and gravel by the J.L. Shiely Company.

In 1981, the firm of Sanders and Associates, Inc., Landscape Architects, was retained by the J.L. Shiely Company to inventory and evaluate vegetation and wildlife on Lower Grey Cloud Island. The purpose of the study was to assist mining operations and recommend mining procedures which would insure the continued presence of diverse biological communities on the Island. The study had four basic objectives:

1. To supply an inventory of biological communities.
2. To evaluate the impact of natural processes (such as elm disease, oak wilt, and succession) on existing biological communities.
3. To evaluate the impact of proposed mining operations upon plant groupings and wildlife habitat.
4. To establish recommendations for mining procedures which ameliorate impacts of mining operations on biological communities.

The inventory of the Lower Island established the location and structure of 23 existing biological groupings. Sections were drawn through key areas to illustrate relationships between existing biological groupings and the abiotic environment. Also included in the inventory was a narrative description of the characteristics of each grouping, an index of plants, mammals and birds on the Island and an evaluation of the status of species protected by governmental mandate. The most significant results of the inventory were that the most biologically diverse area on the Island was a result of previous mining reclamation activities, that the only atypical life forms found on the site was an area of floating aquatics on Mooer's Lake, and that no species were imperiled with extinction or permanent expatriation by mining operations.

The analysis portion of the study included an examination of regional plant growth potential, an examination of the potential biological life forms of the region, the division of biological groupings into management groups, based on similarities in vegetative strategies and structure, and an examination of the successional direction of each management group. The following is a summary of the analysis of the biological potential of Lower Grey Cloud Island:

Stress and disturbance tolerant plants readily inhabit the Lower Island. Disturbance in the form of fire, grazing, mining, or mowing can conceal the site's inherent ability to support vegetation.

Plants that require mesic conditions initially have great difficulty inhabiting the islands. With the formation of knitted woodlands of approximately two acres or more, mesic conditions may exist. Plants like sugar maple may then inhabit the site.

Plants in the aquatic environment have great difficulty competing with algae. The formation of interior lakes may be ideal for the introduction of plant and animal forms displaced from the river. Animals usually require a habitat which consists of more than one grouping of similar plants.

Comparatively, twenty-five years ago the Island was relatively sterile. In the next twenty-five to one hundred years the biological diversity of the Island could reach an optimum. After the one hundred years, the biological diversity of the Island could decrease. The decrease in diversity would be a consequence of succession. Succession would lead to a monocultured knitted woodland eliminating grasslands, shrublands and open woodlands.

The study of Lower Grey Cloud Island observed that mining may interact with a biological grouping in three basic ways:

Mining operations may avoid removing the biological grouping: The avoidance of a biological grouping requires that mining procedures be used which protect the balance of the life form during and after mining operations. Such partial preservation may be required to protect unique life forms.

Mining operations may partially remove the biological groupings: The partial removal of a biological grouping requires that mining procedures be used which protect the balance of the life form during and after mining operations. Such partial preservation may be required for visual and noise buffers between residents of the Grey Cloud Island and the mines.

Mining operations may totally remove the biological grouping: The total removal of the biological grouping requires the reconstruction of another grouping following the termination of mining. During reclamation, introduced life forms may be developed to enhance biological diversity and post-mining land-use opportunities.

Recommendations for Lower Grey Cloud Island were developed by analyzing the reactions each management group would have to its proposed type of mining interaction. The study describes each management group, the problems associated with mining in each area and makes recommendations for effective mining operations. It also suggests opportunities that may exist for the enhancement of plant and animal life through the mining and reclamation process.

Significant recommendations contained in the study are:

1. Illustrative guidelines for maintaining diversity of woodland edge configurations, the importance of major and minor variations in topography, undulations in shoreline treatment, and the interspersion of plant species and plant groupings to maximize edge conditions.

2. Suggestions for plant materials to be used in the initial reforestation of the Lower Island, including concepts for drought tolerant plantings called "Xeric Clumps" and plantings adaptable to wet conditions called "Wetland Rings".

3. The carefully planned removal of certain wooded areas through selective cutting, which is a method that will allow a portion of a knitted forest condition to be mined without having a detrimental effect on the entire forest area.

The study of Lower Grey Cloud Island did not attempt to quantify populations or quantify habitat suitability although such information may be useful in the future. The intent of the study was to establish a comprehensive inventory of existing conditions, evaluate those conditions, and make recommendations for effective mining procedures. The recommendations will be developed in more detail as the planning and reclamation process continues.

DISCUSSION

To produce the preceeding recommendations and forthcoming design details, contemporary ecological concepts were used, leading to decisions that may conflict with some traditional approaches. One contemporary concept expressed by Gleason (1926) and supported by Curtis (1959), is such a departure from conventional concepts (e.g. Clements, 1916) that practical application to design has been negligible. An attempt has been made, using Lower Grey Cloud Island, to incorporate contemporary ecological concepts into a meaningful product serving wildlife, vegetation, client, landowner, and those individuals interested in planning and design of reclaimed areas.

The first contemporary concept used in the design was developed by Gleason (1926). H.A. Gleason suggests that classical biological communities do not exist. Adopting what Gregory Bateson (1972, 1979) would label anthropocentric interpretation, Gleason observed plant ecologists selectively choosing information to support personal convictions, creating biological communities (Barbour, 1980). Today, the quest to detect the presence of biological community structure is conducted with skepticism and objectivity as exemplified by Thomson (1982); however, the early 20th century misrepresentation of biological assemblage has almost completely infected design professions. Using Gleason as an authority, the assembling of plants and animals into communities is significant only to the specific goals or task to be performed. Thus grouping plants for sand/gravel mining may be different than assembling species for purely classification purposes. Therefore, Sanders and Associates, (1981) assembled biological species into management communities that are intended to relate only to sand/gravel activities on the Lower Grey Cloud Island.

Another authority important to the discussion is the work of J.P. Grime (1979). Grime's work appears less controversial than Gleason's. Grime notes plants have identifiable strategies (behaviors) for survival. These strategies provide the link between biological management communities and reclamation, enabling designers to utilize each community's strengths for creating usable land.

The final concept is not controversial, but requires substantial study to support current theories and produce optimal conditions. This concept is the edge effect (e.g. Thomas, 1979) (figure 1). Burger (1974) states that the edge effect is the key to introducing wildlife. However, Robins (1979), indicates that some bird species prefer large woodland tracts with few edges. Therefore a combination of large tracts (20-30 acres), small tracts (.01-.1 acres), and various intermediate tracts may be necessary to provide for diverse wildlife.

Together, Gleason's community concepts, Grime's vegetation strategies and the edge effect have been integrated to form biological management groups designed to reclaim the land for wildlife. The resultant landscape can be expressed through various landscape elements (figure 2) that form the inventory, and design. The following discussion lists only five landscape elements knowingly used in the design: topography, water, soil, dead vegetation, and live vegetation. Other elements undoubtedly exist. Variation in topography is essential to providing opportunities for vegetation; while major topographical relief (10-200') facilitates gross changes in opportunities (Curtis, 1959).

Deep and shallow water bodies, small pools in tree stumps, low and high water tables, and varying water qualities all contribute to the establishment of forming distinct ecological features in the landscape (Cole, 1979).

Soil structure and texture provide a mosaic of distinct and blended edges that work with topography and water to form a resource for plants and wildlife. Areas of exposed substrate as well as vegetated lands are essential (Pettingill, 1970, Williams, 1976).

Snags, logs, and leaf litter must also be considered as resource elements for living plants, fungi, bacteria and animals. (Berner, 1967, Thomas, 1979).

Living vegetation is a major element associated with wildlife diversity (Thomas, 1979). Interspersed plants maximize the creation of wildlife opportunities.

Essentially these five elements had to be compiled at a detail level necessary to complete the project. Increasingly, highly detailed, quantitative measurements are being used to design for wildlife populations. For example, numerical 'habitat evaluation procedures' (Lines, 1980) and 'Patrec' (Russell, 1980) are being used to determine landscape suitability for wildlife. Even though some scientists prefer to state otherwise, these methods are only educated estimates based upon careful analysis, making habitat evaluation a synthesis of art and science. To increase the scientific merit of habitat evaluation, 'HEP' handbooks are being devised for approximately 400 wildlife species in North America. Each handbook assists the investigator to evaluate the landscape. Until complete, testing and adjustments are made for each species and for eco-regional variations (Bailey, 1976). Quantitative habitat evaluation may not be reliably accurate, especially when attempting to design for several hundred species of which very few species handbooks presently exist.

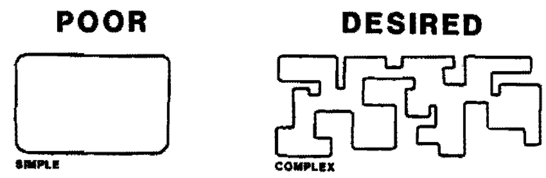


Figure 1. Edge Concept

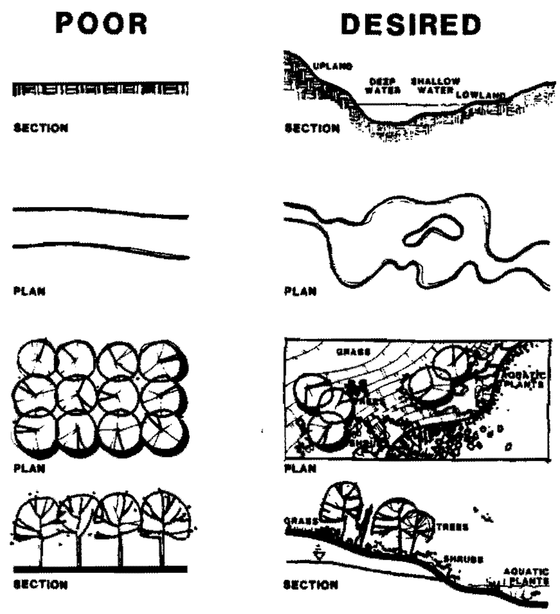
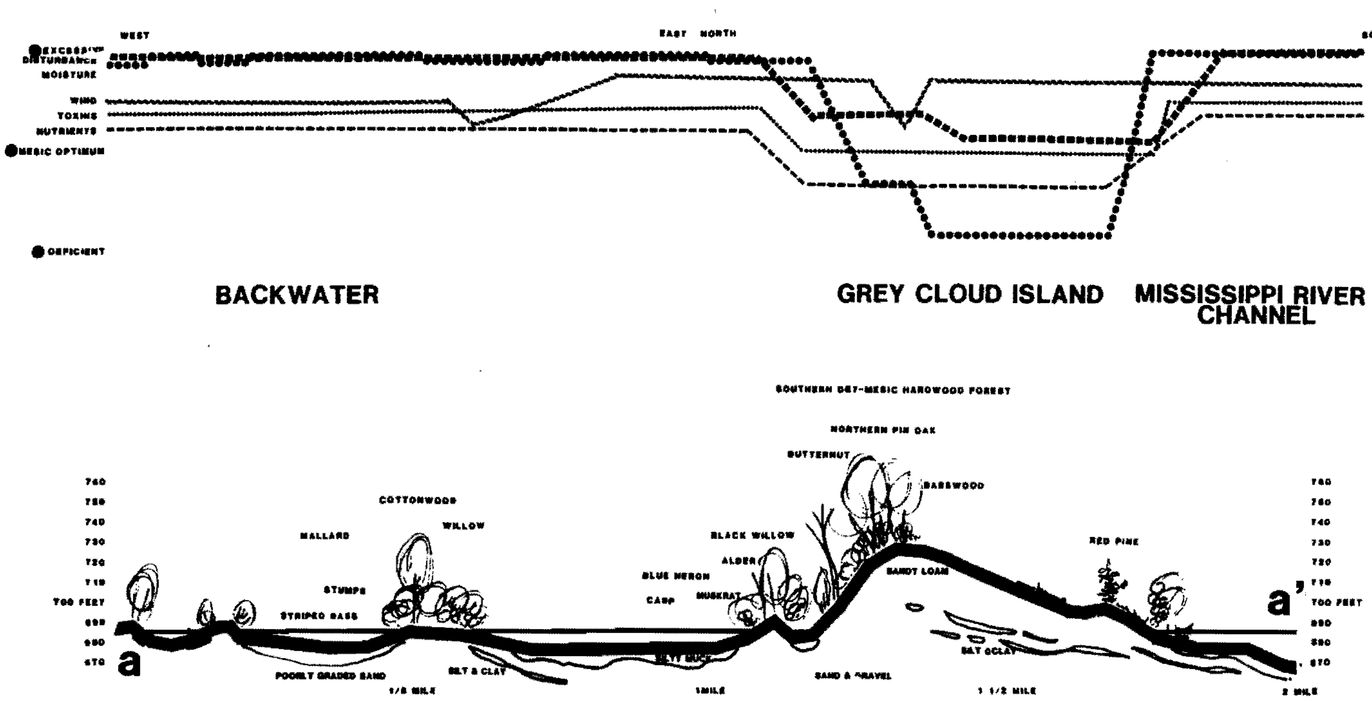


Figure 2. Landscape elements expressing the edge concept.

Therefore, the Lower Grey Cloud Island Biological Survey precluded the present use of quantitative habitat evaluation procedures. (USFWS, 1980, ESM 100, 101, 102, 104, USFWS, 1981, USFWS, 1982). In conjunction with the type of scientific techniques available, the presence of rare, threatened or endangered species affected the level of detail necessary to complete the project. If these species were suspected of inhabiting the site they would be carefully mapped and their population inventoried; however, a literature review revealed that no rare, threatened, or endangered species inhabited the island (Sanders, 1981). Consequently for planning purposes, a list of potential species, and maps (1"=500'), were determined to be adequate detail to produce a document illustrating existing conditions and conceptual proposals (e.g. Marsh, 1978).

Existing conditions on the Grey Cloud Island were evaluated in light of the importance for variation in the five design elements (topography, water, soil, dead vegetation, and live vegetation) (figure 3, 4). Until the advent of mining, the topography of the island essentially consisted of



SECTION

Figure 3. Section of Lower Grey Cloud Island with surrounding land uses. On the Island, notice the relatively uniform topography, hydrology, soils and vegetation.

one big sand dome providing few biological opportunities. Slopes were relatively uniform and gentle. Hydrological variation followed a pattern similar to topography. However, a small lake on the island, fed by river water purified by flowing through sand layers, created a land-locked inland lake (Sunde, 1981) with potential to support aquatic species not found in the river (Leisman, 1959). This was an important hydrological variation useful in the proposed design. The Island's soils have a sandy texture preventing the quick utilization of the landscape by mesic seeking species. Living vegetation is dominated by water tolerant and disturbance tolerant trees around the river bank.

A woodland, predominantly bur oak, (Quercus macrocarpa), and northern pin oak (Quercus ellipsoidalis), reside in the northwest portion of the island and a cropland of corn exists on the island's interior. Dead plant material is confined to dead elms along the riverbank and oaks in the woodland. Excluding mining, the prominent form of disturbance is plowing and cultivation. Due to the low diversity in topography, soil, water, and vegetation, existing assemblages are not optimum, excluding many possible forms of wildlife.

Proposed conditions through the natural processes of sand and gravel mining, can increase wildlife opportunities.

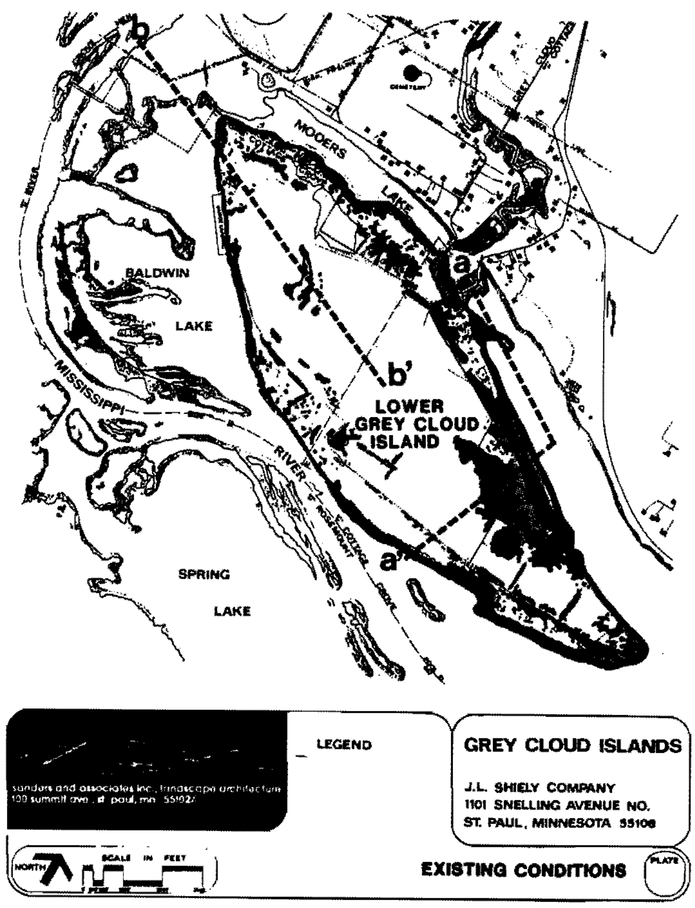


Figure 4: Notice the lack of diversity.

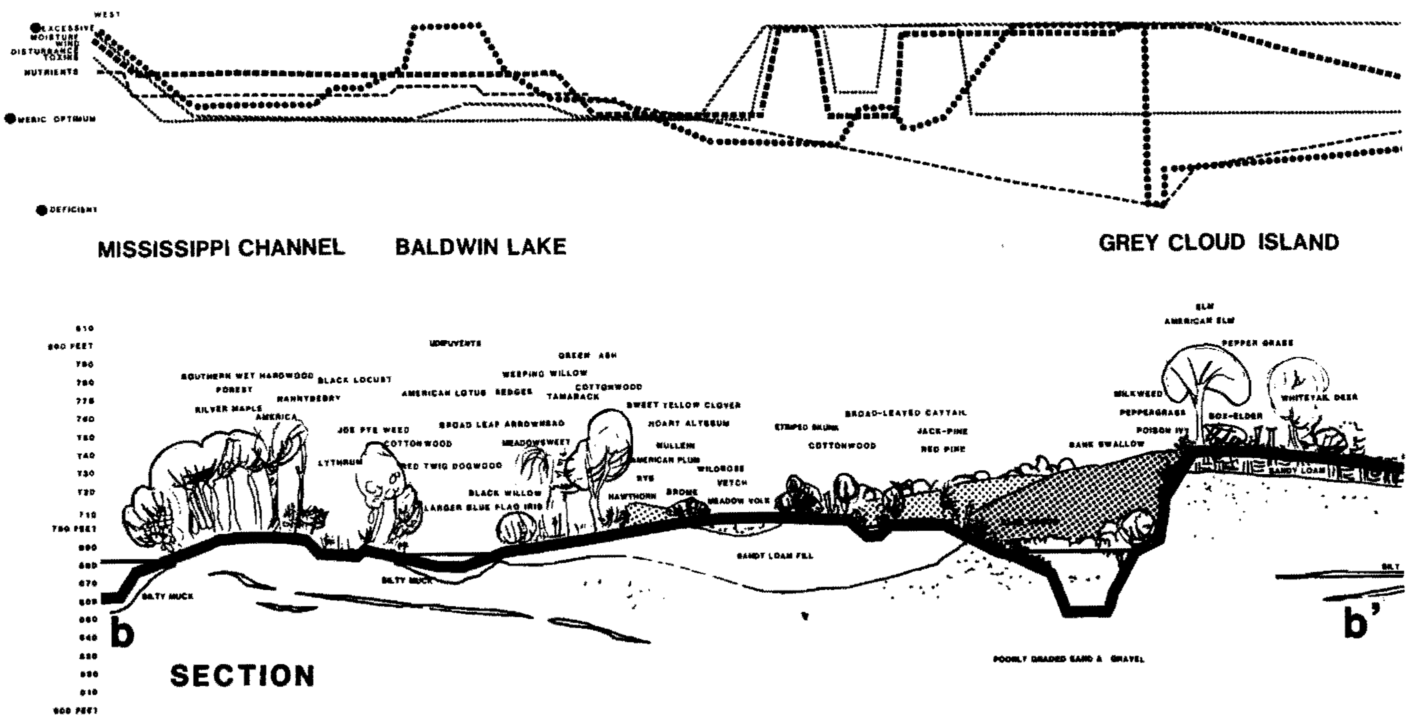


Figure 5. With the introduction of mining to the island the potential for diversification of wildlife opportunities exist.

The minor and major topographical relief created by mining is a positive modification. Reclamation should avoid leveling the terrain. Minor topographical relief (0'-2') will allow subtle changes in vegetation to emerge. Gross changes in vegetation will follow major changes in relief (10'-200'). Slopes and aspect should vary considerably. Depressions should be frequent and of various sizes. Areas of sudden and constant topographic relief need to be offset with areas of little relief (figure 5).

Water will need to occur in small and large pools of deep and shallow water with undulating shorelines and with water quality ranging from diatropic to eutrophic. Facilitated by topography, ground water needs to occur in a continuum between low and high water tables.

Topsoil must be stockpiled to recreate soil variety during reclamation. However, not all areas need to be reclaimed with topsoil. Sandy areas with retarded plant growth can be important to wildlife (Pettingill, 1970).

Standing dead trees, logs, floor detritus, driftwood, deadheads, all act as small isolated or grouped edges which increase opportunities for wildlife (Evans, 1979).

Interspersing plant species with variations in structure (height, breadth, texture), in food value, and strategies maximized the use of edges. This can be accomplished without importation of exotic or nursery grown plants but rather, with the redistribution of existing plants (figure 6-7).

Together these modifications instigated the physical process of sand/gravel mining and the reclamation process can create a matrix of almost infinite dimensions, creating opportunities for wildlife.

The use of selective disturbance in the form of mowing, fire, browsing, trampling, cultivating, plowing, wind erosion, water erosion, grazing and burrowing may be required to arrest succession and to create and maintain vegetative and wildlife diversity. The intensity of disturbance should be moderate as noted by Abugov (1982).

In the future, after the mining and reclamation is complete, the site is scheduled for low density housing (one dwelling unit per five acres). Low housing densities may fit into the landscape without intruding upon current populations creating opportunities for the positive interaction of man and wildlife. The housing configurations and wildlife design forms work together in unison.

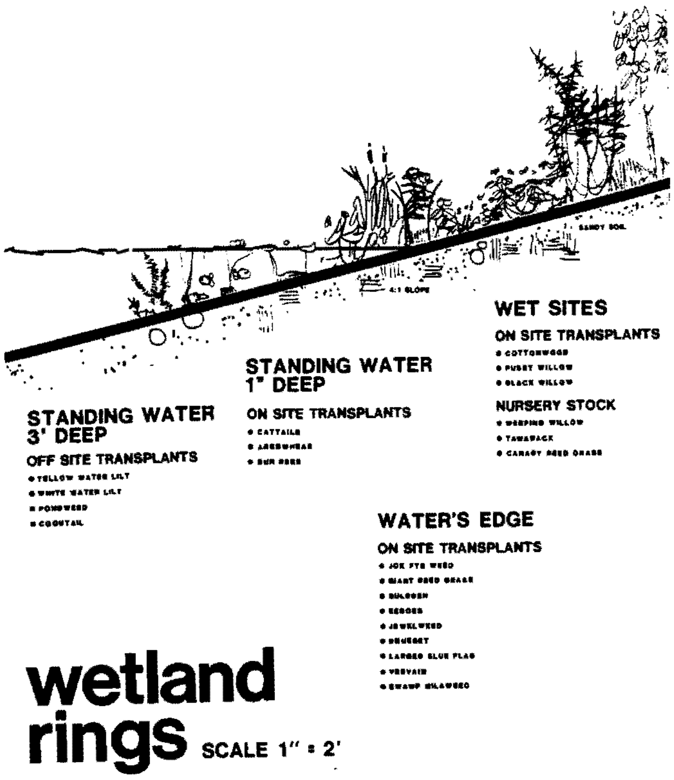


Figure 6: Notice the opportunities for creation and establishment of inland ponds.

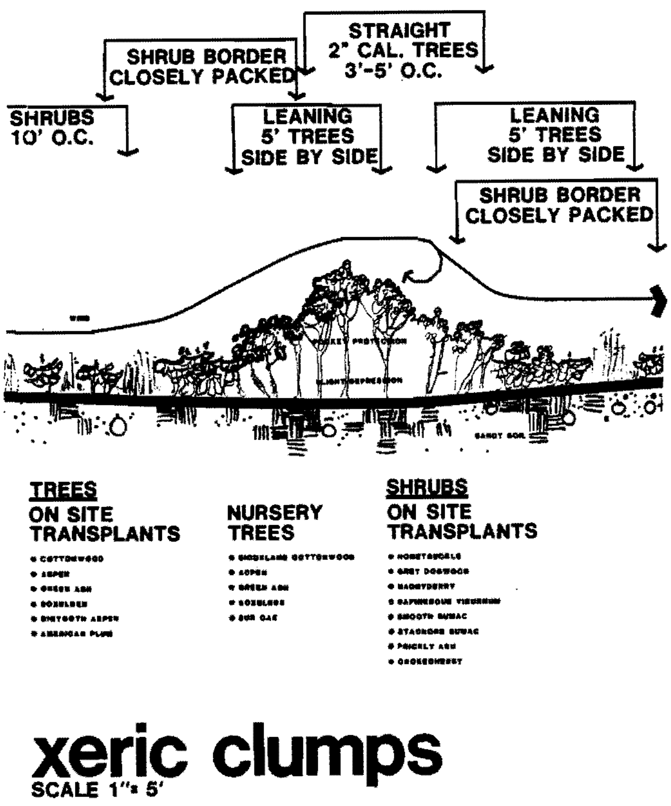


Figure 7: Protective grouping of plants that can invade the surrounding grasslands.

LITERATURE CITED

Abugov, R. 1982. Ecology Species Diversity and Phasing of Disturbance. G3 (2) pp. 239-293.

Bailey, R.G. 1976. Ecoregions of the United States. U.S.D.A. Forest Service, Intermountain Region. Ogden, Utah.

Barbour, M.G., J.H. Burk, W.D. Pitts. 1980. Terrestrial Plant Ecology, The Benjamin/ Cummings Publishing Co., Inc., Menlo Park, California. 604 pp.

Bateson, G. 1972. Steps to an Ecology of Mind. Ballantine Books, New York, New York.

Bateson, G. 1979. Mind and Nature. E.P. Dutton, New York, New York.

Berner, A., L.W. Gyse. 1967. Raccoon Use of Large Tree Cavities and Ground Burrows, J. Wildlife Management 31:706-713.

Burger, G.V. 1973. Practical Wildlife Management, Winchester Press, New York.

Clements, F.E. 1916. Plant succession: An Analysis of the Development of Vegetation. Carnegie Institution of Washington. Publ. 242. Washington, D.C.

Cole, G.A. 1979. Textbook of Limnology. The C. V. Mosby Co. St. Louis, Mo. 426 pp.

Curtis, J.T. 1959. Vegetation of Wisconsin. University of Wisconsin Press, Madison, WI.

Evans, K.E., R.N. Corner. 1979. Snag Management. Management of North Central and Northeastern Forests for non-game birds. North Central Experiment Station, U.S.D.A. Forest Service. NC-51.

Gleason, H.A. 1926. The Individualistic Concept of the Plant Assoc. Bull. Torrey Bot. Club 53:1-20 (and Am. Midl. Nat. 21:92-110).

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley and Sons, N.Y.

Lines, I.L., Jr., C.J. Perry, 1978. A Numerical Wildlife Habitat Evaluation Procedure. Forty third North American Wildlife Conference 43:284-301.

Marsh, W.M. 1978. Environmental Analysis for Land Use and Site Planning, McGraw-Hill, Inc. N.Y., N.Y. 292 pp.

Pettingill, D.S. 1970. Ornithology in Laboratory and Field, Burgess Publishing, Co., Minneapolis, MN. 4th Ed. 524 pp.

Robins, C.S. 1979. Effects of Forest Fragmentation on bird populations in Proceedings of the Workshop Management of Northcentral and Northeastern Forests for Non-game birds. R.M. DeGraf and K.E. Evans, ed., North Central Forest Experiment Station, USDAFS, Gen. Tech. Rep. NC-51.

Russell, K.R., G.L. Williams, B.A. Hughes, D.S. Walsworth. 1980. Patrec & Manalt Systems demonstrated on oil shale development. Co. Coop. Wildlife Research Unit, Colorado State University. Ft. Collins, Co. 265 pp. Unpublished report.

Sanders, W. 1981. Biological Survey of the Lower Grey Cloud Island. J.L. Shiely Co. unpublished report.

Thomas, F. (Editor) 1979. Wildlife Habitats in Managed Forests. The Blue Mountains of Oregon and Washington, Ag. Handbook. 553 pp.

Thomson, J.D., K.A. Rusterholz. 1982. Overlap Summary Indices and the Detection of Community Structure, Ecology 63(2):274-277.

USFWS. 1980. Implementation of Habitat Evaluation Procedures. Division of Ecological Services, Washington, D.C. ESM 100.

USFWS. 1980. Habitat As a Basis for Environmental Assessment. Division of Ecological Services, Washington, D.C. ESM 101.

USFWS. 1980. Habitat Evaluation Procedures. Division of Ecological Services, Washigton, D.C. ESM 102.

USFWS. 1980. Human Use and Economic Evaluation, Division of Ecological Services, Washington, D.C. ESM 104.

USFWS. 1981. Standards for the Development of Habitat Suitability Index Models 103 ESM.

USFWS. 1982. Habitat Suitability Index Models Studies, Biological Services Publication, Washington, D.C.

Williams, C. S. 1976. Honker.Van Nostrand, Princeton, N.J. 179 pp.

Sand and Gravel Pit Reclamation in Louisiana: Creation of Wetlands Habitats and its Integration into Adjacent Undisturbed Bayou

WILLIAM ETTINGER AND CHARLES YUILL. Skelly and Loy Consultants. 2601 North Front Street, Harrisburg, PA. 17110.

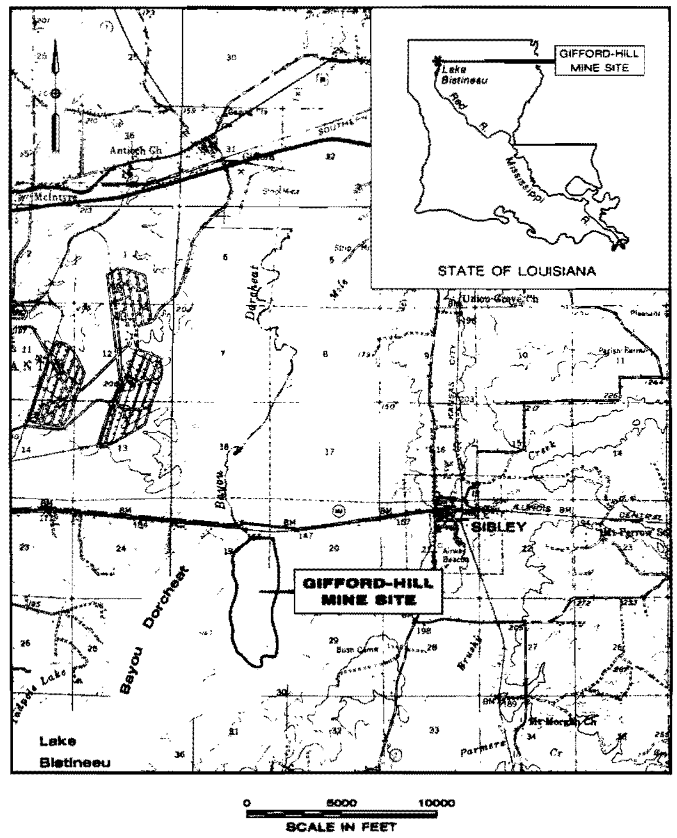
Reclamation of surface mined land to restore pre-existing wildlife habitat/land use conditions frequently is impractical, if not impossible. This is especially true in sand and gravel mining in areas of low relief adjacent to watercourses. Removal of a significant volume of material often lowers the reclaimed land surface to elevations below that of the water table. Reclamation efforts are often only able to reconstruct some dry land with a large percentage of the mined-out areas becoming newly created wetlands.

Recently, such a situation was encountered when Skelly and Loy was retained to prepare a plan for reclamation of a sand and gravel mine site located in north western Louisiana. With the mine site located adjacent to a bayou and reservoir, we designed a plan for site reclamation which included creation of diverse aquatic and terrestrial habitats integrated into adjacent undisturbed bayou. This paper describes the plan.

SITE DESCRIPTION

Gifford-Hill's Sibley Mine site is located in Webster Parish, approximately 6 miles southwest of the town of Minden and 2 miles west of Sibley, Louisiana (Fig. 1). It is immediately adjacent to the confluence of Bayou Dorcheat, a bottomland/wetland area, and Lake Bistineau, a large reservoir. The site contains in excess of 340 acres of what had been bottomland forest interspersed with some wetlands.

The site has been mined over a number of years. On an average, 12 to 20 feet of overburden are removed to expose a sand and gravel deposit of variable thickness (often removed to depths of 30 feet). Because of the mine's proximity to Bayou Dorcheat and Lake Bistineau and the site's low relief, effective water control is a critical part of successful mining. Water is controlled by constructing levees around the perimeter of the active area and then nearly continuously pumping water from within it. Actual mining consists of moving overburden and removing the sand and gravel with a small dragline, resulting in a post-mining landscape of alternate and parallel spoil piles and excavated troughs.



GIFFORD-HILL MINE SITE
PROJECT LOCATION MAP
FIGURE 1

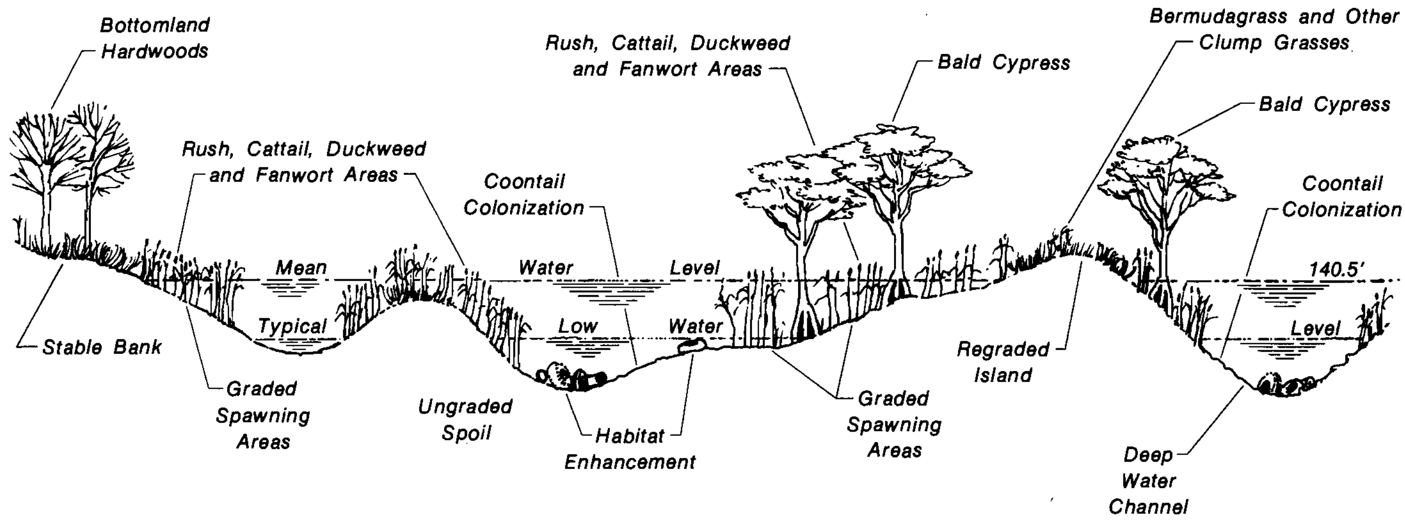
RECLAMATION PLAN

The reduction of land elevation through gravel removal by mining, in conjunction with the site's proximity to Bayou Dorcheat, allows opportunity for development of greater wetland areas than existed prior to mining and integration of these wetland areas into the Bayou Dorcheat -Lake Bistineau ecosystem. Therefore, the reclamation plan designed for this site focused on identifying the activities recommended for development of wetland environments, with an emphasis on suit-

[1]This project was completed for Gifford-Hill & Co., Inc. Mallory May-Vice-President for Environmental Affairs, 3435 Stemmans Freeway, Dallas, TX. 75247.

able warm water fisheries habitat. A typical site cross section illustrating the habitats provided by the reclamation plan is shown in Figure 2.

make their way into site waters. Forage fish, including minnows and mosquitofish, should also enter from Lake Bistineau and provide a food supply for larger fish.



TYPICAL SITE SECTION
FIGURE 2

Regrading spoil piles to provide gently sloping shallow water areas (0 to 6 feet) would provide fish spawning and nursery habitat. Deeper water (6 to approximately 20 feet) would be utilized by larger fish. Furthermore, deeper water channels would be important as havens during low water periods when site waters do not circulate with Bayou Dorcheat.

In addition to colonizing aquatic vegetation, cover for fish would be provided through placement of stumps, roots, logs, and other waste timber from land clearing into the shallow and deeper water areas. In addition, man-made materials such as broken links of 6-12 inch diameter clay or concrete pipe and "artificial reefs" of scrap tires bound together in various configurations would be placed in deeper water to provide fish cover. These artificial reefs would also stimuate biological productivity by serving as surfaces for periphyton attachment and would provide spawning areas for many of the native fish species.

No fish would be stocked. Sport fish (largemouth bass, crappie, and sunfish) should be able to move into site waters during periods of water exchange with Bayou Dorcheat. In addition, other fish such as bullheads, drum, gar, buffalo, and carp that are found in Lake Bistineau would also

The development of this wetland environment would not only benefit fish, but amphibians, reptiles, birds, and mammals as well. Frogs, turtles, and alligators would inhabit near shore areas. Wading and water birds, including anhingas, egrets, herons, and wood storks would also be found there. Migratory waterfowl would use the area for resting stops. Mallards, hooded mergansers, and wood ducks would attempt to nest in the area. To facilitate successful nesting of wood ducks through protection from predation, nesting boxes would be distributed throughout the site.

Islands and other dryland areas, properly revegetated with grasses and small trees to minimize erosion, would provide habitat for small rodents and other mammals. Non-waterfowl birds also would use these dryland areas.

PLAN PREPARATION

The goal of the plan was to convert the barren unreclaimed mining landscape into a diverse assemblage of bottomland forest and shallow and deeper water habitat integrated into the Bayou Dorcheat - Lake Bistineau ecosystem. Important elements in preparation of the plan were: anticipated site water level considerations, regrading and reshaping spoil, and revegetation. Although each is discussed individually, it is important to note that all were planned to interrelate and in combination define the wildlife habitats created.

WATER LEVEL CONSIDERATIONS

The initial step in developing the engineering plan was determining the anticipated water levels on the site. A site mean water elevation was determined after a survey was completed to locate USGS gaging stations in proximity to the mined site. This survey identified two stations in close proximity. Data were collected for the period of 1976 to 1981 and analyzed. This analysis revealed there had been significant water level fluctuations due to seasonal precipitation extremes and planned periodic drawdowns of Lake Bistineau which serves as a flood control reservoir. The project team felt that it was critical to pay close attention to the anticipated water level extremes because with improper regrading a significant water level drop would result in fish being trapped in small isolated ponds. Such ponded water would soon become unsuitable habitat for fish populations. Water level drops and isolated ponding of fish have historically been problems in many projects adjacent to mined areas.

The levees that are used for water control during mining had previously been breached at several locations to permit flooding throughout the entire site except for the active and unmined areas. Elevations at these breaks range from 134 to 137 feet MSL which are 4 to 7 feet below the mean elevation of the lake/bayou wetland system. During the five year analysis period the water level dropped below 134 feet MSL only during major lake drawdowns. Additional drops of this magnitude would greatly impact the habitat viability and appearance of the reclaimed site. Therefore, an integral part of the proposed engineering plan involved raising the elevation of the levee breaks to 138 feet. Water level drops would still occur with the breaks set at this elevation because of seepage and evaporation. However this raised water level elevation would prevent serious water losses and isolated ponding on the site during dry periods or drawdowns of Lake Bistineau.

REGRADING AND RESHAPING

Original pre-mining ground elevations in the project area ranged from 138 feet to 142 feet above sea level. Uniform or gentle slope regrading would have resulted in nearly the entire site being below the water level after the levees were breached. To avoid such uniformity, the project team formulated an engineering regrading plan that provides a mix of dry, periodically flooded and deep water areas. It was felt that such diversity would be more characteristic of a fisheries habitat that would be functionally and aesthetically compatible with adjacent unmined and reclaimed areas. With this plan the site would be regraded selectively, allowing certain spoil piles and mined-out troughs to remain as dryland and deep water channels, respectively. Other spoil piles would be regraded to an elevation within a few feet below the anticipated mean water level. These areas would be shallow water littoral zones. All shallow water zones would be connected to deep water channels to insure that no fish were trapped in isolated ponds during periods of receding water level. These concepts applied to the entire site are shown in Figure 3.

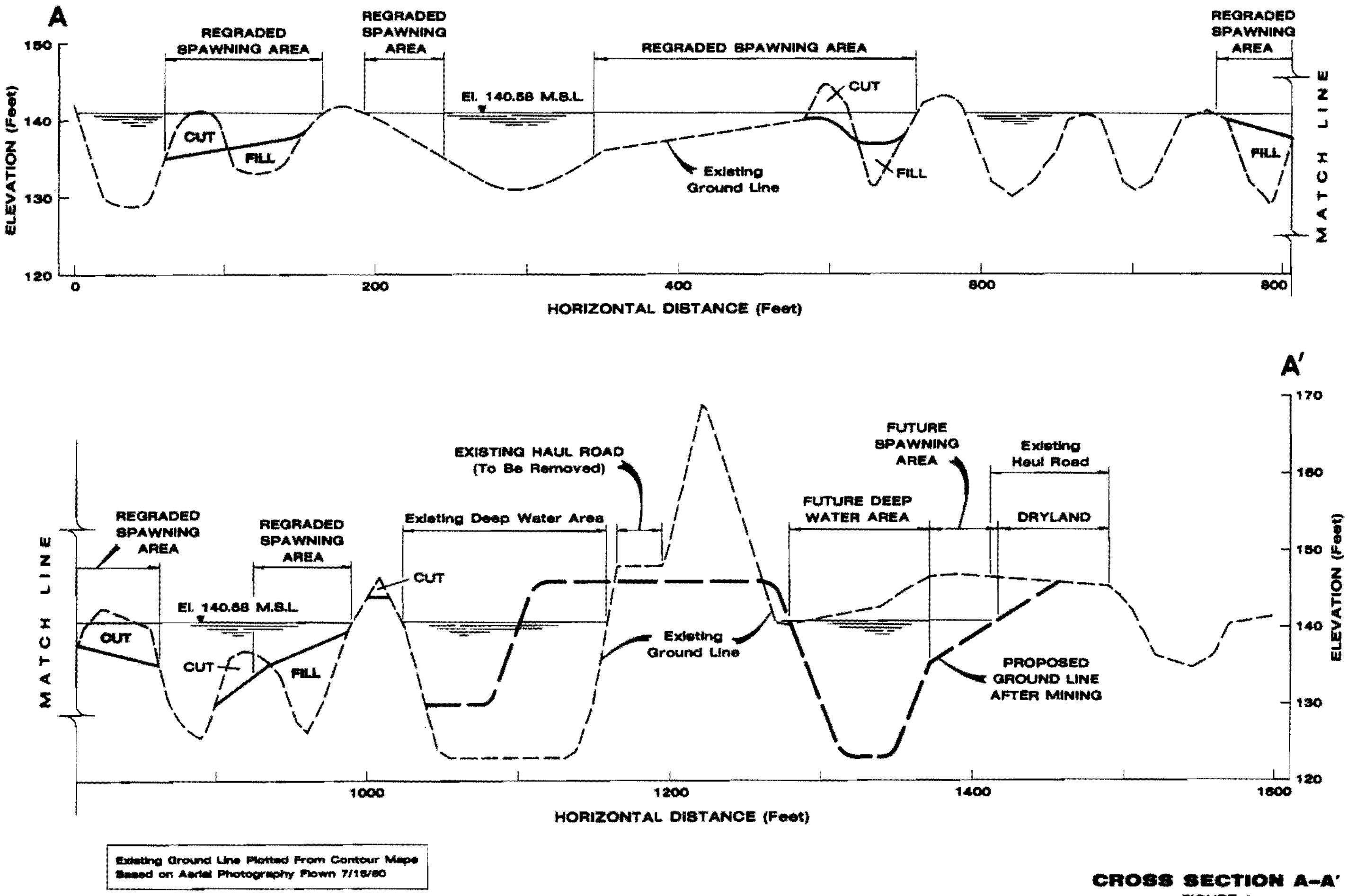
An approximately 25 acre area of the site (Shown on Figure 3) was selected for illustration of the regrading concepts contained in the reclamation plan. A cross section through this area is shown in Figure 4. At the time of preparation of the reclamation plan, the area corresponding to horizontal distance 1000-1600 feet was unmined. Therefore, this cross section indicates how the reclamation plan would be applied to both previously mined and as yet unmined land. In the previously mined areas, 5 spoil piles would be regraded with the removed spoil used as fill material in 4 nearby troughs. The result would be creation of additional shallow water areas. In the unmined areas, 2 dryland areas and 2 deep water channels would remain after post-mining regrading. The spoil material generally is a mixture of sand, silt, and clay. Because of its fine particle nature, the material is subject to sloughing where it touches water. Therefore, all slopes in regraded areas that are destined to be shallow water zones would be limited to 8% or less. Unregraded spoil piles would be expected to slough until stable positions are reached. An extensive grass planting program should assist in maintenance of slope stability.

REVEGETATION

Revegetation efforts were directed primarily toward areas ordinarily above the water surface. No seeding of aquatic species in shallow and deep water areas would be necessary because it was felt that these environments would be colonized following establishment of water circulation with Bayou Dorcheat.

The revegetation component of the reclamation plan had these objectives:

- To plant a rapidly growing vegetative cover to control erosion and sloughing on barren regraded spoil piles,
- To plant species compatible with adjacent undisturbed areas, and
- To plant a sufficiently diverse assemblage of species to maximize wildlife habitat potential.



CROSS SECTION A-A'
FIGURE 4

Most of the site would be seeded with grasses to stabilize spoil areas, levees, and haul roads. This grass cover also would enhance the appearence of the site eliminating barren surfaces as well as providing vegetative forage and cover for wildlife. Bermudagrass, ryegrass, fescue, and clover would be among the species planted.

A limited program of tree planting was also specified for the most stable areas of the site (i.e., above mean water level). Tree planting was emphasized in areas where the trees would provide visual screens discouraging unauthorized site entry as well as for improving aesthetics. Trees would be planted in naturally appearing groups varying species, density, and spacing. On higher areas (above a typical yearly high water mark), species such as hickory, pecan, shumard oak, and willow oak would be planted. Lower areas (seasonally flooded)would be planted with green ash, overcup oak, water hickory, and water oak. As islands and emerging areas stabilize, bald cypress and other bottomland hardwoods would begin to colonize the site from adjacent undisturbed areas.

Analyses of spoil materials from the site by the Louisiana Cooperative Extension Service indicated that very low amounts of extractable calcium, magnesium, phosphorus, and potassium are present. Furthermore, the range of pH of a number of samples was 5.0 - 7.0. Therefore, the following fertilizer and nutrient-soil amendment recommendations for all areas to be planted with grasses were incorporated into the reclamation plan:

Dolomite - 3 tons/acre
Nitrogen - 120 lbs/acre
Phosphorus - 96 lbs/acre
Potash - 96 lbs/acre

SUMMARY

The previously described plan is currently being implemented on the site. The focus has been on the previously mined areas that had not been completely reclaimed. Mining is continuing along the eastern edge of the site and these areas are also being reclaimed according to the strategy outlined in the plan.

ACKNOWLEDGEMENTS.-Gifford-Hill & Co., Inc. and in particular, Mallory May, Vice-President for Environmental Affairs, are recognized for permission to publicize reclamation efforts at the Sibley, Louisiana sand and gravel mine. John R. Ross, P.E., Skelly and Loy, prepared illustrative regrading materials. Dr. Kenneth L. Dickson, North Texas State University, visited the mine and discussed his findings with the authors.

Wildlife Use of Mineral Extraction Industry Sites in the Coastal Plains of New Jersey

JOSEPH L. LOMAX. Joseph L. Lomax and Associates, Box 231 RD 3, Cape May Court House, N.J. 08210

The southern portion of the State of New Jersey is comprised of the Coastal Plains Geologic Province. This area is underlain by unconsolidated and semi-consolidated deposits of the Quaternary, Tertiary and Cretaceous ages. These formations together vary in thickness from shallow deposits in the northwest, to 6000 feet in the Cape May region. Deposited under aeolian, fluvial, deltaic, estuarine and marine conditions; these formations are composed of alternating strata and variable mixtures of sand, silt, clay and organic matter (Gill 1962, N.J. Department of Conservation and Economic Development, 1950).

The extensive deposits of sand, gravel, stone, ilmenite, glauconite and clay are readily obtainable through surface mining techniques. The market demand for these materials has been substantial, because New Jersey is the most densely populated State in the Union; the mining region is geographically centered within the eastern megapolis extending from Boston to Washington between Philadelphia and New York, tourism, the second most important industry in the State, has resulted in significant development along the coast. Mineral deposits have been mined for construction materials, glass sand, industrial sands, titanium oxide, fertilizer, water purification - conditioning materials and fill material. The 2100 persons employed by the mining industry in the southern ten counties generated in 1981 approximately $43,000,000 in wages (N.J. Department of Labor, personal commun.), and produced in 1979 more than 7,000,000 tons valued at greater than $33,000,000 (Mining Association of New Jersey, personal commun.). The production and value data are not available for Mercer and Salem Counties.

Data summarizing extent of mined areas as inventoried in the respective County Soil Surveys (U.S. Department of Agriculture) is presented in Table 1. Data indicates that more than one percent of the land area in the southern ten counties is comprised of active or abandoned mineral extraction mining areas. Although the current state of the economy has reduced the production in some mining operations, the mining industry is continually bringing new areas into production. Thus the extraction sites are continually expanding.

Table 1. Distribution of surface mining areas by County in Southern New Jersey.

County	Year	Pit Acreage	Percent of Total
Atlantic	1978	3,700	1.0
Burlington	1971		
sand/gravel		2,400	0.5
clay/marl		500	0.1
Camden	1966		
clay		100	0.1
sand/gravel		1,500	1.0
Cape May	1977	2,400	1.4
Cumberland	1978	5,100	1.6
Gloucester	1962	700	0.3
Ocean	1980	9,150	2.2
Salem	1969		
clay		20	0.1
gravel		490	0.2
sand		300	0.1
Mercer	1982	221	0.1
TOTAL:		26,581	1.12%

Wildlife utilization of mineral extraction sites have been studied over the last 16 years, while serving as an ecologist, environmental consultant and instructor at Stockton State College. Observations and surveys have been conducted in mined areas in Atlantic, Burlington, Cape May, Cumberland, Ocean and Salem Counties; more intense studies conducted in three mining areas of Cape May County. Observation and data from the following publications were employed in the preparation of this summary report:

Selected field studies and environmental impact statements (Joseph L. Lomax & Associates, 1976-1982,) data obtained in the preparation of '<u>The Wildlife of Cape May County, New Jersey</u>' (Lomax, Galli and Galli, 1980) and '<u>A Most Unlikely Subject</u>' (Lomax and Galli, 1977) and Garcia and Lomax (1980), Anderson and Lomax (unpublished) and Demkowitz and Lomax (unpublished).

HABITAT EVALUATION

Within the Coastal Plains Geologic Province a diversity of biotic communities are produced by mining operations. A discussion of the characteristic features of these biotic communities follows.

Aquatic and Wetlands Habitats

Surface mining operations frequently intersect the water table creating permanent and seasonal aquatic and wetlands biotic communities. Depending upon the depth of the mineral resource; the mining technique and the depth of the water table; a variety of habitats are produced.

Lakes may be hydraulically dredged to a depth of 40 feet establishing littoral, limnetic and profundal zones. The littoral zone supports the following emergent vegetation: cattails (Typha spp.), sedges (Cyperus spp. and Scirpus spp.) and rushes (Juncus spp.) in the early successional stages and subsequently by Black Willow (Salix nigra), Red Maple (Acer rubrum), and Black Tupelo (Nyssa sylvatica). Bladderworts (Utricularia spp.) become established within the first 5 years and frequently dominates the limnetic zone.

Ponds having the size of less than 3 acres and a depth of less than 5 feet are created in smaller mining operations and generally contain only the littoral and limnetic zones. Smaller, shallow ponds are frequently intermittent water bodies, filling in the early winter, reaching their maximum depth in March and receding by early July. The intermittent pond supports the herbaceous and woody species previously described in addition to Bayberry (Myrica pensylvanica), Pitch Pine (Pinus rigida) and such grasses as Beardgrasses (Andropogon spp.) and Switchgrass (Panicum virgatum). As eutrophication has occurred in the older, shallow water pits, bogs have developed. The bogs support Sphagnum Moss (Sphagnum spp.), Sundews (Drosera spp.), Leatherleaf (Chamaedaphne calyculata), High Bush Blueberry (Vaccinium corymbosom) and Cranberry (V. macrocarpon).

Mining operations are currently not conducted in stream corridors or in close proximity to tidal creeks; therefore, lotic and brackish biotic communities are rarely created. In a rare example of a borrow pit created for road fill adjacent to the Bass River, the salt marsh species Salt Hay (Spartina patens), Smooth Cordgrass (S. alterniflora) and Wigeon Grass (Ruppia maritina) have become established.

Upland Habitats

Uplands diversity is closely related to duration of time due to abandonment, current level and type of activity on the site, adjacent biotic communities and slope of the excavation walls. Areas limiting the depth of mining operations to above the water table create upland biotic communities. Since all organisms are generally removed during mining, primary succession begins with a bare substrate of sand and gravel. Such pioneer species as Common Haircap Moss (Polytrichum commune) and Cladonia spp. of lichen become established rapidly. If disturbance by vehicular traffic does not prevent succession; Broomsedge, Sweetfern (Comptonia peregrina), Pitch Pine and Shortleaf Pine (P. echinata), Wildcherrys (Prunus spp.), Low Bush Blueberrys (V. angustifolium and V. vacillans), Bayberry and Dwarf Sumac (Rhus copallina) most commonly represent middle stage of succession. As succession continues either a pine-oak or oak-hickory climax community develops, depending upon the location of the pit within the Coastal Plains. None of the abandoned mining sites are currently old enough to have an established climax upland community.

Two types of ecotones commonly occur in the mining sites; the transition between the wetlands/aquatic and the upland communities and between the undisturbed upland community and the mined area. The grade of the slope has a significant effect on the nature of the ecotones. A gradual slope between the aquatic and upland communities may produce a diverse and well developed littoral zone, wetlands community and mesic community (comprised of a mixture of wetlands and upland species) complex. A steep slope in the case of both ecotones creates an abrupt change in the communities and creates a bank habitat for burrowing birds. Since this type of habitat is uncommon in the Coastal Plains Province, it is considered as an especially valuable feature of mine excavation where safety and erosion is not of particular concern.

The ecotone between the upland forest and mine communities produces an area richer in species composition and an area having better developed shrub and understory layer, i.e., gallery effect. Red Cedar (Juniperus virginiana), Sassafras (Sassafras albidum), American Holly (Ilex opaca), Catbriar (Similax rotundifolia), Poison Ivy (R. radicans) and Wild grapes (Vitis spp.) commonly occur in this ecotone. In addition, the direction of ecotone appears to have an effect on the species composition and plant density.

Within the upland communities cleared vegetation in the form of bush or stump piles and illegally dumped trash and debris, although unsightly, create a habitat and provide cover for a diversity of wildlife species. Stock-piled top soil supports a well developed growth of upland species in addition to a tangle of wild rose (Rosa spp.), brambles (Rubus spp.) and honeysuckle (Lonicera spp.). This feature produces an escape tangle, burrowing opportunities and a diversity of food resources.

The wildlife habitat quality in most mining sites is substantially improved over the wildlife habitat of the expansive pine-oak or oak-hickory forest communities. The habitat quality is improved by the increased diversity in structure, biotic community types, food resources, resting and nesting opportunities, breeding sites and the availability of water within a relatively small area.

WILDLIFE UTILIZATION

The abandoned and active mining operations provide improved and diverse habitat types for a noteworthy variety of wildlife species. The use of the subject habitats by wildlife is summarized in Table 2. The special status is characterized by the following designation:

Status

- F - federally designated
- S - state designated
- E - endangered
- T - threatened

Although the list cannot be considered complete (the third species of lizard was added as this manuscript was in preparation), the inventory acknowledges the observed wildlife use of habitats within the mineral extraction sites. Further, the use of the mining areas by 194 species of vertebrate wildlife, representing 69 families, indicates that the wildlife diversity is commensurate to the biotic community diversity.

The wildlife utilization of mineral extraction areas is enhanced by the location of the Coastal Plain Province of New Jersey. Not only do numerous species reach their northern or southern limit of distribution in this area, but the diversity of habitats within the coastal region support a substantially greater diversity of wildlife species than inland. Wildlife, being opportunistic, readily establish in this ever increasing complex of wildlife habitats. Furthermore, the coastal location provides an opportunity for estuarine species, birds in particular, to spend a substantial amount of time feeding or loafing in fresh water environs. Large numbers of Laughing Gulls, and a diversity of other gulls, terns, long legged waders and shorebirds spend significant periods of time in the aquatic habitats during the breeding season and immediately after fledging their young. Most noteable use has been by Ospreys and Black Skimmers, both of which are listed as endangered in New Jersey. Osprey fish the aquatic habitats early in the spring before the estuarine fishes forage on the surface. Frequently they can be observed resting or feeding on a dead tree adjacent to the mined areas. The Black Skimmer utilization of fresh waters has not previously been reported in New Jersey. Whether they are feeding or drinking while skimming has not yet been determined, however, numerous passes over the

Table 2. Wildlife utilization of mineral extraction sites.

Scientific Name	Common Name	Status
CLASS OSTEICHTHYES (bony fishes)		
Family Anguillidae (freshwater eel)		
Anguilla rostrata	American Eel	
Family Umbridae (mudminnows)		
Unbra pygmaea	Eastern mudminnow	
Family Esocidae (pikes)		
Esox niger	Chain Pickerel	
Family Ictaluridae (freshwater catfishes)		
I. nebulosus	Brown Bullhead	
Family Cyprinodotidae (killifishes)		
Fundulus diaphanus	Banded Killifish	
Lucania parva	Rainwater Killifish	
Family Poecilliidae (livebearers)		
Gambusia affinis	Mosquitofish	
Family Centratchidae (sunfishes)		
E. gloriosus	Bluespotted Sunfish	
E. obesus	Banded Sunfish	
L. gibbosus	Pumpkinseed	
L. macrochirus	Bluegill	
M. salmoides	Largemouth Bass	
Family Percidae (perches)		
Perca flavescens	Yellow Perch	
CLASS AMPHIBIA (amphibians)		
Family Pelobatidae (spadefoot toads)		
Scaphiopus holbrooki	Eastern Spadefoot	
Family Bufonidae (toads)		
Bufo woodhousei fowleri	Fowler's Toad	
Family Hylidae (treefrogs)		
Acris c. crepitans	Northern Cricket Frog	
Hyla c. crucifer	Northern Spring Peeper	
H. andersoni	Pine Barrens Treefrog	E-S
H. versicolor	Northern Gray Treefrog	
H. chrysoscelis	Southern Gray Treefrog	E-S
Pseudacris triseriata	New Jersey Chorus Frog	
Family Ranidae (true frogs)		
Rana catesbeiana	Bullfrog	
R. virgatipes	Carpenter Frog	
R. clamitans melanota	Green Frog	
R. utricularia	Southern Leopard Frog	
R. sylvatica	Wood Frog	

Table 2. Continued . .

Scientific Name	Common Name	Status
Family Ambystomidae (mole salamanders)		
Ambystoma opacum	Marbled Salamander	
A. t. tigrinum	Eastern Tiger Salamander	E-S
Family Salamandridae (newts)		
Notophthalmus v. viridescens	Northern Red-Spotted Newt	
Family Plethodontidae (lungless salamanders)		
Plethodon c. cinereus	Red-backed Salamander	
Pseudotriton r. ruber	Northern Red Salamander	
CLASS REPTILIA (reptiles)		
Family Iguanidae (iguanids)		
Sceloporus undulatus hyacinthinus	Northern Fence Lizard	
Family Scincidae (skinks)		
Eumeces fasciatus	Five-lined Skink	
Leiolopisma laterale	Ground Skink	
Family Colubridae (colubrids)		
Nerodia s. sipedon	Northern Water Snake	
S. o.occipitomaculata	Northern Red-bellied Snake	
Thamnophis s. sirtalis	Eastern Garter Snake	
T. s. sauritus	Eastern Ribbon Snake	
Heterodon platyrhinos	Eastern Hognose Snake	
Carphophis a. amoenus	Eastern Worm Snake	
Coluber c. constrictor	Northern Black Racer	
Opheodrys aestivus	Rough Green Snake	
E. o. obsoleta	Black Rat Snake	
Lampropeltis g. getulus	Eastern Kingsnake	
Family Chelydridae (snapping turtles)		
Chelydra s. serpentina	Common Snapping Turtle	
Family Kinosternidae (musk and mud turtles)		
Kinosternon s. subrubrum	Eastern Mud Turtle	
Family Emydidae (box and water turtles)		
Terrapene c. carolina	Eastern Box Turtle	
Malaclemys t. terrapin	Northern Diamond-back Terrapin	
Chrysemys rubriventris	Red-bellied Turtle	
C. p. picta	Eastern Painted Turtle	
CLASS AVES (birds)		
Family Gaviidae (loons)		
	Common Loon	
Family Podicipedidae (grebes)		
	Horned Grebe	
	Pied-billed Grebe	T-S

Table 2. Continued . . .

Scientific Name	Common Name	Status
Family Phalacrocoracidae (cormorants)		
	Double-crested Cormorant	
Family Ardeidae (herons and bitterns)		
	Great Blue Heron	T-S
	Green Heron	
	Little Blue Heron	
	Cattle Egret	
	Great Egret	
	Snowy Egret	
	Louisiana Heron	
Family Threskiornithidae (ibises)		
	Glossy Ibis	
Family Anatidae (waterfowl)		
	Canada Goose	
	Brant	
	Snow Goose	
	Mallard	
	Black Duck	
	Gadwall	
	Pintail	
	Green-winged Teal	
	Blue-winged Teal	
	Northern Shoveler	
	Wood Duck	
	Bufflehead	
	Hooded Merganser	
Family Catharidae (vultures)		
	Turkey Vulture	
Family Accipitridae (kites, hawks, eagles)		
	Sharp-shinned Hawk	
	Cooper's Hawk	E-S
	Red-tailed Hawk	
	Red-shouldered Hawk	T-S
	Broad-winged Hawk	
	Northern Harrier	T-S
Family Panionidae (osprey)		
	Osprey	E-S
Family Falconidae (falcons)		
	American Kestrel	
Family Phasianidae (quail, pheasants)		
	Bobwhite	
Family Rallidae (rails, gallinules, coots)		
	Common Gallinule	
	American Coot	
Family Charadriidae (plovers and turnstones)		
	Semipalmated Plover	
	Killdeer	
Family Scolopacidae (sandpipers)		
	American Woodcock	
	Common Snipe	
	Spotted Sandpiper	
	Solitary Sandpiper	
	Willet	
	Greater Yellowlegs	
	Lesser Yellowlegs	
	Least Sandpiper	
	Dunlin	
	Semipalmated Sandpiper	
Family Laridae (gulls and terns)		
	Great Black-backed Gull	

Table 2. Continued. . .

Scientific Name	Common Name	Status
	Herring Gull	
	Ring-billed Gull	
	Laughing Gull	
	Forster's Tern	
	Common Tern	
Family Rynchopidae (skimmers)		
	Black Skimmer	E-S
Family Columbidae (pigeons and doves)		
	Rock Dove	
	Mourning Dove	
Family Cuculidae (cuckoos)		
	Yellow-billed Cuckoo	
	Black-billed Cuckoo	
Family Strigidae (owls)		
	Screech Owl	
	Great Horned Owl	
Family Caprimulgidae (goatsuckers)		
	Chuck-will's-widow	
	Whip-poor-will	
Family Alcedinidae (kingfishers)		
	Belted Kingfisher	
Family Picidae (woodpeckers)		
	Common Flicker	
	Red-bellied Woodpecker	
	Hairy Woodpecker	
	Downy Woodpecker	
Family Tyrannidae (flycatchers)		
	Eastern Kingbird	
	Great Crested Flycatcher	
	Eastern Phoebe	
Family Alaudidae (larks)		
	Horned Lark	
Family Hirundinidae (swallows)		
	Tree Swallow	
	Bank Swallow	
	Rough-winged Swallow	
	Barn Swallow	
Family Corvidae (jays and crows)		
	Blue Jay	
	Common Crow	
	Fish Crow	
Family Paridae (chickadees and titmice)		
	Carolina Chickadee	
	Tufted Titmouse	
Family Troglodytiadae (wrens)		
	House Wren	
Family Mimidae (mockingbirds and thrashers)		
	Mockingbird	
	Gray Catbird	
	Brown Thrasher	
Family Turdidae (thrushes)		
	American Robin	
Family Sturnidae (starling)		
	Starling	
Family Vireonidae (vireos)		
	White-eyed Vireo	
	Red-eyed Vireo	

Table 2. Continued. . .

Scientific Name	Common Name	Status
Family Parulidae (wood warblers)		
	Black-and-white Warbler	
	Northern Parula	
	Yellow Warbler	
	Yellow-rumped Warbler	
	Pine Warbler	
	Prairie Warbler	
	Palm Warbler	
	Ovenbird	
	Common Yellowthroat	
	American Redstart	
Family Ploceidae (weaver finches)		
	House Sparrow	
Family Icteridae (blackbirds and orioles)		
	Eastern Meadowlark	D-S
	Red-winged Blackbird	
	Commom Grackle	
	Brown-headed Cowbird	
Family Fringillidae (grosbeaks, finches, sparrows)		
	Cardinal	
	Rose-breasted Grosbeak	
	Indigo Bunting	
	House Finch	
	American Goldfinch	
	Rufous-sided Towhee	
	Savannah Sparrow	T-S
	Dark-eyed Junco	
	Tree Sparrow	
	Chipping Sparrow	
	Field Sparrow	
	White-throated Sparrow	
	Song Sparrow	
CLASS MAMMALIA (mammals)		
Family Didelphiidae		
Didelphis marsupialus	Opossum	
Family Soricidae (shrews and moles)		
Blarina brevicauda	Shorttail Shrew	
Family Talpidae (moles)		
Scalopus aquaticus	Eastern Mole	
Family Vespertilionidae (plainnose bats)		
Myotis lucifugus	Little Brown Bat	
Pipistrellus s. subflavus	Eastern Pipistrel	
Eptesicus fuscus	Big Brown Bat	
Lasiurus borealis	Red Bat	
Family Procyonidae (raccoons)		
Procyon lotor	Raccoon	
Family Mustelidae (weasel, otter, skunk)		
Mustela frenata	Longtail Weasel	
Mephitis mephitis	Striped Skunk	
Family Canidae (dogs, foxes)		
Vulpes fulva	Red Fox	
Urocyon cinero-argenteus	Gray Fox	

Table 2. Continued. . .

Scientific Name	Common Name	Status
Family Sciuridae		
Tamias striatus	Eastern Chipmunk	
Sciurus carolinensis	Eastern Gray Squirrel	
Tamiasciurus hudsonicus	Red Squirrel	
Glaucomys volans	Southern Flying Squirrel	
Family Cricetidae (mice, rats, lemmings, voles)		
Peromyscus leucopus	White-footed Mouse	
Microtus pennsylvanicus	Meadow Vole	
Ondatra zibethica	Muskrat	
Family Muridae (old world rats and mice)		
Rattus norvegicus	Norway Rat	
Mus musculus	House Mouse	
Family Zapodidae (jumping mice)		
Zapus hudsonius	Meadow Jumping Mouse	
Family Leporidae (rabbits)		
Sylvilagus floridanus	Eastern Cottontail	
Family Cernidae (deer)		
Odocoileus virginianus	White-tail Deer	

same area and typical head tipping suggests that they may be feeding on juvenile fish.

The coastal location is of primary importance in attracting migrating birds. Very large numbers of birds use the coast or the Delaware Valley during migration. In the southern part of the state, most of the major rivers and streams adjacent to these systems are brackish to saline. Thus the fresh water habitats of the mined areas are very attractive for drinking, eating and/or resting. Large numbers of waterfowl, passerines and raptors are known to concentrate in the Cape May region during fall migration. From August to October, the avian utilization of the mining areas noteably increases.

Inland, in the New Jersey Pinelands, aquatic and wetlands habitats are relatively uncommon compared with the semi-arid pine-oak communities. As such, the wildlife tends to concentrate around those areas. Concommitantly the aquatic habitats of mining areas become focal points for many of the wildlife species in the Pinelands. The small aquatic habitats serve as breeding areas for a diversity of acid water tolerant fish, amphibians and waterbirds and as a feeding and living area for fish, immature amphibians, reptiles, birds and mammals.

DISCUSSION AND CONCLUSION

The New Jersey Department of Environmental Protection has recognized the potential recreational and wildlife values in mining areas by designating wet and dry borrow pits, wet borrow pit margins, ponds and lakes, wetlands, wetlands buffers and critical wildlife (endangered or threatened species) habitats as Special Area in their Coastal Resource and Development Policies. Thus these areas receive protection from inappropriate future development. In addition, the Soil Conservation Districts and the Pinelands Commission regulate development and operation of mineral extraction activities under the Soil Erosion Sediment Control Act and the Pinelands Protection Act, respectively. All agencies currently require reduced slopes, generally 1:3 or 1:5, at the edge of the excavation and stabilization of bare areas. Although reduced slopes increase littoral, wetland and mesic habitats and create safe bank conditions, it eliminates the vertical bank habitats that are very uncommon in Southern New Jersey. It is currently being proposed by the author that some vertical bank be retained where erosion of the bank sediments will not create significant off-site adverse impacts, i.e., siltation of streams.

It is also being proposed that substantial areas be left bare or only receive initial stabilization with grasses where wind and water erosion will not create off-site damage or road hazards. Permitting natural, primary ecological succession to occur provides more diverse wildlife habitats, instead of the planting of 1000 Pitch Pine seedlings per acre, as required by the Pinelands Commission.

Currently in New Jersey the State Soil Conservation Committee, Soil Conservation Districts and the South Jersey Resource Conservation and Development Council are conducting workshops with interested parties in Southern New Jersey to develop a better understanding of the management of this man-made resource, mineral extraction sites. Concurrently the Mining Association of New Jersey is developing and it is anticipated that they will continue to participate in this process.

The mineral extraction activities in the Coastal Plains Geologic Province of New Jersey constitute virtually the only development activity that provides socio-economic benefits while expanding and enhancing habitats for wildlife. Observations and surveys suggest that the diverse habitats created by surface mining are of significant value to more than 190 species of wildlife by providing aquatic, wetlands and early succession habitats in the coastal and Pinelands areas of New Jersey.

LITERATURE CITED

Anderson, Richard W. and Joseph L. Lomax. 1981. "Fish Utilization of South Jersey Coastal Borrow Pits." Umpublished report. Stockton State College, Pomona, New Jersey.

Demkovitz, Don and Joseph L. Lomax. 1980. "Utilization and Distribution of Aquatic Insects in Coastal Borrow Pits." Unpublished report. Stockton State College, Pomona, New Jersey.

Department of Conservation and Economic Development. (N:J.D.E.P.) 1950. Geologic Map of New Jersey. Atlas Sheet #40. Trenton, New Jersey.

Garcia, J. A. and J. L. Lomax. 1980. "Avian Utilization of Coastal Borrow Pit Habitats in Cape May County, New Jersey." New Jersey Academy of Science. New Brunswick, New Jersey.

Gill, Harold E. 1962. "Ground-water Resources of Cape May County, New Jersey." U.S. Geological Survey. Washington, D.C.

Joseph L. Lomax and Associates. 1976-1982. Selected Environmental Impact Statements. Special Reference to Pleasantville Sand and Gravel, Ricci Brothers Sand and Gravel, Penn Glass and Sand Reports. Cape May Court House, New Jersey.

Kummel, Henry B. 1908. Annual Report of the State Geologist. John L. Murphy Publishing Co. Trenton, New Jersey.

Lomax, Joseph L. and Anne Galli. 1977. "A Most Unlikely Subject - Gravel Pits." Cape May Geographic Society. 31st Annual Bulletin. Cape May, New Jersey.

Lomax, Joseph L., J. Galli and A. Galli. 1980. The Wildlife of Cape May County, New Jersey. Stockton State College. Pomona, New Jersey.

Mining Association of New Jersey. June, 1982. Personal Communications.

New Jersey Department of Labor, Division of Planning and Reasearch. June, 1982. Personal Communications.

Soil Conservation Service. The Soil Survey of the Respective Counties. U.S. Department of Agriculture. Washington, D.C. Atlantic County, 1978. Burlington County, 1971. Camden County, 1966. Cape May County, 1977. Cumberland County, 1978. Gloucester County, 1962. Mercer County, 1982. Ocean County, 1980. Salem County, 1969.

Eugene's Urban Wildlife Area: Delta Ponds

THOMAS J. GALLAGHER, PhD. Natural Resource Planner and Landscape Architect. P. O. Box 11084, Eugene, OR 97440.

Eugene (OR) quadrupled in size, from less than 25,000 to over 100,000 population, between 1950 and 1980. In this same period the 160 acre Delta Ponds were transformed from a pasture to a gravel mine to an informal wildlife reserve. Once located in a rural area, the ponds today are surrounded by a regional shopping center, auto dealerships, office buildings, a high school, planned housing clusters, and vacant land zoned for medium and high density housing and commerical use. Figure 1 shows the location of the ponds relative to the Eugene city center.

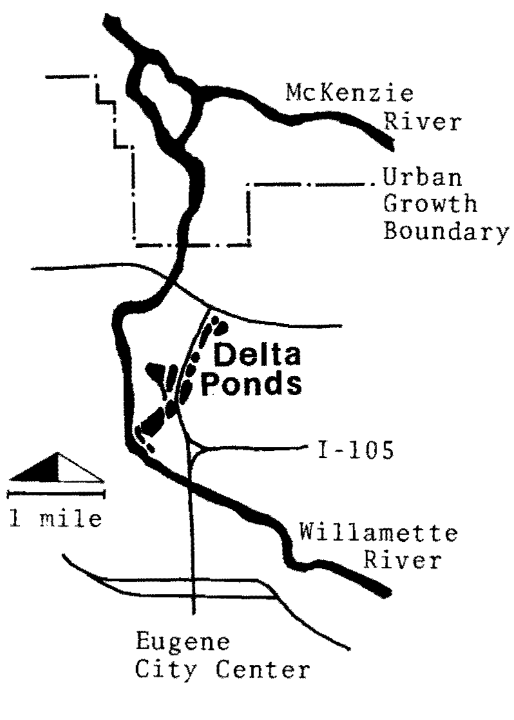


Fig. 1. Location map.

Unmanaged over the years, the ponds have been reclaimed by natural succession to form one of the most extensive urban wild areas in Oregon. This paper describes the history and wildlife characteristics of the ponds and prescribes a management plan for the area. The opportunity to extend the management plan to other mine areas in the region is also presented.

DESCRIPTION

The gravels of the Eugene area, swept from the Cascade Range by the Willamette River, form an extensive gravel deposit 15 miles long a mile wide and 200 feet deep. The Delta Ponds, located in an old meander of the river, were first mined after World War II. Over the next 20 years the dragline operation removed an estimated 2,000,000 cubic yards of sand and gravel from the site. The shape and depth of the ponds were determined by property boundaries, excavation and processing equipment, and the pattern of surface gravel resources.

The ponds are irregular in size, shape, depth, and edge. Pond size varies from over 50 acres to less than 1 acre. Water covers 85% of the surface area of the parcels involved. The shape of the ponds is highly irregular due to dikes used during excavation and edges created when a freeway was routed through the site in the 1960's. The land/water edge is over 12 miles in length.

The pits are about 20 feet deep relative to the original grade. Groundwater fills the pits to a maximum depth of 8 feet, but most water is between 2 and 6 feet deep. There are few shallows less than two feet deep. Levees separate the ponds from the adjacent Willamette River so that groundwater intrusion and local storm drainage provide the only inflow. An outflow channel connects with the Willamette River about two miles downstream of the ponds. Summer water temperatures are near 80 degrees F.

Natural processes of colonization have completely revegetated the site. The primary trees are cottonwood, alder, and willow; the primary brush species is evergreen blackberry (Rubus laciniatus Willd.), an escaped exotic that covers most of the levees. Cattail is the primary emergent plant but is found in only a few areas due to the lack of shallows.

The habitat supports almost all wildlife species typically found in rural areas in the Willamette Valley, including 25 species of ducks and shorebirds, 6 species of raptors, and 47 species of songbirds. Sightings, of interest in this urban setting, include the bald eagle, dunlin, and long-billed marsh wren.

Wildlife populations in general appear stable, except for a rapid expansion of the beaver population. Beaver are increasing apparently as the result of restrictions on trapping. The beaver are rapidly cutting trees throughout the ponds, including some in adjacent residential and commercial landscapes.

During the summer months over 90% of the water surface is covered with a mat of the bottom anchored aquatic plant, Potamogeton spp. Other aquatic plants such as filamentous algae and duck weed are less common. The success of the aquatic vegetation is attributed to the shallow pond depth, the warm summer water, and nutrients brought into the pond in storm drainage. Decompostion of the vegetative mat in the fall reduces water oxygen levels, but fish kills have not been observed. In general, the population of warm water fish is thought to be high, but the opportunity to fish is diminished by the aquatic vegetation. The surface mat also prevents canoeing and rafting, and draws numerous negative comments about its appearance.

In spite of some problems the ponds are a popular open space. The freeway through the ponds provides a close-up view of wildlife. Trails along the levees are used by hikers and birdwatchers. Each year two ponds are stocked with several thousand rainbow trout in the spring, attracting hundreds of fisherman. For an area described as "devastated" only 15 years ago the Delta Ponds have evolved, through natures' own reclamation process, into a resource of considerable value to the City of Eugene.

MANAGEMENT PLAN

The City of Eugene recently acquired the Delta Ponds, making formal management of the area possible for the first time. Such management should follow a plan that best achieves the city's goals. The management plan for the ponds should also consider six major concerns: the environment, recreation potential, educational potential, visual quality, safety, and economics. The preparation of the management plan should follow a process, and concern issues, described in "Planning for Wildlife in Cities and Suburbs" (Leedy et al. 1978).

Environment

Environmental problems include the high summer water temperatures and the dense aquatic vegetation mat. Other potential problems, such as pollutants from runoff, should be examined. The high summer water temperature prevents establishment of a native trout population, increases the hazard of wildlife diseases, and fosters excessive growth of algae and aquatic vegetation. The high temperature water flows into the Willamette River where it harms both trout and salmon. The floating vegetation mat limits the usefulness of the ponds to a variety of wildlife such as diving ducks, and threatens to cause fish die-offs due to reduced oxygen. Both problems could be reduced substantially by providing deep pools that increase the volume of the ponds relative to the surface area. Increased volume will keep water temperatures lower while the increased depth will inhibit growth of the bottom anchored pond weeds.

A variety of opportunites exist to enhance the present conditions of the ponds, which were not designed to support wildlife to the fullest. These opportunities include reshaping of the ponds, active management of both wildlife and habitat, and coordination of adjacent property development to complement the ponds.

Reshaping of the ponds could have very beneficial effects on wildlife. Deepening some ponds would allow use by species, such as diving ducks and rainbow trout, not found on the site. Islands would provide improved nesting habitat, particularly for ducks and geese, free from people and pet predation. Edges that encourage emergent vegetation, are now limited and could be increased. Ponds might be combined or separated to enhance flow, or to permit management for different fish species in different ponds. Water could be diverted from the Willamette River that would flow through the ponds. The reshaping plan should be based on guidelines from such established sources as Bennett's (1971) "Management of Lakes and Ponds".

Direct management of wildlife and habitat offers many opportunities. Planting of favored food and habitat plants could increase species number and diversity, and attract those species of special interest in urban areas. Special plantings of grains that attract migratory waterfowl are possible. Nesting boxes and platforms could increase the breeding success of such species as wood duck and Canadian geese. Management could also keep some areas disturbed, perhaps burned annually, for those species that prefer early successional conditions. Management could also introduce new species or control existing species. Numerous other management opportunities are discussed in the wildlife management literature. An excellent reference is "Wildlife Habitat Improvement Techniques" (Yoakum et al. 1980). A wildlife manager for the ponds would help assure that wildlife values are protected.

The opportunity also exists to coordinate development of adjacent lands so that they complement the pond ecosystem. Almost all adjacent vacant parcels are zoned for "planned development", which permits substantial latitude in site planning and design. Through the planned development process it may be possible to benefit both wildlife and the development. It may be possible to enlarge the ponds or to provide habitat on private land. At the least, it is possible to coordinate development to reduce future wildlife conflicts. Two recent projects demonstrate the opportunity that exists. The latest housing project developed in the area has constructed three small ponds as visual amenities, and to reduce the cost of installing and maintaining landscaping. Future ponds could be designed to serve wildlife needs too. A second example is a church/school complex yet to be constructed that has a 40 feet wide buffer to screen highway views that is also designed as a corridor of habitat and food for songbirds and quail.

Recreation

The recreational value of large urban green spaces is well established in the literature (Driver and Rosenthal 1980) and is a major component of Eugene's metropolitan area plan. The management plan for the Delta Ponds should provide a strategy for achieving recreation goals without diminishing the environmental resources of the area.

At present, only a small portion of the recreation potential of the ponds is being used, primarily due to the aquatic vegetation mat. The plan should identify a strategy to remove the mat in those areas where it diminishes recreation value but is not environmentally important. The mat does keep canoers from accessing portions of the ponds, thus keeping conditions more peaceful for wildlife.

The opportunity exists to dramatically enhance fishing, canoeing, hiking, and wildlife watching, both on the site and on adjacent properties. Fishing activity would boom with removal of portions of the vegetation mat, removal of carp, and construction of access trails and fishing piers. Fishing for youngsters and the handicapped seems particularly appropriate. Canoeing would dramatically increase if even a linear route were offered through the ponds. A six mile loop canoe system is possible utilizing the Willamette River for the downstream leg and the Delta Ponds for the upstream leg. Hiking and wildlife watching would also be enhanced by the provision of trails and blinds near areas where wildlife is expected.

Adjacent properties should be designed to complement the recreational opportunities on the ponds. The medium and high density housing planned for adjacent properties will require open space. Private developments could easily create their own water oriented recreation in association with the Delta Ponds. One housing project already has planned a canoe house on private property adjacent to the ponds.

Education

There is presently little educational value being derived from the ponds except by the local Audubon Society and by the city recreation department. The opportunity exists to create at the Delta Ponds the finest urban wildlife interpretive facility in the state. Facilities might include an interpretive center, trails and boardwalks, and observation points. Programs could range from indoor slide shows to hands-on wildlife management such as construction of nesting boxes.

Education can serve to increase appreciation of the ponds and can help generate support (Roth 1974). Programs at the Delta Ponds can be coordinated with all school levels in the area and with the various resource agencies and city and county departments. An wildlife interpreter or naturalist would be essential for full development of the educational program for the Delta Ponds.

Visual Quality

The primary visual problem with the ponds is the presence of the aquatic vegetation mat during the summer months. The mat gives the ponds a polluted appearance. A second problem is the general brushiness and inpenetrability of the land vegetation. Excavation of the ponds to eliminate pond weeds in visually exposed areas will help reduce negative comments. Similarly, removal of blackberries in foreground view areas will reduce negative comments.

The opportunity exists to create an extremely varied but ordered, ie. beautiful, visual environment. Such an environment need not lose any wildlife value, as demonstrated by Gallagher (1978) and Pudelkewicz (1979). Both wildlife and people enjoy species diversity, and people require strong order and openness only in the foreground, leaving the background plantings (beyond 100 feet) entirely for wildlife. The value of environmental education in reducing visual concerns, as noted by Kaplan (1979), should be utilized to reduce visual concern for "weeds", both aquatic and terrestrial, that will remain.

Safety

There have been few problems with wildlife at Delta Ponds to date, but a range of problems could develop (Smith 1974). Beaver have cut a few backyard trees, and there is some public concern about mosquitoes. Problem beaver have been live-trapped and relocated. Mosquito fish have been partially effective in reducing mosquito problems but are limited in their success by the density of the aquatic vegetation mat. Rabies has not been a problem in the Eugene area for many years but a threat exists where wildlife and pets mix. Education on the importance of maintaining vaccinations and boosters for pets is highly desirable.

As development around the ponds and the number of users increases, safety problems will increase. The management plan should address these problems and recommend design features, such as fencing, or management activities, such as wildlife numbers control to prevent problems from developing.

Economics

Both construction and operation expenses must be considered when planning for the Delta Ponds. Construction costs may include dredging, buildings, trails and boardwalks, interpretive facilities, and habitat improvements. Operation costs may include a wildlife manager, interpreter, ranger, and maintenance personnel with associated equipment and materials.

Funding of these costs may come from several sources: the Eugene general fund, the State of Oregon's Watchable Wildlife Program, and from mining of gravels under the ponds. The city's general fund is the traditional source of recreation construction and operation funds, but as with most communities there are few funds available for new projects.

The State's Watchable Wildlife Program, funded by an income tax check-off box, is managed by the Oregon Department of Fish and Widlife. Acquisition of the Delta Ponds was funded in part by these funds. Additional funds may be available through this program for development of facilities.

Gravels under the ponds provide the greatest opportunity for funding. Gravel deposits in the area are typically 200 feet deep. Much of the remaining gravel under the ponds could be recovered using dry mining techniques not available 20 years ago. The amount of gravel that could be recovered is uncertain, but probably exceeds 2 million cubic yards. There is a need for gravels on adjacent parcels, where several feet of fill are required to raise buildings and streets above flood plain elevations. One recent housing project near the ponds purchased $4,000 of gravel per lot (75 lots) to meet required grades. Given the location and the demand, mining could fund both the development and operation of the Delta Ponds as an urban wildlife area.

If mining is considered, the management plan must address environmental, recreational, educational, visual, safety, and economic concerns. Proposed mining can produce many values but can also produce problems ranging from wildlife habitat loss to noise and dust. The methods used, the timing, and the amount of area impacted at any given time must all be considered.

If mining is considered, it is important that it occur at the same time as development of adjacent properties. After adjacent properties are developed, which will likely occur within the next five years, the access to the gravel will be severely limited. Also, gravel will then have to be exported by truck from the site, reducing revenues. Once housing and commercial development occurs around the ponds, mining will be undesirable due to noise, dust, and safety problems.

THE REGION

Over 12,000 acres in the Eugene area are considered gravel resource lands: 2,250 acres will be mined by the year 2000. Through creative pre-mining planning, and through post-mining reclamation, it is possible to create a water/wildlife parkway extending both downstream and upstream of the City of Eugene. These parkways would be an extension of Delta Ponds, providing the same or similar package of benefits.

The motivation to produce this regional wildlife/open space corridor comes from all parties. The gravel companies, through mining, can increase the value of their property for subsequent uses. Medium and high density housing, in particular, benefits from water. Waterfront lots sell for a premium and the water area can qualify as common open space typically required in such developments. Other types of development, including commerical and institutional facilities, can be creatively designed to draw value from the presence of water.

Environmental and recreational groups also benefit from reclamation of mined lands through the creation of open spaces and wildlands. The City of Eugene benefits through the productive use of land and the creation of attractive, diverse neighborhoods. The ideal role for government planning agencies is to act as a catalyst in bringing participants together to prepare a management plan that is productive for all concerned.

In the Eugene area there is probably no single activity with more influence on the future character of the City than gravel mining. The pattern of ponds created by mining will become the structure that forms future neighborhoods and communities. The Delta Ponds are Eugene°s first opportunity to develop gravel pits and demonstrate the wildlife, recreation, visual, and economic values that can be derived.

ACKNOWLEDGEMENTS - The editorial assistance and advice offered by T. Divine and Dr. B. Slocum of the Animal Foundation of Eugene, OR is greatly appreciated.

LITERATURE CITED

Bennett, G. W. 1971. Management of Lakes and Ponds. Van Nostrand Reinhold, New York. 375 pp.

Driver, B. L. and D. Rosenthal. 1978. Social Benefits of Urban Forests and Related Green Spaces in Cities. Pages 98-112 in Proceedings of the National Urban Forestry Conference Vol. 1(1). (Nov. 13-16,1978) ESF Publ. 80-003, State Univ. of New York, College of Environmental Science and Forestry, Syracuse.

Gallagher, T. J. 1977. Visual Preference for Alternative Natural Landscapes. PhD Dissertation. University of Michigan, Ann Arbor, 152 pp.

Gill, D. and P. Bonnett. 1973. Nature in the Urban Landscape. York Press, Baltimore. 209 pp.

Kaplan, R. 1979. Visual Resources and the Public: An Empirical Approach. Pages 209-215 in Proceedings of Our National Landscape Conference, April 23-25, 1979, Incline Village, Nevada.

Leedy, D. L. et al. 1978. Planning for Wildlife in Cities and Suburbs. American Society of Planning Officials Report No. 331.

Pudelkewicz, P. J. 1978. Visual Response to Urban Wildlife Habitat. M.S. Thesis. Humboldt State Univ., Arcata, CA. 64pp.

Roth, C. E. 1974. An Effective Education Program. Pages 171-174 in Wildlife in an Urbanizing Environment. (Nov. 27-29,1973) Cooperative Extension Service, University of Massachusetts.

Smith, R. N. 1974. Problems with Urban Wildlife. Pages 113-116 in Wildlife in an Urbanizing Environment. (Nov. 27-29,1973) Cooperative Extension Service, University of Massachusetts.

Yoakum, J. et al. 1980. Habitat Improvement Techniques Chapter 20 in S. D. Schemitz, ed. Wildlife Management Techniques Manual, 4th ed. Wildlife Society.

Pits, Ponds and People: Reclamation and Public Use

RICHARD W. KOOPMANN. Boulder County Parks and Open Space Department, P. O. Box 471, Boulder, CO 80306.

Historically, sand and gravel mining operations were concerned primarily with locating, securing and removing the resources. The resultant pits were usually abandoned and forgotten... symbols of progress.

In recent years in Colorado another important element has been added to the sand and gravel extraction process. That element is reclamation. The Colorado Mined Land Reclamation Act of 1976 defines reclamation as, "the employment during and after a mining operation of procedures reasonably designed to minimize as much as practicable the disruption from the mining operation and to provide for the rehabilitation of affected land through the rehabilitation of plant cover, soil stability, water resources, or other measures appropriate to the subsequent beneficial use of such mined and reclaimed lands" (Colorado Mined Land Reclamation Board, 1978).

Experience in local projects has demonstrated that mined areas can be successfully transformed into productive wildlife habitat and environmental education sites. Two such sites in Boulder County have and are continuing to evolve from prairie land into locally significant wetland habitat.

BACKGROUND

Both Sawhill Ponds and Walden Ponds Wildlife Habitat lie in the flood plain of Boulder Creek, five miles (8 km.) northeast of Boulder, Colorado at 40° 02' N. latitude and 105° 11' W. longitude. At an altitude of 5,130 feet (1564 m.) above sea level, these two adjoining properties are a portion of an expanding network of sand and gravel pits that extend in both directions along the Boulder Creek riparian corridor.

The gravel deposits in the area range in size from sand and silt to well-rounded cobbles up to 8 inches (20 cm.) in diameter. The deposits are relatively shallow, averaging 15 to 20 feet (4.6 - 6 m.) in thickness. Underlying the gravel beds is a sedimentary rock formation known as Pierre Shale. It is 5,000 to 8,000 feet (1524 - 2439 m.) thick and consists of clay, siltstones, and sandy shales interbedded with bentonite. Because of the high clay content, the Pierre Shale formation is highly impermeable and generally prevents recharge of water to other lower bedrock units.

Sawhill Ponds (Figure 1) is owned by the Colorado Division of Wildlife and managed by the City of Boulder Parks Department under a 25 year lease agreement. Walden Ponds Wildlife Habitat (Figure 2) is owned by Boulder County and is being reclaimed and operated by the County Parks and Open Space Department.

Around 1950, the Boulder region began to experience considerable population growth (52% increase between 1950 and 1960). Coincident pressures for sand and gravel resources also increased. Farmers along Boulder Creek, including George Sawhill, slowly started selling off their mineral rights and the conversion of pasture to ponds began. Mining of the Sawhill Ponds area was done from the early 1950's to 1971 by several local sand and gravel companies. Reclamation was not a requirement, so much of the overburden was piled out of the way and the pits were abandoned when mining was completed. The land was deeded to the State Division of Wildlife after exhaustion of the gravel resources.

The first 71.5 acre (29 ha.) parcel of Walden Ponds was purchased by Boulder County in 1958. There were known gravel resources which the County needed for road maintenance and part of the site was also desirable as a headquarters for one of the road districts. After fourteen years, most of the original Walden Ponds parcel had been mined so an additional 41.5 acres (16.8 ha.) of adjacent pasture land was purchased for future needs. Sand and gravel extraction continues on that parcel today.

In 1973, public concern over the county gravel pit eyesore stimulated County Commissioner Wally Toevs to spearhead a plan for reclaiming the mined-out area and transforming it into a wetland wildlife habitat. He recruited Colorado State University graduate student Claudia Toburen to develop a reclamation plan for the site. Toburen began the project as an intern with the WICHE (Western Interstate Commission for Higher Education) Bicentennial Intern Program. She was subsequently hired by Boulder County in mid-1974 as the supervising biologist to oversee the reclamation and to provide on-site management as the Habitat became a reality.

The first phases of reclamation on the Walden Ponds site began in mid-1974 with the inventory

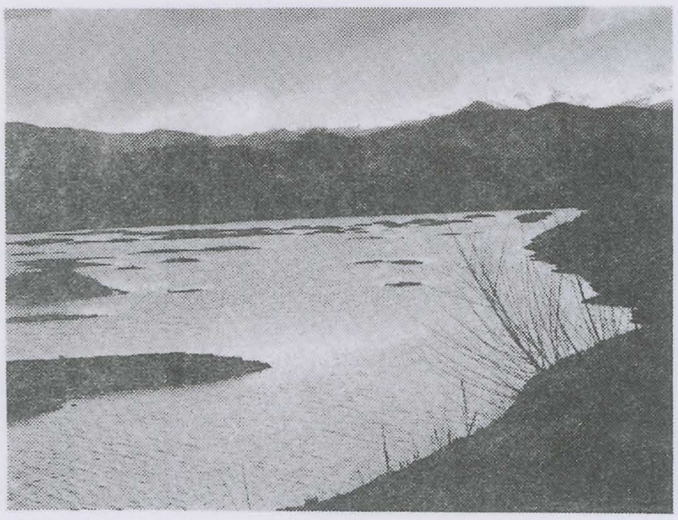


Figure 1. Sawhill Ponds.

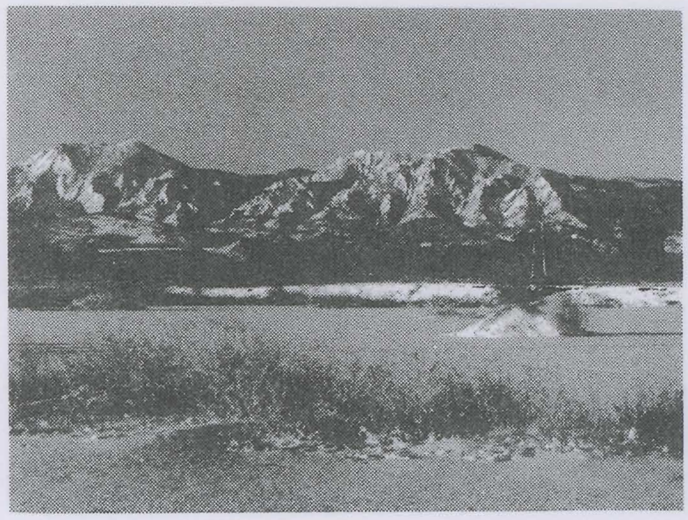


Figure 2. Walden Ponds.

process and construction of two dikes from the pit run to create three separate ponds. Additional pit run was piled to form gentle sloping islands and peninsulas. The largest of the three new water areas was to be reclaimed for a marsh so the bottom was partially filled and graded to create a shallow body of water. Wherever enough upland area adjacent to boundaries remained, the banks of the pit were sloped (approximately 10:1 ratio) and covered with the original topsoil which had been stripped prior to mining. Pumps to dewater the pits continued to operate throughout the reclamation process. Extensive planting of native grasses, shrubs and trees occurred after the pits were shaped and began filling with groundwater.

USES OF THE SITES

Wildlife

An ecological study done on the present Sawhill Ponds property in 1947 (Beidleman, 1947) described the area as being undisturbed by human beings with the exception of irrigation ditches. Cattle grazed over the area most of the year and hunting and trespassing were not permitted. Recorded on the 150 acre (60.7 ha.) site were 125 species of vertebrates including 7 fishes, 4 amphibians, 5 reptiles, 99 birds, and 10 mammals. Twenty species of nesting birds were noted including the first nesting record of the starling in Boulder County. Today, Sawhill Ponds are estimated to be used by 180 species of birds, 38 species of which are locally rare, one endangered nationally and one threatened nationally.

Because of the abundance of surface water and protection from hunting, both Sawhill Ponds and Walden Ponds are favored by migrating waterfowl. Passerines are becoming more numerous as the shoreline and upland food supplies increase. Inventories to date at Walden Ponds show 10 species of fishes, 3 species of amphibians, 7 species of reptiles, 147 species of birds (20 nesting species) and 21 mammal species utilize the site (Boulder County Parks & Open Space, 1982). Twenty-three species of birds have been identified as rare or sensitive and 10 species which occur have declining populations nationwide. In addition to the nesting birds, rabbits, ground squirrels, field mice, beaver, muskrat and red fox are known to raise young at Walden Ponds.

Mining

The most apparent human use of the Walden Ponds site is the active mining and crushing of the remaining sand and gravel resources. Although periodic, these activities can occasionally conflict with public use of the reclaimed areas as well as wildlife intolerant of the noise. During the week there is constant vehicle traffic associated with the county road district operations.

General Public Use and Fishing

Even though there are no developed recreation facilities other than trails, public visitation at Sawhill Ponds is greater than Walden Ponds. The Sawhill gravel mining was completed 10 years ago and the site has become established as a recreation area. Due also to the abundance and diversity of wildlife, many local Audubon members have adopted Sawhill as their special birding spot. Conservative estimates place the annual visitation at 30,000 people. Approximately 60% of the use is for nature study and 40% for fishing. Stocking of warmwater species is done occasionally by the Division of Wildlife. Natural reproduction has apparently been adequate enough to sustain the angling pressure on Sawhill.

One of the first programs started with the official opening of Walden Ponds in October, 1975, was the Trout fishing program for senior citizens and handicapped residents of Boulder County. The deepest of the reclaimed ponds was restricted for this special use and the county stocked the pond with Rainbow Trout during the spring and fall months of the April-November season. Around 6,000 catchable size (8-10 in.) Trout were purchased each year from a private hatchery until 1981 when county financial support ceased. Creel census data indicates 66% of the fish were harvested.

Additional sport fish harvested at Walden Ponds include Bluegill, Bullhead, and Largemouth Bass. There were 14,600 total angler hours recorded in 1980 and 8,300 fish were harvested (44% of the harvest was Rainbow Trout). Today, angler pressure is considerably less because of discontinuation of the Trout stocking program.

Environmental Education

Formal environmental education activities have been an important use of both Sawhill Ponds and Walden Ponds since they were opened to the public. Both sites are popular with local school teachers because of the close proximity to the urban area. In addition to the City and County Rangers working with many of the groups, the County Parks & Open Space Department also has a trained staff of 45 Volunteer Naturalists who are available for leading on-site activities. Students not only gain an understanding of and appreciation for wildlife and open space, but they also become aware of the planning processes and land-use considerations which are involved in gravel mining and subsequent reclamation. At Walden Ponds, the entire "before and after" story can be easily demonstrated because active gravel mining is taking place right next to reclaimed ponds. Exclusive of the considerable numbers of groups using the areas on their own (which is encouraged) the City Rangers work with approximately 600 school children each year at Sawhill Ponds. Over 700 students per school year are given formal programs at Walden Ponds by the County staff.

In addition to school groups, other people visit Walden in response to "Discover Nature" general public programs. On-site nature walks, demonstrations and summer campfire programs are offered by the Ranger staff and Volunteer Naturalists. Most of these programs are scheduled on weekends to encourage family participation. Conservative estimates place the current public use of Walden Ponds at 12,000 visitors per year.

Other past educational activities at Walden Ponds have included summer nature programs for children, Audubon workshops and field trips, in-service training for teachers and Volunteer Naturalists, wildlife photo workshops, and fly-fishing instruction by local experts. The University of Colorado has utilized both sites for field trips and individual student ornithology and geology projects. Local school children and scout groups have been involved in work projects including tree and shrub planting and care, trail work, and installation of nesting structures.

In addition to anglers, birders and photographers, other recreational activities at both sites include picnickers, joggers, bicyclists and equestrians. Swimming is not permitted and only bank fishing is allowed.

MANAGEMENT CONSIDERATIONS

Objectives

The long-term management objectives for both Sawhill Ponds and Walden Ponds are basically the same. Both the City of Boulder and County of Boulder intend to emphasize management of the areas as wildlife refuges, providing natural food, cover, nesting, and resting areas where appropriate. The impact of man's activities will be minimized as much as possible while allowing controlled public sport fishing, environmental education and other passive recreational pursuits.

Since mining has been completed on the Sawhill site for 10 years, the current management direction of the City is to allow natural succession to proceed with minimal human interference. The county has adopted a more active management role at Walden Ponds because of the need to re-establish entire plant communities and other habitat amenities after mining of each of the new areas has been completed.

Reclamation

Reclamation at the Walden Ponds Wildlife Habitat will continue over the next 10 years until gravel mining is completed. Reclamation will basically follow the guidelines approved for the original three ponds (Toburen, 1974). Projects/items identified include:

1. The four new ponds to be created will have different water levels to encourage diversity of wildlife.
2. The stockpiled topsoil and overburden is to be spread on the pit banks after sloping and on the islands prior to seeding both with native grasses.
3. Brush piles, stumps and old logs to be added to new ponds for habitat.
4. Cement rip rap to cover the steep western exposures to minimize destructive wave action.
5. Groupings of trees and shrubs will be planted around perimeter to provide wildlife food, cover and nesting areas. Leave perimeter uncut and unburned.

6. Observe regulations regarding air and noise pollution during mining operations.

Water Level Management

There are no current plans to manipulate water levels at Sawhill Ponds. Walden has no water rights on Boulder Creek so the best use of the natural ground water must be made.

1. Water control culvert structures will be placed between the ponds to allow the greatest flexibility in water level management.
2. Arrangements have been made to purchase up to 51 acre feet of water from the City to augment nearby Boulder Creek for the evaporation and transpiration losses incurred by development of the ponds.
3. Alternate drawdown and flooding of the major marsh area on a 3-4 year cycle. Ponds upstream will be used as holding reservoirs.
4. Replace electric pump at the bottom end of the pond system with a windmill.
5. Discourage Road District from drawing large amounts of water from the ponds unless there is a drawdown planned.

Wildlife

Natural plant succession will be the primary development focus for habitat at both Sawhill and Walden Ponds. Supplemental measures planned at Walden Ponds to encourage and/or manage wildlife species include:

1. Prohibiting public access to some areas all year.
2. Closing some prime habitat areas to human traffic during the nesting season.
3. Enforcing leash laws for pets.
4. Retaining no hunting ban.
5. Adding nest platforms and floating nest structures for waterfowl.
6. Adding bird boxes to substitute for lack of large trees for cavity nesters.
7. Retaining some vertical banks with new pits for bank swallows nesting.
8. Establishing perimeter vegetation.
9. Continue wrapping some cottonwood trees with chickenwire to discourage beaver use.
10. Maintain beaver population at habitat carrying capacity by live trapping and relocating excess individuals.
11. Continue biological control of mosquitos with *Fundulus* and *Gambusia* mosquitofish.

Sport Fisheries

The Sawhill Ponds fisheries program has been left up to the State Division of Wildlife. There seems to be adequate natural reproduction of Largemouth Bass, Crappies, Bullheads, and Bluegill, but periodic stockings of more warmwater fish are planned because of the heavy angler pressure. Management considerations for Walden Ponds include:

1. Providing for proper shorelines and avoiding potential stagnant water areas during reclamation phase.
2. Monitoring fish populations in the current ponds and discouraging buildup of trash fish by poisoning if necessary.
3. Providing gravel bars in shallow areas for spawning.
4. Providing artificial reefs which are tailored to breeding habits as well as territorial "homes" and protection areas.
5. Drawdowns should be gradual and not during May to July spawning.
6. Encourage vegetation in shallow areas to keep water cooler.
7. Provide diversity of fish in various ponds.
8. Maintain bank fishing only and enforce applicable State regulations on licenses and creel limits.

People Control

Both Sawhill Ponds and Walden Ponds ideally have only one vehicle access to the respective sites. Additional access into Walden consists of a bicycle/equestrian trail and a pedestrian gate in the fence between Sawhill and Walden. The County Parks are closed at dark while the City has no similar restrictions. Of the two sites, County visibility is greater because there is a field station at Walden Ponds out of which the Rangers, maintenance and volunteer staff operate. Other management considerations for both sites include:

1. Maintaining public parking at one end of the site, forcing people to get out of their cars to see the area.
2. Having adequate barriers and signing on trails to keep out motorcycles.
3. Providing living fences as much as possible in restricted areas.
4. Proper signing of rules and regulations for use of sites at access points.
5. Boundaries adequately signed.

Outdoor Recreation

Philosophies of both agencies correspond in providing the minimum of developed facilities for these sites. The Sawhill Ponds facilities are limited to trails and several observation blinds. Nothing else is planned. Meanwhile, Walden Ponds has limited picnic facilities at the entrance to the site and a pit toilet. There is a bicycle/equestrian trail around the perimeter of the property and several other trails, including a board walk, are planned after the new ponds are reclaimed. Only day use and passive recreational activities will be permitted at both sites.

Interpretation

Environmental Education will continue as a long term use of both Sawhill and Walden Ponds. The self-guided nature trail at Sawhill and the formal programs arranged with the Park Rangers are anticipated to be the major focus of that site.

With the field station already built on-site and the interpretive program for the County emanating from Walden Ponds, more interpretive facilities are envisioned. Several wayside stations/observation blinds complete with interpretive displays are planned to be constructed along a major interpretive trail connecting some of the ponds. The four basic stories to be interrelated include the continuing process of land erosion and deposition; man's use of specific land resources; reclamation of "used land"; and pond-marsh ecology.

A site has also been chosen at Walden to construct a permanent amphitheater after the gravel mining is completed. It will be centrally located to both Walden and Sawhill and will be used for evening campfire programs as well as daytime nature classes or school use.

A central information shelter is planned to be constructed at the vehicle entrance to Walden. It would function as an orienting facility for visitors, complete with rules and regulations, brochures, and interpretive displays on the background and purposes of Walden Ponds. The variety of interpretive activities currently happening at Walden Ponds are anticipated to continue in the future.

The importance of education regarding uses of unique open space sites such as Walden and Sawhill cannot be emphasized enough. Even though the land has been reclaimed after major disturbance and public open space designations would normally give some assurance against further disturbance, there are often going to be assaults on the integrity of the reclaimed land. Proposals have been made to go back into Sawhill Ponds and mine the remaining gravel, ideas have been expressed to open the area to waterfowl hunting; bicycle trails are suggested to go through critical habitat areas, and proposals have also been advanced to drill for oil and natural gas at Walden Ponds. Stewardship of the land brings forth many different concepts in public forums. However, with constant vigilence to protect against potential assaults on the integrity of the refuges and with careful design of new reclamation, access, facilities and programming, the long-term objectives of management should be achieved in a positive manner without adversely impacting the site further.

ACKNOWLEDGMENTS — I thank Brian Peck and Ann Wichmann, Boulder City Park Rangers, for supplying information on Sawhill Ponds.

LITERATURE CITED

Beidleman, Richard G., 1948. The Vertebrate Ecology of a Colorado Plains Cottonwood River Bottom. M.A. Thesis. Department of Biology, University of Colorado, Boulder.

Boulder County Parks & Open Space Department, 1982. Walden Ponds Wildlife Habitat Management Plan.

Colorado Mined Land Reclamation Board, 1978. Rules and Regulations. 57pp.

Toburen, Claudia, 1974. A Nature Area for Boulder County. Resources Development Internship Program. Western Interstate Commission for Higher Education, Boulder. 38pp.

The Red River Valley Natural History Area: Wildlife Management and Environmental Education in an Abandoned Gravel Pit in Northwest Minnesota

W. DANIEL SVEDARSKY, Agriculture Division, Technical College and Northwest Agricultural Experment Station, University of Minnesota, Crookston, MN 56716

INTRODUCTION

The annual consumption of sand and gravel resources in the U. S. is about 5 tons per capita as we use them for aggregate in concrete and asphalt, road construction and maintenance,and as miscellaneous fill. Since these resources are indispensable for many types of construction and maintenance purposes, extraction will continue into the future and opportunities are presented for the creative planning of post-mining environments. Mining operations can be thought of as a "transitional land use," in that, deposits are limited and after extraction is complete, mining sites are available for another use. In some cases, the lowering and reshaping of the land surface makes available land use options that weren't possible before mining. For example, the creation of wetlands, in areas previously lacking them, can provide new habitats for wetland wildlife.

This paper summarizes the establishment of a Natural History Area project on land containing an abandoned gravel pit in northwest Minnesota. Wildlife and environmental education use of this and other unreclaimed sites in the region is evaluated and general recommendations made for planning similar uses of gravel pits.

LOCATION AND STUDY AREA

The 85-acre Red River Valley Natural History Area is located one mile north of Crookston and one mile west of the University of Minnesota campus (Fig. 1). The regional setting is the very flat lake plain of glacial Lake Agassiz which drained from the region some 10,000 years ago. The Natural History Area is on a lens-shaped gravel deposit which ranges from 7-8 feet thick at the center to 1-2 feet at a distance of 1/2 mile. This deposit commences about one foot below the surface and corresponds to the "off-shore bar" category of Eng and Costello (1974).

The presettlement vegetation was primarily tall grass prairie which is still represented

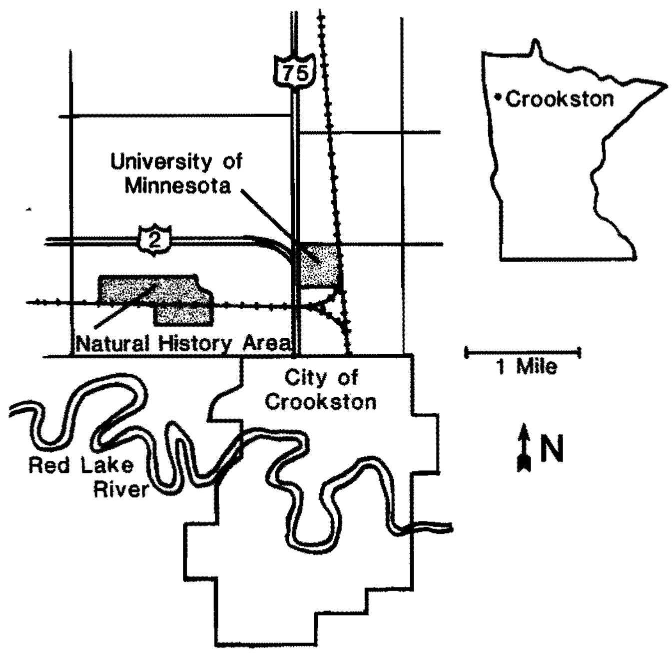


Fig. 1. Location of the Red River Valley Natural History Area.

along the railroad right-of-way bisecting the Area (Fig. 2). Fires associated with trains have helped to maintain the prairie remnant by retarding the natural succession of woody species. Most of the project area north of the railroad tracks presently supports a mixture of grassland and aspen groves, or what is termed "Aspen Parkland" (Bird 1961). The grassland habitat is dominated by big bluestem (Andropogon gerardi), Kentucky blue grass (Poa pratensis) and quack grass (Agropyron repens) and the aspen groves by trembling aspen (Populus tremuloides), American elm (Ulmus americana), green ash (Fraxinus pennsylvanica) and scattered bur oaks (Quercus macrocarpa). This mixture of forest and prairie is largely due to the continental forest-prairie transition being located only about 15 miles to the east.

Approximately 35 acres have been mined for gravel and excavated an average depth of 6 feet with mounds and ridges of overburden occurring

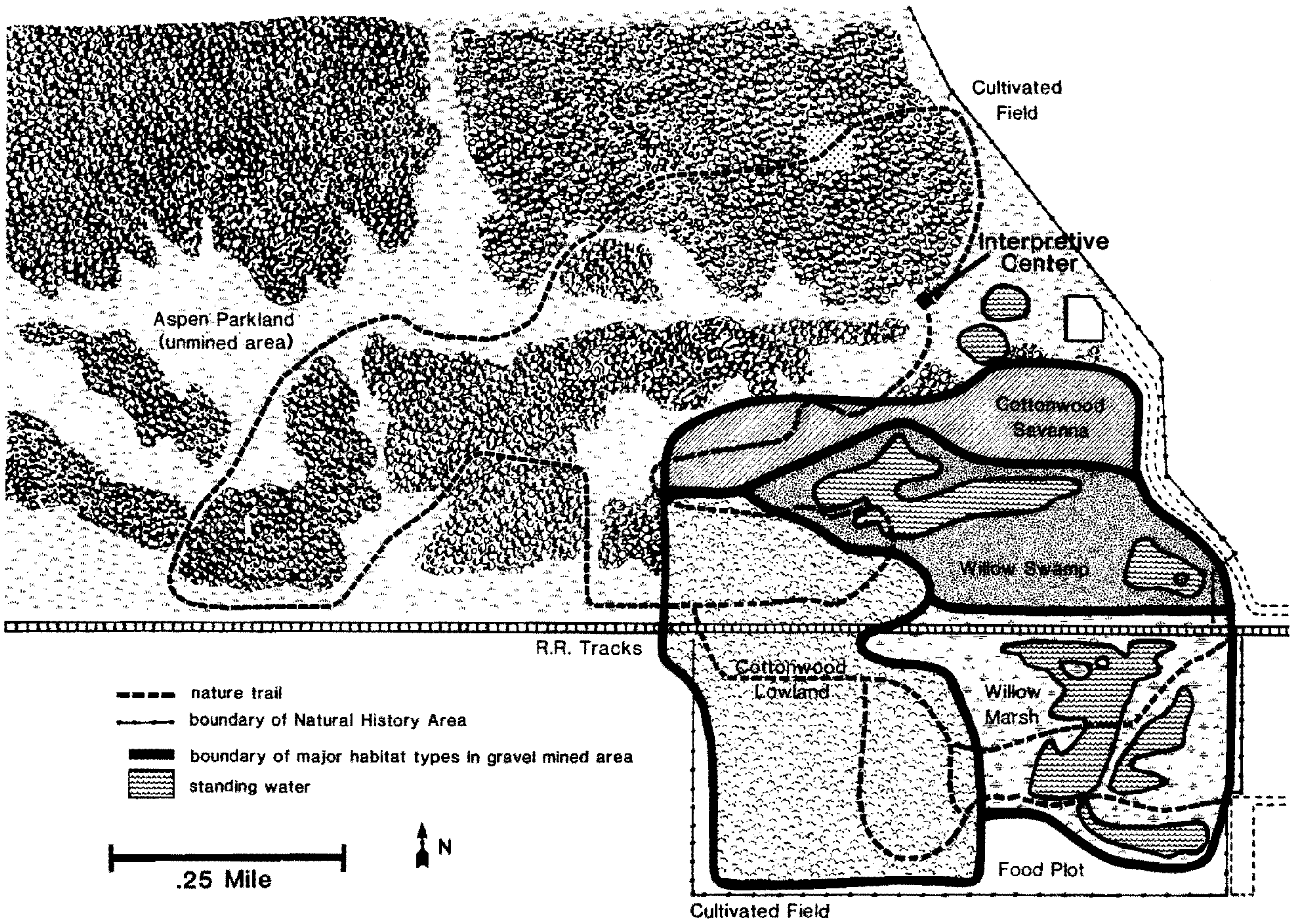


Fig. 2. Habitat types at the Red River Valley Natural History Area.

throughout. Due to differences in excavation depth and time since mining, four major habitats have developed in the mined area (Fig. 2).

The Cottonwood Savanna is characterized by large, open-grown cottonwoods (Populus deltoides) 80-90 years old and 24-30 in. dbh (diameter at breast height). Past grazing and fires had maintained an open understory with a ground cover of Kentucky bluegrass, quack grass, and sweet clover (Melilotus officinalis), but presently, an understory of shrub and tree species is developing. Shrubs include: Tartarian honeysuckle (Lonicera tatarica), service berry (Amelanchier sp.), nannyberry (Viburnum lentago), chokecherry (Prunus virginiana), raspberry (Rubus strigosus), buffaloberry (Shepherdia argentea) and thickets of snowberry (Symphoricarpos orbiculatus) on overburden mounds. Invading trees include: green ash, box elder (Acer negundo), and American elm. This is generally a well-drained area with little standing water in spring.

The Cottonwood Lowland is dominated by relatively dense cottonwood stands in areas mined 35-45 years ago. (Since cottonwood is a pioneering species on infertile, gravelly sites, its age provides a useful reference as to the time of mine abandonment.) Low areas are scattered throughout which contain 2-8 in. of water in the spring and support an understory of sandbar willow (Salix interior), pussy willow (Salix discolor) and red osier dogwood (Cornus stolonifera). Some bluegrass and quack grass-dominated open areas are also present along with shrub species as noted for the Cottonwood Savanna type, although not as abundant.

The Willow Swamp habitat has developed in areas mined some 70-80 years ago that have depressions containing 10-30 in. of water in the spring, but are usually dry by mid-July. Peach-leaved willows (Salix amygdaloides) characterize this type and are 4-8 in. dbh and 10-15 ft. high. Several of these are dead or have snags. Scattered cottonwoods occur along with clumps of red osier dogwood on better drained areas. Four to 6 in. of organic sediments have accumulated over the gravelly bottom of depressions which supports a variety of aquatic plants. Major species include: a dense carpet of hooked moss (Drepanocladus sp.), water parsnip (Sium sauve), water plantain (Alisma triviale), duck weed (Lemna minor, L. trisulca), and cattail (Typha angustifolia, T. latifolia, and a hybrid between the two) in the lowest areas.

Willow Marsh - The dominant element of this habitat type is a centrally located cattail marsh having 2-4 ft. of water in the spring, some of which usually persists throughout the summer. A dense growth of willows is present on the marsh fringe and on mounds of overburden. These are mostly less than 10 ft. except for scattered, 12-15 ft., peach-leaved willows. Nettle (Urtica dioica), Canada thistle (Cirsium arvense), and various grasses occur in better drained areas.

PROJECT HISTORY

The Aspen Parkland portion of the area had a history of grazing and some cultivation. In the remainder, gravel mining occurred sporadically until the early 1960s when most of the acreage was acquired by the Northwest Experiment Station as a sheep pasture and farm storage yard. In 1963 and 1964, two 4.5-acre parcels in the gravel-mined area were acquired by the Station from the City of Crookston and Polk County for $1 each.

The Northwest Agricultural Experiment Station at Crookston is a branch station of the Agricultural Experiment Station of the University of Minnesota at St. Paul, and, as other branch stations, carries out research pertinent to the needs of the region and associated livestock and crop production. The University of Minnesota Technical College at Crookston is a coordinate campus of the University and the Agriculture Division, in particular, engages in cooperative educational efforts with the Station. In 1970, the newly established Natural Resource Program of the Agriculture Division was in need of a field facility where students could gain practical resource management experience. There also seemed to be a need for a demonstration area where land use possibilities of these types of areas could be illustrated. Additional impetus to the early planning came from the environmental concerns generated by the national "Earth Day" in 1970.

In 1971, an Experiment Station Project was developed by B. E. Youngquist and the author in consultation with an advisory committee from the St. Paul campus of the University. One of the committee, William H. Marshall, was the first to point out the unique potential of the gravel pit as a place to demonstrate wildlife management uses of such areas.

The following objectives were identified for the project:

"1. To establish a facility for the demonstration of techniques for development of environmental study areas, with such information being shared with prairie-forest region landowners, educational institutions, and other interested citizens and officials.

2. To establish an outdoor education laboratory serving as a facility for:

a. field trips and exercises in natural science related courses offered at the University of Minnesota Technical College,

b. carrying out independent field study projects by students,

c. guided tours for area high school and elementary school science classes, and

d. augmentation of opportunities for regional teacher training sessions in environmental education.

3. To develop a facility where the following land management activities may be tested: controlled burning, reestablishment of native plants, and different types of wildlife habitat management appropriate to the region. This would provide a special opportunity to demonstrate the usefulness of old gravel pits and/or prairie-forest areas to owners of similar sites within the region."

The initial emphasis of the project involved vegetation and wildlife inventory, nature trail planning, fence construction, miscellaneous clean-up and the renovation of a donated building into a classroom and meeting facility. Later, the remaining 9.5 acres of the gravel-mined area were acquired along with construction of the entrance road and pond through a memorial fund dedicated to conservation activities by a former UMC student, Norman Pankratz. The "Pankratz Nature Trail" in the Natural History Area memorializes this special student.

Projects dealing with forest wildlife management, and prairie restoration and management, especially in relation to fire, are underway in the aspen parkland portion of the Natural History Area and will not be covered in this paper. Instead, observations concerning wildlife and environmental education uses of the gravel pit area will be emphasized.

WILDLIFE STUDIES

The Natural History Area is somewhat of a "habitat island" since it is surrounded by intensively farmed land. This likely affects the species composition for animals with low mobility such as flying squirrels and ruffed grouse, since both occur in the nearby riparian forest of the Red Lake River. None-the-less, 30 species of mammals (Table 1.) and 154 species of birds have been recorded since wildlife observations were commenced in 1970.

Table 1. Mammals recorded at Red River Valley Natural History Area.

Masked Shrew (*Sorex cinereus*)
Short-tailed Shrew (*Blarina brevicauda*)
Hoary Bat (*Lasiurus cinereus*)
White-tailed Jackrabbit (*Lepus townsendii*)
Snowshoe Hare (*Lepus americanus*)
Eastern Cottontail (*Sylvilagus floridanus*)
Woodchuck (*Marmota monax*)
Richardson's Ground Squirrel (*Spermophilus richardsonii*)
Thirteen-lined Ground Squirrel (*Spermophilus*) *tridecemlineatus*)
Franklin's Ground Squirrel (*Spermophilus franklinii*)
Eastern Chipmunk (*Tamias striatus*)
Red Squirrel (*Tamiasciurus hudsonicus*)
Gray Squirrel (*Sciurus carolinensis*)
Fox Squirrel (*Sciurus niger*)
Plains Pocket Gopher (*Geomys bursarius*)
Deer Mouse (*Peromyscus maniculatus*)
Southern Red-backed Vole (*Clethrionomys gapperi*)
Meadow Vole (*Microtus pennsylvanicus*)
Muskrat (*Ondatra zibethica*)
House Mouse (*Mus musculus*)
Meadow Jumping Mouse (*Zapus hudsonius*)
Raccoon (*Procyon lotor*)
Short-tailed Weasel (*Mustela erminea*)
Long-tailed Weasel (*Mustela frenata*)
Mink (*Mustela vison*)
Striped Skunk (*Mephitis mephitis*)
Badger (*Taxidea taxus*)
Red Fox (*Vulpes vulpes*)
White-tailed Deer (*Odocoileus virginianus*)
Moose (*Alces alces*)

From 1976-1980 a breeding bird study was carried out in the gravel mined area (Fig. 2) and a total of 40 species were recorded with 17 breeding every year of the study (Table 2). The diverse, Willow Swamp and Willow Marsh habitats contained the greatest number of breeding bird species with 30 and 28 , respectively. Yellow-headed Blackbirds, Pine Siskins and American Coots have bred in other years bringing the total to 43 species breeding in the gravel pit habitats. These studies were expanded in 1980 to include other gravel pits in the region which represented different stages of post-mining succession. A general pattern or "model" of plant and bird succession after mining has been developed (Fig. 3) which would be applicable in varying degrees to most flat terrain gravel deposits in northwest Minnesota. These deposits are located mostly along the shoreline of glacial Lake Agassiz.

Table 2. Breeding birds of an abandoned gravel pit at the Red River Valley Natural History Area from 1976 - 1980.

Species	Breeding occurence (No. years)
Mallard	3
Common Pintail	3
Blue-winged Teal	2
Northern Shoveler	1
Wood Duck	3
American Kestrel	1
Sora	3
Killdeer	1
Mourning Dove	5
Black-billed Cuckoo	4
Great Horned Owl	1
Common Flicker	5
Red-headed Woodpecker	1
Hairy Woodpecker	1
Eastern Kingbird	4
Willow Flycatcher	5
Least Flycatcher	5
Eastern Pewee	5
Tree Swallow	2
Black-capped Chickadee	1
House Wren	5
Gray Catbird	5
Brown Thrasher	3
American Robin	5
Veery	1
Cedar Waxwing	3
European Starling	5
Yellow-throated Vireo	1
Red-eyed Vireo	4
Warbling Vireo	5
Yellow Warbler	5
Common Yellowthroat	5
Western Meadowlark	1
Red-winged Blackbird	5
Northern Oriole	5
Common Grackle	5
Brown-headed Cowbird	5
American Goldfinch	5
Clay-colored Sparrow	3
Song Sparrow	3

General Vegetation and Wildlife Changes After Gravel Mining in Northwest Minnesota

Two basic types of flat terrain gravel pits occur in northwest Minnesota; "wet pits," where excavation has gone below the water table, and

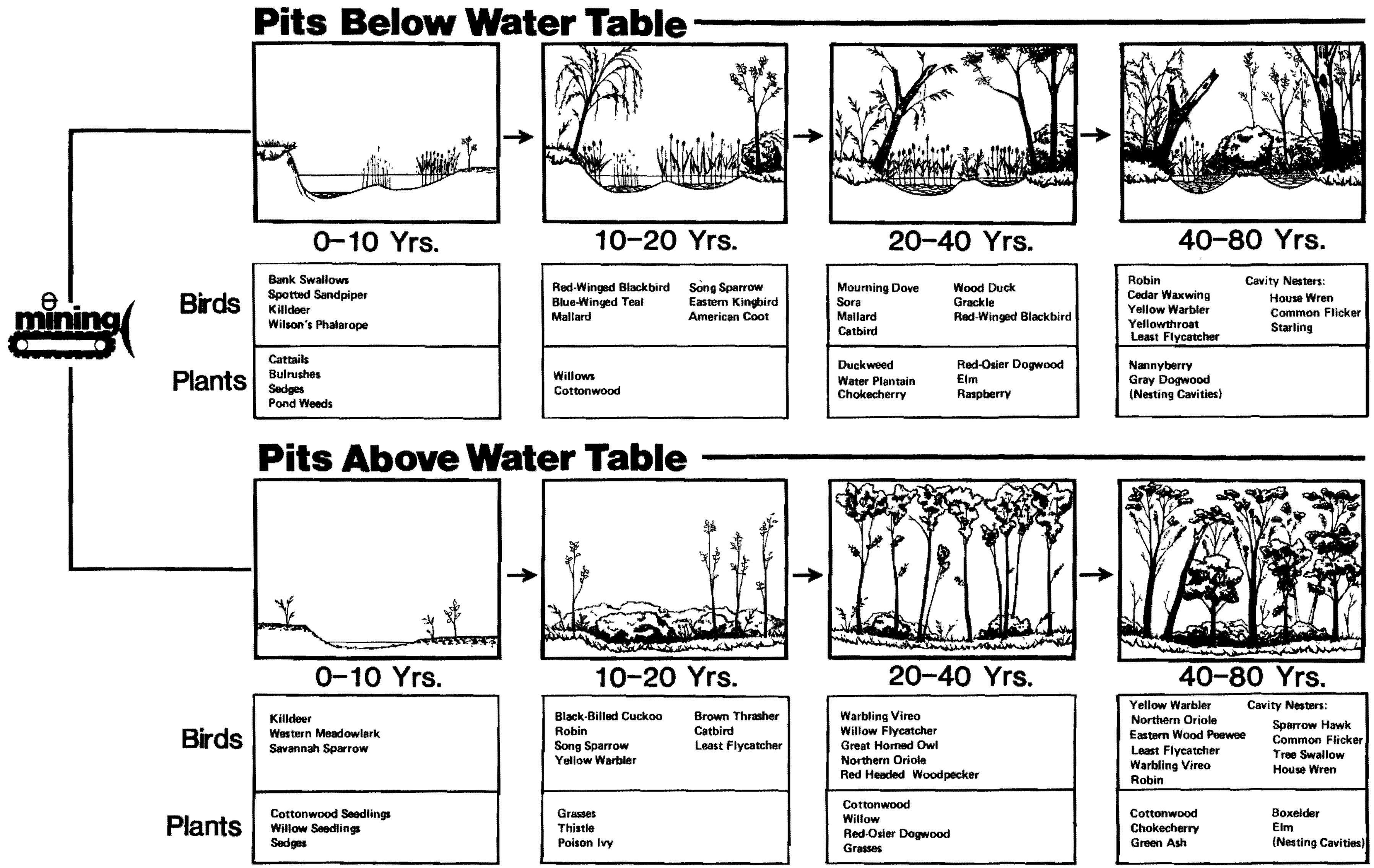


Fig. 3. General changes in breeding bird species following abandonment of gravel pits in northwest Minnesota.

"dry pits," which do not have appreciable amounts of standing water. Water levels have a major influence on vegetation development after mine abandonment since plants vary with regard to water requirements.

Wet pits

Wet pits may have 4 to 5 feet of water in spring which may decrease to 2 ft. in late July of dry years. Since the fertility of gravel deposits is generally low, the invasion of plant life is correspondingly slow. However, in some areas, water fertility may be increased by wind blown topsoil, especially if pit ponds are surrounded with shrubs and small trees, which cause drifting of soil-laden snow during winter. Early stages of "wet pit succession" are attractive resting areas to migrating waterfowl and shorebirds. Waterfowl use these areas for displaying and loafing along the sparsely vegetated shores. Before the shorelines and gravelly flats become vegetated, they serve as feeding areas for shorebirds such as Killdeer,Spotted Sandpiper and Wilson's Phalarope. Killdeer nest in the bare gravelly areas and the latter two species in grassy spots when they are available nearby. Bank Swallows utilize steep cut banks for nesting, particularly if water is present at the base of the bank. Deer and mourning doves commonly use the new wetlands as watering sites.

Later, as water fertility increases, cattails, bulrushes (Scirpus spp.), sedges (Carex spp.), and pondweeds (Potamogeton spp.), become more common as do aquatic invertebrates. At this point, wetlands are attractive feeding areas for dabbling duck adults and broods, but nesting is dependent upon grassy upland habitat being present nearby. Red-winged Blackbirds and American Coots nest in the cattails and bulrushes while Song Sparrows start nesting in the fringe of willows around the wetland edges. Muskrats may begin using these wetlands if sufficient food and necessary water depths are present.

As vegetation density and water fertility continue to increase in the 20-40 year stage, wetlands are still very attractive to waterfowl broods. Abundant insect populations attract Eastern Kingbirds, Least Flycatchers, and Common Yellowthroats which also nest in the willow shrubs and small trees. Spring pools of water with their accumulations of 5 to 10 inches of decaying leaves and other organic matter provide desirable breeding sites for wood frogs, cricket frogs, and toads.

When willow and cottonwoods reach the size when they either start leaning (especially peach-leaved willow) or develop sizable horizontal branches,they become attractive for Mourning Dove nesting. Often, active dove nests may be only a few yards apart in willow fringes of wetlands. Peach-leaved willows commonly die or develop dead branches or "snags" around 30 years and these soon provide habitat for cavity nesters such as House Wrens, Common Flickers, and European Starlings. Although natural cavities would usually not be big enough at this point for Wood Ducks, man-made nest boxes will serve as substitutes. Wood Ducks prefer wetlands having a swampy character with tree and shrub borders.

The older stages of wet pit succession are characterized by accumulations of organic matter in low areas and are dominated by cattail,bulrush, water parsnip,water plantain and duckweed. Areas not so wet are usually covered with a dense growth of shrubs and small trees which include: Tartarian honeysuckle, red osier dogwood, raspberry, snowberry, nanny-berry, chokecherry, American elm, box elder and cottonwood. Many of these produce fruits which are eaten by birds and are likely brought in initially by birds.

Dry pits

While dry pits have generally not been excavated below the water table, they usually have some standing water in the spring. In these depressions cottonwood and willow seedlings become established soon after pit abandonment and may grow rapidly, especially when the water table is close to the surface which is often the case. Killdeer commonly nest on the bare sand and gravel areas before they become vegetated and Savannah Sparrows and Western Meadowlarks nest in grassy areas after they develop or if undisturbed patches are present.

After 10-15 years of "dry pit succession" areas are characterized by a dense community of shrubs and small trees. The uniformity of this vegetation will depend upon the topography. That is; if low pockets remain, these may be too wet for willows and support cattails. If well-drained hummocks are present,they commonly support grassy vegetation or snowberry if soil conditions are too dry for willows and cottonwoods. This habitat mixture is attractive to birds that are associated with shrubs and forest "edges" such as Brown Thrashers, Black-billed Cuckoos, Song Sparrows, Yellow Warblers, Gray Catbirds, and Least Flycatchers. American Goldfinches are common nesters if thistles are available as a food source. Deer also frequent these areas, browsing on willow, sowthistle (Sonchus arvensis), and legumes such as sweet clover.

As the cottonwoods reach a height of 20-30 feet and develop a closed canopy, they begin shading out smaller cottonwoods and shrubs. Willow shrubs, in particular, decline and the more shade tolerant red osier dogwood becomes more common. Birds more typical of taller trees are present at this stage such as Warbling Vireos, Northern Orioles and, occasionally, Great Horned Owls will nest in old squirrel or crow nests.

As the cottonwood forest matures, natural thinning occurs as the shade-intolerant trees die. This opens up the canopy and stimulates the growth of understory shrubs which in turn results in more breeding Yellow Warblers, Gray Catbirds and Least Flycatchers.

The standing dead trees become available for cavity nesters such as Red-headed Woodpeckers and Common Flickers. After cavities are created by woodpeckers, then Tree Swallows, European Starlings, and American Kestrels select the higher ones for nesting. House Wrens select lower cavities, especially those in willow tree snags. As the cottonwood forest thins and horizontal branches develop on the tall trees, habitat for the Eastern Pewee is formed.

In these older cottonwood stands, along with the undergrowth of shrubs is the beginning of a new forest that will be dominated by American elm, green ash, box elder and, occasionally, bur oak, all of which are capable of reproducing in shade. Thus, some 150 or so years after gravel mining, one could expect to find an elm-ash forest with scattered cottonwoods and bur oaks in dry pit situations in northwest Minnesota. In this more closed-in forest, typical forest birds like Red-eyed Vireos, Veerys, Black-capped Chickadees, and Great Crested Flycatchers would likely occur.

Considerations in Planning For Wildlife Habitat in Gravel Mining Operations

By observing the wildlife use and successional trends of unreclaimed gravel pit environments, at both the Natural History Area and other sites in the region, some general wildlife planning considerations can be outlined. Although mostly developed from observations in northwest Minnesota, many of the following considerations would be adaptable to other gravel pit situations.

A key planning consideration is <u>habitat diversity</u>, if a variety of wildlife species are desired. This can be maximized by having ponds of varying depths (if a wet pit is involved) and uplands of rolling topography which would favor a variety of plants. Many wildlife species use different habitats for different activities; all of which are important to their survival. For example; mallards utilize newly created ponds for loafing, older more fertile ponds for feeding and brood-rearing and upland grassy areas for nesting. Thus, a long-term sequential mining operation that would create a series of successional stages might be more valuable to some wildlife than a short-term operation.

Wetland development

The potential for wetland development in gravel pits is usually quite good, at least for flat terrain deposits in high water table areas. Since areas would not usually be large, nor wetlands very deep, the priority would be placed on dabbling ducks rather than diving ducks.

1. Ponds should be designed to have as much shoreline as possible to create areas for waterfowl courtship and feeding.

2. About half of a pond should be 5 feet in depth in mid-summer to prevent rapid filling in with cattails and to secure broods to flight stage. The pond depth could vary so that patches of cattails and bulrushes develop in the central portions of ponds. These can provide shelter for broods and nesting sites for overwater nesting species such as grebes and diving ducks.

3. Upland nesting areas should be available nearby and have residual cover in spring for early nesters. These may need to be periodically burned or mowed to prevent brush encroachment. Blocks of cover are generally more secure from nest predators than narrow strips.

4. Often, large boulders are associated with gravel deposits and make ideal duck loafing sites if they are formed into islands. They are not destroyed by wave action and stay free of vegetation if no soil is mixed with them.

5. Earthen nesting islands may be desirable if they can be isolated so as to prevent predator access during the nesting season.

6. Some topsoil, fertilizer or manure could be added to wetland bottoms to hasten the increase in water fertility and the resulting increase in plant and animal life.

7. Nest boxes can be constructed to attract cavity nesters such as Wood Ducks.

8. In some situations it may be possible and desirable to modify the drainage of surrounding cropland to divert more spring runoff into a gravel pit wetland.

Forest-grassland development

Mining areas that are mostly better drained and in which mining has not penetrated the water table have other development potentials. Left alone, gravel pits eventually develop a covering of vegetation that is adapted to existing fertility and moisture conditions. The object in reclamation is basically to speed up the natural process. Examining an old gravel pit can be a valuable reference in determining what plants grow well in the local area.

1. During the grading phase of reclamation, there are opportunities to create "microhabitats" for different plants. That is, mounds can be built providing cool and moist north slopes and

warmer and dryer south slopes to accommodate different plants.

2. In order to maintain the forest-grassland mix and therefore a larger variety of wildlife, areas should be periodically mowed or burned to maintain open areas. When possible, prescribed burning is more desirable since it tends to be cheaper and improves the forage quality of wildlife plants.

3. As with wetland development, nest boxes in upland areas can attract cavity nesting birds as well as squirrels.

4. Food plots may be desirable and a portion of an area can be reclaimed to have good drainage and fertile topsoil that would support corn or other wildlife plants.

ENVIRONMENTAL EDUCATION USE

The Natural History Area has many features in common with other environmental education facilities--a nature trail system, a meeting facility, interpretive materials, staff or volunteers for interpretation and maintenance, and a use policy. While most facilities are in, more or less, natural settings, the Natural History Area contains an old gravel pit--an area drastically disturbed in the past but today is one of the most interesting parts of the project area. It provides topographic variety in an extremely level landscape. It provides an opportunity to discuss the use of mineral resources by man, the natural vegetation and wildlife succession process, and how man might purposefully design post-mining environments.

User Groups

The priority use group is students of the Technical College whether on class field trips or independent studies in wildlife identification, forestry, limnology, wildlife management or ecology. During the summer, one or two students complete an internship program by assisting with maintenance, data collection and guiding groups.

Each year approximately 600 individuals visit the Area with most coming with a high school, elementary, 4-H, scout, senior citizen or other group. These mostly occur during spring and fall with lesser numbers in the summer and winter seasons.

Use is permitted on a reservation basis which is more to monitor visits than to restrict use. Since the area is relatively small, emphasis is placed on passive nature recreation and snowshoeing and cross-country skiing are permitted as a means of traversing trails in winter. Ordinarily, the naturalist or student assistants will lead a group through for the first visit for orientation and, if it's a school group, instructors often prefer to lead their group themselves on subsequent visits.

The Natural History Area has also been the site of special tours and workshops. These have included: a sectional meeting of the Society for Range Management, Minnesota Naturalists Association, Prairie Management Workshop, and Natural Area Management Workshop, to name some of the more recent ones. Each year the Northwest Experiment Station sponsors a "Crops and Soils Day" where landowners of the region tour the Station to learn of new agricultural developments. A booth and tour of the Natural History Area, emphasizing the use of gravel pits, is held in conjunction with this event. The expectation is that landowners will go home and put to practice what they have seen demonstrated.

Considerations in Planning for Environmental Education Uses of Gravel Pits

In considering the special environmental education attributes that gravel pit environments have, or can be made to have, one must be mindful of wildlife values. What environments will attract interesting animals in a setting where they can be experienced? Generally, people are more interested in chipmunks or deer than big bluestem, cottonwoods or quartz. Animals are the focal point. Other environmental themes and interrelationships can be brought in more easily if they can be related to the animal at hand or at least in view.

To a large extent, one can anticipate what wildlife viewing opportunities are going to one day be available in a gravel pit reclamation plan. Where will duck broods be concentrated? Where will deer be feeding in late afternoon? Will the nature trail be close enough and concealed enough to observe courting waterfowl in the spring?

1. A raised ridge planned for a nature trail route will enhance viewing opportunities. Vegetation screening along the edges or an occasional blind constructed on a high point will assist as well. Obviously, ridge design will have to take into account what sort of maintenance equipment will be used and the special needs of senior citizens and handicapped people.

2. Bridges seem to be popular with all age groups, but especially with school children. They allow ease in viewing or sampling aquatic organisms, quiet movement through marshes and swamps, and provide the special excitement unique to a bridge over water.

3. Reclaimed soil conditions have to be attuned to the desired vegetation (or lack of it, since some birds, such as Killdeer, nest on bare ground). Perhaps a site is to contain a demonstration plot of rare and unusual plants that are native to fragile ecosystems which could not bear heavy human use. There are opportunities to create, at least on a small scale, a variety of plant habitats through soil and slope modification.

4. The proximity of gravel pits to large population centers is also key to their environmental education potential. This factor will become increasingly important as transportation costs continue to increase in the future.

SUMMARY

This paper examined the development of a Natural History Area and how a gravel pit, which was an eyesore to some, became an asset. By noting the wildlife use and successional tendencies of fortuitously created post-mining habitats, we can better develop reclamation guidelines, or to state it another way, if <u>default</u> can produce good wildlife and environmental education areas then <u>design</u> should be able to produce excellent ones! Since habitat diversity is the key to a diversity of wildlife and wildlife experiences, then a gravel pit seems to be a fruitful environment in which to design such diversity.

LITERATURE CITED

BIRD, R.D. 1961. Ecology of the aspen parkland of western Canada. Can. Dept. Agri., Res. Branch. Publ. 1066. 155 pp.

ENG, M.T., and M. J. COSTELLO. 1979. Industrial minerals in Minnesota: a status report on sand, gravel and crushed rock. Minn. Dept. of Nat. Res., Div. of Minerals, St. Paul. 78 pp.

Gravel Pit Reclamation in Ontario: The Crieff Case Study

PAUL F.J. EAGLES, Department of Recreation and School of Urban and Regional Planning, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

Ontario is a big province. At 1,068,587 sq. km, it is larger than Great Britain, Germany and France combined. But the majority of the province's 8.6 million people live in a narrow, densely populated corridor along the northern shores of Lakes Erie and Ontario. Rapid urban development in the last 30 years has created large markets for aggregate products and as a result those deposits within trucking distance of the cities are being heavily exploited.

In 1945, 9.5×10^9 kg of aggregate products were excavated in Ontario. By 1979 this figure had increased nearly 13 times to 120.4×10^9 kg per year (Eagles et al. 1979). The large scale extraction of this commodity has left many abandoned pits scattered across the countryside.

Since the passing of the Pits and Quarries Control Act in 1971, the Ontario provincial government has developed an administrative structure for the planning, operation and reclamation of aggregate operations within the Ministry of Natural Resources. All new proposals must obtain municipal planning and zoning approval as well as fulfill provincial licencing requirements.

The act states in section 4(2) that:

"An application for a licence to operate a pit or quarry shall be filed with the Minister and shall be accompanied by a site plan in quadruplicate, which shall include,

(a) the location, true shape, topography, contours, dimensions, acreage and description of the lands set aside for the purposes of the pit or quarry;
(d) existing and anticipated final grades of excavation, contours where necessary and excavation set backs;
(e) drainage provisions;
(g) as far as possible, ultimate pit development, progressive and ultimate road plan, any water diversion or storage, location of stockpiles for stripping and products, tree screening and berming, progressive and ultimate rehabilitation and, where possible, intended use and ownership of the land after the extraction operations have ceased;
(h) cross-sections where necessary to show geology, progressive pit development and ultimate rehabilitation";

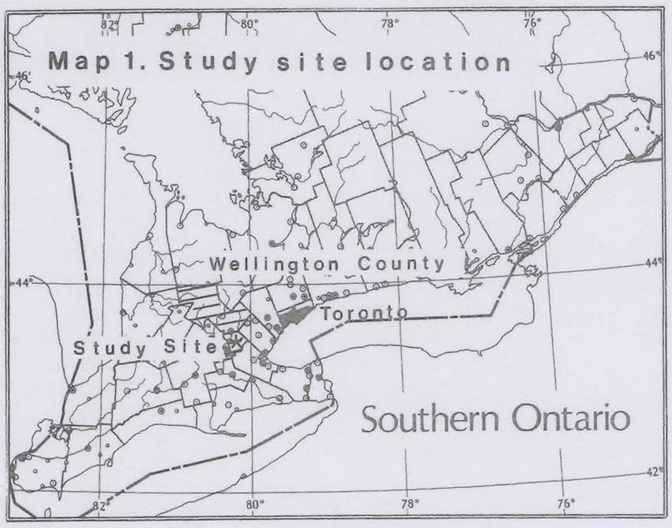
The opening of new pits and quarries is a controversial issue due to the associated negative social and environmental impacts (McLellan 1973, 1975, 1979). The 1971 Act requires that all pits licenced under the Act must have rehabilitation but no definition or guidelines are given in the legislation. Recently, the province has shown interest in developing some (Yundt and Booth 1978). After 10 years of operation an evaluation of the reclamation aspects of the law is possible. First, many sites have been abandoned after extraction is complete with no reclamation being attempted. In these cases the site sits fallow in the condition of the last day of operation. Second, site reclamation where it has occurred has usually been concerned with the creation of suitable conditions for the construction of industrial, commercial or residential structures (Coates 1976, Coates and Scott 1979). In a few cases agricultural uses such as orchards or pasture fields have been developed and occasionally recreation features such as golf courses or swimming lakes were created. (Anonymous 1978a, 1978b). Thirdly, planning for or research into the creation of natural ecosystems or wildlife habitats has been virtually nonexistant. Such areas that have developed are the result of natural ecological succession and not conscious intervention.

Research in Great Britain has shown quite conclusively that ponds and associated wetlands in old gravel pits can become quite valuable as habitat for waterfowl and other wetland species (Glue 1970, Harrison and Harrison 1972, Milne 1974, 1975, Catchpole and Tydeman 1975). Research has shown that some species of plants have the capacity to invade such derelict sites and start the colonization process (Booth 1941, Bramble and Ashley 1955, Dale, Harrison and Thomson 1965, Viereck 1966, Lee and Greenwood 1976, Usher 1979). In Great Britain 75 old mineral workings have been designated as Sites of Special Scientific Interest due to their biological importance (Johnson 1978). Given the rapidly developing conceptual (Dorney 1979) and scientific bases of ecological reclamation, researchers have started to work experimentally on selected areas such as in the Peace River of British Columbia (Errington 1979), Terra Nova National Park in Newfoundland (Richardson 1978) and the University of Guelph in Ontario (Low 1979). And now guidelines for active ecological intervention are becoming available to the environmental manager (Holz 1976, Mason 1978, Vogel 1977, Andresen 1978, 1979, 1981, Rafaill and Vogel 1978, Anonymous 1979, Strattan 1979, Coates and Morney 1980, Schiechtl 1980).

This paper briefly discusses the establishment of a research site for the investigation of the restoration of gravel pits with the aim of producing a natural ecosystem over time. Both natural ecological succession and active intervention will be investigated.

CRIEFF STUDY AREA BACKGROUND

The Crieff study area is a 30 ha gravel pit located 20 km south of Guelph and 40 km north of Hamilton (Map 1). The pit has been in operation



intermittently for over 30 years. It is expected that the remaining gravel will be removed in 1982. The pit and adjacent areas are owned by the Hamilton Region Conservation Authority. Conservation Authorities are independent resource management agencies established on a watershed basis with primary responsibility for water management and near-urban outdoor recreation. Funding is obtained from provincial grants and a tax on private property.

South of the pit is part of an extensive 690 ha forested swamp (Figure 1) that lies in a wide east-west valley between two large terminal moraines. The morainic deposits have partially blocked surface drainage and allowed the development of wetlands including the 20 km long Beverly Swamp and the 5 km long Fletcher Creek Swamp. The wetlands adjacent to the research pit are part of the headwaters of the Fletcher Creek as springwater moves out of the bedrock in numerous locations. The springs feed high quality streams that support a viable and large population of Brook Trout (*Salvelinus fontinalis*). In addition to the wetland forests, marshes and sedge meadows occur frequently and upland deciduous forests are found on dry ground.

Fig. 1. The Excavation site is adjacent to a large and diverse swamp.

The wetland ecosystems have been studied by members of the Guelph and Hamilton Naturalist Clubs since the 1920's. They discovered that the site harbored a high diversity of plants and wildlife including a number that were regionally and provincially rare. Eagles et. al. (1976) and Foster and Eagles (1976) stated that the wetlands could be considered to be Environmentally Sensitive Areas (Eagles 1981) and were worthy of long term protection.

North and east are a series of dry morainic fields that are also considered to be Environmentally Sensitive Areas since they contain several rare species of birds.

West of the pit is a local township road and another, larger gravel pit.

In 1976 the gravel pit was purchased by the Hamilton Region Conservation Authority with funds provided by the Hamilton Naturalist's Club and the Province of Ontario. The Authority wanted a portion of the swamp that was up for sale and the pit was an extra bonus. The Authority was primarily interested in protecting the creek headwaters and the naturalists wanted to protect the rare plant community.

A proposal was made for the establishment of the pit as long-term ecological research and display site for ecological succession and reclamation experiments (Carloss and Kearney 1978, Eagles, Ambrose and Oxby 1979). The site was ideal for research purposes because it was in public ownership and therefore long-term experiments could be established without concern for later land use change. The general intent of the proposal was accepted by the Authority and the naturalists.

The major research questions to be addressed in this study site are:

1) What species of plants and wildlife will naturally move into a derelict gravel pit over time in this part of Ontario?
2) In what order will the ecological succession take place?
3) What design features could maximize the succession rate and ecological diversity?
4) Is it possible to increase the succession rates by low cost planting and introduction experiments?
5) Is it possible to create a natural ecosystem over time in a derelict gravel pit?

THE 1981 FIELD STUDY RESULTS

From June through September 1981 an extensive biophysical survey of the pit and adjacent areas was undertaken (Eagles and Gwertz 1982). Inventories and mapping were done for the vegetation, mammals, birds, reptiles, amphibians, fish, soils and to a lesser extent aquatic invertebrates and groundwater hydrology. Site photography was carried out as well.

The swamp forests to the south were dominated by White Cedar (*Thuja occidentalis*) and Tamarack (*Larix laricina*). The upland forests on the drier soils were dominated by Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*) and Eastern Hemlock (*Tsuga canadensis*). The ground flora in the swamps was particularly rich with a large number of species and close to 100% ground cover. Four species of provincially rare plants (Argus and White 1977); Ram's Head Orchid (*Cypripedium arientinum*), Fragile Fern (*Cystopertis fragilis*), Rough-leaved Goldenrod (*Solidago patula*) and Black Walnut (*Juglans nigra*) grew in the swamp. One species of provincially rare bird (Eagles and McCauley 1982) Blue-winged Warbler (*Vermivora pinus*) breed in a second growth upland forest. In addition 13 species of plants, that were rare within the county, and 26 species of breeding birds, that were rare within the county or on the Blue List (Tate 1981) lived in the wetlands. The wetlands were also important habitat areas for several amphibian and reptile species including Pickerel Frog (*Rana palustris*) which has demanding habitat requirements similar to Brook Trout.

The fields to the north had a sparse growth of grasses and herbs that were adapted to the thin soils over coarse gravel and till deposits. The five most common plants were: Canada Blue Grass (*Poa compressa*), Yellow Hawkweed (*Hieracium floribundum*), Wild Carrot (*Daucus carota*), Black Medick (*Medicago lupulina*) and Common Daisy (*Chrysanthemum leucanthemum*). It was found that the habitat of two of the species of rare birds, Dickcissel (*Spiza americana*) and Henslow's Sparrow (*Ammodramus henslowii*), had been destroyed by all-terrain vehicle use. But the Grasshopper Sparrow (*Ammodramus savannarum*) was still found in large numbers.

The pit is located in well-sorted glacial outwash sands and gravels. Some lacustrine sand deposits are also evident. Dolomite bedrock is close to or at the surface over much of the area of the valley. The bedrock averages 80m in thickness and consists of a cream-coloured medium or fine crystalline limestone-dolomite of thick bedding and high purity. It is highly fractured and serves as an excellent groundwater aquifer. The magnesium concentration of the dolomite make it of commercial value as a steel flux and one large proposal for excavation within and adjacent to the wetlands is a point of considerable dispute (Dyer and Galetin 1978, Wilson 1976).

The gravel pit was found to have two main habitat types: a wetland centered on an old pond (Figure 2) and the dry, gravel deposits and pit workings.

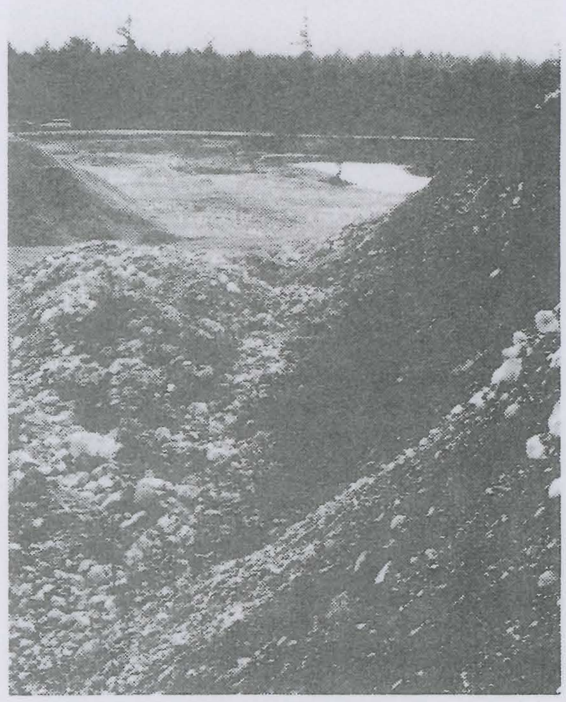


Fig. 2. An isolated pond has developed an interesting vegetative community through primary succession.

The open gravel workings varied from boulders of in size to fine sands and clays scattered in a random distribution around the site. In areas where active e cavation had ceased some plant growth was observed. The majority of the herbs were perennials and biennials including: Bittercress (*Cardamine pennsylvanica*), St. John's Wort (*Hypericum perforatum*), Black Medick, Wild Carrot, Canada Blue Grass, Daisy, Goldenrod (*Solidago sp.*) and Sweet Clover (*Melilotus sp.*). Most of the individuals were growing in pockets of fine material between larger cobbles or in areas of water erosion deposition. Moisture stress was commonly observed on hot summer days. Some woody plants starting to invade included: White Cedar, White Birch (*Betula papyrifera*), Balsam Poplar (*Populus balsamifera*), Chokecherry (*Prunus virginiana*) and Staghorn Sumac (*Rhus typhina*).

Most of the species invading the pit came from the fields and their associated hedgerows. Adaptive invasion characteristics which seemed to be effective were: wind-blown seed dispersal, rhizomatous growth once established, drought resistance and the ability to survive wide fluctuations in temperature. It is reasonable to expect that plant species with these characteristics would slowly turn the pit into an old field community over time.

The dry pit provided breeding habitat for Grasshopper Sparrow, Savannah Sparrow (*Passerculus sandwichensis*), Vesper Sparrow (*Pooecetes gramineus*), Killdeer (*Charadrius vociferus*) and Horned Lark (*Eremophila alpestris*). The last 3 occupied the hardpan area on the pit floor. Sand lenses in exposed banks were heavily utilized with one nest of Belted Kingfisher (*Megaceryle alcyon*), one nest of Rough-winged Swallow (*Stelgidopteryx ruficollis*) and 73 nests of Bank Swallow (*Riparia riparia*). The open areas were not colonized by any mammals, reptiles or amphibians, probably due to lack of cover and water.

The pond and its edge wetlands occurs in a sheltered corner of the pit and over time has developed an interesting biological community. The pond was created by the excavation of gravel below the water table and all succession has been primary. Groundwater constantly enters through the gravels along the northern edge and exists along the south in a similar fashion. The average depth was 40cm with a maximum of 3.5m and a water flow of .84m^3/sec. A dense growth of shrubs and trees has developed along the western edge and was composed of Trembling Aspen (*Populus tremuloides*), White Birch (*Betula papyrifera*), Willow (*Salix sp.*), White Cedar and Tamarack. Under the trees and in fine muds along the shore a herbaceous groundcover has started to develop with sedges (*Carex sp.*), rushes (*Juncus sp.*), bulrushes (*Scripus sp.*) and cattails (*Typha sp.*). Interestingly, four species of regionally rare plants (Eagles et. al. 1976) now grow in this regrowth area. Loesel's Twayblade (*Liparis loeselii*), Nodding Ladies' Tresses (*Spiranthes cernua*), and Northern Green Orchis (*Habenaria hyperborea*) are 3 species of orchids which have seeded naturally while the Fringed Gentian (*Gentiana crinita*) comes from seeds scattered by a wildflower photographer.

The individual plants are growing in areas of fine soil between gravel cobbles or along the water edge. The detritus and vegetation mat has just started to build up. This open condition appears to have deterred the colonization of small mammals as very few were observed. The rapid colonization of this wetland shows the importance of moisture in a gravel pit for seed germination and subsequent plant growth. The seed source for these plants was the swamp and forest land to the south. The lack of topsoil and the associated lack of a dense mat of perennial vegetation may have allowed for easier germination of seeds and kept rodent browsing to a minimum. Girdling and other damage to young trees is a major mortality factor of young trees in old fields.

The pond and primary-growth vegetation was utilized for breeding by Killdeer, Gray Catbird (*Dumetella carolinensis*), Spotted Sandpiper (*Actitis macularia*), Red-winged Blackbird (*Agelaius phoeniceus*), Song Sparrow (*Melospiza melodia*), American Robin (*Turdus migratorius*) and American Goldfinch (*Carduelis tristis*). Several bird species foraged in the area but nested elsewhere. These included: Belted Kingfisher, Bank Swallow, Rough-winged Swallow, Cedar Waxwing (*Bombycilla cedrorum*), American Kestrel (*Falco sparverius*) and Blue Jay (*Cyanocitta cristata*).

The pond water quality was good. Both Red-bellied Dace (*Chrosomus eos*) and Central Mudminnow (*Umbra limi*) were found in the pond. The mechism of colonization was not known but the species have built up a healthy population.

SUMMARY

The research at the Crieff Case Study Site is in the initial stages. To date a number of tentative conclusions are possible:

1) Gravel pits have the potential for reclamation to a relatively natural ecological condition in southern Ontario.
2) The plants which first colonize are most likely to be the result of seed dispersal from nearby ecological communities.
3) Topsoil is not always necessary for woody and herbaceous plant growth.
4) Open, exposed pit faces with sand lenses can provide nesting habitat for birds that dig nest holes, such as swallows and kingfishers.
5) Hot, dry, summer conditions in the open exposed conditions of a pit are a limitation to plant growth.
6) Water bodies and wetlands have the potential

for rapid plant and wildlife colonization and growth. A large number of wetland species have the dispersal capacity that enables movement to a new site, often over considerable distances.
7) Tree seed germination and subsequent growth may be facilitated by the lack of topsoil and a heavy herbaceous plant mat.
8) Birds appear to be the first wildlife group to move into an abandoned pit, with several species such as Killdeer and Horned Lark utilizing the pit during actual operation.
9) Primary and secondary succession is an inexpensive reclamation technique.
10) Natural ecological reclamation has a comparatively low annual maintenance cost.
11) The pit floor with a heavily compacted gravel soil provides a limitation to plant growth. Scarification with heavy equipment should be used to open and break up the surface layer. If possible, a series of ridges and hollows should be created in order to create slight microsite variation.
12) Ponds should contain islands for the nesting of waterfowl. Mammalian predation on nests should be partially limited due to the water barrier.
13) A diversity of slopes, soil types, exposures, moisture regimes and water depth will allow the development of a diversity of ecosystem types.

ACKNOWLEDGMENTS

Special thanks must go to the Hamilton Naturalist's Club whose members first drew my attention to the area, who raised money to buy the property, and who are interested in all aspects of resource conservation. Special thanks to Marion Shivas, Phyllis Morrow and the late Robert McLaren. The Hamilton Region Conservation Authority staff and in particular Ben Vanderbrug, John Coates and Bruce MacKenzie have been very supportive of the project. Thanks to Dr. John Ambrose for establishing the research project on mechanisms of hardwood planting and establishment. Dan Svedarsky commented on an earlier draft.

Monica Gewurz, Ed Poropat, Phil Taylor, Cindy Obee and Sherry Amsden worked on the 1981 field inventories of the site. The research was supported by grants from the Ontario Ministry of the Environment and the Hamilton Region Conservation Authority.

LITERATURE CITED

Andresen, J. 1978. Natural Regeneration and Direct Seeding Techniques to Stabilize Ontario's Roadsides. IR 73 Progress Report 1. Ontario Ministry of Transportation and Communications, Downsview, Ontario. 19 pp.

Andresen, J.A. 1979. Regeneration and Direct Seeding Techniques to Stabilize Ontario's Roadsides. IR 73 Progress Report 2, Ontario Ministry of Transportation and Communications, Downsview, Ontario. 29 pp.

Andresen, J.A. 1981. Natural Regeneration and Direct Seeding Techniques to Stabilize Ontario Roadsides. Policy Planning and Research Division, Ontario Ministry of Transportation and Communications, Downsview, Ontario. 67 pp.

Anonymous. 1978a. Unique Gravel Pit features Golfing and Fishing. Interface 1:1.

Anonymous. 1978b. Former Gravel Pit New Conservation Area. Interface 1:3.

Anonymous. 1979. User Guide to Vegetation Mining and Reclamation in the West. USDA For. Serv. Gen. Tech. Rept. INT-64, Ogden, Utah. 88 pp.

Argus, G. and D. White. 1977. The Rare Vascular Plants of Ontario. National Museum of Natural Sciences, Ottawa, Ontario. 63 pp.

Booth, W.E. 1941. Revegetation of Abandoned Fields in Kansas and Oklahama. Am. J. of Botany 28: 415-422.

Bramble, W.C. and R.H. Ashley. 1955. Natural Revegetation of Spoil Banks in Central Pennsylvania. Ecology 36: 417-423.

Carloss, J. and J. Kearney. 1978. A Design for Gravel Pit Reclamation with Natural Areas as an End Point. Unpublished ms., Department of Man-Environment Studies, University of Waterloo, Waterloo, Ontario. 85 pp.

Catchpole, C.K. and C.F. Tydeman. 1975. Gravel Pits as New Wetland Habitats for the Conservation of Breeding Bird Communities. Biol. Conserv. 8:47-59.

Coates, W.E. 1976. How to Recover a Quarry. Bulletin of the Conservation Council of Ontario 23:4-7.

Coates, W.E. and O. Scott. 1979. A Study of Pit and Quarry Rehabilitation in Southern Ontario. Ministry of Natural Resources, Toronto, Ontario.

Coates, W.E. and P.F. Morney. 1980. Screen Plantings for Pits and Quarries. Aggregate Producers' Association of Ontario. 14 pp.

Dale, H.M., P.J. Harrison and G.W. Thomson. 1965. Weeds as Indicators of Physical Site Characteristics of Abandoned Pastures. Can. J. of Botany 43: 1319-1327.

Dorney, R.S. 1979. The Ecology and Management of Disturbed Urban Land. Landscape Arch (May): 268-272.

Dyer, T. and K. Galetin. 1978. The Quarry Licence Application Process in Ontario - A Case Study of the Resource Use Conflict with the Fletcher Creek Swamp Forest Quarry Proposal. Unpublished ms, Department of Man-Environment Studies, University of Waterloo, Ontario. 66 pp.

Eagles, P.F.J. 1981. Criteria for the Designation of Environmentally Sensitive Areas. Pages 68-79 in S. Barrett and J. Riley, eds. Protection of Natural Areas in Ontario. Working Paper Number 3, Faculty of Environmental Studies, York University, Downsview, Ontario. 185 pp.

Eagles, P., J. Ambrose and B. Oxby. 1979. A Proposal to Establish an Ecologically Based Gravel Pit Reclamation Site Plan and a Long-Term Environmental Monitoring Program on the Crieff Bog Property. University of Waterloo, Waterloo, Ontario.

Eagles, P., W. Elrick, D. Foster, S. Muirhead, M. Stewart, J. Van De Hulst and C. Waterston. 1976. South Wellington Environmentally Sensitive Areas Study. Centre for Resources Development, Publication No. 79, University of Guelph, Guelph, Ontario 212 pp.

Eagles, P.F.J. and M. Gewurz. 1982. The Natural Resources of the Fletcher Creek Swamp Forest Conservation Area. Department of Recreation, University of Waterloo, Waterloo, Ontario.

Eagles, P.F.J. and J.D. McCauley. 1982. The Rare Breeding Birds of Ontario. University of Waterloo Biology Series Number 24, Waterloo, Ontario. 28 pp.

Errington, J.C. 1979. Revegetation studies in the Peace River coal block, 1978. Paper 1979-3. Ministry of Energy, Mines and Petroleum Resources, Province of British Columbia, Victoria, B.C. 79 pp.

Foster, D.A. and P.F. Eagles. 1976. Fletcher Creek Swamp Forest - An Environmental Study. Experience '76, University of Guelph, Guelph, Ontario.

Glue, D.E. 1970. Changes in the Bird Community of a Hampshire Gravel Pit 1963-68. Bird Study 17: 15-27.

Harrison, J. and J. Harrison. 1972. Gravel Pit Management for Wildfowl and Other Birds. Page 217-233 in E. Dennis, ed. Everyman's Nature Reserve - Ideas for Action. David & Charles, Newton Abbot, England. 256 pp.

Holz, P. 1976. South African Operation Uses Ecological Plans. Pit and Quarry Nov: 52-53.

Johnson, M.S. 1978. Land Reclamation and the Botanical Significance of Some Former Mining and Manufacturing Sites in Britain. Env. Cons. 5: 223-228.

Lee, J.A. and B. Greenwood. 1976. The Colonization by Plants of Calcareous Wastes from the Salt and Alkali Industry in Cheshire, England. Biol. Conserv. 10: 131-149.

Lowe, S. 1979. Gravel Pit Rehabilitation Collection. Arboretum, University of Guelph, Guelph, Ontario. 2 pp.

Mason, W.F. 1978. Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities. FWS/OBS-78/30. USFWS, Harpers Ferry, West Virginia. 157 pp.

McLellan, A.G. 1973. Derelict Land in Ontario. Bulletin of the Conservation Council of Ontario 20: 9-14.

McLellan, A.G. 1975. The Aggregate Dilemma. Bulletin of the Conservation Council of Ontario. 22: 12-20.

McLellan, A.G., S.E. Yundt and M.L. Dorfman. 1979. Abandoned Pits and Quarries in Ontario. Ont. Geol. Surv. Mis. Paper 79. 36 pp.

Milne, B.S. 1974. Ecological Succession and Birdlife at a Newly Excavated Gravel Pit. Bird Study 21: 267-278.

Milne, B. 1975. Gravel Pit Studies. BTO News 72: 1-2.

Rafaill, B.L. and W.G. Vogel. 1978. A Guide for Revegetating Surface-Mined Lands for Wildlife in Eastern Kentucky and West Virginia. USFWS/OB-78/74, Berea, Kentucky, 89 pp.

Richardson, J. 1978. Experimental Techniques and Species for Revegetating Gravel Pits in Terra Nova National Park. Newfoundland Forest Research Center Report N-X-163, St. Johns.

Schiechtl, H. 1980. Bioengineering for Land Reclamation and Conservation. University of Alberta Press, Edmonton, Alberta. 404 pp.

Stratton, J. 1979. Cover Crops for Pits and Quarries. Interface 2: 2-4.

Tate, J. 1981. The Blue List for 1981. American Birds 35: 3-10.

Usher, M.B. 1979. Natural Communities of Plants and Animals in Disused Quarries. J. of Env. Manag. 8: 223-236.

Viereck, L.A. 1966. Plant Succession and Soil Development on Gravel Outwash of the Muldrew Glacier, Alaska. Ecol. Monographs 36: 181-199.

Vogel, W.G. 1977. Revegetation of Surface-Mined Lands in the East. Proceedings of Society of American Foresters: 167-172.

Wilson, I. 1976. Preliminary Environmental Impact Study of a Proposed Quarry Operation. Wilson Associates for Steetley Industries Ltd. Unpublished ms. 30 pp + maps.

Yundt, S.E. and G.D. Booth, 1978. Bibliography-Rehabilitation of Pits, Quarries and Other Surface-Mined Lands, Ont. Geol. Surv. Mis. Paper 76. 27 pp.

The Effects of Aggregate Extraction on Deer Habitat Preferences in Southern Ontario

HARRY N. CHABWELA, Department of Zoology, University of Guelph, Guelph, Ontario, and

F. F. GILBERT, Wildlife Biology, Washington State University, Pullman, Washington.

INTRODUCTION

As a result of increasing environmental awareness (Owen 1975), aggregate extraction which has been expanding in southern Ontario since 1947 (Hewit and Karrow 1963, Vos 1972, Hoffman 1974, Proctor and Redfern, 1974) is recognized not only as potentially unaesthetic, but also is associated with the destruction of vegetation, and noise and dust emission (Down and Stocks 1977). Ecological impacts resulting from aggregate extraction have not been carefully assessed in southern Ontario, although numerous studies have been conducted on gravel pit rehabilitation (Coates and Scott 1979, McLellan *et al.* 1979).

A number of previous studies have shown that although most aggregate pits are characterized by their close proximity to urban and agricultural areas (Catchpole and Tydeman 1975), the creation of aquatic and marshland habitats has been a major contribution by aggregate industries to some wildife species (Glue 1970, Harrison 1970, Catchpole and Tydeman 1975). However, these studies have concentrated mainly on abandoned gravel pits. The question still remains as to how wildlife responds to active aggregate pit operations.

The white-tailed deer *(Odocoileus virginianus)* is a very important economic resource in southern Ontario (Cumming and Walden 1970, Chabwela 1978), and although the species is widely distributed in this region (Cumming and Walden 1970, Campbell and Dagg 1972), relatively little is known about the effects of aggregate extraction operations on deer. The study objective was to assess how deer habitat utilization is affected by the activities of aggregate extraction.

METHODS AND STUDY AREA

The present study was one part of a larger investigation on the effects of aggregate extraction operations on wildlife, and studies on deer were conducted for two years (1980 and 1981) at an aggregate site in Wellington County, southern Ontario. The study site was approximately 100 hectares, and was located between 80°08' - 80°10'W and 43°27' - 43°29'N at an altitude of 308-330 m near Aberfoyle. This study site had had active gravel extraction since 1963 (Lowe 1981).

The annual mean temperature in Wellington County is 7.0°C, and the mean annual precipitation 61.96 mm (Hoffman *et al.* 1963). Topographical features in Wellington County mainly consist of glacial deposits which are the principal sources of aggregate minerals (Hewit and Karrow 1963).

Eight primary habitat types in the study sites were identified:

(a) Maple-basswood: A mature, undisturbed hardwoods habitat dominated by sugar maple *(Acer saccharum)* in the overstory and by red ash *(Fraxinus pennsylvanica)* in the understory. The ground vegetation was co-dominated by *Metteuccia struthiopteris, Parthenocissus vitacea* and *Asarum candense.*

(b) Birch-tamarack: A seasonal swamp with scattered trees of mainly white birch *(Betula papyrifera)*, tamarack *(Larix laricina)* and a very dense shrub layer dominated by red osier dogwood *(Cornus stolonifera)*. *Rubus occidentalis* and *Impatiens biflora* were co-dominant as ground cover.

(c) Willow-aspen: A seasonal swamp with scattered trees of mainly trembling ash *(Populus tremuloides)* and a very thick shrub layer consisting predominantly of *Cornus stolonifera.* The ground vegetation was composed of *Solidago* sp., *Rubus occidentalus* and *Impatiens biflora.*

(d) Mixed Cedar: A mixed coniferous and hardwood association with eastern white cedar *(Thuja occidentalis)* most dominant. The ground vegetation was co-dominated by eastern white cedar and *Vitis aestivalis*.

(e) Pine Wood: An even aged coniferous stand consisting mainly of scotch pine *(Pinus sylvestris)*, red pine *(Pinus resinos)* and white pine *(Pinus strobus)*. *Solidago* sp. and *Hieracium florentinum* dominated the ground cover.

(f) Bulldozed Area: An area in which the vegetation cover was previously removed for purposes other than farming. The most common plants were *Hieracium florentinum*, *Solidago* sp. and *Plantago lanceolata*.

(g) Abandoned Field: An area which was previously a cropland and was mostly covered by *Poa pratensis*, *Solidago* sp., *Hieracium florentinum*, *Agrostis alba* and *Echium vulgare*.

(h) Rehabilitated Area: A zone which was proximal to the gravel pit, and had a rehabilitation age of nearly 15 years. The most dominant plant species included *Poa pratensis*, *Agropyron repens*, *Daucus carota*, *Potentilla argentea*, *Trifolium pratense*, *Phleum pratense* and *Agrostis alba*.

Table 1.--The stratification of the area based on the variable ranking or blocking.

Variable	Rank or Block		
	A	B	C
Total mean noise level	<45dB	45<>50dB	>50dB
Mean machinery noise	<50dB	50<>60dB	>50dB
Mean ambient noise	<45dB	>45dB	[1]
Mean differences between ambient and machinery noise	< 5dB	> 5dB	
250 Hz	<40dB	>40dB	
500 Hz	<40dB	>40dB	
1000 Hz	<40dB	>40dB	
2000 Hz	<35dB	>35dB	
4000 Hz	<20dB	>20dB	
Dustfall distribution	<0.5gm/ m^2/day	>0.5gm/ m^2/day	
Habitat exposure to traffic	Exposed	Unexposed	
Canopy occurrence	Closed	Broken	Open
Horizontal habitat visibility	<50%	>50%	
Ground plant diversity	<1.00 decits	>1.00 decits	
Ground plant biomass	<50 gm/ m^2	>50 gm/ m^2	

[1]Blanks indicate rank of category not available.

EXPERIMENTAL DESIGN

The basic study model assumed deer would concentrate their distributions in areas away from the center of aggregate operations. This was based on the assumption that the impact of the disturbance (noise, dustfall and traffic) would decrease with increasing distance away from the source (Holling 1978). The study site was therefore divided into 4 blocks by distance away from the gravel pit (0-.27, .27-.36, .36-.55, and .55-.73 km), but each block also was stratified by habitat types. The study design allowed for the stratification of the area by either variable ranking or blocking (Table 1).

Ground plant composition was quantified within a square meter frame (Muller-Dombois and Ellenberg 1974) and ground plant diversity indices were determined by the Shannon index formula: H' = - Pi log Pi as described by Odum (1971), and the ground plant standing crop was also estimated (Rochow 1974) for each habitat block. Both the diversity indices and dry weight biomass were ranked (Table 1) for the area stratification. Noise levels were quantified by sound level meters (Bruel and Kjaer Company, Models 2204 and 2219) (Hassal and Zaveri 1979). Noise was sampled under ordinary conditions (Peterson and Gross 1972, Harrison, 1978) of daily gravel pit activity for each habitat block, and the distribution of noise was also ranked (Table 1) for the area stratification. Dustfall was sampled by a simple dust collector (Warner 1975) based on the standards set for dustfall survey AMP1, Revision 1 (Herrick, 1966). The dust was analysed in the laboratory (Katz 1977), and the values were ranked (Table 1) for the area stratification. The area was also stratified by habitat visibility measured by a density board (Jones 1968, Nudds 1972).

The distribution of deer was determined by 18 (10 x 2 m) permanently located deer track plots in each habitat block (Kearney and Gilbert 1976). These plots were regularly maintained by using the pellet count method (Neff 1968) in which 20 (40 m^2) plots were spaced at 15 m intervals along the middle transects of each habitat block. Deer densities were calculated by the formula (King 1976):

$$\text{Deer/km}^2 = \frac{\text{mean pellet per plot x 100 ha}}{\text{total sampled area x 205 days/ 12.7 pellet groups/deer/day}}$$

The deposition period was estimated from October 1980 to early April 1981.

Deer habitat selection in relation to gravel pit operations was tested by the Kruskal-Wallis one way ANOVA by ranks (Siegel 1956), and the analysis was performed by using the Statistical Package for Social Sciences (SPSS) computer program (Nie *et al.* 1970, Nie and Hull 1977). The statistical tests were designed to show (a) if there were any differences between/among the distances as we moved away from the gravel pit in the manner in which deer tracks distributed, and (b) if there were any differences between/ among areas based on the variable ranking or grouping (Table 1) in relation to deer track occurrence.

RESULTS

General Habitat Effects

Although deer tracks were recorded in all plots, the analysis based on the plot ranks by deer use (Table 2) showed that the most important habitat in the area was the birch-tamarack (22.2%). The rehabilitated area had the highest "poor" habitat use (83.3%). Based on the pellet group counts, the estimated mean deer population density at the study site was 1.95 km^2 (Table 2), but apparent densities were higher in the birchtamarack (3.31/km^2) and maple-basswood (3.14/km^2) habitats. Although ground plant diversity and ground plant biomass did not show any meaningful relationships with the way deer tracks were distributed, both canopy occurrence and horizontal habitat visibility showed considerable influence on deer track occurrence (Table 3). Deer showed more preference for habitats with low horizontal habitat visibility and a broken canopy.

Effects of Aggregate Pit Operations

Deer track distributions generally showed no specific gradient relationship to distance from the center of gravel pit activity (Table 4); however, the block distances in the maple-basswood and willow-aspen were significantly different ($P \leq 0.05$) and deer track mean ranks were lower in the blocks closer to the gravel pit. Although deer track distributions were not significantly different ($P \geq 0.05$)

Table 2.--Deer densities (/km^2) and percent habitat utilization of each habitat.

Habitat	Pellets		Tracks (%)		
	Deer/ km^2	S.D.	High >50	Moderate <50>0	None 0
Entire Area	1.95	±3.36(360)	4.3	38.3	57.7
Maple-Basswood	3.14	±5.11(40)	2.8	61.1	36.1
Birch-tamarack	3.31	±4.52(40)	22.2	61.1	16.7
Willow-aspen	2.90	±3.82(40)	2.8	27.8	64.4
Mixed cedar	2.03	±5.32(40)	0.0	38.9	61.1
Pinewood	0.18	±0.91(60)	0.0	44.4	55.6
Bulldozed Area	--	-- (40)	0.0	33.3	66.7
Abandoned Field	0.12	±0.51(40)	5.6	33.3	61.1
Rehabilitated Area	--	-- (60)	1.9	14.8	83.3

Table 3.--The mean ranks by Kruskal-Wallis one way ANOVA by ranks for testing the difference in the occurrence of deer tracks among blocks of each variable.

Variable*	Block			Chi-Squared	Significance
	A	B	C		
Canopy occurrence	168.49	191.56	139.90	18.310	0.000
Horizontal habitat visibility	187.73	146.44		18.530	0.000
Ground plant diversity	181.44	150.45		10.440	0.001
Ground plant biomass	146.67	175.15		9.150	0.002

*Refer to Table 1 for variable ranking and blocking.
Significance level is accepted at $P \leq 0.05$.
Blanks indicate rank or category not available.

between blocks in the bulldozed area and the abandoned field (Table 4), the track mean ranks were however lower in the blocks towards the gravel pit, but this pattern was reversed in the birch-tamarack, mixed cedar and pinewood habitats in which lowest mean ranks occurred away from the gravel pits.

Statistical tests on the area stratification based on the variable ranking and blocking of the aggregate effects showed the distribution of deer tracks to be significantly different ($P \leq 0.05$) in general between/among areas for most variables (Table 5). Although the area blocks based on the difference between ambient and machinery noises were not significantly different ($P \leq 0.05$), deer track mean ranks were lower in the areas where this difference was wide (Table 5). Deer also showed considerable preference for the areas in which noise and dustfall ranked low and in areas which were not exposed to traffic (Table 5).

DISCUSSION

The study model in which deer tracks would increase with the distance away from the gravel pit did not seem to work for all habitat types at the Aberfoyle gravel pit. Although Holling (1978) introduced the term "dilution of impact, paradigm" referring to the view that an industrial impact would decrease with increasing distance away from the source disturbance, he also indicated that the response of a species to any gradient effect would depend also on numerous factors including the species' own behavioral characteristics. Reasons for the failure of a gradient model to yield the expected results have been listed by Krebs (1972) and also discussed elsewhere (Pielou 1974, Green 1979). Apart from the usual experimental errors (Beers 1957, Lyon 1970), habitat physiographic factors and species behavior tend to cause considerable influence on the gradient model. However, although use of the coniferous forests and the birch-tamarack did not show the expected response to the gradient model while the maple-basswood and willow-aspen habitats did, it can still be reasonable to conclude that deer activities would be expected to be lowest in areas immediately surrounding an active gravel pit.

Although the generally accepted view is that deer adjust quite successfully to human activities, the present data and other specific field studies on deer behavior (Dorrance *et al.* 1975) seem to contradict this view. For example, the relationship of deer track signs and noise occurrence at Aberfoyle site indicated that deer are sensitive to environmental noise. According to the model, there was a significant difference ($P \leq 0.05$) between high and low noise areas, with deer showing particular preference for the areas where noise was ranked low. There was no indication in the present data that deer had lost any fear for the aggregate pit operations despite the length of the time the mining had been operating.

When deer are often sighted near a construction site or a residential area, the usual speculation is that deer habituate quite readily to human disturbances. But, habituation as defined by Rachlin (1976) suggests that unless the effects of aggregate pit operations such as noise were regularly repetitive in continuous manner, i.e., that these effects were stable or predictable (Krebs 1972, Holling 1978), deer would not be expected to habituate. Although the present assessment was based on continuous noise, the general noise structure was, however, variable in the gravel pit, suggesting that deer

Table 4.--The mean ranks by Kruskal-Wallis one-way ANOVA by ranks for testing the differences in the occurrence of deer tracks between/among distances in each habitat.

Habitat	Blocks A	Blocks B	Blocks C	Corrected for ties: Chi-squared	Corrected for ties: Significance
Maple-basswood	14.06 (.27)	22.94 (.73)		6.772	0.009
Birch-tamarack	19.28 (.27)	17.72 (.55)		0.198	0.657
Willow-aspen	15.03 (.55)	21.97 (.73)		5.881	0.015
Mixed cedar	22.22 (.36)	14.78 (.73)		5.827	0.160
Pinewood	31.83 (.27)	27.42 (.55)	23.25 (.73)	3.241	0.198
Bulldozed area	15.86 (.36)	21.14 (.73)		3.209	0.073
Abandoned Field	17.36 (.27)	19.64 (.36)		0.545	0.460

Sample counts = 18 per each block in each habitat.
Significance level is accepted at $P \leq 0.05$.
Blanks indicate category not available.
Distances (km) of each block from the main gravel pit are given in brackets.

would not ignore the noise at the gravel pit as long as the noise structure was not stable.

The complexity of the factors that are associated with the effects of traffic on deer have been discussed elsewhere (Puglisi *et al.* 1974, Carbaugh *et al.* 1975, Allen and McCullough 1976). However, the significant difference between the habitats which were and were not, exposed to both human and vehicular traffic at Aberfoyle gravel pit seem to confirm previous findings (Dorrance *et al.* 1975) that deer are shy of traffic. Studies which have shown deer not to be greatly affected by traffic along a freeway (Garbaugh 1975) may have been related to the availability of sufficient vegetation and topography to provide suitable cover (Puglisi *et al.* 1974). Therefore the impact of traffic on deer habitat selection would be expected to be greatest in habitats where horizontal visibility was high.

Although there was a significant difference ($P \leq 0.05$) between the areas of less and greater than 0.5 gm/m^2/day dustfall in the manner in which deer selected their habitats at Aberfoyle, the general indication was that since the distribution of dustfall followed the general gradient pattern of decreasing with distance from the source, there is a strong possibility that other factors such as noise, traffic and vegetation structure might have had the most effect. Perhaps, if deer habitat selectivity was dependent on atmospheric visibility, direct effect might have been detected. The available field information on the effect of dustfall on wildlife (Klein 1971, Brandt and Rhoades 1972, Jop 1979, Sawicky-Kapusta 1979) generally emphasizes the deterioration of the habitat as a result of industrial dustfall. Although the present data satisfy the assumption of the model, conclusions would not be possible at this time because there was no field determinations of the effect of dustfall on the quality of deer habitat.

The general conclusion based on this study model is that because the effects of aggregate operations are not stable, and because deer are sensitive to noise and traffic, it is reasonable to speculate that aggregate extraction activities are not compatible with those of deer. However, we strongly believe that the effects of gravel pit operations would be considerably minimized if sufficient vegetation cover was available within the mining site. We also feel that since the present data were based on a single gravel pit, specific recommendations cannot be fully stated at present, and we therefore suggest that further studies are necessary in order to establish a complete picture of the effects of aggregate oeprations on white-tailed deer in southern Ontario.

Table 5.--The mean ranks by Kruskal-Wallis one way ANOVA by ranks for testing difference in the occurrence of deer tracks among blocks of each variable.

Variable*	Block A	Block B	Block C	Chi-squared	Significance
Total mean noise level	181.98	140.37	137.46	31.860	0.000
Mean machinery noise	184.29	146.59	120.13	24.490	0.000
Mean difference between ambient and machinery noise	167.23	155.06		1.611	0.204
250 Hz	184.29	140.71		21.720	0.000
500 Hz	182.05	138.07		21.850	0.000
1000 Hz	191.08	133.92		37.360	0.000
2000 Hz	172.50	142.48		9.170	0.002
4000 Hz	184.29	150.49	121.14	26.100	0.000
Dust fall distribution	172.50	146.30		7.640	0.006
Area traffic exposure	132.48	177.51		20.609	0.000

*Refer to Table 1 for variable ranking and blocking.
Significance level is accepted at $P \leq 0.05$.
Blanks indicate rank or category not available.

ACKNOWLEDGMENTS

We would like to thank the Government of Canada through the Canadian Commonwealth and Fellowship Committee and the Canadian National Research Council for their financial assistance, and we thank the Government for the Republic of Zambia through the Department of National Parks and Wildlife Service, Ministry of Natural Resources also for their financial support. We sincerely express our gratitude to TCG Materials Ltd. for their financial assistance and for allowing us to use their property as a study site, and finally we appreciate the assistance we received from the University of Guelph, School of Engineering and Department of Zoology for the use of their equipment and facilities.

LITERATURE CITED

Allen, R.E., and D.R. McCullough. 1976. Deer-car accidents in southern Michigan. J. Wildl. Manage. 40(2):3117-3125.
Beers, Y. 1957. Introduction to the theory of error. Addison-Wesley Publishing Co. Inc., Reading, Massachusetts, U.S.A. 66pp.
Bellis, E.D., and H.B. Graves. 1971. Deer mortality on Pennsylvania interstate highway. J. Wildl. Manag. 35(2):232-237.
Brandt, C.J., and R.W. Rhoades. 1972. Effects of limestone dust accumulation on composition of a forest community. Environmental Pollut. 3:217-225.
Campbell, C.A., and A.I. Dagg. 1972. Mammals of Waterloo and South Wellington Counties. Otter Press. 130 pp.
Carbaugh, B., J.P.Vaughan, E.D. Bellis, and H.B. Graves. 1975. Distribution and activity of white-tailed deer along an interstate highway. J. Wildl. Manage. 39(3):570-581.
Chabwela, H.N. 1978. Community resource use and an assessment of the exploitation of deer populations on Manitoulin Island. M.Sc. Thesis, Univ. of Guelph, Guelph, Ontario, Canada. 136 pp.
Catchpole, C.K., and C.F. Tydeman. 1975. Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8:47-59.
Coates, W.E., and O.R. Scott. 1979. A study of pit and quarry rehabilitation in southern Ontario. Ontario Ministry of Natural Resources, Queen's Park, Toronto. 67pp.
Cumming, H.G., and F.A. Walden. 1970. The white-tailed deer in Ontario. Fish and Wildlife Branch, Ontario Dept. of Lands and Forests. 24 pp.
Dorrance, M.J., P.J., Savage, and D.E. Huff. 1975. Effects of snowmobiles on white-tailed deer. J. Wildl. Manage. 39(3): 563-569.
Down, C.G., and J. Stocks. 1977. Environmental impact of mining. Applied Science Publishers Ltd., London. 371pp.
Glue,D.E. 1970. Changes in the bird community of a New Hampshire gravel pit, 1963-1968. Bird Study 17:15-27.
Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley-Interscience Publication. John Wiley and Sons, NY. 257pp.
Harrison, J. 1970. Creating a wetland habitat. Bird Study 17:111-123.
Harrison, R.T. 1978. Quantifying the acoustic dose when determining the effects of noise on wildlife. Pages 267-285 in J. L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. Academic Press, N.Y.
Hassal, J.R., K. Zaveri, and M. Phil. 1979. Acoustic noise measurements. Bruel and Kjaer Co. 280pp.
Herrick, R.A. 1966. Recommended standard method for continuing dustfall survey (AMP-1, Revision 1). J. Air Pollut. Control Assoc. 16(7):372-377.
Hewitt, D.F., and P.F. Karrow. 1963. Sand and gravel in southern Ontario. Industrial mineral report No. 11, Ontario Department of Mines. 151 pp.
Hoffman, D.W. 1974. Trends in land use in Ontario. Pages 1-6 in M. Waldron, ed. Ontario aggregate industry, problems and potentials. University of Guelph, Ontario.
Holling, C.S. 1978. Adaptive environmental assessment and management. John Wiley and Sons, N.Y. 377pp.
Jones, R.E. 1968. A board to measure cover used by prairie grouse. J. Wildl. Manage. 32:28-31.
Jop, K. 1979. Quality evaluation of roe deer antlers from an industrial region in southern Poland. Acta Theriol. 24:23-43.
Katz, M. 1977. Methods of air sampling and analysis. Alpha Intersociety Committee. Amer. Public Health Assoc., Washington, D.C. 948pp.
Kearney, S.R., and F.F. Gilbert. 1976. Habitat use by white-tailed deer and moose on sympatric range. J. Wildl. Manage 40:645-657.
King, D.R. 1976. Estimates of the white-tailed deer population and mortality in central Ontario, 1970-1972. Can. Field-Nat. 90(1):29-36.
Klein, R.D. 1971. Reaction of reindeer to obstructions and disturbances. Science 1973:393-398.
Krebs, C.J. 1972. Ecology: The experimental analysis of distribution and abundance. Harper and Row, Publishers, N.Y. 694pp.
Lowe, S.B. 1981. Progressive rehabilitation of a gravel pit - TCG Materials Limited, Aberfoyle. Mimeo. 4pp.
Lyon, J.A. 1970. Dealing with data. Pergamon Press, Oxford, England. 392pp.
McLellan, A.G., S.E. Yundt, M.L. Dorfman. 1979. Abandoned pits and quarries in Ontario. Ontario GEological Survey. Miscellaneous Paper 79. Ontario Ministry of Natural Resources. 36pp.
Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology.

John Wiley and Sons, N.Y. 547pp.
Neff, D.J. 1968. The pellet group count technique for big game trend, census and distribution: A review. J. Wildl. Manage. 32(3):597-614.
Nie, N.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner, and D.H. Bent. 1970. Statistical Package for the Social Science. McGraw-Hill Inc., U.S.A.
Nie, N.H., and C.H. Hull. 1977. Statistical Package for the Social Sciences. Update Manual. Computer Printout. University of Guelph, Science Computer Centre, Canada.
Nudds, T.D. 1977. Quantifying the vegetative structure of wildlife cover. Wildl. Soc. Bull 5(3):113-117.
Odum, E.P. 1971. Fundamentals of ecology. W. B. Saunders, Co., Philadelphia. 574pp.
Peterson, A.P.B., and E.E. Gross, Jr. 1972. Handbook of noise measurement. General Radio Co., Concord, Massachusetts. 322pp.
Pielou, E.C. 1974. Vegetation zones: Repetition of zones on a monotonic environmental gradient. J. Theor. Biol. 47:485-489.
Proctor and Redfern. 1974. Mineral aggregate study, central Ontario planning region. Ontario Ministry of Natural Resources. Rapid Blue Print Ltd., Toronto. (Unpaged).
Puglisi, M.J., J.S. Lindzey, and E.D. Bellis. 1974. Factors associated with highway mortality of white-tailed deer. J. Wildl. Manage. 38(4):799-807.
Rachlin, H. 1976. Behavior and learning. W. H. Freeman and Co., San Francisco. 613pp.
Rochow, J.J. 1974. Estimates of above-ground biomass and primary productivity in a Missouri forest. J. Ecol. 62:567-577.
Sawicka-Kapusta, K. 1979. Roe deer antlers as bioindicators of environmental pollution in southern Poland. Environ. Pollut. 19:283-293.
Siegel, S. 1956. Non parametric statistics for the behavioural sciences. McGraw-Hill Book Co., N.Y.
Vos, M. A. 1972. Aggregate resources of southern Ontario. Can. Mining and Metallurgical 65:65-68.
Warner, P.O. 1975. Analysis of air pollutants. John Wiley and Sons, N.Y. 329pp.

Wildlife Values and Management of Gravel Pits in Forest Ecosystems

JOHN E. MATHISEN, Chippewa National Forest, Cass Lake, MN 56633

An open area in a forested ecosystem is recognized as vitally important habitat, contributing to faunal diversity and to the welfare of many wildlife species (McCaffery and Creed 1969, McCaffery et al. 1981, Lay 1938, Keran 1974, Cross 1963, Taylor 1979). Most forest habitat management programs emphasize the significance and management of these habitats often referred to as "wildlife" or "permanent" openings. (McCaffery et al. 1981, U.S. Forest Service 1975).

Due to their structural characteristics, gravel pits - both operational and abandoned - provide opening types differing in wildlife values from those originating from homesteads, old fields or frost pockets. The purpose of this paper is to assess the value of gravel pit openings to those wildlife species who use them for feeding and breeding, and to provide recommendations land managers can utilize to enhance and manage these habitats in a forest ecosystem.

CHARACTERISTICS OF GRAVEL PITS

Gravel pits occur throughout the forested area of the Lake States in relatively small land units ranging in size from an acre or less to twenty acres or more. On the Chippewa National Forest in north central Minnesota, they account for about 10 percent of the opening community type and vary from 1 - 10 acres in size (Mathisen 1971). Most of these pits originate when relatively small quantities of gravel are extracted for local road construction; often for timber sale haul roads. Abandoned sites, unless totally depleted, are often reopened after many years of inactivity.

The diversity of vegetation and structure of gravel pits depend upon activity status, age, soil conditions and rehabilitation treatment. Unfortunately, from a wildlife habitat perspective, abandoned sites are often degraded by leveling and reforestation practices. A typical, abandoned pit consists of a mixture of grasses, shrubs and forbs, interspersed with bare ground. A steep slope or bank (usually occurring from excavation) is a typical structural feature. Occasionally water, resulting from excavation below the water table, will be present.

Although gravel pit openings proceed through vegetative succession very slowly after abandonment, they will eventually disappear, if unmanaged, due to the encroachment of the forest.

ORIENTATION OF WILDLIFE TO PERMANENT OPENINGS

Although the data presented here apply specifically to the Chippewa National Forest, the concepts and values are generally applicable throughout the forested region of the Lake States.

To provide a systematic way of simultaneously displaying the effects of habitat alteration on all species of wildlife, a Habitat Association Data Base was assembled (Mathisen 1980). The Data Base also facilitates the ranking and assessment of various vegetative communities in terms of vertebrate species richness. Used to evaluate gravel pits in terms of the wildlife community, these data will also provide a rationale for management.

Description of the Data Base

The Data Base consists of nine interrelated elements correlating 310 vertebrate species with habitat, season of use and status. The habitat types (communities) described by Niemi and Pfanmuller (1979) were modified to accommodate the conditions and vertebrate species on the Chippewa National Forest. These 24 communities reflect a combination of vegetation, successional stage and structure. The permanent opening is one of these communities.

Each species was categorized by the communities it utilizes for feeding and/or breeding. Since most species are oriented to more than one community, an attempt was made to assign one of these communities as being particularly important. This was termed the "critical community" for the species. It was impossible to assign a critical community to the more ubiquitous species.

The 310 vertebrates were also classified into 16 Life Forms, adapted from Thomas et al. (1979).

Eight categories were used to relate special habitat requirements to each species, (man-made structures, edge, decaying log, snags, riparian areas, mast and banks or bare ground). Those species having a special requirement of a bank or bare ground are particularly germane to the subject of this paper. Each species was also categorized as to season of use (migration, summer, winter, permanent resident) and status (threatened, endangered, sensitive, game/fur, indicator). The data were entered on an IBM OS/6 Word Processor for storage and manipulation, and to facilitate updating.

A gravel pit is a type of permanent opening, so the information in the Data Base concerning the species associated with openings can be generally applied to this assessment. A more specific and detailed analysis can then be made based on the unique habitat features of gravel pits and their relation to the special requirements of the associated vertebrate fauna.

Although permanent openings account for less than five percent of the upland communities on the Chippewa National Forest, there are 158 vertebrate species (51 percent of 310) having a primary orientation to them (Table 1).

Table 1. Vertebrates that feed and/or breed in permanent openings.

	No. of species			
	Feeds	Breeds	Both	Total
Birds	71	6	34	111
Mammals	15	0	21	36
Herps 1/	3	2	6	11
Total	89	8	61	158

1/ Reptiles and amphibians combined.

Among the 158 species associated with permanent openings, 22 are game/fur species, 7 are classified as sensitive, 2 are Federally endangered or threatened and 5 are management indicator species.

A further refinement of these data can be displayed by considering only those species that have the opening community designated as their "critical" community (Table 2).

Table 2. Orientation of vertebrates to permanent openings in relation to critical community.

	No. of species	Percent of total species in the class
Birds	38	17% (N=233)
Mammals	15	26% (N=57)
Herps	8	40% (N=20)
Total	61	20% (N=310)

Unique Qualities of Gravel Pits

Gravel pits, considered as a type of permanent opening, could potentially accommodate all of the species in Table 1. The animal community associated with specific gravel pits will depend on characteristics of the vegetation, presence of water and structural features.

The "uniqueness" of gravel pits, as compared to other openings in a forest ecosystem, is due to the presence of steep banks, storage piles of excavated material, and exposed mineral soil. There are 21 species (13 percent of the 168) oriented to openings that are associated with these features (Table 3). This group of vertebrates includes bank-nesting birds, such as the belted kingfisher and bank swallow; fossorial mammals such as the badger and woodchuck; and reptiles such as the snapping turtle that require bare ground for excavating a nest.

Unvegetated banks and mounds of surplus material created by excavation are favored "rendezvous" sites for the threatened gray wolf (Mech 1970, Murie 1944) and are frequently used by other canids (Bill Berg, pers. comm.). Deer and other mammals are also attracted to exposed soil typical of gravel pits, possibly for mineral content.

Clearly, gravel pits are important and valuable components of wildlife habitat, and if species diversity is a management goal, land managers should be aware that they deserve thoughtful and careful consideration.

MANAGEMENT OPPORTUNITIES

Of the 158 species associated with openings, 132 have one or more special requirements considered in the Data Base. These special requirements are directly related to habitat management strategies for gravel pits. Again, the Wildlife Habitat Association Data Base provides information

Table 3. Special requirements of species associated with openings.

	Number of species (N=158)						
	Snags	Edge	Riparian	Log	Mast	Banks	Bare Ground
Birds	23	60	34	8	9	5	6
Mammals	11	24	16	21	8	6	0
Herps	0	0	8	7	0	0	4
Total	34 (22%) 1/	84 (53%)	58 (37%)	36 (23%)	17 (11%)	11 (7%)	10 (6%)

1/ Percentage of total species.

(Table 3) and focuses on the importance of various structural features to vertebrates associated with gravel pit habitat.

Snags

Thirty-four (22%) of the species associated with openings also require snags or cavities for nesting, roosting, hibernation or perching. Examples are American kestrel, eastern bluebird, red-headed woodpecker, big brown bat, and white-footed mouse. Three are primary excavators (Evans and Connor 1979) that initiate holes for secondary users.

Normal gravel pit operations will generally preclude the presence of snags within the clearing, although this may be possible in some instances by reserving "islands" or clumps of trees at the time of land clearing. Snags, however, can be provided along the edges of the clearing to accommodate the 34 species that require them. Using the method of Thomas et al. (1979) for determining snag densities by community type, a density of about 2 hard snags per acre (dbh 16 inches or larger) will accommodate the primary excavators and the associated secondary users at the 100% management level (Table 4). Nesting boxes for secondary users may be substituted for snags if trees of suitable size are not present.

Water

Clearly, surface water or wetland habitat within or adjacent to a gravel pit enhances its value to wildlife. If a gravel pit contains surface water due to excavation below the water table, an additional community (pond) is established. Depending on depth and permanency of the water, and whether or not fish are present, animal diversity is significantly affected. The presence of a pond within a gravel pit will potentially accommodate 30 additional species, consisting of 18 birds, 6 mammals and 6 reptiles and amphibians. Fifty-eight (37%) of the species associated with gravel pits are also associated with riparian environments. Examples are spotted sandpiper, eastern kingbird, killdeer, coyote, little brown bat, and eastern garter snake.

When possible, excavation procedures should provide for digging below the water table to produce permanent or temporary aquatic habitats. Water-filled excavations should not be filled in as part of the reclamation activity. In order to produce a varied and productive aquatic plant community, excavations should produce gently sloping and shallow edges, and should not exceed three feet in depth unless a fishery is planned. The pond habitat can be further enhanced by planting willows along the edges.

Table 4. Number of hard snags required to support various percentages of maximum populations of primary excavators associated with openings.

Species	Min. dbh	Snags/100 acres 100%	80%	60%	40%	20%
Common flicker	12	50	40	32	20	10
Red-headed woodpecker	16	200	160	120	80	40
Yellow-bellied sapsucker	10	100	80	60	40	20

Downed Logs

Downed, decaying trees are utilized as cover or foraging sites by 36 (23%) of the species associated with openings. Examples are common flicker, red fox, masked shrew and red-bellied snake.

Prescriptions for gravel pit rehabilitation or management should provide for this structural feature by dropping trees into the pit area along the edge, or hauling logs into the interior. At least two logs per acre are recommended (Maser et al. 1979). Logs should also be placed on the periphery of ponds to provide waterfowl roosting sites and places for amphibians and reptiles to sun and hide.

Mast

Seventeen (11%) of the vertebrates associated with openings also utilize mast, such as acorns and nuts. Examples are white-tailed deer, black bear and eastern chipmunk.

Managers should strive to perpetuate oak adjacent to gravel pits, and promote mast-producing shrubs, such as American hazel, within the clearing.

Banks and Bare Ground

Unvegetated banks and mounds of surplus material created by excavations should be retained and not leveled as a rehabilitation technique. Rehabilitation plans should also provide for patches of bare ground on at least 50% of the area to benefit species such as nighthawks, killdeer, snapping turtles and green snakes.

The "open" character of depleted or abandoned gravel pits should be maintained, and vegetation plans should not provide for reforestation. Seeding and fertilizing to restore vegetative cover on portions of the area should be done with grasses and legumes suitable to the soil and site. In some situations, planting of native shrubs may be appropriate to enhance habitat structure, although - over time - natural invasion may accomplish the same objective. In order to control the invasion of trees, maintenance treatments with herbicide, hand cutting or burning may be required.

LITERATURE CITED

CROSS, W. C. 1963. Wildlife use of small forest clearings in the Adirondacks. M.S. Thesis College of Forestry,Syracuse Univ.

EVANS, K. E. and R. N. CONNOR. 1979. Snag management. In Proceedings, Management of North Central and Northeastern Forests for Nongame Birds pp. 214 - 225.

KERAN, D. C. 1974. Nest site selection by broad-winged hawks. 36th Midwest Fish and Wild. Conf. 7 pp.

LAY, D. W. 1938. How valuable are woodland clearings to birdlife? Wilson Bull. Vol 50 pp. 254-256.

MASER, C., R. G. ANDERSON, K. CROMACK, J. T. WILLIAMS, and R. E. MARTIN. 1979. Dead and down woody material. In Wildlife Habitats in Managed Forests in the Blue Mountains of Oregon and Washington. USDA Agric. Handbook No. 553 pp. 78 - 95.

MATHISEN, J. E. 1971. An inventory and classification of openings in the forest environment. 33rd Midwest Wildlife Conf. 8 pp.

MATHISEN, J. E. 1980. Wildlife habitat associations - a data base. Chippewa National Forest, Cass Lake, MN. 105 pp.

McCAFFERY K. R. and W. A. CREED. 1969. Significance of forest openings to deer in northern Wisconsin. Wis. Dep. Nat. Res. Tech. Bull. No. 44 104 pp.

McCAFFREY, K. R., J. E. ASHBRENNER, AND J. C. MOULTON. 1981. Forest opening construction and impacts in northern Wisconsin. Wis. Dep. Nat. Res. Tech. Bull. 120 40 pp.

MECH, L. D. 1970. The wolf. Natural History Press, Garden City, NY 384 pp.

MURIE, A. 1944. The wolves of Mount Mc-Kinley. U. S. Nat. Park. Serv. Fauna Ser. No. 5 238 pp.

NIEMI, G. J. and L. PFANMULLER. 1979. Avian communities: approaches to describing their habitat associations. In Proceedings, Management of North Central and Northeastern Forests for Nongame Birds. pp. 154-177

TAYLOR, C. M. and W. E. TAYLOR. 1979. Birds of upland openings. In Proceedings, Management of North Central and Northeastern Forests for Nongame Birds pp. 189 - 197.

THOMAS, J. W., R. G. ANDERSON, C. MASER and E. L. BULL. 1979. Snags. In Wildlife Habitats in Managed Forests in the Blue Mountains of Oregon and Washington. USDA Agric. Handbook No. 553. pp. 60-77.

U. S. FOREST SERVICE. 1975. A program for fish and wildlife habitat on the National Forests in Minnesota. 32 pp.

Principal Flora and Wildlife Use of a 35-40 Year Old Gravel Pit in North Dakota

KENNETH F. HIGGINS, Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service, Woodworth, ND 58496.

Gravel pits are common features of North Dakota landscape. A count of symbols on county highway maps indicated 2,697 gravel pits within the state. Of the 53 counties, Richland had the fewest gravel pits (7) and Mountrail had the most (119). The average number of gravel pits per county was 51.

Except for changes in vegetation composition, there have been comparatively few differences in the general appearance of gravel pits during the past several decades. Older sites of gravel extraction were mostly left open and frequently contained stock piles of gravel in reserve for future use. Some of the more recent sites of gravel extraction have been reclaimed to resemble the former landscape. However, the acreage of reclaimed gravel pits in the state is small when compared with the cumulative acreage of all gravel pits.

Wildlife values of North Dakota gravel pits vary considerably with pit size, geographical location, topographic relief, types of habitats, and patterns of socio-economic use. This paper identifies the general wildlife use and the principal flora of the Goldwin gravel pit in south-central North Dakota.

STUDY AREA

The Goldwin gravel pit is 4 miles east of the town of Woodworth and lies within Paris (T142N, R67W) and Roosevelt (T143N, R67W) Townships in Stutsman County. The pit is divided into three parts by N.D. Highway 36 and a Burlington Northern Railroad track. Presently there are four parties of ownership.

Winters (1963) described this area of the Missouri Coteau in Stutsman County as an ice-walled gravel train. This ice-walled gravel train probably formed from deposition of coarse glaciofluvial material in a channel bounded on both the northwest and the southeast by glacial ice. The nature of the gravel train and the adjacent landforms indicates formation in a stagnant ice environment. The northeast part of the ice-walled gravel train has an elevation of about 1,900 feet above sea level; the elevation decreases to about 1,800 feet at the southwest extremity, where the form merges transitionally with a pitted outwash plain. The width of the ice-walled gravel train ranges generally from 1 to 2 miles, and averages 1.5 miles. Before mining, the coarse gravel associated with the ice-walled gravel train was at least 25 feet thick.

Glacial drift on the Missouri Coteau has been aged by carbon-14 methods as less than 13,000 years (Clayton 1966), and 9,000 to 11,650 years (Tuthill et al. 1964), and by pollen analysis as 10,500 to 11,000 years (McAndrews et al. 1967) before the present. The pollen samples were taken from a pothole site located within the boundaries of the Goldwin gravel pit.

SOCIO-ECONOMIC USES

Before 1940, the gravel pit site was used intermittently for livestock pasture and small grain farming on scattered parcels (<20 acres). Initial crushing and extraction of gravel started about 1940. Extensive mining of gravel occurred from 1942 until 1952. About 640 acres of xeric mixed-grass prairie were disturbed by these activities. Because reclamation was not attempted, there is high variability in the topographic relief caused by alternating troughs and piles of gravel and spoils.

Between 1955 and 1965, there was little economic use of the site. From 1966 through 1981, grazing has been the primary use on the two parts in private ownerships; the third part, which is mostly in public ownership, has had little to no economic use but has been managed with prescribed fires with intervals of rest. In 1981, rental rates for grazing averaged \$3.30 per acre and stock-piled gravel sold for \$0.33 per cubic yard. Occasionally the area is a placement site for apiaries.

Recreational uses of the gravel pit have occurred sporatically over the years. These have included sport hunting and trapping, motor biking, snowmobiling, and birding.

PRINCIPAL FLORA

An extensive reconnaissance of the vegetation was made on each of the four ownership tracts of the Goldwin gravel pit on 7 October 1981. The reconnaissance consisted of several replications of comparative observations of the vegetation. The objective was to characterize the principal floral components rather than to develop a total species list. During the reconnaissance the four ownership tracts were treated as independent samples. Since about 1968, three tracts have been grazed annually and one was treated with prescribed fires in May 1968 and 1969 and in June 1971, 1974, 1976, and 1979.

The Goldwin gravel pit does not have extensive areas of a homogenous habitat type but is composed of many scattered patches of various plant communities and associations. This of course is a result of the disturbances to the soil profiles by gravel crushing and mining and the high variability in topographic relief caused by alternating troughs and piles of gravel and spoils.

Basically, the herbaceous cover is sparse, with a discontinuous stand of cottonwood (*Populus deltoides*) trees. Communities of grasses and shrubs are most apparent on sites of moist soils or on protected sites with less exposure to solar radiation.

Trees and Shrubs

Principal woody species included cottonwood, pussy willow (*Salix discolor*), sandbar willow (*S. interior*), peach-leaved willow (*S. amygdaloides*), diamond willow (*S. rigida*), meadow willow (*S. petiolaris*), wolfberry (*Symphoricarpos occidentalis*), silverberry (*Elaeagnus commutata*), and western wild rose (*Rosa woodsii*). Cottonwoods, because of their height and size, were the most conspicuous of all the plant species. There were no obvious differences in woody species among individual tracts.

Forbs

Principal forb species included western sagebrush (*Artemisia campestris*), fringed sage (*A. frigida*), wormwood (*A. absinthium*), rigid goldenrod (*Solidago rigida*), and little rose (*Chamaerhodos erecta*). Forb species of secondary importance included sweet clovers (*Melilotus albus* and *M. officinalis*), white sage (*Artemisia ludoviciana*), Canada goldenrod (*Solidago canadensis*), yellow-headed coneflower (*Ratibida columnifera*), western ragweed (*Ambrosia psilostachya*), hairy golden aster (*Chrysopsis villosa*), purple coneflower (*Echinacea angustifolia*), blazing star (*Liatris punctata*), prairie thistle (*Cirsium flodmani*), and curly-cup gumweed (*Grindelia squarrosa*).

Grasses

Principal grass species included needle-and-thread (*Stipa comata*), slender wheatgrass (*Agropyron trachycaulum*), quackgrass (*A. repens*), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), blue grama (*Bouteloua gracilis*), little bluestem (*Andropogon scoparius*), and Canada wild rye (*Elymus canadensis*).

Noxious Weeds

Wormwood (*Artemisia absinthium*), leafy spurge (*Euphorbia podperae*), and Canada thistle (*Cirsium canadensis*), were the main noxious weeds found in this gravel pit. Wormwood was much more abundant in the grazed tracts than in the one managed by rest and prescribed fires.

ADJACENT FLORA

In contrast to the gravel pit site, adjacent lands that have not been mined or farmed have nearly homogenous stands of xeric mixed-grass prairie interspersed with clones of wolfberry and silverberry. The herbaceous cover format is fairly dense, usually less than 18 inches tall, and litter is usually present between plants, except during periods of intensive grazing or after fires. The general life-form aspect is a medium to dense cover-type composed principally of a variety of grasses and sedges, fewer forbs, no cottonwood trees, and scattered clones of shrubs. Topographic relief is gentle to slightly undulating.

Principal species are needle-and-thread, blue grama grass, upland sedges (*Carex* spp.), Kentucky bluegrass, junegrass (*Koleria pyramidata*), pasque-flower (*Anemone patens*), many-flowered aster (*Aster ericoides*), white sage, stiff sunflower (*Helianthus rigidus*), prairie wild rose (*Rosa arkansana*), silverberry, and wolfberry. A variety of willows (*Salix* spp.) persist around wetlands and low, moist soil sites.

PRINCIPAL WILDLIFE

The primary terrestrial species of game and furbearers using the gravel pit during some or all of the past 35-40 years were white-tailed deer (*Odocoileus virginianus*), sharp-tailed grouse (*Pedioecetes phasianellius*), ring-necked pheasant (*Phasianus colchicus*), gray partridge (*Perdix perdix*), mourning dove (*Zenaida macroura*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), and striped skunk (*Mephitis mephitis*). More recently, white-tailed deer have used the pit extensively as a wintering area (Table 1).

Several species of waterfowl frequent wetlands in or nearby the gravel pit. Waterfowl

Table 1. Aerial counts of white-tailed deer in the Goldwin gravel pit in North Dakota.

Date	Number	Date	Number
4-7-65	6	4-2-75	13
2-1-66	0	3-3-76	12
2-4-69	0	3-4-77	61
3-9-70	0	1-30-78	17
1-11-71	2	3-7-79	60
2-11-74	0	2-5-82	15

species known to have nested in upland cover in the gravel pit area were mallard (*Anas platyrhynchos*), gadwall (*A. strepera*), pintail (*A. acuta*), green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), American wigeon (*A. americana*), northern shoveler (*A. clypeata*), and lesser scaup (*Aythya affinis*).

Many species of non-game birds have frequented the gravel pit each year during migration, but only a few were recorded as nesting species. These were red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*B. regalis*), great horned owl (*Bubo virginianus*), killdeer (*Charadrius vociferus*), upland sandpiper (*Bartramia longicauda*), willet (*Catoptrophorus semipalmatus*), marbled godwit (*Limosa fedoa*), common nighthawk (*Chordeiles minor*), bank swallow (*Riparia riparia*), western meadowlark (*Sturnella neglecta*), red-winged blackbird (*Agelaius phoeniceus*), and Wilson's phalarope (*Steganopus tricolor*).

The following species of non-game birds were recorded as present in the pit area on 17 June 1975 (D. Johnson pers. commun.) but their status as nesters was not determined: eastern kingbird (*Tyrannus tyrannus*), western kingbird (*T. verticalis*), willow flycatcher (*Empidonax traillii*), brown thrasher (*Toxostoma rufum*), American robin (*Turdus migratorius*), yellow warbler (*Dendroica petechia*), common yellowthroat (*Geothlypis trichas*), bobolink (*Dolichonyx oryzivorus*), orchard oriole (*Icterus spurius*), northern oriole (*I. galbula*), common grackle (*Quiscalus quiscula*), brown-headed cowbird (*Molotrus ater*), American goldfinch (*Spinus tristis*), vesper sparrow (*Pooecetes gramineus*), clay-colored sparrow (*Spizella pallida*), and song sparrow (*Melospiza melodia*).

Based on a small sample of field observations and records, wildlife use of this gravel pit area apparently corresponds with the basic cover distribution; i.e., a high degree of wildlife species diversity with a sparse, discontinuous distribution. The sparseness of the cover is further illustrated by the fact that killdeers and common nighthawks were among the species using the area for nesting purposes. The diversity of wildlife ranges from ground-nesting to shrub- and tree-nesting species.

DISCUSSION

The comparative differences between the gravel pit site and the adjacent undisturbed lands indicated that several major differences probably would now be present, if the gravel pit site had been reclaimed. Major differences would likely have included less relief in the topography, no troughs or piles of gravel and spoils, very few or no cottonwood trees, a nearly homogenous stand of herbaceous vegetation, a reduction in the diversity of wildlife species (mainly tree nesting species), and little to no use of the area by wintering deer populations. Relative to socio-economic uses, the site would probably be less attractive for sport hunting, motor biking, snowmobiling, birding, and for placement of apiaries; it would, however, be more attractive as a site for livestock grazing or harvesting of hay.

ACKNOWLEDGMENTS.--I thank L. Kirsch, M. Meyer, D. Johnson, D. Gilmer, and R. Woodward for help in collecting field data and A. Klett for reviewing an early draft of this paper.

LITERATURE CITED

Clayton, L. 1966. Notes on Pleistocene stratigraphy of North Dakota. N.D. Geol. Surv. Rep. Invest. 44. 25pp.

McAndrews, J. H., R. E. Stewart, Jr., and R. C. Bright. 1967. Paleoecology of a prairie pothole: a preliminary report. Pages 101-113 in L. Clayton and T. F. Freers, eds. Glacial geology of the Missouri Coteau and adjacent areas. N.D. Geol. Surv. Misc. Ser. 30.

Tuthill, S. J., L. Clayton, and W. M. Laird. 1964. A comparison of a fossil Pleistocene mulluscan fauna from North Dakota with a recent molluscan fauna from Minnesota. Am. Midl. Nat. 71:344-362.

Winters, H. A. 1963. Geology and ground water resources of Stutsman County, North Dakota. Part I. Geology. N.D. Geol. Surv. Bull. 41. 84pp.

Duck Use of Gravel Pits Near Ft. Collins, Colorado

GORAN E. D. BLOMBERG. Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824.

As man-made wetlands are becoming increasingly important to waterfowl, it is fitting that their suitability as habitat be studied. A study of 15 gravel pits was conducted near Ft. Collins, Colorado, from 1966 through 1968, to find (1) what characteristics of the pits were related to duck use, so the pits could be made into better habitat, (2) species composition of ducks using the pits, and (3) what use ducks made of the pits from spring through fall (Blomberg 1969). Results of the first and last objectives are reported in this paper.

STUDY AREA

Ft. Collins lies at 105° 05' W and 40° 35' N, and has a mean altitude of 1,525 m (Beier 1958). Gravel pits numbered 1 and 2 lie northwest of town, and northwest of the intersection of North Taft Hill Road and the Cache la Poudre River (T 7 N, R 69 W, N ½ Sec. 33). Gravel pits numbered 3-13 lie east of the town, northwest of the intersection of Prospect Street and the Cache la Poudre River (T 7 N, R 68 W, NW ¼ Sec. 17). Gravel pits numbered 14 and 15 lie southeast of the town and northwest and southwest, respectively, of the intersection of Interstate 25 and Harmony Road (T 6 N, R 67 W; SW ¼ Sec. 34 and NW ¼ Sec. 3, respectively). Fig. 1 shows the location of the pits in relation to the town.

The gravel pits differed from natural wetlands in having steep banks, often in association with steep, abrupt shores. The sparse marginal vegetation consisted primarily of common cattail (Typha latifolia), also of narrow-leaved cattail (T. angustifolia), three-square (Scirpus americanus), alkali bulrush (S. paludosus), softstem bulrush (S. validus), and wild millet (Echinochloa crusgalli). Submerged vegetation consisted of water milfoil (Myriophyllum

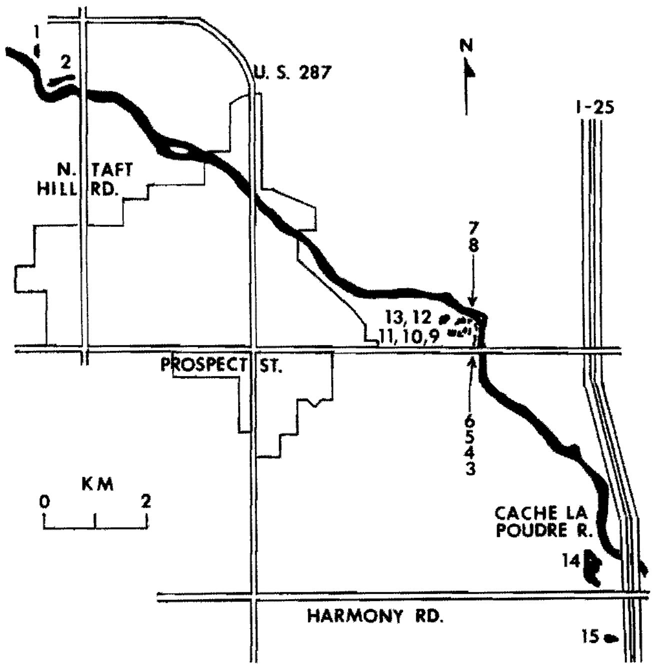


Fig. 1. Location of the gravel pits in relation to Ft. Collins, Colorado.

exalbescens), white water buttercup (Ranunculus aquatilis), waterweed (Anacharis canadensis), bushy pondweed (Najas flexilis), southern naiad (N. guadalupensis), sago pondweed (Potamogeton pectinatus), leafy pondweed (P. foliosus), horned pondweed (Zanichellia palustris), muskgrass (Chara sp.), and stonewort (Nitella sp.). For this study the last 5 were classified as important food plants, in accordance with Martin et al. (1951).

METHODS

Duck counts began in March 1966 and terminated in December 1966. Bank heights were calculated because several authors have stated or implied that banks have an adverse effect on duck use (Bue et al. 1964, Colling 1964, Leitch 1964, Shearer 1960, and U. S. Dep. Inter. 1964). Wooden stakes roughly 1 m tall were driven into the ground, roughly 50 m apart, around each pit. Vertical height of a bank was obtained by multiplying stake height by the length of the entire bank slope, divided by the length of the slope up to the top of the stake. Later, on most pits, the work was facilitated by use of a split image range finder, an Abney level, and trigono-

1 Based on Duck Use of Gravel Pits, a thesis submitted by Goran E. D. Blomberg in partial fulfillment of the requirements for the degree of Master of Science, Colorado State University, Ft. Collins, Colorado, March 1969.

metry.

Submerged vegetation was sampled (Pits 3-15) by throwing and retrieving a rake 4 times per station and 2-3 m from shore (Jessen and Lound 1962), according to the grid system formed by the stakes. Density ratings ranged from 0 to 5, depending on how many retrieves yielded plants; a rating of 5 meant that the teeth of the rake were always full. Density ratings could be made for all plants, for a select group, or for a single species, as necessary. Plants were keyed to species when possible, with Matsumura and Harrington (1955).

Marginal vegetation was sampled (Pits 3-15), and keyed to species via Fassett (1957). Siegler's (1941) method, consisting of use of a tally counter and pacing, was used. The counter was pressed whenever 1 or more plants occurred opposite my foot. A linear count sufficed where marginal vegetation formed a thin, uniform band; where vegetation formed a wide belt the linear count was multiplied by the average width. Separate trips were made for each species, and for all marginal vegetation combined, and from the latter the "unvegetated percent" was calculated. As no pit was completely surrounded by marginal vegetation, the entire shore line had to be paced and treated as a vegetative type, to find ratios of abundance of each species.

The spring migration period was set from 16 March through 28 May, and the fall migration period from 7 September through 3 December, based on field observations. Only data within these periods were used when data analysis involved migrant duck use.

Duck use was classified in several ways. "Duck days use " (U. S. Dep. Inter. 1957) consists of multiplying weekly counts by 7 and adding; this method was modified for shorter intervals in this study. Estimated duck days use were totaled separately for spring and fall. "Mean number of ducks," obtained separately for spring and fall, were obtained for each pit by dividing the total counts by the number of visits, thus obtaining daily averages. These daily means were also divided by the perimeters of the pits to obtain "mean number of ducks per km of shore line." The "mean number of ducks" was also divided by surface areas to obtain "mean number of ducks per ha." Sex ratios were calculated for spring dabblers as a whole, and for all species. (Sex ratios of divers could not be related to gravel pit characteristics, because only Pit 14 held significant numbers of divers.) Reliable "percentages of diving ducks" could be made for spring only. The last classes of duck use were "number of dabbling species," "number of diving species," and "total number of species:" these classes were not divided into spring and fall portions. All the above classes of duck use were related to characteristics of the gravel pits. In addition, territoriality and brood use were recorded.

Characteristics of the gravel pits were as follows: Surface areas, "mean bank height-to-surface area ratio," "air space volume-to-surface area ratio" (the air space contained by the water surface and the banks), perimeters, shore development (an index of irregularity of the shore line; it equals $P/2\sqrt{A\pi}$, where P is the perimeter and A is the surface area; a perfectly circular pond would have the minimal shore development of 1), average density index of submerged plants, average density index of submerged food plants, unvegetated percent of shore lines, and abundance ratios of each type of marginal plant.

A relation between age of pits and duck use could not be obtained, because 3 of the 4 recently dug pits (numbered 2, 14, and 15) had larger surface areas than did any of the older ones. The influence of carp (Cyprinus carpio) on duck use in the area containing Pits 3-13 was considered, but the large carp stayed in deeper water, avoiding the shallow areas used by the ducks. Duck use classes were regressed on gravel pit characteristics by a computer library program.

RESULTS AND DISCUSSION

Important Gravel Pit Characteristics

Elimination of statistically insignificant relationships, and significant ones having no meaning, indicated that 3 characteristics of the gravel pits influenced duck use. They were surface area, mean bank height-to-surface area ratio, and mean density index of submerged food plants. No significant correlation was found between any 2 of these 3 characteristics, so duck use was related to each one independently. Data on the gravel pit characteristics, and on the related classes of duck use, are in Table 1. Correlation coefficients between classes of duck use and the 3 characteristics of the gravel pits are in Table 2.

Effect of Surface Area

The relationships of duck days in spring mean number of ducks in spring, percentage of diving ducks, number of diving species, and total number of species to surface areas of the gravel pits appeared positive. This is exemplified by the relation between duck days use (spring) and surface area in Fig. 2. A weakness in the relationships is that most points cluster around 1 end of the regression line, and the slope is largely determined by 1 point, representing Pit 14, at the other end. Inspection of relations

Table 1. Data on characteristics of gravel pits and on classes of duck use with which they were correlated.

Pit	Gr. pit characteristics: Surf. area (ha)	Mean bk. ht.:area	Mean dens. index food pl.	Classes of duck use: D. days use S	D. days use F	Mean no. S	Mean no. F	Mean no./km sh. l. S	Mean no./km sh. l. F	Mean no./ha (F)	% div. use (S)	No. species dabb.	No. species div.	No. species tot.
1	1.15	1.4	--	96	776	1.33	10.06	3.0	22	8.72	--	3	3	6
2	2.58	0.97	--	817	3448	11.93	31.9	14	3.7	12.36	2.23	5	2	7
3	0.33	5.2	0.400	22	0	0.267	0	1.2	0	0	--	1	0	1
4	0.30	6.0	0.200	102	10	1.53	0.118	7.5	0.57	0.40	--	3	0	3
5	0.36	6.7	0	29	0	0.400	0	1.7	0	0	--	1	0	1
6	0.53	2.8	0.333	351	282	5.27	2.29	8.1	3.4	4.4	2.53	6	1	7
7	0.14	10.	4.60	71	9	0.867	0.059	5.4	0.37	0.42	--	4	0	4
8	0.32	4.7	2.63	23	126	0.333	1.06	1.3	4.1	3.2	--	3	0	3
9	0.45	3.3	0.875	106	71	1.53	0.65	3.7	1.6	1.5	--	3	0	3
10	0.77	3.0	2.64	638	661	8.60	6.18	20	15	8.2	1.55	9	1	10
11	1.61	1.1	0.688	544	39	10.40	0.41	19	0.75	0.25	0	4	0	4
12	1.27	1.4	4.20	936	1488	13.60	13.41	27	26	10.5	10.8	8	5	13
13	1.35	1.7	4.07	1477	3665	19.13	39.76	37	74.5	29.50	0	8	0	8
14	13.5	0.13	2.32	3022	1166	42.0	12.44	22	6.2	0.91	79.8	8	7	15
15	3.1	0.45	1.14	264	103	3.0	0.94	4	1.4	0.30	51.1	5	4	9

Table 2. Statistically significant correlation coefficients between characteristics of gravel pits and classes of duck use. Underscored coefficients are significant at the 1% level.

Classes of duck use	Gr. pit characteristics: Surf. area	Mean bk. ht.:area	Mean dens. index food pl.
D. days use, S	<u>.881</u>	-.542	
D. days use, F			.587
Mean no., S	<u>.882</u>	-.556	
Mean no., F			.567
Mean no./km sh. l., S			.559
Mean no./km sh. l., F			.573
Mean no./ha, F			.560
% diver use	<u>.882</u>		
No. dabbl. species		-.517	.591
No. div. species	<u>.773</u>		
Total no. species	<u>.670</u>	-.643	

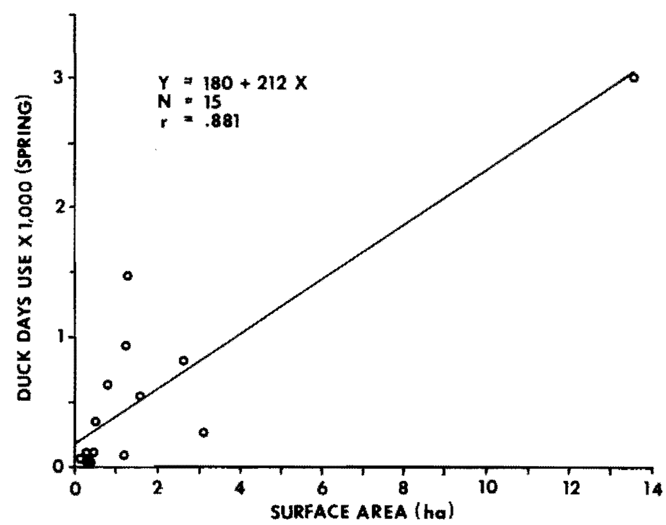


Fig. 2. Relation between duck days use in spring and surface area.

between the above classes of duck use shows that there is significant correlation between 7 of 10 possible combinations of these classes. Each class is correlated with 1 to 3 others.

Effect of Banks

The relations of duck days use in spring, mean number of ducks in spring, number of dabbling species, and total number of species appeared negatively related to the mean bank height-to-surface area ratios. This is exemplified by the relation between total number of species and mean bank height-to-surface area in Fig. 3. It strongly suggests that ducks find closely surrounding banks unattractive. The reason may be the view-blocking effect of the banks. In this case each class of duck use was significantly and positively correlated with all the others.

Effect of Density of Submerged Food Plants

The relations of duck days use in fall, mean number of ducks in fall, mean number per km of shore line in spring, mean number per km of

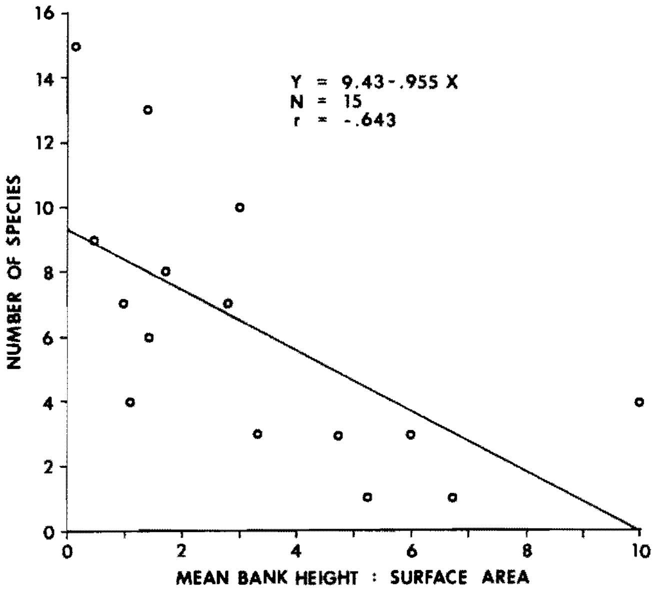


Fig. 3. Relation between total number of species for the entire year and ratio of mean bank height (m) to surface area (ha).

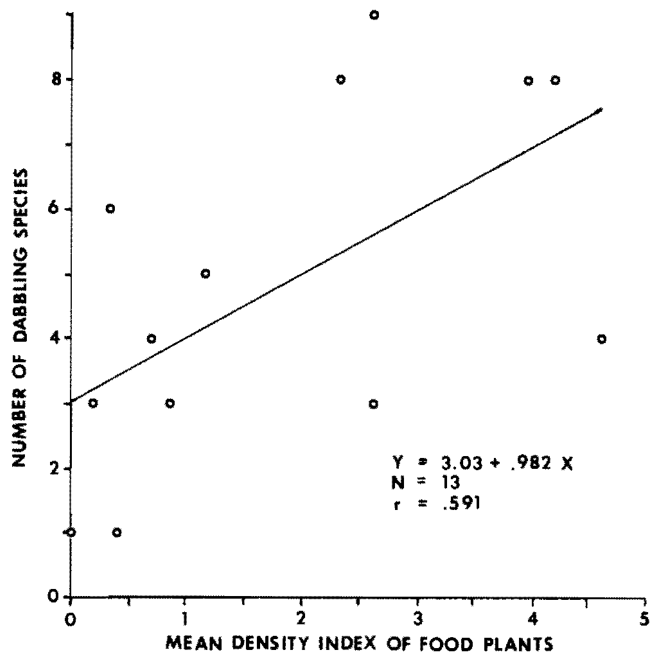


Fig. 4. Relation between number of dabbling species for the entire year and mean density index of submerged food plants.

shore line in fall, mean number per ha in fall and number of dabbling species appeared positively related to mean density index of submerged food plants. This is exemplified by the relation between the number of dabbling species and the mean density index of submerged food plants in Fig. 4. As in the previous analysis, each of the duck use classes was significantly and positively related to all the others.

The reason that the number of diving species did not relate to the mean density index of submerged food plants may be the importance of animalmatter in the diets of Lesser Scaup (Aythya affinis), Common Goldeneye (Bucephala clangula), Bufflehead (B. albeola). These species constituted over 70% of the divers in spring and fall. Rough percentages of animal matter in their diets are 50, 75, and 80, respectively (Baldwin et al. 1964, Bent 1923, Kortright 1953, Martin et al. 1951, and Sprunt and Zim 1961).

The relations of duck use classes to mean density index of food plants suggest that the presence of food plants is more important to the ducks in fall than in spring. My observations of the dabbling ducks support this, since they appeared to feed more busily in fall than in spring. My field notes contain 31 instances of feeding in the spring, and 47 such instances in the fall. Keith (1961) found a nearly 3-fold increase in weight of gizzards of adult ducks between the beginning of May and the end of September. Possibly this finding relates to an apparent need for greater quantities of food in the fall. Such a need in the fall may reflect a considerable expenditure of energy due to replacement of molted feathers and the hen's reproductive activities in the preceding spring and summer.

The sampling technique used for submerged vegetation should not be used indiscriminately (as I did) for smaller pits (e. g. Pits 3-13) if the results are to be related to duck use. These pits are dabbler habitat, and areas deeper than perhaps 0.6 m (which are likely to put food plants below the (dabbler's reach) should not be sampled.

Other Duck Use

Summer Use by Adults.--Summer use by adult ducks was negligible, and the gravel pits at best provided satisfactory migration habitat. This is partly explained by lower waterfowl numbers in the South Platte Valley (of which the present study area is a part) than in the northern prairie states, according to Hopper (1962b). In northeastern Colorado he found higher densities (statistically significant) of ducks in the summer on water areas supporting both marginal vegetation and common or abundant supplies of true aquatics. The marginal vegetation around the gravel pits in the present study was sparse, as stated.

Brood Use.--Brood use was scant. On only 5 pits (numbered 1, 2, 4, 10, and 12) were broods seen during regular morning observations, and at most twice. However, 1 or 2 Mallard (Anas platyrhynchos) broods were often seen in a small creek on the southern edge of the area containing Pits 3-13. The creek had grassy banks that provided cover, and probably invertebrates, needed by ducklings (Chura 1961, Griffith 1948). The importance of cover around shores to duck broods has been mentioned or implied by many (e. g. Bennett 1938; Evans et al. 1952; Hochbaum 1959; Keith 1959, 1961; and Sowls 1955). Hopper (1962b) believed that brood use was primarily determined by presence or absence of marginal cover.

Territoriality.--Territorial Mallard pairs, identifiable by the behavior described by Hochbaum (1959), were seen on Pits 1, 2, 6, 12, and 15. Territoriality of the Mallards here can be attributed to their being the most common breeding duck in the Cache la Poudre Valley, and their adaptability (Delacour 1956, Weller 1964).

RECOMMENDATIONS

General

Management Considerations.--Waterfowl use should have priority over other forms of land use if habitat improvement is to be worthwhile. To ensure lasting management of waterfowl habitat the Colorado Division of Wildlife should concentrate, or work exclusively, on sand and gravel pits located on land it owns, leases, or manages cooperatively. Recommendations in this paper will apply primarily to migration habitat for dabblers and divers, and for Mallard brood and molting habitat, in the South Platte Valley.

Substrate.--Most of the gravel pits studied had fine, often muddy bottom material, and submerged plants were well established in those having no carp. If such substrate is typical of gravel pits in the South Platte Valley, the addition of soil to support plant growth is unnecessary.

Planting Considerations.--Pirnie (1935) listed considerations relative to planting for waterfowl. Planting will hasten natural plant invasion, and give valuable species a start against less desirable competitors (Bellrose 1941, Erickson 1964). If planting is decided upon, the species already present on the sites should be considered (Erickson 1964).

Marginal plants that should be considered are softstem bulrush and three-square, as they were the more common bulrushes. If given a first chance, they may prevent more or less complete takeover by cattails (Keith 1961), and unlike the latter also provide food (Martin et al. 1951).

The most abundant submerged food plant was sago pondweed. A possible advantage of planting it might be to check the tendency of waterweed to crowd out other species (Scheffer and Hotchkiss 1945). Established beds of sago pondweed are more likely to be permanent than those of many other species, due to reproduction by rootstocks which terminate in buds or tubers, that become next season's growth (Pirnie 1935).

It is recommended that a study be undertaken to determine the usefulness of planting in and around gravel pits in the South Platte Valley. Its main objective would be to compare plant invasion and growth in and around pits with no planting, with that in and around pits having had sago pondweed and bulrushes planted.

Control of Carp.--Many pits suitable for dabbling ducks are or will probably be made shallow enough (0.3-1 m) to cause winter kill of carp (H. A. Tanner, pers. comm. in Hopper (1962b)). If established carp prove detrimental, intensive management should include control or removal with rotenone.

Habitat Improvement Specifications

Specifications for improving gravel pits as the habitat type for which they are best suited are presented below. Table 3 summarizes the specifications.

Dabbler Migration Habitat.--Sand and gravel pits the size of Pits 3-9 in this study (0.1-0.5 ha) are physically unable to hold large numbers of ducks at a time, and are therefore not recommended for habitat improvement practices. Pits of 0.8-2.0 ha can hold at least 100 ducks at a time, and habitat improvement practices are recommended for them, provided they are grouped so that the work becomes efficient. Pits larger than 2.0 ha should be able to hold many hundreds of ducks at a time, and this seems to justify improvement practices even if they exist in isolation.

For pits meeting the above specifications, banks over 0.3 m high that form the shore line or lie close should be cut to a 1:10 slope ratio or less, when possible. This should alleviate the view-blocking effects for the ducks. Bank cutting may prove unnecessary around pits at least 6.0 ha, since a large water area will probably nullify the effects of the banks. (An exception might be a pit managed for hunting, as gently sloped banks should allow for establishment of more marginal vegetation.) Cutting of banks will provide some or all the earth needed to make the pits shallower (0.3-1 m deep) and to make small islands and peninsulas for loafing. Cutting of banks has been recommended by Blok (1964), by F. G. Cooch (Bue et al. 1964), by P. J. S. Olney (Graham 1964), and by Uhler (1964). The practice is reported on a 4.5 ha

Table 3. Summary of habitat improvement specifications.

Desired waterfowl use	Specifications: Recommended surface areas	Need for bank cutting	Desirable depths	Desirable plants
Dabbler migration	0.8-2.0 ha (improve if grouped	1:10 slope ratio if over 0.3 m high	0.3-1.0 m	Marginal: Any species for hunting areas, otherwise unimportant Submerged: Sago pondweed
	2.0-6.0 ha (improvement of isolated pits justified)	As above	As above	
	6.0 ha or greater (improvement of isolated pits justified)	As above--hunting areas only	As above	
Diver migration	6.0 ha or greater (improvement of isolated pits justified)	As above--hunting areas only	At least 1.6 m	Marginal: As above Submerged: Possibly sago pondweed
Brood and molting areas	0.6-1.5 ha probably optimal for broods-- for molting ducks, any size allowing much interspersion of marginal plants and open water areas up to 1.5 ha (improvement of isolated pits at least 2.0 ha justified)	1:10 slope ratio if over 0.3 m high	0.3-1.0 m (over 0.6 m desirable for broods)	Terrestrial: Some tall grass for broods Marginal: Bulrushes Submerged: Sago pondweed for molting ducks

pit in Fordingbridge (Anon. 1966) and on another pit near Sevenoaks, England (Harrison and Harrison 1964, Harrison et al. 1962, Olney 1964).

Marginal plants do not seem needed by migrant ducks. The importance of submerged food plants can hardly be overstressed, however, and it is recommended that they be planted if they do not invade naturally, 2-3 years after a pit has been dug, or filled in to the desired depth.

Diver Migration Habitat.--A pit less than 6.0 ha should probably not be considered as potential diver habitat. Pits that size or larger are recommended for development as diver habitat if they are, or can readily be made at least 1.6 m deep. The cutting of banks is considered unnecessary, unless hunting is a management objective. Improvement practices are considered justified on isolated pits.

Unless such areas are managed for hunting, there is no need for planting marginal vegetation. Submerged food plants might prove useful in attracting diving species that have higher percentages of vegetable matter in the diet. These species would be preferred by the hunter.

Brood and Molting Habitat.--In North Park, Colorado, Kirkman (1956) found the greatest brood utilization on lakes of 0.6-1.5 ha, and this may be the most desirable size range for broods in the South Platte Valley. Regarding summer habitat for adults, Hopper (1962b) found significantly greater duck use of ponds with open water areas (not entire surface areas) of 0-1.5 ha, because they were shallower, more likely free of carp, less turbid, had greater abundance of true aquatic vegetation, and were likely to have marginal vegetation. This may mean that adult residents have no size preference. A very large but shallow pit, with much interspersion of marginal plants and open water areas in the above size range might be equally valuable on a unit area basis, and if so, absolutely more useful than any one pit of only 1 or a few ha. The choice of improvement of grouped vs. isolated pits should probably be on the basis of the same sizes as pits intended for dabbler migration habitat. Small, grouped pits may meet the various breeding requirements of ducks, as mentioned by Dzubin (1955) and Evans et al. (1952).

Banks over 0.3 m high should be cut, to facilitate establishment of extensive marginal cover. The excess earth could be used to make small islands on which the broods can loaf, the importance of which Beard (1964) and Sowls (1955) stressed.

Evans et al. (1952) found that in Manitoba's pothole country, depth was important for broods, and that during periods of low water, potholes over 0.6 m deep were preferred. Hopper (1962a) stated that broods avoid extremely shallow water, apparently because diving to escape danger is hampered. Therefore it is recommended that pits managed for brood use average somewhat deeper than those intended solely as dabbler migration habitat. The depths of the latter are probably satisfactory for resident adults.

For the sake of broods, any grazing should be moderate enough to leave some tall grass for the concealed terrestrial feeding mentioned by Girard (1941) and Hopper (1962b). It might be worthwhile to plant bulrushes around the margins. As ducklings do not completely shift from invertebrate food to plant food until they are nearly ready to fly (Chura 1961), planting of submerged food plants is not recommended.

ACKNOWLEDGMENTS.--Mr. J. R. Grieb, Director of the Colorado Division of Wildlife, suggested the project, supplied needed help, and constructively criticized the original manuscript. Mr. R. M. Hopper and Mr. W. H. Rutherford of the Colorado Division of Wildlife offered pertinent information and lent equipment. My adviser, Dr. R. A. Ryder, and Dr. M. Workman constructively criticized the original manuscript and offered advice. Dr. E. Remmenga's advice on the statistical analysis was invaluable. Mr. J. H. Joyner and Ms. K. Harsh provided temporary means of transportation, and Mr. E. Scriven prepared most drawings for the original manuscript.

LITERATURE CITED

ANON. 1966. Eley Game Advisory Sta. Annu. Rev. 1965/66. Fordingbridge, Hampshire, England. 80pp.

BALDWIN, D. H., G. V. BURGER, AND F. H. KORTRIGHT. 1964. Cousins by the dozens. Pages 15-22 in J. P. Linduska, ed. Waterfowl tomorrow. U. S. Dep. Inter., Washington, D. C.

BEARD, E. B. 1964. Duck brood behavior at the Seney National Wildlife Refuge. J. Wildl. Manage. 28:492-521.

BEIER, H. 1958. Fort Collins: physiographic and environmental influences. Planning and Zoning Board of Ft. Collins, Colorado. Res. and Surv. Rep., Part 2. 50 pp.

BELLROSE, F. C. 1941. Duck food plants of the Illinois River Valley. Illinois Nat. Hist. Surv. Bull. 21, Art. 8:237-280.

BENNETT, L. J. 1938. The blue-winged teal: its ecology and management. Collegiate Press, Inc., Ames, Iowa. 144 pp.

BENT, A. C. 1923. Life histories of North American wildfowl: order Anseres (part). Smithsonian Inst. U. S. Nat. Mus. Bull. 126. 250 pp.

BLOK, E. 1964. Artificial waters in the Netherlands. Project Mar: The Conservation and Management of Temperate Marshes, Bogs and Other Wetlands 1(3):407-409.

BLOMBERG, G. E. D. 1969. Duck use of gravel pits. M. S. Thesis. Colorado State Univ., Ft. Collins. 109 pp.

BUE, I. G., H. G. UHLIG, AND J. D. SMITH. 1964. Stock ponds and dugouts. Pages 391-398 in J. P. Linduska, ed. Waterfowl tomorrow. U. S. Dep. Inter., Washington, D. C.

CHURA, N. J. 1961. Food availability and habitat preferences of juvenile mallards. Trans. 26th N. Am. Wildl. Conf. pp. 121-134.

COLLING, A. W. 1964. Wetlands conservation problems: British experience. Project Mar: The Conservation and Management of Temperate Marshes, Bogs and Other Wetlands 1(3):238-247.

DELACOUR, J. T. 1956. The waterfowl of the world II. Country Life, Ltd., London. 232 pp.

DZUBIN, A. 1955. Some evidences of home range in waterfowl. Trans. 20th N. Am. Wildl. Conf. pp. 278-298.

ERICKSON, R. C. 1964. Planting and misplanting. Pages 579-591 in J. P. Linduska, ed. Waterfowl tomorrow. U. S. Dep. Inter., Washington, D. C.

EVANS, C. D., A. S. HAWKINS, AND W. H. MARSHALL. 1952. Movements of waterfowl broods in Manitoba. U. S. Fish and Wildl. Serv. Spec. Sci. Rep.: Wildl. No. 16. 47 pp.

FASSETT, N. C. 1957. A manual of aquatic plants. The Univ. of Wisconsin Press, Madison. 405 pp.

GIRARD, G. L. 1941. The mallard: its management in western Montana. J. Wildl. Manage. 5:233-259.

GRAHAM, E. 1964. Discussion (Wildlife utilization of man-made aquatic habitats). Project Mar: The Conservation and Management of Temperate Marshes, Bogs and Other Wetlands 1(3):365-368.

GRIFFITH, R. 1948. Improving waterfowl habitat. Trans. 13th N. Am. Wildl. Conf. pp. 609-617.

HARRISON, J. G. AND J. M. HARRISON. 1964. The management of a gravel pit wildfowl reserve. Proc. 1st Eur. Meeting on Wildfowl, Scotland. pp. 323-331.

HARRISON, J. M., J. G. HARRISON, AND P. J. S. OLNEY. 1962. A gravel pit wildfowl reserve. Wildfowl Trust 13th Annu.Rep. pp. 101-108.

HOCHBAUM, H. A. 1959. The canvasback on a prairie marsh. 2nd ed. The Stackpole Co., Harrisburg, Pa. and the Wildl. Manage. Inst., Washington, D. C. 207 pp.

HOPPER, R. M. 1962a. Habitat preferences of waterfowl on the breeding grounds. "FS 220 --Professional Literature" Rep. Colorado State Univ., Ft. Collins. 69 pp.

_____. 1962b. Relationships of certain characteristics of small wetlands and waterfowl abundance in northeastern Colorado. M. S. Thesis, Colorado State Univ., Ft. Collins. 102 pp.

JESSEN, R. AND R. LOUND. 1962. An evaluation of a survey technique for submerged aquatic plants. Minn. Div. of Game and Fish. Game Invest. Rep. No. 6. 10 pp.

KEITH, L. B. 1959. A study of waterfowl ecology on small impoundments in southeastern Alberta. Ph. D. Thesis, Univ. of Wisconsin, Madison. 264 pp. (Long abst. in Diss. Absts. 20:833-834.)

_____. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6:1-88.

KIRKMAN, R. L. 1956. An evaluation of waterfowl production on lakes in North Park, Colorado. M. S. Thesis, Colorado A. and M. Coll., Ft. Collins. 95 pp.

KORTRIGHT, F. H. 1953. The ducks, geese and swans of North America. The Stackpole Co., Harrisburg, Pa. and the Wildl. Manage. Inst., Washington, D. C. 476 pp.

LEITCH, W. G. 1964. Water. Pages 273-281 <u>in</u> J. P. Linduska, ed. Waterfowl tomorrow. U. S. Dep. Inter., Washington, D. C.

MARTIN, A. C., H. S. ZIM, AND A. L. NELSON. 1951. American wildlife and plants: a guide to wildlife food habits. McGraw-Hill Book Co., Inc., New York. 500 pp.

MATSUMURA, Y. AND H. D. HARRINGTON. 1955. The true aquatic vascular plants of Colorado. Colo. Agr. Expt. Sta. Tech. Bull. 57. Colorado A. and M. Coll., Ft. Collins. 130 pp.

OLNEY, P. J. S. 1964. Gravel pits as waterfowl reserves. Project Mar: The Conservation and management of Temperate Marshes, Bogs and other Wetlands 1(3):414-420.

PIRNIE, M. D. 1935. Michigan waterfowl management. Mich. Dept. of Conserv., Lansing. 328 pp.

SCHEFFER, T. H. AND N. HOTCHKISS. 1945. Plant-food resources for waterfowl in the Pacific Northwest. Wash. Dep. Game, Biol. Bull. 7. 39 pp.

SHEARER, L. A. 1960. Use of dugouts by breeding ducks. J. Wildl. Manage. 24:213-215.

SIEGLER, H. R. 1941. A water plant census technique. J. Wildl. Manage. 5:423-426.

SOWLS, L. K. 1955. Prairie ducks: a study of their behavior, ecology, and management. The Stackpole Co., Harrisburg, Pa., and the Wildl. Manage. Inst., Washington, D. C. 193 pp.

SPRUNT, A. IV AND H. S. ZIM. 1961. Game birds: a guide to North American species and their habits. Golden Press, New York. 160 pp.

UHLER, F. M. 1956. New habitats for waterfowl. Trans. 21st N. Am. Wildl. Conf. pp. 453-469.

U. S. DEP. INTER. 1957. Fish and Wildl. Serv. Bur. of Sport Fish. and Wildl. Field Manual. Branch of Wildl. Refuges. Loose leaf. n. p.

_____. 1964. Fish and wildlife in man-made and man-modified aquatic environments. Project Mar: The Conservation and Management of Temperate Marshes, Bogs and Other Wetlands 1(3):369-382.

WELLER, M. W. 1964. Ecology. Pages 80-107 <u>in</u> J. T. Delacour, ed. The waterfowl of the world IV. Country Life, Ltd., London.

The Great Linford Project: Waterfowl Research in a Gravel Pit Wildlife Reserve

MICHAEL STREET, A.R.C. Wildfowl Centre, Great Linford, Milton Keynes, Bucks., England.

Natural wetlands in Britain, ranging from rivers and streams, freshwater marshes and fens, mountain and lowland lakes and peat bogs, to saltmarshes and mudflats, have been and still are being destroyed or threatened. Pollution, drainage and canalisation, infilling and reclamation, refuse tipping and more recently intensive recreational activity all take their toll.

In recent years however the value of our wetlands as a natural resource has become more widely realised but despite this, loss of wetlands continues, with the piecemeal drainage of small areas, often grant aided, gradually reducing the area and variety of wetland habitat, and consequently posing a threat to the characteristic flora and fauna of such areas. While no species of waterfowl in Europe is in danger of extinction some species are in decline due to the degradation of their habitat (I.W.R.B. 1975).

It is somewhat paradoxical that while we are destroying those existing wetlands which are not protected (as National Reserves, wildfowl refuges etc.) the gravel industry is actually creating new freshwater wetlands at a considerable rate. These provide important alternative habitats, especially for the common species of waterfowl, and here therefore is a potential opportunity to compensate in some degree for the losses of natural wetlands.

These gravel pit wetlands range from 1-40 ha. in area, can be from 3-30 metres deep, and most are less than 40 years old. They are characteristically flat bottomed, steep sided, take their shape from the original field boundary and show fluctuating water levels due to their variable connection with ground water levels and the receipt of rainfall and surface runoff.

These new waters are not of course available solely for use by wildlife. There is increasing pressure on the gravel producers to restore more quarried land to its former agricultural use, and where lakes are created, the most usual after-use is based upon development towards amenity areas. The majority of such lakes are produced close to large population centres, and we now have approximately 4 million anglers, 2 million sailors, 100,000 water skiers and a growing number of windsurfers in the UK; all demanding water space.

There is however an increasing awareness that a close contact with nature can be an important recreational activity and the new wetlands formed by gravel extraction can be manipulated and managed to considerably increase their potential carrying capacity for wildlife, and in particular waterfowl. The location of wet gravel pits close to conurbations offers the exciting prospect of being able to display high densities of wild waterfowl to the public, in a man-made setting which has been designed to re-create a productive wetland habitat with a natural and aesthetically pleasing appearance.

These were some of the reasons behind the decision taken by the Amey Roadstone Corporation in 1971 to examine the potential of its wet quarries for wildlife, in particular waterfowl. This decision resulted in the establishment of the Wildfowl Research Project, a joint venture between ARC and the Game Conservancy (a private game research organisation) which is funded entirely by the Amey Roadstone Corporation.

This project is a management exercise, the aim of which is to create productive habitats for waterfowl and to learn how to manage them in order to maintain the optimum conditions for a high density and diversity of species. The area of the gravel pit managed as a reserve also functions to demonstrate the techniques of habitat creation and management.

Secondly, but equally important, it is a research project studying the ecology of newly excavated gravel quarries and of the waterfowl populations which make use of them. The aim of this is to ensure that the management practices are based upon a sound understanding of the ecology of the waters and of the requirements of breeding and wintering waterfowl and waders.

The overall objective of the Wildfowl Project is to find the best ways of accelerating the biological development of flooded pits to the state where they are able to support viable populations of wildfowl and other wildlife and at the same time accept a degree of

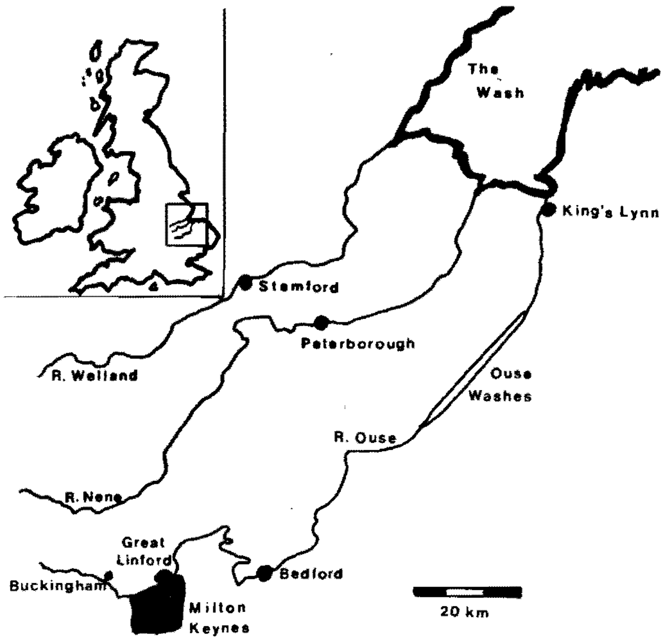


Figure 1a. The geographical location of the Great Linford Gravel pits.

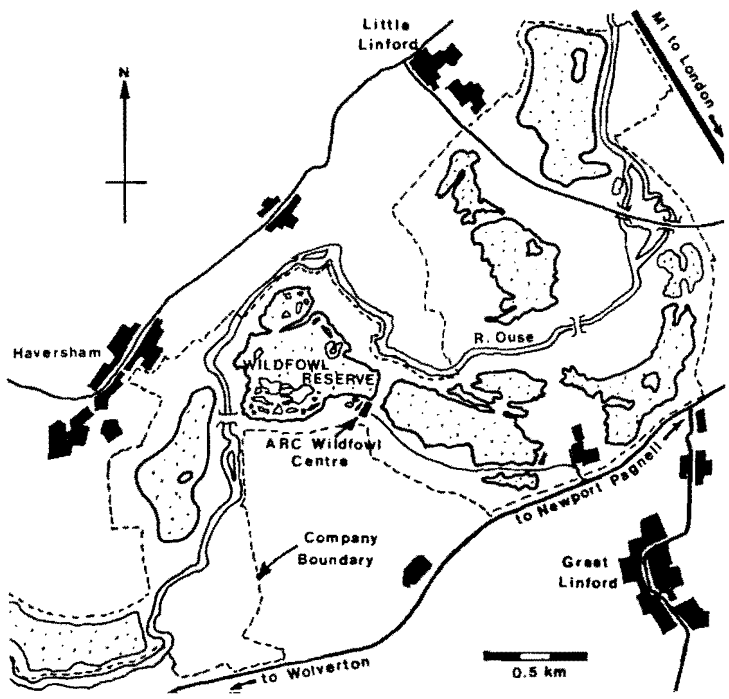


Figure 1b. The location of the Wildfowl Reserve within the gravel pit complex.

use by the public. By setting aside and carefully managing selected areas as breeding sanctuaries and winter refuges for migrating birds it should be possible to maintain the necessary degree of seclusion and freedom from disturbance.

STUDY AREA

The Great Linford Gravel Quarry is a 300 ha. workings in the flood plain of the upper reaches of the River Great Ouse 2.0 km west of Newport Pagnell in North Bucks. (Fig 1a). A small proportion of the workings is approximately 40 years old, but the majority is much more recent, having been excavated in the last 12 years. Most of the wetlands within this study area are therefore ecologically very immature. There are no extensive areas of shallow water and only about one quarter of the area of standing water contains any appreciable amount of submerged aquatic macrophytes. In the remaining water area these plants are restricted by silty sediments, high turbidity and deep water, or they have not yet developed. All of the lake beds are composed of a mixture of gravel, sand and clay on an underlying stratum of Oxford clay. Many areas have thick sub-aquatic accummulations of mineral silt, and only in the older parts of the quarry is there any significant amount of the organically rich sediments associated with high biological productivity.

The area managed by the Game Conservancy as a wildfowl reserve occupies approximately 37 ha. of the quarry, more or less centrally placed. (Fig 1b). It consists of 18 ha. of open water from 0.5 to 4.5 m. deep with an average depth of 3.0 m. plus a 10.5 ha. complex of islands and lagoons 0.5-2.5 m. deep, in the south-west corner. The ratio of land to water in this island/lagoon complex is 3.1:1.0, and there is 0.74 km of shoreline per hectare. This small area was left in this condition following piecemeal excavation and tipping. The remaining 8.5 ha. is permanent pasture around the main lake. The Great Linford site was selected because of its central geographical location, because it was already used by relatively large numbers of wintering waterfowl, but chiefly because of the presence of this particular lake and its surroundings which were seen to have the best potential for development as a breeding sanctuary and winter refuge.

When the habitat creation work began in 1972, the reserve contained virtually no aquatic vegetation and little ground cover. The shores at all points were quite steeply shelving and where erosion occurred had a wave cut platform 2-3 metres wide below a small cliff face. The water takes its level from the adjacent water table, which tends to show seasonal fluctuations.

Within this selected area, the intention is to create a diversity of habitat types that can meet the needs of those species of waterfowl which could be expected to use it for breeding, wintering or as a mid-summer moult area. Providing for the basic needs of all species of waterfowl is quite simple. Primarily they must have safe daytime resting sites, they need areas in which to breed, with ground cover sufficiently tall and dense to conceal their nests, and they need extensive, suitably rich feeding sites. To be productive of waterfowl a breeding site must contain invertebrate rich wetland habitats for brood rearing.

The following section describes briefly the way in which the gravel pit study area has been modified to meet these needs.

Security

The erection of a fence excluded grazing animals and allowed ground cover to grow up, dominated by tufted hair grass. This had the immediate effect of making the reserve more attractive to ground nesting waterfowl.

Disturbance within the breeding sanctuary part of the reserve (the island/lagoon complex in the south west corner) was further reduced by the restriction of anglers to certain zones of the lake shore well away from this area. When fishing ceased completely in 1979 there was a marked increase in the number of birds making regular use of the reserve.

The second "line of defence" is a thorn hedge which was planted between 1972 and 1975. The area immediately inside the hedge is planted with sallows and willows which when established, will be coppiced in a 3 year rotation in linear strips parallel to the perimeter hedge to further thicken the screen, and to provide a range of valuable habitats for small birds, mammals and insects, as well as good quality nest cover for waterfowl. The inner edge of this osier coppice follows the line of security canal. This was dug around the breeding sanctuary to isolate the islands from the mainland to restrict ground predators. The canal forms an effective barrier whilst at the same time growing a wide belt of reeds and rushes on the inner side.

Resting Areas

The need for a safe day roost is met by the main lake, especially important in the winter months for the large flocks of immigrant birds. However, birds roosting on a lake, especially in windy conditions, must expend valuable energy in order to 'keep station' on the water and in rough weather they much prefer to rest on land. To help the reserve attract and hold a high density of roosting waterfowl we have provided several safe, sheltered, shore-based roosting or "loafing" sites where the birds can see the approach of any potential danger at a distance and have unimpeded access to open water. Cattle are allowed to graze the vegetation of an elevated bank on the north-west shore of the main lake, and this has become a popular loafing spot.

In 1978, a "purpose built" loafing bank was made in the reserve. This is surfaced with black polythene sheet, anchored by a 20 cm layer of 6-18 mm gravel spread evenly over it, the combined effect being to suppress the growth of plants. The need for such areas devoid of dense vegetation cover also extends to ducklings. They should not have to struggle through wet vegetation to reach these resting sites. Two islands within the breeding sanctuary are therefore kept almost devoid of vegetation by cutting and the use of long-lasting herbicides. Further loafing spots are provided in the form of floating rafts, either bare wood, turf covered or shingle covered, anchored in sheltered bays, and with the surface very close to water level.

Breeding Sites

For a gravel pit reserve to be productive of waterfowl it must contain a surplus of suitable nest sites. This has been achieved by encouraging the development of a wide diversity of herbs and shrubs. Useful species are tall tussocky grasses such as tufted-hairgrass, hard and soft rush, nettles, rushes and willow herb, cow parsley, hogweeds, willows, gorse, etc. Plants like nettles, rushes and willow herb are especially important to provide cover for early nesting duck such as mallard, as the stems of these plants remain standing over the winter, and are therefore available for use before new growth begins. Most of the nesting cover areas have been provided on island sites, including some on floating raft islands.

Feeding Areas

For a man-made gravel pit reserve to support large flocks of wintering waterfowl and high densities of breeding birds it must provide in some measure for their food requirements, and much of our research has been concerned with dietary studies of gravel pit waterfowl populations as described in the next section.

RESEARCH

The habitat creation work carried out at the Great Linford study area has successfully manipulated the gravel pit to make it meet the varied habitat needs of a range of waterfowl, with a consequent increase in

Table 1. Waterfowl use of the reserve, compared with that of the gravel pits outside the reserve.

	WATERFOWL INSIDE RESERVE (37 ha.)		WATERFOWL OUTSIDE RESERVE (263 ha.)	
Count Date	Birds per ha.	Percent. of total population	Birds per ha.	Percent. of total population
20.1.79	15.46	50.8	1.75	49.2
11.2.79	14.08	58.2	1.44	41.8
4.3.79	6.23	43.0	1.16	57.0
18.4.79	5.99	50.0	0.85	50.0
18.5.79	4.11	35.4	1.07	64.6
25.6.79	3.69	45.1	0.56	54.9
31.7.79	2.44	22.0	1.22	78.0
10.8.79	4.35	28.2	1.49	71.8
22.10.79	35.01	78.2	1.44	21.8
24.11.79	19.25	57.2	1.39	42.8
10.12.79	28.78	65.5	1.84	34.5
2.1.80	38.65	66.0	2.76	34.0

number of birds breeding and wintering within the reserve in preference to the other lakes available to them. (Tables 1 and 2).

These populations are now used as the basis for a research programme, the aim of which is to increase our understanding of habitat requirements of the main species of waterfowl so that future gravel pit rehabilitation techniques can be based on good scientific data.

One our our earliest studies was that of the seasonal changes in the diet of adult mallard which used our gravel pits. We found that as usual, the autumn and winter food consisted chiefly of cereal grains, frosted potatoes and arable weed seeds. However the most important finding was the change from 95% plant material - largely grain - in the winter, to a food intake containing 39% invertebrates in the spring, and 73% in summer, reaching a maximum of 85% in June. Invertebrate foods occurred in 7% of the birds taken in winter and in 90% of those obtained in summer. (Street 1975). It is assumed that this change in diet reflects the increased availability of invertebrate foods in summer, but it is also likely that their consumption may be essential to fulfil the specialised nutritional requirements of breeding and moulting birds. There is now a great deal of evidence that the breeding females of most dabbling duck species change their diet in this way in spring and summer and that this is necessary to allow the production of more and larger eggs which produce larger and more viable chicks (Bartonek, 1972; Krapu, 1974; Pehrsson, 1979; Perret, 1962; Siegfried, 1973; Swanson and Meyer, 1973; Swanson, Meyer and Serie, 1974).

Table 2. The density of duck nests in the wildfowl reserve in 1981 compared with that in the gravel pit as a whole, and that in the Ouse Washes, Cambridgeshire. (Thomas 1980).

	*Number of nests per 100 ha.		
Species	Wildfowl reserve	Great Linford quarry	Ouse Washes
Mallard	58.3	11.3	32.9
Tufted Duck	44.4	9.0	1.4

*Area calculated as the minimum rectangle encompassing all known nests.

The large intake of carbohydrate-rich cereal grain in autumn builds up the birds' reserves to enable them to survive the winter and to be in good condition for breeding in the following spring. The condition and body weight of the birds was seen to change in relation to the quantity and nature of the food consumed. There was a rapid loss in spring, to a minimum of 1,000 gm in May, and the weight of both sexes increased dramatically in autumn to an average of 1,300 gm. This autumn build-up of body reserves could also be essential for the production of viable eggs and strong ducklings.

Observations on the fledging success of Mallard in the study area showed an abnormally high mortality rate among newly hatched ducklings. It was essential to find out when the losses occurred, and brood searches were used to assess the actual mortality. It appeared that at best 40% of broods survived beyond the first 6 days of life and only 57% of the individuals in each brood survived beyond the first week. The overall mortality rate was estimated at 77%; giving an estimated production of 1.8 per pair in a good year. In an average year the recorded production of young Mallard at Great Linford is between 1.3 and 1.6 per pair. Boyd (1962) considered that 4.6 per pair was usual for Mallard in normal habitats. Conditions were considered to be better for ducklings after June 1 and so pre and post June 1 mortality rates were compared. Losses of complete broods were greater among broods which hatched before June 1, and within brood mortality was 56.3% in pre-June 1 broods, but only 18.2% in broods hatched post-June 1. For both pre and post June 1 broods, the mortality rate after 12 days of age was virtually nil; the chances of a Mallard duckling surviving are excellent once the first critical two weeks of life are over. The next step was to examine the diet of the newly hatched ducklings and to compare this with that of ducklings hatched in more natural wetlands.

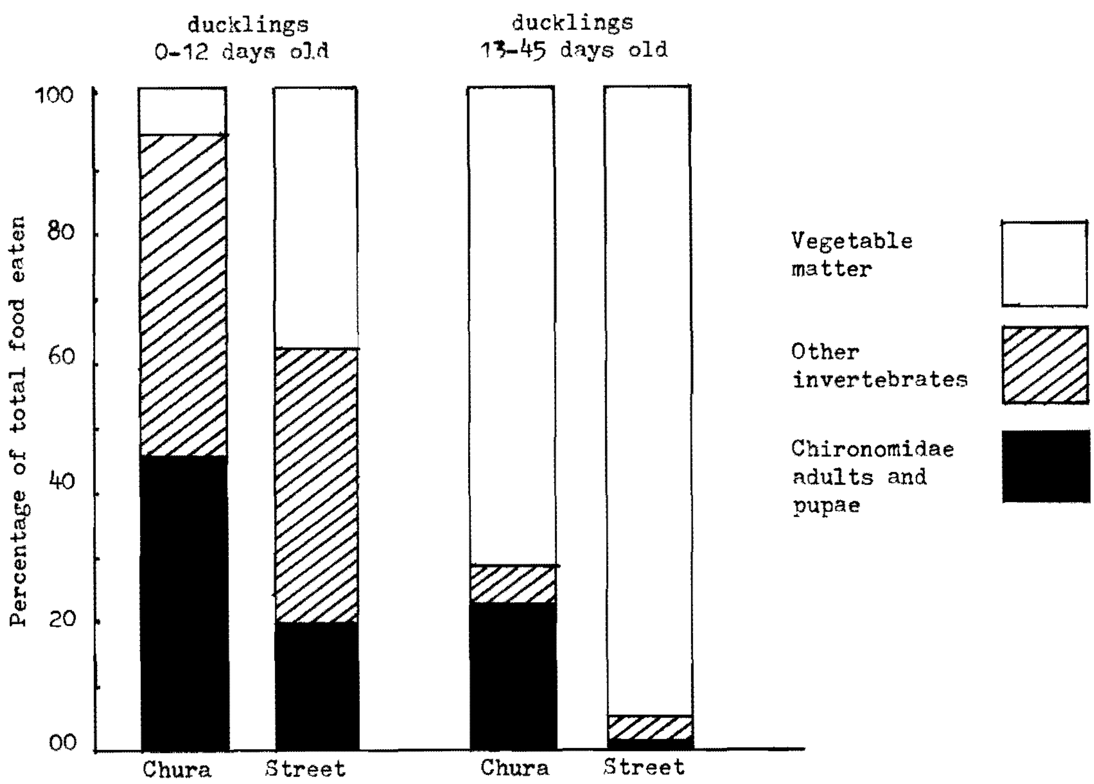


Figure 2. The composition of the diet of mallard (Anas platyrhynchos) ducklings of two age classes in a natural wetland habitat (Chura 1961) compared with that of ducklings of the same age in the Great Linford gravel pits (Street 1977).

Because of the observed mortality in the first 12 days of life the sample of ducklings (106) was divided into those less than 12 days old (67) and those 13-45 days old (39). In the 0-12 days old ducklings only 60.6% of the items eaten were of animal origin, largely aquatic invertebrates, although they were found in 88% of the sample. By comparison, only 5.1% of the items found in the 13-45 days old ducklings were invertebrates, and they occurred in 53% of the sample. Chironomid adults, pupae and larvae were the main invertebrate foods.

This consumption of invertebrate food by the very young ducklings hatched in the study area was much less than that reported by other workers studying this species in natural habitats (Bartonek, 1972; Chura, 1961; Collias and Collias, 1963) and the switch to a vegetable diet was made at a much younger age (Fig. 2).

There is considerable evidence that ducklings need abundant invertebrates as food (Moyle 1961, Sugden 1973) and monitoring of the larval and emergent populations of the chironomid midges (Diptera - Chironomidae, which are the main food item), in the reserve showed that the population was relatively low and the emergence "peak" was confined to a short period in early June (Street 1977). It was therefore suggested that the low consumption of invertebrates as food by the ducklings at Great Linford reflected the low availability of such foods in the habitat, and further that this was largely responsible for the excessive juvenile mortality rate.

In order to test the assumption that invertebrate foods are necessary to give satisfactory growth of ducklings, a feeding trial was carried out to compare the value of animal and vegetable diets. Four groups of ten one-day-old mallard were fed on selected diets. A comparison of growth rates over 14 days demonstrated that the ducklings which fed exclusively on a seed diet (barley meal, 13.5% protein) showed an increase of only 1.6 times their initial weight; whereas those fed exclusively on an invertebrate diet, blowfly larvae (51.8% protein) increased their initial weight by 9.3 times. The two 'control' groups of ducklings, fed on poultry crumbs (21% and 26% protein content by dry weight) increased their initial weight by 7.9 and 9.2 times respectively. The conversion efficiency was measured as grammes weight gain per gramme dry weight of food consumed. For an invertebrate diet this was high at 1.21:1.0, while for barley meal it was only 0.22:1.0. For turkey crumbs and chick crumbs it was 0.7:1.0 and 0.65:1.0 respectively. This showed that a diet of invertebrates is much better than of turkey starter crumbs.

A second feeding trial was designed to measure the growth of mallard ducklings on a seed diet similar to that eaten by wild ducklings in the study area, and to estimate the minimum proportion of invertebrate foods in the diet which would allow satisfactory growth. The group of ducklings fed on the seed mixture plus 20% larvae grew only slowly, and those fed seeds plus 50% larvae showed a reasonable growth rate; better than the barley meal fed group in the first trial, but not as well as the group fed 100% blowfly larvae. The growth of the ducklings over the first four days of these trials showed a high degree of positive correlation with both the level of blowfly larvae in the diet ($r = 0.98$., p 0.001) and with the total amount of protein eaten ($r = 0.88$., p 0.001) and the comparison of the growth rates of the ducklings receiving the different diets indicates that an adequate supply of insect food is essential for the survival of wild Mallard ducklings. (Street 1978).

Clearly, for duckling survival to be high what is needed are areas of water with a very high level of biological productivity. The essential invertebrate foods are produced most abundantly in shallow water, where they are also most available to foraging birds. Water less than 1.5 m deep is preferable, and a large proportion of the total area should be 0.5 m deep or less. This depth of water is rarely produced in the process of gravel extraction and gravel pits normally require manipulation and management if they are to realise their maximum potential for waterfowl production.

The simplest technique to improve the situation is to alter shore profiles. The shoreline is the area with the greatest potential for productivity and is accessible to machinery. Ideally the shore profile should be graded to a slope of 1 in 6 or less right down to the deepest water. This will create a wide littoral band which supports a range of aquatic macrophytes in a characteristically zoned distribution from the marsh plants on the landward side through emergent and floating leaved forms, to the submerged plants of deeper water, ie, down to about 11 m in clear water.

This ideal shoreline grading is obviously only possible before flooding. At Great Linford, the reserve lake was flooded before our work began, so the shallows were extended within the breeding sanctuary by the use of a tractor mounted excavator to cut a 3 m wide shallow "wet shelf" on the accessible shores. Further food production areas have been made in the form of saucer shaped "scrapes" which hold water by ponding and the diversity and richness of these is further improved by the addition of farmyard manure, sewage sludge or cow slurry to promote the production of invertebrates and produce "honey pot" sites for duckling broods.

Further feeding sites can be provided following the peak duckling hatch, or during the spring and autumn passage of migratory species by temporarily flooding normally dry areas of pastureland, thus floating out weed seeds and drowned soil invertebrates. Or by lowering the water level in specific 'scrapes' or marshes to expose the bed with its associated animal life.

The macro invertebrates which are important waterfowl foods are normally found associated with stands of aquatic macrophytes which provide the necessary micro-habitats, food and cover. The invertebrate population of a new gravel pit can therefore be increased by the introduction of suitable plants to the newly graded shore.

This physical introduction of the plants allows the careful positioning of the various species where they will be of greatest value, for example as food plants, reservoirs of aquatic invertebrates, nest cover, escape cover, shelter belts, screens or to prevent shore line erosion. It also ensures that the favoured species are established as dominants in the littoral plant communities. The success rate of planting is normally high, and spread can be rapid and dramatic.

Plantings should be made so that the final effect is of a natural zonation of different types down a shoreline. This is not only more stable and more productive than haphazard planting, but is more pleasing to the eye.

Research at Great Linford into the relationship between emergent waterplants and their associated invertebrate populations showed that the largest number of invertebrates and the greatest variety of species is found where the cover is greatest. The submerged portions of the plants provide the essential shelter and "scaffold" for the animal organisms, and the plants with the greatest submerged surface per unit area held the highest invertebrate populations. This being so the introduction of densely growing plants such as Great Pond sedge (Carex riparia) is of more benefit to invertebrate life, and therefore to waterfowl, than the introduction of species like Phragmites which forms loose, open stands.

A more direct approach to increasing the production of suitable invertebrates has also been developed in our study area. Gravel pit wetlands usually lack a constant inflow of fresh water, and there is thus no topping up of nutrient levels which is necessary for maximum productivity. Also there are normally few mature trees around the margins and often little vegetation in the water to provide a significant accumulation of organic matter as the basis of the food chain leading to waterfowl and fish. Left alone it takes many years for deep gravel pits to develop the high level of organic richness necessary for abundant invertebrate life. To overcome this problem recently dug gravel pit waters clearly need an addition of organic matter which would act directly to promote the growth of the decomposer and consumer organisms which are the potential foods. We have developed a novel management technique using barley straw to stimulate the production of invertebrates as food. By adding straw we are simulating the process of enrichment which occurs naturally from the death of reeds in long established wetlands.

Monitoring of invertebrate populations in the straw treated sites and in untreated control sites showed that in suitable situations, i.e. newly made waters, preferably less than 3 metres deep, with a high calcium level and low nutrient content, over an inorganic base material, the addition in spring of barley straw at about 1kg per square metre has great potential as a practical treatment to stimulate the rapid production of a diverse invertebrate fauna of value to feeding waterfowl. (Street 1979; Street & Titmus 1982).

A study of the population dynamics of gravel pit wildfowl populations was begun at Great Linford in 1979; the aim of this being to produce a computer model which simulates the responses of the population to various changes in the habitat and in the populations themselves. A large part of this study is concerned with breeding success of waterfowl of two species, mallard and tufted duck, and the study of predation on nests has revealed some useful information. Five variables were analysed: the height of vegetation at the nest; mean vegetation height around the nest; minimum height of vegetation around the nest; density of vegetation and the date that laying began. Vegetation was measured at the start of laying.

These analyses showed that nests were significantly less likely to be predated as the mean vegetation height around the nest increased and especially as the minimum vegetation height around the nest increased. Statistical analysis of nest success in both species showed hatching success increases through the season due to the link between the mean height of vegetation around a particular nest and the date that the nest was initiated; later nests were better concealed.

There was also a positive correlation between high nest density and increased predation rates for both species, although this was more important for the tufted duck than for mallard. Hatching success was significantly higher on islands, which are less open to predation by mammals. This work has shown that islands and areas with high vegetation providing good cover increase the success of nests. However, where good nesting areas have been available for some years the nesting population is likely to increase, which in turn will increase the predation rate. Seven years' data from our mallard nest census certainly support this view, (Hill, 1980). It has also been shown that predator control markedly increases the production of fledged young. (Hill 1982).

Islands may increase nest success, but unfortunately, leaving even a small island of unworked land in a gravel quarry effectively sterilises a large volume of aggregate, especially in deep workings, so they are a rare feature in the new gravel pit wetlands.

Most quarries are now worked dry however, and it is relatively simple to create islands during excavation, well before flooding is allowed, by using the overburden stripped off from above the gravel seam. In most cases this reduces restoration costs by reducing the extent of the normal earthmoving operations of restoration. The ideal shape for an island is as a horse-shoe, with a convoluted shoreline and with the mouth of the horse-shoe facing away from the prevailing wind direction. This forms a safe nesting and loafing area, and it encloses an area of sheltered, shallow (and therefore warm and productive) water out in the security of a deeper lake, thus providing for several of the needs of waterfowl on the one site.

The radio tracking technique used in this population study has also confirmed our early findings on the importance of the unusually high mortality rate among ducklings, and analysis has shown that duckling loss is the key factor which controls the size of the breeding population in following years. Female mallard and tufted duck with broods seek out the insect rich lakes as brood rearing sites, and fledging success for both species is highest where suitable aquatic invertebrate food is most abundant. Radiotelemetry studies of mallard with young (where the brood movements and activity levels are monitored via a radio transmitter attached to the adult female) have shown further that broods which move the greatest distance in order to utilise a limited food resource have the highest mortality rate. Where food is abundant, brood movements are much reduced and survival is consequently much greater (Hill 1982). The main loss of ducklings in 1979 was during the first 12 days after hatching. Only 16% of hatched mallard ducklings and only 21.8% of hatched tufted ducklings survived to fledging. The mean brood size at fledging was 3.7 for mallard, and 3.4 for the tufted duck, but this does not allow for the loss of entire broods. Recruitment should be expressed as the number of young females fledged per nesting female. In this case the figures for 1979, not a poor year, are 0.65 young females/nesting female for mallard, and 0.85 young females/nesting female in the tufted duck. By contrast Fog (1964) maintains that in Denmark production needs to average 2.2 young females per nesting female to maintain a mallard population. An initial computer simulation model, using survival data from the literature shows that 0.65 young females per breeding female, certainly cannot sustain a breeding population.

When production is altered in the model, it appears that a minimum value of 1.2 females produced per nesting female is necessary. This is well above the level currently achieved at Great Linford and probably other gravel quarries - due to poor duckling survival. Hill (1980).

Statistical analysis of Wildfowl Count data has revealed that mallard populations show a high degree of density dependent compensation for population changes. For example if production of young is increased, so the September population is high, then the over winter survival is reduced, and a smaller proportion of the autumn population remain to breed in the following spring. Similarly, the production of young is density dependent, in that with a high density of breeding birds the number of young hatched is quite large, but the number of young fledged per brood is quite low, due presumably to greater competition between ducklings for a limited food resource, and to increased interaction between broods at high densities. Conversely, as breeding density decreases the number of young fledged per brood increases (Hill 1982).

The most recent research topic is a study of lead shot ingestion by mallard wintering on gravel pits in S.E. England. Lead pellets have long been recognised as causing some deaths when eaten by birds, but waterfowl appear to be particularly vulnerable. The pellets are probably eaten in mistake for pieces of grit or some kinds of seeds, and can be retained in the gizzard where they are gradually abraded, forming soluble toxic salts. This causes a characteristic set of symptoms, especially marked lethargy, emaciation and, in some cases, death in about two to three weeks. There has been concern for many years, especially in the USA where the use of lead shot has been banned for waterfowl hunting in some areas, and it is increasingly important to establish the precise extent of the problem in Britain.

Between 1973 and 1980 mallard have been shot at monthly intervals through the shooting season, on one of our gravel pit study areas. The gizzards were examined for the presence of ingested lead pellets, i.e. pellets other than the ones which killed the bird. Almost all the duck were shot during the dawn flight into their day roost lake and most of them had been feeding on arable land. Four hundred and fifty two mallard were examined and the incidence of lead shot was found to be highest in the September sample, decreasing in each successive month. This marked seasonal decline in the incidence of pellet ingestion was also noted by Thomas (1975) in the Ouse Washes, and by Mudge (198).

Bellrose (1959) showed by release of experimentally dosed mallard that in a population of wild drakes one No. 6 pellet per bird resulted in a 9% increase in mortality rate, 2 pellets - 23%; 4 pellets - 36%; and 6 pellets - 50%. Mortality of lead dosed females was shown to be higher than that of drakes in the autumn, but less than that of drakes in the late winter, so no correction was made to allow for sex differences.

A number of calculations were made using the corrected monthly incidence values for pellet ingestion and the above mortality rates to estimate successive monthly survival rates. From these a simple mathematical model was produced which can be used to calculate the seasonal lead induced mortality in the population sampled. In this case the seasonal mortality was 1.11%, slightly lower than that of 1.18% using Bellrose's method of calculation.

The lead poisoning mortality calculated from the incidence of shot in this investigation is lower than that found in previous studies of this kind in Britain (Olney, 1960 - 2.66%; and Thomas, 1975 - 5.58%). This is probably because samples of mallard used by Olney and Thomas were shot mainly on feeding grounds, for example the Ouse Washes, where conditions result in a high availability of shot pellets - high shooting intensity over many years, shallow water, lack of natural grit and concentrations of feeding ducks.

This study is not yet complete, but the results so far suggest that the frequent ingestion of spent pellets by waterfowl in the U.K. is a localised phenomenon which occurs only under particular circumstances. The collection of birds for lead shot ingestion studies from such 'hotspots' may give results indicative of a high rate of lead poisoning which is not representative of the country as a whole (Street 1982). What is quite certain is that the eating of shot, even if voided before a fatal dose is absorbed can cause various sub-lethal effects such as impaired visual, auditory and motor reflexes (Finley and Dieter 1979) and such birds are obviously more prone to disease, predation and starvation (Jacobson et al 1977) so more research and monitoring is needed to appraise the situation in the United Kingdom.

There is no doubt that ducks can accumulate lead shot and in some places at a high rate with concomitant mortality and sub-lethal effects but the true significance of this to a waterfowl population can not be known until more is known about the population dynamics of the species concerned. As already described, from our recent study of one local mallard population in Britain there is evidence of density dependence in the winter 'survival' rates which can compensate in part for mortalities such as those caused by hunting and lead poisoning, thus reducing their impact on the size of the breeding population. This density dependence is not complete however, it is only partly compensatory and then only so long as the total winter mortality is around 35% and remains below 46%. Above a 46% reduction in winter population size all mortality factors become additive in reducing the size of the breeding population in the following spring. (D Hill pers. comm.) It seems safe to conclude therefore that the effects of lead poisoning attributable to lead shot are far less important to Mallard populations over most of their range than the effects of shooting itself.

SUMMARY

The exploitation of gravel deposits is currently producing large areas of wetland. If left alone the new wetlands will eventually develop a stable but limited wildlife population, and they really do need careful development and management if they are quickly to attain their maximum potential as waterfowl production areas.

Leaving a gravel pit to colonise and develop naturally results in the establishment of a plant community dominated by one or two species, usually Willow, with a low floral diversity, and Milne (1974) showed that a decline in bird species at an unmanaged gravel pit after a few years was due to increasing informity of vegetation as naturally colonising vigorous species of plant became dominant.

The species composition and size of the fauna populations is influenced mainly by the degree of heterogeneity of the vegetation resulting from the variation of the physiographical and hydrological features of the wetland. Generally speaking, species richness is assumed to indicate habitat quality (although of course there can be habitats of high quality for a limited number of species) and Patterson (1974) showed that waterfowl production was related to wetland heterogeneity.

The particular nature of any gravel pit is a result of a combination of variables such as basin shape, water source, water quality, stability and depth, the ratio of open water to vegetated areas, shore line slope and contour, the ratio of shore length to water area and the plant species diversity.

Thus, where there is scope to alter the physical features during construction of a lake, as in the restoration of wet gravel workings, changes can be made which have profound effects on the composition and size of their eventual wildlife populations.

The results of the creation and management of waterfowl habitat at the Great Linford gravel pit has been to create a "lacustrine oasis" of wildlife within the wetland complex created as a by product of gravel and sand excavation. The reserve regularly supports greater numbers of breeding, wintering and moulting waterfowl, passage migrants and passerine species of birds than the surrounding lakes which are not managed for wildlife. (Tables 1 & 2). As this paper shows, these waterfowl populations provide an ideal opportunity for ecologists to study their precise habitat requirements and population ecology so that the "ecological engineering" undertaken to create new habitat from worked out gravel pits can be more effective.

In conclusion, gravel extraction could have a vital role to play in ensuring the continued well-being of the populations of the common waterfowl species, provided that at least some of the new wetlands are correctly developed and managed. They are by no means the complete answer to the problems of wetland conservation, and we still have a great deal to learn, but with care and sufficient enthusiasm the gravel industry could ensure that their potential is fully realised, so that the contribution of the new wetlands could be of great significance.

Acknowledgements

I would like to record my gratitude to the Amey Roadstone Corporation, whose foresight and generosity has made this project possible. Thanks are also due to the many volunteer workers from the British Trust for Conservation Volunteers who have done so much of the habitat creation and management work in the Reserve. Also my thanks go to the succession of summer students who have contributed to the success of the research project by sharing the seasonal workload, and to David Hill whose post-graduate research has contributed significantly to this paper.

LITERATURE CITED

BARTONEK, J. C. 1972. Summer foods of American Wigeon, Mallards and a Green-winged Teal near

Great Slave Lake, N.W.T., Canad. Field Nat. 86:373-6.

BELLROSE, F.C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Nat. Hist. Survey Bull. 27; 3.

BOYD, H. 1962. Population dynamics of ducks and geese. The exploitation of natural animal populations. Ed. E.D. Le Cren and M.W. Holdgate. Blacwell. Oxford. pp.85-95.

COLLIAS, N.E. and COLLIAS, E.C. 1963. Selective feeding by wild ducklings of different species. Wilson Bull. 75; 6-14.

CHURA, N.J. 1961. Food availability and preferences of juvenile mallards. Trans. N. Am. Wild. Conf. 26; 121-34.

FINLEY, M.T. and DIETER, M.P. 1978. Toxicity of experimental lead - iron shot versus commercial lead shot in mallards. J. Wildl. Manage. 42:1, pp.32-39.

FOG, J. 1964. Dispersal and survival of released mallards. Danish. Rev. Game Biol. 4:3 pp.4-57.

HILL,D. 1980. A new study on ducks. Game Conservancy Annual Review for 1979, No. 11. pp.39-41.

HILL,D. 1981. Nest predation in Mallard and Tufted Duck. Game Conservancy Annual Review 1980. pp.94-97.

HILL,D. 1982. Game Conservancy Annual Review for 1981. (In press).

INSTITUTE OF GEOLOGICAL SCIENCES. 1972. Mineral resources Consultative Committee Dossier No. 4. on sand and gravel.

I.W.R.B. 1975. Minutes of the meeting of the National Contacts in the Western Central Region. Int. Waterfowl Res. Bureau - Resource Harvesting Division. Paris. Sept. 1975.

JACOBSON, E., CARPENTER, J.W. and NOVILLA, M. 1977. Suspected lead toxicosis in a Bald Eagle. J. Am. Vet. Med. Assoc. 171:9, pp.952-54.

KRAPU, G. 1974. Foods of breeding Pintails in North Dakota. J. Wilde. Man. 38:3. pp.408-417.

MILNE, B.S. 1974. Ecological succession and bird life at a newly excavated gravel pit. Bird Study, 21:4, pp.263-278.

MOYLE, J.B. 1961. Aquatic invertebrates as related to larger plants and waterfowl. Minnesota Dept. Conserv. Invest. Rept. No. 233.

MUDGE, G. 1982. An investigation into poisoning of waterfowl in Britain as a result of the ingestion of lead shot. Unpubl. Report of a joint Wildfowl Trust, B.A.S.C. and R.S.P.B. investigation.

OLNEY, P.J.S. 1960. Lead poisoning in waterfowl. Bull. Brit. Ornith. Club. 80:3, pp.53-57.

PATTERSON, J.H. 1974. The role of wetland heterogeneity in the reproduction of duck populations in eastern Ontario. Can. Wildl. Serv. Rep. Ser. No. 29, 31-32.

PEHRSSON, O. 1979. An experimental study of egg and duckling size, and subsequent survival and growth rate as a result of food quality of laying mallards. Proc. XIV Cong. I.U.G.B., Dublin.

PERRET, N.G. 1962. The Spring and Summer foods of the common mallards (Anas platyrhynchos L) in south central Manitoba. M. Sc. Thesis, University of British Columbia, Vancouver. 82pp.

SEIGFRIED, W.R. 1973. Summer food and feeding of the Ruddy Duck in Manitoba. Can. J. Zool. 51:1293-1297.

STREET, M. 1975. Seasonal variation in diet, body weight and condition of fledged mallard (Anas platyrhynchos) in eastern England. Proc. XII Congr. Int. Un. Game Biol. Lisbon.

STREET, M. 1977. The food of Mallard ducklings in a wet gravel quarry, and its relation to duckling survival. Wildfowl 28:113-125.

STREET, M. 1978. The role of insects in the diet of Mallard ducklings - an experimental approach. Wildfowl 29:83-100.

STREET, M. 1979. The management of artificial wetlands for waterfowl - a novel technique to increase the availability of invertebrate food organisms. Proc. XIV Congr. Int. Union Game Biol. Dublin.

STREET, M. 1982. The assessment of mortality resulting from the ingestion of spent lead shot by Mallard wintering in south east England. Proc. XV Congr. Int. Union Game Biol. Trujillo, Spain. (In press).

STREET, M. and TITMUS, G. 1982. A field experiment on the value of allochthonous straw as food and cover for aquatic macro-invertebrates. Freshwater Biology. (In press).

SUGDEN, L.G. 1973. Feeding ecology of Pintail, Gadwall, American Wigeon and Lesser Scap ducklings. Canad. Wildl. Services Rept. No. 24

45pp.

SWANSON, G.A. and MEYER, M.I. 1973. The role of invertebrates in the feeding ecology of Anatinae during the breeding season. Waterfowl habitat management symposium, Moncton, New Brunswick. pp.144-185.

SWANSON, G.A, MEYER, M.I. and SERIE, J.R. 1974. Feeding ecology of breeding Blue-winged Teal. J. Wildl. Manage. 38:3, pp.396-407.

THOMAS, G. 1975. Ingested lead pellets in waterfowl at the Ouse Washes, England. 1968-1973. Wildfowl 26: pp.43-48.

THOMAS, G. 1980. The ecology of breeding waterfowl at the Ouse Washes, England. Wildfowl 31: pp.73-88.

The Ecology of Dolomite Quarries in South Central Minnesota

HENRY W. QUADE, DENNIS M. KUBLY,[2] and DALE E. McMICHAEL.[3] Department of Biological Sciences, Mankato State University, Mankato, MN 56001.

The scientific study of the distribution and abundance of organisms is a central theme in ecological research and has even been used as a definition for the discipline of ecology (Andrewartha 1961). Ecological studies can provide information which allows for the prediction of factors responsible for the occurrence of species in time and space. It is well known that organisms occur in habitats to which they are adapted. Proper environmental conditions allow them to grow and reproduce in association with other species which theoretically will not extirpate them through such interactions as competition or predation. Dominance, persistence, and stability in numbers are usually considered as indicators of success for species within the limits of their distribution whether on a geographical or habitat level. The purpose of this paper is to address the question of the level of heterogeneity of the physiochemical properties and the question of spatial distribution (over dispersion) of the microcrustacean community of a small dolomite quarry in South Central Minnesota. These heterogeneity questions must be answered before a sampling program can be designed to generate information that can be used in prediction, models and management schemes.

DESCRIPTION OF THE STUDY AREA

Between Kasota and Mankato on the east bluff of the Minnesota River there is a rock terrace on Oneota dolomite that is one and one-half miles in width, more than eight miles long, and is about 75 feet above the present Minnesota River. The vegetation covering the rock terrace has been designated as prairie. Thickness of the Oneota dolomite is from 45 feet at Mankato to over 150 feet to the east (Schwartz and Theil, 1958 and Apitz 1863). This terrace is heavily quarried as seen by a series of stripmine ponds (Apitz 1963). The village of Kasota, situated at the northern end of the limestone terrace along the Minnesota River, was the locale of some of the earliest quarry industries in what has been designated as the Mankato-Kasota district in south central Minnesota.

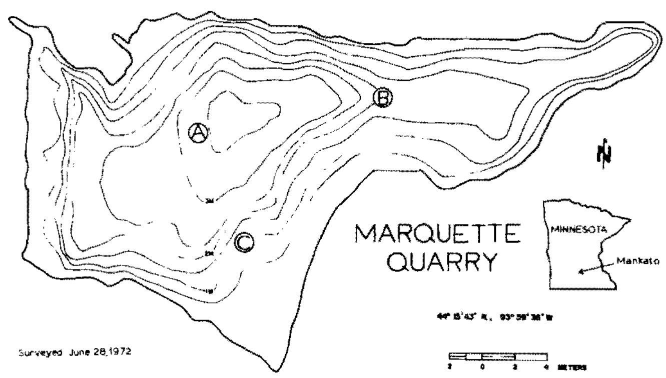


Fig. 1. Contour map of Marquette Quarry showing location of sampling stations A, B, and C. Depth contours at 0.5 meter intervals.

Marquette Quarry (Fig. 1) is a small dolomite limestone quarry which lies approximately 11 miles north of Mankato (44° 15' 43" N. and 93° 59' 36" W.) in south central Minnesota. Pertinent morphometric parameters are given in Table I. Mining of this pit began in 1950 and continued through 1960. It was vacated in 1960 and has remained waterfilled since then. The materials taken from these quarries are a fine-grained, dolomitic limestone, yellow or yellowish-pink in color, and are used chiefly for architectural stone.

The basin of the quarry lies in a pit characterized by steep-walled sides extending approximately 8 meters above the water's edge to the north and south. Protection of the surface from winds emanating out of these directions is significant and allows the quarry waters to become strongly stratified during the summer months.

Much of the pit's bottom consists of large exposed dolomite slabs which produce somewhat

---

[1]Limnological Contribution #23 of the Department of Biological Sciences Mankato State University.

[2]Present address: Department of Zoology, Arizona State University, Tempe, AZ 85218.

[3]Present address: Henningson, Durham & Richardson Power and Energy Division, 300 Parkdale Building, 5401 Gamble Drive, Minneapolis, MN 55416.

Table I. Morphometric parameters for the Marquette Quarry based on a map prepared by the Mankato State Biology Department, 26 June 1972. Terminology and symbols after Hutchinson (1957).

Length (l)	40.75 m
Shoreline length (L)	145.40 m
Shoreline development (D_L)	2.05
Volume development (D_V)	1.55
Maximum breadth (b_{max})	26.25 m
Mean breadth ($\bar{b}$)	9.82 m
Maximum depth (z_{max})	3.50 m
Mean depth ($\bar{z}$)	1.80 m
Area (A)	399.90 m^2
Volume (V)	721.30 m^3

irregular contours. No aquatic macrophytes are present except for a Chara bed in a shallow area at the south side. The long neck extending to the east is covered by a thick floating mat of filamentous green algae consisting of Rhizoclonium interspersed with some Mougeotia and Spirogyra. During the summer months this algal mat grew to cover approximately 75% of the surface, leaving only the central portion open. Sections of the mat broke off periodically and were transported to various positions on the quarry surface, allowing for potential movement of organisms living in and upon the surfaces of this mat. The mat sank to the bottom during the winter months except for that portion entrapped in the ice.

METHODS

Sampling Sites

A sampling station was established on each of the three catwalk platforms which were each constructed of two 30 foot telephone poles strapped together by wire. The catwalks were constructed to prevent the disturbance of the existing algal mat by sampling. During periods of ice, sampling was through the ice and directly below designated sampling stations.

Physiochemical Parameters

Water samples were collected at two-week intervals, on either Saturdays or Sundays, from January 14, 1973, to January 5, 1974. Sampling was initiated on the given dates at approximately 11:00 a.m.

Water samples were taken at each of the three stations having varying depths of from approximately 1 meter to 3 meters. Water level, air temperature, water temperature, dissolved oxygen, and light penetration data were all collected in the field at the established sampling stations and water samples were taken to the laboratory for pH, turbidity, conductivity, total alkalinity, total hardness, calcium hardness, and residual hardness analysis. All laboratory analysis of samples was completed within 3 to 6 hours of the initial collection time.

Selected additional physiochemical measurements to correspond to the biological collections were taken from 1 August 1972 through 13 August 1973. Samples and measurements were accomplished at biweekly intervals, except during the period of winter ice cover when they were taken approximately monthly. Measurements were made of water level, ice thickness, water temperature, dissolved oxygen, and pH. Standard physiochemical procedures were used and are documented in Kubly 1977 and McMichael 1975.

Microcrustaceans

Three different collection sites (Fig. 1; A, B, and C) were chosen to represent three potentially different habitats: Station A being near the deepest part of the quarry and in the open water; Station B at an intermediate depth and beneath the floating algal mat; and Station C in shallow waters containing a Chara bed and often covered by portions of the algal mat. Samples at Station B were taken by making three-sided incisions in the mat and folding it back to expose the underlying waters.

Replicate samples were taken at meter intervals with a 5-liter Juday plankton trap manufactured by Wildco Co. equipped with a plankton bucket containing a net of No. 20 (80 microns) mesh size.

All collections were taken in the morning at first light. The quarry waters were highly transparent and preliminary sampling indicated vertical migrations of certain populations. Species exhibiting typical diurnal migration patterns, congregating near the bottom during bright daylight hours, would have been difficult, if not impossible, to sample in a representative quantitative manner at high light intensities. Field microcrustacean sampling was normally completed within a time period of 40 minutes.

Counts and measurements were performed with the aid of a dissecting microscope equipped with an ocular micrometer at 50X magnification. Samples were examined in their entirety for the enumeration of individuals belonging to the less common species. Where population sizes were excessively large (> 500 individuals), subsamples comprising at least 20% of the total sample were removed and used for counting the major species.

Total counts against these subsamples in several instances revealed a mean error of approximately 10%.

Data Analysis of 1973 Physiochemical Study

Analysis of variance was performed to assess the influence or effect of each factor individually on measured variables for the physiochemical data collected from January 14, 1973 through January 5, 1974. Random factors tested were time (or date the variables were measured), horizontal location in the pond at which variables were measured or samples were taken for measurement of variables, and depth at which variables were measured or samples were taken for measurement of variables. Variables measured were air temperature, water temperature, dissolved oxygen, light penetration, pH, hydroxide alkalinity, carbonate alkalinity, total alkalinity, calcium hardness, magnesium hardness, total hardness, turbidity, conductivity, dissolved solids, ice thickness, snow thickness, water level of the pond, precipitation, and carbon dioxide concentration.

Data Analysis of Microcrustacean Study

Data gathered on the microcrustacean species were subjected to analyses inspecting dispersion, vertical distribution, community composition, and species diversity (Kulby 1977). In this paper the authors are reporting findings on species account relative and total abundance, and spatial distribution only.

Spatial distribution analysis of the quarry microcrustaceans was examined on three different scales: (1) dispersion, also termed microdistribution (Cassie 1963) and pattern (Pielou 1977); (2) large-scale horizontal distribution, that of the deep, intermediate and shallow water columns represented by Stations A, B, and C; and (3) vertical distribution.

RESULTS

Results of 1973 Physiochemical Study

Table II shows the influence of each factor on the response variables. The term "factor" when applied to the analysis of variance, refers to a quantity used to classify or otherwise distinguish experimental units. The approach utilized has been to analyze each two dimensional matrix individually and compare the three results. By compositing the results, the null hypothesis can be tested for each factor incorporating all test results. It is assumed that one indication of significance in any single test is sufficient to cause rejection of the null hypothesis.

Table II. Summary of analysis of variance. A "+" indicates significance or probability values less than 0.05. A "-" indicates nonsignificance or probability values in excess of 0.05. A "0" indicates that values were either nonsensical, not measurable, or both. T stands for time, D stands for depth and L stands for location.

Variable	Results					
	T	D	T	L	D	L
water temperature	+	+	+	+	-	-
air temperature	+	0	+	0	0	0
light penetration	+	-	+	+	+	+
turbidity	+	+	-	-	-	+
ice thickness	+	0	+	0	0	0
snow depth	-	0	-	-	0	-
water level	-	0	-	0	0	0
precipitation	+	0	+	0	0	0
pH	+	+	+	+	-	+
free carbon dioxide	+	+	+	-	-	-
dissolved oxygen	+	+	+	-	+	-
bicarbonate alkalinity	+	+	+	+	+	-
total alkalinity	+	+	+	+	+	-
calcium hardness	+	+	+	+	+	+
residual hardness	+	+	+	+	+	-
total hardness	+	+	+	+	-	+
total dissolved solids	+	+	+	+	+	-
conductivity	+	+	+	+	+	+
number of cells in the design	76		57		9	

The factor "sampling time" has been shown to have highly significant effects on all response variables except snow depth and water level. This indicates that most variables measured fluctuate significantly with changes in time. The null hypothesis that no significant differences occur with changes in time is rejected.

The factor "sampling depth" has been shown to have highly significant effects on all response variables. This indicates that all variables fluctuate significantly with changes in depth. These changes are largely a result of physical and chemical stratifications which existed. The null hypothesis that no significant differences occur with changes in sampling depth is rejected. The variables ice thickness, snow depth, water level, and precipitation would not vary with changes in depth and hence no analysis of variance results are provided.

The factor "sampling location" has been shown to have highly significant effects on all response variables except snow depth, free carbon dioxide and dissolved oxygen. These changes are largely due to specific differences between conditions existing in each of the three water columns. The null hypothesis that no significant differences occur with changes in sampling location is rejected for most response variables.

Microcrustacean Study

Species account. Fifteen species of Cladocera and Copepoda were collected during the microcrustacean study. Cladocerans included Daphnia pulex, Ceriodaphnia reticulata, Simocephalus vetulus, S. serrulatus, Chydorus sphaericus, Alonella nana and Scapholebris kingi. The neustonic S. kingi, undoubtedly sampled inadequately by the plankton trap, appeared in only three summer samples and will not be considered further. Copepods consisted of the diaptomid Diaptomus (Aglaodiaptomus) leptopus and the cyclopoids Eucyclops agilis, E. speratus, Macrocyclops albidus, Diacyclops bicuspidatus thomasi, Acanthocyclops vernalis, Orthocyclops modestus and Tropocyclops prasinus. Eucyclops spp. were treated as a single taxon in all numerical comparisons, because copepodids were not readily distinguishable and the latter species was rare in occurrence.

Relative abundance. Nine species, 3 cladocerans and 6 copepods, were collected during at least 12 months of the 13 month study and were thus considered perennial (Table III). The remaining ephemeral species were mainly summer forms, either displaying peak numbers during or restricted to this period.

Six species, all perennial forms, attained densities exceeding 10% of total within-station microcrustacean numbers (excluding nauplii) for one or more months of the study (Table III). Five of these had a within-station arithmetic mean monthly percent greater than 10%, while only Daphnia pulex exceeded this average at all sampling stations. A single ephemeral species, Tropocyclops prasinus, comprised more than 10% of the total within-station density on one sampling occasion.

Momentary dominant quarry microcrustacean assemblages generally paralleled the pattern reported by Pennak (1957, 1966), Patalas (1964) and Reed (1964) for limnetic and littoral regions of montane and alpine lakes. One cladoceran (Daphnia pulex) and one copepod (Diaptomus leptopus) dominated the open-water region, while one cladoceran (Chydorus sphaericus) and 2 copepods (Eucyclops agilis and Macrocyclops albidus) were generally dominant beneath the algal mat and in the Chara bed. The main exception to this generalization was the major quarry species, Daphnia pulex, which for limited periods maintained highest densities at all three stations.

Pennak (1957, 1966) found a seasonal succession of species to attain dominant rank with populations seemingly in a state of continuous, exaggerated flux. In this respect, the quarry microcrustaceans differed greatly from Pennak's findings. Although significant seasonal changes occurred in quarry microcrustacean densities, the dominant species composition exhibited a considerable constancy.

Total microcrustacean abundance. Based on the presence of large numbers of egg-bearing females and early immature stages, the high, oscillating, late summer microcrustacean densities at Station A (Fig. 2) resulted from heavy, asynchronous reproductive activity in Daphnia pulex and Diaptomus leptopus. Reproduction in both species diminished greatly by mid-September, coincident

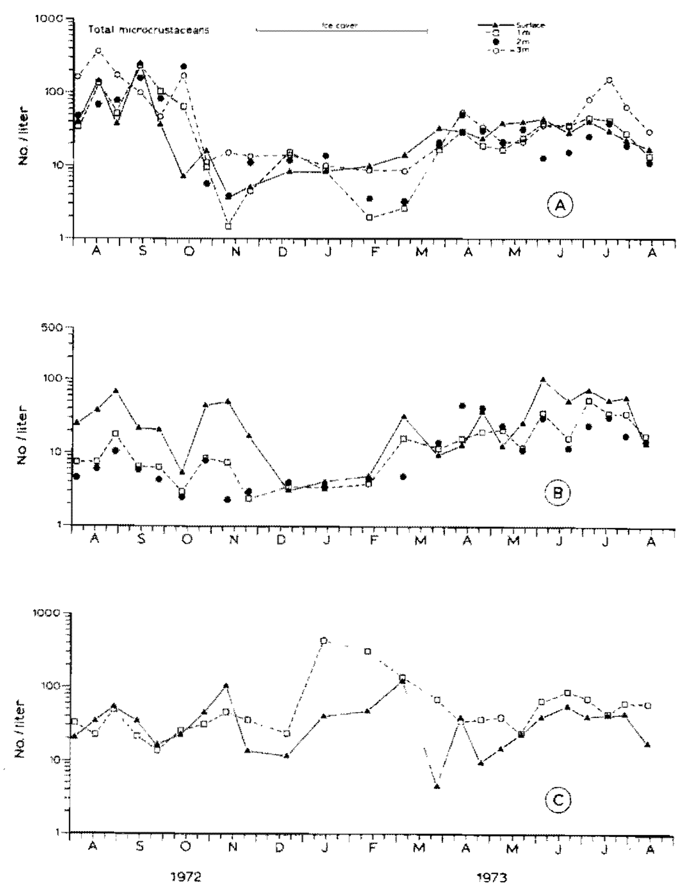


Fig. 2. Population densities for total microcrustaceans, including nauplii, collected from Stations A, B, and C in Marquette Quarry during 1972-1973.

Table III. Synoptic table of annual presence and dominance for the microcrustacean species collected from Stations A, B, and C in Marquette Quarry during 1972-1973. Dominance defined as greater than 10% of individuals, excluding nauplii, after Patalas (1964)

Species	No. months present			No. months > 10%			Rank order			Arithmetic mean monthly %		
	A	B	C	A	B	C	A	B	C	A	B	C
D. pulex	13	13	13	13	12	8	1	1	2	77.87	43.17	22.52
C. sphaericus	13	13	13	3	10	13	3	2	1	4.64	27.81	48.90
Eucyclops spp.	13	12	13	1	5	4	4	3	3	2.72	12.05	10.49
D. leptopus	13	13	13	6	2	1	2	4	5	11.61	7.80	4.32
M. albidus	10	11	13	0	3	5	8	5	4	0.26	7.03	11.04
A. vernalis	13	9	11	1	0	0	5	7	7	1.90	0.48	0.75
T. prasinus	6	7	7	0	0	0	7	6	6	0.28	0.55	1.63
A. nana	5	4	12	0	0	0	10	11	8	0.05	0.08	0.63
O. modestus	10	9	8	0	0	0	9	10	11	0.16	0.21	0.25
S. vetulus	2	6	5	0	0	0	13	8	9	+	0.35	0.34
S. serrulatus	3	5	5	0	0	0	11	9	12	0.03	0.32	0.25
D. b. thomasi	9	4	2	0	0	0	6	12	13	0.46	0.08	0.01
C. reticulata	2	2	2	0	0	0	12	13	10	0.02	0.06	0.32

with decreasing water temperatures, and densities were much lower by mid-October. Ephippial D. pulex females, present except February-April 1973, comprised 72% of the adult population by late November.

In contrast to Station A, total microcrustacean numbers at Stations B and C exhibited a marked bimodality during late summer and autumn of 1972, the latter peak not occurring until November. This pattern was due to nearly synchronous increases in reproductive activity by the 3 littoral dominants, Eucyclops agilis, Macrocyclops albidus and Chydorus sphaericus.

Winter numbers at Stations A and B were low and relatively constant, but increased markedly at Station C. Continued, though greatly diminished, occurrence of naupliar cyclopoids and early instar Chydorus sphaericus suggested a portion of this increase may have resulted from reproduction. The major cause, however, was most certainly concentration of individuals due to loss of habitat space, which resulted from lower water levels and ice cover. An additional source of the increase at Station C, especially from M. albidus and C. sphaericus, may have been migration from that portion of the populations previously associated with the algal mat. Prior to the onset of ice cover, much of the mat sank to the quarry bottom, and the remainder was subsequently frozen into the ice. This was followed by large decreases in M. albidus and C. sphaericus densities in surface waters at Station B.

Initiation of reproductive activity in 1973 varied considerably among the dominant species. Overwintering Daphnia pulex females began producing parthenogenetic young in early March, prior to melting of the ice-cover, while no diaptomid nauplii were collected until early April. Early spring reproduction in D. pulex resulted in a density peak by mid-April, but D. leptopus numbers remained low until late June. A second generation in both species, evident by the early July sampling, was followed in mid-July by their highest 1973 densities.

Littoral dominants--Eucyclops agilis, Macrocyclops albidus and Chydorus sphaericus--all exhibited increased reproductive activity by late March. Following April rises, marked decreases in densities of all 3 species occurred in early May at Stations B and C. This decline did not occur in these species at Station A or in the limnetic dominants. Subsequent to the early May decrease in densities, all 3 littoral dominants increased dramatically to their peak population numbers during June and July. Unlike the decided synchrony exhibited during late summer and autumn of 1972, however, these peaks were asynchronous and lasted for differing periods. By the end of the study, in mid-August, the densities of all 3 species had declined considerably.

Early and mid-summer decreases in the densities of the dominant littoral species, not accompanied by similar effects in the dominant limnetic species, suggests a causative factor associated with their habitat. The presence of odonate naiads, ceratopogonid midge larvae and Hydra, all predators associated with substrates, suggests that predation was probably responsible for this decline in numbers. Individuals of all 3 predator groups were observed to contain microcrustaceans in their gut cavities, and similar predation effects on littoral chydorid cladocerans have been suggested by Goulden (1971) and Keen (1973). Also, ordonate naiads are known to be voracious predators of microcrustaceans, particularly in the spring and early summer prior to their period of emergence (Johnson 1973, Johnson and Crowley 1981). Keen (1973, 1976) also attributed spring declines in chydorid populations to die-off of a submerged aquatic macrophyte, but the quarry Chara did not appear to suffer this mortality. Seasonal changes in the algal mat, however, may have been important. During July, portions of the mat appeared to enter senescence, turning brown and undergoing some fragmentation. By the mid-August sampling, the algal mat at Station B had broken away, and the samples were taken in open water. No Eucyclops agilis or Chydorus sphaericus were collected in surface waters at Station B, and the density of Macrocyclops albidus had decreased greatly from the previous sampling period. At the same time, the density of Daphnia pulex at this location remained stable, while that of Diaptomus leptopus increased.

Spatial distribution. The spatial distribution of quarry microcrustaceans was examined on 3 different scales: (1) dispersion, also termed microdistribution (Cassie 1963) and pattern (Pielou 1977). In the quarry, this measure was applied to replicate (duplicate or triplicate) 5 liter samples taken 0.5 m to 0.75 m apart; (2) large-scale horizontal distribution, that of the water columns represented by Stations A, B, and C; and (3) vertical distribution, the potential segregation of species by depth in the open-water column at Station A, by affinities for the algal mat versus open-water at Station B, and by preference of the algal mat or Chara bed at Station C.

Based on previous reports (Cassie 1963, Goulden 1971, Whiteside 1974, 1978, see also Hutchinson 1967, pp. 788-797), it was expected that replicate samples of quarry microcrustaceans would exhibit over-disperson (clumping). Initial inspection of these samples showed by far the majority of within species $s^2/\bar{x}$ ratios to be greater than 1, indicating over-dispersion. Also, there appeared to be a positive relationship between the magnitudes of the estimated population variances and their respective estimated means. This relationship was tested by regression analyses of log s^2-log $\bar{x}$ values to determine conformance with Taylor's power law (Taylor 1961). This law states that the variance of a population is proportional to a fractional power of the arithmetic mean (Elliott 1971), thus $b^2 = au^b$ and $\log b^2 = \log a + b \log u$, where a and b are population parameters. The slope (b) serves as an index of dispersion and varys continuously from 0 for a regular distribution to infinity for a highly contagious distribution. A value of 1 is expected when dispersion is random (Elliott 1971).

Results for the quarry microcrustacean species which exhibited fairly large ranges in population densities are presented in Table IV. Significance tests applied to the slopes show that all were significantly greater than 1, thereby confirming over-dispersion. Of additional interest is the coefficeint of determination (r^2) which depicts the proportion of the total variation in the estimated variance which is accounted for by the fitted regression (Zar 1974, p. 207). The range of values for this coefficient, from 0.46 to 0.88, suggests a good deal of variation in the fit of points to the regression line. Since the samples utilized in the regression represent different seasons and different habitats, it is possible that temporal and large-scale spatial effects, which vary decidedly among the species, are present in the total variation.

Table IV. Regression statistics for Taylor's power law applied to 7 common microcrustacean species collected from Marquette Quarry during 1972-73. Eucyclops agilis and E. speratus treated as one species.

Species	n	log a	b	r^2
Daphnia pulex	40	-0.20	1.76*	0.88
Chydorus sphaericus	40	-0.01	1.46*	0.70
Diaptomus leptopus	40	-0.25	1.74*	0.79
Eucyclops agilis	35	0.12	1.61*	0.72
Macrocyclops albidus	35	0.14	1.39*	0.66
Tropocyclops prasinus	36	0.08	1.54*	0.64
Acanthocyclops vernalis	39	0.23	1.25*	0.46

*Slope coefficient (b) significantly greater than 1 (P .05, one-tailed t-test).

Measurements of relationships between estimated population variances and estimated population means are important for both their theoretical and applied (management) implications. Over-dispersion implies that populations are clumped in space, and, therefore, a certain number of samples is necessary to adequately measure changes in population densities. Independence of variance and mean is an assumption of commonly used parametric statistics, and where this assumption is violated proper data transformations must be applied before these statistics can be used. It is apparent from this and other studies that such considerations should be made in constructing sampling designs for the measuremnt of small aquatic organisms.

Large scale distributional patterns of the quarry microcrustaceans generally reflected their limnetic or littoral affinities, individual species responses to gross environmental changes in the habitat and, possibly, in the case of certain limnetic species, an avoidance of competition through segregation of the open-water column. The limnetic dominants, Daphnia pulex and Diaptomus leptopus exhibited highly disparate distributions at Station A during ice-free periods (Fig. 3). D. pulex densities were highest at the lowest depth, while D. leptopus was concentrated in near-surface waters. This pattern, also observed by Grover and Coker (1940) during summer, largely disappeared under ice-cover when population densities were low and water temperatures were homogeneous or inversely stratified. Since all samples were taken in early morning, there is no evidence as to whether this segregation was maintained over diurnal cycles. Preliminary studies indicated vertical migration occurred in the quarry waters, but it is not known if these migrations were differential between the two species. Both D. pulex and D. leptopus were rare under the algal mat and at the Chara bed during summer and autumn of 1972, but their relative abundances increased at these locations during the period of ice-cover and remained higher than previously for the remainder of the study.

Eucyclops spp., Macrocyclops albidus, Chydorus sphaericus, Alonella nana and Simocephalus spp., all common littoral inhabitants, exhibited distinct affinities for the algal mat and Chara bed. Only C. sphaericus and Eucyclops agilis showed any tendency to invade the open-water region. Loss of the algal mat during ice-cover resulted in the near absence of perennial littoral species at the Station B surface and in an increased disparity between surface and bottom locations at Station C. With the return of the algal mat in spring 1973, relative abundances of littoral species increased to levels similar to those of the preceding autumn at the Station B and C surface locations.

Two other species which exhibited very disparate distributions were the cyclopoids Tropocyclops prasinus and Orthocyclops modestus. These species occurred in highest numbers in the surface and bottom layers, respectively, at all stations. During the summer and early autumn, the time of T. prasinus active existence in the quarry, this vertical segregation of approximately 3 m represented a maximum temperature difference of 9.5 C. O. modestus is generally considered a littoral inhabitant found typically in aquatic vegetation (Pennak 1978). In the quarry, however, it seemed more allied with the bottom and its cold waters in agreement with the findings of Anderson (1974).

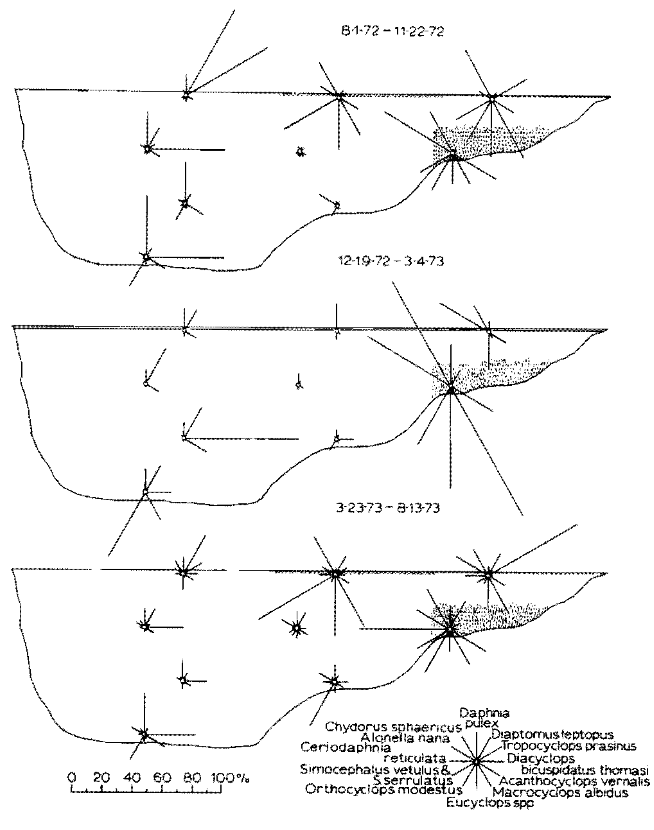


Fig. 3. The relative quantitative distribution of the microcrustacean species collected from Marquette Quarry during contrasting ice-free and ice-cover environments in 1972-1973.

A significant general feature of the quarry microcrustaceans' distribution in the quarry was the low relative abundance of all species in the open-water at Station B. This was a prevalent pattern throughout the year, during both ice-free and ice-cover periods. In the physiochemical study we found vertical attenuation exceeded 90% of summer light levels within 0.3 m beneath the filamentous algal mat. During the ice-cover period of the physiochemical study, light levels at the 0.3 m depth of Station B averaged only 47% of those at the same depth in Station A. This restriction of light penetration most certainly restricted phytoplankton productivity at Station B, making this region one of very limited food resources for filter-feeding microcrustaceans.

DISCUSSION AND SUMMARY

Physiochemical Relationships

Analysis of variance in the physiochemical investigation has shown that the Marquette Quarry is significantly heterogeneous in regards to most variables. Water levels, water temperatures, transparency and oxygen are commented on further here.

A maximum water depth of 3.5 m was measured in May of 1972 after snow melt and spring rains. Limitations on direct precipitation and runoff, due to the quarry's small surface area and surrounding topography, suggest that ground water input may have also contributed to this maximum. Decreases in depth were first noted in early August and continued into the winter months. The lowest level recorded, 2.6 m, produced a decrease in surface area of approximately 15%. This loss of water must be attributed mainly to seepage and lowering of ground water level rather than evaporation. The effect of this reduction in habitat space on littoral microcrustacean abundances is seen especially at Station C.

Quarry thermal profiles showed strong stratification at the beginning and end of the study period. A 9.5 C difference existed between surface and bottom levels at these times. Since the highest temperature change (8 C) occurred in the upper 1.5 m, the characteristic epilimnion of dimictic, north temperate lakes was never present. The marked summer stratification can be attributed to a combination of factors which restricted aeolian disturbance. These factors included: the high, steep, north and south quarry walls; the large, expansive algal mat; and the limited fetch due to small surface area. If present, inputs of cold ground water during spring and early summer would also have added to this stratification. This type of temperature profile, which resembles an exponential light-extinction curve, is rather commonly reported in bodies of water well protected from air currents (Cole 1975, p. 125).

By late August cooling was evident in the surface waters, and in early October the waters were nearly isothermal. An inverse stratification was evident under the ice cover from mid-December through mid-March. Ice thickness reached a maximum of 30 cm with an additional 12 cm of hard-packed snow in certain areas. By the third week of March the ice had melted, and the waters were again isothermal. A marked stratification was evident in mid-May, and by early August maximum temperatures, equalling those seen the preceding year, had been attained.

Restrictions on wind action and solar insolation were important in limiting maximum quarry water temperatures. Surface temperatures never exceeded 19 C, and bottom levels never reached above 9.5 C. The algal mat was especially important in restricting solar insolation during the warming period. The earlier physiochemical study found vertical attenuation exceeded 90% of summer surface light levels within 0.3 m beneath the filamentous mat. The resultant thermal regime, in effect, makes this body of water somewhat of a "geographical misfit". In fact, in spite of a shorter period of ice cover and, therefore, longer warming season in the quarry, its thermal regime resembles that of certain small lakes in the Experimental Lakes Area of northwestern Ontario, Canada (see Schindler 1971).

In the physiochemical study turbidity values (in Jackson Turbidity Units) ranging from less than 1 to 16 units were observed. Higher values were recorded at Station C under the winter ice and attributed to large numbers of microcrustaceans.

Dissolved oxygen levels, although probably never limiting to the microcrustacean species, were low during two periods of the microcrustacean study, late summer and late winter. Summer levels fell to 2.0 mg/liter (18% saturation), and a winter low of 2.6 mg/liter (20% saturation) was recorded. Both low values were recorded from waters collected at the lowest depth at Station A. Summer depletion can be attributed to a combination of highly stratified waters sealing off the small volume of oxygenated water in the lower depths, increased respiration from high plankton abundances, and reduced phytoplankton photosynthesis due to the extensive algal mat cover. Highest dissolved oxygen levels of 11.5 mg/liter (101% saturation) were recorded in the surface waters during early May following spring turnover.

Microcrustaceans

The previous discussion has shown that the quarry microcrustaceans were unequally distributed in both time and space. This fact carries little ecological significance beyond what could have been predicted from previous knowledge of the distribution and abundance of organisms. In contrast to this generalization, the ways in which the particular species were distributed, i.e. the ways in which they temporally and spatially partitioned the physical system in which they lived, is of significance. Communities are looked upon not as random assemblages, but as functional associations coexisting by virtue of their ability to survive the demands of their physical environment as well as the complex suite of biological interactions which result from their coexistence.

Certain species, e.g. Daphnia pulex, Chydorus sphaericus, Diaptomus leptopus, and Eucyclops spp., were perennial in occurrence and consistently utilized a major portion of the quarry waters. Other microcrustaceans, e.g. Alonella nana, Macrocyclops albidus, Orthocyclops modestus, Acanthocyclops vernalis, and Diacyclops bicuspidatus thomasi, while apparently occurring all year long, were more restricted in their spatial distribution. A third category, the decidedly ephemeral Tropocyclops prasinus, Ceriodaphnia reticulata, Simocephalus vetulus, Simocephalus serrulatus, and Scapholebris kingi, were more confined both temporally and spatially. Only taxa belonging to the first two categories ever achieved dominant positions.

If the wider ranges of temporal and spatial conditions utilized by the dominant quarry microcrustaceans were indeed indicative of broad niches and increased niche breadth is favored in uncertain environments as predicted by current ecological theory, it is instructive to view the quarry as an aquatic system in terms of uncertainty. Small water bodies can be viewed as more uncertain than larger ones due to the relative lack of buffering from terrestrial environmental vagaries conferred by smaller water masses. Temporal variation between generations, therefore, is probably greater in ponds than in lakes. Lakes are also more persistent as aquatic environments over longer periods of time simply due to their increased size. Seasonally fluctuating water levels, more common in smaller water bodies, may result in large changes in available habitat space, especially to organisms dwelling in shallow, shoreward regions. Limnetic microcrustaceans may also suffer from decreases in living space due to seasonal encroachment through expansive growth of rooted or floating vegetation. Lowered water levels concentrate organisms, increasing densities far in excess of those realized from reproductive activity. This concentration effect may lead to decreased availability of resources and increased competition. The net effect of these environmental changes is to produce a system undergoing relatively rapid fluctuations which would restrict the advantages held by any species specialized to a limited range of conditions or habitats.

In the quarry, lowered water levels resulted in losses in available habitat space concomitant with increased densities due to concentration at Station C. The extensive degree of seasonal variation in cover provided by the algal mat, as well as its loss to the winter ice, produced further expansions and contractions in habitat boundaries. Spring and summer growth in the mat increased its areal extent and provided additional habitat space to littoral microcrustaceans, while undoubtedly decreasing available resources to limnetic filter-feeders through shading effects. Senescence, break-up, and encapsulation by winter ice, in contrast, severely reduced the extent of this vegetative substrate available to littoral species. In these respects, the quarry was reminiscent of many ponds.

There were also ways in which the quarry maintained the more characteristic stability of a larger lake. It exhibited the typical dimictic thermal progression of north temperate lakes with strong, summer thermal stratification. Ranges in water temperature were unusually small for a water body of this size and geographical location. Relatively low temperatures predominated and undoubtedly played a role in inhibiting rapid population increases. Seasonal changes in habitat character and extent, although significant, never approached those of ponds which are many times pervaded by rooted or floating vegetation during summer and autumn. Thick organic sediments, which in many ponds combine their effects with small water volumes and winter ice cover to produce anoxic environments, have not yet formed to any extent in the quarry. The lack of these oxygen-consuming sediments provided a winter environment which allowed the active existence of many quarry microcrustaceans, including the dominant species.

The characters emphasized in the preceding paragraph were endowed upon the quarry largely through its morphology, the topography of its surrounding terrain, and the physical constitution of its bottom materials. These attributes, in turn, were mainly the result of its mode of origin. Steep basin sides, combined with the dolomitic block nature of the bottom and the extensive algal mat, resulted in the restricted growth of aquatic macrophytes and limited the extent of a realized littoral region. High-rising, nearly vertical, north and south sides, again in conjunction with the algal mat, diminished the wind's influence and limited solar insolation, thereby allowing strong thermal stratification and the maintenance of a relatively cold thermal regime.

Compared to other bodies of water the quarry contained a microcrustacean fauna similar in species richness and momentary dominance to that of small, high mountain or Canadian ponds or lakes. Both the numbers of species and the extended temporal dominance seen in this study may be at least partially attributable to the short-term existence of this water body. It may be considered as an aquatic island, recent in origin, and yet to reach an equilibrium as regards the number of species immigrations and extinctions. Future immigrations may well reduce the long-term dominance observed among certain species in this study. Theoretically, as new species which are better able to compete for available resources enter the system, niche compression will occur and relative abundances will be more evenly spread among the microcrustacean fauna.

The scope and duration of this study makes conclusive statements concerning the nature of this aquatic system and its component species perhaps untenable. It is evident that the system was in a state of almost continuous flux with species responding to environmental changes including those resulting from biological interactions. These responses to the multitude of stimuli which reached each of the individual organisms present at any given time were the result of evolutionary compromises which have insured the success of each of these species in this and other similar aquatic systems. When compared to reports on other water bodies, however, an apparent constancy existed in the quarry system. Rather than the rapid shifts in species dominance reported to be present in many bodies of water, we saw here the maintenance of a dominant numerical position by several species through relatively long periods of time.

ACKNOWLEDGEMENTS. Financial support was received via a faculty research grant awarded to Dr. Henry Quade by Mankato State University. The use of Marquette Quarry as a study site was made possible through the gracious permission of Mr. Steven Babcock. We are indebted to Dr. Gerald Cole and Mr. Richard Watkins of the Zoology Department at Arizona State University for confirmation of identification of the quarry microcrustacean species.

LITERATURE CITED

Anderson, R. S. 1974. Crustacean plankton communities of 340 lakes and ponds in and near the national parks of the Canadian Rocky Mountains. J. Fish. Res. Board Can. 31:855-869.

Andrewartha, H. G. 1961. Introduction to the study of animal populations. University of Chicago Press. 281pp.

Apitz, D. 1963. The Mankato-Kasota Limestone District, A Geographical and Historical Study. M.A. Thesis. Mankato State College, Mankato, Minnesota. 132pp.

Cassie, R. M. 1963. Microdistribution of plankton. Oceanogr. Mar. Biol. Ann. Rev. 1:223-252.

Cole, G. A. 1975. Textbook of limnology. C. V. Mosby Co., St. Louis. 283pp.

Elliott, J. M. 1971. Some methods for the statistical analysis of benthic invertebrates. Freshwater Biol. Assoc. Publ. 25. 144pp.

Goulden, C. E. 1971. Environmental control of the abundance and distribution of the chydorod Cladocera. Limnol. Oceanogr. 16:320-331.

Grover, W. W. and R. E. Coker. 1940. A study of the depth distribution of certain net plankters in Mountain Lake, Virginia. Ecology 21:199-205.

Hutchinson, G. E. 1957. A treatise on limnology. Vol. I. Geography, physics and chemistry. John Wiley and Sons, New York. 1015 pp.

Hutchinson, G. E. 1967. A treatise on limnology. Vol. II. Introduction to lake biology and the limnoplankton. John Wiley and Sons, New York. 1115pp.

Johnson, D. M. 1973. Predation by damselfly maiads on cladoceran populations: fluctuating intensity. Ecology 54:251-268.

Johnson, D. M. and P. H. Crowley. 1980. Odonate "hide and seek": habitate-specific rules. Pp. 569-579 in W. C. Kerfoot, ed. The Ecology and Evolution of Zooplankton Communities. Amer. Soc. Limnol. Oceanogr. Spec. Symp. Vol. 3.

Keen, R. 1973. A probabilistic approach to the dynamics of natural populations of the Chydoridae (Cladocera, Crustacea). Ecology 54: 524-534.

Keen, R. 1976. Population dynamics of the chydorod Cladocera of a southern Michigan marl lake. Hydrobiologia 48:269-276.

Kubly, D. M. 1977. The seasonal distribution and abundance of Cladocera and Copepoda in a Minnesota dolomite quarry. M.A. Thesis. Mankato State University, Mankato, Minnesota. 140pp.

McMichael, D. E. 1975. Selected physical and chemical factors in a limestone strip-mine pond. M.A. Thesis. Mankato State College, Mankato, Minnesota. 107pp.

Patalus, K. 1964. The crustacean plankton communities in 52 lakes of different altitudinal zones of northern Colorado. Verh. Internat. Verein. Limnol. 15:719-726.

Pennak, R. W. 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanogr. 2:222-232.

Pennak, R. W. 1966. Structure of zooplankton populations in the littoral macrophyte zone of some Colorado lakes. Trans. Am. Micros. Soc. 85:329-349.

Pennak, R. W. 1978. Fresh-Water invertebrates of the United States. John Wiley and Sons, New York. 803pp.

Pielou, E. C. 1977. Mathematical Ecology. John Wiley and Sons, New York. 383pp.

Reed, E. B. 1964. Crustacean components of the limnetic communities of some Canadian lakes. Verh. Internat. Verein. Limnol. 15:691-699.

Schindler, D. W. 1971. Light, temperature, and oxygen regimes in selected lakes in the Experimental Lakes Area. J. Fish Res. Board Can. 25:157-169.

Schwartz, G. M. and G. A. Thiel. 1954. Minnesota's rocks and waters. Univ. Minnesota Press, Minneapolis. 277pp.

Taylor, L. R. 1961. Aggregation, variance and the mean. Nature 189:732-735.

Whiteside, M. C. 1974. Chydorid (Cladocera) ecology: seasonal patterns and abundance of populations in Elk Lake, Minnesota. Ecology 55:538-550.

Whiteside, M.D., J. B. Williams and C. P. White. 1978. Seasonal abundance and pattern of chydorid Cladocera in mud and vegetative habitats. Ecology 59:1177-1188.

Zar, J. H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, NJ 620pp.

The Ecology of Gravel Pit Lakes in Southwestern Ohio

THOMAS C. KANE, MICHAEL C. MILLER, WILLIAM H. HOPPLE, MARY SCHONHOFT and KEVINA VULINEC. Department of Biological Sciences, University of Cincinnati, Cincinnati, OH 45221.

Gravel pit lakes represent a large proportion of the standing water habitat in southwestern Ohio due to the absence of naturally occurring lakes in the southern half of the state. Aggregrate is generally located in the river basins, where it was deposited at the end of the Pleistocene Epoch as the glaciers receded. The four county area surrounding Cincinnati, in southwestern Ohio, has a large concentration of sand and gravel mining areas. Thirty-three mining regions can be identified in the basins of the Little Miami and Great Miami Rivers which flow into the Ohio River on either side of the city. In 1977, 27 mining companies extracted over 4.8 million tons of material from Hamilton County alone.

Presently, gravel pit lakes in southwestern Ohio serve a variety of purposes. Many, of course, are still being actively mined. Several others have been made into stocked fishing lakes. Lake Isabella, a reclaimed mining area, has been managed by the Hamilton County Park District since 1977 as a fishing lake, picnic area and boat launching site. The Institute of Environmental Science at Miami University, Oxford, Ohio developed a plan for the use of the St. Claire gravel pit as a natural area and nature center (Colgan et al., 1978). Some gravel pits have been used as sites for the disposal of sanitary and industrial wastes. Many other pits remain fallow or are mined occasionally.

The occurrence of unusual plants and animals in gravel pits has been reported on several occasions in southwestern Ohio. Regular observations have been conducted on the bird fauna in gravel pits near Newtown, Ohio, on the Little Miami River, from 1974-1981 (Worth Randle, pers comm.). Five bird species that had not previously been known to breed in the area have been found breeding in these gravel pits. In addition, a Milbert's Tortoise Shell butterfly (*Vanessa milberti*) and a Northern Fen orchid (*Liparus loeselii*), both rare in southwestern Ohio, have been reported from area gravel pits.

Despite such unusual sitings, it is interesting to note that little, if any, formal research has been done on the ecological characteristics of gravel pits and gravel pit lakes in this area. The purpose of this study was to survey the ecological characteristics of gravel pit lakes in southwestern Ohio in an attempt to understand the factors which influence the nature and quality of these unique habitats.

METHODS

Study Sites

Forty-six artificially formed lakes were surveyed during 1980. These lakes are located along a 30 mile stretch of the Little Miami River, to the east of Cincinnati, Ohio. Forty-five of these lakes have been formed through surface excavation of sand and gravel by commercial mining companies. In addition, a recreational lake near one of the mining areas was included for comparison. This lake was excavated in clay substrate and was not the result of mining.

The 45 gravel pit lakes sampled are located in 26 separate gravel pits, nine of which contain more than one lake. The lakes range in age from one to 72 years and in surface area from 0.01 to 19.74 hectares. The distance from each lake to the Little Miami River varies from 0.05 to 1.3 km with an average distance of 0.41 km.

Gravel pit lakes can be formed by either of two methods of excavation. During the drier months of the year, when the water table is low, front loading bulldozers can remove exposed aggregate from the bottom of a pit. As the water table rises during wetter seasons, shallow (0.5-3.0 m deep) and sometimes temporary lakes are formed in the excavation sites. Lakes up to nine meters in depth are created when dragline cranes are used to extract material from below the water surface in a pit. Twenty-seven of the gravel pit lakes in this study were formed by the latter method, although many of these lakes have accumulated sediment and are now less than two meters deep.

In accordance with the surface mining laws

This project was partially supported by a Research Initiation Grant from the Mining and Mineral Resources Research Institute, Columbus, Ohio.

regulated by the Ohio Department of Natural Resources (ODNR, 1979), eight of the gravel pits, containing a total of nine lakes, have been reclaimed for purposes other than mining. An additional seven pits, with nine lakes, lie fallow and have not been reclaimed because mining was completed before reclamation was required by law. The remaining 27 lakes, occurring in 11 gravel pits, are still active mining sites.

Survey Techniques

A total of 19 physical, chemical and biological parameters were surveyed in each of the 46 lakes during 1980. Most of these parameters were measured for each lake at each of three seasons: spring; summer; and, fall. Techniques for the physical and chemical measurements are, for the most part, standard limnological procedures described in several technical references (e.g., APHA, 1975; Strickland and Parsons, 1968; Wetzel and Likens, 1979). We will restrict our presentation of physical and chemical data in this paper to those parameters which appear to significantly influence the biological characteristics of these lakes. All of the physical and chemical data are available in Hopple (1982).

The amount of photosynthetic production by algae in these lakes was measured using a light and dark bottle radioactive carbon-14 technique (Slack et al., 1973). Productivity is estimated by measuring the amount of radioactive carbon incorporation by algae during a prescribed incubation period in the light. Since lakes are often classified according to the amount of photosynthetic production occurring in them (e.g. eutrophic), this was an important measurement in our survey.

In assessing the animal community of these gravel pit lakes, we chose to concentrate on species of the family Chironomidae (Diptera). The species of this family of non-biting midges are small and spend most of their life cycle in an aquatic larval stage. The flying terrestrial adult stage is brief and functions mainly for dispersal and reproduction. Despite their small size, these midges, as larvae, play an important role in the food webs of aquatic systems. This is due to their densities in aquatic systems which have been reported to reach 50,000 individuals/sq. meter in some studies (Merritt and Cummins, 1978). In gravel pit lakes, specifically, chironomid production has been estimated by Titmus and Badcock (1980) at 45-70 kg/ha/yr. Further, Street (1977) has suggested that chironomid larvae may be an important protein source for Mallard ducklings in gravel pits.

A compelling reason for studying chironomid species composition in gravel pit lakes, in addition to the above considerations, is the value of these species as indicators of environmental quality. As a group, the Chironomidae have a broad range of environmental tolerances. Many individual species within the group, however, have very narrow tolerances. It is this characteristic that makes the group valuable as biological indicators.

Chironomids were sampled in gravel pit lakes using Hester-Dendy artificial substrate multiplate samplers (Hester and Dendy, 1962). Each multiplate sampler consisted of eight 6.5 cm squares of 3.2 mm tempered masonite bolted together with either one or two 2.5 cm squares separating each plate. A sampling device consisted of two multiplate samplers suspended 0.5m below a styrofoam float. Two sampling devices were used per lake. Samplers were kept in place for a four week period during the summer of 1980 in each lake. After the incubation period, samplers were returned to the lab, disassembled and scrubbed. Samples were concentrated and preserved in 70% ethanol. Chironomid larvae were mounted on glass slides using a procedure developed by Beckett and Lewis (1982) and identified to genus and when possible to species.

RESULTS AND DISCUSSION

Limnological data gathered during the summer of 1980 for the 46 lakes (Table 1) show that the lakes are small with only three larger than 10 hectares. Most of the lakes are shallow and thermal stratification was observed in only nine lakes, all of which were deeper than five meters. The pH and alkalinity data (Table 1) indicate that these are hardwater and relatively alkaline lakes which would be expected based on the geology of the area.

Phosphorus levels in many of the lakes were higher than what might be expected for natural waters of this type (Table 1). Wetzel (1975) indicates that total phosphorus content in groundwater is generally on the order of 20 ug/l, whereas total phosphorus concentrations in the gravel pit lakes averaged 169.2 ug/l for the spring 1980 sampling. There is indirect evidence to suggest that high phosphorus levels observed in five lakes may be related to the presence of refuse dumps and landfill sites near the lakes. This suggests an area for concern in maintaining these aquatic habitats.

Primary productivity estimates determined from the carbon-14 technique (Table 1) indicate that these lakes range from moderately to highly productive. This is consistent with what would be expected based on lake chemistry. On the basis of their overall characteristics, these gravel pit lakes range from mesotrophic to ultraeutrophic (Likens, 1975), with the majority falling in the mesotrophic category.

Table 1. Limnological data gathered in summer, 1980 for 46 artificially formed lakes in southwestern Ohio.

Parameter	Range	Median
Age (Years)	1-72	13
Depth (Meters)	0.20-9.00	2.00
Area (Hectares)	0.01-19.74	1.66
Alkalinity (mg/l $CaCO_3$)	68.0-290.8	135.2
pH	7.80-10.02	8.45
Orthophosphate (ug/l)	0.00-323.1	3.08
Primary Productivity (mg C/m^3/hr)	16.6-3070.6	143.05

Table 2. Characteristics of the midge (Chironomidae) communities of southwestern Ohio gravel pit lakes.

Parameter	Range	Mean	Median
Chironomids as % of Total Macroinvertebrates Sampled	7.5%-98%	62%	NA
No. Chironomid Individuals Sampled/Lake	15-3850	617.7	402
No. Chironomid Species/ Lake	6-18	11.6	11
Total No. Chironomid Species Collected = 38			

The Hester-Dendy multiplate samplers yielded large numbers of macroinvertebrates with an average of 1700 total individuals collected per lake. Individuals of the family Chironomidae comprised from 7.5% to 98% of all the macroinvertebrates collected with an average of 62% (Table 2). In general the chironomids, as expected, were the dominant macroinvertebrates and in only five lakes did the chironomids account for less than 40% of the total macroinvertebrates collected. A total of 38 different chironomid species were identified among all the lakes sampled.

In an attempt to understand how chironomid species number and abundance was controlled among the lakes sampled, we considered several possible factors and explanations. The mean number of chironomid species per lake was 11.6 with a range of 6-18 species (Table 2). Perhaps the simplest explanation for the number of chironomid species in lakes that could be suggested would involve lake age. It might be expected that time would be required for colonization to occur and therefore older lakes would have, on average, more species than more recently formed lakes. This is clearly not the case for the gravel pit lakes in this study. The three youngest lakes sampled, all formed within one year of the survey, contained an average of nine chironomid species per lake, very close to the value for all lakes combined (Table 2). In fact these lakes contained a wealth of macroinvertebrate species in general. The two lakes which contained the maximum number of chironomid species (i.e., 18) were only 5 and 13 years old respectively. By contrast, the three lakes with the fewest number of chironomid species (i.e., 6) had an average age of 25.7 years, with two of the three lakes older than 30 years. Rapid colonization of these lakes is not restricted to macroinvertebrates but may also be true for bird species (Worth Randle, pers. comm; Philip Prior, pers. comm.). In fact one of the interesting general findings of this study is how quickly a rich and diverse biota becomes established in these lakes after they are formed.

A second potential explanation for the control of chironomid species number in gravel pit lakes comes from the theory of island biogeography (MacArthur and Wilson, 1967). This theory predicts that the number of species on an island at equilibrium will be a function of the immigration rate of new species to the island and the extinction rate of species already present on the island. Immigration rate is greatly influenced by the distance the island is located from the source of colonists. Extinction rate is influenced by island size, in that large islands permit larger population sizes than small islands and therefore large islands have lower extinction rates than small islands. Although the model was developed for true oceanic islands, several studies (e.g., Faeth and Kane, 1978; Vuilleumier, 1970) have shown it to be applicable to isolated pieces of habitat on continents as well. In this context gravel pit lakes could be considered to be "islands." Further, because of the above considerations and because the model makes very simple biological assumptions, island biogeography theory is very attractive as a management tool for such things as nature preserve design (Wilson and Willis, 1975).

If gravel pit lakes do act as islands for chironomid species, then island biogeography theory predicts that species number should be related primarily to the area of each lake. Since all the lakes examined are approximately equidistant from the Little Miami River, and since each lake serves as both an "island" and as a source for other lakes, the effects of distance should be approximately the same for all lakes. Therefore, a plot of the $\log_{10}$ of chironomid species number vs. $\log_{10}$ of lake area should produce a straight line of positive slope. However, a regression analysis of these data for all the gravel pit lakes surveyed shows that no such statistical relationship exists. The number of chironomid species in a lake is independent of the size (area) of the lake. Further analyses, using only lakes of the same age, or of the same mining status, or of lakes located in the same geographic area, still fail to provide a fit to the island biogeography model. From this we must conclude that, despite the wide applicability of the island model in other such studies (e.g., Driver, 1977), the distribution of chironomid species in the lakes of this study is controlled by more complex biological processes.

Several lines of evidence in this study suggest that chironomid species distribution is determined by the habitat characteristics of the individual gravel pit lakes. Spearman's Rank Correlation (Sokal and Rohlf, 1968) was used to compare statistically chironomid distribution patterns with several of the limnological parameters discussed earlier. The number of chironomid species in these gravel pit lakes is negatively correlated (P=0.006) with the productivity (carbon-14) of the lakes and is also negatively correlated (P=0.02) with the total phosphorus content of these lakes. By contrast, the number of chironomid individuals in a lake is positively correlated (P=0.01) with lake productivity. This is a pattern typically seen in polluted waters (Wilhm and Doris, 1968) where resulting high productivity favors only a few species which may be present in high abundance. Since there is strong evidence that phosphorus levels in some of these lakes have been influenced by human activity, it appears that the general pattern of chironomid distribution does reflect potential pollutional insults in these lakes.

A closer examination of the distribution of individual chironomid species among these lakes further emphasizes the importance of habitat characteristics to these species, and further supports the value of these species as indicators of environmental quality in gravel pit lakes. Several species were found which are known to occur only in stillwater and would therefore not be present generally in the nearby Little Miami River. One such species is *Lauterborniella varipennis*, which is further restricted to lakes with aquatic vegetation and soft sediment. This species was the dominant (i.e., most abundant) chironomid in only one lake and that was the only lake which had sediment composed predominantly of clay and fine particles and also contained emergent vegetation. The only other two lakes in which *L. varipennis* was found also contained large aquatic plants. The recreational lake sampled in this study did not result from gravel mining but rather was created from excavation of clay substrate. The chironomid community of this lake was distinguished from those of the gravel pit lakes by the presence of two species of the genus *Cricotopus*. One of these, *C. intersectus* which is the dominant chironomid species in this lake, is reported (Simpson and Bode, 1980) to be common in waters subjected to high organic inputs and is also characteristic of highly eutrophic lakes. This recreational lake is highly productive (1770 mg $C/m^3/hr$), and has a resident population of domestic geese which contribute considerably to the organic input. One final chironomid species of note is a species of the genus *Einfeldia*. This species was found in only two lakes and in one of these it was the dominant, accounting for 47% of all the chironomid individuals collected. The lake in which *Einfeldia* was dominant was one which had a very high level of productivity and low levels of dissolved oxygen in the bottom waters. Such habitat conditions have been shown previously (Beck, 1977) to be typical for the genus *Einfeldia*.

The findings of this survey indicate that gravel pit lakes support an abundance of macroinvertebrates in general and chironomids in particular. This finding is important from a management point of view, since macroinvertebrates provide a critical food source for many vertebrate species (e.g., fish and waterfowl). Chironomid species composition in these lakes appears to be determined to a great extent by such factors as lake productivity, substrate characteristics, and nutrient and oxygen levels. It has been shown in turn that many of these factors have been influenced by human activity. Therefore, chironomids appear to be sensitive indicators of environmental quality in gravel pit lakes, just as they are in other types of aquatic systems. This finding also has management value because it suggests that water quality or changes in water quality may be indicated early on by the chironomid composition or by changes in the chironomid composition in these lakes. This is, of course, a much more obvious indicator of environmental quality, when regular or continual monitoring of the water is not being done.

SUMMARY

1. Gravel pit lakes offer a unique habitat in southwestern Ohio due to the absence of naturally occurring lakes in the area.

2. These lakes develop a rich and diverse biota soon after formation. Further, they have been shown to attract some plants and animals which are otherwise unusual in the area.

3. There is strong evidence in our data that some of these lakes are being subjected to pollution from nearby refuse dumps and landfill sites.

4. The macroinvertebrate communities of these

lakes are dominated by species of the midge family Chironomidae (Diptera). From a management perspective, this group is important for two reasons. First, these species have been shown to be an important food source for some fish and waterfowl species. Further, other studies have shown chironomids to be valuable indicators of environmental quality. Our data suggest that they serve this role in gravel pit lakes as well.

LITERATURE CITED

AMERICAN PUBLIC HEALTH ASSOCIATION. 1975. Standard methods for the examination of water and wastewater. A.P.H.A., Washington, D.C. 1193pp.

BECK, W.M. 1977. Environmental requirements and pollution tolerance of common freshwater Chironomidae. U.S.E.P.A. Cincinnati, Ohio. EPA 600/4-77-024. 260pp.

BECKETT, D.C. AND P.A. LEWIS. 1982. An efficient procedure for slide mounting of larval chironomids. Trans. Am. Microsc. Soc. 101: 96-99.

COLGAN, P., D. CRANDALL, L. GOLDSTEIN, N. GREENSLADE AND D. SIGLER. 1978. The educational and recreational potential of the St. Claire Avenue gravel pit. M.S. Thesis. Miami University, Oxford, Ohio. 63pp.

DRIVER, E.A. 1977. Chironomid communities in small prairie ponds: some characteristics and controls. Freshwater Biology 7:121-133.

FAETH, S.H. AND T.C. KANE. 1978. Urban biogeography: city parks as islands for Diptera and Coleoptera. Oecologia 32:127-133.

HESTER, F.E. AND J.S. DENDY. 1962. A multiple-plate sampler for aquatic macroinvertebrates Trans. Amer. Fish. Soc. 91:420-421.

HOPPLE, W.H. 1982. Environmental characteristics and the Chironomidae (Diptera) composition of gravel pit ponds. M.S. Thesis. University of Cincinnati, Cincinnati, Ohio. 122pp.

LIKENS, G.E. 1975. Primary production of inland aquatic systems. Pages 314-348 *in* H. Lieth and R.H. Whittaker, eds. The primary productivity of the biosphere. Springer-Verlag, N.Y.

MACARTHUR, R.H. AND E.O. WILSON. 1967. The theory of island biogeography. Princeton University Press, Princeton, N.J. 203pp.

MERRITT, R.W. AND K.W. CUMMINS. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publ. Corp., Dubuque, Iowa. 441pp.

OHIO DEPARTMENT OF NATURAL RESOURCES. 1979. Division of Reclamation, Ohio Surface Mining Law, Chapter 1514 of Ohio Revised Code.

SIMPSON, K.W. AND R.W. BODE. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and rivers with particular reference to the fauna of artificial substrates. N.Y. State Museum Bull. No. 439, Albany, N.Y. 105pp.

SLACK, R.V., R.C. GREENSSON, P.E. AVERETT AND R.G. LIPSCOMB. 1973. Methods for collection and analysis of aquatic biological and microbiological samples. U.S. Department of Interior, Geological Survey, Book 5(A4), Washington, D.C. 165pp.

SOKAL, R.R. AND F.J. ROHLF. 1968. Biometry. W.H. Freeman and Co., San Francisco, Ca. 776pp.

STREET, M.S. 1977. The food of Mallard ducklings (*Anas platyrhnchos*) in a wet gravel quarry and its relation to duckling survival. Wildfowl 28:113-125.

STRICKLAND, J.H.D. AND T.R. PARSONS. 1968. A practical handbook of seawater analysis. Fish. Res. Bd. Canada Bull. 167. 311pp.

TITMUS, G. AND R.M. BADCOCK. 1980. Production and emergence of chironomids in a wet gravel pit Pages 299-305 *in* D.A. Murray, ed. Chironomidae: ecology, systematics, cytology and physiology. Pergamon Press, N.Y.

VUILLEUMIER, F. 1970. Insular biogeography in continental regions. I. The northern Andes of South America. American Naturalist 104: 373-388.

WETZEL, R.G. 1975. Limnology. W.B. Saunders and Co., Philadelphia, Pa. 743pp.

WETZEL, R.G. AND G.E. LIKENS. 1979. Limnological analyses. W.B. Saunders and Co., Philadelphia, Pa. 357pp.

WILHM, J.L AND T.C. DORRIS. 1968. Biological parameters of water quality. Bioscience 18: 447-481.

WILSON, E.O. AND E.O. WILLIS. 1975. Applied biogeography. Pages 522-534 *in* M.L. Cody and J.M. Diamond, eds. Ecology and evolution of communities. Belknap Press, Cambridge, Mass.

Development of Aquatic Habitat Potential of Gravel Pits

EDWIN E. HERRICKS, Department of Civil Engineering, University of Illinois Urbana-Champaign, Urbana, Illinois 61801.

INTRODUCTION

The potential for resource recovery does not end when economically valuable mineral resources are exhausted on a mine site. A number of financially rewarding options are available for further land use which take advantage of renewable resources which may require little or no continuing maintenance. Definitions of renewable resources are often narrowly limited to agricultural or forest products, but any end use which can provide largely self-sustaining "products," including recreation and fish and wildlife use, will be considered a renewable resource in this discussion. For gravel mines, a major advantage for renewable resource development is the proximity of these areas to centers of population where recreation resources may be limited. Since the typical sand and gravel operation is small [the National Academy of Sciences identified 99% of all sand and gravel mines with an annual production of less than one million tons (NAS, 1979)], a viable option for final land use is the development of recreation potential following mining.

The elements of recreational use are typically centered around both land and water resources and, for best results, require the development of a recreational use plan. This plan can be somewhat flexible when considering general site planning or revegetation but must be much more specific when water resources, including fisheries and water-based recreation are a desired outcome of mined land development. The critical planning paths for development of land and water based recreation diverge following initial selection of desired final land use. Land development requires surface grading and revegetation. While both of these activities can be easily modified and most are executed after mining activities end, modification of water bodies is very difficult following the termination of mining operations. For water bodies to support recreational use and/or fish and wildlife, excavation and development of final basin configuration is best accomplished as mining progresses. Thus, water resource development requires selection of expected use early in the mining operation. For example, since the availability of water is often the key element for development of mined lands for housing or other uses it should be recognized that all site development activities except modification of water body characteristics can easily follow mining suggesting again that early planning of water resource presence and use is an essential element of all sand and gravel mining.

This paper has been prepared to provide a brief review of the requirements for water resource development on gravel mines, and will provide a summary of best current practices for pond and lake and fisheries development with an emphasis on identification of specifications and/or activities required during mining operations.

INITIAL PLANNING ACTIVITIES

The initial planning activities for the development of water resources and aquatic habitat are typically associated with pre-mine development but can be initiated at any stage of the mining process (e.g., where value of water resoruces may be perceived for an existing mine, incorporation of best current practices is possible as mining progresses). The first step is selection of the final use for the ponds or lakes on the mine site. Although final use may be poorly defined early in an operation, especially if the planned life of the mine is 10 or more years, a general intent to provide fisheries, sailing, or other water based recreation activities will provide enough guidance for planning and mining management. When specific uses are identified, for example, final use by a sportsman's club where fisheries management is the goal or a housing development is planned where access to the lake or pond is to be maximized, it is relatively straightforward to develop a set of specifications for the mining operation.

Initial specifications are developed to define lake geometry. Specifications will be based on deposit configuration, operational requirements (e.g., process water storage and treatment, equipment

Table 1. Parameters Considered in Lake Development

Standard Parameters:

Surface Area (A)
Volume (U)
Length (L)
Breadth or Width (b_x)
Depth
  maximum depth (2_m)
  mean depth ($\bar{2}$)
Shoreline (L)

Lake Feature Descriptions:

Shoreline development (D_L) $= \frac{L}{2\sqrt{\pi A}}$

Volume development (D_u) $= 3\ \bar{2}/2_m$

Islands
  number
  size

Banks
  minimum slope
  maximum slope
  % in slope categories

Underwater shelves
  minimum and maximum depth
  minimum and maximum width
  area of width or depth categories

Lake Bottom
  minimum and maximum slope
  irregularity (mounds, depressions)

availability, etc.), permit requirements, and anticipated final use. As these specifications are being developed the decision is usually made concerning the mine operators interest in participating in the final development of the site. Although the mining operator may or may not be the land owner and neither may actually develop the site, the value of the land can be enhanced if the foundation for development is established as the mining operation progresses (e.g.,the depth and extent of the excavation is suitable for intended use or mining operations include preliminary site preparation which limit equipment requirements for the developer). An initial list of excavation specifications can be developed from Table 1 which lists the parameters typically considered when dealing with lake geometry.

Although not previously mentioned, an essential element of water resources development is the actual availability of water on the site. For most gravel mining operations, particularly those in alluvial deposits, the issue of water availability may be taken for granted or, when excess water is present, may be dealt with as a problem requiring extensive site engineering. When sand and gravel operations are located in upland areas a shortage of water may actually exist. When there is a concern about water supply a hydrologic evaluation may be required. At a minimum, the items regarding water availability listed in Table 2 should be considered early in pond or lake planning.

Table 2. Water Supply Parameters Considered in Lake Development

Water Budget

  Ground water yield
  Surface water yield
  Stream inflow
  Stream outflow
  Seepage loss
  Evaporation loss

Water Management

  Process requirements
  Inflow controls
  Outflow controls
  Acceptable minimum and maximum depths
  (seasonal depth requirements)

The final planning activities should center around the development of suitable aquatic habitat for the species to be managed or the use intended for the site. Although many physical habitat requirements can be met as mining progresses, water quality is of critical importance when mining terminates. Even though water quality problems are usually minimal with sand and gravel operations an analysis of water chemistry in any impoundments during mining is a valuable indicator of expected water quality in ponds or lakes. If chemical parameters exceed values in Table 3 remedial measures for improvement may be considered or final use expectations adjusted.

The total planning effort for a sand and gravel mine is much more extensive than portrayed in the previous paragraphs. A planning guide has been prepared by the Bureau of Mines to assist small operators in reclamation and pollution control (Banks et al., 1981). When fish and wildlife or recreational use which will benefit from the presence of fish and wildlife are considered for final land use, those fish

Table 3. Water Quality Parameters Typically Measured and Ranges which Support Fisheries Management

pH[1]	6.5 - 9.0
Alkalinity[1]	20 mg/L or greater
Hardness[2]	20 - 150 mg/L
Dissolved Oxygen	natural minima[1] 4 mg/L floor[3] 5 mg/L minimum[4]
Dissolved Solids (TDS)	higher TDS generally higher fisheries productivity
Temperature	maximum 20 - 30°C depending on species and acclimation

1) Thurston et al 1979
2) Stickney 1979
3) NAS/NAE 1973
4) EPA 1976

and wildlife resources can be enhanced by implementing practices identified in several documents developed specifically for coal mine reclamation. Herricks et al. (1981) provide a summary of best current practices for fish and wildlife development on mined lands in the eastern interior coal basin. A second document, Herricks et al. (1980) provides a reference for fish and wildlife habitat requirements in the same region. Hinkle et al. (1981) through the Office of Surface Mining have provided A Handbook for Meeting Fish and Wildlife Information Needs To Surface Mine Coal - OSM Region III which can also provide valuable information to sand and gravel mine operators. Of specific interest to sand and gravel mines where ponds and lakes are planned is Nelson and Associates (1981) Manual for Planning and Management of Mine-Cut Lakes at Surface Coal Mines which provides detailed information for lake planning and management. The following practices have been selected from Herricks et al. (1981) and Nelson and Associates (1981) to provide benefits to fish and wildlife in sand and gravel mine reclamation, specifically aquatic habitat and fisheries reclamation.

PRACTICES FOR AQUATIC HABITAT DEVELOPMENT

The practices which can be selected for aquatic habitat and fisheries development include both habitat development and fisheries and/or wildlife management. The sand and gravel operator should be aware of two fundamental ecological principles. The first is that management for any one species necessarily requires development of a complex supporting ecosystem if overall maintenance costs are to be minimized. A corolary is that if conditions are optimized for development of a healthy ecosystem the management of a desired species is facilitated and maintenance costs are similarly minimized. Thus an operator should strive first for the development of relatively stable land and water conditions, allowing the area to naturally develop or enhancing development throughproperly selected management (e.g., reclamation planting, species selection, and planting design).

The second fundamental principle is that development time plays an important role in the quality and productivity of any ecosystem. The goal of reclamation is development of a stable ecosystem which will be largely self-supporting. A stable ecosystem will not develop overnight although it will develop naturally if given enough time. A corolary to this principle is that development time can be minimized through careful management. The sand and gravel mine operator may not be interested in the development of the site following mining, but he should be aware that the value of the site can be significantly increased if use is not delayed by the time required for ecological development. To this goal, discussions are included in this section which deal with both practices which can be implemented during mining to enhance aquatic habitat and fish and wildlife resources and post mining reclamation and management activities. The discussions related to practices implemented during mining emphasize practices which deal with excavation and site topography development which may require modification of day-to-day operations.

Site Topographic Development

The planning of excavation and material placement is the first and possibly the most important step in aquatic habitat development on a sand and gravel mine. If planned and executed well, the water body which is "built" will have characteristics which will support balanced flora and fauna (algae, aquatic macrophytes, invertebrates, and fish) in the lake or pond.

The first consideration is generally maximum depth. Depth is measured in terms of maximum and average depth and is particularly important in determining the capacity to support year round fisheries.

If the excavation provides only shallow habitat, the likelihood of high fish mortality due to winter kill(low dissolved oxygen caused by ice and snow cover on the water) will prevent maintenance of healthy fish populations as the lake ages. Depth will also be important in limiting unwanted weed growth. A shallow lake will have all of its bottom in the photic zone leading to nuisance weed growth and corresponding fisheries impairment. Thus depth should be variable, with both deep and shallow areas. In northern areas a maximum depth of 10 to 15 feet over approximately 25% of the lake area should be planned. If greater depths are possible they should be provided.

When planning a waterbody depth, some guidance can be provided by an empirical relationship proposed by Ryder (1965), the morphoedaphic index (MEI). The MEI was designed as a simple model to assist fisheries managers in the prediction of fish yield. The MEI uses mean depth and total dissolved solids to predict fish yield. The equation takes the form:

$$\log (Y/A) = f + g + \log \ TDS - h \log z$$

Where: Y/A = yield per unit area
TDS = total dissolved solids
z = mean depth
f, g, h = empirical constants

Although the MEI is empirical and is still subject to some controversy, recent evidence and discussions (Jenkins, 1982; Schlesinger and Regier, 1982; Youngs and Heimbuch, 1982; and Ryder, 1982)suggest the MEI can provide valuable guidance in fisheries development. In sand and gravel mining the calculation of mean depth for the excavation, determination of total dissolved solids for the water, and application of constants which may be regionally specific, Schlesinger and Regier (1982) can provide a prediction of fisheries success.

In addition to maximum or average depth, special consideration should be given to shallow areas. Shallow (littoral) areas or shelves with a depth of approximatley 2 to 6 feet should be provided over 20% or more of the lake surface area. By increasing the littoral area fisheries are generally enhanced since shallow water provides conditions favorable to fish food organisms (largely benthic invertebrates). Plant growth in these areas also provides protection for spawning and early life stages of fish. Shallow water habitat can also be provided by connecting

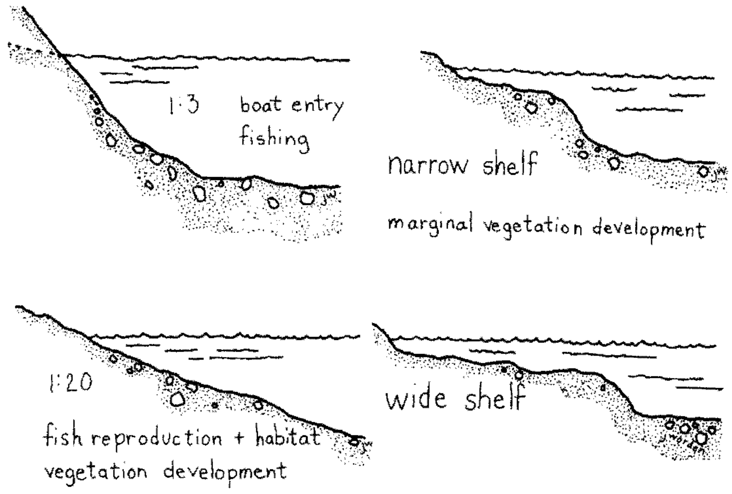


Figure 1. Bank grading schemes to provide for aquatic habitat and recreational use.

channels between water bodies, (Burner, 1973). Connecting channels on gravel mines can be developed when mining will produce more than one impoundment. These multiple impoundments are particularly valuable when site waters are used for material processing or benefaction. Since water treatment (often only settling) can be accomplished by using one lake as a settling basin before water is returned to a lake being managed for fisheries, connecting channels will exist between lakes and increase the littoral habitat when mining operations end. Associated with depth is bank grading. Figure 1 illustrates several grading schemes which can provide for different uses. Nelson and Associates (1981) specify stable perimeter slopes not steeper than 2h:1v or 27°. Allen and Lopinot suggest slopes according to the soil present. Heavy soils should be 1h:1.5v, with lighter soils having a 2h:1v slope. Bank grading will obviously be related to the amount of littoral area planned. To provide habitat diversity, both narrow and shallow shelves should be provided. Since fish often select areas where depth changes rapidly, rather steep drop-offs should be provided for some slopes. With steep drop-offs a compromise can often be reached between a desire for shallow areas and the demand for full utilization of the product on the site. In the typical sand and gravel mine deep areas where all material is recovered can make up the majority of the lake while shallow shelves or littoral areas can be provided around the margins of the excavation. As noted on Figure 1, areas which provide boat entry or lake access may be included. If the lake is to be used for swimming,

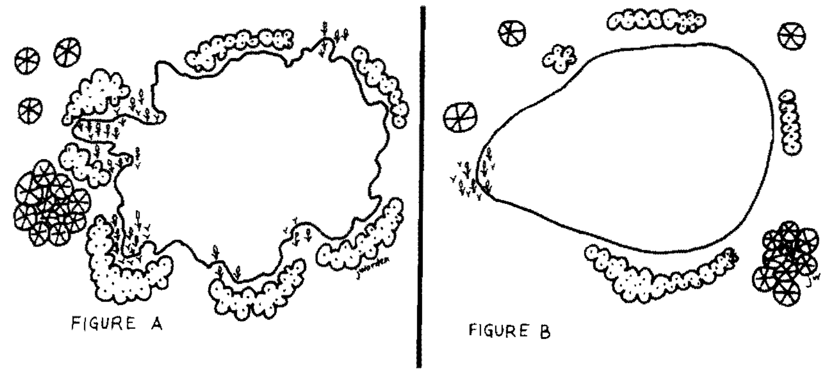


Figure 2. Edge sculpturing to maximize shoreline length and aquatic habitat. A is preferable to B.

shallow areas without sharp drop-offs should be provided.

Excavation and bank grading should also include provisions for edge sculpturing. An absolutely circular basin often limits opportunities for establishing depth heterogeneity. By sculpturing the margins of the excavation it is often possible to provide ample littoral areas (at minimal excavation costs), again allowing maximum product removal. Figure 2 illustrates how edges might be sculptured. In sand and gravel mining, edges can be enhanced by channels which connect one or more water bodies or proper planning of waste material movement or placement. Again no detailed specifications are provided for edge development but an approximate rule of thumb suggests that the greater the edge (e.g., shoreline length) the greater the potential productivity of the lake.

A final topographic development which is best accomplished during initial excavation is the development of bottom topography. Figure 3 illustrates the type of bottom topography which is preferable on a lake bottom. The depth variation should be large, 3 to 5 feet.

The final excavation plans should also include provisions for a variety of substrates around the lake margin and throughout the lake basin. Aquatic organisms are often quite selective of the size particles they use for reproduction and maintenance. For example, some fish species will only spawn in gravel of a certain size while many plants and benthic organisms require silt or fine sand substrates for maintenance. Thus different sized substrates should be available in the lake. By matching substrate requirements of fish and other aquatic organisms with the area of that substrate available it is possible to control or enhance aquatic resources. Table 4 illustrates several general size classes and the aquatic organisms which prefer that size class. In sand and gravel mining, a variety of substrate materials can generaly be provided. For example large cobbles and small boulders are often considered waste material. Placement of these materials in the final excavation can provide essential substrates. Mixtures of sand, gravel, and even topsoil may be used to enhance fisheries.

Previous discussions have all been directed to the development of aquatic habitat for fisheries development. Several topographic features can also be incorporated in excavation planning which will enhance wildlife. The provision for littoral areas and the availability of a variety of substrate types along the shoreline will typically provide habitats suitable for aquatic furbearers. Littoral area and edge sculpturing will also affect wildlife. Sandusky (1978) found that shoreline irregularity (the ratio of shoreline length to water surface area) determined the amount of usable nesting area for waterfowl. To encourage use of the lake by waterfowl, other factors should also be considered. For example, Allaire (1977) found that length and width of impoundments was important for some waterfowl species. He noted that because loons need long water runways to become airborne a minimum lake size of 165 by 660 feet was required. Thus surface area should be an important consideration in lake development.

Another topographic consideration for wildlife in gravel mine excavation is islands. Figure 4 illustrates how an island might be designed in a lake. These islands provide protected nesting sites for

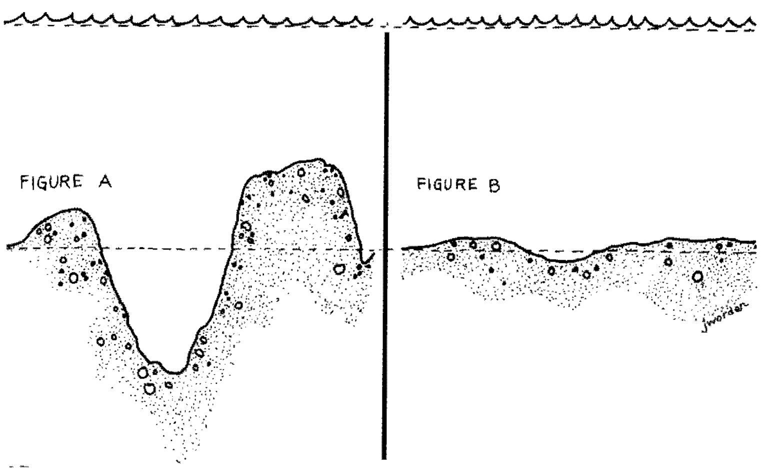


Figure 3. Configuration of bottom in lakes produced by mining. A is preferable to B.

many waterfowl species as well as adding to general habitat diversity. Islands may be very compatible with sand and gravel mining. For example, in mines where products are discontinuous, the planning of excavations may leave both large and small islands. This again allows for maximum resource recovery while providing extremely valuable aquatic habitat.

In summary, site topographic development is the first and often the most critical step in the proper development of aquatic habitat. Selection of depth specifications, lake configuration, and final surface substrate characteristics are all relatively straightforward. Once these elements are in place, the long term management of the site is initiated. Management costs can also be minimized.

PRACTICES APPLICABLE DURING MINING

The implementation of reclamation practices during mining operations should be considered when the life of the operation is quite long or the opportunity for isolation of areas on the mine is possible. The essential element is that no, or at least minimal additional disturbance, is anticipated for the site. This does not mean that the water body must be isolated from use. It is possible to have a water body available as a water supply for process water and still maintain suitable environmental conditions for fish and wildlife. The major concern during mining is the maintenance of aquatic habitat conditions. This can be achieved through treatment of any process waters. The typical treatment requirement is sediment removal. A low cost treatment option is the construction of one or more settling ponds which will receive process waters, allow sediment to settle, then return the water to the lake. A series of ponds will assure proper treatment. The size of sediment ponds is subject primarily to engineering requirements (EPA,1976a) such as depth,volume, detention time, etc., while the location is often limited by the processing site. Factors such as the number of ponds, the drainage between ponds, and the length and configuration of connecting channels are important to aquatic habitat resources. If accounted for in the mine plan, these small ponds can provide varied aquatic habitat. If coordinated with landscape planning a treatment structure can become a valuable area during final land development. Thus, major advantages can be noted for treatment both during and following mining.

If the lake or pond on a sand or gravel mine is developed and will remain relatively undisturbed, fish stocking can be initiated. One of the major elements of any aquatic habitat development plan is the time necessary for the development of an ecologically stable and recreationally valuable resource. The earlier aquatic resources and fisheries management can begin, the better the quality of the resource will be when mining operations cease. Mine owners may have little interest in development of a fisheries resource, but again the argument is made that with appropriate planning, implementation of a lake or pond management plan will improve the overall quality of the site and may provide significant additional value when the site is considered for development.

Table 4. Bottom Composition and Associated Aquatic Life and/or Use.

Detritus	
Associated Organisms:	microorganisms*, microscopic and macroscopic plants, aquatic invertebrates, fish
Use:	food resource or nutrient supply
Silt	
Associated Organisms:	rooted plants, burrowing aquatic invertebrates
Use:	growth medium for plants, habitat for aquatic invertebrates
Sand	
Associated Organisms:	microscopic plants, fish, aquatic invertebrates
Use:	fish spawning, aquatic invertebrate habitat
Gravel	
Associated Organisms:	microscopic plants aquatic invertebrates, fish
Use:	fish spawning, aquatic invertebrate habitat

*will occur in all habitats

In summary, the practices which can be implemented during mining operations to develop or improve aquatic resources, in addition to topographic development, include water quality control and early development of aquatic and fisheries resources. Water quality control for sand and gravel mines is mainly sediment and suspended solids control. Aquatic resources and fisheries development should be initiated as early in the mining schedule as possible to provide the greatest stability when mining operations cease.

POSTMINING AQUATIC RESOURCE MANAGEMENT

The practices which can be implemented following mining can be conveniently separated into three categories: 1) water

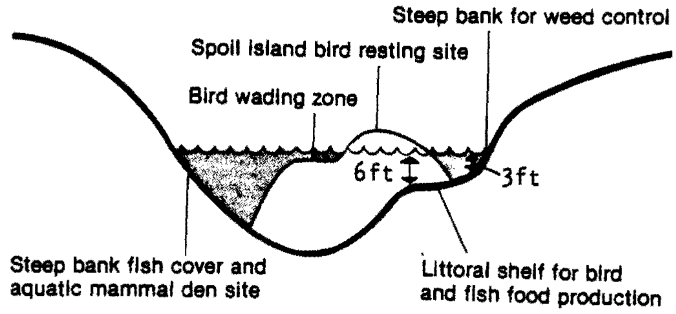


Figure 4. Island development in lakes (adapted from Nelson and Associates, 1981).

quality related practices (generally dealing with maintenance or improvement of chemical characteristics), 2) aquatic resource and fisheries management practices, and 3) aquatic habitat enhancement practices. The latter two categories are directed toward maximizing productivity of desired species. The following discussions provide several practices in each category which should be considered as part of sand and gravel mine reclamation planning

Water Quality

Water quality maintenance and management practices can span a range from simple, low maintenance processes such as sedimentation basins to complex treatment plants. On sand and gravel mines low cost treatment options, such as sedimentation basins, provide adequate treatment because chemical characteristics of process waters are little altered by mining or processing activity. Thus the major concern of water quality maintenance and management is providing water quality conditions conducive to fisheries development and sustained high productivity. As previously mentioned, the morphoedaphicindex (MEI) can be used to predict fisheries yield. The water quality component of the MEI is a measurement of total dissolved solids (TDS). TDS is easily measured, and when accompanied by measurements of pH, alkalinity, and hardness, provides a good indication of general water quality. The TDS of waters on sand and gravel mines will vary depending on site conditions (e.g., watershed soils and chemical characteristics of the materials exposed by mining. Expectations for fisheries production should match watershed limitations.

A second water quality indicator is pH. The pH is related to characteristics of the material mined, site geology, and overburden characteristics. A common problem in coal mining is the production of acid water (pH 5.0 or below) due to the presence of pyritic minerals. For most sand and gravel mines the pH will not present water quality problems because pyritic materials are not present. In fact, drainage from the mine may actually improve water quality, especially if limestone is associated with the sand and gravel deposit. The pH of water on the site should be between 6.0 and 9.0 with a goal of maintaining neutrality (pH of 7.0).

Alkalinity, a measure of the capacity of the water to react with a strong acid and is primarily a function of carbonate, bicarbonate, and hydroxide content of the water. Alkalinity is typically related to soil fertility. In terms of aquatic resource development, alkalinity has been shown to affect fish production. Alkalinity of greater than 100 mg/l is considered good, 50-100 mg/l average, and less than 50 mg/l only fair. Boyd (1979) suggests that the limiting factor is the availability of carbon dioxide which reduces plant growth thus affecting fish production by limiting food resources.

Hardness, a fourth water quality indicator, is produced by the presence of calcium, magnesium in water and is an indicator of buffering capacity. Hardness can be related to general aquatic community characteristics because many invertebrates require calcium for growth and reproduction. The complexity of the aquatic community often increases as water hardness increases (Macan 1961). Soft water generally has a hardness of less than 50 mg/l (as calcium carbonate) while hard water has a hardness of 150 mg/l or greater. Treatment to reduce hardness is generally not employed on a large scale for wastewater treatment. In some situations increasing water hardness through addition of limestone, lime, or other calcium bearing materials (such as fly ash) should be considered if very soft water, which limits aquatic productivity, is present. Costs of this treatment for most sand and gravel mines are often prohibitive because large quantities of material are required to make even a minor modification in water quality.

In many sand and gravel mines, the water will be low in TDS which includes dissolved nutrients which support plant growth. As with alkalinity, if food resources are limited, fish and wildlife productivity will be low. To improve production, ponds and lakes can be

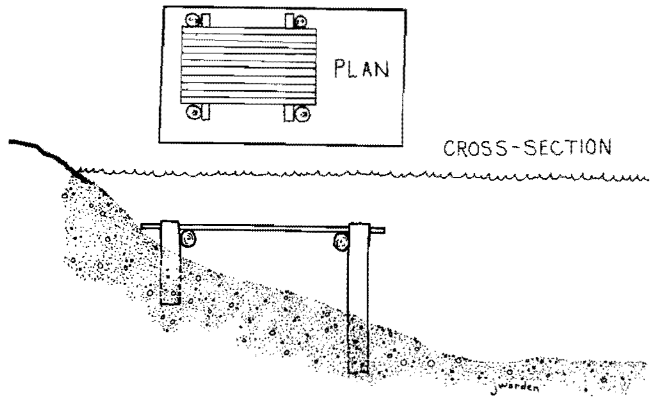


Figure 5. Fertilization platform for use in lakes.

fertilized. Boyd (1979) found fertilization to improve production in catfish ponds. The fertilizer can be added as a liquid or a solid. A useful technique for liquid handling is addition of the fertilizer through the propwash of an outboard motor. An apparatus for liquid addition can be easily constructed, Illinois Department of Conservation (1972). When solid fertilizers are used, techniques which assure complete dissolution should be employed. Figure 5 illustrates a fertilization platform which is useful for fertilizer addition. Fertilizer is placed on the platform supported 1 to 2 feet under the water surface where it can slowly dissolve. This procedure limits the loss of fertilizer to the sediment and places the nutrients in the photic zone where they can be most readily used by algae and plants.

Since water quality is of primary importance in establishing and maintaining aquatic resources, a water quality monitoring program should be established by the mine operator. Often permit requirements specify some monitoring, if so, that data can also be used to evaluate water quality conditions for aquatic life. The maintenance of pH values near 7.0, alkalinity near 100 mg/l, and hardness of 50 to 100 mg/l should promote aquatic resource and fisheries development.

Aquatic Resources Management

The management of aquatic resources will typically be directed to the management of sport fisheries. Although the following discussion will emphasize fisheries, it should be recognized that fish are only a component of the ecosystem and all ecosystem components must be

Table 5. Typical Stocking Rates for Warmwater Fish Species

	Life Stage	#/acre
Largemouth Bass	fingerling	50-100
Smallmouth Bass	fingerlings	50-100
Bluegill & Redear Sunfish	fingerlings	500-1000
Hybrid Sunfish	fingerlings	500-2500
Channel Catfish	fingerlings	50-100
Northern Pike*	fry	100-1000
	fingerlings	2-10
Tiger Muskie*	fry	100-1000
	fingerlings	2-10
Walleye*	fry	1000

Figure 6. Materials which may provide habitat enhancement on lake bottoms.

supported to achieve successful fisheries management. Typical sport fish in warm water areas include largemouth and smallmouth bass, bluegill, and channel catfish, coolwater species include walleye and northern pike, and coldwater species include trout and salmon. Depending on the location of the mine, water depth, and management interests, sport fish will usually be selected from these species. State fish and game agencies will usually provide guidance in species selection.

Since warmwater species are found in most areas of the country, some specific management guidelines will be provided for these species. The mine operator should start by consulting the local fish or game agency or seek advise from the U. S. Fish and Wildlife Service. Typical stocking levels for warmwater species are provided in Table 5. Once fish are stocked, a yearly monitoring program should be established to evaluate stocking success and further management requirements. These management requirements may include additional stocking and rough fish control. Rough fish are species which are undesirable, uncatchable and/or detrimental to the sport fish population. Rough fish species include carp, drum, buffalo, bowfin, and gar. If population balance is not maintained useful forage fish such as gizzard shad, bluegill, and several sunfish species may limit sport fish populations through competition for food resources. Control measures include angling regulations for sport fish, netting and trapping, and, in some instances chemical poisoning. The success of control and management programs is general proportional to the cost and effort expended. A fisheries management program can develop additional value for land to be developed but because some investment in stocking and monitoring is essential, careful review of management plans should be made before being implemented as a part of a mining reclamation plan.

Habitat Enhancement

Habitat enhancement should be considered as fisheries management objectives are identfied. In earlier discussions, an emphasis was placed on habitat development as part of mine excavation and regrading activities. On mines where these procedures are not feasible or cost effective (including active operations), aquatic habitat can be enhanced through the addition of structures which will meet habitat requirements of fish and other aquatic organisms. A common term used for habitat structure is cover. One of the easiest habitat structure improvement procedures is the addition of logs, brush, or masonary blocks to the lake bottom, Figure 6. These materials can be added as the lake is filling or can be placed on the ice during winter to sink as spring thaws occur. The materials selected, however, should not impair water quality.

A number of other cover-providing structures have been shown to be effective for fisheries enhancement (Johnson and Stein, 1979; Prince and Maughn, 1978). These structures can be constructed from logs or dimension lumber and even used tires (Figure 7). Floating reefs pyramid, and high profile shelters constructed from tires have all been effective in improving fisheries habitat.

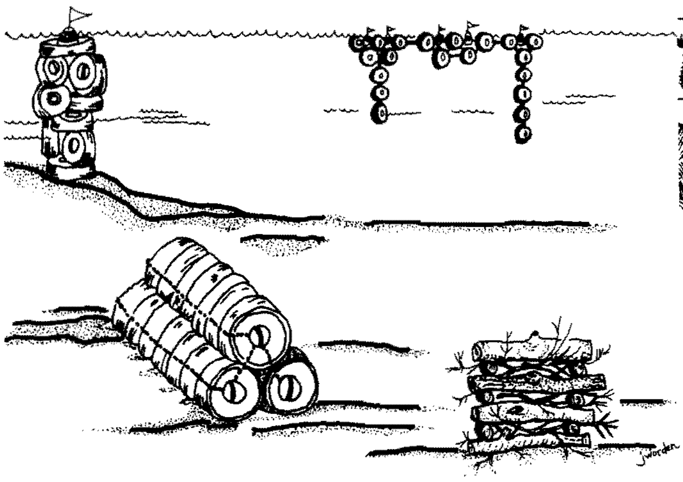


Figure 7. Fisheries habitat enhancement structures.

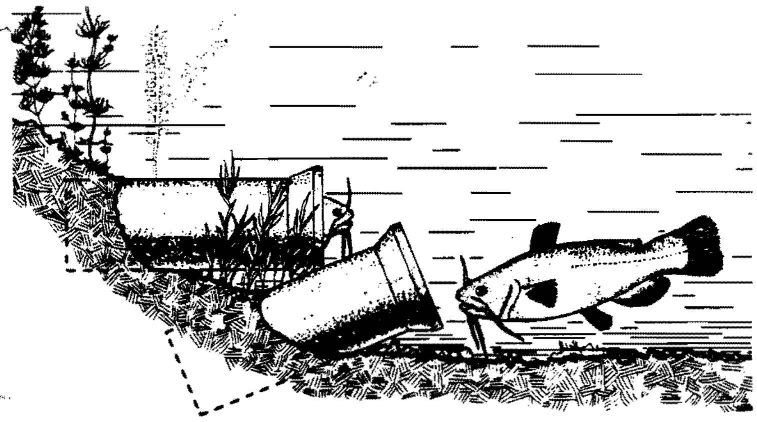


Figure 8. Spawning habitat enhancement for catfish using imbedded drain tiles (from Nelson and Associates, 1981).

Other modifications of habitat structure should be considered to meet species specific habitat requirements, in particular, spawning or reproductive habitats. The modification may be as simple as the proper size gravel placed at a particular depth or it may include the addition of tiles, culverts, or other protective structures to meet the requirements of the species being managed. Figure 8, taken from Nelson and Associates (1981), illustrates the type of retreat required for catfish spawning. Guidance for substrate type selection as well as general habitat requirements for a number of warmwater fish species is provided in Table 6.

Other habitat enhancements are dependent on development of riparian and watershed vegetation. An important component of the cover requirements of many species is shade thus riparian vegetation is of paramount importance (note: riparian vegetation also provides food directly in the form of insects which fall into the water and indirectly by contributing organic carbon which can affect not only plant and animal productivity but also water quality in the lake). Although shade may be provided by artificial structures (such as the floating tire reef), the presence of trees along the banks of a lake or pond may be very important to the maintenance and reproduction of a number of fish species.

CONCLUSIONS

Sand and gravel mines have the potential to produce valuable fish and wildlife habitat. This value can be judged not only as an externality associated with environmental quality, but also as a real economic asset where recreational or development properties with diverse aquatic habitats are in short supply. If the values of sound reclamation and development are recognized early in the mine planning process, resource value can be maximized while reclamation and development costs are minimized.

This paper has presented a number of practices for the development of aquatic habitat and fisheries resources on sand and gravel mines. The most important practices are those implemented as a part of pre-operational planning. If properly planned, resource recovery will be maximized and the resulting excavation will provide abundant and diverse aquatic habitat. Practices have also been identified which are applicable to existing or abandoned operations. The key element of aquatic resources and fisheries development is the availability of suitable habitat. Habitat includes structural components such as depth and natural or artificial cover as well as suitable water quality. If suitable habitat conditions are provided, the aquatic resource will develop with minimal management. Management and maintenance requirements are dependent on the demands placed upon the aquatic resource. For example, intensive fishing will require intensive management.

Fish and wildlife resource development should be considered on sand and gravel mines. The balance between providing sand and gravel and an aesthetically pleasing, recreationally valuable resource can be easily struck but planning as well as sound

Table 6. Habitat requirements for a number of warmwater fish species. Spawning habitat information based on spawning guild relationships.

	Spawning Guild: Simple Spawners (non-guarders)						Spawning Guild: Complex Spawners (nest builders and guarders)						Habitat: Near Shore											Habitat: Open Water					
Species	Free-floating non-adhesive eggs	Free-floating adhesive eggs	Eggs deposited on rocks, gravel	Eggs deposited on rocks or plants	Eggs deposited on plants	Eggs deposited on sand	Nests in rock and gravel	Nests in plants	Nests in natural holes/cavities/burrows	Not selective in nest-building material	Spawning period (5 = May, etc.)	Spawning temp. (°F)	Weedy shallow	Mixed bottom	Sloping shelf	Weedy deep	Vertical face	Rocky shelf	Big stones	Gravel	Sandy sheltered	Sandy exposed	Clay exposed	Surface	Midwater	Deep	Turbidity tolerance (L - low, M - med., H - high)	Spawning depth (ft)	Reproductive maturity
Bowfin								X			4-6	60-70	X													X	L	<4	
Longnose Gar					X						5-6	50-60	X											X			M	<8	3-6
Gizzard Shad		X									4-6	60-70												X			H	<2	3-4
Northern Pike					X						3-5	40-50	X			X											L	<3	2-4
Carp				X							5-7	59-64	X	X									X				H	<5	2
Golden Shiner					X						5-7	68-70	X											X	X		M	?	1-2
Smallmouth Buffalo					X						5-6	60-65														X	M	?	3-4
Bigmouth Buffalo					X						4-6	60-65		X										X			H	<5	4-5
Black Buffalo					X																				X				
Lake Chubsucker					X						3-4	70-75	X														L	?	?
Black Bullhead							X				4-6	?	X	X													H	1-4	2-4
Brown Bullhead									X		5-6	70				X										X	H	<10	3
White Bass				X							4-6	55-60												X			L	2-6	2
Yellow Bass				X							4-5	55-60												X	X		L	2-3	2-3
Green Sunfish							X	X			5-8	60-62	X														H	<2	2
Bluegill							X				5-8	67	X													X	M	<5	1-3
Redear Sunfish								X			5-6	70-75				X									X		L	3-10	1-2
Largemouth Bass								X			5-6	60-65	X							X				X			L	2-6	2
White Crappie								X			5-6	64-68	X											X			M	<5	2-3
Black Crappie								X			5-6	58-64	X														L	<4	2-3
Yellow Perch				X							4-5	45-55													X	X	L	<10	3
Sauger			X								4-5	40-50															H	<3	3-4
Walleye			X								3-5	45-50														X	M	<3	4-5

technical advise are required. Planning only requires identification of reclamation goals. The technical advice may be more difficult to obtain, but is being developed as part of mandated reclamation requirements of the coal industry. A valuable aquatic resource is not difficult to develop, it only requires a desire to meet the full potential of the entire mining operation, including reclamation.

ACKNOWLEDGEMENTS

The author wishes to acknowledge partial support provided by the U. S. Fish and Wildlife Service, Eastern Energy and Land Use Team, Contract # 14-16-0009-79-068. Mark Wetzel assisted in reproduction of figures and invaluable assistance was provided by Connie Parsley in the final preparation of the manuscript. Early drafts of the manuscript were reviewed by Mr. Robert Szafoni.

LITERATURE CITED

ALLAIRE, P. N. 1977. Coal mining reclamation in Appalachia: Low cost recommendations to improve bird/wildlife habitat. In The Mitigation Symposium. USDA General Technical Report Rm-65.

ALLEN, J. S., A. C. Lopenot (no date). Small Lakes and Ponds Their Construction and Care. Illinois Dept. of Conservation, Springfield, IL. 23 pp.

BANKS, P. T., R. E. Nickel and D. A. Blome 1981. Reclamation and Pollution Control: Planning Guide for Small Sand and Gravel Mines. Final Report Contract #J0199052 Bureau of Mines, U.S. Dept. of Interior. 143 pp.

BOYD, C. E. 1979. Water Quality in Warmwater Fish Ponds. Agriculture Exp. Sta. Publication. Auburn Univ.

BURNER, C. C. 1973. Fisheries management in strip-mine lakes. In 1st Res. Applied Tech. Symposium. Mined Land Reclamation Preprints. Natl. Coal Assoc/Bituminous Coal Research, Inc. Pittsburgh, PA.

Environmental Protection Agency 1976a Erosion and Sediment Control Surface Mining in the Eastern U.S. Planning EPA-625/3-76-006, Washington, D.C.

Environmental Protection Agency 1976b Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D. C.

HERRICKS, E. E., D. J. Tazik, J. R. Karr, and M. E. Leary 1980. Planning for Fish and Wildlife on Illinois Coal Surface Mines FWS/OBS-80/36. 579 pp.

HERRICKS, E. E., A. J. Krzysik, R. E. Szafoni and D. J. Tazik. Best Current Practices for Fish and Wildlife on Surface-Mined Lands in the Eastern Interior Coal Region. FWS/OBS-81-68. 204 pp.

HINKLE, C. R., R. E. Ambrose, and C. R. Wenzel 1981. A Handbook for Meeting Fish and Wildlife Information Needs to Surface Mine Coal-OSM Region III FWS/OBS-79/48.3.3

JENKINS, R. M. 1982. The Morphoeduphic Index and Reservoir Fish Production Trans Am Fish Soc 111 (2): 133-140.

JOHNSON, D. L. and R. A. Stein eds 1979. Response at Fish to Habitat Structure in Standing Water. Spec. Pub. #6 North Central Div. Am. Fisheries Soc. 77 pp.

LOPINOT, A. C. 1972. Pond Fish and Fishing in Illinois Fishery Bulletin #5 Illinois Dept. of Conservation, Springfield, IL. 72 pp.

MACAN, T. T. 1961. Factors that limit the range at fresh water animals. Biol. Rev. 36:151-198.

National Academy of Sciences 1979. Surface mining of non-coal minerals. Washington D. C. 339 pp.

National Academy of Sciences, National Academy of Engineering 1973. Water Quality Criteria 1972. EPA-R3-73-033. U.S. EPA, Washington, D. C.

NELSON, R. W., and Associates 1981. Manual for Planning and management of mine-cut lakes of surface coal mines. Second Draft Office of Surface Mining, U.S. Dept. of Interior.

PRINCE, E. O., and O.E. Maughn 1978. Freshwater artificial reefs: Biology and Economics. Fisheries 3 (1): 5-7.

RYDER, R. A. 1965. A method for estimating the potential fish production of north-temperate lakes. Trans. Am. Fish. Soc. 94:214-218.

RYDER, R. A. The morphoedaphic Index-Use, Abuse, and Fundamental Concepts. Trans Am Fish Soc 111 (2):154-64.

SANDUSKY, J. E. 1978. The potential for management at waterfowl nesting habitat on reclaimed land. In Surface Mining and Fish and Wildlife Needs in Eastern United States. FWS/OBS-78/81.

SCHLESINGER, D. A. and H. A. Ragier 1982. Climatic and morphoedaphic Indices of Fish Yields from Natural Lakes. Tran Am Fish Soc 111 (2): 141-150.

STICKNEY, R. R. 1979. Principles of Warmwater Aquaculture. Wiley and Sons, N. Y.

THURSTON, R. V., R. E. Russo, C. M. Fetherolf, T. A. Edsall and Y. M. Barber 1979. A Review of the EPA Red Book: Quality Criteria for Water. American Fisheries Soc. Bethesda, MD.

YOUNG, W. D. and D. G. Weimbuch 1982. Another Consideration at the Morphoetaphic Index. Trans. Am. Fish. Soc 111 (2): 151-153.

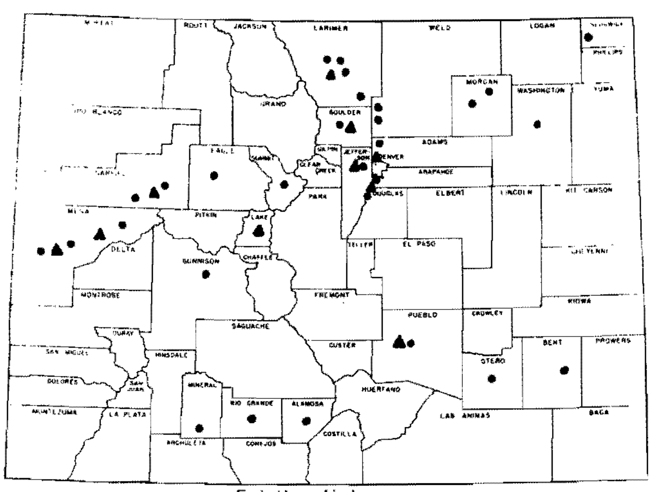
Fishery Management in Colorado's Gravel Pit Lakes

ROBIN F. KNOX, Aquatic Habitat Specialist, Colorado Division of Wildlife, 6060 Broadway, Denver, Colorado 80216

INTRODUCTION

Water, in any form, has become a precious commodity in the west. Public fishing water is also becoming an increasingly difficult commodity to find and develop. With current interest rates and federal budget cuts, the only reliable source of new fishing lakes in Colorado are those created through the mining of sand and gravel. Approximately 35 million tons of aggregates are mined in Colorado each year. Assuming one cubic yard weighs approximately 1.5 tons, the total excavation approaches a volume of 23 million cubic yards. Although the percentage of excavation that eventually yields ponded water is unknown, it is estimated that 100 to 200 surface acres of gravel pit ponds could be created each year statewide. However, due to increasing problems with water appropriations and evaporation augmentation, there has been increased effort to keep the new pits dry or refill them with land-fill material. These activities preclude their future use as a fishery.

Figure 1 depicts the location of active and potential gravel pit fisheries in the state of Colorado. As might be expected, these lakes are closely associated with major metropolitan areas of the state and also with major drainages.



• Existing fishery
▲ Potential fishery

Figure 1. Location of existing and potential gravel pit fisheries in Colorado, 1982.

The proximity of these lakes to major urban areas enhances their importance to the Division's Fishery Management Program.

The Division of Wildlife actively manages approximately 75 individual gravel or borrow pits statewide. These gravel pits have a combined surface acreage of almost 1500 acres. Although this comprises only 1 percent of the total lake acreage in the state open to fishing, the proximity of these lakes to urban areas makes them valuable to the fishing public. In terms of fishing pressure, the hours per acre per month vary greatly from area to area. Gravel pits close to population centers sustain 500-600 hours per acre per month while outlying pits may have pressures as low as 15 hours per acre per month. It should be noted that while a figure of 500 hours per acre per month is not "intensive" for some states, any figure greater than 250 hours per acre per month is considered heavy pressure in Colorado.

FISHERY MANAGEMENT STRATEGIES

As with any body of water, management strategies are the result of analysis of the chemical and physical properties of the water in individual gravel pits. These preliminary analyses are especially important along Colorado's Front Range area where ground water unsuitable for fish production has filled gravel pits and made them unsuitable for inclusion into the fishery program. In the Denver metro alone, over 200 acres of water have been determined to be devoid of oxygen below the surface due to underground flow impacted by poor sewage treatment facilities.

The temperature regimes of these lakes in Colorado partially dictate which species are used in fish management programs. The only coldwater species used is rainbow trout. The most common warmwater species used include largemouth bass, bluegill, channel catfish, crappie, carp and bullhead.

Coldwater gravel pits: the management of the 15 gravel pits that are suitable for only coldwater species is based strictly on a "put and take" trout concept. Approximately 22,000 pounds of catchable-sized rainbow trout, about 75,000 fish, are stocked annually in these lakes. Most are located close to population centers and have a 100 percent return to the creel. The fish are usually stocked every 2nd or 3rd week during late spring and early summer months. Late fall stocking in the Denver Metro area may be tried in 1982 if sufficient numbers of catchable rainbow trout are available.

Warmwater Gravel Pits: the management of the warmwater gravel pits is more oriented to the classic bass-bluegill-catfish, predator-prey type of fishery. Each pond is managed individually, based primarily on size and chemical-physical characteristics. Largemouth bass are stocked as both adults and subcatchables at rates of 50-250 per acre. Bluegill and crappie are the most common forage species used. They are stocked also as catchables and subcatchables at rates of 100-500 per acre. Channel catfish are stocked mainly as catchable-sized fish, due to a lack of reproduction at Colorado's altitudes. These fish are commonly stocked at a rate of 50/acre. The lakes that receive catchable-sized catfish are most often found in the urban centers of the state.

Some of the extremely small gravel pits (less than 5 acres in size) are managed as "salvage" lakes, i.e., lakes that are stocked with fish salvaged from other lakes by Division personnel. There is no real attempt to maintain proper "fish community relationships" in these lakes. Nonetheless, these lakes often provide many hours of successful angling for many of Colorado's younger anglers.

Warm-and cold-water gravel pits: several lakes around the state are used for both warmwater and coldwater fishing. Basically these are lakes with good water quality that will support rainbow trout in the periods March to June; and, October through December. There will be increased emphasis in future years on gaining access to this type of multipurpose lake because they do support more intensive fishing pressure, offer better angling variety and greater return to the fisherman.

HABITAT AND ACCESS DEVELOPMENT

Habitat: One problem with gravel pit lakes is that quite often they are lacking in what a fisherman likes to call "structure." Pre-mining planning, where possible, can be extremely important to the success or failure of a gravel pit fishery. Items that are currently supported by the Division for inclusion into lake management plans include:

1. Proper sloping of the banks for fisherman safety and access;
2. Leaving small shallow enbayments to enhance limited vegetation growth and encourage waterfowl use;
3. Creation of underwater reef areas for fish dover;
4. Placement of artificial tire and brush structure in gravel pits where contours were not left after mining (Figure 2).
5. Pre-construction planning between the Divisions of Wildlife and reclamation and mining companies to minimize post-mining revoking of the land can reduce costs to the gravel companies.

The Division funds $350,000 of stream and lake habitat improvement each year and a certain portion of these funds are used to build artificial reefs and tire habitats.

Figure 2. Typical artificial structure being placed in a Colorado gravel pit lake. 1 to 2 structures, 10' x 10' x 6', are constructed per surface/acre of water.

Access: the Division of Wildlife is continuing its program of gaining public access to gravel pit lakes, especially in the Front Range metropolitan areas. Quite often these gravel pit areas are donated to municipalities or county park districts by the mining companies. However, funds are often lacking to properly develop these areas for fishing access. Recently, the Division of Wildlife has been increasing funds available for facility development to insure that fishing is allowed. Facility development includes, but is not limited to: parking area development; sanitary facilities; walk-through fencing; fishing piers; and handicapped access (Figures 3 and 4).

Figure 3. Typical example of a highly developed urban gravel pit fishing area.

Figure 4. Highly developed urban gravel pit that has a pier suitable for use by handicapped persons for fishing.

FUTURE CONSIDERATIONS

Within the next several years the Division will have the opportunity to manage an additional 300 to 500 acres of gravel or borrow pit waters. The potential growth are mainly along the Front Range and in the Colorado River Basin of western Colorado. In some respects, the Division will be limited only by manpower and desire, the potential resource is there, and will continue to grow as Colorado continues to grow. Recent predictions call for a continued 1 to 3 percent growth in population per year. In the growth areas, gravel pit fisheries will help fill the need for additional fishing waters, especially in relation to the metropolitan fishing public.

LITERATURE CITED

Colorado Division of Wildlife.1982. Fish Planting Schedule - Subcatchalbe and Warmwater Fish. 148 pages.

The Chain of Lakes Project Along Interstate 80 in Nebraska

HAROLD K. EDWARDS, Nebraska Game and Parks Commission, Box 30370, Lincoln, NE 68503.

Many gravel pit type lakes were constructed along Interstate 80 in Nebraska adjacent to the Platte River, from 1960 to 1970. A considerable number of these land and water areas are currently owned and managed for public fishing, hunting, and recreation. This review will include early planning and expectations, the construction period, and a decade of management and use experience.

STUDY AREA

The subject area is about 223 miles long, from near Grand Island to Big Springs, Nebraska. Throughout this distance, Interstate 80 is adjacent to the Platte or South Platte rivers. Most of the sand pit lakes are no more than 1/4 mile from the Interstate, or from the Platte rivers.

The soil is sandy throughout the area. Vegetation is riparian in nature, composed of trees and shrubs suited to a high water table. Some of the more common species are cottonwood (Populus deltoides), American elm (Ulmus americana), green ash (Fraxinus pennsylvanica lanceolata), hackberry (Celtis occidentalis), mulberry (Morus rubra), Russian olive (Elaeagnus angustifolia), red cedar (Juniperus virginiana), roughleaf dogwood (Cornus drummondii), redosier dogwood (Cornus stolonifera), boxelder (Acer negundo), peachleaf willow (Salix amygdaloides), sandbar willow (Salix interior), wild plum (Prunus americana), and chokecherry (Prunus virginiana).

The rivers involved can range from flood stage to dry bed, depending on the time of year and yearly fluctuations. The Platte rivers have been subjected to withdrawals and storage-release, and are currently anything but static. Several plans and applications are on file for additional surface withdrawals or storage-release schemes. In addition, ground water withdrawals in the Platte River basin are substantial, and increasing. Irrigation return flows are also a factor to consider. Thus, the situation 15 years ago is no longer true. As we approach the end of this century, no one can predict with confidence a clear picture of the next century for the Platte. Certainly it will be anything but a free flowing natural stream. Nonetheless, opportunities will develop for fish, wildlife, and recreation enhancement, as well as certain negative impacts on these resources.

PLANS AND EXPECTATIONS

In the period from 1959 to 1965, the Interstate system was in the planning and early implementation stage. The path of Interstate 80 through Nebraska was reasonably clear. It would enter Nebraska at Omaha, proceed to near Big Springs, then divide. A south route would go to Denver, and the western route to Cheyenne. From Grand Island west to Big Springs, the path of the Interstate would follow the Platte and South Platte rivers. Interestingly, this was also a heavily used route by early settlers of the West.

Considering the engineering feasibility of this route, it was probably ideal when compared to other Interstate site selections. The land was flat, and thus required very little cut and fill. An ample supply of fill materials, primarily for interchanges, was readily available. The fill material could be pumped, or moved by standard scraper push-pull methods, utilizing dewatering by pumping. In either instance, the result would be a sand pit lake, generally of desirable depth for fisheries management and other recreational uses.

The Director of the Nebraska Game and Parks Commission during the planning and construction phases of the "Chain of Lakes" system was M. O. Steen. In fact, the name of the complex originated with him. More importantly, his vision, salesmanship and political acumen provided leadership for realization of the "Chain of Lakes" in Nebraska. Of course, Interstate 80 would have been constructed, but with far less benefits to the traveling public as well as for Nebraska residents. It should be stated that the Nebraska Department of Roads extended every consideration to this concept throughout the planning and construction phases. After construction, a considerable number of the land and water rights-of-way areas were given to the Commission for public use management.

Early planning identified many of the major interchanges for future intensive recreational development. The projected traffic flow along this Interstate in Nebraska was dramatic, but it was made prior to anything resembling an oil shortage or energy crunch. Traffic flows were increasing every year, and were expected to radically increase with the completion of the federal Interstate System. The official title of this highway complex was the National Interstate and Defense System.

It was fully intended that this "Chain of Lakes" would attract the traveling public to remain an extra day or two in Nebraska. The ingredients for attraction of clear, clean water, sandy beaches, and trees for shade were available. It should be understood that Nebraska was not favored with natural or glamorous attractions such as seashores, mountains, or forests. To many it was just someplace between eastern population centers and the Rocky Mountains, or the West Coast.

Thus, the "Chain of Lakes" was conceived more as a tourist attraction than as a playground for native Nebraskans. It should be noted that, during the 1960's, the Nebraska Game and Parks Commission was also charged with tourism promotion in the state.

Regarding planning for fish and wildlife development and management along this "Chain of Lakes," the potential was good for reasonable application of management principles. The sand pits were not overly fertile, but were suited to the warm water fish species. Trout were tried, and as expected, failed to survive. This was due to excessively high summer temperatures. Initial and supplemental stocking of warm water fish species, as well as limited natural reproduction was the plan.

As for wildlife management, relatively little attention was accorded to this factor in early planning. It is important to note that the central Platte Valley in Nebraska is host to several million migrating waterfowl each spring. This is a significant occurrence readily available for viewing by residents of Nebraska, as well as those traveling through the state. Thus, it is understandable that little attention was paid in early planning to wildlife management.

Recreational development planning was the prominent activity. The plans were glamorous, attractive, even sophisticated. It is probable that some of the concepts were original, if not unique. The term "road ranch" was heard often; in fact, it became a common reference among involved personnel. The major Interstate interchanges were intended to offer a high quality overnight camping experience, with water as the pivotal resource. This included swimming, fishing, hiking, food, laundry facilities, and with modern rest rooms and showers.

CONSTRUCTION AND DEVELOPMENT

The construction period on this portion of Interstate 80 in Nebraska extended from 1960 through 1968. Land rights were acquired and being acquired. Earlier political battles over the location of Interstate 80 were settled. Sand pit lakes were being created daily. Over 140 sand pit lakes resulted from this Interstate construction, providing over 700 surface acres of water.

Estimated average depth of these lakes was about 9 feet; considerably less than the average depth of normal sand pit operations. Deep pits may result in very dangerous banks which slough off unexpectedly. Obviously, attracting the public to these types of pits would be extremely hazardous, so essentially all of the Interstate 80 pits were constructed or formed to avoid this hazard.

Since most of the sand pit lakes were located in the flood plain, early concern was expressed in protecting the newly constructed pits from flooding and filling by the river. Through the 1960's, the Commission spent considerable money and effort in diking to protect the lakes. The most commonly used equipment was a heavy duty front-end loader, referred to in the trade as a traxcavator. This was a rubber-tired unit with four-wheel drive. It possessed considerable ability to travel and work in the extremely sandy soils. Some standard bulldozer work was also done.

Most diking efforts were focused on the upstream and riverside of the lakes. The primary concern of the Commission was to protect the lakes from being filled by river sand deposition. Of secondary concern was contamination of the lake with undesirable fish species.

The lakes most difficult to protect were those immediately adjacent to main channel flows of the river. Even in more pronounced danger and jeopardy were those lakes located on the outside curve of the river channel bends. In this latter situation, rock riprap was utilized in some instances, but with limited long-term effectiveness. Costs of acquiring and placing the riprap were high, and probably prohibitive on a cost/benefit basis.

Even the annual cost of constructing dikes with sand, and maintenance of dikes, became cost prohibitive. It is estimated that 70% to 80% of the sand pit lakes returned to private ownership have been lost. On public lands owned by the Commission, it is estimated that only 50% of the lakes have been lost. In a number of instances, the lakes were separated from the river by Interstate 80. Essentially all of these lakes remain as constructed.

The early intent of the Commission in developing land and water areas along Interstate 80 was to designate the interchange areas as recreation areas. Selected interchanges would have a considerable volume of public use capacity, with the other interchanges having a lesser designed capacity, but still meeting intensive recreation use criteria. For those areas between interchanges, wildlife management area designation was scheduled.

To say that all went according to plan would be inaccurate. Perhaps no more than 50% of the planned recreational development at interchanges was eventually developed. This shortfall occurred for two reasons. Lack of funding was the obvious first reason. Secondly, considerable objection from private commercial interests was responsible for failure to develop some areas. These interests perceived that state sponsored and operated recreational and camping facilities would provide unwanted competition to privately developed camping and overnight facilities.

The end result was that a sizeable number of interchange areas became wildlife management areas. Some interchange areas remained with the Department of Roads, and received no development. Other interchange areas returned to private ownership. Essentially, all of the publicly owned land and water between interchanges became wildlife areas.

As for public access, it is obvious that interchange areas provided ready access. Conversely, public access was quite difficult to achieve on areas in between interchanges. However, rather than causing a serious problem, this was an advantage. Wildlife areas are not normally intensively developed as far as facilities, and serve the designed purpose best when they receive modest use.

Fishery management was applied in a similar manner on both recreation and wildlife areas. Fishery management consisted of initial stocking of adapted and desired warm water species. Since all the lakes provided similar habitat, except for size, there was a commonality of management applied throughout the "Chain of Lakes." This was especially true during the construction period. However, by late in the decade, the fishery management mode moved to consideration of each lake. Probably the primary reason for this was that so many of the lakes became contaminated with rough fish from river flooding.

Specifically, the initial stocking combinations were smallmouth bass (Micropterus dolomieui), rock bass (Ambloplites rupestris) and channel catfish (Ictalurus punctatus). The spotted bass (Micropterus punctulatus) was used in place of the smallmouth bass in the above combination in a number of lakes.

By the early to mid-1970's, when certain lakes had been contaminated by river flooding, the supplemental stocking composition was largemouth bass (Micropterus salmoides), bluegill (Lepomis machrochirus), and channel catfish.

Relatively little wildlife management was applied to the areas so designated during 1960 through 1968, except for diking.

MANAGEMENT AND PUBLIC USE

This section of the paper deals with the time period of 1968 through 1981. For the most part, this section relates to wildlife management on those areas so designated, as well as analysis of public use.

The wildlife species receiving primary management attention on the "Chain of Lakes" wildlife areas were whitetail deer (Odocoileus virginianus), ring-necked pheasant (Phasianus colchicus), bobwhite quail (Colinus virginianus), and furbearer and waterfowl species common to the area.

As mentioned earlier, all areas were composed of riparian habitat. Much of the land had been grazed or overgrazed prior to public ownership. Many of the areas contained fields formerly devoted to grain crops or legume hay production. Thus, mature timber was commonplace, with limited understory and timber edge shrub growth. Adapted trees and shrubs were planted during the period. Former crop fields were commonly utilized for food plots of standard grain crops. Perpetuation of existing alfalfa haylands, or establishment of alfalfa plots was also a common practice.

Commission biologists commonly believed that bobwhite quail was the wildlife species that could be most easily increased by management practices. The habitat requirements of the ring-necked pheasant could also be improved rather easily. Thus the target was to improve the habitat for production or attraction of desired species.

Public use was greatest on Interstate 80 interchange areas. Unfortunately, because some of these were designated as wildlife areas, natural conflicts could be predicted and did occur. Heavy public use, limited or no public use facilities, swimming, and camping all caused regular and continuing problems. Control of vehicular traffic was also a problem, especially in the earlier use period. Problems pertaining to this array of public uses have not been resolved and remain as a problem.

On the wildlife areas between interchanges, management and public use has achieved a satisfactory balance. Because these areas were generally less available to the interstate traveler, overcrowding generally does not occur. Fishermen, hunters, and other public users tend to scatter and achieve resource allocation to an acceptable degree.

RECOMMENDATIONS

Several recommendations are evident based on Commission experience with the Interstate 80-Chain of Lakes in Platte Valley.

The land and water areas under public ownership in many instances had too little land area. Especially on recreation areas, the narrow take line made establishment of adequate facilities difficult or impossible. A number of the areas had only a few feet of land between the lake and the boundary fence. Thus, consideration of future public use should be an early concern in planning and land acquisition.

The manageability of the lakes would have been considerably enhanced if the shorelines would have been curvilinear rather than rectilinear in design.

Finally, forethought and planning could have resulted in retention of a greater number of lakes if the pit lakes had been located on the inside rather than the outside curve of the river. It is probable that no thought at all was given to this feature in the planning stage. This preference could not have been accommodated in all instances, but it would seem that a much higher retention rate would have been achieved had this factor received early consideration.

In conclusion, the "Chain of Lakes" are a tremendous asset to persons interested in outdoor recreation in Nebraska, as well as those traveling through Nebraska. Projects such as this should be considered in other states.

Gravel Pits as Fish and Wildlife Habitat at the Max McGraw Wildlife Foundation

R. C. OLDENBURG, R. A. MONTGOMERY, T. M. HARDER, and G. V. BURGER, Max McGraw Wildlife Foundation, Dundee, Illinois 60118.

INTRODUCTION

In Illinois, from 1866--the establishment of the first mine--to the enactment of the first surface-mining law in 1962, 107,000 acres of land have been strip-mined. To date, only 57,000 acres of that total have been reclaimed. It is these unreclaimed acres that have helped give the industry a bad name in Illinois (Illinois Wildlife 1972).

In 1971, in Illinois, there were 36 active coal strip-mines, 53 limestone quarries, 5 sand and gravel quarries, and 9 shale and 5 silica (fine sand) quarries. In Kane County, Illinois, specialists estimate that there now lies underground more than twice the amount of sand and gravel than has been taken from the area since mining began in 1940. Gravel removed from Kane County in the past has formed and patched every road and parking lot in an area of some 600 square miles. Additionally, this material has been used to construct numerous roads (including the Northwest Tollway), plus most of Chicago's world-renowned architecture. During 1978, in Kane and McHenry counties alone, over 100,000 tons of sand and gravel were mined daily, at 53 sites (Harger 1981). This amount of gravel is the equivalent of 1 acre/day--40 ft. deep.

Background

A realistic appraisal of current economic, political, social, and ecological needs and moods in the U.S. dictates adherence to 2 basic principles when formulating and conducting surface-mining operations:

1. "A practical compromise between the 'perfect' mining goal (removal of the maximum mineral resource commercially feasible, with little concern for reclamation) and the 'perfect' reclamation goal (creation of an aesthetically and ecologically ideal landscape, with little regard for the value to society of the resource mined, or for the economic solvency of the miner). In such a compromise, industry must recognize that natural resources cannot be exploited with no thought for the future, and environmentalists must recognize that reclaiming North America for prairies, wolves, and bison is unfeasible. Both parties should remember that 'conservation' means wise use of resources; let the miners remember 'wise,' and the reclaimers remember 'use' and we've made a good start.

2. An additional burden rests upon the reclaiming agency to design and implement a plan that--in addition to being feasible--takes cognizance of the conservation-land use principle of 'the greatest good for the greatest number of people for the longest period of time.' In brief, reclamation must be based on realistic appraisals of current and future local and regional land-use plans and needs; it must not be tied to short-range, esoteric playthings" (Max McGraw Wildlife Foundation 1973).

Most surface-mined lands are owned by the mining company. In our instance, however, the Foundation retains title to (and thus responsibility for and post-reclamation use of) reclaimed lands. Consequently, our reclamation plan incorporates requirements of the Foundation, in addition to recognizing the role of the land area itself in local and regional planning.

History

The Max McGraw Wildlife Foundation is located on 1,350 acres of land in Dundee Township, Kane County, Illinois. The Foundation was established in 1962 by the late Max McGraw as a charitable, scientific, educational, not-for-profit Illinois corporation.

Since the Foundation is entirely self-supporting, expansion of its programs is possible only through increased income. Consequently, the Foundation's Board of Directors decided in 1971 to sell mining rights to a deposit of gravel located under 178 acres used for farming and for farm-wildlife management.

The Contract

Bids were let to major gravel companies early in 1971 (with the written statement that basic reclamation of mined land would be the responsibility, and at the expense of the successful bidder). Meyer Material Co., Des Plaines, Illinois, was the high bidder, and a contract was signed with this company in 1971.

In addition to various details in the basic contract, mining and processing guidelines spelled out hours and days of operation, adherence to the basic reclamation plan, maximum slopes, use of berms, and separation of topsoil from other overburden. The reclamation plan included the mining schedule and parcel plat, a topographic survey (to help determine depth of material), and an aerial view of the property. The final development plan detailed preparation, progressive rehabilitation, and final reclamation, including an area profile and a detailed entrance plan.

RECLAMATION

The Plan

The chartered purposes of the Foundation, the importance of contributor support for its programs, and the nature of the reclaimed landscape combined to guide reclamation toward a water-oriented fisheries and wildlife research and recreation area. Within this framework, provision of as great a diversity of terrain and of aquatic and upland features as feasible best serves wildlife, research, and present and future use potentials. Hence, we envisioned the following major features in the reclaimed area:

1. Five bodies of water, ranging from 5 to 30 acres. Tentatively, at least 3 (the largest) of these lakes are to be suitable for "cool-water" fisheries management and research. The remaining 2 water bodies are to be designed for waterfowl and (possibly) warmwater fisheries management.
2. Sufficient dry-land acreage, suitably contoured and landscaped, to provide (a) a diversity of upland wildlife habitat for research and management, (b) maximum aesthetic appearance, (c) adequate vegetation maintenance and erosion control, (d) adequate and suitable areas for put-and-take upland-game hunting (we operate a shooting preserve on part of the property), and (e) sufficient space for amenities.
3. Creation of a road system adequate to reach, service, and view all key points within the reclaimed area.
4. As a long-term option, minor modifications to provide for first-class residential or office building sites.

Reclamation features include primary hunting areas, wildlife food and cover strips, large wildlife food-plots, hills and "overlooks," islands, peninsulas, retention ponds, enhancement of other dry-land areas, deep-water lakes, shallow lakes and marshes, a road system, parking areas, picnic-camping sites, and a "headquarters" site.

Operations

During 1972, Meyer Material Co. cleared and stripped a 10-acre plant site (later enlarged to cover 15 acres), at the southeast corner of the tract. Plant equipment was installed, with a 3-piece, 3,600-ft. belt-conveyor system running east-west through the center of the site on a buried gas-line which could not be disturbed, and which now provides a high ridgeline between the lakes. The conveyor reduced noise, truck travel, and the dust associated with moving equipment. This type of hauling system benefited our hunting program--and wildlife.

For efficiency, Meyer commenced operations at the farthest point from the plant site, mining linearly and in sections not exceeding 10 acres/year. In preparation for gravel removal, the overburden from each section was separated into subsoil and topsoil, and set aside by the scrapers. The first 10 acres to be mined had to be bermed, since there was no place to put the overburden. Subsequent mining left space for laying the overburden in parallel, contoured terraces within the edges of each previously mined section, struck off with "cats" into rough-graded features. It is our feeling (and Meyer Material personnel agree) that the detailed plans, required prior to mining, allow time to plan in advance exactly how and where to place the dirt, rather than moving it 2-3 times, as under older systems. The present reclamation system is now cheaper for the operator than the "old" berming and pushing-off system, and topsoil is not lost by mining or burying. Since stripping and reclamation occur at the same time, supervision of the reclamation is easier. One knows when the equipment will be in use, and mistakes can be corrected before the mole hill becomes a mountain (literally).

Working with the gravel-pit "cat," scraper, and drag-line operators has been an enjoyable task. It gives one the power of creation--whether a hill, an island, or a "goof!"

It has been our experience that the plan should be to scale, and quite detailed, since the plan is the "bible" for both lessor and lessee. If a particular feature or setback is on the plan, it can be measured--located on the ground and required--but any change, addition, or deletion requires negotiation. Heavy-equipment operators are well paid and well schooled in efficient operation of their equipment. One must work through their chain of command and, here, the plant superintentent is God.

But the man that can be of greatest help in day-to-day problems is the plant foreman. Once he is on your side, you can get more of the refinements you would like, but which may not appear on the plan. If the foreman allows you the freedom to work directly with the "cat" operator, you have made it to the top (actually, the bottom) of the chain where the work is really done. Surveying and staking is almost useless once the equipment is moving. A rough sketch or descriptive phrase to the "cat" operator, such as "make it as if you were going to build a house on this location," will achieve more diversity and better cooperation, since you are allowing the operator freedom to create--an opportunity he doesn't often get.

A few other tips: When working into groundwater for gravel, a firm footing of gravel 1-2 ft. above the waterline makes reclamation a simple task for heavy equipment. Overburden pushed into water clouds the water, stabilization of fill can take years, and reclamation can be slowed to a crawl. Also, determining the natural fluctuations in the groundwater table prior to mining can help determine elevations for specific features that otherwise could be lost during high water not previously anticipated.

Plantings

Since our reclamation plan is oriented toward wildlife and recreation, as well as fisheries, a variety of terrain and cover features is encompassed. Major cover types include grasslands (both warm- and cool-season grasses), annual food patches, and tree and shrub plantings (as woodlots and travel lanes).

The grasslands consist of mixtures of 18 species of grasses and forbs. These plantings are designed for the habitat needs of both game and non-game wildlife--including nest sites, escape cover, and food--as well as grass waterways and lawns for picnic and camping areas.

Annual plantings provide wildlife food, and hunting cover for pheasants and other gamebirds in our controlled hunting program. We use 3 varieties of grain sorghums in these food patches and hunting strips, as well as sunflowers and corn.

In an attempt to soften the "hole-in-the-ground" appearance caused by strip mining, such terrain features as knolls, hills, and flats have been planted to trees and shrubs. Hopefully, these should provide a pleasing mixture of growth forms, textures, and colors, as well as furnishing wildlife food and cover. We are also trying to create some aspects of native northern Illinois woodlots by using native bur, white, and red oaks, as well as sugar maple, ash, and a variety of native shrubs on 2 hills and associated slopes. Once the canopy has developed, we hope to plant a typical woodland understory.

Other areas were planted with conifers to provide winter cover for pheasants and other wildlife. Clumps of shrubs and trees, plus travel lanes, using a wide variety of species, are planned, and many already planted. To date some 36 species of trees and 15 species of shrubs have been established, providing a variety of growth forms for nest sites, and food sources for wildlife throughout the year. Other terrain features include at least 6 islands to provide nesting and loafing sites for breeding and migrating waterfowl.

We've tried many sources for plant materials, ranging from commercial and state nurseries to trees dug from our own woodlots. Size has varied from 1- and 2-year-old seedlings to 15- to 20-ft. specimens. Most of our stock has been purchased from private or state sources as bare-root stock. For such materials, survival of 3- to 8-ft. whips, balled and burlaped materials, and "wild" material dug and transplanted has been good to excellent, while survival of 1- to 2-year-old seedlings has been poor.

Factors affecting survival include competition from thick, heavy grass stands; girdling by rodents; drought; and flooding. To reduce losses we cut back competing grass (using a weed trimmer), carefully used "Roundup" (a contact herbicide), mulched with wood chips, and installed plastic tree-wraps on those species susceptible to girdling. We also watered during drought periods.

Planting methods varied, depending on the size of materials, from planting bars and spades for seedlings, to backhoe and tractor-mounted diggers for larger trees, and 12-in. posthole augers. The posthole digger is excellent, since it pulverizes the compacted soils frequently encountered on our area. Fine-textured soils firm up very well and eliminate the problem of air pockets in the root zone.

The reclaimed soils end up with a fairly narrow topsoil of about 8 in., over some 20-40 ft. of clay material. This arrangement allows only limited internal drainage, with all drainage occuring in the top 12-18 in., and then following the slope down to lower levels. Thus it is not uncommon to have the upper slopes and flats undergoing drought stress while the lower reaches are too wet to drive upon. This condition creates reclamation problems: in working the lower slopes, tractors frequently slide sideways, pushing the topsoil down the slope, and exposing the clay subsoils.

Generally, the planting zone has adequate topsoil depth, and plant survival often is excellent. However, when the scrapers are laying down materials which are too wet, they can compact the soil until it is as hard as concrete. Our best seedling stands have been established when we can finalize the grades as soon as the heavy equipment is finished. Frequently, rough grading occurs too late in fall for seeding, or in spring when our equipment is unavailable or soils are too wet to finish the sites.

All of our final grading and seeding is done with farm tractors and other standard farm equipment. Most grass-legume seeding is accomplished by a landscape seeder; prairie grasses via a Nesbitt drill.

Erosion control is a major problem in reclamation, particularly on slopes. We have incorporated settling basins in some major waterways. These basins intercept the silt before it enters the lakes, provide shallow-water feeding sites for waterfowl (especially in the spring), and also serve as breeding sites for frogs and toads. Other water-control structures include water bars to slow runoff, terraces, sodded waterways, and step-terraces at the bottom of major waterways to reduce gullying along steep shorelines.

WILDLIFE MANAGEMENT AND RESEARCH

Since October, 1974, we've counted waterfowl use of our gravel lakes, as a measure of their attractiveness to these birds. Beginning with the appearance of open water, and continuing through freeze-up, all lakes are checked 2-3 times per week to determine species composition and populations. Nesting structures and islands are checked for nesting waterfowl, and migrant ducks and geese are trapped and banded.

Breeding Canada geese and mallards use our 3 islands, 6 floating nest structures, and upland nest sites. Waterfowl use during the breeding season has averaged 1-2 pairs of Canada geese and up to 6 pairs of mallards (bringing off a total of 2-3 broods per year). Despite undisturbed nesting cover, islands, and nest structures, nesting success and brood survival is low. Females are killed, nests destroyed, and entire broods disappear soon after hatching.

Fall migrants have contributed the majority of our waterfowl "use-days," with peak counts of over 2,000 mallards and 500 Canada geese. Recently, fall waterfowl use has decreased substantially, due to a combination of factors.

Waterfowl use in spring usually is low, since the lakes do not provide open water until after the peak migration period. Still, our lakes have attracted 49 species of water birds, including 2 loon species, 4 heron species, 3 goose species, 19 duck species, plus ospreys, coots, 10 species of sandpipers, and 5 species of terns and gulls.

We have monitored breeding songbird populations on this area since before any mining impact. This work aims at documenting how songbird diversity and populations respond to conversion of typical crop fields to mined and, finally, to reclaimed habitats. The technique we adopted is the Williams (1936) spot-mapping technique, which involves mapping the location of territorial males to determine the number of territories on the area. While widely used, this technique normally is employed on areas of 60 acres or less of similar habitat. Our area totals nearly 180 acres, and includes a diversity of habitats. The standard time-frame and weather conditions described by Williams (1936) were adhered to, with 2 observers each censusing ½ the area (approximately 90 acres per observer), on 8 mornings from mid-April to mid-July. In addition, nest searches are made in 1 of the treelines to measure nesting use by common grackles.

As would be expected, as the diversity of habitats has increased (by the addition of permanent grass, water, and sandy veins of till), the number of species breeding on the area has increased, as have some species' populations. In 1972, the first census year, 20 species were recorded, while about 26 species have been counted annually during the past 5 years. Overall, 32 breeding species have used the area since 1972. Species increasing include the redwing blackbird, savanna sparrow, rough-winged swallow, and spotted sandpiper; decreases include the common grackle, vesper sparrow, indigo bunting, and horned lark. The response of grassland species (meadowlark and sparrows) has been disappointing, and may be due to structure, density, and size of our grasslands (Weins 1969).

FISHERIES MANAGEMENT AND RESEARCH

Although 3 of our gravel lakes have substantial water acreage at present, fish stocking and monitoring have only been carried out on Lake #1 long enough to gather significant data. This lake is approximately 30 acres in surface area. It has a maximum depth of 40 ft. at high water, an average depth of 23 ft., and a water level which has fluctuated some 14 ft. during the last 7 years (but which has remained fairly stable for the past 3 years). Water hardness nears 375 ppm, and total alkalinity measures 227 ppm. Secchi transparency readings fluctuate between 3 and 17.5 ft., depending on seasons and plankton bloom. The lake bottom is comprised of silted-over rock and gravel, with little contour variation.

Lake #1 was stocked in 1975 and 1976 with walleye and yellow perch fingerlings. Smallmouth bass fingerlings were added in 1977 and 1978. Hybrid sunfish, reared in our ponds until 4-6 in. long, were stocked in 1980 and 1981. Brown trout were introduced (at lengths of 7-9 in.) in 1981. Forage fish, predominantly fathead minnows, were stocked periodically, but could not maintain themselves in the face of the existing predator population. Golden shiners and lake chubsuckers were stocked as they became available from our rearing ponds. Crayfish were stocked in 1977, increased rapidly, and have maintained an excellent population. Burrowing mayfly nymphs are abundant, and are available throughout the growing season as forage for all fish species.

Walleye growth has been somewhat slow, due in part to a low initial forage base. Nevertheless, walleyes spawned for the first time at age IV and at lengths of 32-35 cm. Stomach samples indicate that walleyes have continuously depended on the great abundance of mayfly nymphs as a food base. Smallmouth bass adapted well to the crayfish introduction, and grew accordingly, spawning at age II and at lengths of 25-29 cm.

To ensure better initial growth of fish stocked into a new body of water, we believe that carefully sorted forage fish should be stocked at least 1 year prior to any game-fish introduction. This should allow ample time for forage species to become established and produce a food base.

In dealing with a newly created and stocked body of water, we have initiated several research and monitoring projects. These include a study of nesting requirements and capabilities of smallmouth bass; a tagging program to monitor the growth and condition of individual walleye and smallmouth bass; a stomach-content analysis on all fish brought in by anglers; monitoring of crayfish densities and relative abundance, as well as the importance of crayfish as forage-food organisms; and an evaluation of artificial reefs.

All anglers must bring their fish to us to be processed. This enables us to collect nearly complete creel data, including catch rates, fishing pressure, and estimates on the numbers of fish caught and released for each major species.

In 1980, Lake #1 was opened to anglers for the first time, on an experimental basis. Subsequent opening dates have varied, depending primarily on smallmouth bass nesting activity and on recruitment. Limits remain flexible so as to adjust to angling pressure. With a limit of 2 walleye per adult angler, the walleye catch-rate (nos./hr.) for the past 2 years compares favorably with those of several older Minnesota walleye lakes (Strand 1980, Osborn 1980), and the walleye yield-rate (nos./acre), is comparable to those found in a private Wisconsin walleye lake (Serns 1981) and in some Minnesota lakes (Strand 1980). The lake's smallmouth bass catch-rate is comparable to that of Clear Lake in Wisconsin (Marianac-Sanders and Coble 1981), and the yield similar to that of several Wisconsin lakes (Serns and McKnight 1974).

Overall, our fishermen have had many good fishing experiences on this lake. We are interested in seeing that the quality of these experiences is maintained.

CONCLUSION

By 1982, we were in our tenth year of actual mining, and our ninth year of reclamation. We have learned much, but have much still to learn. In general, we are quite pleased with such aspects as erosion control (via successful grass-legume establishment, water-control devices, and other methods), grassland habitat development, waterbird diversity, development of a sport fishery, and our monitoring-research programs on vegetation growth, water quality, fisheries, and wildlife use. Less satisfactory has been the slow growth and, in some cases, loss of woody plant materials. It seems likely that we overestimated the speed and ease with which this last goal could be achieved.

In any event, a new 5-year contract has been negotiated. The next 5 years should see the conclusion of mining, and of most basic reclamation. However, additional reclamation refinements likely will continue for years, as we study and learn from past successes and failures. So, too, will our monitoring studies, which we trust will furnish useful data on the long-range impact of gravel mining and planned reclamation on wildlife and fisheries resources.

LITERATURE CITED

HARGER, K. 1981. Tougher controls sought over gravel mining. Elgin (Ill.) Herald-Cardunal Free Press. June. A4-A5pp.

ILLINOIS WILDLIFE FEDERATION. 1972. The strip mine story. Ill. Wildl. 8(12):16.

MARIANAC-SANDERS, P. and D. W. COBLE. 1981. The smallmouth bass population and fishery in a northern Wisconsin lake, with implications for other waters. N. Am. J. Fish Manage. 1:15-20.

MAX McGRAW WILDLIFE FOUNDATION. 1973. Gravel pit reclamation--reclamation, wildlife, recreation. Wildl. Manage. Note 5, Max

McGraw Wildl. Fndn., Dundee, IL. 33pp.

OSBORN, T. 1980. The long-term effects of increased fishing pressure on percids and esocids in a northern Minnesota lake. Minn. Volunteer 44(255):46-56.

SERNS, S. L. 1981. Effects of a minimum length limit on the walleye population of Wolf Lake, Vilas County, Wisconsin. Wis. Dept. Nat. Resour. Fish Manage. Rep. 106. 11pp.

_____ and T. C. McKNIGHT. 1974. A summer creel census of Stormy, Black Oak and Laura lakes, Vilas County, Wisconsin. Wis. Dept. Nat. Resour. Fish Manage. Rep. 71:27pp.

STRAND, R. F. 1980. The walleye sport fishery in 3 Upper Mississippi reservoir lakes--Cass, Andrusia, and Big Wolf, 1971-1975. Paper presented at 42nd Midwest Fish, Wildl. Conf., Dec. 7-10, St. Paul, MN.

WIENS, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornitholog. Monogr. 8. 93pp.

WILLIAMS, A. B. 1936. The composition and dynamics of a beech-maple climax community. Ecol. Monogr. 6:317-408.

Research Needs and Priorities of Gravel Pits

DANIEL L. LEEDY, Senior Scientist, Urban Wildlife Research Center, Inc., 10921 Trotting Ridge Way, Columbia, MD 21044

INTRODUCTION

In the assigned title, the words "research" and "priorities" each could mean different things to different people. In this paper, "research," "investigation," and "study" are used more or less interchangeably to mean studious inquiry, examination, investigation or experimentation to discover new facts and interpret them correctly. Because some seemingly irrelevant bit of basic research may turn out to be highly relevant and important, I shall not spend much time trying to list research needs in a descending order of importance. Research priorities for fish and wildlife, in fact, may depend largely on post-mining land use priorities of mined-out sites. The research and information needs suggested here include investigations on the effects on fish and wildlife of various mining and reclamation methodologies in different situations, responses of fish and wildlife to altered habitats, and what can be done to protect or enhance fish and wildlife populations and their habitats, prior to, during, and after mining has been completed. I believe results of most of the studies suggested would be useful to planners, developers, land managers, and biologists interested in fish and wildlife management of gravel pits and other mine sites whether in cities or in rural areas.

Gravel pit, highway borrow pit, and quarry sites comprise fish and wildlife habitats which, like areas surface-mined for coal, and rights-of-way for electric utility lines, gas/oil pipelines, and highways, are a kind of "no man's land" in the field of wildlife conservation. They have been largely neglected in the research, planning, and management efforts of Federal, State and private conservation agencies and organizations; yet they offer many opportunities for mitigating against loss of habitat elsewhere. Though this presentation is not intended as a state-of-the-art report, it is hoped that it will stimulate wildlife research and management efforts. Selected references are included not only for documentary purposes, but for any help they may be in facilitating additional research.

NATURE AND EXTENT OF MINING

Sand and Gravel

According to Paone et al. (1974), 3.7 million acres of land were used for all mining during the period of 1930-71 compared with 3.3 million for airports, 3.2 million for railroads and 1,808 million for agriculture, including grazed and ungrazed forest land. Of the land disturbed by mining during this period, 906,200 acres were disturbed by sand and gravel production of which 264,259 acres were reclaimed, not including land put to other uses, such as building construction. Land disturbed by mining for sand and gravel accounts for only about 18% of all the land disturbed by mining, something like 0.03% of the area of the United States. Sand and gravel are produced in all States and the mined sites, mostly in private ownership, can provide valuable habitat for fish and wildlife.

As described by the National Research Council (1980), sand and gravel deposits occur in active or former stream channels (fluvial deposits); marine continental shelf deposits; estuary deposits; glacial deposits of the type commonly found in the northern United States; and alluvial fan deposits such as are formed at the mouths of canyons in arid and semi-arid areas of southwestern United States.

Above the water level, excavation is often done by power shovels or mobile rubber-tired loaders and the material is carried by trucks to plants or to the place of use. Where excavation is below water, the material may be excavated by dragline scoops, "clamshells" or other types of dredging equipment. Processing plants where the mined materials are crushed or screened and separated into different sized particles are usually in a permanent location. At wash-water settling basins, process water is passed into a series of basins where the silt and clay are allowed to settle out. Care must be taken to recycle the water and prevent sediment from entering local waterways.

Borrow pits

As treated here, borrow pits, e.g., those along highways, will be considered as gravel pits. There are about 4 million miles of roads and streets in the United States (U. S. Department of Transportation 1979) and the number of borrow pits from which sand and gravel were extracted for their construction must number in the thousands. In Ohio, for example, Taub et al. (1974) reported that there were 211 interstate highway borrow pits impounding 1,280 surface acres (exclusive of the Ohio Turnpike) as of July 1, 1970. Most of the borrow pits are located near interchanges, close to human population centers, and, with proper management, represent an existing or potential source of fishing waters as well as habitat for many other species.

Crushed Stone Quarries

In 1977, crushed stone was purchased by 1,936 companies from 5,665 quarries located in all States except Delaware and North Dakota, the production accounting for 14% of all land disturbed by mining or 0.02% of the land area. The stone is initially broken by blasting so it can be moved to the plant. It may be taken from above the water table or from below the water table in quarries that have been dewatered by pumping. Dewatering usually yields effluents of the same quality of the local groundwater. Agricultural, chemical, and metallurgical limestones and dolomites are produced largely from quarries and often as a byproduct of crushed stone operations. Quarrying-crushed stone operations may run for longer than 100 years whereas sand and gravel operations may last for only a few decades (National Research Council 1980).

Phosphate Rock

Another type of mining I shall mention only briefly here, but which is important locally for wildlife, is stripmining for phosphate rock in west-central Florida. As reported by Montalbano et al. (1978), current technology results in the use of approximately 40 percent of the mined acreage for phosphatic clay settling areas referred to as slime ponds. These ponds serve as wintering areas for large numbers of migratory ducks. Greatest use occurs on ponds exhibiting a high degree of interspersion of open slime-water and emergent vegetation. The authors suggest that inasmuch as the slime ponds have levees and water control structures in place, there are probably opportunities for management. Presumably these would be directed primarily toward preventing the proliferation of too much emergent vegetation when water is drawn off in the stabilization of the slime ponds. Research might point the way for accomplishing this control for the benefit of waterfowl. It is the type of research--primarily related to habitat management--that will be addressed in this paper.

RESEARCH AND INFORMATION NEEDS FOR PLANNING AND MANAGEMENT

Information and the methods for obtaining information of various kinds are needed as a basis for planning as well as for conserving and managing fish and wildlife prior to, during, and after mining, whether the mined site has been abandoned, is in the process of being reclaimed, or has been reclaimed. Certain kinds of information are generally applicable, but, for specific situations, other information may be needed. Though many of the techniques for obtaining the needed information are available, I suspect there are many instances in which suitable methodologies for obtaining the information need to be developed or refined. I believe, also, that there is need for biologists to demonstrate the detail of information needed for planning and management purposes and how it can be used.

General Needs

For planning and management it is desirable to know what resources there are to work with, what the goals are, and what the legal requirements are, and to have an understanding of human preferences and socioeconomic factors applicable to the area.

Biological and physico-chemical

Information is needed on the species and population levels of fish and wildlife present on a proposed mine site or on a mined area, and in adjacent areas as well. This is true, especially, of threatened and endangered species on either State or Federal lists. Because plants are at the base of fish and wildlife food chains and vegetation management is of primary importance in habitat management—the principal approach to fish and wildlife management--rather detailed vegetation and land use maps are considered important. And because soil, water, and climatic conditions and land use regulate, to a large extent, the type of vegetation present in an area, information on these factors is needed. But how much information is needed? What detail is needed in preparing vegetaion maps? Is it the species or the structure and layering of vegetation that is more important to wildlife? What kind of soil sampling and testing is needed to determine the pH of the slopes of a gravel pit? Are the portable kits for testing the pH of water in gravel pit ponds sufficiently accurate to satisfy the needs of planners and managers? Is enough known about the requirements of the species present to necessitate having sophisticated soil and water quality measurements?

Socioeconomic and legal

Aside from physico-chemical and biological information, there are other needs viz. socioeconomic and legal. These include location of the site with respect to potential users, ownership, access, possibilities of acquiring the site by purchase or lease for fish and wildlife purposes, competing land uses on and adjacent to the area, and legal aspects of using the site for fish and wildlife or for public recreation.

Is there a fence around the area so visitation can be controlled? R. Weldon Larimore, aquatic biologist of the State Natural History Survey Division, indicated (in litt. 11 May 1982) that there was a real reluctance in Illinois to do anything with development of gravel pits--especially roadside borrow pits--for public use because of public liability. He asked: "How does one provide access and yet control the use of such public areas, which are especially attractive to midnight skinny dippers and beer drinkers?" Public liability--access and control for maximum utilization and minimal responsibility--was listed first among Larimore's suggested topics for research applicable to gravel pits.

Are funds, equipment, and manpower available for managing the site? Are the neighborhood residents or faculty and students in nearby schools sufficiently interested to conduct studies or provide voluntary assistance with the planting of shrubs and with other work? Are State and county officials, or perhaps local contractors, willing to make manpower and machinery available to reshape gravel pits or construct earthen islands within wet pits to render them more suitable for fish and wildlife? What would most of the people in the neighborhood like to have done with a gravel pit or quarry insofar as fish and wildlife conservation is concerned? Manage it for fish, for waterfowl, as a bird sanctuary? All such information should be useful in planning for research and management, but it is not all easy to develop. Getting information on human preferences, getting public input in decision-making, and keeping the public informed and supportive of a project merit attention and research to develop the most effective approaches, just as does collection of physico-chemical and biological data.

Pre-Mining Research Needs

The law may require that certain conditions must be met before a permit for mining and reclamation is issued. Researchers can help develop the information required by law and supplement or complement the information especially relevant to fish and wildlife. There is still room for improving methodologies for censusing fish and wildlife and for evaluating their habitats. Where it is possible that threatened or endangered species may occur, researchers can make careful surveys. If any such species are found, biologists' reports might result in changing the proposed mine site. They can suggest wildlife management measures, based on research, for sites which some municipalities or counties have thoughtfully set aside as gravel reserve areas for future use rather than permitting unplanned housing or industrial development which would prevent the gravel from being used. I saw such an area in Los Angeles while serving on the Panel on Construction Minerals of the National Research Council's Committee on Surface Mining and Reclamation in 1979. Gravel reserves can serve as wildlife sanctuaries over a considerable period of time. Setting aside such reserves should be encouraged because many metropolitan areas are facing shortages of sand and gravel (Dunn 1975, and Hoagberg and Rajaram 1981). In making inventories of potential mineral reserves, biologists could assist engineers and geologists by identifying areas particularly valuable for wildlife. Conceivably, through their studies, they could devise wildlife management plans which, when carried out before mining, would mitigate damage done to the habitat when the reserves are opened up to mining.

Researchers can also play a valuable role in providing information for incorporation in State, Provincial or local laws and ordinances regulating the removal of gravel. The "Order Respecting the Removal or Displacement of Gravel in or About Certain Waters of the Province of British Columbia" (Department of Fisheries and Oceans Canada 1978) is an example of an order designed to protect the spawning grounds of fish--principally, Pacific salmon. It is included as a section of an informative publication entitled "Guidelines for Land Development and Protection of the Aquatic Environment."

Likewise, engineering and biological information might be prepared showing the relative costs of reclaiming mined lands for fish and wildlife habitat as a post-mining land use in comparison with reclamation costs for agricultural, industrial, or other uses. A case study of an abandoned mine (lime rock quarry) at Live Oak, Florida was made for the U. S. Bureau of Mines by Herbert and Turner (1981). These authors estimated that reclamation of 861 acres of the quarry for industrial sites would cost $1.13 million while reclamation of 964 acres to woodland agriculture would cost $142,200. It is likely that costs of reclamation for fish and wildlife would be less, but the authors indicated that fish and wildlife use of existing areas was generally compatible with other uses because of the large land area involved.

When it is certain that a site is going to be mined, researchers can provide useful guidelines for the protection and/or enhancement of fish and wildlife habitats. Through research and experimentation done elsewhere, biologists can suggest how limbs from trees and the brush removed in clearing the site can be piled for cover, or arranged to serve as travel lanes, for wildlife. They can suggest how, with the cooperation of the mine operators, and through slight alteration of mining procedures, the pits remaining after gravel removal can be of a size and shape conducive to fish production or use by waterfowl, fur animals and other wildlife. This is important because creating land forms, either through excavation or disposal of overburden, spoil, or large boulders frequently found in glacial gravel deposits, can be done far more economically during mining than after mining has been completed. For example, Carlson (1978) has provided an interesting account of how, at the suggestion of a Utah Division of Wildlife Resources fishery biologist, and the cooperation of his Division, and the Bureau of Land Management and the Fish and Wildlife Service of the U. S. Department of the Interior, an estimated $100,000 was saved in constructing a sophisticated 6-pond striped bass rearing system in the course of reclaiming the Wahweap Wash alluvial gravel site in Utah. The fish are used for stocking Lake Powell. In this project, engineers of the Utah Division of Wildlife Resources designed the pond system, the Salt River Project agreed to use their contracted equipment to build the ponds, BLM supervised the construction to State standards, the Fish and Wildlife Service provided Dingell-Johnson funds, and water for the interconnected rearing pond system comes from an industry-financed well drilled at the site to wash the gravel.

Guides based on research are needed to show the dimensions and nature of pit ponds—especially water depth, slope of bank, type of shoreline, number and size of islands within a pond, and other characteristics--desirable for different kinds of fish and wildlife. A start has been made, e.g., Moulton (1970) and Taub et al. (1974) have suggested some desired features for constructing future, or improving existing, borrow pit lakes for fish production. Some good information on the value and characteristics of highway borrow pit ponds and shallow wetlands in relation to waterfowl use and production has been generated by Steward and Kantrud (1973), Krapu (1974), and Swanson and Meyer (1977). The findings of these researchers reveal some of the interrelationships of water depths, permanancy of water, vegetation, and tillage or no tillage of the bottoms of temporary wetlands to the production of invertebrates and their consumption by different species of ducks. There is a need for interpretation of these findings, possibly more research, and development of guides that can be used in designing future gravel or borrow pit ponds or lakes and in managing highway rights-of-way. Blair and Sather-Blair (1979), in a project with the North Dakota State Highway Department, have made a beginning toward showing how constructing shallow impoundments 100 to 300 feet long and 20-25 feet wide in highway rights-of-way add to, and diversify, natural wetland complexes and provide invertebrate food and breeding territories for resident and migratory wildlife species.

Fish and Wildlife Research During Mining and Reclamation

Ideally, if adequate guidelines were available and followed during mining and reclamation, little research would be needed for wildlife management in these stages. However, there is much that can still be learned about the effects of mining on fish and wildlife in different situations and how mined areas can be reclaimed most advantageously for these resources.

Griffith and Andrews (1981) evaluated some of the effects on aquatic organisms of an experimentally operated small suction dredge on four small Idaho streams. They found that uneyed cutthroat trout (Salmo clarki) eggs experienced 100% mortality within 1 hour after entrainment, while eyed cutthroat trout eggs showed means of 29% and 5% for 1-hour & 36-hour mortalities respectively. After 10 days, the 19% mortality of eyed eggs of hatchery rainbow trout (Salmo gairdneri) was similar to that of a control group but, after 20 days, the mortality of hatchery rainbow trout sac fry was 83% as compared with 9% for the controls. Fewer than 1% of the 3,623 invertebrates entrained showed injury or died within 24 hours, most of the dead being Centroptilum mayflies that were undergoing emergence at the time of dredging. Most of the recolonization of dredged plots by benthic invertebrates was completed after 38 days. Detailed information of this kind is scarce; more is needed. Investigators in this area of research may wish to examine a report on effects of dredging and disposal on aquatic organisms by Hirsch et al. (1978). This report synthesizes data from the U. S. Army Corpos of Engineers' Dredged Material Research Program, Task ID, and includes 35 references on the subject.

With quarries, where quarrying may be done over a period of 50-100 years, what is the best use of the removed top soil for wildlife purposes? How long and under what conditions can top soil be piled or stored without losing its microorganisms, a valuable component of the soil? Can it be used to develop a soil layer capable of supporting vegetation useful to wildlife on the rock bottom of a dry quarry? Can it be used to form a soil incorporating organic matter in the bottom of a quarry pond? What are the effects of blasting on wildlife in the area surrounding the quarry or on cliff-nesting birds in sections of a quarry already mined? There are few studies dealing with these matters. Allaire (1978) found that ground-nesting birds like the ovenbird, Kentucky warbler, worm-eating warbler, and black-and-white warbler may be adversely affected by the dust and debris blown over areas adjacent to a mine; but the hooded warber, eastern wood peewee, red-eyed vireo, scarlet tanager, and cerulean warbler appeared to be extremely tolerant to nearby blasting. Can a vegetative screen be developed around quarries or mines to reduce injurious effects on wildlife? Serve as nesting cover for wildlife?

What effect does dust from rock crushing and processing plants, or from vehicles transporting materials on mine haul roads, have on use of adjacent dust-covered vegetation by insects, an important source of food for birds? How important to wildlife is it that air pollution be controlled? With respect to sediment ponds used in connection with gravel or other mineral washing operations, are there any improvements that can be made to save water, minimize water pollution, or increase the use of the settling basins for fish and wildlife?

More information is needed on the impacts on fish and wildlife of extracting, by dredging or other means, construction minerals from various types of water areas. Mining operators should be appraised of the location of important fish spawning grounds, nursery areas, shellfish beds, and other sites where mining would be particularly damaging. They should be advised, also, as to the time of year when mining is most harmful, and when least harmful, not only to fish, but to fish food organisms. Are there ways of altering the methods of mining, e.g., stepping up the progress already being made in reducing and confining the siltation caused by underwater mining, and perhaps avoiding the creation of deep holes in intermittent streams which may entrap fish during dry periods? Do we know enough about the effects of these holes and other alterations of the streambed? Do we know enough about the tolerances of different organisms to siltation and turbidity? I doubt it!

But what are the opportunities for improving habitat and creating new habitat in the course of dredging? We have mentioned the creation of islands which add edge habitat and diversity. What about creating improved spawning grounds or other gravel or rock structures in the form of shelves, bars, reefs etc. which would be valuable for fish and wildlife? Dredge operators would have to have adequate guides to create them. And, to use a suggestion from George Burger (<u>in litt</u>. 6 April 1982) how best can marsh habitat be developed in pits--by pushing overburden into water until shallow; mining only to the water table, and blasting or digging potholes; or trying to use the settling basin for sediment-filled water used in the washing process? Some useful guidelines for the deliberate establishment of marshes and leads to relevant literature, particularly for tidal areas, are given by Garbisch (1977) in a report prepared for the Office, Chief of Engineers, U. S. Army, Washington, D. C. in connection with the Dredged Material Research Program of the Waterways Experiment Station.

One way of rehabilitating filled-in reservoirs or lakes is to remove some of the accumulated sediments. Is it feasible to separate gravel and sand from silt in the deposits removed? Can silt be used to improve soil conditions for wildlife plantings on some of the upland gravel pit areas?

In long-term and extensive mining operations, what can be done to reclaim mined portions of the site while mining is still underway in other portions? One approach might be to develop a vegetative border around the site which serves both as an aesthetic screen and as valuable habitat for wildlife. How wide should such a screen be and what plant species can be used that are most valuable to wildlife in different geographic areas and situations? From the standpoint of various kinds of wildlife, how important is it to control erosion, except possibly for reducing siltation in gravel pit ponds, when the drainage is confined to the mined area? Are some of the annual plants that invade disturbed areas perhaps more valuable than a thick cover of grass? In this connection, permit me to quote a few sentences from George Burger's letter.

"I believe that we still have much to learn about waterfowl and gravel areas. For instance, we had far more goose use when our first lake was just mined and still largely 'raw' and shorelines unreclaimed than we do now, when we're all nicely 'managed.' In our case, there are other circumstances involved that explain some--but not all--of this difference. Should many bare gravel areas be left instead of vegetating everything..?" Coming from the author of <u>Practical Wildlife Management</u>, a man who, indeed, has had much practical management experience, this says a lot. In fact, we have much to learn about reclaiming mined areas for most species, from minute invertebrates to foxes and falcons.

Research on Mined Areas

As of 1965, it was estimated that probably only one-third of the total acreage disturbed by surface mining had been adequately reclaimed by natural forces or by man's effort (U. S. Department of the Interior 1967). Despite enactment of laws requiring reclamation and, undoubtedly, leading to an increase in percentage of reclaimed mines, much of the current habitat available for fish and wildlife is on unreclaimed sites or sites reclaimed by nature. We can learn much by studying these sites and determining under what conditions they are productive of fish and wildlife and when they are not. Through research comparing abandoned and non-managed mined areas--gravel pits and quarries--with reclaimed and managed areas of the same age, following mining, we can assess the effectiveness of deliberate fish and wildlife management. These studies should also permit us to develop predictive abilities. Few comparisons of this type involving in-depth ecological research and assessment of fish and wildlife populations in gravel pits or quarries have been made.

Svedarsky et al. (1982) have discussed the occurrence and composition of breeding bird populations in various plant communities of an abandoned gravel pit in northwest Minnesota. Similar studies in other regions and with mammals and other fish and wildlife species would be desirable. In another paper, Svedarsky et al. (1980) sketched changes in habitats and accompanying changes in the species composition of bird populations of abandoned gravel pits over an 80-year period. A desirable distinction was made between pits below the water table and pits above the water table. Keys or guides of this type, elaborated as research findings permit, should have much value to planners and managers in that they show changes likely to occur in biologic communities if the pits are left unmanaged and unreclaimed by man. Similar keys are needed, however, to predict changes expected under various types of reclamation and management. It might be rewarding to evaluate, through research, some of the management measures suggested by Svedarsky et al. (1980), e.g., how nearby upland areas managed for wildlife food and cover affect the wildlife use of gravel pit or quarry ponds, the practicality of using large boulders associated with some gravel deposits to create rock islands in the ponds for duck loafing sites, and the desirability of modifying the drainage of surrounding areas to divert more spring runoff into a wetland.

Getting back to the question of revegetating bare gravel banks, the law may require it, but there are problems involved. In his 6 April 1982 letter, Burger stated that in managing the steep gravel banks at Dundee, Illinois, establishment of grasses and/or legumes to control erosion is not too difficult, but 2 difficulties are encountered as a consequence: (1) a good catch of grasses like timothy, redtop, and orchard grass means intense root and shade competition for shrubs and trees--especially young stock--planted later; and (2) the need for quickly revegetating the slopes works against use of desirable warm-season prairie grasses, which take 2-3 years to develop a good stand. Burger pointed out the need to determine what are apt to be the most successful shrubs and trees with wildlife values for use on the unstable and/or highly compacted and disturbed gravel reclamation areas. Then, he asked, in establishing shrubs and trees on such sites: Is it more efficient and economic to kill out grasses by spraying? Plowing and fallowing? Or perhaps, cheaper in the long haul to use expensive, larger stock or seedlings? Or is it, perhaps, worthwhile to delay planting woody species for several years on the assumption that the grass/legume cover will improve soil and fertility (or will it?)? These questions should all be answered by research and experimentation. We feel certain, for example, that disturbed and compacted gravel soils will change in structure and fertility, but how, and over how long a time?

Biologists concerned with the revegetation of abandoned or reclaimed gravel pits or with research on species selection,plantings, and vegetation management to improve fish and wildlife habitat may get helpful leads by consulting publications dealing with surface mining for coal, highway fills and rights-of-way, and dredging and disposal of dredged materials in which similar problems are discussed. For example, a 2-volume work by Leedy (1981) and Leedy and Franklin (1981) on coal surface mining and reclamation in relation to fish and wildlife, and another publication (Leedy and Adams 1982, in press) on managing highway rights-of-way for fish and wildlife contain much information and cite many references--including several bibliographies--on managing vegetation on areas of disturbed soil. Likewise, a handbook for terrestrial wildlife habitat development (Coastal Zone Resources Division, Ocean Data Systems, Inc. 1978) contains much relevant information on useful wildlife food and cover species that could be established on dredged material.

Svedarsky et al. (1980) observed that during the grading phase of reclaiming dry gravel pits there are opportunities to create "microhabitats" for different plants, e.g., mounds of spoil, overburden, or gravel providing relatively cool and moist north-facing slopes and warmer and drier south-facing slopes to accommodate different plants. But how large and how high must the mounds be to significantly diversify and add to the value of the habitat for wildlife? By observing wildlife use of some abandoned pits where such mounds have been left accidentally, i.e., without planning, and have contributed importantly to wildlife habitat conditions, it may be possible to draw some conclusions without long-term experimentation. Through some appropriate approach, perhaps systems analysis, guidelines should be developed for indicating under what conditions it might be most feasible to let plant invasion do the job of revegetating, and when plantings would be desirable, when it is feasible to use mulch or soil amendments, when to irrigate, and so forth.

Extraction of sand and gravel from flood plain areas with a high water table creates many wet pits where the fluctuation of water levels, dependent primarily on ground water, may be less than in upland pits having runoff as a major source of water. Is a stable water level desirable or not? Some of the deeper ponds may be suitable for fish production. Probably, in times of flood, many of these ponds will be flooded and there will be an exchange of nutrients and aquatic organisms from river to pond and pond to river. An interesting study would be to determine the extent to which these floodplain ponds serve the biological role of natural oxbow lakes in enriching the floodplain-river ecosystem. Could something be done. e.g., by constructing connecting tree-or shrub-lined dikes or leeves, that would channel the water during floods and serve as travel lanes? Larimore (op. cit.) agreed that streamside pits can contribute substantial production of fish and fish food resources to the neighboring stream, but, at the same time, may receive both fish and fish foods from the stream. He was skeptical about what could be done to control these sites. It is possible also, that river flooding of these pit ponds can introduce undesirable species of fish.

Some gravel pit ponds are used by both fish and waterfowl as well as by many other wildlife species. The question has been raised by Swanson and Nelson (1970) of the compatibility of fish and wildlife for available food and cover in "winterkill" lakes and deep marshes on midwestern prairies. Their concern about the potential effects on waterfowl of the current promotion of trout rearing and other fish production in these lakes and marshes may apply to some gravel pit lakes too. The question that needs answering is whether the fish consume enough of the same aquatic invertebrates as consumed by ducks during egg production and early development of ducklings, and whether fish management practices which tend to alter or destroy emergent vegetation used for nesting or nest construction seriously affect waterfowl use of the areas. If the answer is yes, planners and managers should decide which species should be favored in management.

There is much about the basic biology of mined sites, both terrestrial and aquatic, which we need to know. For example, research done by Riley and Brown (1978) suggests that the poor survival of planted and seeded deciduous tree species, understory, and ground cover on many bituminuous coal spoil banks may be caused by the absence of suitable mycorrhiza fungi. Different species of fungi are associated with the roots of many different species of plants in natural situations. Apparently among the nonmycorrhizal higher plants are mustards, chenopods, sedges, and some aquatic plants. The authors recommended that nurseries be developed on surface mine spoil, using the wildlife food and cover species and mycorrhizal fungi they had identified, for testing and comparing with planting stock from standard nurseries. Perhaps this research has application to revegetating gravel pit sites.

To manage gravel pit ponds, more information is needed on primary productivity and how to increase or regulate it, along with nutrient levels. For fish management, Larimore (op. cit.) mentioned the need for studies on the relationships of water quality and runoff, ground water, and basin soils to fertility, and on the growth and reproduction of fish in relation to fertility, cover, and exploitation. More specifically, he suggested that research be done on basin design and modification to improve spawning areas and benthic production; installation of cover to protect young fish and provide substrate for fish food organisms; fertilization or diversion of run-off waters to enrich the system if water quality is such that good growth is not supported; and methods for estimating reasonable yield and for controlling exploitation.

More information is needed, too, on the habitat requirements and tolerances of invertebrates and other species to water pH, temperature, turbidity, fluctuating water levels etc. We need to know how to combat turbitidy caused by crayfish, for example. Francis Uhler, a retired Fish and Wildlife Service field ecologist, told me recently that he had successfully transplanted a species of bladderwort from a New Jersey marsh into a Patuxent Wildlife Research Center pond near Laurel, Maryland which was made turbid by crayfish. For whatever reason, this plant, which formed a layer of vegetation near the pond bottom, was helpful in precipitating the suspended soil particles and in reducing the turbidity in the pond. We have only scratched the surface in such research and experimentation.

Abandoned quarries may be 100 feet deep with nearly vertical walls constituting a hole many acres in extent. In quarries which partially fill with water, there are some opportunities for fish production. There is often a slow turnover of water and a lack of organic matter, however. Also, wave action may be limited because of the high walls reducing wind at the water surface. Research may be warranted to determine the need for, or feasibility of, installing aerators in quarry ponds to supply oxygen needed by aquatic organisms. Studies might be directed towards devising methods for developing a soil base on the bottom of dry quarries or of incorporating some organic matter in water areas, thus improving conditions for biologic organisms.

What soil amendments are needed and what materials can best be used to provide needed organic matter? Are lawn clippings and hay satisfactory? If so, how much material can be put into a quarry pond of X size and X depth without depleting the dissolved oxygen in the water? Does it make sense to develop a soil layer on dry quarry bottoms sufficient to support terrestrial vegetation that could be used by wildlife? Can this vegetation supply a wildlife need not satisfied in the area surrounding the quarry? Can anything practical be done to increase the suitability of quarry walls for the nesting of cliff swallows, cave swallows, bank swallows, violet-green swallows, prairie or peregrine falcons, and belted kingfishers?

What is the relative use of deep (100-foot wall) versus moderate depth (40-50-foot wall) quarries by waterfowl? Would dumping overburden and spoil against the vertical quarry walls at the bottom of the quarry improve conditions for waterfowl and other wildlife? Is it desirable or feasible to anchor floating boxes or rafts in quarry ponds for waterfowl resting and/or nesting sites? If so, what size should they be? How far apart? Should they be filled with earth to support vegetation? Under what conditions should nesting material be provided? I understand that the J. L. Shiely Company of Minneapolis diked off a part of the floor of one of its quarries to create an impoundment suitable for fish and waterfowl use. What are the conditions necessary to make such a management measure successful?

Secondary Use of Gravel Pits and Quarries by Wildlife

Unless acquired by purchase or some kind of leasing arrangement for fish and wildlife use, gravel pits and quarries are likely to be put to other uses. This is true in urban and suburban or other developed areas where the reclaimed areas are used for building sites, landfills, and parking lots, and in rural areas where the sites are often reclaimed for agriculture or forestry. This does not mean that there is nothing that can be done for wildlife, however.

In reclaiming mined areas for agriculture, if the owner wishes to encourage wildlife,some of the wet pits can be retained as ponds. Travel lanes, possibly connecting the ponds to wooded areas and separating the fields, can serve wildlife well. We still have things to learn about the most appropriate species or mixtures of grasses, shrubs and trees to use, and the desired width and height of the travel lane vegetation, keeping in mind the potential effects of such vegetation on adjacent crops through shading or serving as reservoirs of crop damaging diseases and insects.

A gravel pit used for a sanitary landfill can be an environmentally acceptable means of municipal waste disposal. Landfills provide land needed for recreational uses near urban-suburban areas and, depending on the type of vegetative growth on the site, they can provide wildlife habitat. Unless handled correctly, however,landfills can cause ground-water pollution. Also, there are problems in revegetating the sites because of the production of gases, surface settlement, and high ground temperatures. Flower et al. (1981) believe a principal problem in revegetation stems from the presence of landfill gases and anaerobic soil conditions. Among other factors affecting the vegetation they consider important, are lack of oxygen in the root zone, toxicity of carbon dioxide to the roots, or anerobic conditions of the soil permitting heavy metals such as iron, manganese, and zinc to become available to vegetation in toxic concentrations.

Based on studies at a 14-year-old landfill in East Brunswick, New Jersey, Gilman et al. (1981) concluded that:

"1. Woody species differ in their adaptability to landfill soil.

2. Slow-growing trees appear to be better adapted to landfill conditions than rapid-growing trees.

3. Trees and shrubs planted as small specimens appear to be better adapted to landfill conditions than large specimens.

4. Species with a natural propensity for producing shallow roots are better suited for landfill vegetation projects than naturally deeper-rooted species.

5. Species reportedly tolerant to low oxygen environment will not grow well on landfills unless they are irrigated very thoroughly.

6. Balled and burlapped plant material appears to be better adapted than barerooted material to landfill soil.

7. Landfill gases (primarily carbon dioxide and methane) must be kept away from the root system of trees and shrubs to promote good vegetation growth. Two types of methods shown to be effective are (a) a mound of soil (0.9 m) over existing cover (with or without a clay liner), and (b) a lined and vented trench backfilled with suitable soil."

Of 19 woody plant species planted at the Edgeboro landfill, black gum and Japanese black pine proved to be the most tolerant and green ash and hybrid poplar the least tolerant to landfill conditions. Perhaps, through study and experimentation on such sites, wildlife biologists could identify other species tolerant to unfavorable growing conditions that would be more valuable to wildlife. Biologists might also help develop methods for ameliorating the growing conditions; and for landfill sites still in operation, they might devise planting schemes for screening the sites with a border of vegetation valuable for wildlife. Similarly, through research and cooperation with urban landscape architects, planners, and developers, biologists might prepare lists of shrubs and trees of special value to wildlife for use in the landscaping of housing and commercial developments on reclaimed gravel pit sites. Even paved parking lots developed on reclaimed mine sites can serve as stormwater detention basins and contribute to conservation, if properly designed and landscaped.

In some cases it may be possible to use an area, like a quarry, for fish and wildlife during its transition from mined out land to reclaimed property. Research of the kinds suggested in this paper should provide information useful in promoting such use.

SYNOPSIS OF GRAVEL PIT/ROCK QUARRY WILDLIFE RESEARCH NEEDS

My manuscript was developed to this point without having read the papers presented at this symposium. Subsequently, advance copies of most of these papers were kindly provided to me by Program Chairman Dan Svedarsky. I would like, now, to update my evaluation of the status of gravel pit wildlife research and supplement or complement the research needs previously identified by referring briefly to the presentations made here. Research needs are organized under the same general headings used earlier and are largely oriented to planning and management.

General Needs

Practical but effective methods are needed for obtaining information on what resources there are to work with, establishing goals and objectives, devising and interpreting legal requirements, and understanding human preferences and socio-economic factors that relate to planning and management for wildlife. Though methodologies, most of which were developed for other purposes, exist, there are opportunities for revising them or developing new techniques especially adapted for use in gravel pits and quarries.

1. Methods for developing adequate biological and physico-chemical information for planning and management are needed.

(a) Herricks, in his generalized account, listed many of the planning and management needs and suggested some methodologies for fish and wildlife habitat development extending from premining to the postmining use of an area. Some of the methods described as successful in areas surface-mined for coal may be useful in gravel pit areas.

(b) Approaches described for wildlife planning and management on specific areas may have application elsewhere. Relevant papers were presented by Oldenburg et al. (Illinois), Gallagher (Oregon), Koopman (Colorado), and Stoecker (Colorado). Research by Stoecker showed the need for intensive small mammal trapping to determine the effects of gravel pit ponds on the abundance and distribution of voles.

2. Improved means of identifying and assessing the potentials of gravel resource areas for fish and wildlife are needed

(a) Eng stated that railroad pits probably represent the largest pit excavations resulting from using conventional dry pit mining methods.

(b) Knox estimated that in Colorado, alone, 100 to 200 surface areas of gravel pit ponds could be created each year. However, due to increasing problems with water appropriations and evaporation augmentation, there has been increased effort to keep new pits dry or refill them with land-fill material. (Some research has been done on the use of a chemical film on the surface of reservoirs to reduce evaporation; would it have application here?)

(c) Edwards reported that construction of Interstate 80 in Nebraska resulted in creating over 140 pits providing over 700 surface acres of water.

(d) Szafoni suggested that tremendous potential exists for creating wildlife habitat in new riparian areas created by mining. Because vegetation management is a very important means of wildlife management, tables such as he prepared showing wildlife use of ground cover plants, shrubs, and trees suitable for use in Illinois probably should be developed for other areas.

(e) Potential problems of pollution in ponds created by sand and gravel mining were pointed out by Kane et al. and by Knox. Pollution may stem from runoff and landfill materials.

3. Gravel pit demonstration areas documented by research and development reports are needed as an aid in getting public support for future projects. Such areas may serve multiple purposes and their development should be encouraged.

(a) Through careful wildlife monitoring and other investigations at the White Rocks Sand and Gravel Pit near Boulder, Colorado, Stoecker demonstrated that mining and reclamation can be accomplished in an environmentally acceptable manner, and enhance wildlife.

(b) Gallagher, Koopman, and other speakers mentioned the use of gravel pit lakes in environmental education programs. Well informed researchers can help promote such programs, e.g. by developing information for self-guided tours.

(c) Street described both the management and the use for waterfowl research of the Great Linford Gravel Quarry in England.

(d) Eagles stated that planning for research into the creation of natural ecosystems or wildlife habitats in connection with mining for gravel in Ontario has been virtually nonexistent. He discussed the establishment of a research site (The Crieff study area south of Guelph) for investigating restoration of gravel pits with the aim of producing a natural ecosystem, over time.

(e) Higgins documented the flora and general wildlife use of a 35-40 year-old unreclaimed gravel pit in North Dakota. By comparing differences between the gravel pit site and adjacent undisturbed lands, he suggested that, had the site been reclaimed for agriculture, it would have been less attractive for wildlife, sport hunting, motor biking, snowmobiling, birding, and placement of apiaries, but more attractive for livestock grazing or harvesting of hay. Such information is useful for deciding what the postmining land use of other similar areas should be.

4. More research into the socioeconomic, legal, and human dimension aspects of sand and gravel mining and rock quarrying is needed. I was impressed, however, with the number of papers given at this symposium which dealt with these important topics. Relevant papers included those by Alden, Chenoweth et al., Crunkilton, Eagles, Edwards, Gallagher, Knox, Lappegaard, Leitch, Morris, Patchett, Stoecker, Tydeman, Youngquist, and Zmuda. Though little attention was given to problems of liability, a topic which I think merits more research, problems of ownership, land acquisition, access, legal requirements, economics, and human preferences were addressed.

(a) Problems of, and progress in, regulating lowland sand and gravel excavation in Wisconsin to protect the environment and recognize the value of natural beauty were described by Zmuda and by Chenoweth et al. Although the ability to evaluate scenic beauty has been furthered by Chenoweth et al., better ways of evaluating esthetics, and fish and wildlife and recreational resources vis-a-vis dollar values of sand and gravel, timber, and agricultural crops are still needed.

(b) Youngquist, in discussing postmining land uses of gravel mining areas, suggested that the rough, untended terrain after gravel removal is a least cost option with a reasonably encouraging and successful record. However, legal requirements must be met, and uses other than for wildlife must be considered. Also, methods should be developed for estimating and weighing costs and benefits for reclaiming and rehabilitating mined lands for fish and wildlife in comparison with leaving mined lands untended.

(c) Edwards stated that the public owned too little land around the pit lakes created in constructing Interstate 80 across Nebraska for establishing adequate facilities for public recreation. He also managed problems of control of vehicular traffic and potential hazards of deep lakes with steep banks. The latter problem was partially solved by creating lakes with shallow shorelines. How much area and what facilities are needed to accommodate public use of such areas?

(d) Alden reported on a case study of successful involvement of citizens in Fort Collins, Colorado in a capital improvement program concerned with open space acquisition and development, including reclaimed gravel pits. This suggests to me the desirability of assessing various civic programs that have worked to determine the essential ingredients, followed by preparation of guidelines for developing other new programs.

Pre-Mining Research Needs

Some research needs relevant to wildlife planning and management prior to mining and reclamation were discussed under General Needs. These would include needs for practical and effective methods for collecting and interpreting required, but not unnecessary, physico-chemical, biologic land use, and socioeconomic information. Special attention should be given to inventory techniques which will help ensure that endangered and threatened plant and animal species and their critical habitats will be identified and protected in areas scheduled for mining. Similarly, ways of identifying areas of sand and gravel areas being held in reserve, and of developing plans for their effective management for wildlife prior to, during, and following mining are needed. Some of these research needs stem from observations of past mining and reclamation activities.

1. More research attention should be given to siting mining operations, where there is a choice, to protect critical habitat, improve existing habitat, or create new habitat suitable for fish and wildlife management.

(a) Edwards observed that had more of the pit lakes created in constructing Interstate 80 across Nebraska been located on the inside rather than the outside curves of the Platte Rivers, greater numbers of the lakes would have been retained and available for management more than 20 years later.

(b) In connection with highway borrow pit lakes in North Dakota, Crawford suggested that they be excavated outside rights-of-way, when possible, so that each borrow area, beginning with the area nearest the ROW collects runnoff water from the ROW, fills up to a certain level, and then overflows to the next basin. Could this same arrangement, with the first pit of a series being at a lower elevation than the ROW ditch, be accommodated within publicly owned ROWs? Under what situations would upland nesting habitat be more valuable for waterfowl management than borrow pit wetlands? (You will recall that Blair and Sather-Blair (1979) suggested that constructing shallow impoundments in North Dakota highway ROWs added to habitat diversity).

2. Is it feasible from an engineering standpoint to attempt to design the size and shape of gravel pit ponds prior to mining? If so, how, and what features should be incorporated in the design to favor the desired fish or wildlife species? In addition to those features suggested earlier -

(a) Edwards mentioned that the Chain of Lakes in Nebraska would have been easier to manage if the shorelines had been curvilinear rather than rectangular. Are hexagonal-shaped pits feasible?

(b) Bauer addressed the question of how and to what extent new landscapes can be determined before mining is initiated and suggested that often the shaping of predetermined land forms can proceed as an integral and simultaneous part of the mining operation.

(c) Koopman stated that the banks of a pit he studied were sloped approximately 10:1 for marsh development. Blomberg also recommended a 10:1 ratio. Street recommended that, ideally, the shore profile should be graded to a slope of 6:1 or less right down to the deepest water. Several speakers, including Herricks, commented on preferred depths of pit ponds for fish and for wildlife. Apparently little attention is being given to research on management of shorelines for shorebirds.

(d) There is much to be learned about the deliberate creation of islands within gravel pit ponds. How large should they be? How far apart? How high above the water level should they extend? Should they be covered with top soil? Built of gravel or rocks? What slopes should be sought? Should they be vegetated? Riprapped? How should they be oriented? Answers to these questions for various species would be desirable. Street pointed out that, especially in deep workings, leaving even a small island of unworked land in the quarry or pit effectively sterilizes a large volume of aggregate. He considers the ideal shape for an island is as a horseshoe, with a convoluted shoreline and with the mouth of the horseshoe facing away from the prevailing wind direction.

(e) Premining and reclamation plans may also include, when feasible, provisions based on research for bars, reefs, spawning beds, and other substrates that enhance conditions for fish or other aquatic organisms. Herricks suggested some ways of accomplishing this.

Research During Mining and Reclamation

More research is needed on effects on fish and wildlife of active mining and the processing and transportation of materials. For example -

1. What are the effects on wildlife of noise and dust accompanying mining operations?

(a) Adding to the minimal information cited earlier with respect to birds, Chabwela and Gilbert speculated that aggregate extraction activities in southern Ontario are not compatible with deer use of a mine site. Although they suggested need for further research, they believe that with sufficient cover in the mining site, mining operation effects can be considerably minimized. Research should point the way to how much of what kind of cover is needed.

2. What are the effects of instream dredging on aquatic organisms?

(a) Crunkilton summarized some of the effects, or potential effects, of instream gravel dredging on the stream channel, water quality, recreational use, and aquatic populations of Ozark streams in Missouri with particular reference to endangered naiades (mussels). Studies of this type are to be commended. This study indicated that the few positive aspects that instream dredging might afford, like the opening of pools, are far outweighed by the detrimental aspects of the mining. It indicated, further, that off-stream mining (in the flood plain) should be encouraged vis-a-vis instream dredging, whenever possible.

3. What are the effects of gravel washing on receiving water bodies?

(a) Crunkilton's study related in part to the harmful effects on mussels and fish of turbidity and siltation resulting from the return of river water used for processing sand and gravel directly to the river without settling. He also mentioned difficulties of regulating such practices under the State law.

4. Additional research is needed on ways of reclaiming and rehabilitating mined areas.

(a) Patchett suggested that further research is needed on progressive rehabilitation or the simultaneous extraction and rehabilitation of sand and gravel sites, according to a preconceived plan providing additional information on methods for planning and implementing cost effective, yet environmentally sound, sand and gravel operations.

(b) Ettinger and Yuill described a plan including provisions for water level control, regrading and reshaping, and revegetating a sand and gravel mine site in Webster Parish, Louisiana so the habitat for fish and wildlife would be integrated with that of an undisturbed adjacent bayou.

(c) The treatment and use for habitat improvement of vegetation and top soil removed from a mine site were treated only to a limited extent in the symposium. Sanders et al. stated that top soil must be stockpiled to recreate soil variety during reclamation, but they recognized that sandy areas with retarded plant growth can be important to wildlife.

Oldenburg et al. suggested that the overburden from a mine site be separated into soil and subsoil and set aside by scrapers, the first batch in a bermed area, rather than pushed off the area where it might be lost or buried. Subsequently, the soil is placed in contoured terraces within the edges of a mined area where it is left until used, without having to move it 2-3 times. Questions remain, however, about how long top soil can be stored without deterioration and what its best use is for fish and wildlife habitat management.

Mathisen stated that in the Chippewa National Forest, downed, decaying trees are used as cover or foraging sites by 23% of the species associated with gravel pit openings. He recommended that prescriptions for gravel pit rehabilitations provide for dropping trees along the edge or hauling logs into the interior (2 per acre) and for placing logs on the periphery of ponds for wildlife roosting or sunning sites. Herricks and perhaps others mentioned the possible use of brush shelters on pond bottoms for fish and other aquatic organisms. More descriptive details are still needed.

(d) Research reports dealing specifically with the reclamation of rock quarry areas appeared to be lacking in this symposium. Because quarry operations may extend over a period of 50-100 years, research on progressive reclamation for fish and wildlife would seem desirable.

Research on Mined Areas

Several papers presented at this symposium contributed to our knowledge of fish and wildlife in mined areas which have been "abandoned" or are being reclaimed. There is still much we need to know, however, about responses of plants and animals to the altered (mined) conditions and about management techniques.

1. As suggested above, more information is needed on the living organisms in rock quarries. One paper dealt with this in depth.

(a) Quade et al. presented a good account of the ecology of the Marquette dolomite quarry in south-central Minnesota with particular reference to microcrustaceans. They found that the steep basin sides, combined with the dolomitic block nature of the quarry bottom and an extensive algae mat resulted in the restricted growth of aquatic macrophytes and limited the extent of a realized littoral region. Also they discovered that because of a lack of oxygen-consuming thick organic sediments which in many ponds, when combined with small water bottoms and winter ice cover produce anoxic environments, the quarry provides a winter environment allowing the existence of many microcrustaceans like daphnia and copepods. Management implications for fish were not mentioned.

2. More research is needed on primary productivity and the basic biology of gravel pit lakes.

(a) Kane et al. reported on a limnological study of gravel pit lakes in southwestern Ohio with emphasis on midges, the larvae of which are important in the food webs of aquatic systems. They found that a rich and diverse biota became established rather quickly.

3. More research is needed on larger insects, crustacea, and other invertebrates important as food for wildlife and fish.

(a) Street was the only one in the symposium to address this topic at length and he did so in relation to foods of adult mallards and ducklings. He observed that the macroinvertebrates which are important waterfowl foods are normally associated with stands of aquatic macrophytes which provide necessary microhabitats, food, and cover. He suggested that the invertebrate population of a new gravel pit can therefore be increased by plantings and by adding farmyard manure or slurry and sewage sludge to saucer-shaped "scrapes" which hold water by ponding.

(b) Oldenburg et al. are monitoring crayfish densities and relative abundance, and evaluating their importance as food organisms. These investigators are also examining the stomach contents of all fish brought in from their ponds by anglers.

4. Although considerable attention is being given to waterfowl management and research in gravel pit areas and ponds, there is still room for research.

(a) Research findings from Great Linford as reported by Street are impressive.

(b) Oldenburg et al. are learning about waterfowl use of islands in gravel pit ponds, upland nesting areas, and floating nest structures at the Max McGraw Wildlife Foundation in Illinois. They are concerned about low nesting success and brood survival despite their management efforts. Will more research supply the answers?

(c) Blomberg reported some significant findings based on work in gravel pits near Ft. Collins, Colorado relative to waterfowl habitat improvement specifications, including size of pit needed to hold so many ducks, preferred shore slope ratio, height of banks, depth of ponds and so forth.

5. Research is needed to improve management of terrestrial wildlife in gravel pit areas. Although several speakers reported on the presence of terrestrial wildlife in such areas, few discussed active research on these species.

(a) Mathisen described the "uniqueness" of gravel pit openings in a forest ecosystem, identified species associated with the unique features and suggested management opportunities.

(b) Oldenburg et al. are in the process of documenting how songbird diversity and populations respond to conversion of typical crop fields to mined and, finally, reclaimed habitats. Some species are increasing; others are decreasing. Do we really know why?

(c) Street reported that the wetland complex created by sand and gravel mining at Great Linford in England regularly supports greater numbers of migrants and passerine species of birds than the surrounding lakes which are managed for wildlife.

(d) Tydeman reported that just under half the total number of bird species that breed regularly in Britain may be found breeding on gravel pits. He advanced the idea that gravel pit habitats act as "generative centres" for the commoner bird species and, by holding many species (often at high densities) in relatively isolated areas, help to buffer local populations against adverse factors operating in the surrounding urban/agricultural environment. This suggested wildlife refuge function of gravel pit areas merits further attention.

6. Research is needed to provide information for improving the suitability of gravel pit lakes and wet rock quarries for fish. Relatively little attention was given this topic in the symposium. It would seem that more research is warranted.

(a) Oldenburg et al. are experimenting with the stocking of different species of fish in their ponds, studying nesting requirements of smallmouth bass, and evaluating the use of stocked crayfish by these bass.

7. There is need for research to develop better techniques and guides for managing vegetation, both aquatic and terrestrial, in gravel pit ponds and quarries, and on surrounding areas. Topics meriting consideration are how best to identify and save from destruction existing unique or wildlife-productive plant communities, how to determine when it is best to let nature revegetate a mine-disturbed area by natural plant succession, and when, why, and under what circumstances it is best to intervene by making plantings and/or using various approaches for controlling vegetation. These questions are not easily answered, but if they can be answered through research and experimentation, we will have taken a major step toward improved management of mined areas for fish and wildlife. While many papers presented at this symposium described in general what type of vegetation management has been implemented on various mined sites, relatively few papers dealt with the details of how and why.

(a) Morrison's discussion of the principles and strategies of revegetating mined lands was excellent and the case study of revegetating the iron ore tailing deposit in Jackson County, Wisconsin was very informative. He suggested--and I agree--that long-term studies need to be made in a variety of revegetation situations to determine which species--native or introduced--act as facilitators, or as inhibitors of successional processes on a site.

(b) Street, on the basis of studies at Great Linford, England, believes that vegetation management is necessary and plantings are desirable to achieve and maintain the plant diversity required for a diverse fauna. He suggested that plantings should be made so that the final effect is of a natural zonation of different types from emergent water plants to shoreline and upland plants.

(c) Blomberg discussed the pros and cons of planting aquatic species like sago pondweed, softstem bulrush, and three-square for waterfowl management. He recommended that a study be undertaken to determine the usefulness of plantings in and around gravel pits in the South Platte Valley of Colorado. The major objective would be to compare plant invasion and growth in and around pits with no planting with that in and around pits having had sago pondweed and bulrushes planted. I would second this recommendation. Many plantings of aquatic species in the United States have had limited success.

(d) As indicated above, Eagles described the establishment of the Crieff study area in Ontario for research on the restoration of gravel pits with the aim of producing a natural ecosystem over time through both natural ecological succession and active intervention. It will be interesting to see the results of this proposed long-term study.

(e) Oldenburg et al. described in considerable detail the planting and vegetation management program implemented near Dundee, Illinois and they provided helpful tips. Some of the problems they encountered were described. Research needs were cited earlier.

(f) Mathisen suggested the reasons for (whys) and possible means of maintaining the "open" character of abandoned gravel pits in the Chippewa National Forest. He recommended that at least 50% of the mined areas be left as bare ground for the benefit of certain wildlife species.

8. Research is needed to develop more effective or practical methods for controlling nuisance species in mined areas, especially those used for recreational purposes.

(a) Gallagher pointed out that only a small portion of the recreational potential of the Delta gravel pit ponds in Eugene, Oregon is being used, primarily due to the aquatic vegetation mat that keeps canoers from using portions of the ponds. He mentioned that beavers were cutting trees throughout the pond area and including some adjacent residential and commercial landscapes. He also stated that there was some public concern about mosquitoes and that introduced mosquito fish had been only partly successful in controlling the mosquitoes.

(b) Koopman also cited problems with beaver and mosquitoes at the Sawhill Ponds and Walden Ponds area near Boulder, Colorado. Cottonwood trees are wrapped with chickenwire to discourage beaver and mosquito fish (Fundulus and Gambusia) are used for mosquito control. Can better means of control be devised through research?

(c) Although no details were given, Sanders et al. intimated that algae may be causing a problem by competing with the growth of other aquatic plants at Lower Grey Cloud, Minnesota. Are there problems peculiar to gravel pit and quarry ponds that indicate need for new or modified techniques for controlling algae?

Wildlife-Oriented Research on Mined Areas Reclaimed For Other Uses

Although this topic was not addressed specifically in the symposium, it would seem to merit attention because of the large number of mined areas that are reclaimed or used for agriculture, forestry, housing developments, land fills, and other purposes. With preplanning and the application of research findings, many of these areas can still provide useful wildlife habitat.

CONCLUSIONS

Gravel pits, quarries,and related mine sites occupy a very small percentage of the total land area of the United States. Like rights-of-way for highway, electric utility, and oil/gas lines, and lands surface-mined for coal, they have received relatively little attention from wildlife managers and researchers. Yet, there are opportunities, nation-wide, to protect, conserve and manage fish and wildlife and their habitats prior to, during, and following the mining of gravel and other non-coal minerals in urban and rural areas alike. Additional reseach is needed to develop information, methods for collecting information and preparation of guides, to serve as a sound basis for planning and conducting mining and reclamation operations in a manner that will not only prevent unnecessary environmental damage, but will result in improvement of existing habitats or the creation of desirable new habitats. Needs for research and information are urgent, not only concerning the environmental impacts of mining and the response of fish and wildlife to altered bio-physico-chemical habitat conditions, but with respect to human preferences and the socio-economic and legal aspects of land use. Especially needed is research to develop information and methodologies which will permit gravel and other mineral resource mining for development and which, at the same time, will be acceptable in a land use and ethical sense, keeping in mind the resource needs of future generations.

LITERATURE CITED

ALLAIRE, P.N. 1978. Effects on avian populations adjacent to an active strip-mine site. Pages 232-240 in D. E. Samuel et al., eds. Proceedings of a symposium, Surface Mining and Fish/Wildlife Needs in the Eastern United States. West Virginia Univ. and Fish and Wildlife Service, FWS/OBS-78/81.

BLAIR, C.L., and SATHER-BLAIR. 1979. Highway planning coordination between resource and transportation agencies. S. Dak. Coop. Wildl. Res. Unit, S. Dak. State Univ., Brookings, S. Dak. 57006. Typescript. 148 pp.

CARLSON, STU. 1978. Alluvial valley bass. A paper prepared for but not delivered at the symposium on Surface Mining and Fish/Wildlife Needs in the Eastern United States, West Virginia University. Typescript. 10 pp. + illustrations.

COASTAL ZONE RESOURCES DIVISION, OCEAN DATA SYSTEMS, INC. 1978. Handbook for terrestrial wildlife habitat on dredged material. Technical Report D-78-37, Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314. 391 pp.

DEPARTMENT OF FISHERIES AND OCEANS CANADA. 1978. Guidelines for land development and protection of the aquatic environment. Fisheries and Marine Service (1090 West Pender Street, Vancouver, British Columbia V6E 2P1) Technical Report No. 807. 55 pp.

DUNN, J. R. 1975. Construction materials: aggregates--sand and gravel, chapter in Industrial Minerals and Rocks, 4th Edition, Society of Mining Engineers of AIME. pp. 97-108.

FLOWER, F.B., E. F. GILMAN, and I. A. LEONE. 1981. Landfill gas, what it does to trees and how its injurious effects may be prevented. J. of Arboriculture, 7(2):43-52.

GARBISCH, E. W. JR., 1977. Recent and planned marsh establishment work throughout the contiguous United States-a survey and basic guidelines. Contract Report D-77-3, Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314. Various pagings.

GILMAN, E. F., I. A. LEONE, and F. B. FLOWER. 1981. Critical factors controlling vegetation growth on completed sanitary landfills. U. S. Environmental Protection Agency, Research and Development, EPA-600/52-81-164. (Available from NTIS, 5285 Port Royal Road, Springfield, VA 22161. Order No. PB81-246324; cost $17 subject to change).

GRIFFITH, J. S., and D. A. ANDREWS. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. N. Am. J. Fisheries Manage., 1:21-28.

HERBERT, T. A., and R. G. TURNER. 1981. Abandoned mine reclamation: a case study at Live Oak, Florida. A minerals research contract report. 113 pp. Bureau of Mines, U. S. Department of the Interior, Denver Federal Center, Denver, CO 80225.

HIRSCH, N. D., L. H. DISALVO, and R. PEDDICORD. 1978. Effects of dredging and disposal on aquatic organisms. Technical Report DS-78-5, Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314. 41 pp. (Available from National Technical Information Service, Springfield, VA).

HOAGBERG, R. K., and V. RAJARAM. 1981. Minnesota aggregate resource study, Local Road Research Board (LRRB) Investigation No. 652, December, 1980--Vol. 1, Executive Summary, 9 pp., and Vol. II, Report, 179 pp.

KRAPU, G.L. 1974. Foods of breeding pintails in North Dakota. J. Wildl. Manage., 38(3):408-417.

LEEDY, D. L. 1981. Coal surface mining reclamation and fish and wildlife relationships in the eastern United States. Vol. I, Past findings, the Surface Mining Law of 1977 (P.L. 95-87), planning and management considerations, and information sources. Fish and Wildlife Service, U. S. D. I., FWS/OBS-80/24. 75 pp.

LEEDY, D. L., and T. M. FRANKLIN. 1981. Coal Surface mining reclamation and fish and wildlife relationships in the eastern United States. Vol. II, Opportunities and approaches for fish and wildlife planning and management in coal surface mining reclamation and postmining land uses. Fish and Wildlife Service, U. S. D.I., FWS/OBS-80/25. 169 pp.

LEEDY, D. L., and L. W. ADAMS. 1982. Wildlife considerations in planning and managing highway corridors. U. S. Dept. of Transportation, Federal Highway Administration and Office of Biological Services, U.S.D.I. In press.

MONTALBANO, F., W.M. HETRICK, and T. C. HINES. 1978. Duck foods in Central Florida phosphate settling ponds. Pages 247-255 in D. E. Samuel, J. R. Stauffer, C. H. Hocutt, and T. C. Hines, eds. Surface Mining and Fish Wildlife Needs in the Eastern United States, proceedings of a symposium. FWS/OBS-78/81. 386 pp. (Available from Office of Biological Services, Fish and Wildlife Service, Rt. 3, Box 44, Kearneysville, W. A. 25430).

MOULTON, J. C. 1970. The fishery potential of four aquatic environments created by Interstate Route 91 construction in Massachusetts. M.S. thesis, Univ. of Mass., Amherst. 86 pp.

NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCES, COMMITTEE ON SURFACE MINING AND RECLAMATION. 1980. Surface mining of noncoal minerals. Appendix 1: Sand and gravel mining, and quarrying and blasting for crushed stone and other construction minerals. Washington, D. C. 91 pp.

PAONE, J., J. L. MORNING, and L. GIORGETTI. 1974. Land utilization and reclamation in the mining industry, 1930-71. U. S. Bur. of Mines, Information Circular 8642. Washington, D. C. 61 pp.

RILEY, R.K., and M. L. BROWN. 1978. The natural invasion of wildlife food and cover species onto bituminous coal spoil. Pages 376-380 in D. E. Samuel et al., eds. Proceedings of a symposium, Surface Mining and Fish/Wildlife Needs in the Eastern United States. West Virginia Univ. and Fish and Wildlife Service, FWS/OBS-78/81.

STEWART, R. E., and H. A. KANTRUD. 1973. Ecological distribution of breeding waterfowl populations in North Dakota. J. Wildl. Manage. 37(1): 39-50.

SVEDARSKY, W.D., T.A. FEIRO, and D.N. SANDSTROM. 1980. Breeding birds of abandoned gravel pits in northwest Minnesota and some management opportunities. Paper presented at 42nd Midwest Fish and Wildlife Conf., St. Paul, MN, 7-10 December, 1980. A contribution from the Northwest Agr. Expt. Sta., U. of Minn., Crookston.

SVEDARSKY, W.D., T.A. FEIRO, and D.N. SANDSTROM. 1982. Breeding birds of an abandoned gravel pit in northwest Minnesota. (Unpublished manuscript. 9 pp.)

SWANSON, G.A., and M.I. MEYER. 1977. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. J. Wildl. Manage., 41(3): 426-233.

SWANSON, G.A., and H. K. NELSON. 1970. Potential influence of fish rearing programs on waterfowl breeding habitat. Pages 65-71 in E. Schneberger, ed. Proceedings of a symposium on the management of midwestern winterkill lakes. North Central Division, American Fisheries Society. 75 pp.

TAUB, S.H., C.F.CLARK, D.A.MAYHEW, and J. B. LISIECKI. 1974. Suitability of Ohio interstate highway borrow pit ponds for sport fishing. Research Bull. 1064. 21 pp. Ohio Agr. Res. and Dev. Ctr. Wooster, OH.

U.S.DEPARTMENT OF THE INTERIOR. 1967. Surface mining and our environment: a special report to the nation. U. S. Government Printing Office, Washington, D. C. 124 pp.

U.S. DEPARTMENT OF TRANSPORTATION. 1979. Highway statistics 1978. Federal Highway Admin. vii + 172 pp. (Superintendent of Documents, U. S. Gov't. Printing Office, Washington, D. C. 20402).

Selected Bibliography

AHEARN, VINCENT P. JR. Land use planning and the sand and gravel producer. National Sand and Gravel Association, Silver Spring, Maryland.

ALLAIRE, P.N. 1978. Reclaimed surface mines: new potential for some North America birds. Am. Birds 32(1): 3-5.

ALVAREX, HELEN, JOHN A. LUDWIG and K.T. HARPER. 1974. Factors influencing plant colonization of mine dumps at Park City, Utah. Amer. Midl. Nat. 92:1.

AMIR SHAUL. 1975. Surface gravel excavation and environmental quality: a resource management policy. J. Env. Management 3(2):77.

ANON. 1965. Eley Game Advisory Sta. Annu. Rev. 1964/65. Fordingbridge, Hampshire, England. p. 30,32.

ANON. 1975. Slackline cableway and scraper force convert wasteland to homeland. Constr. Methods Equip. 57(5):42-43.

ANON. 1970. Long Island sand and gravel mining. New York State Office of Planning Coordination, Albany. 116 pp.

APPLEGATE, R.L., and W. L. KRUCKENBERG. 1978. First-year growth and food of largemouth bass in a South Dakota borrow pit stocked with fathead minnows. The Progressive Fish-Culturist, 40(1):7-8.

ARCHITECTURAL RESOURCES, INC. 1975. Minnesota mineland reclamation; a program for the reclamation of metallic mined lands. Minnesota Department of Natural Resources, St. Paul, MN.

ASHBY, W. C., C. KOLAR, M. L. GUENKE, C. F. PINSELL and J. ASHBY. 1978. Our reclamation future with trees. Coal Extraction and Utilization Research Center. Ill. Univ., Carbondale, Ill. 99 pp.

BARR ENGINEERING CO., BATHER-RINGROSE-WOLSFELD-JARVIS-GARDNER, INC., and J. P. BOROVSKY. 1980. Enhancement of fish and wildlife resources in the reclamation of hard rock mined lands in the upper midwest: a guidelines manual. FWS/OBS-80/64. U.S.F.W.S., Route 3, Box 44, Kearneysville, W. Virg. 123 pp.

BAUER, ANTHONY M. 1965. Simultaneous excavation and rehabilitation of sand and gravel sites. National Sand and Gravel Association, 900 Spring Street, Silver Spring, MD.

BAUER, A.M. 1970. Guide to site development and rehabilitation of pits and quarries. Ind. Miner Rep. 33. 62 pp.

BELL, E. A. and M. G. SHERRILL. 1974. Water availability in central Wisconsin, an area of near-surface crystalline rock. Geological Survey Water Supply Paper 2022. University Extension - the University of Wisconsin Geological and Natural History Survey, Madison.

BENNETT, G. W. 1970. Management of lakes and ponds, 2nd Edition. Van Nostrand Reinhold Company, New York. 375 pp.

BENNETT, G. W. and W. F. CHILDERS. 1972. Thirteen-year yield of smallmouth bass from a gravel pit pond. J. Wildl. Manage. 36(4): 1249-1253.

BLAUCH, B. W. 1976. Reclamation of lands disturbed by stone quarries, sand and gravel pits, and borrow pits. F. W. Schaller and P. Sutton eds. Skelly & Loy. Harrisburg, PA.

BLOOM, RONALD C. 1980. State regulation of non-coal surface mining: a summary and comparison of state programs. Office of Science and Natural Resources, National Conference of State Legislatures.

BOOKHOUT, T. A., C. P. STONE, and J. D. BITTNER. 1968. Potential of a strip-mined area for fish and wildlife reclamation. RF Project 2296, Report No. 3. Ohio State Univ., Columbus. 84 pp.

BOYD, JAMES, Chairman. 1979. Surface mining of non-coal minerals. Nat. Acad. Sciences, Washington, D. C. 339 pp.

BRAMBLE, W. C., and R. H. ASHLEY. 1975. Natural revegetation of spoil banks in central Pennsylvania. Ecology 36: 417-423.

BRENNER, F.J., R. B. KELLY, and JEFFREY KELLY. 1982. Mammalian community characteristics on surface mine lands in Pennsylvania. Environmental Management. 6(3): 241-249.

BREWER, R. 1958. Breeding bird populations of strip-mined land in Perry County, Illinois. Ecology 39(3): 543-545.

BRIGGS, R. C. and M. E. OSTROM. 1975. The mineral industry of Wisconsin. Bureau of Mines, U. S. Department of the Interior and the Wisconsin Geological and Natural History Survey, Madison.

BROOKS, D.R. 1976. Rehabilitation following mineral sand mining on North Stradbroke Island, Queensland. in Landscaping and land use planning as related to mining operations. Australia Inst. Min. Metall., Symp. Ser. 13. Adelaide, Australia.

BROOKS, D.R. 1978. National Parks vs. mineral sand mining: proclamation is so permanent. Queensland Gov. Min. J. 79:370-374.

BURGER, G.V. 1975. Practical wildlife management. Winchester Press, New York, NY. 218 pp.

BURGER, G.V. and C.G. WEBSTER. 1964. Instant nesting habitat. Pages 655-666 in J. P. Linduska, ed. Waterfowl tomorrow. U. S. Dep. Inter., Washington, D. C.

CAIRNS, J. JR., 1979. Ecological considerations in reclaiming surface mined lands. Minerals and the Environment. 1:83-89.

CAIRNS, J. JR., 1981. Restoration and management: an ecologist's perspective. Restoration and Management Notes. 1(1):6-8.

CAIRNS, J. JR., K.L. DICKSON, and E.E. HERRICKS, eds. . 1977. Recovery and restoration of damaged ecosystems. University of Virginia Press, Charlottesville. 531 pp.

CARLANDER, K. D. 1951. An unusually large population of fish in a gravel pit lake. Proceedings, Iowa Acad. Sci. 58:435-440.

CARLOZZI, CARL A. 1964. Enhancement of ecologic and aesthetic values of water associated with interstate highways. Water Resources Research Center, University of Massachusetts, Amherst, MA.

CARLSON, STUART F. 1979. Utah project shows mining and environmental advocates need not be adversaries. Pit & Quarry, (April) 205 W. Wacker Drive, Chicago, IL 60606.

CARREIRO, K. and D. REINING. 1975. Reclamation of sand and gravel pits. Calif. Geol. 28: 267-273.

CATCHPOLE, C.K. and C.F. TYDEMAN. 1975. Gravel pits as new wetland habitats for the conservation of breeding bird communities. Biol. Conserv. 8:48-59.

CHAKROFF, MARILYN. 1976. Freshwater fish pond culture and management. Action/Peace Corps Training Manual Series #18. VITA Publications Manual Series # 36E, U. S. Supt. of Docs. 056-000-00013-5. 191 pp.

CHENOWETH, R.E., B.J. NIEMANN, and W. TLUSTY. 1981. Scenic beauty as a requirement of NR 340: compliance requires more than a reclamation plan. Reclamation News Vol. I, No. 4, University of Wisconsin, Madison.

CHEPIL, W.S., N. P. WOODRUFF, F.H. SIDDOWAY, D.W. FRYREAR, and D.V.ARMBURST. 1963. Vegetative and non-vegetative materials to control wind and water erosion. Proceedings of the Soil Science Society of America 27: 86-89.

CLARK, O.R. 1940. Interception of rainfall by prairie grasses, weeds, and certain crop plants. Ecol. Monogr. 10: 243-277.

COATES, W. E. 1975. Can surface mining be compatible with urbanization? W. E. Coates & Assoc. Ontario. ClM·B 68:41.

COATES, W. E. and O.R. SCOTT. 1979. A study of pit and quarry rehabilitation in southern Ontario. Miscellaneous Paper 83, Ministry of Natural Resources, Ontario Geological Survey, Ontario, Canada.

COLLINS, R.J. and R.H. MILLER. 1976. Availability of mining wastes and their potential for use as highway material. Vol. I. classification and technical and environmental analysis. Valley Forge Labs., Inc., Devon, Pa. Federal Highway Administration, Washington, D. C. 308 pp.

COLORADO DIVISION OF WILDLIFE. 1967. Nesting structures for Canada geese. Game Information Leaflet #48. 4 pp.

CORNELIUS, DONALD R. 1944. Revegetation in the tallgrass prairie region. J. of Amer. Soc. Agron. 36: 337-346.

CZAPOWSKYJ, MIROSLAW, M. 1976. Annotated bibliography on the ecology and reclamation of drastically disturbed areas. USDA Forest Service General Technical Report NE-21. N. E. For. Exp. Sta., Upper Darby, Pa. 98 pp.

DEAN, K.S., R. HAVENS and M.T. GLANTZ. 1974. Methods and cost for stablizing fine-sized mineral wastes. U. S. Bureau of Mines, Report of Investigations 7896. Salt Lake City Metallurgy Research Center, Salt Lake City, Utah.

DEPARTMENT OF NATURAL RESOURCES. 1974. Mechanical and habitat manipulation for aquatic plant management: a review of techniques. Technical Bulletin No. 77. Madison, Wisconsin.

DICKENSON, SAM. 1972. Experiments in propagating plant cover at tailings basins. Mining Congress Journal 58: 21-26.

DICKINSON, S.K. 1975. Revegetation of taconite tailing. in Proceedings of the Mineral Waste Stabilization Liaison Committee. Vail, CO.

DICKINSON, S.K. 1978. Mineland stabilization. in Proceedings of the thirty-ninth annual mining symposium. University of Minnesota, Minneapolis, MN.

DICKINSON, S.K. and D. G. Youngman. 1971. Taconite tailing basin reclamation; a phase of multiple resource management. in Proceedings of the thirty-second annual mining symposium, University of Minnesota, Minneapolis, MN.

DINSMOOR, PHILIP C. 1977. An evaluation of the performance of some native plants on iron mine wastes in Wisconsin. M. S. Thesis, Dept. of Landscape Architecture and Botany, University of Wisconsin, Madison.

DODD, J. D., and J.W. Webb. 1975. Establishment of vegetation for shoreline stabilization in Galveston Bay. U. S. Army, Corps of Engineers, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060 (Miscellaneous Paper No. 6-75).

DONOVAN, R. P., et al. 1976. Vegetative stabilization of mineral waste heaps. EPA-600/2-76-087. U. S. Environmental Protection Agency, Research Triangle Park, N. C. 306 pp.

DRURY, W. H.,and I. C. Nisbet. 1973. Succession. J. Arnold Arbor. Harvard University 54: 331-368.

DUDLEY, T., and J. L. BECKER. 1975. Mined land reclamation on northern Great Plains. Mining Congress Journal 61: 18-23.

DUFFEK, R. 1969. Vegetative reclamation of iron ore tailings. M.S. Thesis. Michigan Technological University, Houghton.

ENG, M.T. 1970. Gravel: gift of the glaciers. Minn. Volunteer. (Mar-April)

ENG, M.T., and M.J. COSTELLO. 1979. Industrial minerals in Minnesota: a status report on sand, gravel and crushed rock. Minn. Dept. Nat. Resources., St. Paul. 76 pp.

ENVIRONMENTAL QUALITY LABORATORY, INC. 1977. Chapter IV: technical wetlands manual. U. S. Army Engineer Institute for Water Resources, Kingman Building, Fort Belvoir, VA 22060.

ERICKSON, PAUL A., GEORGE CAMOUGIS, and E. J. ROBBINS. 1978. Highways and ecology: impact assessment and mitigation. U. S. Department of Transportation, Federal Highway Administration, Washington, D. C.

ESTES, C. 1980. Mississippi surface mining and reclamation; a working example. Mississippi Geology. 1:4-5.

FELDMANN, R. M., H. GLAZER, and D. McCOY. 1980. A model of sequential land use planning of a sand and gravel pit, Portage County, Ohio. Compass of Sigma Gamma Epsilion. 57: 63-81.

FENTON, M.R. 1973. Landscape design principles for strip-mine restoration. pages 485-495 in R. J. Hutnik and Grant David, eds. Ecology and reclamation of devastated land; Proc. of International Symposium. Univ. Park, PA.

FORSYTH, RAYMOND A. 1976. Use of waste materials and soil stabilization. Transportation Research Board, Washington, D. C. 72 pp.

FOX, R.A. 1973. Sand and gravel in the British environment. Environment and Change. 2(3): 187-191.

FRISCHKNECHT, N. C. 1978. Use of shrubs for mined land reclamation and wildlife habitat. in Proc. Workshop on Reclamation for Wildlife Habitat. Ecology Consultants, Inc. Ft. Collins, CO. 14 pp.

FRITZ, THOMAS O. 1975. Mineral resources, mining and land-use planning in Wisconsin. Information Circular Number 26, University of Wisconsin Extension, Geological and Natural History Survey.

GAME CONSERVANCY. 1975. Annual Review #7. The Amey Roadstone-Game Conservancy Wildfowl Project. pages 55-60.

GAME CONSERVANCY. 1976. Annual Review #8. Amey Roadstone-Game Conservancy Wildfowl Project. Game Conservancy Annu. Rev. 9:49-59.

GAME CONSERVANCY. 1976. Annual Review #8. Amey Roadstone Wildfowl Project. pages 35-43.

GARR, J. J. 1980. Extraction, reclamation and after use at gravel quarries near Canterbury, Kent. Miner. Environ. 2(3): 124-144.

GARR, J.J. 1981. Extraction, reclamation and after use at gravel quarries near Canterbury, Kent. Minerals & Env. 2:124.

GLAZER, H.N., and R. M. FELDMANN. 1979. A model for sand and gravel pit reclamation. The Geological Society of America, Northeastern Section 14th Annual Meeting, Hershey, PA.

GLUE, D.E. 1970. Changes in the bird community of a Hampshire gravel pit 1963-68. Bird Study 17: 15-27.

GOODLER, J.L. 1971. Reclaiming sand and gravel from the sea pages 27-33 in A. D. Little, ed. Proceedings - New England Coastal Zone Management Conference. Boston, Mass.

GOODMAN, G. T., and S.A. BRAY. 1975. Ecological aspects of the reclamation of derelict and disturbed land: an annotated bibliogrpahy. Natural Environment Research Council, Alhambra House, 27/33-Charing Cross Road, London. WC2H OAX.

GRANDT, A F. and A.L. LANG. ?. Reclaiming Illinois strip coal land with legumes and grasses. Univ. Ill. Agric. Exp. Sta. Bull. 628. 64 pp.

GROAT, C. G. 1973. Mined-land inventory: data for reclamation and multiple-use planning (abstr.) Min. Eng. 25(12): 48-49.

HALL, U.L., and J.D. LUDWIG. 1975. Evaluation of potential use of vegetation for erosion abatement along the great lakes shoreline. U. S. Army, Corpos of Engineers, Coastal Research Center, Kingman Building, Fort Belvoir, VA 22060 (Miscellaneous Paper No. 7-75).

HARDELL, JULIE. 1980. Response of prairie species planted on iron ore tailings under different fertilization levels. M.S.Thesis. Department of Landscape Architecture, University of Wisconsin,Madison.

HARRISON, JAMES and JEFFERY HARRISON. 1962. Gravel pits where birds abound. Country Life. (July 26, 1962) pages 196-197.

HARRISON, JEFFERY. 1974. The sevenoaks gravel pit reserve. Wildfowler's Assoc. of Gr. Britain and Ireland., Grosvenor House, 104 Watergate Street, Chester. (England). 116 pp.

HART, JAMES L. 1973. Swampy site turned into prize-winner. Civ Eng (N.Y.) 43 (6):82-84.

HARTWRIGHT, TIMOTHY U. 1974. Worked-out gravel land; challenge and an opportunity. Environ. Conserv. 1(2): 139-144.

HERRICKS, E. E., and J. CAIRNS, JR. 1974. The recovery of streams stressed by acid coal mine drainage. pages 11-24, in Fifth Symposium on Coal Mine Drainage Research. Louisville, KY October 21-23.

HERRICKS, E. E., and J. CAIRNS, JR. Biological monitoring part III---receiving system methodology based on community structure water research 16: 141-153.

HERRICKS, E.E., J. CAIRNS, JR., and V.O. SHANHOLTZ. 1975. Preplanning mining operations to reduce the environmental impact of mine drainage on streams. Proc. of Water Resources Problems Related to Mining. 18:1-11.

HERRICKS, E.E., A.J. KRZYSIK, R.E.SZAFONI, and D.J. TAZIK. 1981. Best current practices for fish and wildlife on surface-mined lands in the eastern interior coal region. FWS/OBS -80/68. 204 pp.

HERRICKS, E.E., and M. J. SALE. 1978. Preplanning mining operations for mitigation of impacts on fish and wildlife resources. Pages 69-75, in Surface Mining and Fish and Wildlife Needs in Eastern United States. FWB/OBS-78/81.

HERRICKS, E. E., V.O. SHANHOLTZ and D.N. CONTRACTOR. 1975. Hydrologic and water quality modeling of surface water discharges from mining operations. Research Division Report 150, Virginia Polytechnic Institute and State University, Blacksburg, VA.

HERRICKS, E.E., V.O. SHANHOLTZ, and D.N. CONTRACTOR. 1975. Models to predict the environmental impact of acid coal mine drainage. Trans. American Society Agricultural Engineers. 18(4): 657-667.

HERRICKS, E.E., V.O. SHANHOLTZ, and D.N. CONTRACtor. 1976. Models to predict the environmental impact of mine drainage on stream biology. Trans. American Society of Agricultural Engineers. 19(2):271-281.

HERRICKS, E.E., D.J. TAZIK, J.R.KARR, and M.E. LEARY. 1980. Planning for fish and wildlife on Illinois coal surface mines. FWS/OBS-80/36, 579 pp.

HEWITT, D.F., and M.A. VOX. 1970. Pit and quarry rehabilitation: the state of the art in Ontario. Ministry of Natural Resources. Rm 1640 Whitney Block, Toronto, Ontario, M7A 1W3.

HILL, DAVID. 1980. The Amey Roadstone Game Conservancy Wildfowl Research Project. Game Conservancy Annu. Rev. 11:32-41.

HILL, J.J. and T. J. EVANS. 1979. The mineral industry of Wisconsin. Bureau of Mines, United States Department of Interior, Washington, D. C., and the Wisconsin Geological and Natural History Survey, Madison, Wisconsin.

HITTMAN ASSOCIATES, INC. 1981. Reclamation and pollution control: planning guide for small sand and gravel mines. Contract J0199052, Bureau of Mines, United States Department of the Interior.

HOAGBERG, R.K., and V. RAJARAM. 1980. Minnesota aggregate resource study. LRRB Investigation No. 652. Vol II. Lehmann & Associates, Inc. Minneapolis, MN. 179 pp.

HOLE, W.F., JR. 1974. Conservation and reclamation in the sand and gravel industry. Ohio, Div. Geol. Surv., Misc. Rep. 1: Tenth forum on geology of industrial minerals proceedings.

HUNTER, G., and P.C. WHITEMAN. 1974. Problems associated with the revegetation of metal-mining wastes. J. Aust. Inst. Agric. Sci. 40: 270-278.

HUTCHINSON, JOSEPH. 1974. Land restoration in Britain: by nature and by man. Environ. Conserv. 1: 37-41.

HUTNIK, RUSSEL J., and GRANT DAVIS, eds. . 1973. Ecology and reclamation of devastated land, Vols. I and II. Gordon and Breach.

JENSEN, DAVID R. 1967. Selecting land use for sand and gravel sites. University of Illinois Project No. 3, National Sand and Gravel Association, Silver Spring, Maryland.

JOHNSON, CRAIG. 1965. Practical operating procedures for progressive rehabilitation of sand and gravel sites. University of Illinois Project No. 2, National Sand and Gravel Association, Silver Spring, Maryland.

JOHNSON, H. C. 1969. Gravel and refuse = recreation. Parks and Recreation (Sept.).

JOHNSON, L.E., and W. V. MCGUINNES, JR. 1975. Guidelines for material placement in marsh creation. Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180 (Contract Report D-75-2).

JONES, L.M. 1972. Vegetation establishment in iron mine tailings, dam berms and waste rock dumps. M. S. Thesis. Michigan Technological University, Houghton.

JOYCE, M.R. 1979. Gravel removal study in artic and subartic Alaskan streams: terrestrial aspects. in B. R. Melteff ed. . Alaska Fisheries; 200 years and 200 miles of change: 29th Alaska Science Conference. Fairbanks, Alaska. Aug. 15-17.

KADLEC, JOHN A., and W. ALAN WENTZ. 1974. State-of-the-art survey and evaluation of marsh plant establishment techniques: induced and natural. Volume I: report of research. U. S. Army Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060 (Contract Report D-74-9).

KARN, RICHARD W. 1977. Reclamation of open-pit quarries for multiple uses. J. Urban Plann. Dev. 103:127-135.

KARR, JAMES R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. The Condor 70(4):348-357.

KEYES, D.L. 1976. Land development and the natural environment: estimating impacts. Urban Institute (2100 M st., N.W., Washington, D.C. 20036). 128 pp.

KLIMSTRA, W.D., R.J. JAUMES and E.E. FILER. 1977. Resume of the utilization of nearly 200,000 acres of surface-mined land in Illinois. in Soil Conserv. Soc. Am. Ann. Mtg. Proc. Aug. 7-10, 1977. Richmond, VA.

KLOSTERMAN, G.D. 1973. Preplanning: key to reclamation. Min. Eng. 25(12):49.

KREMMEL, DONALD G. 1976. Chemical additives as an aid in reclamation programmes. pages 251-257, in Seminar on landscaping and land use planning as related to mining operations. Australia Institute of Mining and Metallergy, Adelaide Branch (Symposium Series No. 13), Parkville, Victoria, Australia.

KRZYSIK, A.J., E.E. HERRICKS, D. J. TAZIK, and R.E. SZAFONI. 1981. A primer of successful ecology. Landscape Architecture. 71: 482-487.

KUBLY, D.M. 1977. The seasonal distribution and abundance of Cladocera and Copepoda in a Minnesota dolomite quarry. M. A. Thesis. Mankato State University, Mankato, Minnesota. 140 pp.

LAPPEGAARD, RAY. 1981. Press and media relations. Stone News.

LEROY, J. C., and H. KELLER. 1972. How to reclaim mined areas, tailing ponds, and dumps into valuable land. World Mining. pages 34-41.

LEWIS, L. R., A.O. PERRY and J. R. LaFEVERS. 1977. Integrated mined-area reclamation and land use planning. Volume 3A: A case study of surface mining and reclamation planning South Boulder Creek Park Project, Sand and Gravel Operation, Boulder, Colorado. Argonne National Lab., Ill. 96 pp.

MASON, W.T., ed. 1978. Methods for assessment and prediction of mineral mining impacts on aquatic communities: a review and analysis. U. S. Fish and Wildlife Service. Office of Biological Services. FWS/OBS-78/30. U. S. Government Printing Office, Washington, D. C. 157 pp.

LI, R.M., and D.B. SIMONS. ? . Mathematical modeling of erosion and sedimentation associated with instream gravel mining. Colo. State Univ., Eng., Fort Collins. Colo.

LIMSTROM, G. A., and G.H. DEITSCHMAN. 1951. Reclaiming Illinois strip coal lands by forrest planting. Univ. Ill. Agric. Exp. Sta. Bull. 547:201-250.

LINDQUIST, PETER S. 1981. The importance of slope aspect in restricting the establishment of prairie vegetation on iron ore tailings in Wisconsin. M. S. Thesis, Department of Landscape Architecture, University of Wisconsin. Madison.

LLOYD, J.W. 1976. Inter-related problems of gravel extraction and water supply. Trans. Inst. Min. Metall.,Sect. A 85: 163-166.

LOWE, S.B. 1979. Trees and shrubs for the improvement and rehabilitation of pits and quarries in Ontario. Ministry of Natural Resources, Ontario, Canada.

MACKENTHUN, KENNETH M. 1973. Toward a cleaner aquatic environment. Environmental Protection Agency. U. S. Supt. of Docs. 273 pp.

MARTIN, A.C., and H.S. ZIM and A.L. NELSON. 1951. American wildlife and plants: a guide to wildlife food habits. Dover, NY 500 pp.

McKEATING, G.B. 1975. Nature and urban man: proceedings of a symposium. Special Publication No. 4. Canadian Nature Federation (46 Elgin St., Ottawa, Ont. K1P 5K6) 134 pp.

McLELLAN, A.G., S.E.YUNDT, and M.L. DORFMAN. 1979. Abandoned pits and quarries in Ontario. Miscellaneous Paper 79, Ministry of Natural Resources, Ontario Geological Survey.

McMICHAEL, D.E. 1975. Selected physical and chemical factors in a limestone strip-mine pond. M. A. Thesis. Mankato State College, Mankato, Minnesota. 107 pp.

McRAE, STUART G. 1979. The agricultural restoration of sand and gravel quarries in Great Britain. Reclamation Review. 2(3-4):133.

MENDALL, H.L. 1949. Breeding ground improvements for waterfowl in Maine. Trans. 14th N. Am. Wildl. Conf. pp. 58-63.

MIH, WALTER C. 1978. Hydraulic restoration of stream gravel for spawning and rearing of salmon species. Washington State Univ., Pullman. Dept. of Civil and Environmental Engineering. Washington State Water Research Center, Pullman.

MILNE, B. 1969. Birds and gravel pits. Countryside 21:164-8.

MILNE, B.S. 1974. Ecological succession and birdlife at a newly excavated gravel-pit. Bird Study 21: 263-278.

MINISTRY OF NATURAL RESOURCES. 1970. A guide to site development and rehabilitation of pits and quarries. Industrial Mineral Report 33, Ontario Department of Mines.

MINISTRY OF NATURAL RESOURCES. 1976. A policy for mineral aggregate resource management in Ontario. Ontario, Canada.

MINISTRY OF NATURAL RESOURCES. 1978. Vegetation for the rehabilitation of pits and quarries in Ontario. Ontario, Canada.

NAWROT, J.R., A. WOOLF, AND W. D. KLIMSTRA. 1982. A guide for enhancement of fish and wildlife on abandoned mine lands in the eastern United States. USDl, Fish and Wildlife Service, Eastern Energy Land Use Team, Office of Biological Services, Rt. 3, Box 44, Kearneysville, WV 25430. FWS/OBS-80/67. 101 pp. (Available Supt. of Documents, U. S. Gov't. Printing Office, Washington, D. C. 20402.

NEIRING, W. A. 1967. The life of the marsh. McGraw-Hill.

NEWEY, C.O.; and J. W. LEWIS. 1976. Landforms and revegetation after mineral sand mining. pages 105-117, in Landscaping and land use planning as related to mining operations. Australia Inst. Min. Metall., Symp. Ser. 13. Adelaide, Australia.

NEWPORT, B.D. 1974. State-of-the-art: sand and gravel industry. EPA. Robert S. Kerr Environmental Research Lab., Treatment and Control Technology Branch, Mining Wastes Section, P.O. Box 1198, Ada, Ok 74820.

ODUM, E.P. 1969. The strategy of ecosystem development. Science 164: 262-270.

OLIVER, COLIN. 1977. Take a closer look. Sand and Gravel Assoc., 48 Park St., London, England. WY1 4HE. 12 pp.

OLSCHOWY, GERHARD. 1973. Landscape planning on an ecological basis. pages 477-484, in R. J. Hutnik and Grant Davis eds. Ecology and reclamation of devastated land: proc. of international symposium. Univ. Park, PA.

ONETH, H. W. 1977. Reclamation of sand and gravel mined areas in New York. in Soil Conserv. Soc. Am., Annu. Mtg., Proc. 32 Richmond, Va. Aug 7-10.

OSTROM, MEREDITH E. 1968. Directory of Wisconsin mineral producers. Information Circular No. 12: University of Wisconsin Extension, Geological and Natural History Survey.

PAONE, JAMES, JOHN L. MORNING, and LEO GIORGETTI. 1974. Land utilization and reclamation in the mining industry: 1930-71. U. S. Bur. Mines. Infor. Circ. No. 8642. 61 pp.

PICKELS, G. 1970. Realizing the recreation potential of sand and gravel sites. Univ. Ill. Agri. Exp. Sta., Urbana. 75 pp.

PLASS, W.T. 1974. Revegetating surface-mined land. Mining Congress J. 60(2):53-59.

PRATHER, J.G. 1973. Vegetative stabilization of reclaimed copper stamp-sands. M. S. Thesis. Michigan Technological University, Houghton, MI.

PROVOST, M.W. 1948. Marsh-blasting as a wildlife management technique. J. Wildl. Manage. 12:350-387.

RAFAILL, B. L. and W. G. VOGEL. 1978. A guide for vegetating surface-mined lands for wildlife in eastern Kentucky and West Virginia. U. S. Dept. Int. Fish & Wildl. Serv. FWS/OBS-74/84. 89 pp.

RALSTON, S., D. HILBERT, D. SWIFT, B. CARLSON, and L. MENGIES. 1977. The ecological effects of coal strip-mining: a bibliography with abstracts. U. S. Dept. Int., Fish & Wildl. Serv. FWS/OBS-77/09. 416 pp.

REED, AVERY H. 1978. Sand dredging helps town turn liability into asset. 7th World Dredge and Marine Conf. Bureau of Mines, Washington, D. C.

REILLY, J. D. 1965. Planning surface mine reclamation before mining. Mining Congress J. 53:93-96.

REUSS, J.L., P. LATOUR, and T. J. EVANS. 1977. The mineral industry of Wisconsin. Bureau of Mines, United States Department of Interior, Washington, D. C., and the Wisconsin Geological and Natural History Survey, Madison, Wisconsin.

RITZER, H. J. 1967. Gravel pit becomes a beauty spot. Soil Conservation. (Sept.).

ROBERTSON, JOSEPH L. 1975. Dredging & reclamation plans govern Kenosha materials sand and gravel operations. Rock Prod. 78(4): 42-45.

ROWE, J. E. 1977. Surface-mine reclamation: the back-to-contour constraint. J. Soil and Water Cons. 32: 74-75.

RUBLOWSKLY, J. 1967. Nature in the city. Basic Books.

SAMUEL, D. E., and R. C. WHITMORE. 1976. Reclamation and management of surface mined areas for game and non-game birds in West Virginia. Paper presented at International Hill Land Symposium. October 3-5, 1976. Morgantown, West Virginia.

SAMUEL, D. E., J. R. STAUFFEN, C. H. HOCUTT, and W. T. MASON eds. 1978. Surface mining and fish/wildlife needs in the eastern United States. Proceedings of a Symposium Dec. 3-6, 1978. U. S. Dept. Int., Fish & Wildl. Serv. FWS/OBS-78/81. 386 pp.

SCHELLIE, K. L. ed. 1977. Sand and gravel operations: a transitional land use. National Sand and Gravel Association, Silver Spring, Maryland.

SCHELLIE, KENNETH L., and ANTHONY M. BAUER. 1968. Shaping the land: planned use of industrial sand deposits: National Sand and Gravel Association, 900 Spring Street, Silver Spring, MD.

SCHELLIE, K. L., and D. A. ROGIER. 1963. Site utilization and rehabilitation practices for sand and gravel operations. National Sand and Gravel Association, Silver Spring, Maryland.

SCHIVLEY, WILLIAM W. 1977. An industry approach to environmental legislation. Rock Products (May).

SCHWACHOW, S.D., R. R. SHROBA, and P.C. WICKLEIN. 1974. Sand, gravel, and quarry aggregate resources: Colorado Front Range counties. Colo. Geol. Sur., Spec. Publ. No. 5-A, 43 pp.

SHETRON, S.G., and R. DUFFEK. 1970. Establishing vegetation on iron mine tailings. J. of Soil and Water Cons. 25: 227-230.

SOIL CONSERVATION SOCIETY OF AMERICA. 1980. Surface mine reclamation. S.C.S.A. Special Report.

STALL, J. B., and E.E.HERRICKS. 1980. Evaluating aquatic habitat using stream network structure and streamflow predictions: applied geomorphology. in Proc. 11th Binghamton Geomorphology Symposium. Richard G. Craig, ed Oct. 2-4, 1980 (in press).

STALL, J. B., and E.E. HERRICKS. 1981. Evaluation of instream flow needs for fish in the midwest. Proc. of the 2nd Symposium of the Indiana Water Resource Association (June 26, 1981).

STEARN, ENID W. 1976. Two facets of land use in Minnesota...wild beauty is restored. Rock Products. (Oct.).

STEARNS, F., and T. MONTAG. 1974. The urban ecosystem: a holistic approach. Community Development Series, Vol. 14. Dowden, Hutchinson and Ross. 203 pp.

STEVENS, J. H. 1974. Sand stabilization in Saudi Arabia's Al Hasa Oasis. J. Soil & Water Conservation 29 (3):129.

STREET, MICHAEL. 1977. The food of mallard ducklings in a wet gravel quarry, and its relation to duckling survival. Wildfowl 28:113-125.

SUMMER, R.M. 1978. Sand and gravel reclamation factors, Colorado County, Texas pages 45-47 in Soc. Min. Eng. AIME, Trans. 264.

THAMES, JOHN L., ed. 1977. Reclamation and use of disturbed land in the southwest. The University of Arizona Press, Tucson. 362 pp.

THIEME, W.T. 1969. Present status of reclamation in the sand and gravel industry. pages 116-125 in Proc Mining Environmental Conference. U. of MO, Rolla.

THOMAS, P., and P. BELTEMACCHI. 1976. Sand and gravel pits in Algonquin Township, Southeastern McHenry Co. (Ill.). Intercommunity Planning Counc.

TOBUREN, C. 1974. Reclaiming boulder county gravel pit as a wildlife area. Intern Report. Boulder, Western Interstate Comm. for Higher Ed., Boulder cty. Dist. No. 1. Boulder, CO. 41 pp.

TRAUFFER, W. E. 1979. Meyer material company, Illinois gravel producer, makes lakes to order for Max McGraw Wildlife Foundation. Pit & Quarry, (March).

TYDEMAN, C. F. 1977. The importance of the closed fishing season to breeding bird communities. J. of Environ. Manage. 5:289-296.

U.S.D.A. FOREST SERVICE. ? .Trees for reclamation. Leaflet Series, Northeastern Forest Experment Station Northeastern Area, Broomall, Pennsylvania.

U.S.D.A., SOIL CONSERVATION SERVICE. 1972. Minimizing erosion in urbanizing areas; guideline standards and specifications. Madison, Wisconsin.

U.S.D.A. SOIL CONSERVATION SERVICE. 1977. The status of land disturbed by surface mining in the United States: basic statistics by state and county as of July 1, 1977. SCS-TP-158.

U.S. DEPARTMENT OF THE INTERIOR. 1976. A guide to state programs for the reclamation of surface mined area. Geological Survey Circular 731.

U.S. DEPARTMENT OF INTERIOR. Out of the pits. Heritage Conservation and Recreation Service, Denver, CO GPO #856-350. 7 pp.

U.S. E.P.A. MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY. 1979. Evaluation of selective erosion control techniques. EPA/600/2-79-124, Cincinnati, Ohio.

U.S. FISH AND WILDLIFE SERVICE. 1978. Mined land reclamation for fish and wildlife in the eastern United States. U. S. Department of the Interior, Washington, D. C.

U.S.F.W.S. 1980. Gravel removal studies in artic and subarctic floodplains in Alaska. FWS/OBS-80-08. (Will be available from NTIS--Region 7)

U.S.F.W.S. Gravel removal guidelines manual for artic and subarctic floodplains. FWS/OBS-80/09. (Will be available from NTIS--Region 7)

UNIVERSITY OF WISCONSIN EXTENSION. 1980. Programs and activities of Geological and Natural History Survey. University of Wisconsin Extension Geological and Natural History Survey, Madison, Wisconsin.

VOGEL, W. G. 1981. A guide for revegetating coal mine soils in the Eastern United States. General Technical Report NE-68, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky.

VORIES, K.C., and P.L. SIMS. 1977. The plant information network, Vol. IV: a subject guide and annotated bibliography to selected literature on land reclamation and rehabilitation in the Western United States. Fish and Wildlife Service, U. S. Department of the Interior.

WENTZ, W. A., R. L. SMITH, and J. A. KADLEC. 1974. State-of the art survey and evaluation of marsh plant establishment techniques: induced and natural. Volume II: a selected annotated bibliography on aquatic and marsh plants and their management. U. S. Army Coastal Engineering Research Center, Kingman Building, Ft. Belvoir, Virginia 22060.

WETLAND MANAGEMENT RESEARCH GROUP. 1972. Manual of wetland management. International Waterfowl Research Bureau, Slimbridge (Glos.), GL2 7BX, England. 130 pp.

WHITMORE, R.C. 1979. Short-term change in vegetation structure and its effect on grasshopper sparrows in West Virginia. The Auk 96(3): 621-625.

WHITMORE, R.C. 1980. Reclaimed surface mines as avian habitat islands in the eastern forest. Am. Birds 34(1): 13-14.

WHITMORE, R. C., and G.A. HALL. 1978. The response of passerine species to a new resource: reclaimed surface mines in West Virginia. Am. Birds 32(1): 6-9.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES. 1975. Characteristics of a northern pike spawning population. Technical Bulletin No. 86, Madison, Wisconsin.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES. 1979. Sand, gravel or rock excavation and reclamaation associated with navigable waterways and adjacent areas. Chapter NR 340, Wisconsin Administrative Codes.

WOODHOUSE, W.W. JR., E.D. SENECA, and S.W.BROOME. 1972. Marsh building with dredge spoil in North Carolina. Agricultural Experiment Station, North Carolina State University at Raleigh, Raleigh, North Carolina (Bulletin 445).

YAHNER, R.H., A.W. GARTON, and J. C. HOWELL. 1975. Breeding avifauna associated with two strip mine areas. J. Tenn. Acad. Sci. 50(3):95-98.

YAHNER, R. H., and J. C. HOWELL. 1975. Habitat use and species composition of breeding avifauna in a deciduous forest altered by strip mining. J. Tenn. Acad. Sci. 50(8): 142-147.

YOCKIM, S.R. 1975. An investigation into the identity and function of the red pigmentation of the Copepods: Diaptomus leptopus, Diaptomus stagnalis, and Diaptomus sanguineus. M. A. Thesis. Mankato State College, Mankato, Minnesota. 60 pp.

YOUNG, C.A. 1969. The use of vegetation to stabilize mine tailings areas at Copper Cliffs. Canadian Mining Journal,(June): 43-46.

YUNDT, S.E., and D.B. AUGAITIS. 1979. From pits to playgrounds: aggregate extraction and pit rehabilitation in Toronto - an historical review. Ministry of Natural Resources, Ontario, Canada.

List of Attendees

Anthony Bauer
School of Urban Plan. & Land. Architecture
Michigan State University
East Lansin, MI 48824

Katie Beard
447 W. Doty
Madison, WI 53703

Ronald L. Bell
Agassiz N. W. R.
Fish & Wildlife Service
Route 1, Box 79
Middle River, MN 56737

Kenneth Bickel
U. S. Bureau of Mines
5629 Minnehaha Avenue South
Minneapolis, MN 55417

Goran E. D. Blomberg
Dept. of Fisheries & Wildl.
Mich. State University
2275 Knob Hill Drive #17
Okemos, MI 48864

Gerald Brademan
MN Dept. of Trans.
Box 727
Bemidji, MN 56601

Ed Brekke-Kramer
MN D.N.R.
Box 756, Highway 15 S.
New Ulm, MN 56073

Chris & Sue Brokl
MN D.N.R.
P.O. Box 1014
Bemidji, MN 56601

Lynette Brouwer
USDA Forest Service
Cass Lake, MN 56633

George V. Burger
Max McGraw Wildlife Foundation
P.O. Box 194
Dundee, IL 60118

Jon Bryan Burley
4550 Aspenwood Trail
Minnetonka, MN 55343

Richard A. Carlson
MN D.N.R. - Wildlife
658 Cedar Street
St. Paul, MN 55155

Craig Allen Churchward
4550 Aspenwood Trail
Minnetonka, MN 55343

Richard Crawford
Dept. of Biology
University of North Dakota
Grand Forks, ND 58201

Ronald Crunkilton
Missouri Dept. of Cons.
1110 College Avenue
Columbia, MO 65201

Steve Dermand
IA Conservation Commission
Box 121
Indianola, IA 50125

Harlan Doehrmann
Linn County Conservation Bd.
RR 2
Central City, IA 52214

Gregg A. Draeger
U. S. Bureau of Mines
5629 Minnehaha Avenue South
Minneapolis, MN 55417

Paul F. J. Eagles
University of Waterloo
Dept. of Recreation
Waterloo, Ontario N2L 3G1
CANADA

Morris T. Eng
MN D.N.R. - Minerals
1118 Lexington Avenue
St. Paul, MN 55103

Chuck Ennen
Hoffman, MN 56339

William S. Ettinger
Skelly & Loy
4601 Hillside Road
Harrisburg, PA 17109

Thomas Feiro
UMC - Owen Hall
Crookston, MN 56716

Steve Finegan
Black Hawk County Conserv. Bd.
2410 W. Lone Tree Road
Cedar Falls, IA 50613

Gary Fritz
U. S. Forest Service
District Ranger
Deer River, MN 56636

Thomas J. Gallagher
Consultant
1740 Lemming
Eugene, OR 97401

Joan M. Galli
Rd 3, Box 391
Robbinville, NJ 08691

Nigel Gray
ARC Wildfowl Centre
Great Linford, Milton Keynes
Buckinghamshire, ENGLAND

Ben Van Gundy
Cerro Gordo County Cons. Bd.
Rural Route 4
Mason City, IA 50401

Jack Gustafson
Route 2, Box 16
Cass Lake, MN 56633

Duane J. Hanson
Route 4, Box 76M
Bemidji, MN 56601

Bonnie L. Harper
1160 Cannon Valley Drive
Northfield, MN 55057

John Harrington
25 Ag. Hall
University of Wisconsin
Madison, WI 53706

James G. Hart
Ill. Dept. of Conservation
524 South Second
Springfield, IL 62706

Carrol Henderson
MN D.N.R.
640 119th Lane N. E.
Blaine, MN 55434

Gretel E. Hengst
U of WI-Dept. of Landscape
Architecture
130 N. Hancock #201
Madison, WI 53703

Jon Henslin
MN Dept. of Trans.
John Ireland Bldg.
St. Paul, MN

Edwin Herricks
Civil Engineering Lab.
3215 Nathan M. Newmark Lab.
University of Illinois
208 North Romine Street
Urbana, IL 61801

Edmund A. Hibbard
Northern States Power Co.
RR 1
St. Cloud, MN 56301

Ken Higgins
U. S. Fish & Wildlife Service
Box 68 Woodworth, ND 58496

P. R. Hildebrand
Province of Manitoba Nat. Res.
1495. St. James Street
Winnipeg, Manitoba
CANADA

John V. Hoene
MN Asphalt Pavement Assn.
555 North Wabasha Street
St. Paul, MN 55102

Wendy Hogan
UMC - Owen Hall
Crookston, MN 56716

Ken Holtje
USDA Forest Service
Chippewa National Forest
RR 1, Box 25
Cass Lake, MN 56633

Robert Jessen
Minnesota D.N.R.
102 23rd Street
Bemidji, MN 56601

Dan Johnson
MN Dept. of Trans.
P.O. Box H
Brainerd, MN 56401

David M. Johnson
USDA Forest Service
Walker Ranger District
Walker, MN 56484

Glen Kajewski
Box 612
Madison, MN 56256

Thomas C. Kane
Dept. of Biological Sciences
University of Cincinnati
Cincinnati, OH 45221

Richard O. Kimmel
MN D.N.R.
Route 1, Box 181
Madelia, MN 56062

Richard B. Kjonaas
Morton County Hwy. Dept.
Route 3, #12, Capt. Leach Dr.
Mandan, ND 58454

John J. Klinkner
Barton Sand and Gravel
10633 89th Avenue North
Maple Grove, MN 55369

Robin F. Knox
CO Div. of Wildlife
6060 Broadway
Denver, CO 80216

Rich Koopmann
Boulder County Parks &
Open Space Dept.
P.O. Box 471
Boulder, CO 80306

Kevin Kotts
MN D.N.R.
1010 Stearns
Crookston, MN 56716

Ken Krantz
Story County Cons. Board
Hickory Grove Park
Colo, IA 50056

Tom Kuennen
Rock Products Magazine
300 West Adams
Chicago, IL 60606

Thomas J. Larson
U. S. Fish & Wildl. Service
P.O. Box 96
Montrose, MN 55363

Dennis Laurie
Lake County Forest Preserve Dist.
2000 N. Milwaukee
Libertyville, IL 60048

Daniel Leedy
Urban Wildlife Research Center
10921 Trotting Ridge Way
Silver Spring, MD 21044

Jay A. Leitch
Dept. of Agricultural Econ.
NDSU
Fargo, ND 58105

Richard E. Lewis
Planning Director
7516 80th Street
Cottage Grove, MN 55016

Bernie Lieder
Polk Co. Highway Dept.
911 Thorndale
Crookston, MN 56716

Joseph L. Lomax
Joseph L. Lomax & Associates
Box 231, Rd 1
Cape May Court House, NJ 08210

Gladwin Lynne
MN DNR- Parks & Rec.
523 North Montana
Warren, MN 56762

Robert E. Manninen
MI Dept. of Trans.
321 Village Drive
Lansing, MI 48910

John Mathisen
U. S. Forest Service
Chippewa National Forest
Cass Lake, MN 56633

R. A. Montgomery
Max McGraw Wildl. Foundation
P.O. Box 194
Dundee, Il 60118

Jack Mooty
MN Dept. of Nat. Res.
Route 3, Box 247
Grand Rapids, MN 55744

Richard A. Morris
Nat'l Sand & Gravel Assn.
900 Spring Street
Silver Spring, MD 20910

Darrel G. Morrison
Dept. of Landscape Architecture
U of WI
6202 Piping Rock Road
Madison, WI 53711

Dean A. Mueller
North County Cons. Board
308 1/2 13th
Northwood, IA 50459

David W. Nelson
Nelson's Tree Farm
Box 101
Wannaska, MN 56761

R. C. Oldenburg
P.O. Box 194
Dundee, IL 60118

Arthur T. Olson
School Teacher
Box 103
Belview, MN 56214

Eldor Omdahl
Route 2
Warren, MN 56762

Frank Pafko
MN Dept. of Trans.
807 Trans. Bldg.
St. Paul, MN 55155

Jim Patchett
Story County Cons. Board
Hickory Grove Park
Colo, IA 50056

Ron Peterson
MN Dept. of Trans.
807 Trans. Bldg.
St. Paul, MN 55155

Lee Ann Pfannmuller
Nongame Program - MN D.N.R.
Box F, Centennial Bldg.
St. Paul, MN 55155

Warren O. Pladsen
MN Dept. of Trans.
2185 Randy
White Bear Lake, MN 55110

Art Poll
LeSueur County Planning & Zoning
800 Columbia
Cleveland, MN 56017

Larry Pollard
Soil Cons. Service
4101 Northbrook Boulevard
Stillwater, MN 55082

Henry Quade
Mankato State University
Mankato, MN 56001

Neil Ramsey
Route 2, Box 272
Cass Lake, MN 56633

Robert G. Rollings
N. D. Game & Fish Dept.
Route 5, Box 245
Devils Lake, ND 58301

Gerald R. Rustad
USDA Forest Service
1809 South Drive
Virginia, MN 55792

Nancy Salustro
J. L. Shiely Company
1101 North Snelling
St. Paul, MN 55108

John Schladweiler
DNR Regional Hdqtrs.
Box 756
New Ulm, MN 56073

Dean Schluter
Willmar Ready Mix-
New London Materials
Box 917
Willmar,MN 56201

Gary J. Schroeher
U. S. Bureau of Mines
5629 Minnehaha Avenue South
Minneapolis, MN 55417

Ron Spengler
Box 121
Indianola, IA 50125

K. Stoechell
P. O. Box 194
Dundee, IL 60118

Bob Stoecker
Stoecker-Keammerer Ecological
Consultants
329 Forest Lane
Route #SJR
Boulder, CO 80302

Michael Street
ARC Wildfowl Centre
Great Linford, Milton Keynes
Buckinghamshire, ENGLAND

W. Daniel Svedarsky
University of Minnesota
Crookston, MN 56716

Gustav A. Swanson
CO State University
Dept. Fishery & Wildl. Bio.
1404 West Lake
Ft. Collins, CO 80521

Robert Szafoni
University of Illinois
Urbana, IL 61801

Wayne Tlusty
U of WI-Extension
202 North Avenue
Antigo, WI 54409

Ralph H. Town
U. S. Fish & Wildlife Service
7196 W. 145
Apple Valley, MN 55124

William J. Trebs
Box 15
Talmoon, MN 56657

Chris Tydeman
World Wildlife Fund
11-13 Ockford Road
Godalming, Surrey
ENGLAND GU7 1QU

Robert Vogel
Cottage Grove, MN 55016

Diane L. Wade
The Nature Conservancy
1720 Hampshire Lane
Golden Valley, MN 55427

Stuart D. Wallace
Lake County Forest Preserve Dist.
2000 N. Milwaukee
Libertyville, IL 60099

Paul Walvatne
MN Dpt. of Trans.
John Ireland Bldg.
St. Paul, MN

Kevin Walz
UMC - Owen Hall
Crookston, MN 56716

Jeffery Weigel
The Nature Conservancy
328 East Hennepin Avenue
Mineapolis, MN 55414

Norman L. Weiland
U. S. Forest Service
Box 36
Blackduck, MN 56630

Alton J. Westover
MI Dept. of Trans.
432 Pinewood
Lansing, MI 48910

Terry Wolfe
MN D.N.R.- Wildlife
716 Pine
Crookston, MN 56716

B. E. Youngquist
Northwest Experiment Station
Crookston, MN 56716

Mitchell Zmuda
WI D.N.R.
202 North Avenue
Antigo, WI 54409

Mark Zdunczyk
Jesses, Morie & Son Inc.
Tenn. Silica Div.
P.O. Box 507
Camden, TN 38320