Graduate Education in Water Resources at University of Minnesota – 1969

A Report of a Subcommittee of the Center's Advisory Committee

Publication of this Bulletin was supported by funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, Public Law 88-379

AUGUST 1969
MINNEAPOLIS, MINNESOTA

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

CONTENTS

TABLES

APPENDICES

FOREWORD

One of the stated purposes of the Water Resources Research Act of 1964, Public Law 88-379, is to stimulate and support the education of future scientists in the area of water resources through research. At most universities, research and graduate education are closely related, with each supporting the other in various ways.

Courses and programs in water resources at the University of Minnesota are provided by a wide variety of departments and schools of the University. Although the Graduate Bulletin contains all the essential information about courses and basic requirements, this information is distributed throughout the bulletin and is, therefore, not readily available. Also, the Graduate Bulletin gives only general requirements for graduate programs and, obviously, cannot offer suggestions for planning programs in specific areas.

The first objective of this bulletin is to collect all the existing information on graduate courses and programs related to water resources and make this information available to new graduate students, faculty members and others. A second major objective is to provide information not included in the Graduate Bulletin which can be helpful in planning graduate programs in any of the various aspects of water resources. This is accomplished by indicating appropriate, alternative ways of satisfying general requirements, by listing the many relevant courses, and by giving a number of actual M.S. and Ph.D. programs in water resources as examples. It is not a complete guide, however, since needs and practices vary with individual departments.

This bulletin is a joint effort of the members of the Subcommittee on Graduate Education in Water Resources of the Advisory Committee of the Water Resources Research Center and the Graduate School. The members of the Subcommittee, all of which participated in the preparation of the bulletin, are listed below. Assistance was obtained from several other persons, principally Dr. George R. Blake, Department of Soil Science, and Dr. Herbert E. Wright, Director, Limnological Research Center.

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INTRODUCTION

Water is our most important natural resource. Without it, there would be no plant, animal or human life. Large amounts of water are necessary just to grow the food we need to maintain our existence. Large quantities of water are used in food processing, in manufacturing, and in a variety of domestic uses which are increasingly considered essential to our way of life. Water is recognized as a major factor, too, in the quality of our environment.

The demands on our water resources are continually increasing for several reasons. First, our population increases steadily year by year. Secondly, the per capita use of water continues to increase with our standard of living and with the steady trend toward a highly urbanized society. Thus, during the 20-year period from 1960 to 1980, it is estimated that our national water use will more than double. At the same time, urban living, shorter working hours, greater mobility and higher incomes are creating an unprecedented demand for water-based, outdoor recreation. Lakes, reservoirs, and streams are used more heavily for recreational purposes every year.

There are many problems to be solved if we are to meet the water resources demands of the immediate future, to say nothing of several generations ahead. A greater appreciation for water resources is needed to accomplish this goal. In the past, water has been plentiful in most areas and available at costs far below its real value. Fortunately, the resulting indifference has given way to a general public attitude of concern. However, this has not yet been fully translated into a general willingness to accept the major costs and the changes in institutional arrangements necessary to make the kind of progress needed.

Water resources problems are of several general types. First, there are many quantitative problems, such as adequate annual supplies for various uses, shortages in certain localities, or during certain times of the year, drouths, floods, and other problems. Secondly, there are many problems related to water quality, or pollution, both natural and man made. One general definition of water pollution is any aspect of water quality which interferes with an intended use. Water that is of satisfactory quality for some uses may be considered polluted for other uses. Since water can be reused many times if adequately treated, problems of water quantity and quality are interrelated.

In developing solutions to water problems, a third category of problems is often encountered. These are the decisional or institutional problems of water resources, including the questions of cost, source of funds, priorities, regulations, laws, education, public acceptance, and institutional change. Problems of this type are often more difficult to solve than the technological aspects of water resources, since people, laws and institutions tend to change more slowly than technology.

It follows that such a wide variety of problems requires a wide variety of professional skills to achieve genuine solutions of water resources problems. In a given situation, civil engineers, agricultural engineers, geologists, hydrologists, chemists, biologists, ecologists, bacteriologists, soil scientists, foresters, economists, lawyers, political scientists, recreation specialists and/or others may be needed. The contribution of one of these specialists invariably affects the work of others. It is quite possible to "solve" a specific water problem in such a way that future action on other water problems becomes very difficult. It is evident, therefore, that the various specialists concerned with water recources must work together to preserve, develop and manage our water resources for the greatest benefit to society as a whole.

To work effectively with each other on water resources problems, the various specialists must have a common goal and some appreciation for the work of other specialists. The common goal stated above should take precedence over serving a single segment of society. Appreciation for anything comes through knowledge of it. Thus, a person engaged primarily in one aspect of water resources should take advantage of every opportunity to learn how other specialists can contribute to the overall or common objectives.

In most of the above disciplines, the undergraduate curriculum provides little if any opportunity for direct application to problems of water resources. This is as it should be, since each discipline has many important applications other than those related to water resources. Also, it is generally agreed that, in our rapidly changing technology, undergraduate education should concern itself first with basic skills and knowledge. College graduates should be adaptable to methodologies not yet developed and, in fact, be capable of developing new or better techniques.

The skill of applying a discipline to water resources problems, therefore, often must be developed after completion of a Bachelor's degree program. In some cases, this can be done on the job with the help of "in-service" training, supervised work experience, short courses, or individual initiative. For those who are able to take advantage of it, graduate education that is both "sound" and relevant has several advantages that are commonly recognized and will not be enumerated here. The knowledge obtained through work experience is essential and, combined with a period of concentrated graduate study, becomes even more valuable.

This report deals primarily with graduate education in water resources and has several objectives. The first is to outline a concept or philosophy of graduate education as applied to water resources intended to guide graduate students as they assess their potential and formulate their educational goals. The second objective is to provide a listing of current graduate courses at the University of Minnesota having either direct or indirect application to the field of water resources. The third and final objective is to show how an individual can formulate a graduate program that will prepare him in the best possible way for achieving his career goals.

The concepts, courses and programs described here are, for the most part, directly applicable only for University of Minnesota graduate students. Another university, however, may have similar courses and similar requirements for graduate programs. Thus, it is hoped that the general principles or concepts involved in this report will be useful or at least of interest to others, including students, faculty members, practicing professionals, and others having some interest in water resources education.

Concept of Water Resources Education

The term "water resources" is used in several ways. First, it is used to describe and measure the resource itself. It is also used to indicate a broad area of public concern, leading to action programs at local, state and national levels. Water resources is also an area of professional activity in which many people specialize. As such, there is a need for specialized education related to water, hence the term "water resource education."

Water resources is not a discipline in itself. Rather, it is an area of application and specialization *within* many established disciplines. For example, it is appropriate to speak of specialized training in water resources engineering, in economics of water resources, and other aspects of water resources. Each is but a part of a discipline of long standing which has been developed to fulfill a variety of needs. The scope and power of each discipline is far too great to justify its being directed primarily toward problems of water resources.

A wide variety of disciplines (or parts of disciplines) is now being brought to bear on water problems. The sum of all these parts is the broad area we now call water resources. Water resources education, then, consists of various types of specialized education within many disciplines, intended to develop a variety of capabilities useful in solving water resources problems and a mutual understanding between various disciplines.

Graduate education in any field may have several objectives. A common objective is to increase one's depth of knowledge or understanding in a specialized area. If specialization is carried out to a high degree, especially in a Ph.D. program, the program is often said to be "research oriented." Other programs, especially at the Master's degree level, are designed to develop the types of skills and knowledge that will be more useful in the planning or problem-solving aspects of water resources. The world of application is advancing rapidly and is now able to make use of many techniques commonly taught at the graduate level. At the same time, some graduate students find it necessary to broaden their basic education by devoting a portion of their study to related disciplines. This is especially true in a highly interdisciplinary area such as water resources. Thus, it is often advisable to plan a graduate program that will combine emphasis on both depth of knowledge in a specific area of water resources with a breadth of understanding in other aspects of water resources.

Graduate education in water resources can be divided into three broad areas or categories, based primarily on the general nature of one's undergraduate preparation. These are (a) the Physical Sciences and Engineering (b) the Biological Sciences and (c) the Social Sciences. It is assumed that, in general, a graduate student interested in water resources will have a basic education in one of these broad areas and that he will do a major part of his graduate study somewhere within that same broad area.

Each department of the University of Minnesota concerned with water resources can be considered as belonging to one of these three broad categories (Table 1). In certain cases, the classification is not clear cut, since a department may have activity in more than one area. Some examples are Geology, Soil Science, Forestry, and Environmental Health. Despite this difficulty the general classification has proved helpful in considering and formulating graduate programs.

The various departments listed in Table 1 vary considerably in their extent of involvement in water resources and, of course, all have other concerns. Possible areas of specialization within each department are shown also in Table 1. These are areas in which a graduate student might specialize through choice of a thesis topic and through selection of related courses. For each area of specialization listed, there is at least one faculty member in the department who has a genuine interest in that area and who is capable of serving as adviser to graduate students wishing to specialize in the area. In most (if not all) cases, the department will have active research projects of the types indicated by the areas of specialization; these often stimulate and support thesis studies.

Table 1. Broad areas of water resources, departments concerned with water resources, and areas of specialization within departments at the University of Minnesota.

Department	Areas of Specialization
A. PHYSICAL SCIENCES:	
Agricultural Engineering	Drainage and Irrigation, Hydrology, Erosion Control, Agricultural Waste Management
Civil Engineering	Hydrology, Hydromechanics, Sanitary Engineering
Geology and Geophysics	Hydrogeology, Limnology, Geophysics
Soil Science	Soil Physics, Climatology, Nutrient and Residue Pollution
B. BIOLOGICAL SCIENCES:	
Ecology and Behavioral Biology	Freshwater Ecology, Ecology
Entomology, Fisheries and Wildlife	Fishery Biology and Management, Wildlife Biology and Management
Environmental Health	Environmental Biology, Water Quality, Ground Water Supply
Forestry (School of)	Forest Hydrology, Outdoor Recreation, Watershed Management
C. SOCIAL SCIENCES:	
Agricultural Economics	Resource Economics, Recreation Economics
Geography	Climatology, Cartography
Law (School of)	Resource Law
Public Administration	Resource Administration

What type of undergraduate preparation is required for entering the broad field of water resources at the graduate level? The answer is a good basic education emphasizing one or more of the physical sciences (including engineering), one or more of the biological sciences, or the social sciences. The graduate should also have a good degree of proficiency in communication and an appreciation of human as well as material values.

An undergraduate major in one of the departments listed in Table 1 is not required. For example, physics, chemistry, mathematics or biology majors will be considered for graduate study by a number of the departments listed and, in fact, are encouraged to specialize in some facet of water resources. Neither is any undergraduate coursework specifically directed toward water resources required. The important factor is a basic knowledge in one of the three broad areas, physical, biological or social science, which provide the basis for further development or specialization in that area.

In general, graduate students will find it advisable to continue their education within the same broad area (physical, biological or social science). A person changing from a physical science area to a biological science area, for example, or vice versa, may find that he will have to make up a number of deficiencies.

Within each of the three broad areas, on the other hand, a change of major upon entering graduate school is entirely feasible. Such a change is usually made without any significant difficulty and, in most cases, does not require making up deficiencies. A change of this type is often desirable, since the individual develops a broader outlook and a wider range of capabilities without sacrificing the quality of his educational experience.

Faculty members concerned with water resources at the University of Minnesota as of June 1969, are listed, by department, in Appendix A. Shown also are the areas of specialization in which each faculty member is active. The list includes a total of 52 regular faculty members who are currently engaged in teaching, research and/or advising in water resources. It does not include the many temporary or part time instructors, research appointees, teaching and research assistants and laboratory technicians who are either conducting water resources research, including thesis studies, or assisting others. Thus, only those faculty members who are qualified to serve as project leaders and/or graduate advisers are listed. Inquiries of any type can be directed either to individual faculty members or to the department head. Appendix B is a listing of departments and department heads concerned with water resources, with addresses, to which general inquiries would normally be addressed. Where appropriate, the name of the chairman of the departmental graduate program or committee has been added.

Courses in Water Resources

At a large university such as the University of Minnesota, the Graduate School Bulletin may contain several thousand course offerings. Students interested mainly in a single department, or a few departments, can easily find the courses of potential interest to them. In water resources, however, appropriate courses are found in a wide variety of departments and schools, including quite a number of departments in addition to those listed in Table 1.

The purpose of this section is to call attention to the many graduate level courses of potential interest to graduate students in any area of water resources. The various courses have been divided into two groups, Category A and Category B. Category A includes those courses which are directly concerned with the quantity, quality, availability and use of water resources. These courses, numbering about 80, are listed in Table 2. Since the University of Minnesota operates on the quarter basis, the credits shown are quarter credits. The four-digit numbers, shown in parentheses are not shown in many of the current bulletins but will replace the other numbers in the fall of 1970.

Graduate Programs in Water Resources

Educational needs in water resources are extremely varied, as indicated earlier, for two basic reasons: (1) the wide variety of disciplines involved and (2) the inherently interdisciplinary nature of water resources. It follows that a graduate program or programs intended to satisfy the needs of all graduate students interested in water resources must have a great deal of flexibility.

Flexibility in graduate programs can be obtained in several different ways. The first is by providing a sufficient number of different programs each specifically planned for a group of students having similar career goals. The second method is to provide a broad, single framework of general requirements having sufficient flexibility to permit any graduate student to plan a program that will satisfy his individual needs or goals. A third approach would be to provide a limited number of different programs, each having moderate flexibility, so that the overall effect is a high degree of flexibility.

The first of these approaches is inadequate for such a broad area as water resources, simply because such a large number of programs would be required. The second and third approaches are feasible and are used in various ways for graduate education in water resources at various universities.

At the University of Minnesota, a broad framework of general or minimum requirements is set forth by the Graduate School and these are applicable throughout the University. These requirements are very flexible, thus permitting each graduate student to plan a program of study to satisfy his individual needs and interests. In graduate study at the University of Minnesota, the general requirements may be interpreted, added to, or made more explicit by the graduate faculty of individual departments. The various schools and colleges do not as a rule play a direct role either in administering graduate programs or setting policies with respect to graduate study, except for professional, advanced degree programs.

Initial planning of a graduate program is done jointly by the student and his adviser, subject to general requirements of the graduate school and any additional guide lines set forth by the department. The department graduate faculty may, if it wishes, review the program before its submission to the Graduate School. Final approval of a graduate program rests with one of seven group committees of the Graduate School. For each of the departments concerned with water resources (Table 1), graduate programs go to the Agriculture, Biological Sciences, Physical Sciences or Social Sciences Group Committee.

Table 2. Current (1969) graduate level courses directly concerned with the quantity, quality, availability and use of water resources, (Category A) – department, course number, course title and quarter credits.

Agricultural Economics			
113	(5130)	Land Resource Use	3
163	(5630)	Resource Economics Policy	3
264	(8264)	Resource Economics	3
364	(8364)	Seminar: Resource and Regional Economics	3
Agricultural Engineering (Institute of Technology)			
124	(5500)	Drainage and Irrigation	3
144	(5510)	Advanced Drainage and Irrigation	3
164	(5520)	Advanced Soil and Water Engineering	4
165	(5530)	Watershed Engineering	3
184	(5590)	Problems in Agr. Eng.; Soil and Water	2-4
211,212,213	(8190-1-2)	Advanced Problems and Research	2-6 ea.
254	(8500)	Hydrologic Modeling – Small Watersheds	3
Agricultural Engineering (Institute of Agriculture)			
115	(5400)	Drainage and Irrigation	3
134	(5410)	Soil and Water Eng. Design Procedure	3
174	(5420)	Problems in Soil and Water Management	2-4
Botany			
150	(5231)	Introduction to study of Algae	5
151	(5233)	Biology of Algae	5
155	(5811)	Freshwater Algae	5
Chemistry (Analytical)			
140	(5106)	Water Analysis	2
Civil Engineering (Hydrology and Hydraulics)			
101A	(3400)	Fluid Mechanics	4
160	(5401)	Engineering Hydraulics I	4
161	(5405)	Hydrology	3
162	(5402)	Engineering Hydraulics II	3
163	(5425)	Groundwater Hydraulics	3
164	(5420)	Water Conservation	3
166	(5415)	Water Power	3
167	(5416)	Hydraulic Measurements	3
168	(5417)	Hydraulic Pumps and Turbines	3
169	(5418)	Lake, Reservoir and Ocean Hydrodynamics	3
184	(5410)	Open Channel Hydraulics I	3
185	(5411)	Open Channel Hydraulics II	3
191,192,193	(5494-5-6)	Adv. Hydraulic and Hydrologic Problems	1-3
289	(8413)	Mechanics of Sediment Transport	3

Civil Engineering (Sanitary)

170	(5500)	Water Supply	3
171	(5505)	Sewerage and Waste Water Treatment	3
172	(5510)	Sanitary Engineering Laboratory	3
173	(5501)	Sanitary Engineering Problems (Water)	3
174	(5506)	Sanitary Engineering Problems (Waste Water)	3
176-177-178	(5597-8-9)	Sanitary Engineering Seminar	1 ea.
179	(5502)	Ground Water & Surface Water Quality Problems	3
181	(5515)	Chemical & Biological Aspects of Sanitary Engineering I	3
182	(5516)	Chemical & Biological Aspects of Sanitary Engineering II	3
261	(8500)	Water Plant Design	3-5
262	(8505)	Waste Water Plant Design	3-5
276	(8501)	Advanced Sanitary Engineering (Water)	3-5
277	(8506)	Advanced Sanitary Engineering (Waste Water & Industrial Wastes)	3-5

Ecology and Behavioral Biology

152	(5816)	Ecology of Freshwater Algae (at L. Itasca)	5
230	(5603)	Methods for Analysis of Natural Waters	3

Entomology, Fisheries and Wildlife

118	(5400)	Experimental Ecology	3
119		Aquatic Ecology (at L. Itasca)	5
151	(5451)	Ecology of Fishery Populations	3
153	(5453)	Techniques of Fishery Biology	3
251	(8451)	Production Biology of Fishery Environments	3

Environmental Health

112		Environmental Aspects of Water Systems	3
113		Environmental Aspects of Liquid Waste Systems	3
117 A, B, C		Environmental Biology	3 ea.
231		Ground Water Development	arr.
232		Field Work in Ground Water Development	arr.
233		Water Quality Investigation and Research Techniques	6
234		Water Quality Research	6

Forestry

148	(5235)	Forest Hydrology	2
154	(5255)	Advanced Forest Hydrology	3
221	(8103)	Research Problems in Forest Influences	

Geography

151		Climatology	3
152		Advanced Climatology	3
152A		Advanced Climatology: Field Course	3
154		Dynamic and Synoptic Climatology	3

Geology and Geophysics

128	(5601)	Limnology	4
131	(5611)	Ground Water Geology	3
132	(5612)	Analytical Geohydrology	3
227	(8608)	Seminar: Limnology	arr.
228	(8602)	Advanced Limnology	3
229	(8603)	Research in Limnology	arr.
230	(5603)	Methods for Analysis of Natural Waters	3
231	(8619)	Research in Ground Water Geology	arr.
232	(8618)	Seminar: Ground Water Geology	arr.

Law School

		Natural Resources Seminar	cr.

Physics

165	(5441)	Introduction to Physics of the Atmosphere	3
166	(5442)	Meteorology I	3
167	(5443)	Meteorology II	3

Soil Science

103	(5220)	Soil and Water Management and Conservation	2
126	(5232)	Soil Physics	4
133	(5240)	Microclimatology (Soils)	3
136	(5340)	Organic and Pesticidal Residues	3
220		Fluid Flow in Soils	3

General Requirements for a Master's Degree

There are two types of Master's degree programs in water resources, the Master of Science degree and the professional Master's degree. The M.S. program is more common.

The M.S. degree is offered by most departments under two plans: Plan A, which includes a thesis study, and Plan B, which requires more coursework and no thesis. Under Plan A, an M.S. candidate is required to take 18 or more quarter credits in the major field and 9 or more credits in a minor field. He also carries out a thesis investigation under the general supervision of his adviser and prepares a thesis covering the results of this research. The thesis investigation represents one or more quarters of full time research. Plan A is preferred by some departments or advisers, since it provides a good opportunity for independent study and research, and for attaining a greater depth of knowledge in a specific area.

A Plan B Master of Science program must include at least 45 quarter credits of graduate course work. At least 21 of these credits should be in the major field. Not less than 18 credits of the 45 should be taken in two or more related fields, with a minimum of 6 credits in each. Also, a Plan B M.S. candidate must present papers prepared for or in conjunction with 3 advanced courses, seminars or independent study courses. There is no general language requirement for the M.S. degree, and most departments do not require language study at the M.S. level. All credits for the Master's degree must be earned at the University of Minnesota.

Of the departments or schools listed in Table 1, a professional Master's degree is offered by Agricultural Engineering, Civil Engineering, Environmental Health, Public Administration and the School of Forestry. The Master of Engineering and the Master of Public Administration programs were approved only recently. The former requires a total of 45 quarter credits, including an 18-credit major, a 9-credit minor and a major analysis and design project equivalent to about 18 credits.

A Master's degree requires a minimum of one academic year of full time study. This is on the assumptions that the department requirements do not exceed the general requirements, that the student is adequately prepared for graduate study in the department of his choice, and that he is a full time student. Most graduate students hold teaching or research assistantships which require part of their time. Such students usually require from 5 to 7 quarters (including summer) to complete an M.S. degree, depending on their course loads, degree of effort and other factors.

Planning a Master's Degree Program in Water Resources

A Master's degree program specializing in water resources may be arranged in a wide variety of areas or departments at the University of Minnesota (Table 1). It may be discipline-oriented or interdisciplinary in nature, although there is no such formal distinction or designation. Examples of Plan A and Plan B Master's degree programs in water resources are given in Table 3. Further examples are given in Appendix D.

A discipline-oriented M.S. program is one in which all or nearly all of the course work listed for the major is taken in the major department. If it is under Plan A, the thesis study would be on a closely related topic chosen within the major department. Thus, with Plan A, a relatively high degree of specialization within a single discipline is possible, for those with such an objective. It is also possible in some cases with Plan B, since the M.S. minor (or minors) may be within the same department if in a distinctly different subject matter area.

Interdisciplinary M.S. programs are easily arranged for those graduate students who wish to increase the breadth of their knowledge. With Plan A, this might be done in three ways. First, a number of courses in related departments may be included as a part of the major field. Secondly, with the approval of the adviser, the thesis topic may be somewhat interdisciplinary in nature, rather than highly specialized. It must, however, deal with a specific problem which will lend itself to a detailed investigation. Finally, another discipline would be chosen for the minor field. With Plan B, several courses can be chosen from at least three other disciplines to form an interdisciplinary program. Two of these would serve as minor fields, and others included in the major field, where appropriate.

Table 3. Examples of Master of Science Programs, Plan A and Plan B

Master of Science Program, Plan A

Major Field – Agricultural Engineering

Ag. E.	165	Watershed Engineering	3 cr.
Ag. E.	180	Radioisotope Measurements	3 cr.
Ag. E.	254	Hydrologic Modeling – Small Watersheds	3 cr.
Ag. E.	184	Probs. in Agric. Eng. – Soil and Water	3 cr.
Geol	131	Ground Water Hydrology	3 cr.
C.E.	163	Ground Water Hydraulics	3 cr.
C. E.	164	Introd. to Water Resources Management	3 cr.
			21 cr.

Minor Field – Hydromechanics

C. E.	167	Hydraulic Measurements	3 cr.
C. E.	184	Open Channel Hydraulics I	3 cr.
C. E.	289	Mechanics of Sediment Transport	3 cr.
			9 cr.

Thesis Topic – Hydrology of a Typical Ice Block Glacial Lake

Master of Science Program, Plan B

Major Field – Civil (Sanitary) Engineering

C. E.	172	Sanitary Engineering Laboratory	3 cr.
C. E.	173	Sanitary Engineering Problems: Water	3 cr.
C. E.	174	Sanitary Engineering Problems: Waste Water	3 cr.
C. E.	175	Industrial Waste Disposal	3 cr.
C. E.	176	Sanitary Engineering Seminar	1 cr.
C. E.	177	Sanitary Engineering Seminar	1 cr.
C. E.	178	Sanitary Engineering Seminar	1 cr.
C. E.	179	Ground Water and Surface Water Quality Prob.	3 cr.
C. E.	181	Chemical & Biological Aspects of Sanitary Eng.	3 cr.
C. E.	261	Water Plant Design	3 cr.
C. E.	262	Waste Water Plant Design	3 cr.
C. E.	264	Sanitary Engineering Unit Operations	3 cr.
			30 cr.

Minor Field – Hydromechanics

C. E.	162	Engineering Hydraulics II	3 cr.
C. E.	167	Hydraulic Measurements	3 cr.
C. E.	168	Hydraulic Pumps and Turbines	3 cr.
			9 cr.

Minor Field – Public Administration

PA	280A	Seminar: Local Administration	3 cr.
PA	280B	Seminar: Local Administration	3 cr.
PA	281	Law and Urban Affairs	3 cr.
			9 cr.

In planning an interdisciplinary program, a graduate student may wish to take courses in an area where he has little or no previous coursework. Since most graduate level courses have prerequisites, this sometimes becomes a constraint, unless the student is willing to "make up" undergraduate, prerequisite courses. In some cases, however, an instructor will make special arrangements for a graduate student to enroll in a class without formal satisfaction of the prerequisites.

In planning an M.S. program, the first step, of course, is selection of the major field and adviser. The next step is to decide whether Plan A or Plan B is most appropriate and whether the objective should be specialization or an interdisciplinary program. Step 3 would be the choice of the minor or minor fields. Following this, courses can be chosen for the major and minor fields. In doing so, one should avoid using courses from a single department in both major and minor(s), unless they represent different subject matter areas.

Professional Master's degree programs are intended for students who wish to emphasize design and application rather than research and scientific aspects. They are usually administered jointly by the College and the Graduate School. Two examples of professional Master's degree programs are given in Appendix D. These programs will not be described further, since the requirements vary between colleges. For specific information about professional Master's degrees one should inquire of the department or college concerned.

General Requirements for the Ph.D. Degree

The requirements for the Ph.D. degree are very flexible, with a number of alternatives for satisfying the various requirements. This is particularly advantageous to graduate students desiring an interdisciplinary program, which is often the case for graduate students in water resources.

The basic requirement for the Ph.D. degree is a high degree of understanding and attainment in a particular field of study, as shown by passing special examinations and by preparation of an acceptable doctoral thesis. Thus, there is no prescribed amount of course work for the Ph.D. degree. Individual programs most commonly contain from 70 to 90 quarter credits, including the coursework for the M.S. degree, or 40 to 50 quarter credits beyond the M.S. degree. The exact amount of coursework needed by a Ph.D. candidate depends on his educational goals and the nature and extent of his previous preparation in relation to his present major interest. Thus, some individuals may find it desirable if not essential to take more coursework than indicated above.

Each Ph.D. candidate files a proposed program of study or coursework and designates a major field and a minor field or supporting program. Graduate level courses taken as an M.S. candidate and those taken at other universities may be included if related to the objectives of the program. There is no limit on transfer of graduate credits to a Ph.D. program at the University of Minnesota, nor is there a general requirement for a specified number of credits to be taken in residence. There is, however, a residency requirement of one academic year.

Major fields usually correspond to departments of the university, except for a few interdepartmental majors previously approved by the Graduate School. A complete listing of all approved Ph.D. (and M.S.) majors is given in the Graduate Bulletin. It includes nearly all of the departments or schools listed in Table 1.

The major program may and often does include a number of courses in related subjects from other departments and, of course, half or more of the total coursework.

A minor field on a Ph.D. program must include at least 22½ quarter credits from a single department or single subject matter area. In lieu of a minor, a doctoral candidate may choose a supporting program, where appropriate. This consists of a "coherent pattern of studies, possibly embracing several disciplines, but clearly forming a purposeful part of the doctoral program –". Many candidates with interdisciplinary interests find this option very useful.

The doctoral thesis research is carried out in the major department under the general guidance of the major adviser and represents an academic year or more of full time work. It must embody results of research that represent a significant contribution to the knowledge in the major field of study. The thesis must be read and approved by at least three members of the graduate faculty.

The language requirement for doctoral programs may be satisfied in any one of three ways, as follows:

1. Reading knowledge of two foreign languages.
2. High proficiency in one foreign language, including reading, writing and speaking.
3. Reading knowledge of one foreign language plus 9 credits of study representing a "special research technique" or a "collateral field of knowledge."

Choices of foreign languages, research techniques and collateral fields require approval by the appropriate group committee. As at a number of other universities, the language requirements are currently (June, 1969) undergoing a thorough review which will probably lead to significant changes.

Two special examinations are required of all doctoral candidates. The first is the preliminary examination, taken after completion of the minor and usually prior to the main effort on a thesis study. It covers both the major and minor coursework, including fundamentals. The final oral examination follows completion of the thesis and is largely a defense of the thesis.

Further details on the general requirements for the Ph.D. degree are, of course, given in the Graduate School Bulletin. Departmental requirements and practices can be obtained by correspondence or consultation with the major department or prospective major adviser.

Planning a Ph.D. Program in Water Resources

Ph.D. programs specializing in the physical, biological or social science aspects of water resources may be arranged in most of the departments at the University of Minnesota listed in Table 1. Although there is no such designation, Ph.D. programs may be discipline-oriented, indicating a high degree of specialization, or interdisciplinary to a considerable degree.

The choice of major field and major adviser are, of course, the first steps in planning a Ph.D. program. Many continue in the same discipline for their graduate study, perhaps at a different university. Others find that, because of career goals or some shift in interest, it is advisable to choose a different discipline within the same broad area (physical, biological or social sciences) for their Ph.D. (or MS) program. The major adviser, ideally, is the professor whose subject matter interests most closely match those of the student, as indicated by his current and past research as well as teaching. Also, before laying out a program, a Ph.D. candidate should decide which suits his career objectives best, a specialized program, a highly interdisciplinary program, or something in between.

The next step is to choose the minor field or the fields to be used in formulating a supporting program. A traditional minor, which usually involves about 24 quarter credits provides a moderate degree of specialization in that area. If specialization is the goal, an area closely related to the major is the logical choice, or one that is directly supportive, such as mathematics, statistics, economics,ecology, or some branch of chemistry. The Ph.D. minor is normally quite homogeneous, i.e., with all or nearly all courses from a single discipline or department. The minor department may require a certain level of proficiency as indicated by satisfactory completion of specified courses or by passing a special examination. Thus, it is advisable to consult the minor department before embarking on the minor coursework.

The option of choosing a supporting program instead of a minor field is especially useful to those who wish to develop an interdisciplinary Ph.D. program. The supporting program can include courses from two or more different disciplines provided that the combination is a coherent one that supports the major and the objectives of the overall program. In an interdisciplinary area such as water resources, this provides a great deal of flexibility. For example, a person with a major in some branch of engineering may choose a supporting program in the social sciences, choosing from economics, public administration, law or other disciplines, as applied to natural resources. Many other examples could be given, since the principal limitations are relevancy and prerequisites. More commonly, of course, the supporting field is more closely related to the major than in the above example.

The number of credits required for a supporting field is the same as for a minor, 22½ or more quarter credits. It may be desirable, however, to increase this to 30 to 40 quarter credits to obtain a greater depth of understanding in the areas represented in the supporting field. A candidate who chooses a supporting program is not expected to have competency in each of the fields represented comparable to that of a person with a traditional minor.

Table 4 gives two examples of Ph.D. programs in water resources recently completed at the University of Minnesota, one discipline-oriented and the other strongly interdisciplinary. A number of additional examples of Ph.D. programs are presented in Appendix D. These programs represent quite a variety of majors, minors and supporting programs and also vary considerably in degree of specialization. It should be noted that some of the programs include courses which have been discontinued or replaced by new courses.

The coursework chosen for the major should first provide the depth of understanding necessary to enable the person to proceed independently on a thesis investigation in that field. The courses should be chosen with that in mind. Certain courses in other departments may be needed for this purpose and thus are logically included in the major. Although there is no actual requirements to this effect, it is generally understood that a number of 200-level (for graduate students only) courses should be included in the courses constituting the major.

Secondly, a small portion of the courses in the major might be used to provide a broader training or background in the major discipline or other areas. The courses may be important and valuable in relation to future work in the major field, though not needed as preparation for the thesis investigation, which often is rather specialized.

Table 4. Examples of Ph.D. programs, discipline-oriented and interdisciplinary

(a) Discipline-Oriented Program for Ph.D. Degree

Major Field – Environmental Health

Pub. H.	102	Environmental Health	3 cr.
Pub. H.	180	Intro. Biostatistics	6 cr.
Pub. H.	100A	Elements of Pub. H.	3 cr.
Pub. H.	117	Sanitary Biology	3 cr.
Pub. H.	125	Public Health Education	2 cr.
Pub. H.	155	Air Pollution Probs.	3 cr.
Pub. H.	100B	Elements of Pub. Health	1 cr.
Pub. H.	106	Administration	3 cr.
Pub. H.	104	Epidemiology I	3 cr.
Pub. H.	115	Food Sanitation	3 cr.
Pub. H.	118	Sanitary Biology	3 cr.
Pub. H.	100C	Elements of Pub. Health	2 cr.
Pub. H.	119	Sanitary Biology	3 cr.
Pub. H.	123	Topics – Biol. Prep.	2 cr.
Pub. H.	186	Probs. Air Pollution Control	3 cr.
Pub. H.	210	Seminar	1 cr.
Pub. H.	212	Seminar: Pub. Health Eng.	1 cr.
Pub. H.	233	Water Quality Investigations	6 cr.
Pub. H.	154	Radiological Health	3 cr.
Bot.	150	Introd. to Study of Algae	5 cr.
Pub. H.	152	Industrial Hyg. Eng.	3 cr.
Pub. H.	123	Topics – Periphyton	2 cr.
Pub. H.	234	Water Qual. Research	6 cr.
Pub. H.	200	Research	6 cr.
			76 cr.

Minor Field – Entomology

Ent.	131	Adv. Insect. Taxon.	3 cr.
Ent.	146	Helminthology	3 cr.
Zool.	144	Medical Entomology	3 cr.
Ent.	128	Aquat. Entomology	2 cr.
Ent.	125	Insect Morphology	5 cr.
Ent.	126	Insect Embryology	5 cr.
Ent.	118	Experimental Ecology	3 cr.
			24 cr.

Thesis – The Productivity of Lake Superior Periphyton as Reflected by Pigment Analysis and Respirometry.

Appendix A. Full time faculty members concerned with teaching and/or research in water resources

Department	Faculty Member	Teaching*	Research*	Area(s) of Interest*
Agricultural Economics	Uel O. Blank	x	x	Water oriented recreation
	Wilbur R. Maki		x	Water and regional development
	Lee R. Martin		x	Public investment in water resources
	Philip M. Raup	x	x	Land economics, National resources policy
	Robert W. Snyder			Seasonal home ownership in rural areas
	Jerome M. Stam		x	Water and regional development
	John J. Waelti		x	Economics of water quality
Agricultural Engineering	Evan R. Allred	x	x	Irrigation, agricultural waste disposal
	James R. Gilley	x	x	Irrigation, drainage
	Curtis L. Larson	x	x	Hydrology, erosion and sediment control
	Philip W. Manson	x	x	Agricultural drainage
	James A. Moore	x	x	Agricultural waste disposal
Botany	Eville Gorham	x		Aquatic ecology
Chemistry	Ernest B. Sandell	x		Water Analysis
Civil Engineering	Alvin G. Anderson	x	x	Sediment transport in open channel flow
	C. Edward Bowers	x	x	Hydrology, hydraulic design
	John W. Hayden	x	x	Flow in porous media, hydromechanics
	Walter K. Johnson	x	x	Waste water treatment
	Walter J. Maier	x	x	Chemical and biological processes
	John F. Ripken	x	x	Hydraulic measurements, machinery
	George J. Schroepfer	x	x	Water supply and waste treatment
	Edward Silberman		x	Water resources
	Heinz Stefan	x	x	Diffusion processes
Ecology and Behavioral Biology	Alan J. Brook	x	x	Fresh water ecology
	Robert O. Megard	x	x	Limnology, biology of algae
	William H. Marshall		x	Wetland ecology
Entomology, Fisheries and Wildlife	Edwin F. Cook	x		Aquatic entomology
	Lloyd L. Smith, Jr.	x	x	Fishery biology, production
	Thomas F. Waters	x	x	Fishery biology

*Activities related to water resources only

Appendix A. (Continued)

Department	Faculty Member	Teaching*	Research*	Area(s) of Interest*
Environmental Health	Richard G. Bond	x	x	Environmental aspects, water system
	Theron O. Odlaug**	x	x	Limnology, environmental biology
	Theodore A. Olson	x	x	Limnology, environmental biology
	Orlando R. Ruschmeyer	x	x	Limnology, environmental biology
	Rexford D. Singer	x		Groundwater development
	Conrad P. Straub	x	x	Water pollution, radioactivity
Forestry	Arnett C. Mace	x	x	Forest climatology, hydrology
	Lawrence C. Merriam	x	x	Forest recreation
Geology	Ward J. Barrett	x		Climatology
	Richard H. Skaggs	x		Climatology
Geology and Geophysics	Roger LeB. Hooke	x	x	Geomorphology
	Hans O. Pfannkuch	x	x	Hyrogeology, porous media phsics
	Joseph Shapiro	x	x	Limnology
	Frederick M. Swain	x	x	Sedimentology
	Herbert E. Wright, Jr.	x	x	Limnology
	William C. Walton		x	Water resources
Law	David K. Bryden	x		Resource law
Mineral Engineering	W. David Lacabanne	x		Fluid flow in porous media
Physics	Homer T. Mantis	x	x	Meteorology, atmospheric physics
Public Administration	George A. Warp	x	x	Resource administration
	Orville C. Peterson	x		Local government
Soil Science	Russell S. Adams	x	x	Organic and pesticidal residues
	Donald G. Baker	x	x	Microclimatology, evapotranspiration
	George R. Blake	x	x	Soil physics, unsaturated flow
	Richard H. Rust	x	x	Infiltration, soil classification
Zoology	James C. Underhill	x		Aquatic ecology

**Department of Biology, University of Minnesota at Duluth

Appendix B.

Departments concerned with water resources and department heads, with addresses, University of Minnesota

Department of Agricultural Economics
Vernon W. Ruttan, Head
Selmer A. Engene, Chairman of Graduate Committee
Institute of Agriculture
St. Paul, Minnesota 55101

Department of Agricultural Engineering
Landis L. Boyd, Head
Institute of Agriculture
St. Paul, Minnesota 55101

Department of Botany
Eville Gorham, Head
John W. Hall, Director of Graduate Study
College of Biological Sciences
Minneapolis, Minnesota 55455

Department of Analytical Chemistry
Edward J. Meehan, Chief
Institute of Technology
Minneapolis, Minnesota 55455

Department of Civil Engineering
Lawrence E. Goodman, Head
John T. Hanley, Director of Graduate Study
Institute of Technology
Minneapolis, Minnesota 55455

Department of Ecology and Behavioral Biology
Alan J. Brook, Head
College of Biological Sciences
Minneapolis, Minnesota 55455

Department of Entomology, Fisheries and Wildlife
Alexander C. Hodson, Head
Institute of Agriculture
St. Paul, Minnesota 55101

Department of Environmental Health
Richard G. Bond, Director
School of Public Health
Minneapolis, Minnesota 55455

School of Forestry
Frank H. Kaufert, Director
Institute of Agriculture
St. Paul, Minnesota 55101

Department of Geography
John W. Webb, Chairman
College of Liberal Arts
Minneapolis, Minnesota 55455

Department of Geology and Geophysics
Tibor Zoltai, Head
Hans O. Pfannkuch, Coordinator of Graduate Study in Hydrogeology
School of Earth Sciences
Minneapolis, Minnesota 55455

Law School
William B. Lockhart, Dean
Minneapolis, Minnesota 55455

School of Physics
Morton Hamermesh, Head
Institute of Technology
Minneapolis, Minnesota 55455

Public Administration Center
George A. Warp, Director
School of Public Affairs
Minneapolis, Minnesota 55455

Department of Soil Science
William P. Martin, Head
Institute of Agriculture
St. Paul, Minnesota 55101

Appendix C. Current (1969) graduate level courses to a minor extent concerned with water resources *or* indirectly applicable but important to solution of water resources problems (Category B) – department, course number, course title, quarter credits.

Agricultural Economics

160	(5600)	Land Economics	3 cr.
162	(5620)	Regional Economic Analysis	3 cr.
171	(5710)	Agricultural Policy	3 cr.
360	(5360)	Seminar: Land Economics and Tenure	3 cr.

Agricultural Engineering (Institute of Technology)

180	(5120)	Radioisotope Measurements	3 cr.
257	(8700)	Moisture and Heat Transfer	3 cr.

Agricultural Engineering (Institute of Agriculture)

160	(5010)	Agricultural Waste Management	3 cr.
127	(5000)	Principles of Radioisotope Measurements	3 cr.

Architecture

131-132-133	(5131,2,3)	Planning	3 ea.

Biochemistry (Biological Sciences)

119	(8251)	Physical Biochemistry	3 cr.
141-142-143	(5741,2,3)	General Biochemistry	3 ea.
145-146	(5745,6)	General Biochemistry Laboratory	3 ea.
147	(5747)	Advanced Biochemical Techniques	3 cr.
204	(8225)	Tracer Techniques	3 cr.

Biophysics

170-171-172		Radiation Biophysics	3 ea.

Botany

112	(5805)	Aquatic Flowering Plants	5 cr.
141	(5141)	Survey of Plant Physiology	3 cr.
141A	(5142)	Plant Physiology Laboratory	2 cr.
182-183-184	(5182,3,4)	Plant Physiology	3 ea.

Chemical Engineering

101-102-103	(5101,2,3)	Principles of Chemical Engineering	5 ea.
111-112-113	(5401,2,3)	Chemical Engineering Laboratory	2 ea.
181-182-183	(5751,2,3)	Biological Engineering Analysis	3 ea.
205-206-207	(8001,2,3)	Physical Rate Processes & the Transfer Operations	3 ea.
208	(8101)	Intermediate Fluid Mechanics	3 cr.
209-210	(8004,5)	Physical Rate Processes	3 ea.
224	(8102)	Problems in Fluid Mechanics	3 cr.
228	(8106)	Advanced Topics in Fluid Mechanics & Transport Processes	3 cr.

Chemistry, Analytical

105	(5102)	Quantitative Inorganic Microanalysis	3 cr.
111-112	(5120,5121)	Physiochemical Methods of Analysis	3 ea.
115	(5122)	Advanced Analytical Chemistry	2 cr.
117	(5123)	Electrochemical Methods of Analysis	4 cr.

Chemistry, Inorganic

103	(5701)	Inorganic Chemistry I	3 cr.
112		Radioactivity and Nuclear Chemistry	3 cr.
122	(5751)	Inorganic Chemistry Laboratory	2 cr.

Chemistry, Physical

101-102-103-104	(5501,2,3,4)	Physical Chemistry	4 ea.
106A-B	(5511,2)	Physical Chemistry Laboratory	1-2 ea.
107-108	(5520,1)	Elementary Physical Chemistry	3 ea.
128		Colloid and Surface Chemistry	3 cr.

Civil Engineering (Hydrology and Hydromechanics)

186	(5412)	Mechanics of Similitude and Dimensional Analysis	3 cr.
187	(5435)	Intermediate Fluid Mechanics	3 cr.
188	(5436)	Incompressible Potential Flow	3 cr.
189	(5437)	Incompressible Boundary Layer Flow	3 cr.
190	(5430)	Hydraulic Transients	3 cr.
194-195-196	(5497,8,9)	Advanced Hydraulics Laboratory	2 cr.
287	(8410)	Fluid Turbulence	3 cr.
290-291-292		Advanced Fluid Mechanics	3 ea.
293-294-295	(8401,2,3)	Hydrodynamics, of the Boundary Layer	1 ea.

Civil Engineering (Sanitary)

175	(5507)	Industrial Waste Disposal	3 cr.
180	(5508)	Solid Waste Disposal Problems	3 cr.

Ecology and Behavioral Biology

118	(5400) (Ent)	Experimental Ecology	3 cr.
131	(5015)	Structures and Function of Ecosystems	5 cr.
138	(5018)	Wetland Ecology	5 cr.
158	(5153) (For.)	Theory & Practice in Environmental Measurement	5 cr.

Economics

178 A-B	Public Finance	3 ea.
140	Economics of Location	3 cr.
195 A-B-C	Decision Making and Operations Analysis	3 ea.
185 A-B-C	Microeconomic Theory	3 ea.

Electrical Engineering

107-108 (5000,1)	Linear System Analysis	3 cr.
187 A-B (5700,1)	Information Theory and Coding	3 ea.
194 A-B (5750,1)	System Analysis and Optimum Control	3 ea.
195 A (5752)	Nonlinear System Design	3 cr.
196 (5753)	Linear Stochastic Systems	3 cr.

Entomology, Fisheries and Wildlife

103-104-105 (5103,4,5)	Basic Fishery or Wildlife Biology	arr.
133 (5131)	Aquatic Entomology	2 cr.
152 (5452)	Fishery Management	3 cr.
178 (5678)	Fisheries and Wildlife Administration	4 cr.
161 (5551)	Wildlife Ecology & Management I	4 cr.
162 (5552)	Wildlife Ecology and Management II	4 cr.
248-249 (8448,9)	Fishery Biology	5 ea.
250 (8450)	Fisheries Resources of the United States	3 cr.
201 (8300)	Experimental Ecology Laboratory	2 cr.

Environmental Health

118	Environmental Microbiology	3 cr.
100 A-B-C	Elements of Public Health, I, II, III	3-2-2 cr.
102-102A	Environmental Health	3-2 cr.
114	Environmental Health Programs	3 cr.
118	Environmental Microbiology	3 cr.
143	Measurement & Application of Ionizing Radiation	3 cr.
145	Low Level Radioactivity Measurements	3 cr.
147	Environmental Radioactivity	3 cr.

Forestry

109 (5200)	Aerial Photo Interpretation	3 cr.
116 (5233)	Outdoor Recreation Design and Planning	4 cr.
146 (5252)	Advanced Aerial Photo Interpretation	3 cr.
152 (5103)	Forest-Tree Physiology	3 cr.
157 (5257)	Recreation Land Policy	3 cr.
158 (5153)	Measurements of the Forest Environment & Plant Behavior	5 cr.
160 (5258)	Outdoor Recreation Economics	3 cr.
161 (5259)	Recreation Land Amenities and the User	3 cr.
162 (5260)	Advanced Management of Recreational Lands	3 cr.
165 A-B-C (5154,5,6)	Measurement of Plant-Environment Interactions	1-4 cr.

Geography

157-157 A	Land Form Geography	3 ea.
158	Geomorphometry	3 cr.
171-171 A	Geography of Economic Localization	3 ea.
181	Statistical Cartography	3 cr.
182	Advanced Cartography	3 cr.
183	Elements of Remote Sensing	3 cr.
184-184 A	Air Photo Interpretation	3 ea.

Geology and Geophysics

104 (5101)	Advanced General Geology	3 cr.
115 (5251)	Geomorphology	4 cr.
116 (5261)	Glacial Geology	3 cr.
118 (5252)	Problems in Geomorphology	3 cr.
119 (5255)	Glaciology	3 cr.
125 (5651)	Sedimentary Geochemistry	4 cr.
149 (5301)	Introductory Geochemistry	3 cr.
175 (5511)	Principles of Gravity and Magnetic Exploration	3 cr.
176 (5512)	Principles of Seismic Exploration	3 cr.
177 (5514)	Principles of Electrical Exploration	2 cr.
202	Marine Geology	arr.
213	Organic Geochemistry	3 cr.

Horticulture

112 (5012)	Principles of Recreational Design	3 cr.
116 (5010)	Outdoor Recreational Design and Planning	4 cr.

Mathematics

127-128-129 (5527,8,9)	Applied Mathematics for Social & Biological Sciences	3 ea.
133B-134B (5774,5)	Probability with Technological Applications	3 ea.
149 (5209)	Determinants and Matrices	3 cr.
169 (5540)	Mathematical Theory of Fluid Flow	3 cr.
178 (5776)	Probability	
184-185-186	Numerical Analysis in Engineering	3 ea.
290 A-B-C	Mathematical Theory of Fluid Dynamics	3 ea.

(Many other courses of potential application)

Mechanical Engineering

134 (5340)	Thermodynamics of Fluid Flow	3 cr.
232 (8350)	Advanced Fluid Thermodynamics	3 cr.
236 (8333)	Advanced Theory of Heat Transfer	3 cr.
120 (5420)	Probability Models in Industrial Engineering & Operations Research	3 cr.
133A-134A (5430,1)	Mathematical Methods in Operations Analysis	3 ea.
173 (5340)	Engineering Economic Analysis	3 cr.
193 (5432)	Introduction to Optimal Control & Dynamic Programming	3 cr.

Microbiology

103	(5612)	Ecology of Soil Microorganisms	4 cr.
111	(5611)	Advanced Microbiology	4 cr.
121	(5321)	Physiology of Bacteria	3 cr.
153	(5105)	Biology of Microorganisms	4 cr.
222		Physiology of Bacteria Laboratory	3 cr.

Mineral Engineering

171-172	(5530,2)	Fluid Flow Through Porous Media, I, II	2-3 cr.
171A-172A	(5531,3)	Fluid Flow Laboratory I, II	1 ea.

Plant Pathology and Physiology

183-184	(5183,4)	Plant Physiology	3 ea.
280		Growth and Differentiation of Plants	3 cr.
284		Ecological Physiology	3-5 cr.

Political Science

108	(5308)	Legislative Organization and Procedure	3 cr.
115	(5315)	State Government	3 cr.
116	(5316)	Introduction to Community Politics	3 cr.
118	(5318)	Metropolitan Government and Politics	3 cr.
266		Seminar: Public Policy	3 cr.
295 A		Fundamental Concepts of Public Law	3 cr.

Public Administration

200		Public Administration	3 cr.
210		Public Administration & the Political Process	3 cr.
211		The Public Economy	3 cr.
214		Current Issues of Public Administration & Policy Development in Minnesota	3 cr.
278		Legal Environment of Public Administration	3 cr.

Sociology

146	(5410)	Formal Organization	3 cr.
140	(5401)	Social Organization	3 cr.
161	(5660)	Rural Community Analysis	3 cr.
162	(5651)	Rural Social Institutions	3 cr.

Soil Science

125	(5520)	Soil Development and Classification	3 cr.
105	(5512)	Soil Geography	3 cr.
134	(5550)	Organic Soils	3 cr.
137	(5532)	Soils and the Ecosystem	3 cr.

Zoology

121	(5121)	Ichthyology	3 cr.

Statistics

101		Introduction to Decision Theory	3 cr.
121-122-123		Theory of Statistics	3 ea.
191		Introduction to Multivariate Analysis	3 cr.

Statistics in Other Departments

Agr. Econ. 101	(5010)	Statistical Methods for Social Science	4 cr.
Agronomy 248	(8380)	Applied Statistics	3 cr.
Biometrics 100	(5010)	Statistical Analysis I	5 ea.
Biometrics 101	(5011)	Statistical Analysis II	5 ea.
Economics 111		Elements of Statistics	3 cr.
Economics 131		Elements of Econometrics	3 cr.
Economics 201A-B-C		Econometrics	3 ea.
Public Health 110A		Biometry I	3 cr.
Public Health 111A		Biometry Laboratory I	2 cr.

Appendix D. Additional examples of Master's degree programs in water resources

Program for M.S. Degree, Plan A

Major Field – Civil Engineering (Hydraulics)

Hydr.	183	Open Channel Flow	3 cr.
Hydr.	187	Interm. Fluid Mechanics	3 cr.
Hydro	190	Mechanics of Similitude	3 cr.
Hydr.	192	Natural & Artificial Waterways	3 cr.
Hydr.	193	Hydraulic Measurements	3 cr.
CE	161	Hydrology	3 cr.
			18 cr.

Minor Field – Agricultural Engineering

Ag.E.	142	Erosion Control	3 cr.
Ag.E.	143	Irrigation	3 cr.
Ag.E.	181	Field Probs. Soil & Water Engineering	3 cr.
			9 cr.

Thesis Topic – Hydrograph Linearity in an Elementary Channel

Program for M.S. Degree, Plan A

Major Field – Agricultural Economics

Ag Ec	264	Resource Economics	3 cr.
Ag Ec	175	Agricultural Trade and Commercial Policy	3 cr.
Ag Ec	186	Economics of Agricultural Production	3 cr.
Ag Ec	160	Land Economics	3 cr.
Econ	101A	Foundations of Mathematics for Social Scientists	3 cr.
Econ	166	Elements of Economic Analysis: Income and Employment	3 cr.
Econ	185A	Microeconomic Theory	3 cr.
Econ	185B	Microeconomic Theory	3 cr.
			24 cr.

Minor Field – Statistics

Biom	100	Statistical Analysis I	5 cr.
Stat	101	Introduction to Decision Theory	3 cr.
Ag Ec	101	Statistical Methods for Social Science	4 cr.
			12 cr.

Thesis – The Marginal Cost of Alternative Water Quality Standards

Master of Science Program, Plan B

Major Field – Forestry (Hydrology)

C.E.	160	Engineering Hydraulics I	4 cr.
C.E.	161	Hydrology	3 cr.
For.	154	Advanced Forest Hydrology	3 cr.
For.	221	Res. Probs. Forest Influences	3 cr.
Ag. Eng	254	Adv. Hydrology – Small Watersheds	3 cr.
Biom.	100	Statistical Analysis I	5 cr.
Biom.	101	Statistical Analysis II	3 cr.
Biom.	110	Computers in Ag. & Biol. Research	3 cr.
			27 cr.

Minor Field – Soil Science

Soil	128	Soil Chemistry	3 cr.
Soil	135	Soil Analytical Chem. Tech.	3 cr.
Soil	280	Radioisotope Tech. Applied to Bio.	3 cr.
			9 cr.

Minor Field – Public Health

Ph.	117a	Environmental Biology	3 cr.
Ph.	117b	Environmental Biology	3 cr.
Ph.	117c	Environmental Biology	3 cr.
			9 cr.

Master of Science Program, Plan A

Major Field – Soil Science

Soil Sci.	125	Soil Development and Classification	3 cr.
Soil Sci.	126	Soil Physics	4 cr.
Soil Sci.	133	Microclimatology	3 cr.
Soil Sci.	220	Fluid Flow in Soils	3 cr.
Chemistry	101	Physical Chem.	4 cr.
Chemistry	102	Physical Chem.	4 cr.
			21 cr.

Minor Field – Agricultural Engineering

Ag. Eng.	124	Drainage and Irrigation	3 cr.
Ag. Eng.	144	Advanced Drainage and Irrigation	3 cr.
Ag. Eng.	160	Ag. Eng. Instrumentation	3 cr.
			9 cr.

Alternate Minor Field – Fluid Mechanics

Thesis – Soil moisture tension – field capacity relationships in some sandy soil profiles.

Program for M.S. – Degree, Plan A

Major Field – Geology and Geophysics: (Hydrogeology)

P.Ch.	101	Physical Chemistry	4 cr.
P.Ch.	102	Physical Chemistry	4 cr.
Geol.	116	Glacial Geology	3 cr.
Geol.	117	Pleistocene Geology	3 cr.
Geol.	128	Limnology	3 cr.
Geol.	131	Ground Water Geology	3 cr.
Geol.	216	Seminar: Pleistocene Geology	1 cr.
Geol.	226	Seminar: Sedimentology	3 cr.
Geol.	230	Methods for Analysis of Natural Waters	3 cr.
Geol.	231	Research in Ground Water Geology	3 cr.
Geol.	232	Seminar: Ground Water Geology	2 cr.
			32 cr.

Minor Field – Civil Engineering and Hydraulics

CE	101A	Fluid Mechanics	4 cr.
CE	161	Hydrology	3 cr.
CE	164	Water Conservation	3 cr.
			10 cr.

Thesis – Mathematical Modeling of Lake and Ground Water Hydrology in the Lake Sallie Area (Minn.)

Program for Master of Public Health

Major Field – Environmental Health

Pub H	100 A,B,C	Elements of Public Health	6 cr.
Pub H	102	Environmental Health	3 cr.
Pub H	104	Epidemiology I	3 cr.
Pub H	106	Public Health Administration	3 cr.
Pub H	125	Introduction to Public Health Education	2 cr.
Pub H	107 A	Administration of Public Health Nursing	1 cr.
Pub H	180	Introduction to Biometry	6 cr.
Pub H	112	Environmental Aspects of Water Systems	3 cr.
Pub H	231	Ground Water Development	3 cr.
Pub H	232	Field Work in Ground Water Development	3 cr.
Pub H	233	Water Quality Investigation and Research	6 cr.
		Techniques	6 cr.
			39 cr.

Minor – Sanitary Engineering

C.E.	173	Sanitary Engineering Problems: Water	3 cr.
C.E.	172	Sanitary Engineering Laboratory	3 cr.
C.E.	174	Sanitary Engineering Problems: Waste Water	3 cr.
C.E.	179	Ground Water and Surface Quality Problems	3 cr.
			12 cr.

(Major includes comprehensive papers covering 9 credits)

Program for Master of Public Administration

Major Field – Public Administration

PA	209	The Policy Making Process	3 cr.
PA	210	Administrative Agencies in the Political Process	3 cr.
PA	211	The Public Economy	3 cr.
PA	212	Issues in American Public Policy	3 cr.
PA	270A	Administrative Theory and Behavior	3 cr.
PA	270A	Administrative Management	3 cr.
PA	270C	Administrative Management	3 cr.
PA	278	Legal Environment of Public Administration	3 cr.
PA	282A,B,C	Administrative Internship (with an agency concerned with water resources)	9 cr.
PA	283	Research Seminar (topic in water resources administration)	3 cr.
		Approx.	36 cr.

Minor Field(s)

Coursework in one or more approved areas	18 cr.
	54 cr.

Program for Ph.D. Program

Major Field – Agricultural Economics*

Ag. Econ	101	Statistical Methods for Social Science	4 cr.
Ag. Econ	113	Land Resource Use	3 cr.
Ag. Econ	162	Regional Economic Analysis	3 cr.
Ag. Econ	163	Resource Economic Policy	3 cr.
Ag. Econ	205	Research Methodology in Agricultural Economics	3 cr.
Ag. Econ	231	Agricultural Prices	3 cr.
Ag. Econ	245	Agricultural Marketing	3 cr.
Ag. Econ	264	Resource Economics	3 cr.
Ag. Econ	287	Production Economics (I)	3 cr.
Ag. Econ	288	Production Economics (II)	3 cr.
Ag. Econ	346	Law & Agricultural Economics	3 cr.
Ag. Econ	360	Land Economics & Tenure	3 cr.
Ag. Econ	364	Resource & Regional Economics	3 cr.
Biom	100	Statistical Analysis I	5 cr.
Biom	101	Statistical Analysis II	5 cr.
			50 cr.

Minor Field – Economics

Econ	103	Economic Development	3 cr.
Econ	106	Income and Development	3 cr.
Econ	175	Welfare Economics	3 cr.
Econ	176A	Income Theory	3 cr.
Econ	176B	Dynamic Macroeconomics	3 cr.
Econ	185A	Price Theory	3 cr.
Econ	185B	Advanced Microeconomics	3 cr.
Econ	213A	Economic Growth & National Planning	3 cr.
Econ	213B	Economic Growth & National Planning	3 cr.
			27 cr.

Thesis – An Economic Analysis of Small Watershed Management in Minnesota

*Because several new courses in resource economics have been added recently, a currently typical program is substituted for the actual major program.

Program for Ph.D. Degree

Major Field – Environmental Health

Pub. H.	102	Environmental Sanitation	3 cr.
Pub. H.	117	Sanitary Biology	3 cr.
Pub. H.	210	Seminar	1 cr.
Pub. H.	110A	Elements of Public Health	3 cr.
Pub. H.	100B	Elements of Public Health	1 cr.
Pub. H.	100C	Elements of Public Health	1 cr.
Pub. H.	113A	Public Health Engineering, Field Visits	2 cr.
Pub. H.	212	Seminar, Public Health Engineering	1 cr.
Pub. H.	154	Control of Radiation	3 cr.
Pub. H.	180	Biostatistics	5 cr.
Pub. H.	230	Field Practice	5 cr.
C.E.	125	Computer Applications in Civil Engineering	3 cr.
C.E.	161	Hydrology	3 cr.
C.E.	164	Water Conservation	3 cr.
C.E.	121	Applications of Linear Programming	3 cr.
C.E.	174	Sanitary Engineering Problems (Sewage)	3 cr.
C.E.	173	Sanitary Engineering Problems (Water)	3 cr.
C.E.	172	Sanitary Laboratory	3 cr.
C.E.	261	Water Plant Design	5 cr.
Math.	149	Determinants and Matrices	3 cr.
Math.	184	Numerical Analysis in Engineering	3 cr.
So. Sc.	133	Microclimatology	3 cr.
Ag. Eng.	254	Advanced Hydrology-Small Watersheds	3 cr.
Hydr.	191	Hydraulic Motors	3 cr.
			69 cr.

Minor Field – Hydrogeology

Geo.	125	Sedimentary Geochemistry	4 cr.
Geo.	128	Limnology	4 cr.
Geo.	131	Ground Water Geology	3 cr.
Hydr.	183	Open Channel Flow	3 cr.
Hydro.	193	Hydraulic Measurements	3 cr.
C.E.	191	Advanced Hydraulics & Hydrologic Problems	3 cr.
C.E.	163	Ground Water Hydraulics	3 cr.
			23 cr.

Thesis – Methodology for Integrating Water Quality Management with Management of the Total Water Resources in Minnesota

Program for Ph.D. Degree

Major Field – Civil (Sanitary) Engineering

CE	172	Sanitary Engineering Laboratory	3 cr.
CE	173	Sanitary Engineering Problems: Water	3 cr.
CE	174	Sanitary Engineering Problems: Waste Water	3 cr.
CE	175	Industrial Waste Disposal	3 cr.
CE	176	Sanitary Engineering Seminar	1 cr.
CE	177	Sanitary Engineering Seminar	1 cr.
CE	178	Sanitary Engineering Seminar	1 cr.
CE	261	Water Plant Design	3 cr.
CE	262	Waste Water Plant Design	3 cr.
CE	264	Sanitary Engineering Unit Operations	3 cr.
CE	276	Advanced Sanitary Engineering (Water)	5 cr.
CE	277	Advanced Sanitary Engineering (Waste Water)	5 cr.
CE	280	Civil Engineering Research	3 cr.
CE	281	Clvil Engineering Research	3 cr.
CE	282	Civil Engineering Research	3 cr.
			43 cr.

Minor Field – Chemical Engineering

Hydr.	183	Open Channel Flow	3 cr.
Hydr.	191	Hydr. Motors and Pumps	3 cr.
Hydr.	193	Hydr. Measurements	3 cr.
P Ch	101	Physical Chemistry	4 cr.
P Ch	102	Physical Chemistry	4 cr.
P Ch	103	Physical Chemistry	4 cr.
Ch En	101	Principle Chemical Engineering	5 cr.
Ch En	102	Principle Chemical Engineering	5 cr.
Ch En	103	Principle Chemical Engineering	5 cr.
Ch En	122	Biochemical Engineering	3 cr.
Ch En	123	Biochemical Engineering Laboratory	3 cr.
			42 cr.

Research Technique – Statistics

Math.	132	Introduction to Statistics and Probabilities	3 cr.
Math.	133	Statistical Theory with Applications	3 cr.
Math.	134	Statistical Theory with Applications	3 cr.
			9 cr.

Thesis – Small Scale Investigation of Mechanical Surface Aeration Units

Program for Ph.D. Degree

Major Field – Agricultural Engineering

Ag. Eng.	180	Agric. Hydrology	3 cr.
Ag. Eng.	181	Field Problems	3 cr.
Ag. Eng.	142	Erosion Control	3 cr.
Ag. Eng.	211	Adv. Probs. Research	3 cr.
Ag. Enc.	212	Adv. Probs. Research	3 cr.
Ag. Eng.	213	Adv. Probs. Research	3 cr.
Ag. Eng.	191	Probs. in Ag. Eng.	3 cr.
Ag. Eng.	192	Probs. in Ag. Eng.	3 cr.
Geog.	134	Adv. Climatology	3 cr.
Soils	126	Soil Physics	4 cr.
C.E.	147	Foundations	3 cr.
C.E.	159	Soil Mechanics	3 cr.
C.E.	112	Aerial Photogrammetry	3 cr.
Biometrics	100	Statistical Analysis	4 cr.
Biometrics	101	Statistical Analysis	4 cr.
Math.	147	Methods: Engineering	3 cr.
Math.	148	Methods: Engineering	3 cr.
Math.	149	Methods: Engineering	3 cr.
Math.	184	Numerical Analysis	3 cr.
Math.	185	Numerical Analysis	3 cr.
Math.	186	Numerical Analysis	3 cr.
			66 cr.

Minor Field – Hydromechanics

Hydro.	183	Open Channel Flow	3 cr.
Hydro.	187	Int. Fluid Mechanics	3 cr.
Hydro.	190	Mechanics of Similitude	3 cr.
Hydro.	191	Hydro. Motors, Pumps	3 cr.
Hydro.	192	Nat., Artificial Wtwys	3 cr.
Hydro.	193	Hydraulic Measurements	3 cr.
C.E.	160	Applied Hydraulics	3 cr.
C.E.	166	Water Power Planning	3 cr.
			24 cr.

Thesis – The Effect of Runoff Supply Rate and Duration on Runoff Time Parameters and Peak Outflow Rates

Program for Ph.D. Degree

Major Field – Biology (Ecology)

Bot.	131	Structure, Function of Ecosystems	5 cr.
Bot.	133	Boreal Forests	3 cr.
Bot.	141	Survey of Plant Physiology	3 cr.
Bot.	151	Biology of Algae	5 cr.
Bot.	152	Ecology of Algae	5 cr.
Ecol.	120	Advanced Limnology	5 cr.
Ecol.	135	Structure, Function of Communities	5 cr.
Ecol.	299	Research Problems	6 cr.
Ecol.	299	Research Problems	6 cr.
Ecol.	299	Research Problems	5 cr.
Ecol.	299	Research Problems	5 cr.
Ecol.	299	Research Problems	5 cr.
Ecol.	299	Research Problems	5 cr.
Zool.	119	Limnology	5 cr.
			68 cr.

Minor Field – Geology

Geol.	116	Glacial Geology	3 cr.
Geol.	117	Pleistocene Geology	3 cr.
Geol.	128	Limnology	4 cr.
Geol.	230	Analysis of Natural Waters	3 cr.
Geol.	216	Seminar Limnology	1 cr.
Geol.	216	Seminar Pleistocene Geology	1 cr.
Geol.	229	Research in Limnology	2 cr.
Ecol.	139	Paleoecology	5 cr.
			22 cr.

Thesis – Ecology of Oscillatoria agardi v. isothrix

Program for Ph.D. Degree

Major Field – Geology (Limnology, Hydrogeology)

Geol.	128	Limnology	3 cr.
Geol.	228	Advanced Limnology	3 cr.
Geol.	230	Methods for Analysis of Natural Waters	3 cr.
Ecol.	139	Paleoecology	3 cr.
Geol.	116	Glacial Geology	3 cr.
Geol.	125	Sedimentary Geochemistry	4 cr.
Geol.	160	X-Ray Mineralogy	3 cr.
Geol.	110	Sedimentology and Stratigraphy	3 cr.
Math.	148	Differential Equations	3 cr.
Ph.C	107,108	Elementary Physical Chemistry	6 cr.
CE	101A	Fluid Mechanics	4 cr.
CE	161	Hydrology	3 cr.
CE	171	Sewerage, Waste Water Treatment	3 cr.
Geo	131	Ground Water Geology	3 cr.
Geo	132	Analytical Geohydrology	3 cr.
Chem	115	Advanced Analytical Chemistry	2 cr.
Ecol.	120	Advanced (Production) Limnology	5 cr.
Geol.	213	Organic Geochemistry	3 cr.
Geol.	227	Seminar: Limnology	1 cr.
Ecol.	198	Seminar: Ecology	2 cr.
Geol.	232	Seminar: Ground Water Geology	2 cr.
			65 cr.

Minor Field – Ecology

Ecol.	131	Structure and Function of Ecosystems	5 cr.
Ecol.	116	Population Dynamics	2 cr.
Ecol.	138	Wetland Ecology	5 cr.
Soil	125	Soil Development and Classification	3 cr.
Bot	165	Pollen Morphology, Taxonomy	3 cr.
Ecol	169	Quaternary Phyto Geography	4 cr.
Ecol	284	Ecological Physiology	4 cr.
			26 cr.

Thesis – Relative Significance of Surface and Ground Water Waters in Determining the Productivity of a Glacial Lake.

Program for Ph.D. Degree

Major Field – Soil Science (Soil Physics)

Soil Sci.	105	Soil Geography	3 cr.
Soil Sci.	125	Soil Development, Classification	3 cr.
Soil Sci.	126	Soil Physics	4 cr.
Soil Sci.	127	Soil Microbiology	4 cr.
Soil Sci.	128	Soil Chemistry	3 cr.
Soil Sci.	131	Physical Chemistry of Soils	3 cr.
Soil Sci.	132	Soil Fertility	3 cr.
Soil Sci.	133	Microclimatology	3 cr.
Soil Sci.	203	Seminar: Soils	2 cr.
Soil Sci.	220	Fluid Flow in Soils	3 cr.
Math	106	Differential Equations	3 cr.
Math	147	Vector Analysis	3 cr.
Math	167	Partial Differential Equations	3 cr.
Biom.	100,101	Statistical Analysis I, II	8 cr.
			49 cr.

Meteorology Emphasis

Hort.	138	Light & Temperature Requirements of Horticultural Plants	3 cr.
Bot.	130	General Plant Ecology	3 cr.
Bot.	130A	General Plant Ecology Lab.	2 cr.
Geog.	133	Climatology	3 cr.
For.	152	Forest Tree Physiology	3 cr.
			14 cr.

Fluid Flow Emphasis

Phy Ch	101,102,103	Physical Chemistry	12 cr.

Supporting Field (Alternate A) – Meteorology and Heat Transfer

Phys 165	165	Introd. to Physics of Atmosphere	3 cr.
Phys	166,167	Meteorology I, II	6 cr.
Hydr.	103	Fluid Mechanics	5 cr.
M.E.	133	Heat Transmission	3 cr.
M.E.	160Aq	Thermal Environmental Engineering	4 cr.
M.E.	233,234,25	Conduction, Convection, Radiation	9 cr.
M.E.	236	Advanced Theory of Heat Transfer	3 cr.
			33 cr.

Thesis – The Photosynthetic Response of Plants to their Environment: A Holocoenotic Method of Analysis

Supporting Field (Alternate B) – Fluid Flow

Geology	131	Groundwater Geology	3 cr.
Hydr.	101,104	Fluid Mechanics, Fluid Mechs. Lab.	4 cr.
Mech Eng.	134	Thermodynamics of Fluid Flow	3 cr.
Min Eng	171,172	Fluid Flow Through Porous Media (incl. labs)	6 cr.
Phy Chem	128	Colloid and Surface Chemistry	3 cr.
Agr Eng	124	Drainage and Irrigation	3 cr.
Agr Eng	144	Advanced Drianage and Irrigation	3 cr.
Agr Eng	160	Ag. Eng. Instrumentation	3 cr.
			28 cr.

Thesis – Unsaturated Flow in Soils with Textural or Structural Discontinuities