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BURNTSIDE LODGE
WASTEWATER TREATMENT
SYSTEM MONITORING REPORT
SUMMER 1996 AND 1997

By:

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INTRODUCTION

The treatment and dispersal of domestic wastewater from resorts are a significant issue in northeast Minnesota due to restrictive site and soil conditions. Within the Iron Range Resources & Rehabilitation Board (IRRRB) service area (Taconite Tax Relief Area), there are approximately 400 resorts that depend on onsite wastewater treatment systems. Of these, it is estimated that 200 resorts are likely to be in non-compliance with state rules (Minnesota Rules Chapter 7080).

Two pilot projects were initiated in 1995 within the IRRRB service area to demonstrate the use of alternative wastewater treatment technologies for resorts with difficult site conditions. This project is a cooperative effort between the IRRRB, Northern Lights Tourism Alliance (NLTA), counties within the IRRRB service area, the Natural Resources Research Institute (NRRI), University of Minnesota-Duluth, and Ayres Associates Inc. The wastewater treatment systems for the first pilot projects were constructed in 1996 at Burntside Lodge and at Dodge's Log Lodges. This report summarizes the water quality performance data from the Burntside Lodge wastewater treatment system that operated successfully during the summers of 1996 and 1997.

ALTERNATIVES ANALYSIS AND DESCRIPTION OF THE BURNTSIDE TREATMENT SYSTEM

Burntside Lodge is located ~5 miles northwest of Ely on the south shore of Burntside Lake. The resort is owned and operated by Lou and Lonnie LaMontagne. The resort was established in 1913 and has been a family-owned and operated business for more than 80 years by three generations of the LaMontagne family. The resort operates seasonally from mid-May through September and is closed during the winter months. The resort has 24, 1-3 bedroom log cabins, with a maximum occupancy of 88 persons occurring in July and August. The resort also has a central lodge with a full-service kitchen and a dining room (with restrooms) that serves between 50-120 meals daily. The restaurant is also open to the general public for dining.

The report entitled "Onsite Wastewater Treatment Pilot Project, Burntside Lodge, Alternatives Analysis" was prepared by the consulting firm Ayres Associates Inc. (Ayres Associates 1995). The report summarizes projected flows and wastewater composition, existing site and soil conditions at the resort, potential onsite treatment systems that may be appropriate for the site, and estimated costs for construction of several types of onsite treatment systems.

Clusters of cabins and the lodge all discharge wastewater into numerous tanks located near the cabins and lodge. The septic tank effluents are then pumped through a small diameter pipe laid on the surface, due to shallow bedrock, to a central septic tank/lift station. The effluent is then pumped to the new wastewater treatment system constructed in May-June 1996.

The design flow for the wastewater treatment system is 9,000 gal/day. The system is composed of two septic tanks in series (6,000 gal and 3,000 gal), a recirculating gravel filter (RGF) with a 6,000 gal recirculation tank, and a subsurface drip irrigation system installed in three zones with a 6,000 gal dose/surge storage tank. The effluents are temporarily stored in the recirculation tank or dose tank, and the effluents are time-dosed to both the gravel filter and drip system. The precast, watertight tanks were obtained from Crest Precast in LaCrescent, Minnesota. The pre-treatment system, a recirculating gravel filter, was needed because the effluent was expected to have elevated levels of organic matter, solids, and oil & grease as a result of food preparation and cleaning associated with restaurant activities. The gravel filter was designed to lower the biochemical oxygen demand (BOD_5) of the wastewater to levels at, or below, the strength of typical domestic septic tank effluent.

Based upon a screening of wastewater treatment alternatives, and estimated construction costs, a subsurface drip irrigation system was chosen by the owners for final treatment and dispersal of wastewater in the soil. The PERC-RITE drip system from Waste Water Systems, Inc., Lilburn, Georgia, was the selected drip technology. The drip irrigation fields are located on a south-facing slope on a wooded hillside. The drip tubing was installed at a shallow depth in the soil (<3 inches) in three zones. Each drip zone is sequentially dosed with a specific volume of wastewater at timed intervals.

PERFORMANCE MONITORING

The wastewater treatment system was monitored by NRRI during the summers of 1996 and 1997. During this time, monitoring included multiple sample collection and recorded physical parameters which began in August 1996, after the system was more or less fully automated. In 1997, sample collection took place at approximately two week intervals. A total of 10 monitoring events were completed during this period.

Duplicate wastewater samples were collected at 3 locations in the system: 1) at the inflow of the "main" septic tank, 2) at the outflow of the "second" septic tank, and 3) at the outflow of the gravel filter. In 1996, grab samples were taken at all sampling locations. In 1997, composite samples were generally taken at the inflow to the septic tank (24-hour drip from a tee located on the forcemain), and at the outflow of the "second" septic tank (24-hour composite using an ISCO sampler).

At the time of sample collection, temperature and specific conductivity were measured using a YSI Model 33 S-C-T meter or a YSI Model 85 Multiprobe. The wastewater samples were collected, kept cool, and delivered to the Western Lake Superior Sanitary District (WLSSD) laboratory, or to the NRRI Central Analytical Laboratory, both certified by the Minnesota Department of Health. Biochemical oxygen demand (BOD_5), total suspended solids (TSS), fecal coliform bacteria, total phosphorus, and dissolved phosphorus were analyzed at the WLSSD laboratory using standard methods (APHA 1995). Nitrogen (total-N, ammonia-N, nitrate-N), pH, alkalinity, and oil & grease (O&G) were analyzed at NRRI using standard methods (APHA 1995, Ameel et al. 1993, Owen and Axler 1991). Due to the high cost of trichlorotrifluroroethane, a freon commonly used in O&G analysis but is no longer available at a reasonable price, EPA method 1664 for n-hexane extractable material (HEM) was developed as an alternative freon-free methodology for this study. Hexane is also one of the substitute solvents recommended in standard methods (APHA 1995).

At the time of sample collection, the general condition of the gravel filter and drip fields were observed. The gravel filter was inspected for clogging of the orifices on the distribution network and ponding at the surface. The drip fields were inspected for signs of hydraulic overload at the surface, including damaged drip tubing and manifold connections. At the end of each season, the drip tubing was partially exposed at several locations and visually inspected for signs of biomat development near the drip tubing. No sampling was done within the drip fields.

RESULTS

The temperature of the effluents (inflow=into the septic tank; STE=outflow from the septic tank or septic tank effluent; RGF=outflow from the recirculating gravel filter) ranged between 10-26 °C during the summers of 1996 and 1997 (Table 1). There were few differences between temperature of STE and RGF effluent. As expected, inflow temperatures were slightly cooler and more variable than the other effluent temperatures.

Table 1.--Temperature, conductivity, and pH at Burntside Lodge wastewater treatment system during two operating seasons in 1996 and 1997.

	Temperature (°C)			Conductivity (umhos/cm)			pH		
	Inflow[1]	STE	RGF	Inflow	STE	RGF	Inflow	STE	RGF
Mean	17.9	18.8	18.5	718	711	468	6.6	6.6	6.5
Median	17.5	18.9	18.7	716	701	456	6.6	6.5	6.3
SD	4.8	3.1	3.1	109	107	79	0.2	0.2	0.4
Min	10	13	12	543	545	378	6.3	6.4	6.1
Max	26	23	22	888	882	620	6.9	7.0	7.3
N	10	10	10	10	10	10	7	7	7

[1]Inflow is the wastewater that enters the first septic tank at the main facility, STE is septic tank effluent from the second septic tank, and RGF is the effluent from the recirculating gravel filter.

Specific conductivity is a method used to describe the total dissolved solids/ionized materials in wastewater. The average conductivity of the inflow and septic tank effluent was similar (~715 umhos/cm), ranging between 543-888 umhos/cm. The gravel filter effluent had a lower conductivity than either the inflow effluent or STE, with an average of 468 umhos/cm and a range between 378-620 umhos/cm. The lower conductivity of the gravel filter effluent indicates that ions in the wastewater were being assimilated by microorganisms thriving within the gravel filter. The pH of the effluents was typical of domestic wastewater with an average pH of 6.6, and ranging between 6.4-7.0 for the septic tank effluent and 6.1-7.3 for the gravel filter effluent.

The overall performance of the system, especially the gravel filter in removing organic matter and solids, was excellent. Inflow BOD_5 ranged from 178-760 mg/L, while BOD_5 of septic tank effluent ranged from 135-333 mg/L (Table 2). Typical untreated wastewater is reported to have a BOD_5 between 100-400 mg/L, with an average of 250 mg/L BOD_5 (Burks and Minnis 1994). The Burntside Lodge's wastewater fell within this range for BOD_5. The gravel filter effluent was typically very low (2-28 mg/L) in BOD_5, significantly less than the design BOD_5 of <100 mg/L. The gravel filter performed exceptionally well during both summers of operation, removing 90-99% of BOD_5 from septic tank effluent. Furthermore, in the drip fields, there was no indication of any biomat development at the drip tubing emitter/soil interface in either 1996 or 1997.

Table 2.--BOD_5, TSS and fecal coliform at Burntside Lodge wastewater treatment system during two operating seasons in 1996 and 1997.

	BOD_5 (mg/L)			**TSS (mg/L)**			**Fecal coliform bacteria[2] (MPH/100mL)**		
	Inflow[1]	STE	RGF	Inflow	STE	RGF	Inflow	STE	RGF
Mean	301	218	10	155	37	9	791,767	209,377	3,052
Median	247	20	6	55	30	3	840,000	210,000	4,600
SD	173	66	8	275	15	14	490,952	183,903	5,488
Min	178	135	2	29	18	1	330,000	61,000	300
Max	760	333	28	885	63	43	1,950,000	630,000	18,050
N	10	10	10	9	9	9	10	10	10

[1] Inflow is the wastewater that enters the first septic tank at the main facility, STE is septic tank effluent from the second septic tank, and RGF is the effluent from the recirculating gravel filter.
[2] Geometric mean.

The wastewater system also performed well in removing solids (TSS) before being applied to the soil for final polishing and dispersal. Inflow TSS averaged 155 mg/L (median only 55 mg/L), with TSS ranging between 29-885 mg/L. Typical TSS levels of untreated wastewater reported in the literature is 100-400 mg/L, with an average of 220 mg/L (Burks and Minnis 1994). The septic tank effluent had an average TSS of 37 mg/L, but it ranged between 18-63 mg/L. The gravel filter performed well in removing suspended solids from septic tank effluent, generally with a $>80\%$ reduction in TSS. The gravel filter effluent had a mean TSS of 9 mg/L, with a range between 1-43 mg/L TSS. Periodic spikes in TSS are expected to occur with a gravel filter and with other types of fixed-film media systems (i.e., sand filter/trickling filter). Intermittent 'sloughing' of the slime layer (zoogleal mass) in the gravel filter may occur as a function of hydraulic and organic loading and cool temperatures (EPA 1992). Higher levels of TSS occurred in the gravel filter effluent in September 1996, although this was not observed in September 1997. Overall, the recirculating gravel filter did an excellent job, generally achieving an effluent with an average TSS <10 mg/L.

The gravel filter was quite effective in removing fecal coliform bacteria, indicators of disease-causing organisms. The recirculating gravel filter removed 95-99% of fecal coliform bacteria from septic tank effluent at Burntside Lodge. Fecal coliform bacterial counts in the gravel filter effluent ranged between 300-18,050 MPN/100mL, with a mean of 3,052 MPN/100 mL. The soil provided final treatment and dispersal of the effluent through a system that incorporates timed-dosing of effluent to the soil through pressure compensating drip emitters placed in the most biologically active layer of the forest soil litter layer.

Total nitrogen (TN) content of the inflow ranged between 37-77 mg/L, with a mean of 48 mg/L (Table 3). In comparison, TN concentration of typical untreated wastewater ranges between 15-90 mg/L TN, with an average of 40 mg/L TN (Burks and Minnis 1994). Similar TN levels were measured in septic tank effluent at Burntside Lodge, ranging between 31-65 mg/L, with a mean of 43 mg/L of TN. Overall, TN was reduced to a fairly low level after passing through the gravel filter, ranging from 8-26 mg/L, with a mean of 16 mg/L TN.

Table 3.--Total nitrogen, ammonia-nitrogen, nitrate-nitrogen, and alkalinity at Burntside Lodge wastewater treatment system during two operating seasons in 1996 and 1997.

	Total Nitrogen (mg/L)			**Ammonia-Nitrogen (mg/L)**			**Nitrate-N (mg/L)**	**Alkalinity (mg/L)**		
	Inflow[1]	STE	RGF	Inflow	STE	RGF	RGF	Inflow	STE	RGF
Mean	48	43	16	36	34	3	10	153	153	40
Median	45	42	15	35	34	2	9			
SD	12	11	6	10	9	4	7	25	24	24
Min	37	31	8	25	24	0.4	2	124	134	20
Max	77	65	26	58	50	13	20	167	180	66
N	10	10	10	10	10	10	10	3	3	3

[1]Inflow is the wastewater that enters the first septic tank at the main facility, STE is septic tank effluent from the second septic tank, and RGF is the effluent from the recirculating gravel filter.

Most of the nitrogen in the inflow and septic tank effluent was in the form of ammonia-nitrogen, with negligible levels of nitrate-N (Table 3). Ammonia-N was within the range typical of domestic strength wastewater, ranging between 24-58 mg/L in the inflow and septic tank effluent, with a mean of ~35 mg/L ammonia-N. Low levels of ammonia-N, 3 mg/L, were discharged from the gravel filter, indicating that adequate oxygen levels were available for microorganisms to nitrify the effluent (change ammonia-N to nitrate-N). Lastly, relatively low nitrate-N levels were also discharged from the gravel filter, with an average nitrate-N concentration of 10 mg/L, and ranging between 2-20 mg/L nitrate-N. The drinking water standard for nitrate-N is 10 mg/L.

In 1996 and 1997, the septic tank/recirculating gravel filter components removed 40-75% TN, with an average TN reduction of 66%. Much of the nitrogen removal (~63%) was associated with the recirculating gravel filter. Nitrogen removal through denitrification occurs by routing aerobic effluent from the gravel filter back into the recirculation tank, where aerobic effluent mixes with anaerobic effluent (and a carbon source) from the septic tank, resulting in the gaseous loss of nitrogen to the atmosphere.

Inflow alkalinity was determined on a few samples, and it ranged between 124-167 mg/L. The alkalinity of untreated wastewater typically ranges between 50-200 mg/L (Burks and Minnis 1994). Alkalinity did not change appreciably after passing through the septic tanks, but it was reduced substantially after passing through the gravel filter. It does not appear that alkalinity limited the conversion of ammonia-N to nitrate-N, as it is estimated that ~7 mg alkalinity is needed to oxidize 1 mg ammonia-N to nitrate-N.

O&G summary results are shown in Table 4. The average inflow O&G level at Burntside Lodge was 104 mg/L, but it ranged between 26-631 mg/L. Typical O&G levels in untreated wastewater ranges between 50-150 mg/L, with an average of 100 mg/L (Burks and Minnis 1994). The septic tanks reduced O&G levels to an average of 25 mg/L, ranging between 15-41 mg/L. The gravel filter did an excellent job at removing most of the remaining O&G, down to an average level of 2.4 mg/L, and a range between 0.5-7.8 mg/L.

Table 4.--Oil & grease, total phosphorus and dissolved phosphorus at the Burntside Lodge wastewater treatment system during two operating seasons in 1996 and 1997.

	Oil & Grease (mg/L)			**Total P (mg/L)**			**Dissolved P (mg/L)**		
	Inflow[1]	STE	RGF	Inflow	STE	RGF	Inflow	STE	RGF
Mean	104	25	2.4	7.0	6.8	5.4	5.4	5.4	4.8
Median	34	25	1.1	7.0	6.6	5.2	5.3	4.9	4.4
SD	198	8	2.5	1.5	1.6	1.5	1.2	1.4	1.4
Min	26	15	0.5	5.1	4.9	3.8	3.7	3.9	3.4
Max	631	41	7.8	10.0	9.5	8.2	7.9	8.1	7.3
N	9	9	7	10	10	10	10	10	10

[1] Inflow is the wastewater that enters the first septic tank at the main facility, STE is septic tank effluent from the second septic tank, and RGF is the effluent from the recirculating gravel filter.

Inflow phosphorus levels (TP) ranged between 5-10 mg/L, with a mean of 7 mg/L (Table 4). Phosphorus levels were consistent with typical phosphorus levels (5-20 mg/L) found in untreated domestic wastewater (Burks and Minnis 1994). As expected, there was little reduction of phosphorus in the septic tanks, which had a mean phosphorus outflow of 6.8 mg/L. Even though the gravel filter was not designed to remove phosphorus, TP was reduced by an average of 20%, presumably through biological assimilation of organisms growing on gravel surfaces within the filter.

WASTEWATER FLOWS, SYSTEM OPERATION AND MAINTENANCE

Wastewater flows were monitored by the owners during the summer of 1996 and 1997. Flows were measured at both the fresh water intake (Burntside Lake is the drinking water supply for the resort) and at the water meter on the drip unit. In 1996, for a period of 91 days (July 20 through October 18), approximately 250,000 gal were pumped to the drip fields. In 1997, a daily log of flows was maintained by the owner, beginning in August 1997. During that time, effluent flow (timed-dosed) to the drip fields varied from a low of 1,800 gal/day to a high of 6,500 gal/day, significantly less than the design flow of 9,000 gal/day.

The system had a few 'bugs' to work out at the time of start-up, predominately related to automation of the drip unit itself. The owner is to be commended for doing an excellent job of inspecting, operating, and maintaining the system. In July 1997, a dead tree blew down and damaged a tee on a drip supply manifold laid on the ground surface. The zone was temporarily bypassed until the tee could be replaced. In August 1997, a power surge caused the drip unit to temporarily shut down, but it was re-started after inspecting the system. A visual alarm (light) that would alert the owner to a system shut down is planned to be installed at a more conspicuous location. Otherwise, the system was reliable and operated effectively.

The drip fields were inspected on a routine basis in 1996 and 1997. As previously described, no evidence of a biomat was found around the drip tubing. The general condition of the drip fields, after the first season of operation, was excellent. During the second season of operation in July/August, the understory vegetation appeared to have fully recovered from the disturbance associated with installation of the drip fields. A thick understory of vegetation was prominent on the drip fields in 1997, while maintaining the overstory of 100-year-old white and red pines.

SUMMARY AND CONCLUSIONS

The Burntside Lodge wastewater treatment system operated successfully in 1996 and 1997. Overall, performance of the system in removing pollutants from septic tank effluent was excellent. Average removal efficiencies and concentrations for the wastewater system (exclusive of the drip/soil component) were >95% for BOD_5 (10 mg/L), >90% for TSS (9 mg/L), >99% for fecal coliform bacteria (3,052 MPN/100ml), ~65% for TN (16 mg/L), ~20% for TP (5.4 mg/L), and ~97% for O&G (2.4 mg/L).

In the drip fields, there was no evidence of a biomat at the emitter/soil interface. The understory vegetation appeared to have fully recovered from the disturbance associated with installation of the drip system during the second season of operation, and the 100-year-old white and red pines were intact. Besides being a visually attractive alternative to an at-grade system at this location, the drip system was estimated to cost less and construction required only limited disturbance to the site. The drip system delivers pre-treated, aerobic effluent to the most biologically active layer of the soil, where final polishing and dispersal of the effluent are occurring successfully.

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