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Reuse of Municipal Wastewater by Volunteer Freshwater Wetlands

Vermontville, Michigan

INTRODUCTION

Vermontville is a rural community located 25 miles southwest of Lansing. The local maple syrup industry is active; each year a festival brings thousands of visitors to this community of 825 residents. Vermontville considers itself "the sweetest little town in Michigan." There is no evidence of the high growth and bustle of more urban areas; in fact the local Amish folk tie up their horses and buggies on Main Street. Mayor Beverly Sue Billanueva runs the town and its only restaurant.

The Clean Water Act of the early 1970's dictated that Vermontville upgrade its wastewater treatment capabilities. In common with many other small communities, Vermontville could not afford to own or operate a "high tech" physical-chemical wastewater treatment plant. But it was situated to utilize the land-intensive natural systems technology, and decided to do so. In 1972, they opted for facultative lagoons followed by seepage beds. Those seepage beds unexpectedly became wetlands, a system which works remarkably well and is liked by the operators.

Cover: Wetland number one is bordered by lagoons and Anderson Highway, and is in close proximity to an operating farm. Cattails dominate the vegetation, with a few willow shrubs in evidence. Late summer senescence is in progress, the cattails are beginning to turn brown.

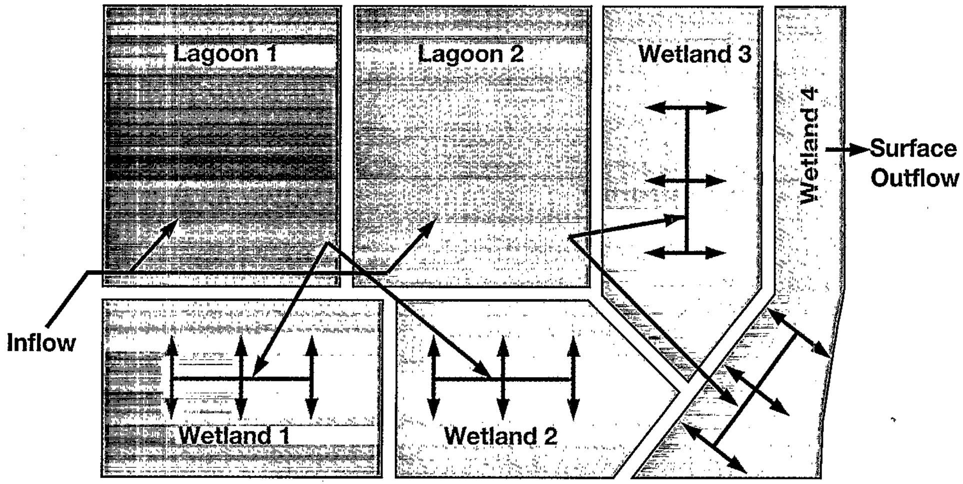


Figure 1. *Layout of the Vermontville wastewater treatment system. Inflow may be directed to either of the two lagoons. The lagoons are discharged into wetlands 1-3. Wetland 4 no longer receives a direct discharge; but seepage water from the uphill units re-emerges into wetland 4.*

System Description

The municipal wastewater treatment system at Vermontville, Michigan consists of two facultative stabilization ponds of 10.9 acres (4.4 ha), followed by four diked surface (flood) irrigation fields of 11.5 acres (4.6 ha) constructed on silty-clayey soils. The system is located on a hill with the ponds uppermost and the fields at descending elevations (Figure 1). After 1991, the nineteenth year of operation, the fields are totally overgrown with volunteer emergent aquatic vegetation, mainly cattail. The system was designed for 0.1 MGD and a life of twenty years. It is presently operated at about three-quarters of design capacity.

The Vermontville system was intended, in the conceptual stages, to provide phosphorus removal both by harvesting of terrestrial grasses and by soil-water contact as wastewater seeps downward from the irrigation fields. Up to four inches of water applied over several hours time once each week would flood the fields briefly until the water seeped away. The upper pond (Lagoon 1, Figure 1), has separate discharge lines into fields 1 and 2, and the lower pond (Lagoon 2) has separate discharge lines into fields 3 and 4. Fields 1-4 have all been colonized by volunteer wetland vegetation, and are now eutrophic emergent marshes.

Pond-stabilized wastewater is released into each wetland by gravity flow through 10-in. (0.25 m) main and 8-in (0.2m) manifold pipe having several ground level outlets in each wetland. The lagoons and wetlands are terraced on a steep hillside (Figure 2), providing ample driving force for gravity flow. Should the water level exceed 6 in. (15.2 cm), water would overflow to the next wetland by means of standpipe drain. All applied water would seep into the ground before leaving the treatment area.

The system is operating nearly in this manner today. There is a constant surface overflow from the final wetland, made up of ground-recycled wastewater which enters the final field at springs. The direct surface overflow from wetland 3 has been taken out of service. Essentially, the system is a seepage wetland complex and very similar to a conventional flood irrigation facility. The vegetation and relatively small surface overflow from the final wetland provides an established system in which to evaluate the treatment aspects of seepage combined with lateral flow-through wetlands, the potential nutrient removal and wildlife values of these strictly voluntary wastewater wetland, and the economics of the system.

A thorough study of water quality and other aspects of system was conducted in 1978, by Dr. Jeffrey Sutherland of Williams and Works and Professor Frederick Bevis of Grand Valley University. This work was sponsored by The National Science Foundation.

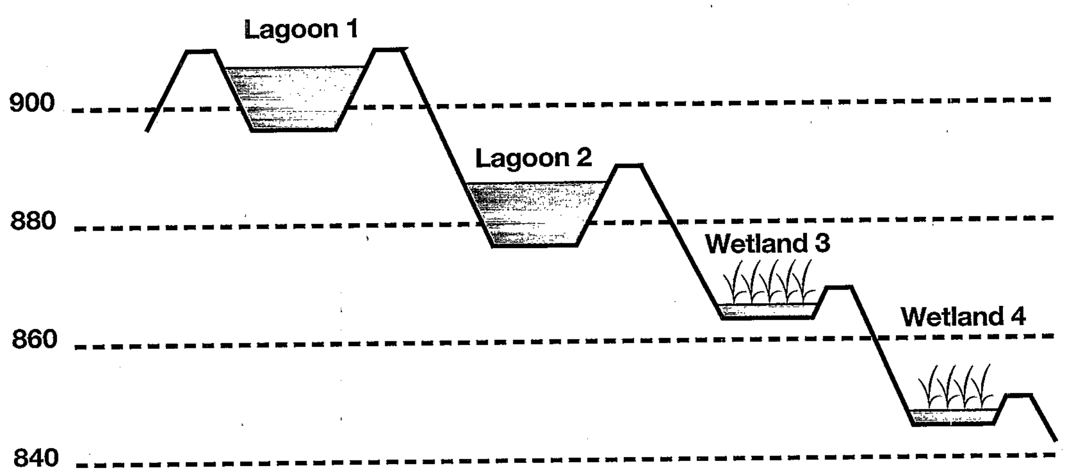


Figure 2. *Cross section of the Vermontville wastewater treatment system. The units are set on a steep hillside, with large driving forces for the gravity flow from lagoons to wetlands. Elevations shown on the left are in feet above sea level. Overflow occurs out of wetland 4 to the right.*

HYDROLOGY

During 1990, approximately 29 MG of wastewater was introduced into the lagoons. This was a dry year. Evaporation exceeded rainfall and snowmelt, leaving only about 22 MG to discharge to wetlands 1, 2, and 3. There was no lagoon discharge to wetland 4. About 7 MG were lost to evaporation in the wetland cells, 13 MG infiltrated to groundwater, and 2 MG overflowed from wetland 4 to the receiving stream.

Wetland 4 receives its water from interior springs fed by the groundwater mound under the upgradient wetlands, most importantly wetland 3. The direct discharge to wetland 4 was discontinued, since it was in close proximity to the system outflow point, and was clearly short-circuiting water across wetland 4. Effluent discharged from the system has therefore passed through the lagoons, then through the upper wetlands, the soils under the site, and finally through the last wetland.

PERMITS

The facility operates under an NPDES Permit issued by Michigan DNR. The outflow from wetland 4 is to an unnamed tributary of the Thornapple River, which is protected for agricultural uses, navigation, industrial water supply, public water supply at the point of water intake, warm water fish and total body contact recreation. There are presently no industrial dischargers. The discharge limitations from the treatment wetlands (Table 1) are set for a design flow of 0.1 MGD. Discharge is limited to the ice free high flow periods from May 1–October 31.

Table 1. Discharge limitations for the Vermontville wastewater treatment facility.

Parameter	Dates	Daily Minimum	Daily Maximum	30-Day Average	7-Day Average
CBOD5	4/15-4/30		25 mg/l	17 mg/l 14 lb/d	21 lb/d
	5/1-9/30		10 mg/l	5 mg/l 4.2 lb/d	8.3 lb/d
	10/1-10/31		16 mg/l	11 mg/l 9.2 lb/d	13.3 lb/d
TSS	4/15-4/30			20 mg/l	30 mg/l
	5/1-10/31			30 mg/l	45 mg/l
NH4-N	4/15-4/30			7 mg/l	
	5/1-9/30			2.2 mg/l	
	10/1-10/31			5 mg/l	
TP	All Year			1.0 mg/l 0.83 lb/d	
DO	4/15-4/30	5 mg/l			
	5/1-9/30	6 mg/l			
	10/1-10/31	5 mg/l			
pH	All Year	6.5	9.0		

Compliance Monitoring

The overflow from final wetland field 4 contains a fairly constant volume of effluent which has seeped from the higher elevation wetlands, flowed through the ground, and entered field 4 springs. This treated effluent is of high quality, as is the ground water recovered from the project's monitoring wells.

The outflow is monitored weekly. Total suspended solids (TSS) was well within permit limits at all times during 1990 (Figure 3), indicating that the wetlands had effectively filtered and settled particulate material.

Carbonaceous biological oxygen demand (CBOD) also remained within 30-day average permit limits in 1990, and there was only one excedance of the seven-day permit limit of 5 mg/l. The CBOD load in the surface discharge was less than 10% of that allowed by the permit.

Total phosphorus in the surface discharge was also well within permit limits, with an average 1990 value of 0.24 mg/l compared to the permit level of 1.0 mg/l (Figure 4). The same was true for ammonium nitrogen, which averaged 0.86 mg/l compared to the 2.2 mg/l permit requirement. Both phosphorus and nitrogen display considerable variability, which is characteristic of many wetland systems. The seasonal trends in ammonium nitrogen—an increase followed by a decrease—have been observed at other sites, and are therefore probably real. They are likely due to the changing processes of plant uptake and decomposition.

Figure 3. Both CBOD and TSS fluctuate in the outflow from the wetlands, but the seasonal averages are quite low; 3.5 mg/l for CBOD; 4.2 mg/l for TSS. (Data are for 1990)

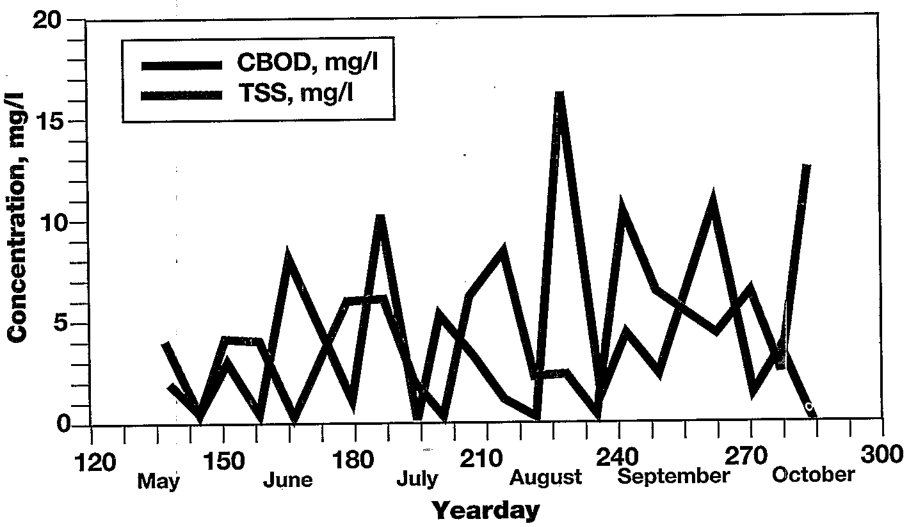
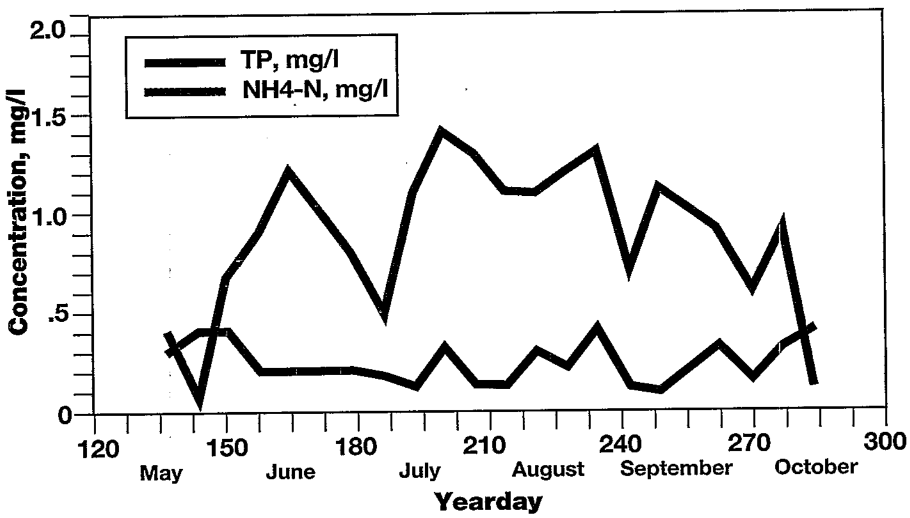


Figure 4. The nutrients phosphorus and ammonium nitrogen were well within limits in the wetland outflow in 1990. The seasonal average total phosphorus was 0.24 mg/l; ammonium nitrogen averaged 0.86 mg/l.



Dissolved oxygen averaged 7.0 mg/l in 1990, with a range from 5.4 to 9.4, which included a four excedances of minor nature. pH ranged from 6.6 to 7.2, well within the permit range.

Fecal coliform counts (Figure 5) are within limits for surface water discharges, but are higher than at other comparable wetland sites.

Research Results

Some of the more detailed water quality results for 1978 are summarized in Figure 6. Greater than two-fold dilution across the system was evident in the decreasing chloride concentration from 280 mg/l in the effluent to 124 mg/l in the ground water. Pond effluent was 25% diluted with respect to influent. Although a few inches of precipitation in excess of evaporation from the ponds occurred during the summer, the 25% dilution was more importantly due to excessive snow and ice meltwater added to the ponds in spring 1978. The 25% dilution between the pond effluent and the water standing in the wetlands was due principally to a large number of sampling dates coinciding with significant rainfall. Greater than 20 inches (50.8 cm) of rain fell in the 4½ months from June to mid October, which was approximately 50% higher than the normal rate. The decrease in concentration between irrigation fields and ground water was due to mixing of wastewater with more dilute ambient ground water.

Phosphorus was removed to the extent of around 97% between the wetland fields and the ground water, which was sampled from monitoring wells placed at depths ranging from roughly 10 ft. to 25 ft. (3.0 m to 7.6 m) below the wetland floors. Most removal of phosphorus occurs in the upper 3 ft. (0.9 m) of soils judging from a small number of lysimeter samples which averaged 0.11 mg/l total P and 0.06 mg/l ortho-P, with ranges of 0-0.3 mg/l and 0-0.2 mg/l, respectively. The average removals of phosphorus effected in the upper 3 ft. (0.9 m) of soils were approximately 95%.

Levels of nitrate-nitrogen increased approximately 60% between the pond discharge and the wetland standing water, indicating that aerobic bacteria were at work in the wetland waters. On the other hand, the sediments were anaerobic as evidenced in the fetid odor which evolved when they were disturbed. Loss of some of the nitrate by denitrification was apparently

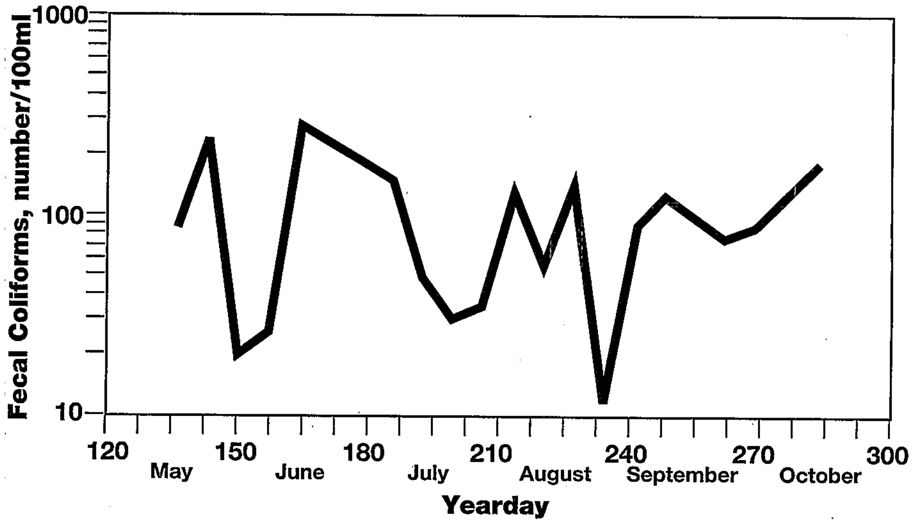


Figure 5. Fecal coliform bacteria counts also fluctuate in the outflow from the wetlands, but the seasonal average is quite low; the geometric mean value was 77. (Data are for 1990)

occurring. Lysimeter samples showed nitrate-nitrogen ranging from 0.0 to 0.9 mg/l, which suggested that denitrification of approximately 60% of the nitrate occurred in the shallow wetland soils. The ambient ground water contained higher levels of nitrate-nitrogen than did the seeping wastewater, perhaps indicating some further nitrification during passage through the soil.

Levels of TKN and ammonia-nitrogen seemed not to change much between the pond discharge and the wetland waters. But this constancy was likely only apparent, with organic nitrogen and ammonia probably being produced through anaerobic decomposition in the wetland sediments and being consumed in the aerobic wetland waters.

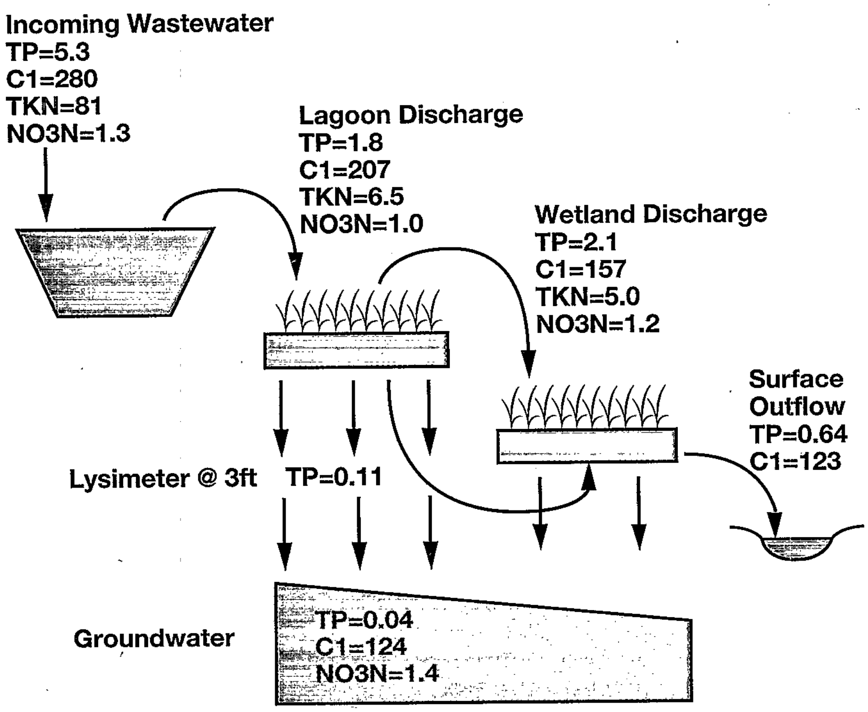


Figure 6. Profiles of water quality in 1978. Lagoons and wetlands and soils are functioning to remove nutrients in this system. During the early life of the facility, there were lagoon discharges directly to wetland 4; and there was surface overflow directed from wetland 3 to wetland 4. This resulted in some short-circuiting to the surface outflow, and consequently higher phosphorus numbers than in the present mode of operation.

VEGETATION

The wetlands were observed to contain eight plant communities in 1978. These included areas dominated by grassland, duckweed, cattail and willow. In 1991, the grassland and duckweed communities were no longer significant. The wetlands are now dominated entirely by cattail and willow shrubs and trees.

Standing crops (above ground plant parts) for the wetlands varied from a minimum of 830 to over 2,200 gm/m2 in the wetlands in 1978. Visual estimates in 1991 indicate that the standing crops are presently somewhat higher than that maximum, and more uniform. There appears to be approximately 3,000 gm/m2 at all locations, not counting trees. Because the wetlands are located on an exposed hillside, winds can and do blow down the cattails. The result is a patchy stand of cattail, about three meters in height where it is erect, and flat on the surface elsewhere.

The phosphorus in the prevailing cattail standing crop is significant compared to the phosphorus released into the wetlands. Cattail harvesting would therefore be a means of reducing effluent phosphorus. But harvesting is not needed for phosphorus removal in seepage wetland settings where sub-surface soil types and volumes are adequate to effect phosphorus removal before effluent ground water reaches receiving streams. The expense and difficulty of harvesting further preclude its use at Vermontville.

WILDLIFE

Casual observation reveals the wastewater-grown wetlands have significantly added to the acreage of suitable, adequately isolated habitat for waterfowl and other wildlife in the Vermontville area. Natural, interrupted zones of attached aquatic plant life fringe the nearby Thornapple River, but these are narrow, small and easily accessible to fisherman and other recreationists. The wastewater wetlands are part of a restricted public access area.

The Vermontville volunteer wetland system created marshland habitat suitable for waterfowl production otherwise not present in the immediate area. Many other types of birds also nest in the marshes, including red-wing blackbirds, American coot, and American goldfinch. Waterfowl (blue-winged teal and mallard), shorebirds (gallinule, killdeer, lesser yellow-legs, and sandpiper) and swallows use the wetland pond system for feeding and/or resting during their migration. Great blue heron, green heron, ring-neck pheasant, and American bittern have also been seen frequenting the wetlands.

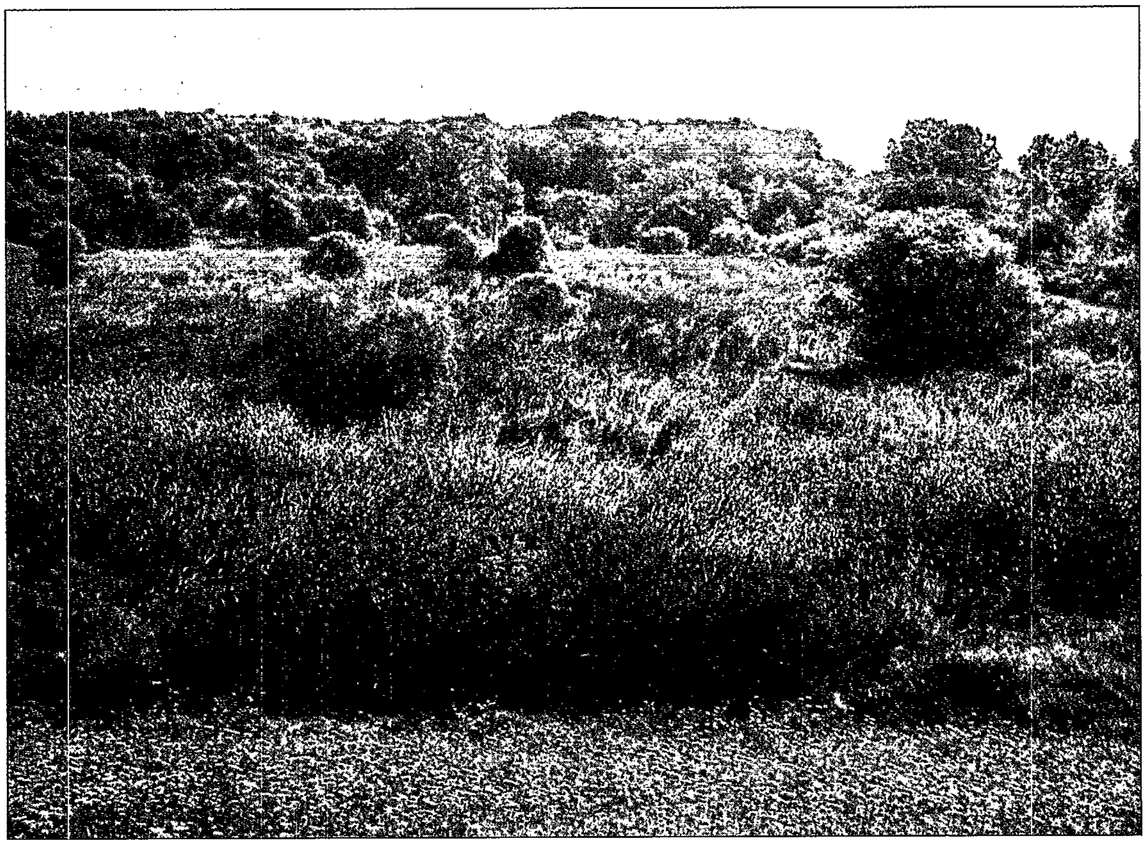
These volunteer wetlands are also important habitat for numerous amphibians and reptiles. These include snapping and painted turtles, garter and milk snakes, green and leopard frogs, bullfrogs and American toads. Muskrats inhabit the wetlands, while raccoon, whitetail deer, and woodchuck are seen feeding in the wetlands.

OPERATING AND MAINTENANCE ACTIVITIES

Very little wetland maintenance has been required at Vermontville. The berms are mowed three or four times per year, for aesthetic reasons only. Water samples are taken on a weekly frequency at the surface outflow. The discharge risers within the wetlands are visited and cleaned periodically during the irrigation season. There is essentially nothing to be vandalized, and there have been no repairs required.

The dikes are monitored for erosion, which has not been a significant problem. Muskrats build lodges and dig holes in the dikes; and woodchucks also dig holes in the berms. Therefore, a trapper is allowed on the site to remove these animals periodically. The operator also periodically tears the muskrat lodges apart.

There are no bare soil (tilled) areas to be plugged through siltation caused by rain splash, spray irrigation, or flood-suspension of inorganic soils. The Vermontville wetlands showed buildup of three or four inches (0.1 m) or organic residues largely in the form of cattail straw after six irrigation seasons (1972-78). That litter mat is still of the same thickness today, but is accompanied by a small accretion of new organic sediments and soils. There was one attempt to burn the accumulated detritus, which proved to be difficult, and of no value in the system operation or maintenance. The amounts of this material have not compromised the freeboard design of the embankments over the system's 19+ year operational period. Tree control has not been practiced at Vermontville, and the wetlands now contain willow trees up to several meters in height. No hydraulic problems have been experienced due to these trees, or any other cause.



Wetland number two contains more and larger willows. Together with the narrow leaved cattail, these two species dominate the wetland.

COSTS

The Vermontville ponds and wetlands cost $395,000 to build in 1972. Much of this expense was incurred for grading, because of the uneven topography of the site.

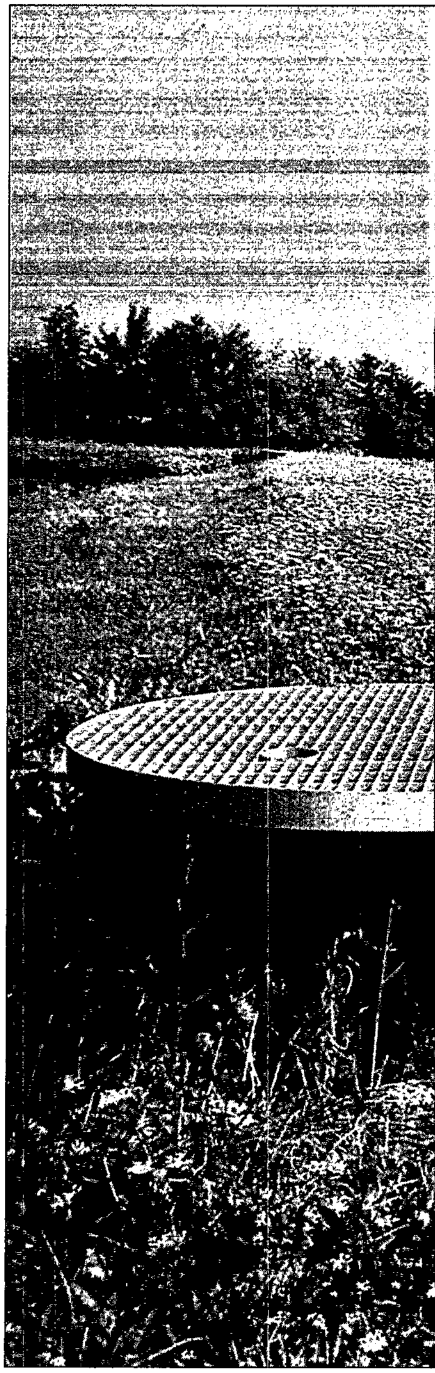
The operating and maintenance costs associated with the wetlands portion of the treatment system are quite low. In 1978, these were approximately $3,500 per year, of which $2,150 was labor and field costs, and the balance for water quality analytical services. In 1990, these same costs totalled about $4,200, including $3,400 for labor and field costs.

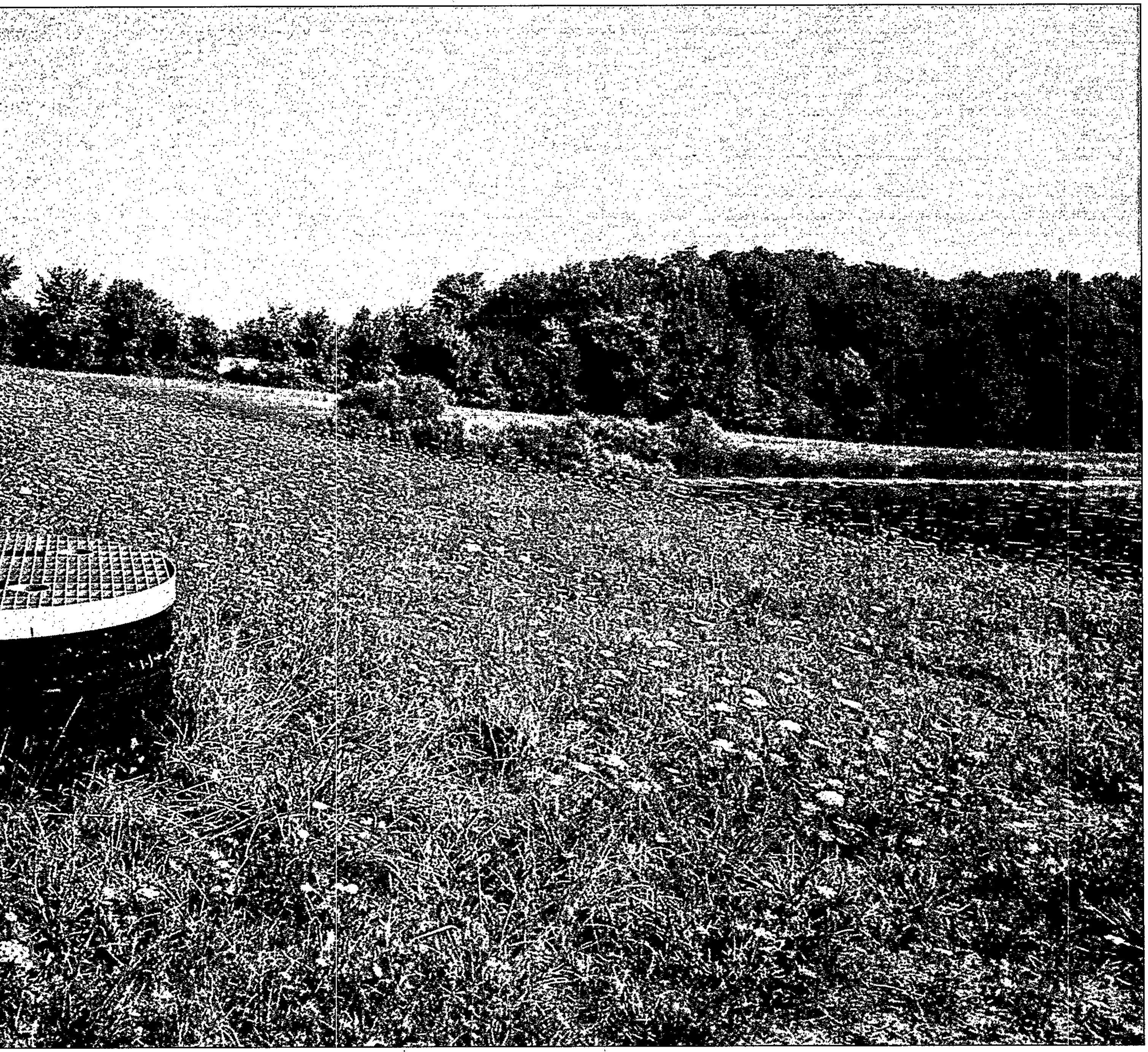
CONTACTS

The treatment system is under the supervision of Mr. Tony Wawiernia, Superintendent, Department of Public Works, 121 South Main Street, Vermontville, MI 49096. Phone (517) 726-1429.

The designers and engineers for this facility were Williams and Works, Inc., 611 Cascade West Parkway S.E., Grand Rapids, MI 49506. Phone (616) 942-9600.

Professor Fred Bevis visits the site with his students on a regular basis, and collects information on vegetation and other aspects of the ecosystem. Fred is Chairman of the Department of Biology, Grand Valley State University, Allendale, MI 49401. Phone (616) 895-3126.





The ponds at Vermontville are set into a hillside that drops off more than 70 feet. This view of lagoon 2 shows the high and wide berms that this relief necessitates. In late summer, these are covered with a profusion of wildflowers.

FURTHER INFORMATION

The 1978 research work is detailed in a report to The National Science Foundation under Grant No. NSF ENV-20273, May 1978. This report is available from the National Technical Information Service. Conference reprints summarizing the work were prepared, and may be obtained by contacting Professor Bevis:

Applied Ecology Group
11628 104th Ave.
West Olive, MI 49460-9632

Sutherland, J. C. and F. B. Bevis, 1979. *Reuse of Municipal Wastewater by Volunteer Fresh-Water Wetlands.* *IN*: Proceedings of Wetland Reuse Symposium, Vol. 1, p. 762-781. AWWA Research Foundation, Denver, CO.

Bevis, F. B., 1979. "Ecological Considerations in the Management of Wastewater-Engendered Volunteer Wetlands," presented at the Michigan Wetlands Conference, MacMullan Center, Higgins Lake, MI.

A brief summary description also may be found in:

Sutherland, J. C., 1982. "Michigan Wetland Wastewater Tertiary Treatment Systems," Chapter 16 in: *Water Reuse,* E. J. Middlebrooks, ed., Ann Arbor Science Publishers, Inc., Ann Arbor, MI.