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Release of Nutrients from On-Site Wastewater Disposal Systems, Point Pelee National Park, Ontario, Canada

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MANAGEMENT PERSPECTIVE

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EC Priority/Issue: This work was conducted as part of a larger study on the water quality of the Point Pelee coastal barrier bar/wetland complex funded by Parks Canada, and by the GL2000 program. The work supports the ESD issue "Conserving Canada's Ecosystems" (nutrients and wetlands). It supports the business plan deliverable Thrust #1 under Conserving Canada's Ecosystems (nutrient loading, great Lakes coastal wetlands). Under EC Action Plan, the work supports the action item "Conserving Canada's Ecosystems" with the focus "Understand the impacts of human activities on ecosystems; develop and implement strategies to conserve ecosystems".

Current Status: This paper provides an overview of hydrogeological and geochemical studies conducted to determine the fate of wastewater derived nutrients in the shallow sand aquifer at Point Pelee. Point Pelee National Park relies on tile beds for wastewater treatment for over 500,000 park visitors annually. The groundwater chemistry was monitored in the vicinity of two active tile beds, a recently decommissioned tile bed and a site which last received sewage input two decades ago. Large plumes of nutrient-rich groundwater were observed downgradient of the tile beds. The transport of nitrate, phosphate and ammonia was observed to be closely related to redox zones developed within the plumes. At the decommissioned site, nitrate and ammonia concentrations increased, but phosphate concentrations remained unchanged. At the oldest site, elevated concentrations of ammonia and phosphate were present in the vicinity of locations of past sewage release.

Next Steps: Groundwater monitoring at the recently decommissioned tile bed will continue to monitor the long-term fate of sewage-derived nutrients at this site. The results will assist in evaluating the persistence of nutrient plumes in the groundwater zone after tile bed abandonment.

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Abstract

Point Pelee National Park relies on the use of on-site methods to dispose of wastewater generated in the Park. The Park is located on the southern half of a 15 km long cuspate, consisting of two narrow barrier bars and a large interior protected marsh. There are more than 30 active tile beds, excavated directly into the native sands of the western barrier bar. These tile beds receive wastewater from more than 0.5 million day-visitors each year. Past methods of sewage disposal for up to one million day-visitors each year included direct disposal to the barrier bar, the use of holding tanks, and dispersed discharge through tile lines. Because of limited land mass, wastewater disposal often occurred close to the marsh. At two recent tile-bed sites, located within 60 m of the marsh, concentrations of NO_3 between 1 and 80 mg/L (as N) are present more than 40 m from the tile beds. In reducing zones at the marsh edge and at the base of the aquifer, bacterial denitrification processes lead to the removal of NO_3 to concentrations < 0.01 mg/L N. Phosphate concentrations approach 3 mg/L P up to 10 m from the tile beds, and 0.1 - 1 mg/L P in a reducing zone at the base of the aquifer up to the marsh edge. Elevated concentrations of NH_3 are present more than 60 m from the tile beds. At a site which last received sewage input two decades ago, NO_3 is absent, but elevated concentrations of PO_4 and NH_3 are present in the groundwater zone close to the marsh edge. Monitoring at the groundwater/marsh interface indicates that nutrient-rich groundwater is seeping into the marsh for most of the year. The

eutrophic conditions observed in several marsh ponds adjacent to the barrier bar are attributed to PO_4 release from recent and past on-site wastewater disposal practices.

Introduction

The Point Pelee marsh is a major protected coastal wetland located on the north shore of Lake Erie (Figure 1). Several ponds within the marsh experience prolific algal blooms as a result of excess nutrient concentrations (total P > 0.3 mg/L) in the marsh water column (McCrea, 1993). At the end of the growth cycle, the biomass dies, settles to the marsh bottom, and decay processes begin. Mayer et al. (1998) reported elevated concentrations of nutrients in the upper 30 cm of marsh sediments below a hypereutrophic marsh pond. These nutrients, released from anaerobic decay processes, occur as dissolved phosphate and ammonia in interstitial pore waters and as accumulated phosphate solids. A portion of these nutrients reenter the water column and are available for renewed algal growth.

This study was conducted to determine whether input of sewage-derived nutrients is a potential cause of the elevated nutrient concentrations observed in the marsh ponds and sediments. Point Pelee National Park, like many parks in Ontario, relies on the use of septic-tanks and tile-bed leach fields to dispose of sewage generated in the Park. Sewage released to the subsurface from tile beds typically leads to the development of plumes of groundwater which contain elevated concentrations of nutrients and other dissolved constituents. These plumes are often many 10's of meters in length, and, in some cases, discharge to surface water bodies.

At Point Pelee, there are more than 30 active tile beds, including conventional and raised beds, installed in the western barrier bar of the Park (Figure 1). These tile beds receive wastewater seasonally or year-round from comfort stations, the visitor's centre and Park support buildings. The Park receives approximately 0.5 million visitors each year. In the 1950's and 60's, the number of visitors to the Park was higher, approaching 1 million visitors each year. There were also a number of private dwellings which have been removed through a land acquisition and naturalization program.

The presence and persistence of sewage-derived components in the subsurface was evaluated by conducting hydrogeological studies at active tile beds, a tile bed which had been decommissioned for two years, and a site which last received wastewater more than two decades ago. Measurements of groundwater seepage and nutrient transport directly into the Point Pelee marsh were also made. These measurements assist in the determination of the current rate of release of nutrients to the marsh, and the potential for future release as a result of ongoing discharge of sewage.

Study Methods

Networks of stand-pipe and multilevel bundle piezometers were installed at the Blue Heron and Camp Henry active tile bed sites, and the formerly used Marsh - Boardwalk site (Figures 1 and 2). The Blue Heron tile bed receives about 10,000 L/day of blackwater year-round from a visitor comfort station. It was installed around 1980. The Camp Henry "old" tile bed received blackwater seasonally from an overnight camp for about 17 years. It was sampled while it was active, and two years after it was decommissioned. The Marsh-Boardwalk area had a number of cottages and other buildings, vault toilets, and possibly a tile bed. Buildings at the site were removed and wastewater disposal in the area ceased in the late 1970's. Samples of groundwater were collected from more than 300 locations at the three sites and analysed for concentrations of nutrients (NO_3, NH_3, PO_4, and DOC), major ions, and trace metals, and field pH, Eh, alkalinity and temperature. Groundwater flow directions and rates were measured at the groundwater/marsh interface using nests of minipiezometers and seepage meters (Figure 2).

Active Tile Beds

The composition of effluent entering the active beds is typical of blackwater. It contains elevated concentrations of dissolved organic carbon (DOC), nitrogen, phosphorous, and pathogens (Table 1). When effluent is discharged to tile beds and allowed to infiltrate to the subsurface, a series of reactions occurs. In the unsaturated zone above the water table, DOC and ammonia (NH_3) are oxidized to carbon dioxide and nitrate (NO_3). Organic phosphorous and phosphate (PO_4) are removed through adsorption and precipitation reactions, and pathogens are removed through a variety of physical and chemical processes. If the residence time in the unsaturated zone is sufficient, large declines in concentrations of DOC and ammonia are observed, and some removal of PO_4 and pathogens occurs. Wastewater entering the saturated zone, however, typically has elevated concentrations of NO_3 and PO_4, and potentially elevated concentrations of NH_3, bacteria, viruses and trace contaminants.

At the active sites instrumented, elevated concentrations of NO_3, PO_4 and NH_3 were observed in the groundwater below and adjacent to the tile beds (Figures 3 and 4) (Ptacek et al., 1994; 1997; Ptacek, 1998). At the Blue Heron tile bed, concentrations of NO_3 ranged between 1 and 30 mg/L (as N) in a plume that extends more than 40 m from the edge of the bed. At Camp Henry, concentrations of NO_3 were higher, ranging between 1 and 80 mg/L in a plume that extends more than 40 m from the edge of the "old" bed. These concentrations are well in excess of the WHO drinking water guideline of 10 mg/L NO_3-N. At both sites, in reducing zones at the marsh edge and at the base of the aquifer, bacterial denitrification processes result in the removal of NO_3 to concentrations < 0.01 mg/L N. At both sites, concentrations of NH_3 are elevated to distances more than 60 m from the tile beds. These elevated concentrations of NH_3 suggest oxidation of the septic tank effluent was incomplete during its transport through the unsaturated zone. Phosphate concentrations exceed 1 mg/L P up to 10 m from both beds. At the base of the aquifer at both sites, in a reducing zone, concentrations of PO_4-P range between 0.1 - 1 mg/L, up to the marsh edge. These concentrations represent a large decline from approximately 5 - 10 mg/L in the original effluent (Table 1). The large volume of groundwater containing concentrations > 0.1 mg/L P, however, represents sufficient PO_4 to be of concern if discharged to surface water bodies. Similarly, elevated concentrations of NH_3 represent a potential input of N into the marsh.

Recently-Decommissioned Tile Bed

In 1995, wastewater discharge at the Camp Henry site was switched to a new "raised" tile bed to enhance oxidation of the wastewater. The plume at the "old" tile bed was sampled two years after input had been terminated to evaluate the rate of dissipation of the sewage at the site. This sampling showed large declines in concentrations of NO_3 and NH_3, but virtually no change in PO_4 concentrations (Figure 4). Analyses of PO_4 conducted on core material collected from the site while sewage disposal was active indicated substantial accumulations of PO_4 were present on the aquifer solids. The elevated concentrations of PO_4 in the groundwater are consistent with release of PO_4 into the flowing groundwater from these earlier accumulations on the aquifer solids.

Formerly-Developed Area

At the site where records show the presence of vault toilets, numerous buildings, and possibly a tile bed, elevated concentrations of PO_4 and NH_3 are present in the groundwater zone (Figure 5, NH_3 not shown). Very high concentrations of PO_4 (1-2 mg PO_4-P) were observed in isolated pockets close to locations of earlier discharges (Thompson et al., 1997). There are also very high concentrations of PO_4 in isolated pockets along the edge of the marsh (> 8 mg/L PO_4-P), close to the former location of a vault toilet.

The natural anaerobic degradation of organic matter results in the release of PO_4 and NH_3 into groundwater. The elevated concentrations of nutrients observed close to the marsh may be a result of this natural process or as a result of past wastewater release to the subsurface. The highest concentrations were observed close to wastewater release sites. Elsewhere along the groundwater/marsh interface concentrations are much lower than in this zone where previous releases where known to have occurred. These results suggest that the elevated concentrations observed along the marsh edge away from the sewage disposal areas are a result of the degradation of natural organic matter, and the higher concentrations the result of residual sewage. Therefore, it appears that even after 20 years, there is the potential for sewage-derived PO_4 and NH_3 to persist in the groundwater zone.

Discharge into Marsh

Hydraulic head and seepage meter measurements indicate groundwater flow is directed into the marsh for most of the year. For example, in May 1996 groundwater was observed to be discharging into the marsh at a rate of 0.02 and 0.13 litres/m^2/day (Ptacek et al., 1997). Even higher discharge rates are expected to occur during periods of high infiltration (spring melt, autumn rains) or in response to large declines in the elevation of the marsh.

Implications

The results from the sampling at the active tile beds indicate that elevated concentrations of NO_3, NH_3, and PO_4 are present in the groundwater zone as a result of recent sewage discharge to the subsurface. Sampling at the site two years following decommissioning indicates concentrations of NO_3 and NH_3 declined, but high concentrations of PO_4 remain. At a location where sewage release ceased two decades ago, concentrations of PO_4 and NH_3 are elevated, suggesting there is a long-term potential for nutrient persistence.

Geochemical monitoring at the marsh interface shows elevated concentrations of nutrients are in the groundwater zone close to the marsh edge and in the bottom sediments of the marsh ponds. Hydraulic head measurements show groundwater flow is directed toward the marsh for most of the year. Groundwater seepage measurements indicate seepage of groundwater into the marsh for most of the year.

Many Parks in Ontario rely on subsurface disposal of wastewater. Groundwater plumes emanating from these sites typically contain elevated concentrations of nutrients. These plumes can discharge into surface water bodies increasing the nutrient pool. After tile bed abandonment, release of phosphate from previously accumulated solid-phases can lead to additional release to surface water bodies.

Sewage effluent typically contains between 5 and 15 mg/L P and loadings of 10,000 L/day are common at large Park comfort stations. These comfort stations operate for many decades, therefore the total phosphorous released can be on the order of 100's to 1000's of kg over the life of a bed. Typical groundwater concentrations of PO_4 are in the range of 0.1 to 3.0 mg/L P. Even if only a portion of this phosphorous is eventually leached at these concentrations, the loadings can be sufficiently large to cause a significant increase in the nutrient pool of marsh ponds. Once nutrients are present in the marsh water column and sediments, a portion will be buried, but a portion can also be regenerated each year for renewed biomass growth.

Acknowledgements

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References

Mayer, T., Ptacek, C.J., Zanini, L., 1998. The role of sediments in nutrient dynamics in hyper-eutrophic marshes of Point Pelee, Ontario, Canada. Water Res., in submittal.

McCrea, R., 1993. An Assessment of the Trophic Status of the Point Pelee Marsh, Environmental Quality Branch Inland Waters Directorate, Ontario Region, 16 pp.

Ptacek, C.J., 1998. Geochemistry of a septic-system plume in a coastal barrier bar, Point Pelee, Ontario, Canada. J. Contam. Hydrol., in press.

Ptacek, C.J., Blowes, D.W., Robertson, W.D. and Baker, M.J., 1994. Adsorption and mineralization of phosphate from septic system effluent in aquifer materials. Proc.

Waterloo Centre for Groundwater Research Annual Septic System Conference, Waterloo, Ontario, June 6, 1994, pp. 26-44.

Ptacek, C.J., Crowe, A.S., and Durham, L., 1997. Groundwater transport of wastewater nutrients at a coastal barrier bar, marsh complex, Point Pelee, Ontario, Canada. Proc. Waterloo Centre for Groundwater Research Annual Septic System Conference, May 5, 1997, Waterloo, Ontario, pp. 54-69.

Thompson, D., Mouland, G., Ptacek, C.J., Crowe, A.S., 1997. The effect of past land use on groundwater nutrient concentrations, Point Pelee National Park, Ontario, Canada, Proc. Waterloo Centre for Groundwater Research Annual Septic System Conference, May 5, 1997, Waterloo, Ontario, pp. 132-143.

Table 1. Composition of septic-system effluent collected from Camp Henry and Blue Heron holding tanks, May, 1996.

Parameter	Concentration	
	Camp Henry	Blue Heron
NO_2+NO_3 (mg/L as N)	0.05*	<0.05
NH_3 (mg/L as N)	97.9	36.4
P, total (mg/L)	11.8	4.12
DOC (mg/L)	31.8	34.7

* Concentration equal to analytical detection limit

Figure 1. Map of Point Pelee, Ontario, showing locations of western barrier bar, interior marsh, and Blue Heron, Camp Henry and Marsh-Boardwalk sites.

Figure 2. Schematic diagram showing instrumentation techniques used in this study.

Figure 3. Concentrations of nitrate, ammonia and phosphate in groundwater near the Blue Heron active tile bed. At the time of sampling, the bed had been in operation for 18 years.

Figure 4. Concentrations of nutrients in the groundwater near the Camp Henry tile bed. The bed was active for 16 years at the time of sampling.

Figure 5. Concentrations of nutrients in the groundwater two years after the Camp Henry tile bed was decommissioned.

Figure 6. Concentrations of phosphate in area where on-site wastewater disposal last occurred 20 years ago (central area). Also shown are the locations of two active tile beds (top and bottom). This area had numerous buildings, a barn, vault toilets and possibly a tile bed prior that were removed by the Park.

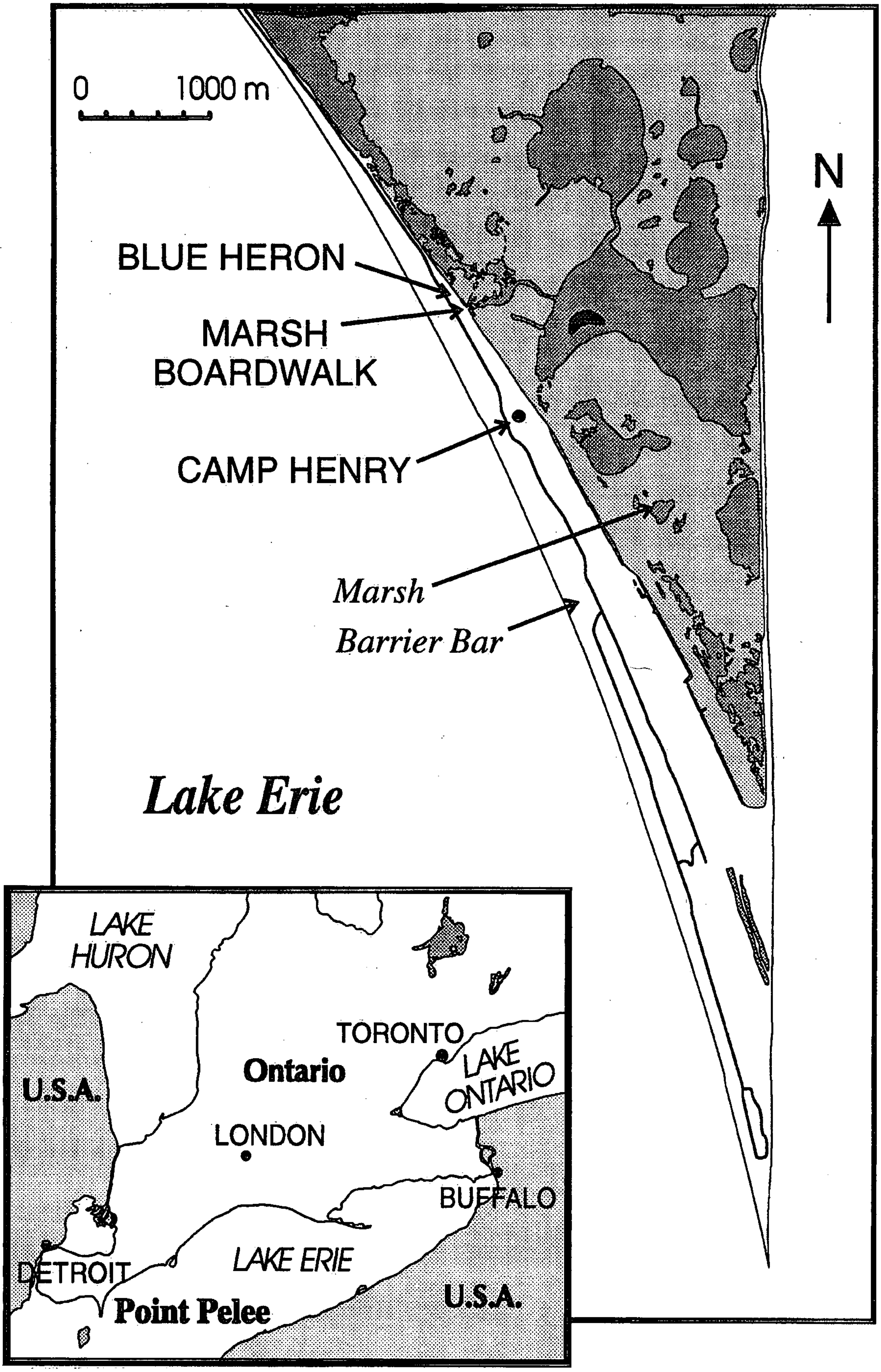

0 1000 m
N
BLUE HERON
MARSH
BOARDWALK
CAMP HENRY
Marsh
Barrier Bar
Lake Erie
LAKE
HURON
TORONTO
LAKE
ONTARIO
Ontario
U.S.A.
LONDON
BUFFALO
LAKE ERIE
DETROIT
Point Pelee
U.S.A.

Fig. 1

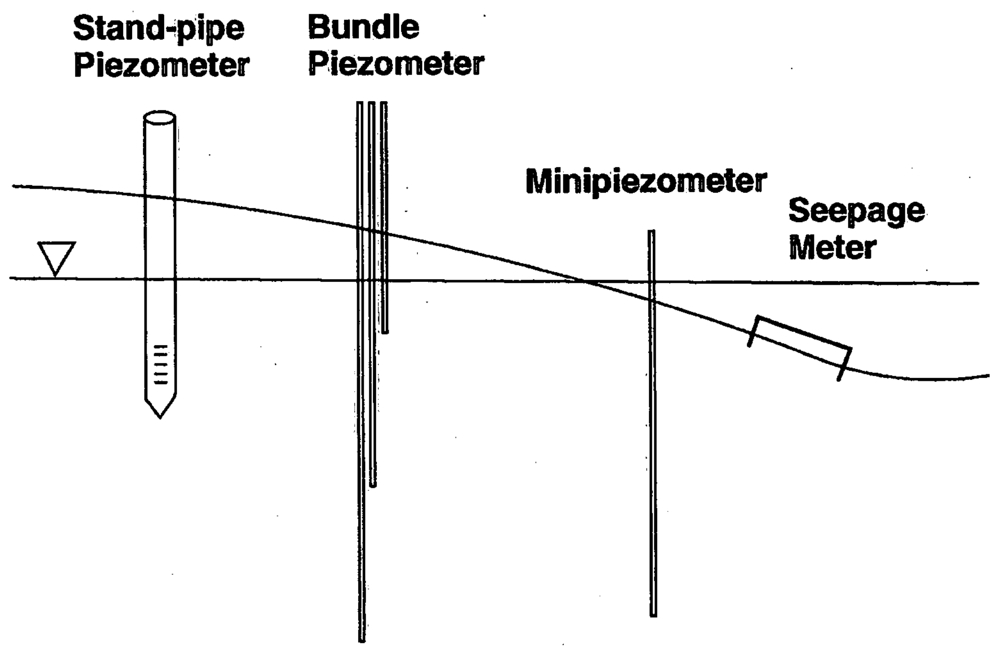
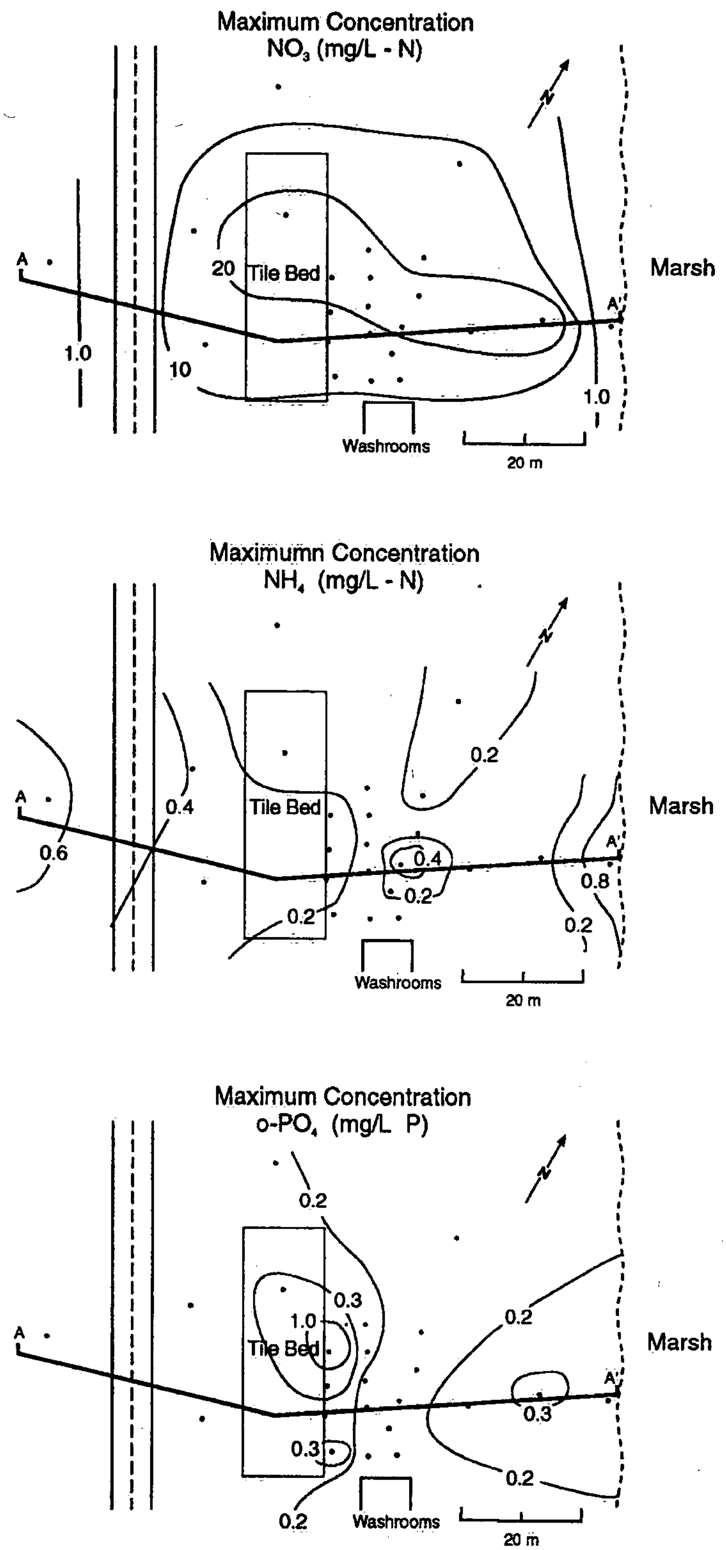

Stand-pipe Piezometer
Bundle Piezometer
Minipiezometer
Seepage Meter

Fig. 2



Maximum Concentration
NO3 (mg/L - N)
A
A'
20
Tile Bed
1.0
10
1.0
Marsh
Washrooms
20 m
Maximumn Concentration
NH4 (mg/L - N)
A
A'
0.2
0.4
Tile Bed
0.6
0.4
0.2
0.8
0.2
0.2
Marsh
Washrooms
20 m
Maximum Concentration
o-PO4 (mg/L P)
0.2
0.3
1.0
Tile Bed
0.2
0.3
0.3
0.2
0.2
A
A'
Marsh
Washrooms
20 m

Fig. 3

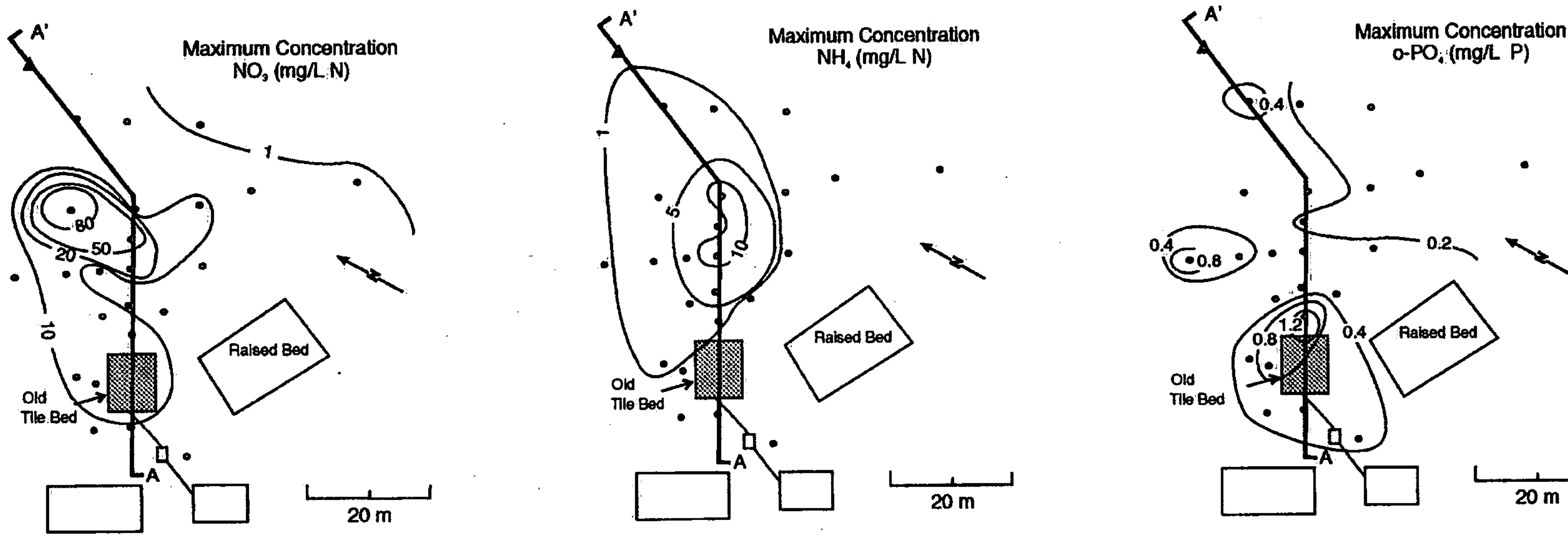
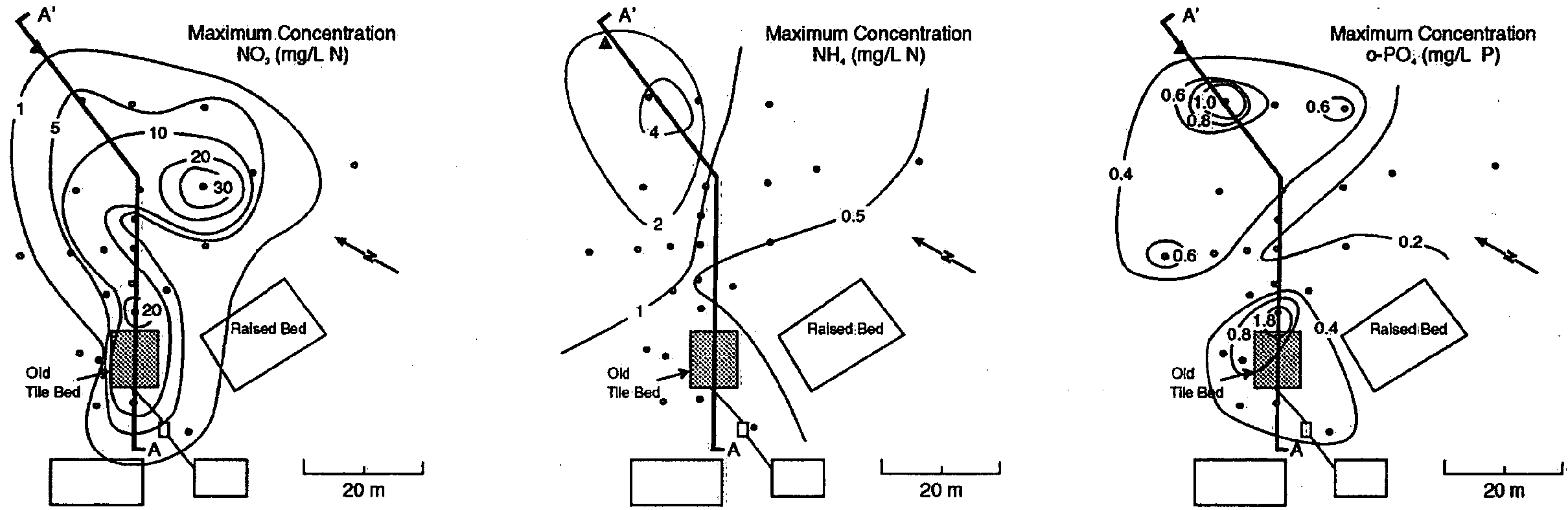

Maximum Concentration
NO3 (mg/L N)
A'
A
1
10
20
50
80
Old
Tile Bed
Raised Bed
20 m
Maximum Concentration
NH4 (mg/L N)
1
5
10
Maximum Concentration
o-PO4 (mg/L P)
0.4
0.2
0.8
1.2

Fig. 4



A'
Maximum Concentration
NO_3 (mg/L N)
1
5
10
20
30
20
Raised Bed
Old Tile Bed
A
20 m
A'
Maximum Concentration
NH_4 (mg/L N)
4
2
0.5
1
Raised Bed
Old Tile Bed
A
20 m
A'
Maximum Concentration
o-PO_4 (mg/L P)
0.6
1.0
0.8
0.6
0.4
0.6
0.2
1.8
0.8
0.4
Raised Bed
Old Tile Bed
A
20 m

Fig. 5

Maximum Phosphate Concentrations, October 1996

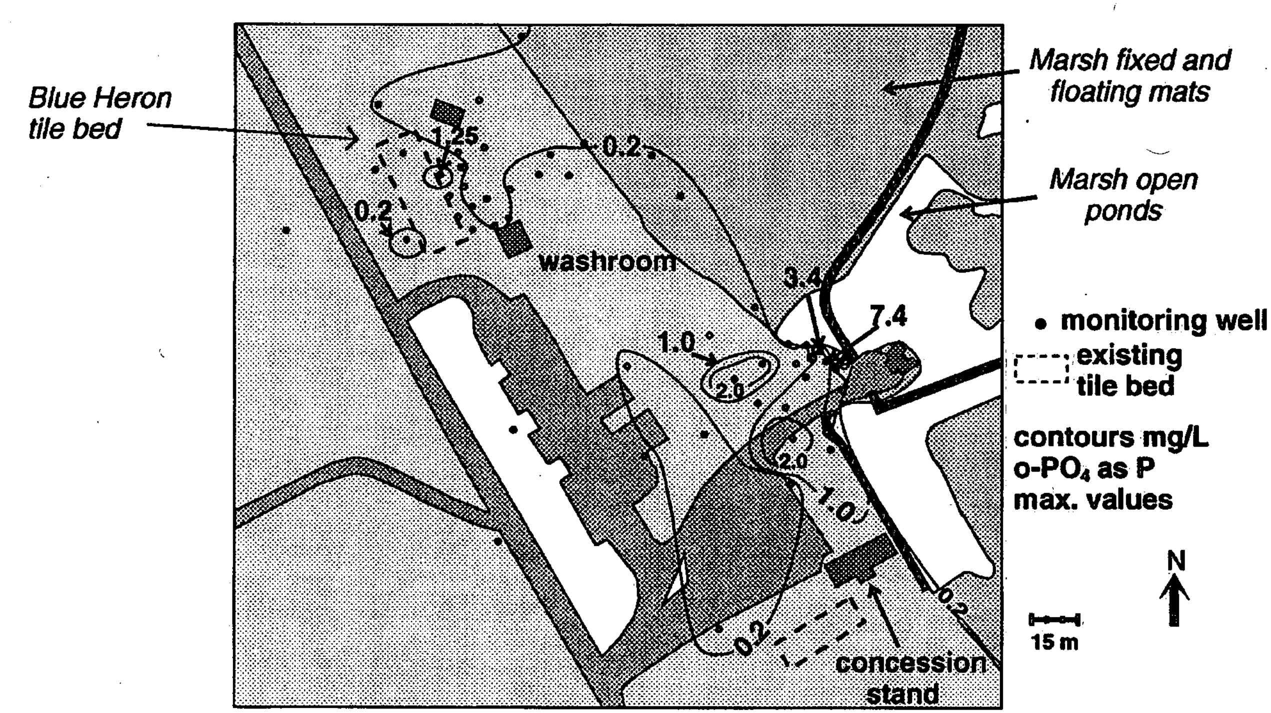


Fig. 6

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