OW Box 700

Prepped by Ollie Stewart

Document Number:

25) 00188

Docket Number:

W-02-06

4.2.4

Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins

Final Report for Task *5* of Grant Agreement

No. TAX90096-Issaquah/East Lake Sammamish Nonpoint Plans

October 1995

King County Department of Public Works — Paul Tanaka, Director

Surface Water Management Division — Jim Kramer, Manager
Ken Guy, Assistant Manager
Bill Eckel, Manager, Water Quality Unit

Contributing Staff — Tim Cheatum, Engineer
Luke Bloedel, Engineering Technician
Helene Bourget, Graphics
David Funke, Engineer
John Koon, Engineer
Laurel Preston, Graphics
Lorin Reinelt, Senior Engineer
Ruth Schaefer, Senior Ecologist
Sharon Walton. Senior Limnologist

For Information Call or Write: **John Koon, Water Quality Engineer**

King County Surface Water Management Division
700 Fifth Avenue, Suite 2200
Seattle, WA 98104

(206) 296-8062

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Executive Summary

Introduction

Task 5 of the Washington State Department of Ecology grant supporting the Issaquah/East Lake Sammamish Nonpoint Plans calls for the preparation of a report on the effectiveness of selected water quality best management practices (BMPs) in the Issaquah/East Lake Sammamish basin. Originally conceived as a pair of inflow/outflow performance evaluations of two wetponds, the focus of the project expanded from the quantification of removal efficiencies of wetponds, to include the documentation of the overall status of wetponds and biofiltration swales.

Five separate facility evaluations were attempted, (two detention ponds, two wetponds, and one biofiltration swale); however, these efforts were only partially successful because of problems with the facilities in terms of functioning and performance, and the inexperience of the monitoring staff. The problems encountered at the study facilities prompted the SWM Division to expand the study scope to include a general survey of wetponds and biofiltration swales in the basin. This survey focused on the condition of the facilities relative to design specifications both in terms of design and construction.

This report provides information on the status of BMPs in the Issaquah/East Lake Sammamish basin, and makes recommendations concerning the improvement of these facilities.

Results

Facility Pollutant Removal

Pollutant levels measured in the study were generally moderate to low for typical urban stormwater. Based on five data pairs from the most thoroughly evaluated detention facility, removal rates were 20 percent for total suspended solids, and 33 percent for total phosphorus. Removal rates for soluble phosphorus were surprisingly good at 66 percent. At a second detention facility, only one sample was collected. The removal rates for this event were 78 percent for total suspended solids and 24 percent for total phosphorus.

Data from the two wetponds used in the study suggested removal rates of 53 percent and 86 percent for total suspended solids, and 43 percent and 61 percent for total phosphorus. Due to the small data set and problems encountered with the ponds, these values should be considered preliminary.

The wetland-vegetated biofiltration swale had an average removal rate of 63 percent for total suspended solids and 33 percent for total phosphorus. These values were comparable to the values obtained in past studies using grass-lined swales; however, the wetland swale appeared to release soluble phosphorus during the winter months.

For metals, removal rates were generally low, or the data were inconclusive.

Survey

The comprehensive survey of water quality ponds in the basin revealed that both extended-detention ponds and true wetponds were rare, and that few of the wetponds were working properly. Of the seventeen wetponds identified, only six (35%) appeared to be working properly, nine (52%) had significant defects and one (6%) was not yet on line.

Of the thirty-three biofiltration swales surveyed, nine (28%) were in good condition and had a relatively complete

and uniform vegetative cover, thirteen (41%) were in fair condition, being in need of at least some repair, and eleven (34%) were considered poor, having little or no vegetation, or extensive channelization.

Conclusions

The project concluded that the implementation of wetponds and swales in the Issaquah/East Lake Sammamish is, at best, marginal. The failure of these facilities appears to be due to a combination of design, construction, and inspection shortcomings, and inadequate maintenance standards. Most of these problems may be attributed to the newness of stormwater treatment facilities and the general lack of understanding regarding the level of effort needed to make them work

The evaluation of stormwater treatment facilities is also a relatively new and evolving field. While the SWM Division 's ability to conduct these evaluations improved through participation in the project, definitive information concerning the performance of wetponds, and to a lesser extent, biofiltration swales in King County can not be obtained until deficiencies in the implementation and maintenance of these stormwater facilities are corrected.

Recommendations

1. Review and update design, construction, inspection and maintenance guidelines to accommodate better the special needs of water quality facilities.

2. Improve training opportunities for those involved in the design, construction, inspection, and maintenance of water quality facilities.

3. Using the lessons learned during the study, evaluate the effectiveness of facilities and maintenance levels.

4. Implement a program to review and rehabilitate defective facilities using cost/benefit information obtained from the evaluation efforts proposed above.

Organization of the Report

The main body of the report presents findings from surveys of facilities in the basin, and includes a summary of the facility-specific evaluations. More detailed descriptions of these case studies are included in Appendixes I - V

Appendix VI provides a brief description of lessons framed regarding the evaluation of water quality facilities. These descriptions should be of particular interest and value to those planning to evaluate water quality facilities.

Introduction

Task 5 of the Washington State Department of Ecology grant supporting the Issaquah/East Lake Sammamish Nonpoint Plans calls for the preparation of a report on the effectiveness of selected water quality best management practices (BMPs) in the Issaquah/East Lake Sammamish basin. Originally conceived as inflow/outflow performance evaluations of two wetponds, the focus of the project has shifted and expanded from the quantification of removal efficiencies, to include the documentation of the overall status of two treatment BMPs: water quality ponds and biofiltration swales. This shift is the result of observations that the design, installation and maintenance of these two types of facilities in the Issaquah/East Lake Sammamish basin is, at best, marginal. In nearly all cases, these implementation problems precluded any attempt at conducting rigorous performance evaluations.

This report combines results from the grant effort with other BMP-evaluation activities carried out by the Surface Water Management (SWM) Division. While reference to the technical aspects of facility implementation and evaluation have been minimized so as to broaden the potential audience, this report assumes the reader has a general understanding of the operating principles of the facilities discussed.

The main body of the report provides an overview of the status of water-quality wetponds and biofiltration swales in the study area. More detailed descriptions of the intensive evaluation efforts are presented in Appendices I through V. While the performance evaluations described in the appendices were not entirely successful, the monitoring and evaluation skills developed during this project will help King County meet the monitoring requirements in its NPDES stormwater discharge permit. Major monitoring lessons learned during the project are summarized in Appendix VI. Those considering doing field evaluations of water quality facilities are strongly encouraged to review this brief appendix.

Wetponds

Introduction

Two separate data-collection efforts were pursued for the wetpond portion of the study, including a survey of existing wetponds and intensive performance-evaluations of four facilities. Survey findings are presented in their entirety in the main body of this report. Findings from the performance evaluations are summarized in the main report; details of each of the performance evaluations are presented in Appendices I to IV. Structural problems found during the performance evaluations are included in the discussion of survey results. The following section provides a brief introduction to pond history and development in King County.

Wetponds

Pond History and Development

Stormwater detention ponds have been required in King County since the early 1970's and have been based on four different combinations of design methods and detention criteria. While most of these facilities include some spill control, few are believed to be effective at removing pollutants because of their small volumes, high release rates, and tendency to allow previously trapped pollutants to be re-entrained.

The majority of the ponds in King County are small, single-celled detention facilities. Also called "dry" ponds, these facilities generally drain between events. A number of two-cell detention ponds have also been constructed. [1] The two-cell configuration was designed to improve water quality by increasing sedimentation. Increased sedimentation was to be achieved through the incorporation of dead-storage areas, and through biofiltration.

In some cases, either by design, or through over-excavation during maintenance, detention facilities are able to maintain an appreciable dead-storage area. Such facilities are sometimes referred to as "wetponds"; however, this term is misleading since in most cases the "wet" cells are simply sediment-storage areas that maintain a shallow pool (typically one foot or less). Indeed, this confusion was so prevalent when this study began that neither King County nor Ecology staff fully appreciated the distinction between a permanent pool intended to be a wetpond, and the standing water created when the unused sediment storage area of a detention pond fills with water. While the permanent pool in a wetpond is an integral part of the design, at times requiring that the pool to be lined, the pool created in a typical detention facility is an artifact of the low permeability of the pond bottom. These shallow pools seldom, if ever, meet the depth requirements associated with wetponds (typically three feet or more).

Varying maintenance practices have also created some confusion regarding the designation of some detention facilities as "constructed wetlands." In many cases, County maintenance inspectors have reduced or eliminated mowing in the bottom of ponds and allowed wetland vegetation to become established. While in some instances this maintenance prescription is in response to the design engineer's attempt to include stormwater treatment in a detention facility, it is more often. simply the result of the pond bottom being too wet to mow.

Figures 1 and 2 provide schematics of a single-celled detention pond (1979 design) and a two-cell detention pond (1990 design).

During the last revision of the Surface Water Design Manual (1990) a formal wetpond design was added. This addition constituted the first requirement for ponds specifically designed for stormwater treatment. In addition to the depth requirements mentioned above, wetponds differ from detention facilities in that they have little or no live storage. The dead-storage volume in the 1990 manual is based on the runoff volume produced by 1/3 of the two-year, 24-hour, event.

As shown in Figure 3 from the 1990 Surface Water Design Manual, this volume is to be split between three cells with ten percent of the volume in the first cell and the remaining volume split between the second and third cells. The berms between cells are to be configured such that water in the first cell flows over an armored berm into the second cell, while the flow between the second and third cell is conveyed through a pipe near the bottom of the pond.

Wetponds must be installed with sufficient flow splitting and bypass to ensure adequate residence times. The wetpond schematic in the 1990 Surface Water Design Manual refers to a diversion control manhole, but does not provide guidance as to how the appropriate flow splitting is achieved.

A wetpond may also be constructed in the bottom of a detention facility. These facilities are referred to as combined facilities. In this configuration, water quality volumes and detention volumes are not separated, rather the wetpond is constructed as a series of permanent pools in the bottom of the detention facility.

[1] The terms "extended detention" and "retention/detention" are variously used to describe these facilities (and others) that maintain some dead storage. In the Surface Water Design Manual "retention" is used to describe infiltration facilities or closed depressions that do not release water through an outlet. In the literature, a pond that

"retains" a portion of each storm volume in a dead-storage area is sometimes called a "retention" facility, even though the retained volume is displaced during subsequent rainfall events.

Wetponds

Survey of Wetponds in the Issaquah/East Lake Sammamish Basin

King County maintenance records indicate that there are 58 County-operated residential stormwater ponds in the Issaquah/East Lake Sammamish basin. Of these facilities, 48 are designed as single-cell detention ponds, one is a two-cell extended-detention pond, one is an infiltration facility, and the remaining eight are natural wetlands used for stormwater detention and/or treatment. None of the facilities in the residential records are wetponds designed per the 1990 design standards.

Nine residential wetponds were identified through interviews with County staff working in the study area. These facilities were either recently constructed, and had not yet been turned over to the County, or were not readily identifiable as wetponds in the County maintenance information system.

Commercial facilities were reviewed only for the presence of wetponds, or wetpond-like facilities; detention facilities were not tabulated. Because of space constraints, commercial sites are more likely to have underground tanks and vaults than surface facilities. Wetponds were identified at one office building, two schools, and three churches in the unincorporated portion of the study basin. The addition of these facilities brought the total number of wetponds to fifteen. These facilities are listed in Table 1.

Review of the wetponds in the city of Issaquah was less extensive owing to the lack of readily accessible records and the limits of the study effort. City staff were able to identify two facilities that are intended to maintain a permanent pool for stormwater treatment. These facilities are listed in Table 2.

Of the seventeen ponds clearly identified as wetponds, five appeared to be working properly and five had problems that resulted in the ponds being essentially empty when they should have been full. In most cases, the lack of water in the ponds could be attributed to improperly installed conveyance systems, poor flow-splitter design or construction, or leaking clean-out gates. In one other facility (Klahanie) the pond volume was under-sized by sixty percent. Five additional wetponds were identified at sites that are currently under construction.

Conveyance and flow-splitter problems were sometimes difficult to distinguish. At one of the school sites, a flow splitter could not be located during the field inspection. This pond was always empty. At the Spyglass Hill facility in Issaquah, there was no evidence that the pond had ever filled up. Again, a flow splitter was not located. At each of these sites it is not clear whether a flow-splitting device was left out, or whether pipes were installed improperly.

Table 1. Wetponds in the Unincorporated Portion of the Study Basin

Name	Built	Land Use	Condition
Klahanie	1992	Single Family Residential	Undersized by 60%. (Currently maintained by King County)
Sammamish View East (3-cell wetpond followed by biofiltration swale.)	1992	Single Family Residential (Development complete)	Does not maintain permanent pool. Failed flow splitter and clean-out gate. (Soon to be signed over to County.)
The Park at Pine Lake (3-cell wetpond followed by biofiltration swale.)	1993	Single Family Residential (Developing)	Appears to be working properly. (Not yet signed over to County.)
Pine Lake Estates #1 (3-cell wetpond followed by two shallow pools with a gravel cone outlet.)	1994	Single Family Residential (Developing)	Contains some water, but water level at invert of clean-out. (Not yet signed over to County.)
Pine Lake Estates #2 (2-cell wetpond followed by	1994	Single Family Residential	Contains some water, but water level at invert of clean-out. (Not yet signed

biofiltration swale.)		(Developing)	over to County.)
Pine Lake Estates #3 (3-cell wetpond followed by biofiltration swale.)	1994	Single Family Residential (Developing)	Contains some water, but water level at invert of clean-out. (Not yet signed over to County.)
Highland Creek Estates #1	1994	Single Family Residential (Developing)	Appears to be being used as a detention/sediment control pond. Normal outlet control blocked, gate opened (dry weather). (Not yet signed over to County).
Highland Creek Estates #2	1994	Single Family Residential (Developing)	Not yet on line. (Not yet signed over to County.)
Beaver Lake Estates (Two cell wetpond followed by infiltration facility)	1994	Single Family Residential (Developing)	Appears to be working properly. (Not yet signed over to County.)
East-Side Christian Assembly	1993	Church (Completed)	Does not maintain permanent pool despite minor baseflow. (Privately Maintained)
LDS Church	1992	Church (Completed)	Appears to be working properly. (Privately Maintained)
Faith United Methodist Church (3-cell combination facility)	1994	Church (Completed)	Appears to be working properly. (Privately Maintained)
Beaver Lake Middle School (3 cell wetpond)		School (Completed)	Appears to be working properly. (Privately Maintained)
East Lake Washington High School (3-cell wetpond followed by biofiltration swale.)		School (Completed)	Pond does not appear to receive water. (Privately Maintained)
Sammamish Park Place (3 cell wetpond)	1992	Commercial	Does not maintain permanent pool. Clean-out gate and outlet back-fill leaks. (Privately Maintained)

Table 2. Wetponds in the City of Issaquah

Name	Built	Land Use	Condition
Pickering Place	1994	Commercial	Unusual design consisting of two very large ponds in a commercial development.
Spyglass Hill . (3-cell wetpond followed by biofiltration swale.)	?	Townhouses	Empty. Very little water beyond the first cell. Suspect conveyance problem. No flow splitter.

A more easily identified conveyance problem was at the pond located at the Sammamish Park Place office building. Here the combination of failed grouting around a bypass control and a faulty pump-switch, resulted in only a fraction of the design flow reaching the pond. Once these two problems were fixed, the facility appeared to

be working; however, upon closer inspection it was apparent that there was a leak in either the pond bottom or the back fill around the outlet pipe. This facility still does not maintain the required dead storage.

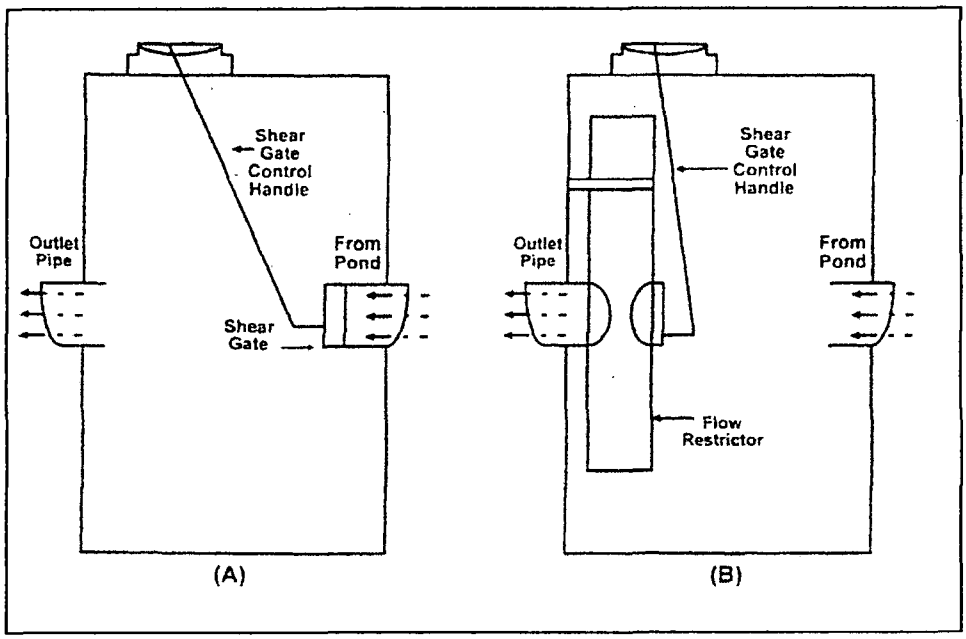
At the Sammamish View East pond, poor design, sloppy construction, and defective or damaged materials resulted in a flow-splitting structure that allows very little water to enter the pond. The poor design feature is in the placement of the bypass pipe; the invert of the bypass pipe is lower than the invert of the pipe leading to the wetpond. This design leaves the flow splitting absolutely dependent on the integrity of the solid-bottomed T section grouted into the bypass pipe. A more sound design would have placed the bypass well above the pond inlet pipe.

Poor construction at the Sammamish View East site was evident when the grout on the flow-bypass T-section failed, allowing most of the flow to bypass the pond. After this was repaired, water continued to escape at the bypass through a leak in the bottom of the T section. This conveyance defect was corrected, but the function of the flow splitter is still partially compromised by the height of the berm between the first and second cells. This berm appears to be too high and backwaters the flow control structure even when there is no storm flow.

At least three facilities (Sammamish View East, Sammamish Park Place, and East Side Christian Assembly), and possibly three others (Pine Lake Estates Ponds 1-3), have leaky clean-out gates that keep the facility from maintaining a permanent pool. At two of these facilities, the clean out gate is a shear gate installed in the location and manner shown in the Design Manual (Figure 4A). This arrangement allows water pressure on the pond side of the gate to push the gate away from its seal, causing the pond to drain. Four other facilities that appear to be failing due to the inadequacy of the. shear gate, have the shear gates installed in the manner typical of detention facilities (Figure 4B). While the seal obtained in this configuration may be adequate for detention facilities in which a small leak merely reduces the detention time, even minor leaks in a wet pond compromise the basic operation.

Figure 4. Clean-Out Gate Configurations.

(A) Shear gate installed at outlet from pond. Water pressure on the upstream side of the gate pushes the gate away from the seal, allowing the pond to drain.
(B) Typical shear gate configuration for detention facilities. While an improvement over "A", it is not certain whether this configuration will maintain a permanent pool.



One of the five ponds that appeared to be working properly (i.e., was full of) had a gate-valve, rather than a shear gate, on the clean-out pipe. This option, while reportedly more expensive, has been observed at other wetponds

in King County and appears to be the most reliable clean-out control. Gate valves have the added advantage of being more easily adjusted, allowing facilities to be drained at a rate that will not disturb downstream resources.

Four of the functional ponds were built within a larger detention basin. At three of these combination facilities, there was no provision for draining the wetpond. Instead, the shear gate was located at maximum water level of the wetpond, but at the bottom of the detention basin. While this means that the wetpond must be pumped out during maintenance, it ensures that the pond will maintain a permanent pool. The inaccessibility of the fifth functional facility (LDS Church) prevented identification of the clean-out control.

Six of the ponds visited were in new developments. The pond at The Park at Pine Lake is in good operating condition, while the three facilities at Pine Lake Estates all have shear gates and appear to drain down to the clean-out level between storms. These facilities should be watched closely and, if necessary, be modified to maintain the required permanent pool. At Highland Creek Estates, one pond is being used as a sediment control pond for the site, while a second pond is still under construction.

Wetponds

Performance Evaluation Results: Introduction

The case studies in the appendices describe attempts to monitor four different stormwater ponds. Two of these facilities, (Glenwood and Gunshy), were built as two-cell detention ponds. The other two facilities, (Sammamish View East and Sammamish Park Place), are off-line wet ponds. While evaluations of a combined facility (wetpond within a detention pond) would have been valuable, none were constructed in time to be included in the study. Table 3 lists the ponds included in the performance evaluations.

Table 3. Design and Site Characteristics of the Facilities Studied.

Name	Design Criteria	Land Use
Glenwood Pond	Two-Cell, Extended Detention Pond	Residential
Gunshy Pond	Two-Cell, Extended Detention Pond	Residential
Egghead Pond	1990 Three-Cell wetpond	Employee Parking
Sammamish View East	1990 Three-Cell wetpond	Residential

These monitoring efforts were the first attempts by the SWM Division to evaluate water quality BMPs in the field. A combination of the Division's inexperience with this type of monitoring and the structural problems described above, limited the quality and completeness of the sampling efforts. Nonetheless, some of performance data were collected. This section summarizes the data-collection and interpretation methods used, and provides the sampling results from the four pond studies.

Wetponds

Performance Evaluation Results: Data Collection and Sampling

The performance evaluations were centered around the collection of flow-proportional composite samples at the inlet and outlet of each facility. Most samples were collected on an event-basis; however, the study team did experiment with variations of the traditional single-event sampling strategy. These alternative strategies are described below. Storm events were defined by a three-day antecedent dry period and a minimum rainfall of 0.2 inches of rain. While the event duration was not specified, most event samples were collected over a ten- to twenty-hour period. Rainfall data were obtained from existing County rain gauges or gauges set up at the study site.

One of the alternative sampling strategies involved initiation of both the upstream and downstream samplers when storm runoff first reached the upstream flow meter. This modification was intended to force the downstream sampler to begin sampling as soon as water was displaced from the dead-storage area. This method was used with some success during three events at the Glenwood site.

A second, more dramatic modification to the basic sampling scheme, involved sampling over several storms. During these "long-term" sampling events, individual composite samples were collected over a period of several days. The purpose of this strategy was to improve the relationship between the upstream and downstream samples. The rationale for this approach is as follows:

When collecting samples from a system in which there is no dead storage (such as a biofiltration swale), the samples collected at the downstream location may be drawn from the same mass of water sampled at the upstream location. In a system that includes a dead-storage area, (such as a wetpond) composite samples from the downstream location include a substantial number of aliquots of water displaced from the dead storage area. The pollutant concentrations in this displaced water are entirely unrelated to the concentrations in the associated inflow sample. This condition precludes the calculation of performance efficiencies for individual events. The "long-term" sampling approach is intended to reduce this error by sampling across several dead-storage volumes. If all of the water entering and leaving the pond is sampled as the pond is flushed several times, the error is limited to that caused by the aliquots collected at the outlet during the first displacement of the dead-storage water, and at the inlet during the last rainfall event. While this error is never eliminated, collecting samples over a large number of dead-storage volumes should reduce the error to a level comparable to other sources of error inherent in the sample collection and analysis procedures.

A major drawback of collecting samples over a long period of time is that laboratory holding times are exceeded. Without AC power and costly refrigeration equipment, keeping samples cooled is impractical. In order to minimize the impact of these problems, samples collected outside of the normal holding times were analyzed for only the most conservative parameters: TSS, TP, and total copper, lead and zinc. A total of seven "long-term" samples were collected (two at Glenwood and five at Sammamish View East). Unfortunately, only one of the five long-term sampling attempts at the Sammamish View sites successfully captured both the inflow and outflow samples.

Wetponds

Performance Evaluation Results: Data Interpretation

The preferred method of data interpretation for BMP evaluations is to calculate a pollutant-reduction efficiency using event-mean-concentrations and flow records. The quality of loading estimates used in this analysis is heavily dependent upon the quality of the flow data; a small error in the flow record will dramatically impact loading calculations. During each of the four performance studies, flow monitoring of at least one sampling location (inflow or outflow) was questionable. For this reason, loadings were not calculated.

If one assumes there are no losses to infiltration, the flow components cancel out, and the efficiency of the facility may be calculated based on the inflow and outflow event-mean-concentrations. This approach is the most appropriate means of quantifying performance if flow records are absent or of questionable quality. If losses to infiltration do occur, this limitation should be noted.

Pollutant-removal performances for the four pond studies were quantified using inflow and outflow concentrations. These removal rates were calculated using the following equation:

Removal Rate = Inflow Concentration - Outflow Concentration * 100 Inflow Concentration

Beyond calculating the performance efficiencies (percent removal) for a pond, a facility may be evaluated in terms of the degree to which the outflow meets downstream resource-protection needs. The measure used for this type of interpretation varies with the resource being protected. For lakes, loading estimates are most appropriate. For in-stream resources, concentrations are most important. Concentration data may be compared to Washington state water quality standards, and, where the goal is to treat stormwater to pre-development conditions, to data from similar, undeveloped areas. Data from samples collected prior to development may also be used, but are seldom available.

In this study, dissolved metals concentrations, where available, are compared to Washington state standards. In some instances, inflow and outflow concentrations for other potential pollutants are compared to data from other local studies.

Wetponds

Performance Evaluation Results: Sampling Results and Discussion

The following sections discuss each of the major parameter groups included in the study. These pollutant groups include total suspended solids (TSS); phosphorus, as soluble reactive phosphorus (SRP), bioavailable phosphorus (BAP) and total phosphorus (TP); nitrogen, as nitrate and nitrite nitrogen (N03-N) and ammonia nitrogen (NH3-N); and metals, including copper (Cu), lead (Pb) and zinc (Zn). Complete data sets for each facility are included in Appendices I-IV.

Tables 4 and 5 list the removal rates calculated from the mean inflow and outflow concentrations for data from each of the four facilities. Note that for two of the facilities (Gunshy and Sammamish Park Place), only one sample set was collected. At the (Sammamish View East facility), most of the inflow and outflow data are not from the same events. Given the small sample size and the variations in the sample-collection methods, these data should be viewed as extremely preliminary. Additional caveats concerning the limitations of the data are discussed in the section on total suspended solids. These qualifiers also apply to most of the remaining pollutants.

Table 4. Removal Rates for TSS and Nutrients.
The percent removal, based on mean inflow and outflow concentrations is shown for each site and each parameter. The number of sample sets is the total number of sets collected at the site. Not all samples were analyzed for all parameters. Where the number of samples analyzed for a given parameter differs from the total, the number analyzed is given in parentheses.

Site	Sample Sets	TSS	TP	BAP	SRP	NO3-N	NH3-N
GW [1]	10	20% (5)	33% (4)	56% (3)	66% (3)	67% (2)	72% (2)
GS	1	78%	24%	-	-	-	-
SV	3	53%	43%	-	-	-	-
SF	1	86%	61%	-	-	-	-

[1] Removal rates of the (Glenwood facility are based on, the last five events sampled. These samples were collected after the pond had stabilized,

Total Suspended Solids

TSS was the parameter most universally sampled during the study. A total of fifteen samples were analyzed. Inlet values for all events ranged from 5 to 65 mg/L with an average value of 15 mg/L. Outlet values ranged from 3.3 to 41 mg/L with an average of 12 mg/L. Both inflow and outflow values for nearly all samples were fairly low for stormwater. Merrill (1989) reports a range of 46 to 100 mg/L for the City of Seattle. All but one of the samples in the current study were below this low-end value of 46 mg/L. Similarly, the median TSS values for three streams in the City of Bellevue (Bellevue, 1995) were well above all but two of the TSS values reported for the current study. The land use around the Bellevue sites was similar to that around the study ponds.

The Glenwood facility underwent a major retrofit during the summer of 1991 that included re-grading the side slopes. According to the monitoring staff the pond was nearly always turbid during the sampling season following the retrofit. Using all of the data for the Glenwood facility results in a calculated *release* rate of 23 percent, indicating that more sediment was leaving than entering the facility. Using only the last five events, which were sampled after the facility appeared to have stabilized, results in a removal rate of 20 percent for TSS. This value is probably more indicative of the long-term performance of the facility.

Data from the Sammamish View wetpond indicate a removal rate of 53 percent for TSS. The data from this facility are unusual in that inflow and outflow values are generally not from the same event, and samples were collected using the "long-term" sampling strategy described above.

Data for two of the facilities (Gunshy Ridge Detention Pond and Sammamish Park Place Wetpond) suggest very good performance (78% and 86%, respectively); however, these values are based only on one sample at each facility. At both sites, the outflow samples were collected over a very short time and were not representative of the event mean concentrations (EMC). Nonetheless; bias due to partial sampling of an event is more likely to affect results at the inlet than at the outlet. Mixing within the facility should reduce the effect of sampling water treated between events. In both facilities, the limited dead-storage further reduces the likelihood that outflow sample concentrations were dramatically reduced by previously treated water. Unlike normal wetponds, in which the large volumes stored between events make comparing inflow and outflow concentrations of a single event unwise, samples collected from facilities with little dead-storage are more directly comparable. If sampling is well timed, inflow and outflow samples from these facilities will be collected from the same mass of water. While the removal rates listed above are probably optimistic, they suggest that facilities that drain between events, but maintain at least some wet storage, have the ability to retain more solids than generally attributed to small detention ponds. This issue should be studied further, either directly, or through the literature, as it could affect the way we design, build, and maintain water quality facilities.

An overall effectiveness of the ponds studied may be obtained using by weighting the removal rates listed in Table 4 using the number of samples collected as the weighting factor. Using the Glenwood samples collected after the pond appeared to have stabilized, and all of the data from the other ponds, results in an average removal rate of 42 percent for TSS.

Phosphorus

Total phosphorus (TP) was measured at all four of the study sites, and for all but one sample set. TP values ranged from 38 µg/L to 159 µg/L at the inlets, and 44 µg/L to 113. µg/L at the outlets. The mean of all inlet samples collected was 102 µg/L (standard deviation = 36, coefficient of variance = 0.35) and 73 µg/L (sd = 20, cv = 0.27) for the outlet. These concentrations are low compared to the values reported by Kulzer (1994) and Bellevue (1995).

Removal rates for TP at all sites ranged from 24 percent to 61 percent. At the Glenwood facility, TP concentrations were essentially unchanged by the facility during the first half of the study; however, the mean removal rate during the second half was 33 percent.

Total phosphorus removal was better than the TSS removal for the facility. TSS removals were -66% and 14 % respectively for the first and second half of the study. compared to 5% and 26% for TP. This difference in removal rates, along with the good BAP and SRP removal rates seen at the facility during each of the sampling sequences (32% and 51% for BAP; 50 % and 65% for SRP) indicate the facility was removing soluble phosphorus even when suspended solids (including particulate phosphorus) were being released. These results are of particular interest because it is the soluble forms of phosphorus (along with other dissolved pollutants) that are generally of greatest concern and more difficult to control. Additional monitoring efforts in the area of phosphorus removal should focus on seasonal variations in soluble phosphorus removal rates. Identification of the mechanisms responsible for phosphorus removal may allow the conditions in the facilities to be managed to favor these processes. Mechanisms that should be examined included plant uptake, precipitation, and adsorption.

At the remaining three facilities, TP was the only form of phosphorus evaluated. While the data are limited, removal rates were all positive. The average removal rate for all samples, and all facilities (excluding the first five Glenwood sample sets) was 38 percent.

Nitrogen

Nitrogen data were collected only at the Glenwood facility, and only on two occasions. Both samples were collected in the spring, and both showed promising removal. Mean nitrate + nitrite nitrogen (NO3-N) concentrations at the inlet and outlet were 587 µg/L and 195 µg/L, respectively, for a 67 percent reduction. Mean ammonia nitrogen (NH3-N) values were 176 µg/L at the inlet and 49 µg/L at the outlet, a 72 percent.

While conclusions based on two samples must be treated as preliminary, the magnitude of the apparent removal rates suggests the facility is able to remove these soluble forms of nitrogen. Likely mechanisms for nitrogen removal include plant uptake, denitrification, and mineralization. A more definitive study of nitrogen removal in ponds would include sampling outside the active growing season, and a larger number of samples.

Metals

Total metals data were collected for copper, lead and zinc at all sites and for all but one event. Dissolved metals data were collected only at the Glenwood facility, and were analyzed for only two events. Table 5 summarizes the removal rates for each of the data sets.

Table 5. Removal Rates for Metals.
As in Table 4, the percent removal based on mean inflow and outflow concentrations is shown for each site and each parameter. The number of sample sets collected at each site is the same as shown in Table 4. Not all samples were analyzed for all parameters. Where the number of samples analyzed for a given parameter differs from the total, the number analyzed is provided in parentheses.

Site	Total Copper	Total Lead	Total Zinc	Dissolved Copper	Dissolved Lead	Dissolved Zinc
GW	25%(4)	35%(4)	52%(4)	39%(2)	0%(2)	27%(2)
GS	-31%	25%	-18%	-	-	-
SV	14%	80%	53%	-	-	-
SP	18%	76%	28%	-	-	-

Total copper values ranged from 2.4 to 10.1 µg/L at the inlets, with a mean for all events of 5.8 µg/L. At the outlets, concentrations ranged from 2.4 to 28.4 µg/L with a mean concentration for all samples of 6.7 µg/L. All but one of the value were below the low end of the range of data from the City of Seattle (Merril, 1989), and below the mean value for a comparable watershed in the City of Bellevue (City of Bellevue, 1995).

Calculated removal rates for total copper ranged from -31 percent to +25 percent; however, differences in inflow and outflow concentrations for individual data sets, and between mean values, were close to detection limits. On the whole, data from the study do not suggest that the facilities affect total copper concentrations.

One of the data pairs for dissolved copper at the Glenwood facility suggests a removal rate of around 50 percent; however, the second data set indicated no change in dissolved copper. All dissolved copper concentrations were below Washington state water quality standards.

Total lead concentrations ranged from 1.3 to 16.2 µg/L at the inlet (mean value = 3.7 µg/L) and below detection limits (0.5 µg/L) to 3.9 µg/L at the outlet. Values were comparable to those reported by the City of Bellevue, but were much lower than those reported for the City of Seattle. Dissolved lead values for the two sample sets tested were at or below the detection limit of 0.5 µg/L. Net removal rates for lead were positive at all of the test facilities and for all but one data set. Calculated removal rates ranged from 25 to 80 percent.

Zinc concentrations were below the City of Seattle values, but were comparable to the data from the City of Bellevue. Inflow values for the study ranged from 3 to 84 µg/L with a mean concentration of 31 µg/L. Outflow concentrations ranged from 5 to 52 µg/L with a mean of 20 µg/L. Removal rates for zinc were modest with an average for the study of about 30 percent.

For one outlet sample set at the Glenwood facility, the dissolved zinc concentration exceeded Washington state

criteria for chronic exposure and was equal to the minimum value for acute toxicity (after correction for hardness).

Wetponds

Conclusions

Of the seventeen facilities identified as wetponds in the Issaquah/East Lake Sammamish basin, six were observed to be in good conditions and nine had clearly identifiable problems, or exhibited questionable characteristics which could not be linked to a specific problem. The remaining pond was still under construction and was not scrutinized.

Removal rates for total phosphorus in the detention facilities were between 20 and 30 percent, while at the wetponds, removal rates ranged from 40 to 60 percent. Total suspended solids removals were more variable with the best data set from a detention pond indicating a 20 percent removal, while data from the wetpond suggest a range of 50 to 90 percent. A weighted TSS removal rate for all ponds in the study was calculated at 47 percent. All results should be considered preliminary given the small data set, and variations in the way samples were collected.

Failure of ponds to receive the water they are intended to treat was the most severe problem observed during the study. The inability of several ponds to maintain a permanent pool was also widespread.

While inspectors have been able to have some of the problems repaired, the number of facilities found in a state of complete failure indicates a need for more frequent and thorough inspection, and a more aggressive approach to correcting defects.

Wetponds

Recommendations

1. Review and update design, construction, inspection and maintenance guidelines to accommodate better the special needs of water quality wetponds.

2. Improve training opportunities for those involved in the design, construction, inspection, and maintenance of wetponds.

3. Using the lessons learned during the study, evaluate the effectiveness of detention ponds, wetponds and combination ponds, and the maintenance practices associated with each of these types of facilities.

4. Implement a program to review and rehabilitate or retrofit defective facilities using cost/benefit information obtained from the evaluation efforts proposed above.

Biofiltration Swales

Introduction

Two separate data collection efforts were pursued for the swale portion of the study. These efforts included a survey of existing swales and swale-like facilities, and an intensive performance evaluation of one facility. Survey findings are presented in their entirety in the main body of this report. Findings from the performance evaluation are summarized and used to estimate the effect of correcting problems identified during the survey. Details of the performance evaluation are presented in Appendixes V.

Biofiltration Swales

Swale History and Development

The water quality treatment requirements of the 1990 Surface Water Design manual specify the construction of a biofiltration facility (grass swale or filter strip) for new projects that include more than 5000 square feet of impervious surface that is subject to vehicular traffic or chemical storage. Wetponds, wet vaults, and detention facilities may also be required, but the manual does not state whether these facilities should be above or below the biofiltration swales.

Basic design requirements for biofiltration swales include treatment of the 2-year, 24-hour design storm at a maximum depth of 0.25 feet and maximum velocity of 1.5feet per second. A Mannings "n" value of 0.35 is to be used for design calculations. A minimum of 200 feet of biofiltration swale is required for each five acres of impervious surface subject to vehicular traffic or chemical storage.

Biofiltration Swales

Survey of Biofiltration Swales in the Issaquah/East Lake Sammamish Basin

County maintenance records list approximately seventy residential biofiltration swales in the SWM service area, only two of which are in the Issaquah/East Lake Sammamish basin. Interviews with city and county field staff identified 39 additional swale-like facilities in the study area. These additional swales included facilities at commercial sites and new residential developments.

Each swale was visited during the spring of 1995 to establish the condition of the facility and estimate its effectiveness. Jurisdiction, land-use, vegetation type and general condition were documented. Each swale was also examined for the presence of problems commonly observed in swales. These problems include: (1) poor vegetation due to poor soil conditions, excess shade, or insufficient planting; (2) poor drainage or uneven grading resulting in unvegetated pools; (3) channelization caused by high flows and/or excessive baseflow; and (4) excessive sediment deposition and burial of the grass. In addition, an attempt was made to determine whether the facility was constructed as a biofiltration swale, or whether it was simply a well vegetated conveyance system that resembled a water quality facility. The results of the survey are presented in Table 6.

Thirty-two of the 39 facilities visited appeared to be designed as treatment facilities, while the remaining seven drainage features were simply vegetated conveyance systems. Of those identified as biofiltration swales, nine (28%) were in good condition, with relatively complete and uniform vegetative cover, thirteen (41%) were in fair condition, being in need of at least some repair, and eleven (34%) were considered poor, having little or no vegetation, or being extensively channelized. Swales described as "fair" appeared to be providing some water quality treatment while those in "poor" condition were assumed to be providing essentially no water quality benefit. Swales with poor drainage were considered poor unless wetland vegetation had become well established. While unvegetated systems containing standing water are likely to provide some improvement in water quality through reduced velocities and sealing, this benefit is probably off-set during higher flows when this sediment is resuspended.

Of the nine biofiltration swales identified as being in "good" condition, four were constructed within the landscaped areas of commercial facilities. In contrast, only one landscape swale was described as less than ideal (fair-poor). While the sample is small, facilities constructed as part of a commercial landscape appear to be more successful than those relegated to out-of-sight areas. Eighty percent of the swales that were integrated into lawns or used to separate rows of parking slots were in "good" condition. Only eighteen percent of the remaining swales in the survey were in "good" condition. The success of the commercial swales is probably due to the quality of maintenance these highly visible facilities receive.

Of the remaining four "good" facilities, two were new facilities and two were older facilities that had well-established wetland vegetation. It is unclear whether these two wetland swales were designed as wetland swales, or whether the moisture and soil conditions resulted in the natural establishment of this alternate vegetation.

The most common problems observed were poor vegetative cover due to inadequate planting and early care practices or poor soil conditions (28%), and saturation resulting from poor grading or excavation below the water-table (also 28%). The next most common causes of failure were channelization either by peak or base flows (15%), and loss of vegetation due to shading (8%). Four of the facilities visited (10%) were at constructions sites. Of these, two (Faith Methodist Church and Pine Lake Estates #1) were non-functional due to the absence of mature or healthy vegetation. The other two facilities at construction sites (Highland Creek Estates and Marionwood) had been damaged by excessive sedimentation. Several other swales were observed at very new construction sites, but were not included in the survey since it would be unreasonable to expect vegetation in these newly excavated facilities.

Table 6. Biofiltration Swales in the Issaquah/East Lake Sammamish Basin

Good Condition:	Uniform or nearly uniform vegetation coverage, little or

	no channalization or scaring. Appropriate drainage.
Fair Condition:	Some bare patches, channalization or scaring. Poor drainage without wetland vegetation.
Poor Condition:	Extensive bare areas or channelization.

Name	Land Use	Jur.	Purpose	Vegetation	Condition	Comments
High Valley	Single Family	KC	Conveyance?	Grass	Poor	Steep, rock-lined ditc
Above La Criant	Single Family	KC	Conveyance?	Grass	Poor	Very thin vegetation, sediment trap.
Sunset Valley Farms	Single Family	KC	Conveyance?	Mixed	Poor	Standing water, very
Faith Methodist Church	Church	KC	Treatment	Grass	Poor	Very thin grass. New
LDS Church	Church	KC	Treatment	Mixed	Poor	'V-shaped cross secti vegetated.
Pine Lake Shopping Center	Commercial	KC	Treatment	Mixed	Poor	Scour, unplanted?
Highland Creek Estates	Single Family	KC	Treatment	Grass	Poor	New construction.
Sammamish View East	Single Family	KC	Treatment	Grass	Poor	Channelized due to b
Pine Lake Estates #1	Single Family	KC	Treatment	Grass	Poor	
Pine Lake Estates #2	Single Family	KC	Treatment	None	Poor	Very Poor Drainage -
Pine Lake Estates #3	Single Family	KC	Treatment	None	Poor	Very Poor Drainage -
Klahanie @ Yellow Lake Outlet	Single Family	KC	Treatment	Saplings	Poor	Channelization and e
LDS Church	Church	KC	Treatment	Wetland	Good	Bypass swale paralle
Siemens Office Building	Commercial	KC	Treatment	Grass	Good	Landscape feature. S
ELS Firehouse	Fire Station	KC	Treatment	Grass	Good	Landscape feature.
Discovery Elementary	School	KC	Treatment	Mixed	Good	Relatively unmaintain end.
Audubon Park	Single Family	KC	Treatment	Grass	Good	New site. Very few hc
Pine Lake Park	Single Family	KC	Treatment	Grass	Good	Standing water. Gras
Brown Bear Carwash	Commercial	KC	Treatment?	Wetland	Good	Moderately dense, bu
Forest Village	Townhouses	KC	Treatment	Grass	Fair - Poor	Poor drainage.
The Uplands	Single Family	KC	Conveyance	Wetland	Fair - Good	
Cambria	Single Family	KC	NGPE	Wetland	Fair-Good	Old pasture/ditch.
Pine Lake Shopping Center	Commercial	KC	Treatment	Grass	Fair - Good	Long grass clippings
Eastside Christian	Church	KC	Treatment	Grass	Fair	Poor drainage, sever

Assembly						
High School (ELW district)	Commercial	KC	Treatment	Grass	Fair	Facility does not appe
Beaver Lake Middle School	School	KC	Treatment	Wetland	Fair	Rock-bottomed ditch
Swan Ridge	Single Family	KC	Treatment	Grass	Fair	No vegetation in lowe
Marion Wood	Townhouses	KC	Treatment	Grass	Fair	Appears to have unde reach.
Issaquah Condominiums	Condominiums	ISS	Treatment	Grass	Fair - Poor	Poorly drained with la
Vista Royal	Apartments	ISS	Treatment	Mixed	Poor	Short, wet, rocky. Ma
Eastside Mental Health	Commercial	ISS	Treatment	Grass	Fair - Poor	Landscape feature. V wetland pond.
Virginia Mason Hospital	Commercial	ISS	Treatment	Grass	Fair - Poor	Drainage.
Pickering Place Swales (several)	Commercial	ISS	Treatment	None	Poor	New construction.
City of Issaquah SE 56st Street	Regional	ISS	Treatment	Wetland	Fair - Poor	Poor drainage.
Andrews Arms Apartments	Residential	ISS	Treatment	Grass	Good	Landscape feature - c
Creek Bend Townhouses	Residential	ISS	Treatment	Grass	Good	Three foot-wide grass
Tibbets Creek Townhouses	Townhouses	ISS	Treatment	Mixed	Fair	Drainage, channaliza
Spyglass Hill Townhouses	Townhouses	ISS	Treatment	Grass	Fair-Good	Thin vegetation.

The purpose of most of the drainage features identified in Table 6 as "conveyance" was uncertain. The "LDS Church Bypass" and "The Uplands" exemplify conveyance systems in which volunteer wetland vegetation appears to provide some water quality benefits. Of the remaining four "conveyance" systems, three are described as "poor" in terms of biofiltration due to the near absence of vegetation cover, and one (Cambria), which is listed as "fair-good", appears to be an old agricultural ditch which was integrated into a more recent detention facility.

Biofiltration Swales

Performance Evaluation Results

Grass-lined swales in good condition could be assumed to perform in a manner similar to that described in the Montlake Terrace Biofiltration Study (Kulzer, 1992). At the other extreme, channelized swales, and swales with little or no vegetation, are likely to provide little treatment. Conversion of poorly drained swales to wetland vegetation (either naturally, or through deliberate management efforts) may provide a low maintenance, but effective swale management strategy.

In order to estimate the effectiveness of swales vegetated with emergent wetland plant species, King County SWM conducted an intensive evaluation of the wetland-vegetated conveyance ditch at "The Uplands" residential development on the East Lake Sammamish Plateau. Results of this study are presented in Table 7 along with results from the Montlake Terrace and Dayton Avenue Biofiltration Studies. A more complete presentation of the Uplands study is provided in Appendix V.

Table 7. Performance Data from Three Biofiltration Swales

Parameter	The Uplands Wetland Swale (350 feet long)	Montlake Terrace Grass-Lined Swale [1] (200 feet long)	Dayton Avenue Grass-Lined Swale [2] (570 feet long)
TSS (mg/l)	67%	83%	67.8%
TP	39	29	4.5
SRP	-45	0	35.3
BAP	-31	>40	31.9
NO3	9	-81	31.4
NH3	16	—	—
Total Cu	-35	46	41.7
Total Pb	6	—	62.1
Total Zn	-3		

1. Kulzer, Louise (1992) *Biofiltration Swale Performance, Recommendations, and Design Considerations*, Municipality of Metropolitan Seattle.
2. Goldberg, Jennie S. (1993) *Dayton Avenue Swale Biofiltration Study*, Seattle Engineering Department.

Biofiltration Swales

Estimate of the Potential Performance of East Lake Sammamish Swales

Using data from the Montlake Terrace study as an indicator of the performance of swales in good condition, and making some assumptions regarding the effectiveness of facilities defined as being in fair and poor conditions, the overall effectiveness of biofiltration swales in the Issaquah/East Lake Sammamish basin can be estimated. While certainly only a rough estimate, the exercise is valuable in that it reveals that existing surface water facility design requirements may not protect water resources to the extent previously assumed by stormwater managers.

The spreadsheet models in Tables 8 and 9 illustrate the potential disparity between assumed and actual swale performance in the study watershed. This disparity should be taken into account both when estimating the effect of current watershed management strategies, and when prioritizing future maintenance and retrofit efforts.

For these models, all swales were assumed to serve equal land areas. Removal rates from the Montlake Terrace were used for swales that were in "good" condition. Swales in "fair" condition were assumed to be half as effective as the "good" swales, and swales in "poor" condition were assumed to provide no treatment.

If we accept the results presented in Tables 8 and 9, and calculate a weighted removal rate for TSS and TP, upgrading the defective swales to "good" condition would increase the overall performance of biofiltration swales in the Issaquah/East Lake Sammamish basin from 40 percent to 83 percent for TSS and from 17 percent to 33 percent for TP.

Given the broad assumptions used in creating these estimates, the above analysis represents an example of how the effectiveness .of current management practices can be assessed rather than the final word on how much (or little) would be gained by altering these practices. As additional performance data for biofiltration swales become available, estimates of this type could support more definitive management recommendations.

Table 8. Spreadsheet Model for Total Suspended Solids.
Model compares TSS loadings based on assumed and actual conditions.

30 % Commercial Land Use **Inlet Loading Rate: 242 kg/ha-yr**

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.83	11.1	100	0.83	41.1
Fair	39	0.42	55.2	0	0.42	0.0
Poor	33	0.00	79.9	0	0.00	0.0
Total			146.2			41.1
Contribution from Commercial Areas			43.9			12.3

40 % Multi-Family **Inlet Loading Rate: 133 kg/ha-yr**

(includes schools and churches)

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.83	6.1	100	0.83	22.6
Fair	39	0.42	30.3	0	0.42	0.0
Poor	33	0.00	43.9	0	0.00	0.0
Total			80.3			22.6
Contribution from Multi-Family Areas			32.1			9.0

30 % Single Family Residential **Inlet Loading Rate: 50 kg/ha-yr**

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.83	2.3	100	0.83	8.5
Fair	39	0.42	11.4	0	0.42	0.0
Poor	33	0.00	16.5	0	0.00	0.0
Total			30.2			8.5
Contribution from Single Family Areas			9.1			2.6

	Observed		**Assumed**
Land-use weighted loading (kg/ha yr)	141		141
Load not captured by swales (kg/ha yr)	85		24
Reduction in load (kg/ha/yr)	56		117
Percent reduction	40%		83%

Table 9. Spreadsheet Model for Total Phosphorus.
Model compares TP Loading based on assumed and actual conditions.

30 ¶%Commercial Land Use Inlet **Loading Rate: 0.69 kg/ha-yr**

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.33	0.12	100	0.33	0.46
Fair	39	0.17	0.22	0	0.17	0.00
Poor	33	0.00	0.23	0	0.00	0.00
Total			0.58			0.46
Contribution from Commercial Areas			0.17			0.14

40 % Multi-Family **Inlet Loading Rate: 0.59 kg/ha-yr**
(includes schools and churches)

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.33	0.11	100	0.33	0.39
Fair	39	0.17	0.19	0	0.17	0.00
Poor	33	0.00	0.19	0	0.00	0.00
Total			0.49			0.39
Contribution from Multi-Family Areas			0.20			0.16

30 % Single Family Residential **Inlet Loading Rate: 0.30 kg/ha-yr**

Condition	Swales in Observed Condition			Assuming Swale in Good Condition		
	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr	Percent of Swales	Removal Efficiency	Loading Out kg/ha-yr
Good	27	0.33	0.05	100	0.33	0.20
Fair	39	0.17	0.10	0	0.17	0.00
Poor	33	0.00	0.10	0	0.00	0.00
Total			0.25			0.20
Contribution from Single Family Areas			0.07			0.06

	Observed		**Assumed**
Land-use weighted loading (kg/ha yr)	0.533		0.533
Load not captured by swales (kg/ha yr)	0.444		0.356
Reduction in load (kg/ha/yr)	0.089		0.177
Percent reduction	17%		33%

Biofiltration Swales

Conclusions

Of the thirty-three biofiltration swales identified, nine (28%) were found to be in good condition, with a relatively complete and uniform vegetative cover, thirteen (41%) were in fair condition, being in need of at least some repair operating at less than optimum efficiency, and eleven (34%) were considered poor, having little or no vegetation, or extensive channelization.

Upgrading existing sub-standard swales could increase the overall efficiency of biofiltration facilities from 17 percent to 33 percent for total phosphorus, and from 40 percent to 83 percent for total suspended solids. These values are, however, based on extremely limited performance data and a minimal modeling effort.

Conversion of swales that are too wet to support terrestrial grasses to wetland vegetation may be a viable means of retrofitting dysfunctional systems. Removal rates for one swale transformed (albeit naturally) to a wetland system appear to be comparable to grass-lined swales for total suspended solids, and perhaps better than these facilities for total phosphorus. However, such facilities may convert particulate phosphorus to more biologically-available soluble forms.

Biofiltration Swales

Recommendations

1. Greater emphasis should be placed on inspection during and immediately after construction to ensure that facilities are in good condition upon acceptance by the county. While at this time there are relatively few biofiltration swales in this basin that are maintained by the county, five additional problem-facilities will be transferred to the county in the near future.

2. Additional intensive evaluations (inflow/outflow monitoring) should be conducted to determine whether the performance values assigned to swales in "fair" or "poor" condition are reasonable.

3. Information on the condition of existing swales, and from future performance evaluations, should be used to determine more accurately how much could be gained by aggressively improving the condition of biofiltration swales in the Issaquah/East Lake Sammamish basin. Such analyses should include a cost/benefit analysis that compares swale upgrades with other pollution prevention and treatment strategies.

4. Retrofit of existing county-owned swales should be considered as a means of improving water quality in the Issaquah/East Lake Sammamish basin and reducing pollutant loadings to Lake Sammamish. At this time there are at least six facilities owned by the county that could be included in retrofit plans. Retrofit plans should be expanded to include the rest of King County.

5. Inspection of facilities already transferred to the county, as well as those not maintained by the county, should be improved to allow the substandard facilities in the basin to be repaired and properly maintained. Inspection criteria are available in the Surface Water Design Manual.

Closing Comments

This report has presented preliminary findings concerning implementation of two water quality BMPs (wetponds and biofiltration swales) in the Issaquah/East Lake Sammamish basin. The net efficiency of these two treatment systems was estimated; however, the accuracy of these estimates is severely limited by the sample small size and variability of data on biofiltration swale performance. Attempts to obtain information on the overall effectiveness of water quality facilities is further complicated by the variety of conditions that exist in these facilities. Obtaining definitive data on the performance of wetponds was essentially impossible because of the preponderance of fundamental failures in the implementation of these facilities.

The potential for a high degree of resource protection in the Issaquah/East Lake Sammamish basin is good because of the early implementation of basin plan recommendations and advanced Design Manual regulations relating to the use of water quality facilities. Unfortunately, the execution of these advanced measures has been poor, resulting in a level of resource protection that is unlikely to be much better than in other, less intensively managed, regions of King County.

To this end, the Issaquah/East Lake Sammamish basin provides an important barometer of the ability of city and county agencies to respond to BMP evaluation efforts. In light of the high value placed on Lake Sammamish as a regional resource, efforts should be made to correct the shortcomings identified in this report, and monitor the success of future pollution control efforts. The results of these efforts, which include the next generation of treatment facilities, and business outreach/education efforts, should be used to guide other management efforts in the region.

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