Product Evaluation

Lake Stevens North Field Evaluation:
Stormwater Management StormFilter with ZPG™ Media

As part of a performance assessment of the Stormwater Management StormFilter® (StormFilter) in the State of Washington, a system using ZPG™ multipurpose media installed at South Lake Stevens Road Bridge, Everett, WA, was evaluated. This StormFilter system treats stormwater runoff draining from the deck of the South Lake Stevens Road Bridge, a two-lane bridge spanning a small wetland area on the SE shore of Lake Stevens, as well as portions of the adjoining roadway. For research purposes, the removal characteristic of the system with respect to solids, metals, and nutrients was simultaneously assessed.

Over the course of the 13 storm events monitored over the course of a year, statistically significant (a<0.05) removal of solids, metals, and nutrients was observed. A detailed analysis of the residual material found within the system at the end of the study confirmed the capture of a substantial mass of solids, metals, and nutrients. All of the data suggest the substantial improvement of stormwater quality through the use of the StormFilter.

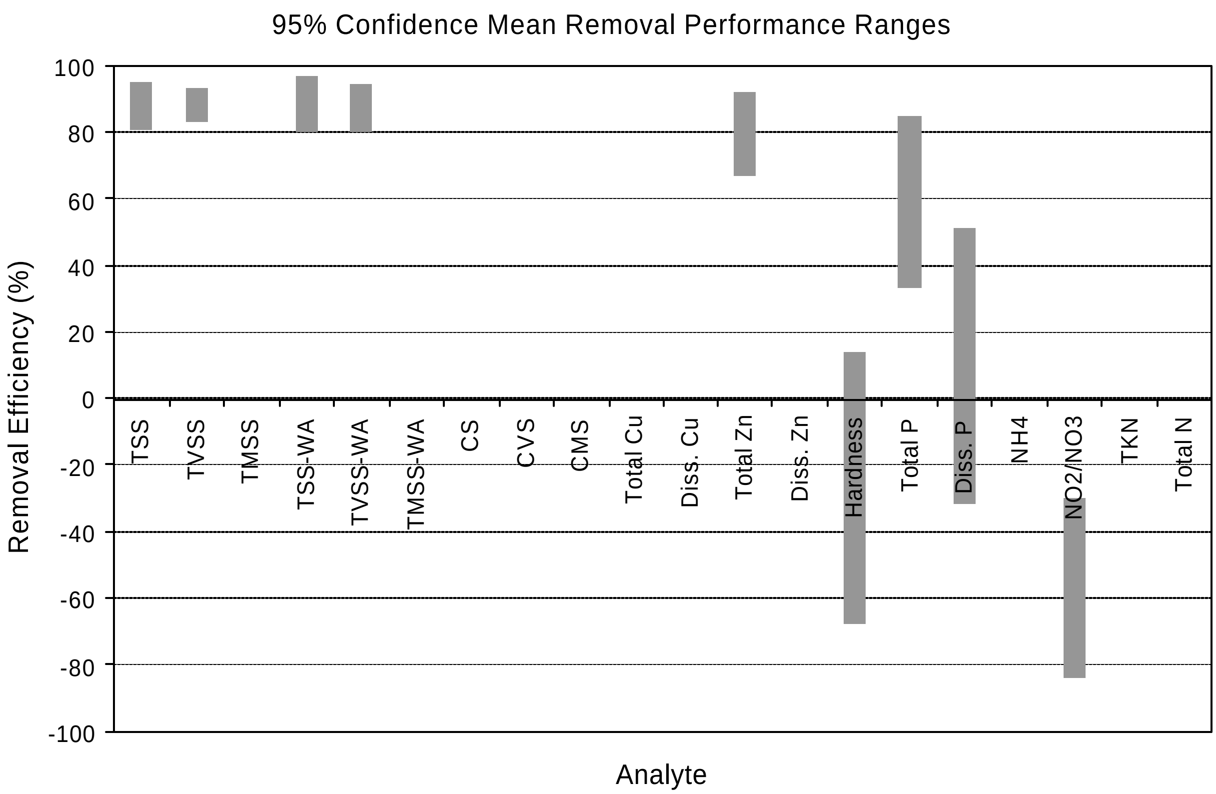

Figure 1. 95% confidence, mean removal performance ranges for the Lake Stevens North StormFilter based upon Regression of EMC analysis. Refer to Table 1 for acronym definitions.

Figure 2. Aerial view of the Lake Stevens North StormFilter site.

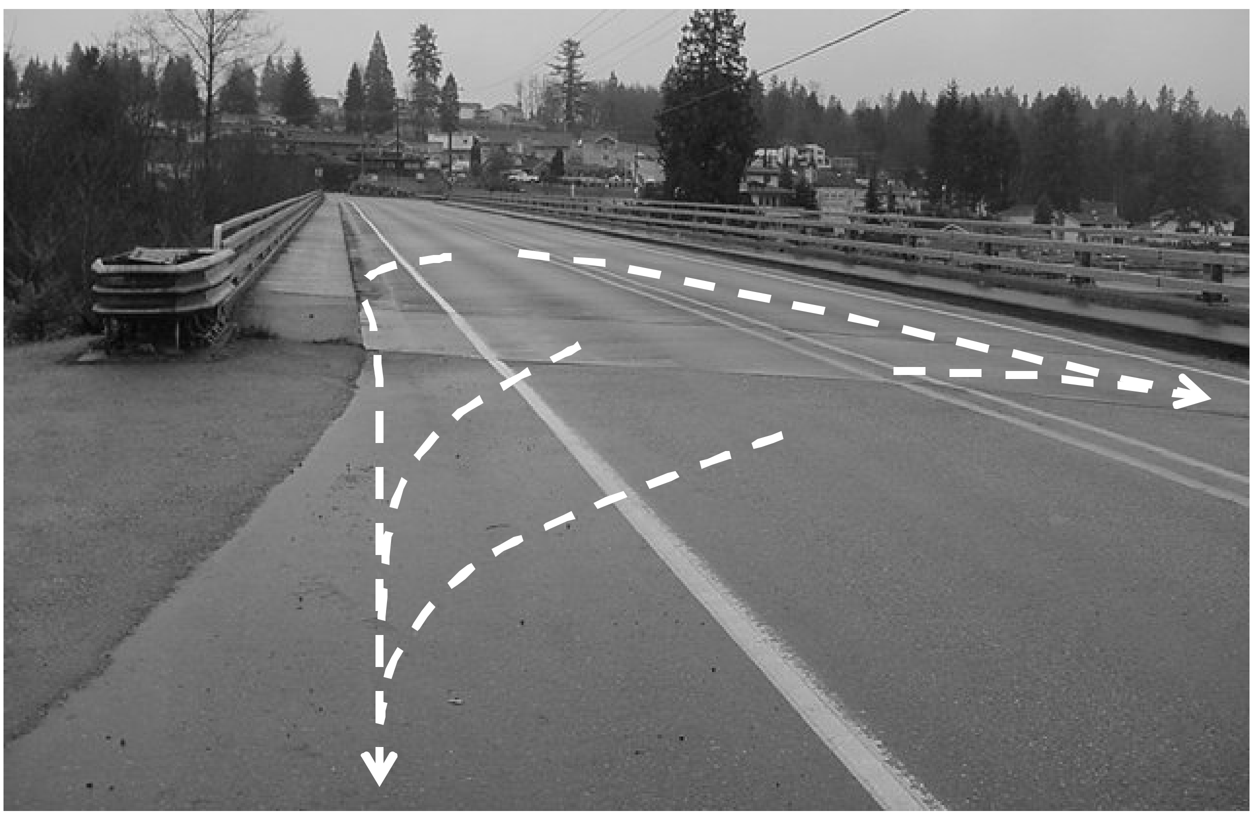

Figure 3. View of part of the Lake Stevens North site drainage area. Arrows indicate flow to the StormFilter system via gutters and catchbasins located at the foot of the bridge.

Figure 4. View of the Lake Stevens North StormFilter with the South Lake Stevens Road Bridge in the background. Effluent discharges directly into the lake visible in the background.

Site and System Description

Drainage Area

The StormFilter system under evaluation is installed adjacent to Lake Stevens and east of South Lake Stevens Road at the north end of the bridge deck (Lat: 47.9877442, Long: -122.07719), and will be referred to as the Lake Stevens North StormFilter. The drainage area is 1200-m^2 (0.29-ac) of 100% impervious arterial road bridge decking and adjoining roadway. Primary sources of pollution within this drainage area include solids, metals, trash, and debris from automobiles, maintenance activities, and atmospheric fallout. Treated runoff is discharged directly into Lake Stevens.

The StormFilter System

The typical StormFilter unit is composed of three bays: the inlet bay, the filtration bay, and the outlet bay. Stormwater first enters the inlet bay of the StormFilter vault through an inlet pipe, which is plumbed to catch basins throughout the drainage area. Stormwater in the inlet bay is then directed through a flow spreader, which traps some floatables, oils, and surface scum, and over the energy dissipator into the filtration bay where treatment will take place. Once in the filtration bay, the stormwater begins to pond and percolate horizontally through the media contained in the StormFilter cartridges. After passing through the media, the treated water in each cartridge collects in the cartridge's center tube from where it is directed into the outlet bay by an under-drain manifold. The treated water in the outlet bay is then discharged through a single outlet pipe to Lake Stevens.

The StormFilter system installed at Lake Stevens consists of a 1.8-m x 3.7-m (6-ftx12-ft) vault housing 10 cartridges. The StormFilter cartridges contain ZPG™ multipurpose media, a proprietary blend of organic and inorganic media. These 10 cartridges operate at a per-cartridge filtration rate of 28 L/m (7.5-gpm), yielding a peak system operating rate of 280 L/min (0.17-cfs) as tested. Flows in excess of design are bypassed via an internal bypass mechanism, and thus the system is considered by Ecology to be "online" with respect to bypass.

The peak system operating rate of the Lake Stevens North StormFilter as tested is approximately 10% less than the 320 L/min (0.19-cfs) peak system operating rate recommended for the site based upon the sizing standards specified by Ecology at the time of writing (Western Washington Hydrology Model v2.5A). Undersizing increases the bypass potential for the Lake Stevens North StormFilter and effluent water quality data corresponding to bypass events reflects combined flows (treated and bypass) within the StormFilter.

Water Quality Sampling Methods

The equipment and sampling techniques used for this study are in accordance with a Quality Assurance Project Plan developed by Stormwater360 according to the Washington State Department of Ecology (WADOE) TAPE protocol. SMI personnel were responsible for the installation and maintenance of the sampling equipment and Taylor Associates, Inc. of Seattle, WA, was utilized for sample retrieval, system reset, and sample submittal activities. A general overview is provided.

Equipment Specifications

Samples were collected using two ISCO 6700 compact portable automated samplers with factory-installed modems, containing 24, 1000-ml, polypropylene, ISCO wedge shaped bottles. Each sampler was connected to individual 12VDC, deep cycle power supplies recharged by a solar panel. Flow measurements were made using ISCO 750 area velocity modules with low profile area velocity sensors.

Sample intakes from each of the automated samplers' peristaltic pumps were connected to 3-m (10-ft) lengths of 10-mm (0.4-in) diameter Acutech Duality FEP/LDPE suction line. A stainless-steel, low-profile sample strainer (14-mm [0.56-in] diameter with multiple 6-mm [0.25-in] openings) was installed at the end of the suction line to protect the pump head. All fittings were polyethylene in composition.

Internal overflow was monitored using an Overflow Detection System (ODS) consisting of a float switch connected to a Onset Hobo State Logger. Rainfall was monitored using an Onset RG2 data logging rain gauge connected directly to the influent ISCO 6700 compact portable sampler for data logging purposes.

Equipment Installation

All sampling and flow monitoring equipment was installed inside the vault for security and protection reasons. The automated samplers and 12-VDC batteries within the vault were placed on top of a platform to achieve minimal suction line length and eliminate dips in the suction line. Maximum inline velocity (= 2 ft/s) was maintained by avoiding extraneous suction line length, excessive bends, and kinks in suction lines. The rain gauge was secured to a fixed post above the StormFilter system with no overhead obstructions.

Individual automated samplers, suction lines, and flow sensors were used to monitor the influent entering and effluent exiting the StormFilter system; one sampler, flow sensor, and suction line was placed in the inlet pipe and another sampler, sensor, and suction line was placed in the outlet pipe. Thus, each sampler was independently controlled; the influent sampler by flow entering the system and the effluent sampler by flow leaving the system.

The flow sensors and suction lines were mounted on ISCO stainless steel spring rings sized to match the inner pipe diameter at the sampling locations shown in Appendix A. The spring rings were inserted as far up into the pipe as possible, keeping the suction lines and flow sensors in a fixed position at the invert of the pipe with no vertical offset. The suction lines and flow sensor cables were bound together and routed out of the pipe and up to the samplers. Samples were taken as water entered and exited the first StormFilter vault and did not measure pollutant removal associated with treatment by upstream structures or catch basins.

The Overflow Detection System (ODS) was attached to a cartridge located towards the rear of the filtration bay such that the switch would activate at a water surface elevation of 21-in from the floor of the filtration bay (design overflow elevation). The state logger was placed in a waterproof housing and secured to a cartridge inside the vault.

Equipment Operation

Flow meters were set to record measurements every 1 to 5 minutes, which was typically extended to allow for extended deployment and minimal power usage during colder weather. To further minimize power consumption and avoid false starts caused by dry weather flows, samplers were programmed to begin sample acquisition after a minimum flow rate condition was met. Once enabled, the equipment collected samples on a volume-paced basis.

Sample Collection Program

The sample program input into each of the automated samplers was a two-part program developed to maximize both the number of subsamples collected and the coverage of an individual storm event. The first part of the program sequentially filled the first set of bottles every X-gal. The second part of the program sequentially filled the remaining bottles every 2X-gal. This increased the probability of adequate coverage of both small and large precipitation events by allowing the use of subsamples collected according to X or 2X sample pacing. The sample pacing value was changed on an as-needed basis based upon anticipated storm size. A record of each of the program changes was made by the automated sampler and was reflected in the collected data.

Sample Retrieval and Analysis

Upon the collection of samples following a precipitation event, SMI personnel remotely communicated with the automated sampling equipment to confirm sample collection and dispatch personnel from Taylor Associates, Inc. to retrieve and replace the samples and reset the automated sampling equipment.

Sample bottles were capped, labeled, and transferred from the sampler base section directly to a cooler stocked with gel ice packs. The samples were then taken to a Taylor Associates, Inc. facility where they were composited and split at the direction of SMI using an appropriately sized churn sample splitter (Bel-Art Products) to create flow-weighted, influent and effluent, event mean concentration (EMC) sub-samples for submittal to North Creek Analytical, Inc., Bothell, WA, (Oregon and Washington State accredited laboratory) for analysis using the methods listed in Table 1.

Table 1. Analytical methods for water quality sample analysis. Shading denotes extrapolation.

Analyte	Analytical Method
Total Suspended Solids (TSS)	ASTM D3977B
Total Volatile Suspended Solids (TVSS)	SM 2540E
Total Mineral Suspended Solids (TMSS)	[TSS] – [TVSS]
Washington Total Suspended Solids (TSS-WA)	500-um Filtration + ASTM D3977B
TVSS-WA	500-um Filtration + SM 2540E
TMSS-WA	[TSS-WA] – [TVSS-WA]
Coarse Solids (CS)	[TSS] – [TSS-WA]
Coarse Volatile Solids (CVS)	[TVSS] – [TVSS-WA]
Coarse Mineral Solids (CMS)	[TMSS] – [TMSS-WA]
Total Zn, Cu	EPA 200.8
Dissolved Zn, Cu	0.45-um Filtration + EPA 200.8
Hardness	SM 2340B
Total Phosphorus	EPA 365.1
Dissolved Phosphorus	Filtered + EPA 365.2
Ammonia-N	EPA 350.1
Nitrate/Nitrite-N	EPA 353.2
Total Kjeldahl-N	EPA 351.2
Total-N	[Total Kjeldahl-N] + [Nitrate/Nitrite-N]
pH	EPA 150.1/9040A

Field QC

To avoid contamination issues, disposable and certified clean materials were used whenever possible. Upon installation of the sampling equipment, new sampler tubing was used so as to avoid the need for decontamination and the associated equipment rinsate blank. During the course of the project, wedge-shaped ISCO bottles were only used once and sent to North Creek Analytical for cleaning and acid-washing. On 10/7/03, and upon completion of the study on 8/13/04, sampling equipment field blanks were collected from the influent sampling equipment.

Sampling equipment field blanks were performed according to SMI (2004a), and involved pumping deionized water through the fully assembled samplers. Samples were then submitted to North Creek Analytical and analyzed for TSS, total metals, total phosphorus, and TKN. The results returned non-detects for these analytes.

Residual Solids Assessment Methods

At the end of the study period, the system was maintained for the purpose of assessing the quantity and quality of the solids captured by the system. This procedure was performed according to SMI (2004a) and SMI (2004b) and involved the following activities: 1) the removal of the StormFilter cartridges and selection of two cartridges for solids content and media analysis; 2) the manual removal of residual solids from the system for direct volume measurement (as opposed to estimation); 3) the methodical collection of a large (20-L to 30-L), composite sample of the residual solids for analysis; and 4) the installation of new cartridges.

The StormFilter cartridges selected for the assessment were analyzed using direct methods as much as possible. The cartridges were first allowed to air-dry indoors for several weeks, and the media was then emptied into shallow, tared trays for compositing and sun-drying. Upon the stabilization of the moisture content of the media, the trays were weighed and representative samples were collected for analysis according to Table 2. Data for the two cartridges was averaged and used to represent the other cartridges within the system.

The composite sample of the residual solids was homogenized by hand and representatively sampled for analysis. Samples were submitted for the analytes shown in Table 2. Data for this material was used in conjunction with the volume of residual solids removed from the system in order to determine the mass of contaminants contained within the residual solids on a dry weight basis.

Table 2. Analytical methods for residual solids and media sample analysis. Shading denotes extrapolation.

Analyte	Analytical Method
Percent Solids	NCA SOP
Total Solids	EPA 160.3 (modified)
Total Volatile Solids	EPA 160.4
Total Mineral Solids	[Total Solids] – [Total Volatile Sollids]
Total Zn, Cu, Cd, Pb	EPA 6020 (ICP/MS)
Total Phosphorus	EPA 2010B (ICP/AES)
Nitrite-N	EPA 300.0
Nitrate-N	EPA 300.0
Total Kjeldahl-N	EPA 351.2
Total-N	[Total Kjeldahl-N] + [Nitrite-N]+[Nitrate-N]
Diesel and Heavy Range Hydrocarbons	NWTPH-Dx
Particle Size Distribution	SMI SOP

Calculations

Most of the data collected during the study were based upon direct measurement. Some reported values, such as event coverage, are based upon calculated values. Coverage was calculated by multiplying the number of sample aliquots representing the influent or effluent of a storm event by the volume used to pace the sample collection program and expressing this value as a percentage of the total influent or effluent volume recorded by the flow meter.

Water Quality Results

Data Verification, Validation, and Reconciliation

Data corresponding to 13 storm events covered by this interim report were captured between April 2003 and March 2004. Of these 13 storm events, data verification led to the elimination of one event due to obvious handling, analytical, or monitoring errors[†]. LSN120203 was also eligible for disqualification due to exceedance of holding time requirements, however Ecology did not consider this hold-time violation to be serious enough to merit disqualification since only solids were analyzed for this event and thus disqualification was overturned by Ecology (M. Blosser, personal communication, October 22, 2004). The invalidation of storm events due to confirmed exceedance of design operating parameters (i.e. substantial overflow confirmed by ODS) was not observed. Thus 12 of the 13 storm events were deemed representative of system operation within design parameters and thus were deemed acceptable for qualification through reconciliation with the data quality objectives (DQOs) of SMI (2003).

The DQOs presented in SMI (2003) and used throughout the project were based directly upon the “Storm Event Criteria” (Criteria) and Guidelines presented by WADOE (2002). However, Ecology currently proposes revisions to the Criteria presented by WADOE (2002) (M. Blosser, personal communication, October 22, 2004). These revisions are: 1) reduction of minimum Event Depth from 0.15-in to 0.10-in; 2) elimination of Antecedent Dry Period criteria. In addition, the Ecology-approved TEER Consultant suggested that for the StormFilter system it

[†] Event LSN040803 represents system equilibration following maintenance activities during which time marginal performance can be observed at low influent concentrations. This condition is discussed in section 6.2.2 of SMI (2003) and this type of event is not typically monitored as it does not represent steady-state performance and should be considered separately. It is provided here for disclosure purposes.

was reasonable to relax the Guidelines in two respects: 1) accept storm samples with a minimum of 5 rather than 10 aliquots; 2) accept storm samples that represent a minimum of 50% rather than 75% of the storm. Rationale in support of these Guidelines is provided by RPA (2004). Thus the original DQOs presented in SMI (2003) were modified accordingly and are presented in Table 3.

In order to make the most use of the available data set, events that failed to strictly meet the DQOs were reevaluated based upon best professional judgment and knowledge gained over the course of the project. Events that failed to satisfy the Number of Aliquots DQO were not disqualified since the number of aliquots collected for those events appeared appropriate relative to the small volume and flashy nature of the corresponding hydrographs. This decision produced 3 additional qualified events. Additionally, the LSN012204 event was disqualified as an obvious outlier[†] with respect to the other events, since its inclusion in the final data set inhibited statistical data analysis due to the relatively small data set. The result of these decisions is shown in Table 3, where a total of 11 events were qualified and used for performance summarization based upon best professional judgment.

Inability to consistently meet the original DQOs was primarily due to the inherent variability of the weather and the limitations of modern weather forecasting. The remote location of the site and the static sampling equipment technology available at the time of project initiation required the use of a fixed sample pacing value for extended sampling periods. Sample pacing values are purely based upon intuition and take into consideration the characteristics of the site, the characteristics of the system, local rainfall characteristics, seasonal rainfall characteristics, maximum sample volume capacity, the goal of collecting >10 aliquots, and the goal of attaining 100% coverage. More often than not, successful sample pacing estimation was confounded by a combination of situations such as excessive or inadequate storm size, expenditure of sample capacity on minor antecedent events and non-synchronous influent and effluent samplers. This hindered attainment of aliquot and coverage goals, and the data thus reflect best attempts at attaining WADOE (2002) Criteria and Guidelines.

[†] Outlier decision based upon uncharacteristically low solids removal relative to other events in the data set. Also, this event presents an instance of substantial nitrate/nitrite removal which is very unexpected for the system (only such instance within the data set). These very uncharacteristic observations suggest a handling error beyond the scope of the quality control associated with the project.

Table 3. Results of reconciliation of the storm events observed as part of the Lake Stevens North StormFilter performance evaluation.

Event ID	Data Quality Objectives (DQOs): Event Depth (in) [minimum 0.10]	Event Duration (hr) [minimum 1]	Number of Aliquots [minimum of 5 (Inf:Eff)]	Event Coverage (%) [minimum of 50 (Inf:Eff)]	Qualification based upon Best Professional Judgement	Other Event Characteristics: Influent Volume (gal)	Peak Operating Rate** (%)	Antecedent Dry Period (hr) [minimum 6-hrs <0.04-in]
LSN040803	0.29	7	12:9	69:71		8756	69	32
LSN051503	0.18	14	5:6	97:88	✓	1332	76	4
LSN091603	0.30	15	5:5	96:97	✓	2591	81	60
LSN100603	0.17	5	6:7	55:62	✓	2703	77	408
LSN101503	0.20	5	4:5	71:90	✓	2836	71	48
LSN101603	0.17	5	4:5	72:88	✓	2790	59	7
LSN102203	0.28	4	6:8	81:97	✓	3709	144	31
LSN111003	0.97	15	21:21	80:90	✓	13080	137	48
LSN120203	0.54	5	9:11	82:88	✓	5474	188	3
LSN012204	0.39	10	6:6	86:68		3475	87	86
LSN012904	0.69	8	10:13	71:64	✓	7007	120	32
LSN020304	0.19	9	5:4	69:83	✓	2174	93	34
LSN030604	0.14	5	6:6	53:67	✓	2840	56	36

* 500-um pre-filtration, whole volume analysis
** expressed as percentage of effluent design Q
bold = off-site data used due to equipment error
shading = DQO met

Table 4. Summarized performance for the StormFilter performance evaluation of the Lake Stevens North StormFilter. Refer to Table 1 for acronym definitions.

		Descriptive Statistics			Regression of EMC				Aggregate Load Reduction	
	Analyte	*n*	Range of Influent EMCs (mg/L)	Median Influent EMC (mg/L)	Mean Removal Efficiency Estimate (%)	95% Confidence Interval for the Mean Removal Efficiency Estimate (%)	Median Effluent EMC Estimate (mg/L)	95% Confidence Interval for the Median Effluent EMC Estimate (mg/L)	Mean Removal Efficiency Estimate (%)	One-Tailed Sign Test* (H0=H1=0.5)
Solids	TSS	11	18 to 269	110	88**	81 to 95	23	17 to 28	80	R
	TVSS	10	9 to 73	27	88***	83 to 93	7	6 to 8	78	R
	TMSS	9	15 to 212	79	---	--- to ---	---	--- to ---	79	R
	TSS-WA	11	17 to 264	95	88*	80 to 97	22	16 to 28	77	R
	TVSS-WA	10	8 to 47	24	87**	80 to 94	7	6 to 8	70	R
	TMSS-WA	10	15 to 217	71	---	--- to ---	---	--- to ---	77	R
	CS	5	12 to 40	20	---	--- to ---	---	--- to ---	52	R
	CVS	5	6 to 36	8	---	--- to ---	---	--- to ---	72	R
	CMS	2	13 to 16	15	---	--- to ---	---	--- to ---	---	---
Metals	Total Cu	6	0.0112 to 0.0264	0.0219	---	--- to ---	---	--- to ---	45	R
	Diss. Cu	1	0.0110 to 0.0110	---	---	--- to ---	---	--- to ---	---	---
	Total Zn	10	0.0353 to 0.255	0.136	80**	67 to 92	0.0471	0.0387 to 0.0556	66	R
	Diss. Zn	3	0.0206 to 0.0316	0.0230	---	--- to ---	---	--- to ---	---	---
	Hardness	10	17.0 to 39.6	27.0	-27***	-68 to 14	29.0	26.0 to 31.9	-4	A
Nutrients	Total P	10	0.0498 to 0.255	0.127	59**	33 to 85	0.0652	0.0454 to 0.0850	52	R
	Diss. P	9	0.00245 to 0.0152	0.00436	9**	-32 to 51	0.0057	0.0039 to 0.0076	---	~
	NH4	5	0.123 to 0.334	0.207	---	--- to ---	---	--- to ---	---	~
	NO2/NO3	10	0.0622 to 0.931	0.146	-57***	-84 to -30	0.332	0.261 to 0.402	-103	A
	TKN	3	1.6 to 1.88	1.62	---	--- to ---	---	--- to ---	---	---
	Total N	3	1.8 to 2.8	1.95	---	--- to ---	---	--- to ---	---	---

*** = P < 0.001
** = 0.01 > P > 0.001
* = 0.05 > P > 0.01
--- = undeterminable due to insufficient data quantity
R = removal is significant at the 5% level or less
~ = no significant difference
A = addition is significant at the 5% level or less

Performance Summarization

Since many methods for summarizing performance exist, and since performance summarization is a critical part of this study, a detailed discussion of the methods employed to summarize system performance for this study is warranted.

System performance over the course of the monitoring period was determined according to SMI (2003) which promotes the parametric test statistics provided by the Regression of EMC data summarization method. Analytes with a statistically significant relationship between influent and effluent EMCs ($a<0.05$; >95% probability of true relationship) were determined according to the parametric Regression of EMC method; analytes that did not yield a statistically significant ($a<0.05$) relationship between influent and effluent EMCs were determined as "aggregate pollutant loading reduction" (WADOE, 2002 method #2), using the influent flow data to determine runoff volume, and accompanied by a nonparametric test of significance.

Appendix B details system performance on an individual storm basis (discrete removal efficiency) using the Washington State Department of Ecology "individual storm reduction in pollutant concentration" method (WADOE, 2002 method #1)—the performance of the system over the course of a single storm event based upon EMC. It is important to note that it is generally accepted that discrete removal efficiencies should not be used for performance summarization by arithmetic averaging, as these efficiencies have been shown to be both sensitive to analytical error and susceptible to negative bias (EPA, 2002). Hydrograph and rainfall data from the events are also shown in Appendix B.

Both parametric (Regression of EMC) and non-parametric (Aggregate Load Reduction) performance statistics for the performance of the Lake Stevens North StormFilter are provided in Table 4. Results of parametric testing are shown in Appendix C and Table 4, and indicate significant ($a<0.05$) removal of TSS, TVSS, TSS-WA, TVSS-WA, Total Zn, and Total Phosphorus; marginal performance for Hardness and Dissolved Phosphorus; and the significant ($a<0.05$) conversion and release of Nitrate/Nitrite (see Table 1 for analyte definitions). Where parametric methods could not be used, non-parametric performance statistics indicate the significant ($a<0.05$) removal of TMSS, TMSS-WA, CS, CVS, and Total Cu. Performance with regard to, CMS, Dissolved Cu, Dissolved Zn, NH4, TKN, and Total N could not be confidently assessed due to insufficient data quantity/quality or insufficient quantity of detectable concentrations.

In order to summarize the performance of the system with regard to effluent water quality, median influent EMC values for analytes with statistically significant ($P<0.05$) Regression of EMC analyses were used with their respective regression equations to estimate median effluent water quality. Results are shown in Table 4. This approach is similar to the Effluent Probability Method recommended by EPA (2002) in that it focuses on median water quality as a measure of performance. The use of the median is most appropriate for stormwater quality data since stormwater quality is not normally distributed. Estimated rather than empirical median values were used in order to provide the statistics necessary for confidence intervals.

Influent Suspended Solids Characteristics

Since suspended solids is the most popular analyte for stormwater BMP performance evaluation and comparison, the influent suspended solids data was analyzed in order to characterize the suspended solids associated with the study. As shown in Figure 5, regression analysis of different influent suspended solids analytes revealed consistent relationships. Comparison of influent total and volatile solids results reveals that 24% of influent TSS and 17% of influent TSS-WA is composed of combustible solids that are assumed to be organic in nature. Comparison of influent TSS and TSS-WA data indicates that 92% of the suspended solids captured within the influent samples were less than 500-um in size. This data suggests that the suspended solids encountered by the system and reflected in the suspended solids removal efficiency calculations is represented predominantly by mineral solids less than 500-um in size.

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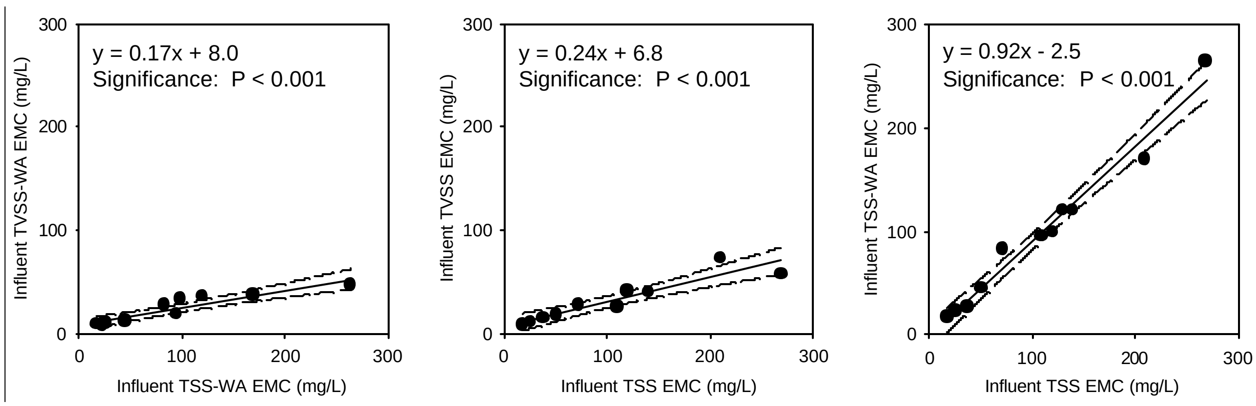

Figure 5. Significant influent relationships between solid analytes for the Lake Stevens North site. Refer to Table 1 for acronym definitions.

Residual Solids Assessment Results

Assessment of the mass of materials captured by the StormFilter as a whole revealed a net capture and retention of 276.2-kg of material. 22% of this material was found inside of the cartridges and 78% was found outside of the cartridges in the inlet bay and on the floor of the cartridge bay. Particle size analysis of materials <2000-um revealed that the total solids had a silt loam texture (USDA classification). Chemical analysis of the residual solids and used media confirmed the removal and retention of chemical contaminants such as metals and nutrients as suggested by the removal performance calculations. As shown in Figure 6, generally 75% of the contaminant load removed by the system was found outside of the cartridges and thus removed via settling. Particle size distributions and analytical results for the residuals removed from the StormFilter at the end of the monitoring period are provided in Appendix D.

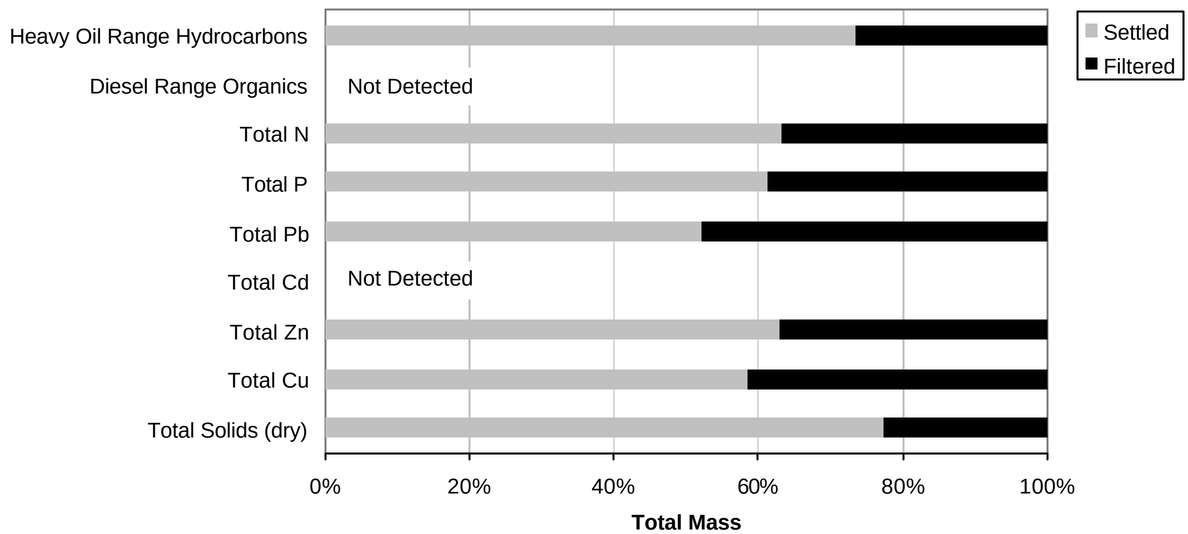

Figure 6. Distribution of the total mass of contaminants found within the Lake Stevens North StormFilter at the end of monitoring. The reader is reminded that these percentages do not directly indicate overall performance afforded by either the settling or filtering aspect of the StormFilter (i.e. approximately 40% of the 59% total phosphorus removal demonstrated by the system may have been due to filtering while the remaining 60% would have been due to settling prior to filtration.

Discussion

The evaluation of Stormwater best management practices (BMPs) in the field is a challenging task. Not only is the progress of such a project controlled by regional weather patterns, but the characteristics of anticipated precipitation events are difficult to predict. The challenge transcends monitoring activities and includes the reporting process as well, and the range of possible discussions to be had based upon the information contained within this report is too large to effectively manage.

The primary purpose of this project was to document StormFilter performance for a number of important stormwater quality parameters and quantify performance. However, this information could also be used for a number of related and unrelated discussions. This document should be used as a source of information to be used by the reader to evaluate their own hypotheses regarding stormwater topics.

Conclusion

As demonstrated in Figure 1, the Lake Stevens North StormFilter, using ZPG media at a filtration rate of 28 L/min/cartridge provided statistically significant removal of total and volatile solids; total Zn; and Total P. A comprehensive parameter menu and residual solids assessment process yielded additional information such as the strong association between the chemical contaminant load and the material that is settleable within a StormFilter for this type of site. This additional information will also prove critical in the comparison of the performance of the Heritage Marketplace StormFilter to that associated with other sites.

This project also serves as an example of the successful use of linear regression methods to support the use of parametric statistical methods for the field evaluation of a stormwater BMP. Despite the small number of qualifying storm events captured over the course of a year, statistical significance and error were quantified. This demonstrates that statistical methods can be successfully used for BMP field evaluation purposes.

References

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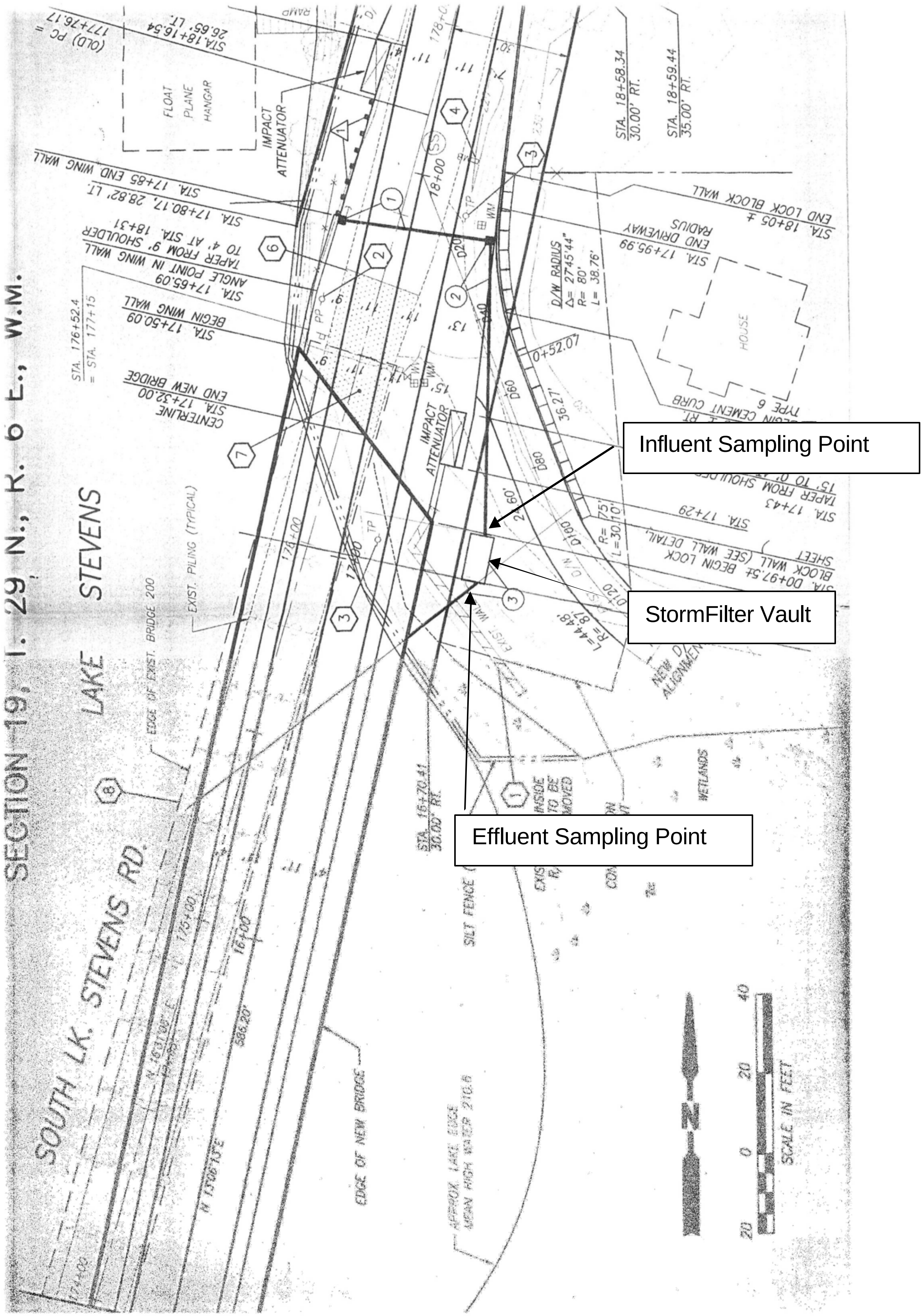
Appendix A

Site Map



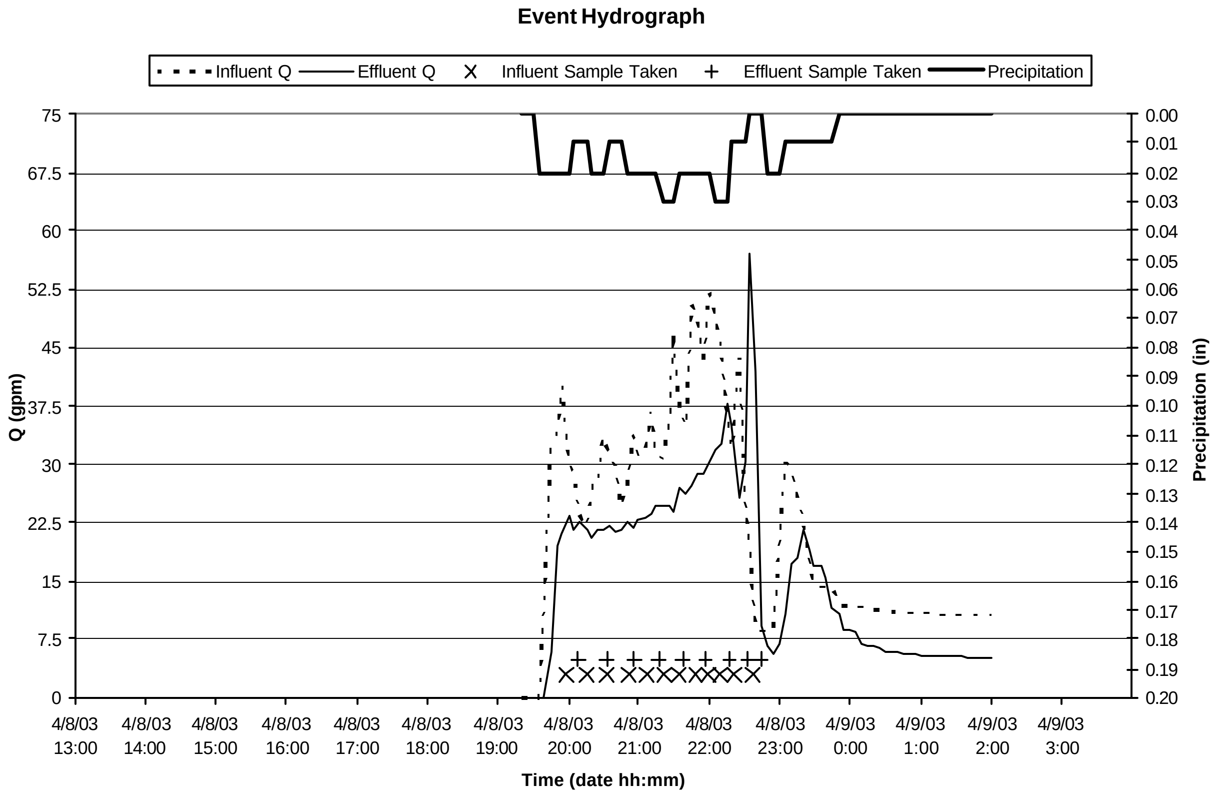
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	04/08/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	32 hours since last rain event, 0.05”

Hydrology

Total Precipitation (in):	0.28
Peak Flow (gpm):	Influent 52, Effluent 57
Total Runoff Volume (gal):	Influent 8756, Effluent 6382



Analytical

Bottles Used:	Parameter	Influent EMC	Effluent EMC	PQL	Dup. RPD	Efficiency
		Concentrations (mg/L)				
IN 2,4,6,8,10,12-18	TSS	50	48	10	20%	undeterminable
EFF 2,4,6,8,10,12-15	Total Cu	ND	0.0116	0.0100	0.398%	release
	Dissolved Cu	ND	ND	0.0100	8.00%	undeterminable
	Total Zn	0.0857	0.0798	0.0200	14.0%	undeterminable
	Dissolved Zn	ND	0.0267	0.0200	0.00%	release
	Total P	0.117	0.116	0.00500	0.976%	undeterminable
	Ortho-P	ND	ND	0.0020	0.705%	undeterminable
	NH4-N	0.256	0.994	0.100	0.741%	release
	NO2/NO3-N	0.227	0.298	0.0100	0.788%	release
	TKN	ND	ND	1.0000	2.76%	undeterminable
	pH	7.41	7.31	N/A	0.541%	1%
	Hardness	28.8	31.9	1.00	3.37%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. TVSS, TSS(<500µm), and TVSS (<500µm) analysis not performed.

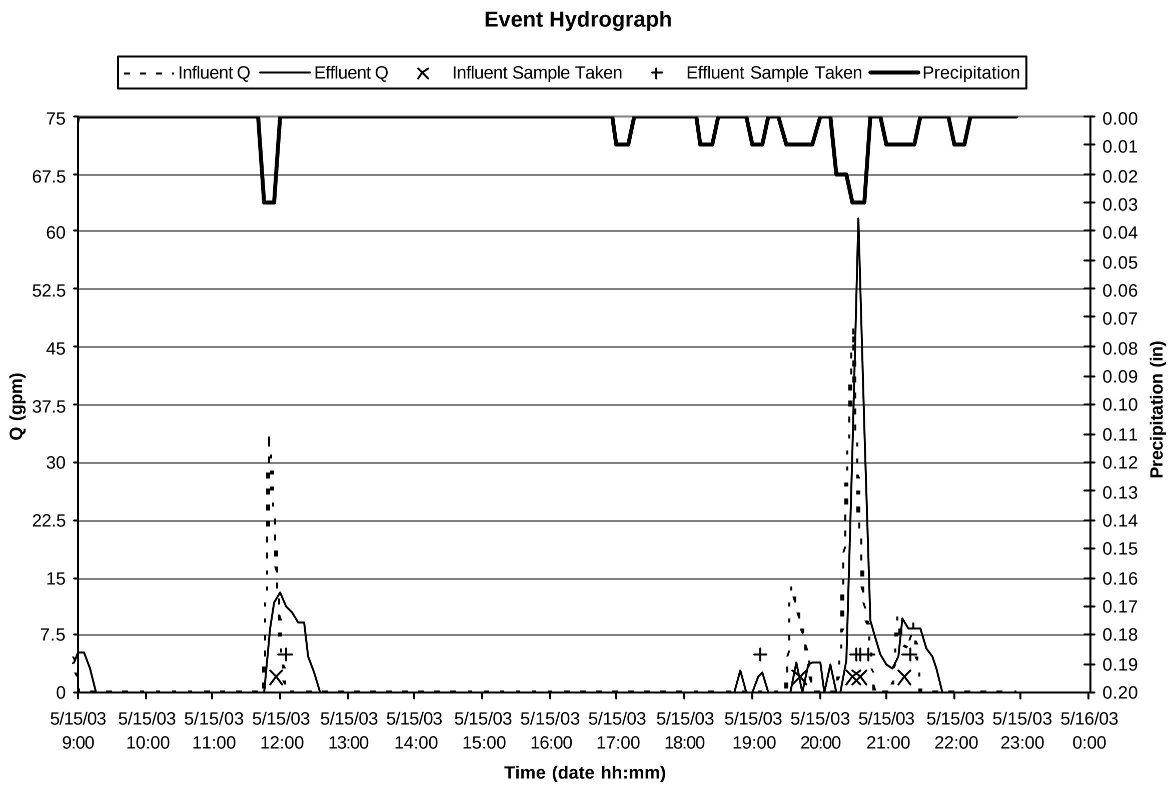
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	05/15/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	4 hours since last rain event, 0.06”

Hydrology

Total Precipitation (in):	0.18
Peak Flow (gpm):	Influent 48, Effluent 62
Total Runoff Volume (gal):	Influent 1332, Effluent 1695



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 1-5	TSS	130	30	10	20%	77%
EFF 1-6	TSS (<500µm)	120	29	10	20%	76%
	Total Cu	0.0218	0.0116	0.0100	2.15%	47%
	Dissolved Cu	ND	ND	0.0100	12.0%	undeterminable
	Total Zn	0.179	0.0748	0.0100	2.67%	58%
	Dissolved Zn	0.0206	0.0261	0.0100	5.92%	release
	Total P	0.233	0.138	0.00500	7.26%	41%
	Ortho-P	0.00624	0.00598	0.00200	1.98%	4%
	NH4-N	0.207	0.268	0.100	1.72%	release
	NO2/NO3-N	0.327	0.511	0.0100	0.482%	release
	TKN	1.62	1.29	1.00	0.522%	20%
	pH	7.55	7.35	N/A	0.00%	3%
	Hardness	34.3	38.5	1.00	1.41%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. TVSS and TVSS (<500µm) analysis not performed. All No Data:253 adjusted to zero for both influent and effluent.

Appendix B
Individual Storm Reports

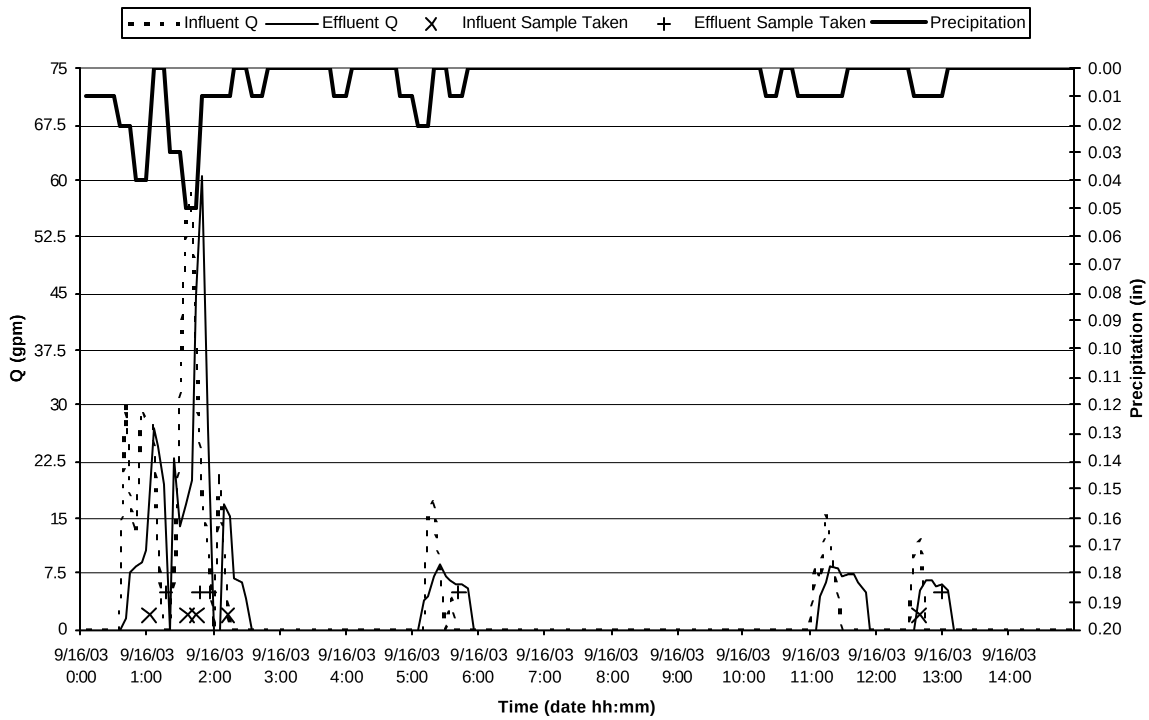
General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	09/16/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	64 hours since last rain event, 0.05”

Hydrology

Total Precipitation (in):	0.30
Peak Flow, (gpm):	Influent 58, Effluent 61
Total Runoff Volume (gal):	Influent 2591, Effluent 2568

Event Hydrograph



Analytical

Bottles Used:
IN 7-11
EFF 2,4,6-8

Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
TSS	120	21	10	20%	83%
TVSS	41	6.0	5.0	20%	85%
TSS (<500µm)	99	21	10	20%	79%
TVSS(<500µm)	33	6.3	5	20%	81%
Total Cu	0.0264	ND	0.0100	4.26%	62%
Dissolved Cu	ND	ND	0.0100	13.9%	undeterminable
Total Zn	0.205	0.0435	0.0200	1.40%	79%
Dissolved Zn	ND	ND	0.0200	2.70%	undeterminable
Total P	0.255	0.0851	0.00500	1.36%	67%
Ortho-P	0.0104	0.0112	0.00200	6.55%	release
NH4-N	0.190	0.270	0.100	1.72%	release
NO2/NO3-N	0.189	0.517	0.0100	3.17%	release
TKN	1.60	ND	1.00	4.26%	38%
pH	8.14	7.62	N/A	0.856%	6%
Hardness	25.5	26.2	1.00	3.10%	undeterminable

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. TVSS and TVSS (<500µm) analysis not performed. All No Data:253 adjusted to zero for both influent and effluent.

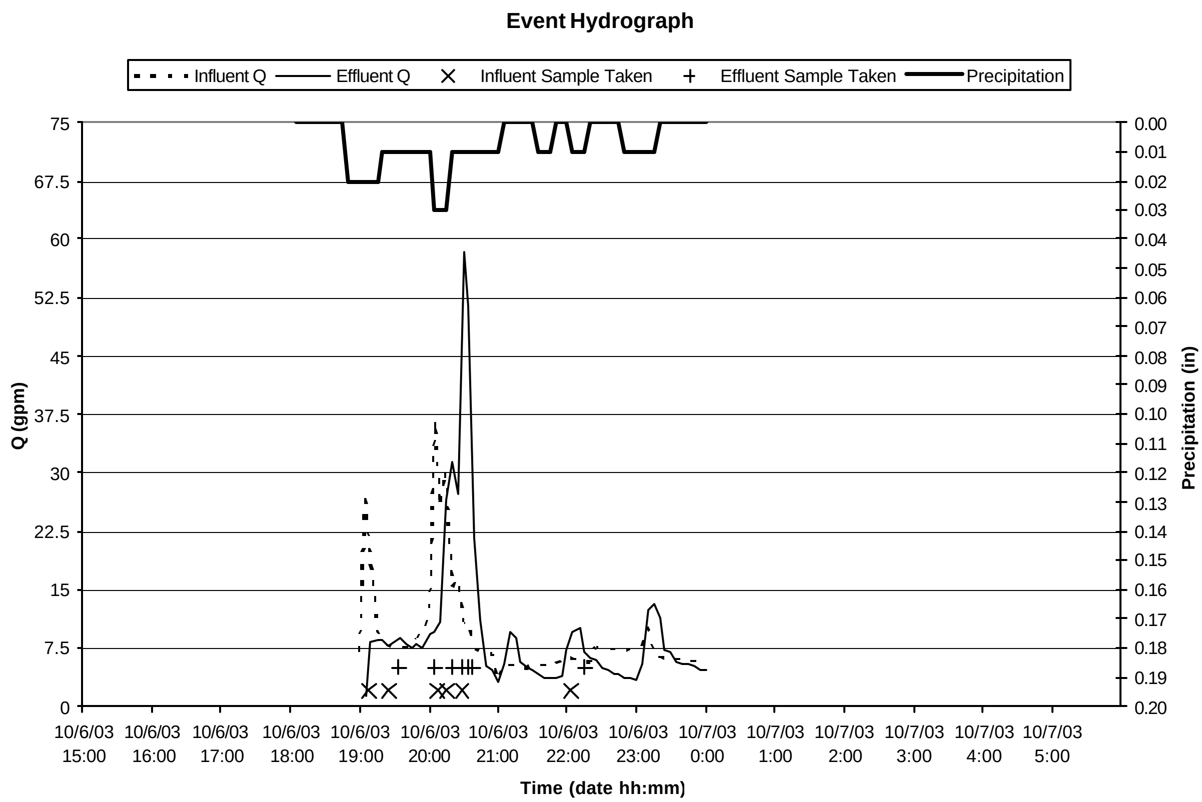
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	10/06/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	17 days since last rain event, 0.07”

Hydrology

Total Precipitation (in):	0.17
Peak Flow, (gpm):	Influent 37, Effluent 58
Total Runoff Volume (gal):	Influent 2703, Effluent 2845



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
1-6 IN	TSS	72	23	10	20%	68%
1-7 EFF	TVSS	27	8.8	5.0	20%	67%
	TSS (<500µm)	83	22	10	20%	73%
	TVSS (<500µm)	28	6.0	5.0	20%	79%
	Total Cu	0.0220	0.0162	0.0100	8.96%	26%
	Dissolved Cu	0.0110	ND	0.0100	6.41%	9%
	Total Zn	0.146	0.0572	0.0200	8.39%	61%
	Dissolved Zn	0.0316	0.0214	0.0200	5.04%	32%
	Total P	0.239	0.151	0.00500	2.93%	37%
	Ortho-P	0.00436	0.00833	0.00200	5.86%	release
	NH4-N	0.220	0.490	0.100	1.54%	release
	NO2/NO3-N	0.931	1.58	0.0100	0.00%	release
	TKN	1.88	2.18	1.00	0.00%	release
	pH	7.23	7.58	N/A	0.132%	release
	Hardness	39.6	50.2	1.00	5.51%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

Appendix B
Individual Storm Reports

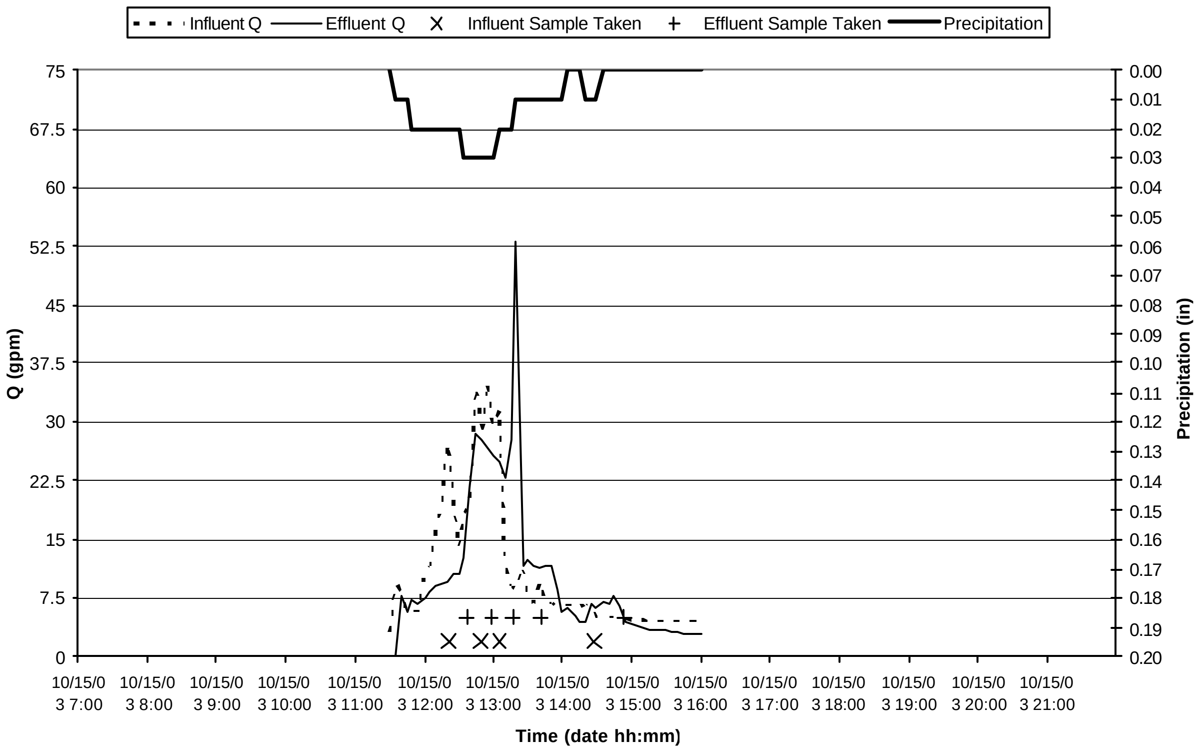
General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	10/15/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	2 days since last rain event, 0.01”

Hydrology

Total Precipitation (in):	0.20
Peak Flow, gpm):	Influent 35, Effluent 53
Total Runoff Volume (gal):	Influent 2836, Effluent 2788

Event Hydrograph



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 2,4,6,7	TSS	26	ND	10	20%	62%
EFF 2,4,6-8	TVSS	11	ND	5.0	20%	55%
	TSS (<500µm)	23	ND	10	20%	57%
	TVSS (<500µm)	8.1	ND	5.0	20%	38%
	Total Cu	ND	ND	0.0100	5.20%	undeterminable
	Dissolved Cu	ND	ND	0.0100	4.55%	undeterminable
	Total Zn	0.0527	0.0211	0.0200	1.42%	60%
	Dissolved Zn	ND	ND	0.0200	2.76%	undeterminable
	Total P	0.0996	0.0648	0.00500	13.8%	35%
	Ortho-P	0.00754	0.00866	0.00200	10.5%	release
	NH4-N	ND	ND	0.100	1.54%	undeterminable
	NO2/NO3-N	0.0967	0.237	0.0100	0.844%	release
	TKN	ND	ND	1.00	0.00%	undeterminable
	pH	7.19	7.21	N/A	0.698%	undeterminable
	Hardness	17.0	19.0	1.00	0.662%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

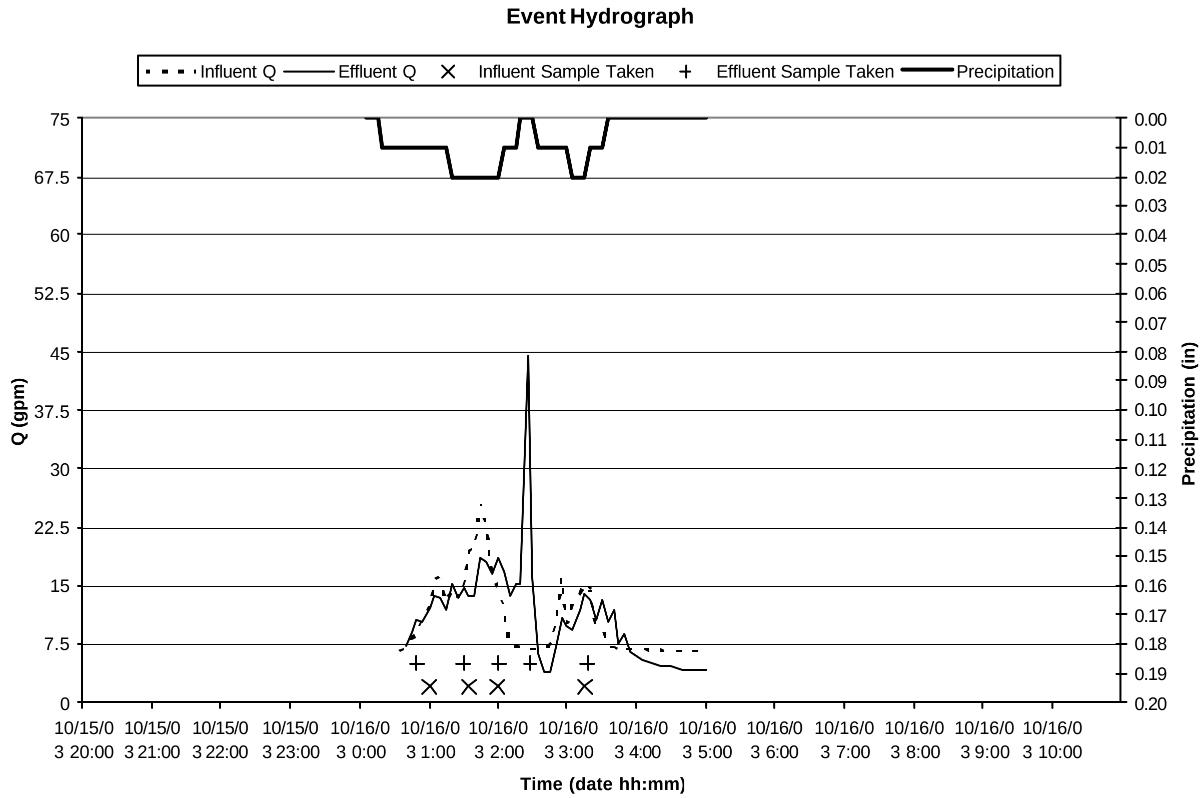
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	10/16/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	7 hours since last rain event, 0.25”

Hydrology

Total Precipitation (in):	0.17
Peak Flow (gpm):	Influent 25, Effluent 44
Total Volume (gal):	Influent 2790, Effluent 2840



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 8-11	TSS	18	ND	10	20%	44%
EFF 9-13	TVSS	8.6	ND	5.0	20%	42%
	TSS (<500µm)	17	10	10	20%	41%
	TVSS (<500µm)	8.8	ND	5.0	20%	43%
	Total Cu	ND	ND	0.0100	5.20%	undeterminable
	Dissolved Cu	ND	ND	0.0100	4.55%	undeterminable
	Total Zn	0.0353	0.0261	0.0200	1.42%	26%
	Dissolved Zn	ND	ND	0.0200	2.76%	undeterminable
	Total P	0.0806	0.0606	0.00500	13.8%	25%
	Ortho-P	0.00363	0.00866	0.00200	10.5%	release
	NH4-N	ND	ND	0.100	1.54%	undeterminable
	NO2/NO3-N	0.0639	0.156	0.0100	0.844%	release
	TKN	ND	ND	1.00	0.00%	undeterminable
	pH	7.38	7.28	N/A	0.698%	1%
	Hardness	27.1	27.7	1.00	0.662%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

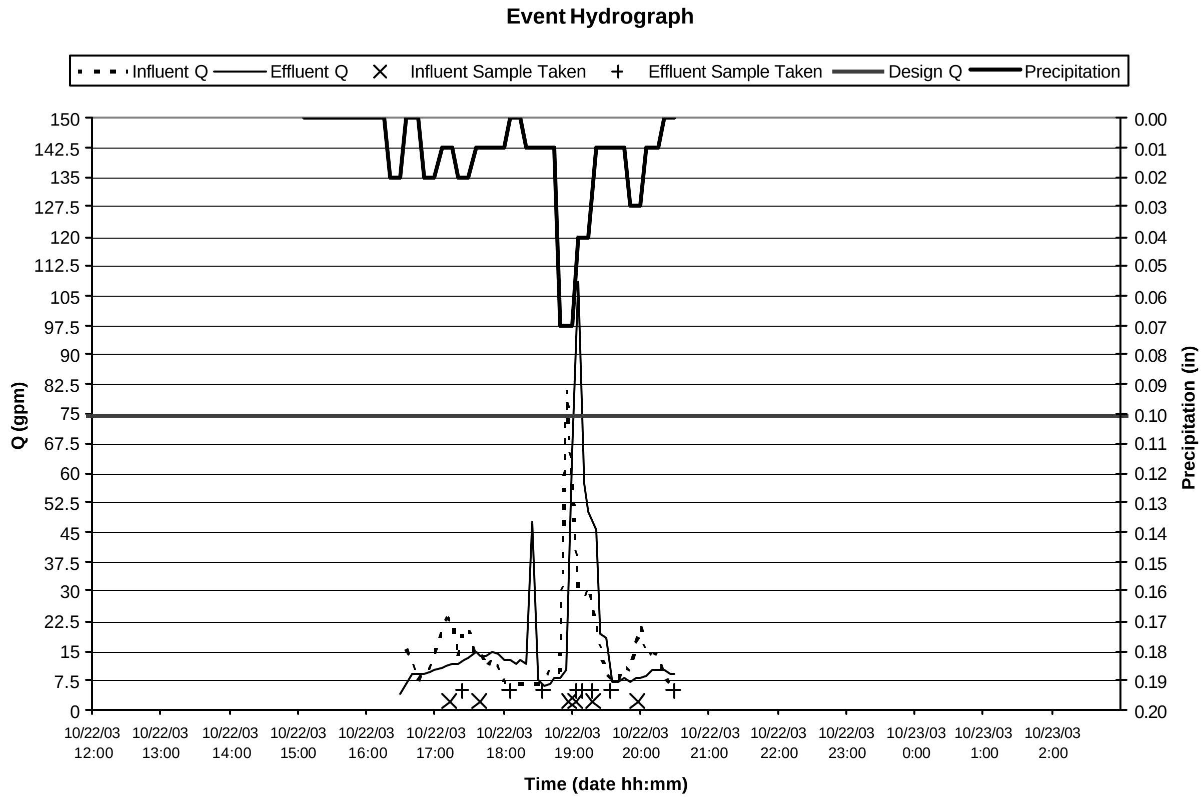
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	10/22/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	31 hours since last rain event, 2.66”

Hydrology

Total Precipitation (in):	0.28
Peak Flow (gpm):	81 Influent, 108 Effluent
Total Runoff Volume (gal):	3709 Influent, 4112 Effluent



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 7-12	TSS	110	11	10	20%	90%
EFF 7-14	TVSS	26	ND	5.0	20%	81%
	TSS (<500µm)	95	11	10	20%	88%
	TVSS (<500µm)	19	5.3	5.0	20%	72%
	Total Cu	0.0150	ND	0.0100	5.81%	33%
	Dissolved Cu	ND	ND	0.0100	0.605%	undeterminable
	Total Zn	0.145	0.0400	0.0200	13.3%	72%
	Dissolved Zn	0.0230	ND	0.0200	1.00%	13%
	Total P	0.198	0.0592	0.00500	5.14%	70%
	Ortho-P	0.00272	ND	0.00200	2.05%	26%
	NH4-N	ND	ND	0.100	0.770%	undeterminable
	NO2/NO3-N	0.153	0.325	0.0100	0.844%	release
	TKN	ND	ND	1.00	1.75%	undeterminable
	pH	7.32	7.28	N/A	0.681%	undeterminable
	Hardness	23.0	27.9	1.00	2.24%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. System operated above design flow for a brief period around 19:00.

Appendix B
Individual Storm Reports

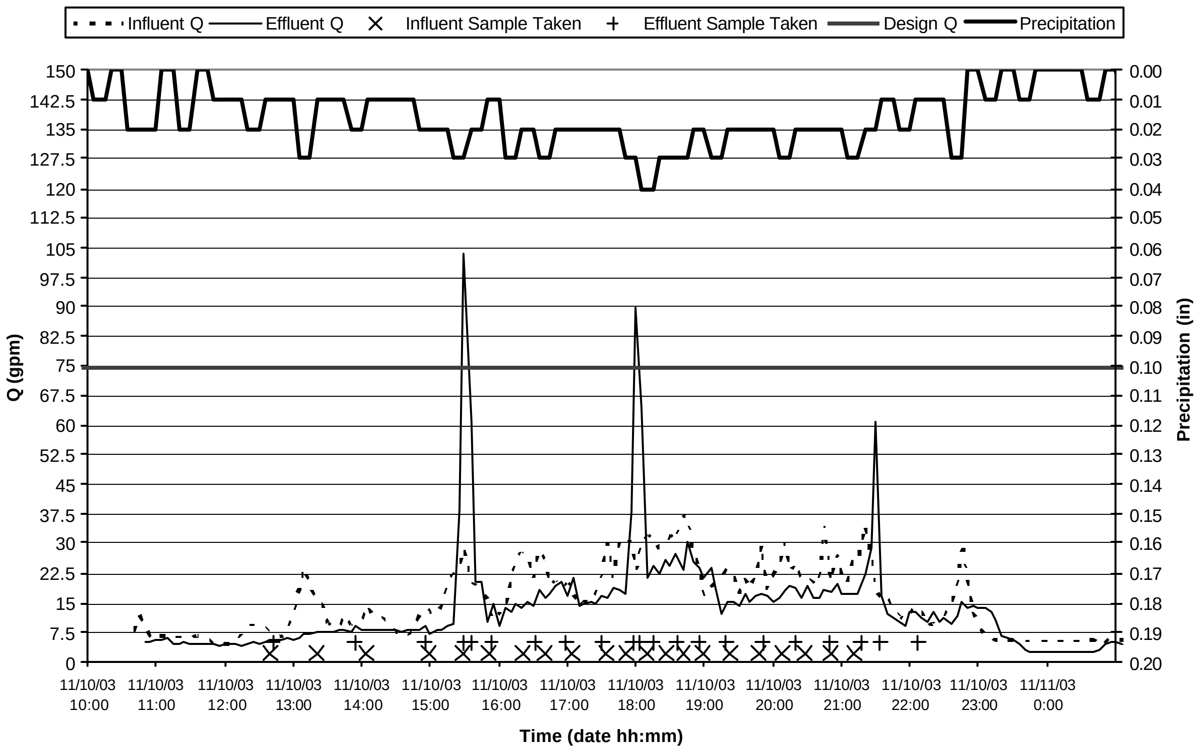
General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	11/10/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	54 hours since last rain event, .03"

Hydrology

Total Precipitation (in):	0.97
Peak Flow (gpm):	37Influent, 103 Effluent
Total Runoff Volume (gal):	13080 Influent, 11608 Effluent

Event Hydrograph



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 2,4,6,7-24	TSS	38	12	10	20%	68%
EFF2,4,6,7-24	TVSS	15	ND	5.00	20%	67%
	TSS (<500µm)	26	ND	10	20%	62%
	TVSS (<500µm)	10	ND	5.00	20%	50%
	Total Cu	ND	ND	0.0100	9.84%	undeterminable
	Dissolved Cu	ND	ND	0.0100	31.6%	undeterminable
	Total Zn	0.0597	0.0271	0.0200	3.21%	55%
	Dissolved Zn	ND	ND	0.0200	1.94%	undeterminable
	Total P	0.0721	0.0392	0.00500	3.07%	46%
	Ortho-P	0.00245	0.00401	0.002	0.699%	release
	NH4-N	0.123	0.188	0.100	0.810%	release
	NO2/NO3-N	0.113	0.184	0.0100	5.10%	release
	TKN	ND	ND	1.00	4.89%	undeterminable
	pH	7.39	7.10	N/A	0.562%	4%
	Hardness	17.6	18.6	1.00	11.0%	undeterminable

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. System operated above design flow for short period of time, but no overflow detected by ODS.

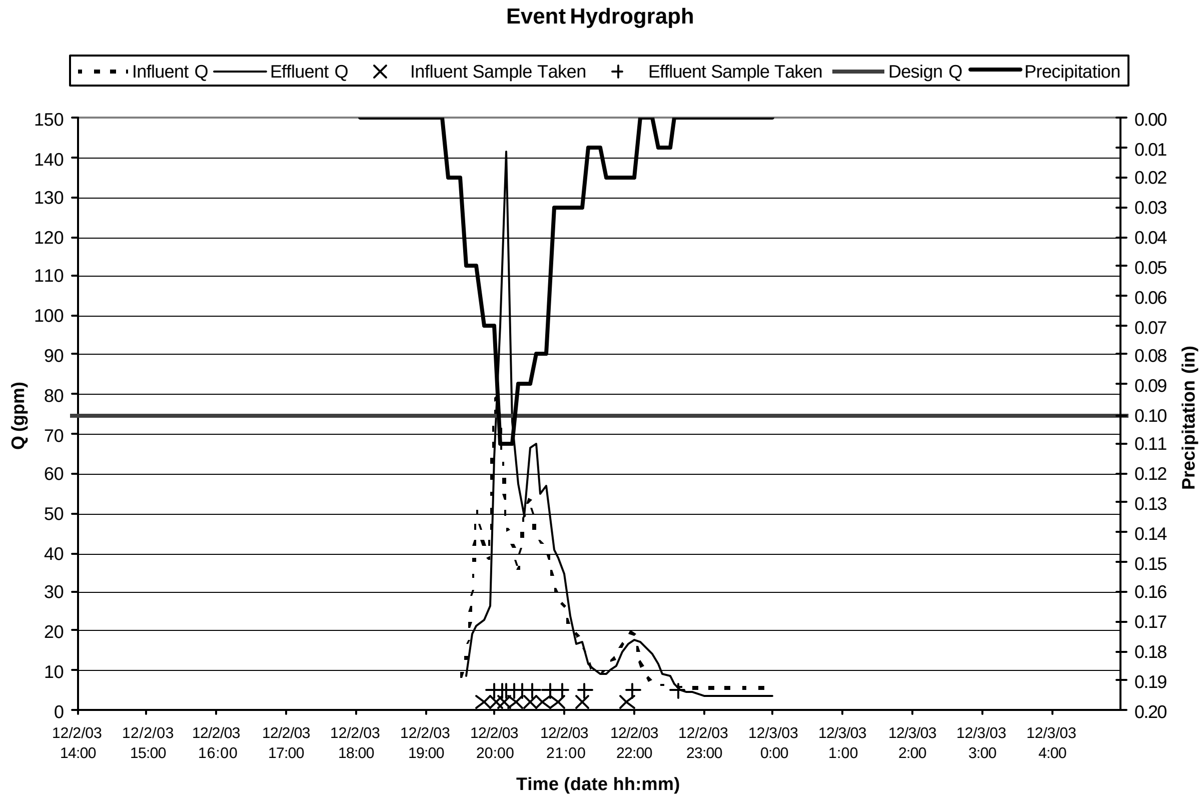
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	12/02/03
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	3 hours since last rain event, 0.11"

Hydrology

Total Precipitation (in):	0.54
Peak Flow (gpm):	79 Influent, 141 Effluent
Total Runoff Volume (gal):	5474 Influent, 6281 Effluent



Analytical

Bottles Used:	Parameter	Influent EMC (mg/L)	Effluent EMC (mg/L)	PQL (mg/L)	Dup. RPD	Discrete Removal Efficiency
IN 2,4,6-12	TSS	269	32.6	4.00	20%	88%
EFF 2,4,6-14	TVSS	57.3	11.3	7.09	20%	80%
	TSS (<500µm)	264	32.6	4.00	20%	88%
	TVSS (<500µm)	47.0	11.1	7.58	20%	76%

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. System operated above design flow for short period of time.

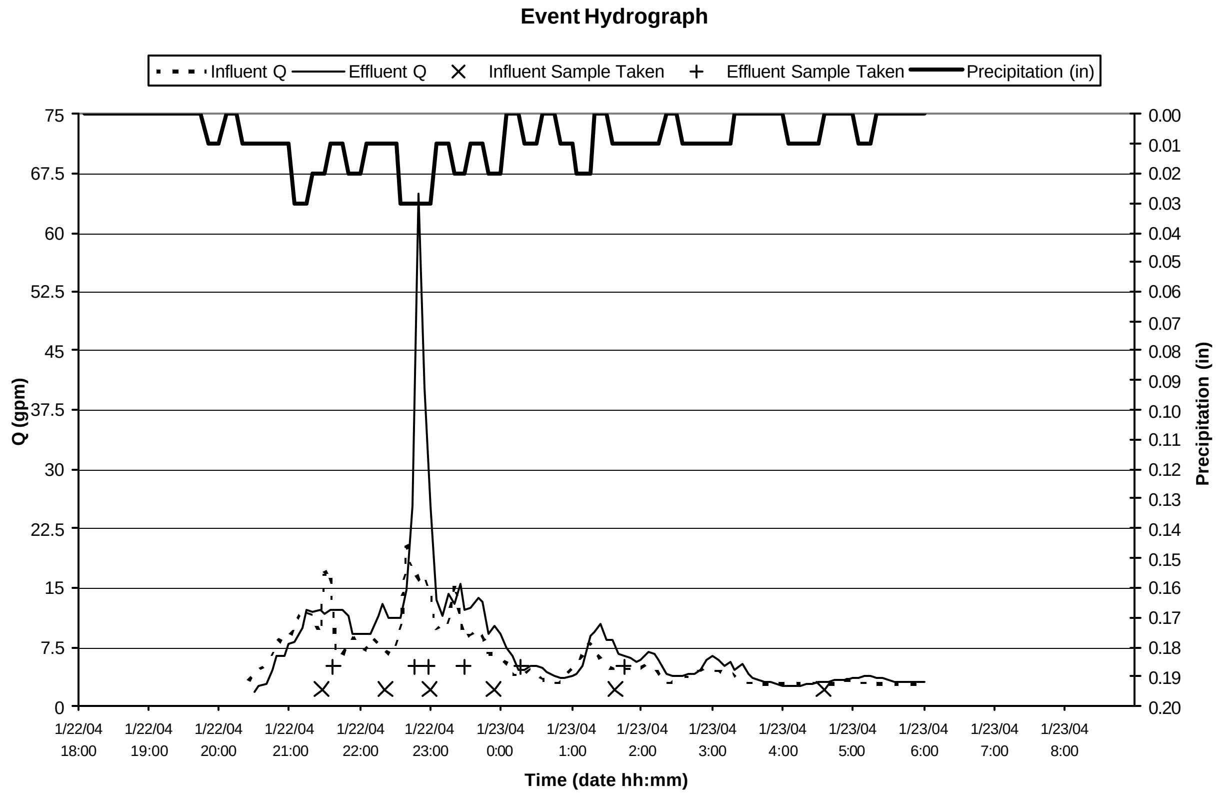
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	01/22/04
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	3.6 days since last rain event, 0.12”

Hydrology

Total Precipitation (in):	0.39
Peak Flow (gpm):	20 Influent, 65 Effluent
Total Runoff Volume (gal):	3475 Influent, 4416 Effluent



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 2,4,6-9	TSS	53	50	10	20%	undeterminable
EFF 2,4,6-9	TVSS	12	9.8	5.0	20%	18%
	TSS (<500µm)	54	46	10	20%	undeterminable
	TVSS (<500µm)	12	8.5	5.0	20%	29%
	Total Cu	0.0112	ND	0.0100	6.90%	11%
	Dissolved Cu	ND	ND	0.0100	2.41%	undeterminable
	Total Zn	0.0706	0.0575	0.0200	1.86%	19%
	Dissolved Zn	ND	ND	0.0200	4.93%	undeterminable
	Total P	0.0544	0.0550	0.00500	0.550%	release
	Ortho-P	0.0108	0.0169	0.00200	1.79%	release
	NH4-N	0.130	0.170	0.100	0.00%	release
	NO2/NO3-N	0.329	0.155	0.0100	9.60%	53%
	TKN	ND	ND	1.00	9.78%	undeterminable
	pH	7.33	7.20	N/A	0.410%	2%
	Hardness	27.3	28.7	1.00	1.10%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

Appendix B
Individual Storm Reports

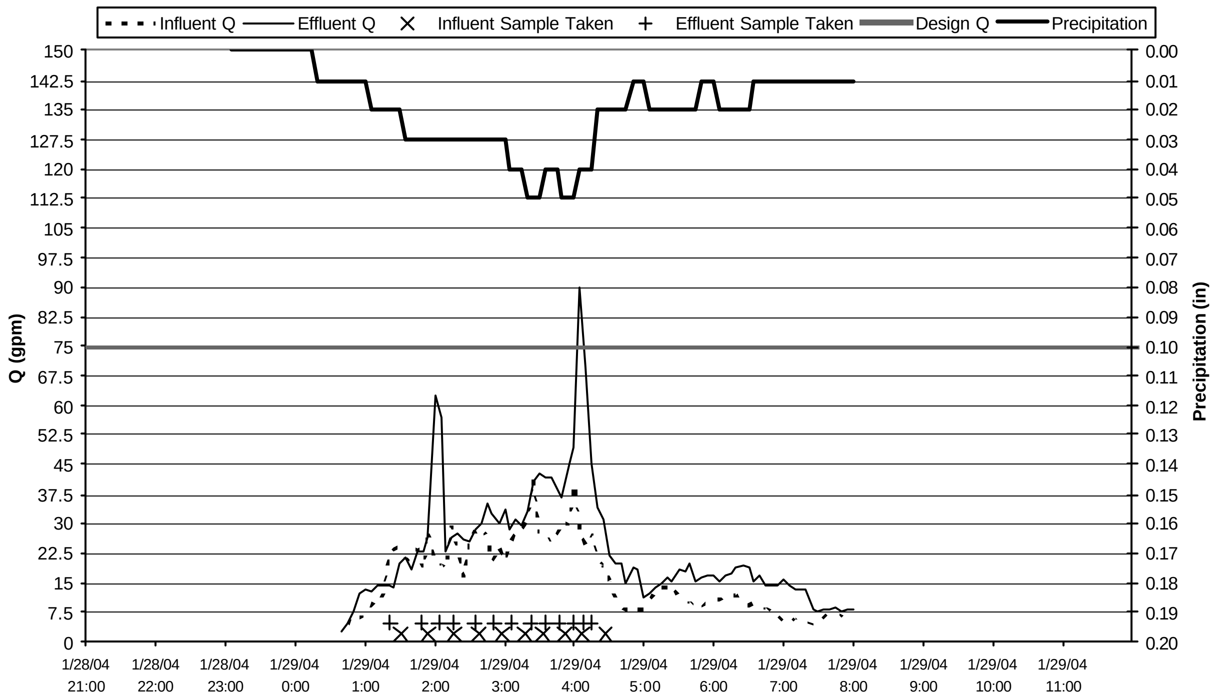
General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	01/29/04
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	32 hours since last rain event, 0.03”

Hydrology

Total Precipitation (in):	0.69
Peak Flow (gpm):	41 Influent, 90 Effluent
Total Runoff Volume (gal):	7007 Influent, 10218 Effluent

Event Hydrograph



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 10-19	TSS	210	49	10	20%	77%
EFF 12-24	TVSS	73	12	5.00	20%	84%
	TSS (<500µm)	170	48	10	20%	72%
	TVSS (<500µm)	37	10	5.00	20%	73%
	Total Cu	0.0225	ND	0.0100	5.43%	56%
	Dissolved Cu	ND	ND	0.0100	1.20%	undeterminable
	Total Zn	0.255	0.0702	0.0200	3.74%	72%
	Dissolved Zn	ND	ND	0.0200	0.639%	undeterminable
	Total P	0.134	0.0549	0.00500	32.8%	59%
	Ortho-P	0.0152	0.0154	0.00200	8.20%	undeterminable
	NH4-N	ND	ND	0.100	2.09%	undeterminable
	NO2/NO3-N	0.0622	0.210	0.0100	9.60%	release
	TKN	ND	ND	1.00	9.78%	undeterminable
	pH	7.18	7.20	N/A	0.139%	release
	Hardness	26.8	20.6	1.00	4.72%	23%

Notes

Shaded RPD values defaulted to 20% standard due to QC complications. Storm event started at 19:55 on 012704 but no samples taken due to low depth in pipe during storm event up until 012904. Possible obstruction in influent pipe to SMI SF. All flow and precipitation data recorded.

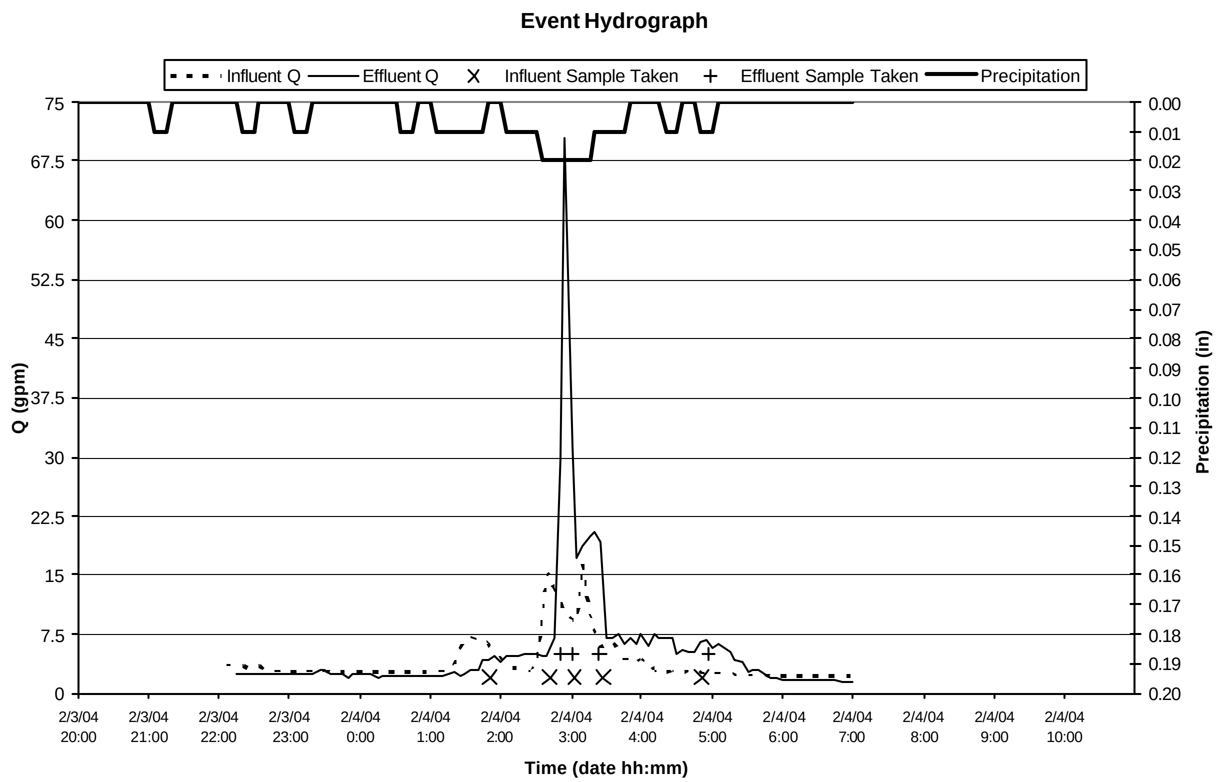
Appendix B
Individual Storm Reports

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	02/03/04
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	34 hours since last rain event, 0.03"

Hydrology

Total Precipitation (in):	0.19
Peak Flow (gpm):	17 Influent, 70 Effluent
Total Runoff Volume (gal):	2174 Influent, 2903 Effluent



Analytical

Bottles Used:	Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
IN 1-5	TSS	51	22	10	20%	57%
EFF 2,4,6,7	TVSS	18	ND	5.0	20%	72%
	TSS (<500µm)	45	27	10	20%	40%
	TVSS (<500µm)	12	7.1	5.0	20%	41%
	Total Cu	ND	ND	0.0100	16.4%	undeterminable
	Dissolved Cu	ND	ND	0.0100	10.5%	undeterminable
	Total Zn	0.0753	0.0440	0.0200	4.42%	42%
	Dissolved Zn	ND	ND	0.0200	1.46%	undeterminable
	Total P	0.0498	0.0368	0.00500	6.06%	26%
	Ortho-P	0.00281	ND	0.00200	0.00%	29%
	NH4-N	0.334	ND	0.100	8.27%	70%
	NO2/NO3-N	0.301	0.546	0.0100	3.64%	release
	TKN	ND	ND	1.00	3.25%	undeterminable
	pH	7.51	7.32	N/A	0.121%	3%
	Hardness	28.5	29.1	1.00	1.74%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

Appendix B
Individual Storm Reports

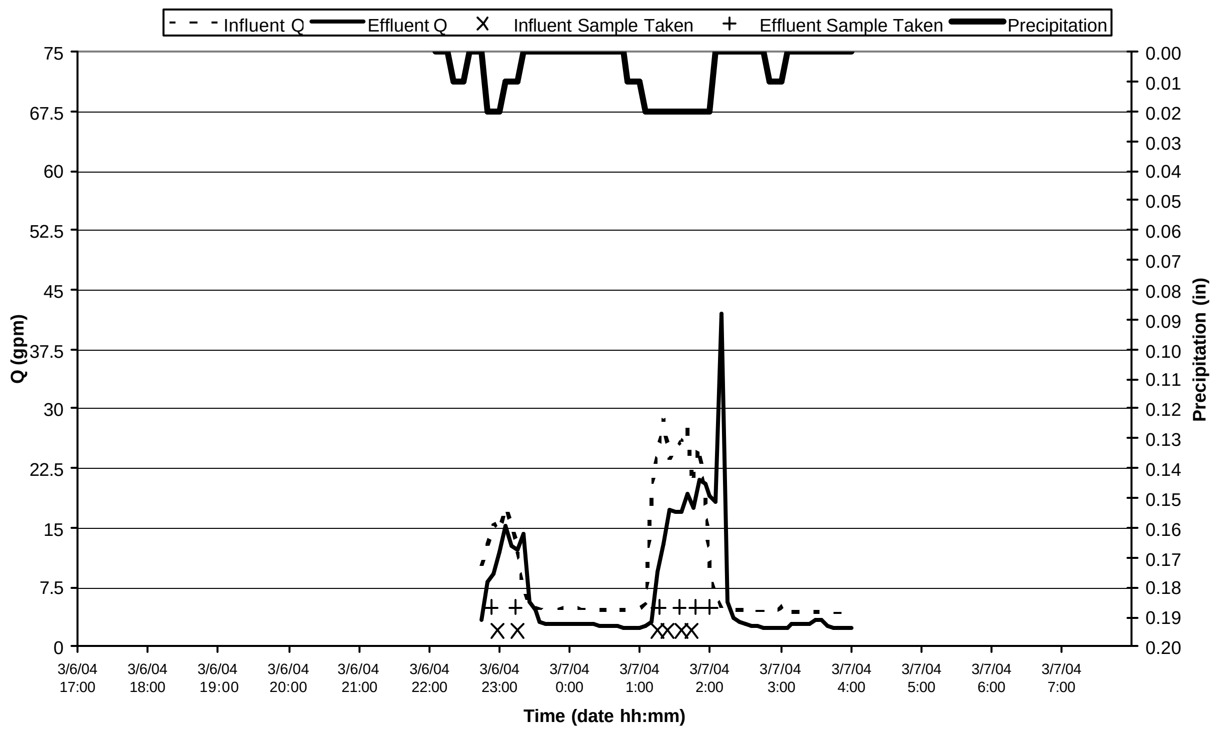
General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6x12, ZPG, 10 cartridges, 7.5 gpm
Event Date:	03/06/04
Date of Last Maintenance:	03/03/03
Antecedent Conditions:	36 hours since last rain event, 0.15”

Hydrology

Total Precipitation (in):	0.14
Peak Flow (gpm):	29 Influent, 42 Effluent
Total Runoff Volume (gal):	2840 Influent, 2228 Effluent

Event Hydrograph



Analytical

Bottles Used:	Parameter	Influent EMC	Effluent EMC	PQL	Dup. RPD	Discrete Removal Efficiency
		Concentrations (mg/L)				
IN 1-6	TSS	140	26	10	20%	81%
EFF 1-6	TVSS	40	8.1	5.00	20%	80%
	TSS (<500µm)	120	26	10	20%	78%
	TVSS (<500µm)	36	8.0	5.00	20%	78%
	Total Cu	0.0112	ND	0.0100	33.8%	undeterminable
	Dissolved Cu	ND	ND	0.0100	3.10%	undeterminable
	Total Zn	0.126	0.0520	0.0200	4.54%	59%
	Dissolved Zn	ND	ND	0.0200	20.8%	undeterminable
	Total P	0.119	0.0501	0.00500	25.9%	58%
	Ortho-P	NT	NT	---	---	---
	NH4-N	ND	ND	0.100	1.27%	undeterminable
	NO2/NO3-N	0.139	0.488	0.0100	0.602%	release
	TKN	ND	ND	1.00	0.820%	undeterminable
	pH	7.63	7.47	N/A	0.131%	2%
	Hardness	36.2	39.5	1.00	3.94%	release

Notes

Shaded RPD values defaulted to 20% standard due to QC complications.

Appendix C
Regression of EMC Analyses

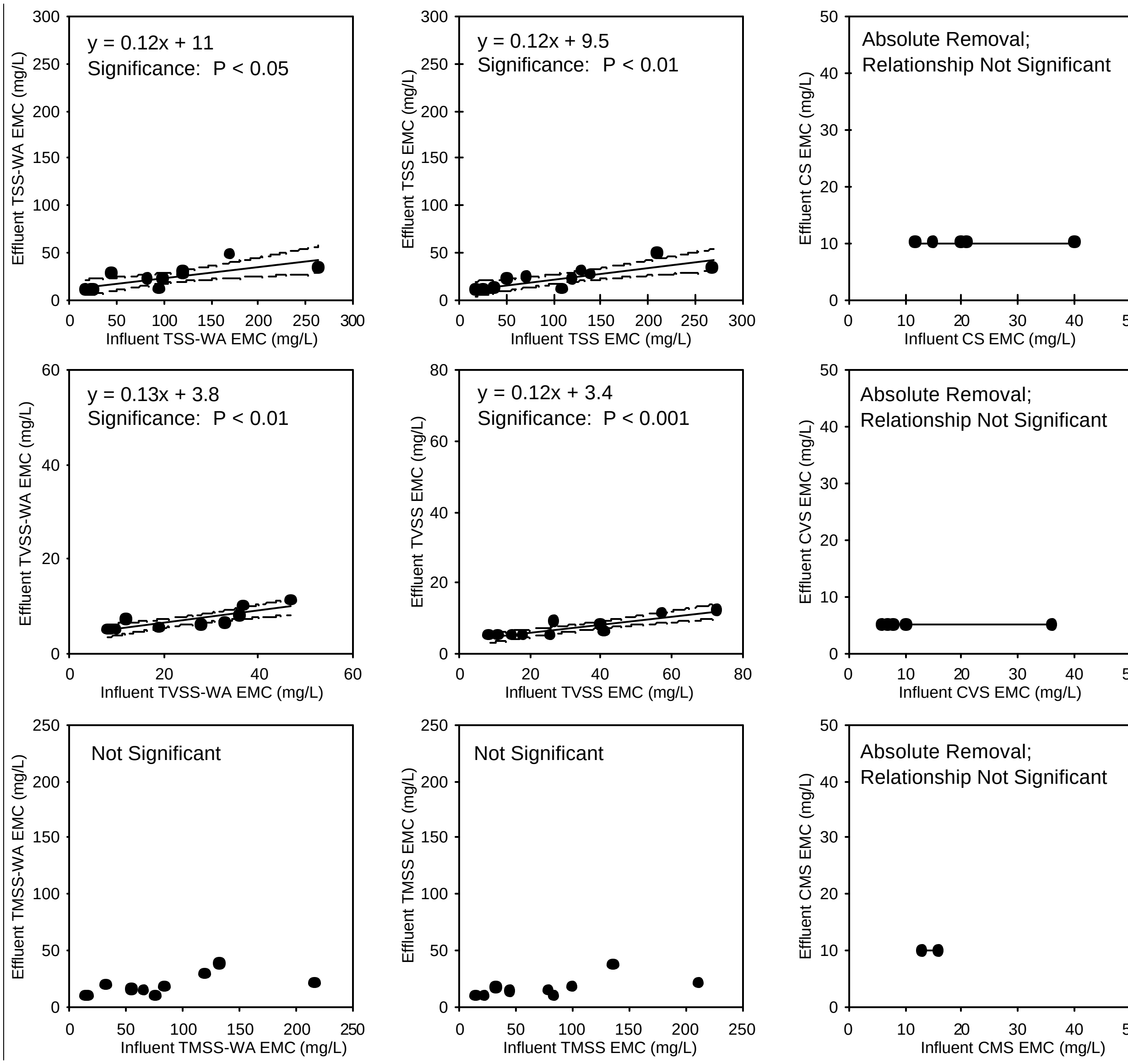


Figure A. Regression analysis of the influent and effluent relationships between solid analytes for the Lake Stevens North StormFilter. Refer to Table 1 for acronym definitions. Grouped solid and dashed lines illustrate linear regression and 95% confidence intervals.

Regression of EMC Analyses

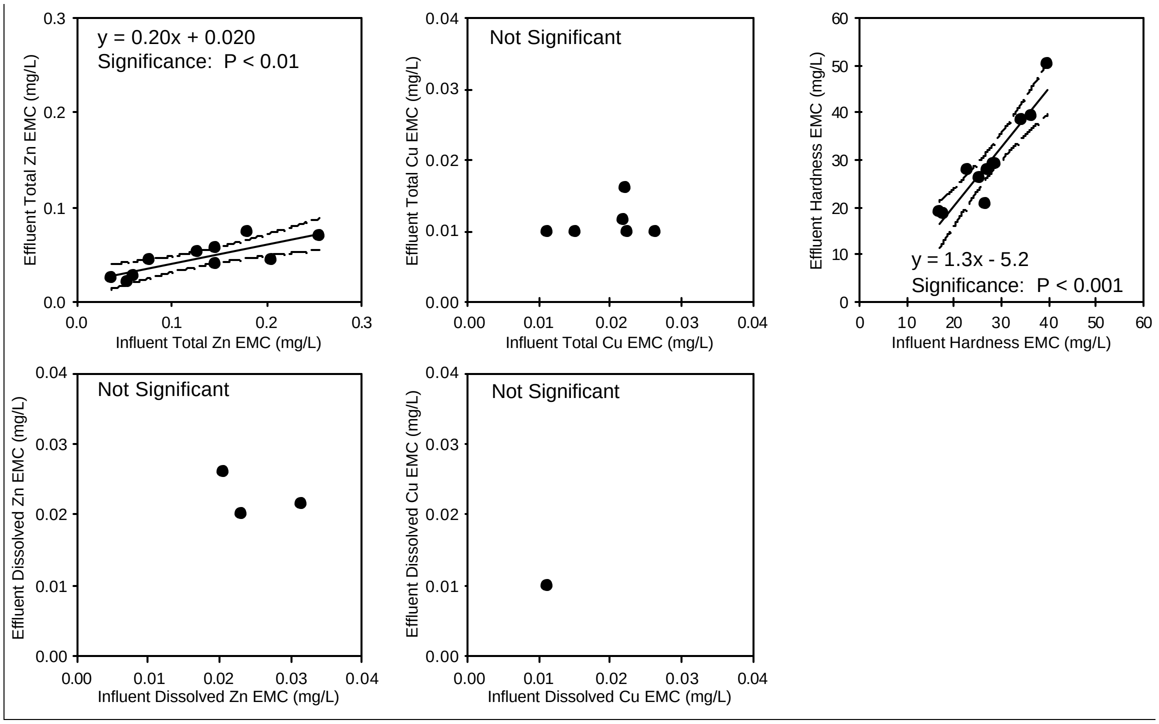


Figure B. Regression analysis of the influent and effluent relationships between metal analytes for the Lake Stevens North StormFilter. Refer to Table 1 for acronym definitions. Grouped solid and dashed lines illustrate linear regression and 95% confidence intervals.

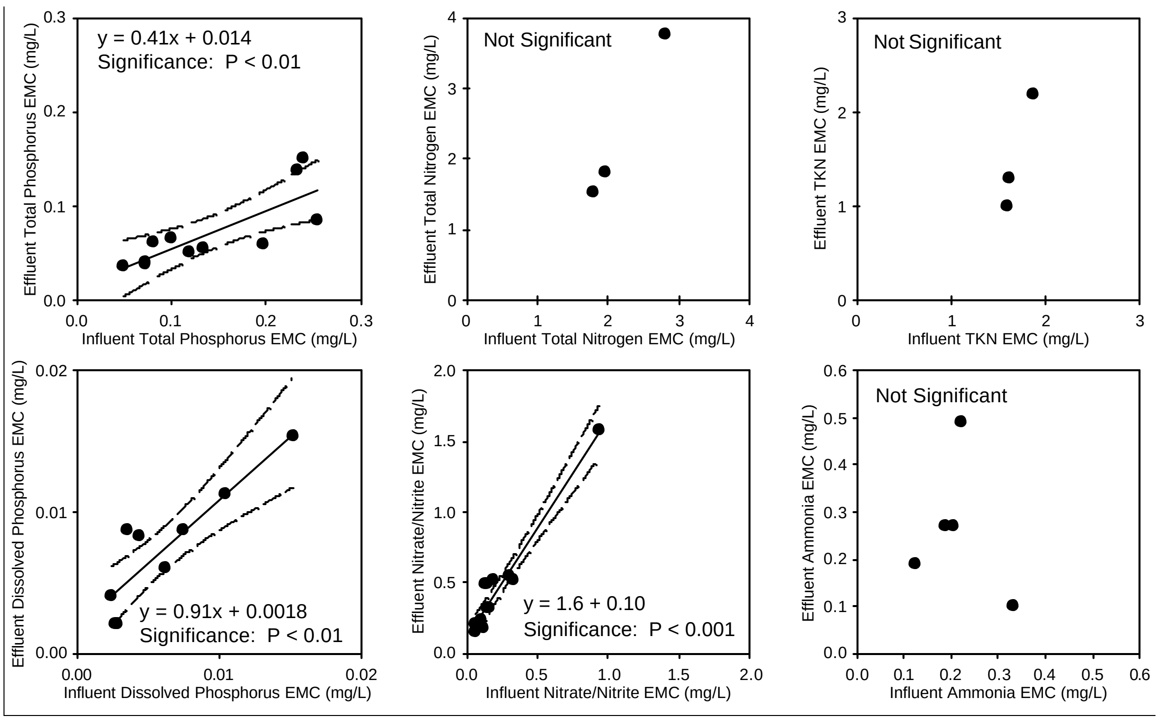


Figure C. Regression analysis of the influent and effluent relationships between nutrient analytes for the Lake Stevens North StormFilter. Refer to Table 1 for acronym definitions. Grouped solid and dashed lines illustrate linear regression and 95% confidence intervals.

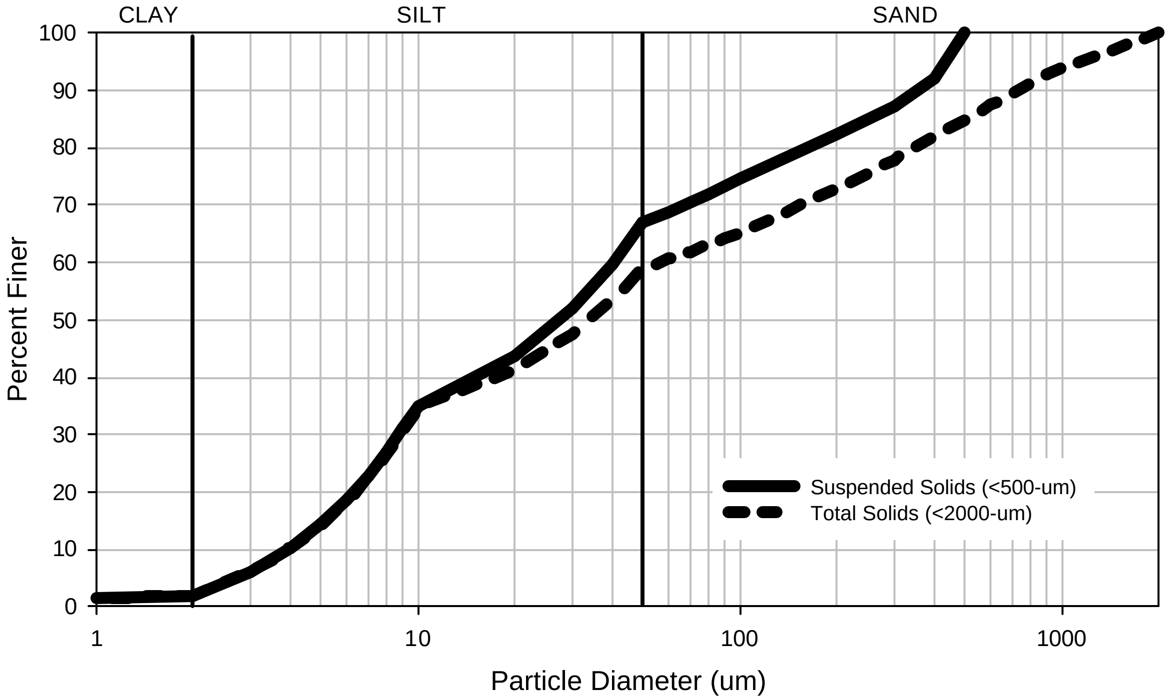
Appendix D
Post Sampling Residuals Analysis

General Information

Site:	Lake Stevens North (1641), Lake Stevens, WA
System Description:	6'x12', ZPG media, 10 cartridges @ 7.5 gpm per cartridge
Date of Maintenance:	8/13/04
Date of Previous Maintenance:	3/03/03

Reconstructed Influent Particle Size Distribution (assuming 80% removal)

Total Solids:	Silt Loam (41% Sand, 57% Silt, 2% Clay)
Suspended Solids:	Silt Loam (33% Sandy, 65% Silt, 2% Clay)



Retained Material Analytical Results

Parameter	units	Mass Retained by StormFilter System: Settled	Filtered	Total
Total Solids (dry)	kg	213.8	62	276.2
Total Cu	g	10.05	7.13	17.18
Total Zn	g	102.7	60.2	162.9
Total Cd	g	ND	ND	ND
Total Pb	g	5.59	5.1	10.71
Total P	g	135.0	85	220.0
Total N	kg	0.494	0.286	0.779
Diesel Range Organics	kg	ND	ND	ND
Heavy Oil Range Hydrocarbons	kg	0.789	0.285	1.074

Notes

Results based upon hydrometer and sieve analysis. 1.2% of Total Solids were greater than 2000-um and is not included in the particle size distribution above.

Revision Summary

PE-E012
Document number changed; document rebranded; no substantial changes.

PE-04-001.1
Major revision to report format and layout; some major sections of text modified or removed; some tables modified or removed; data content essentially the same; residual solids assessment data added.

PE-04-001.0
Original.