2010 Monitoring Report for King County Stormwater Monitoring Under S8.E of the NPDES Phase 1 Municipal Permit WAR04-4501 (Issued February 2007) Targeted Stormwater Management Program Effectiveness Monitoring

Roadside Ditch Water Quality Treatment

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King County

King County Department of Transportation
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2010 Monitoring Report for King County Stormwater Monitoring Under S8.E of the NPDES Phase 1 Municipal Permit WAR04-4501 (Issued February 2007) Targeted Stormwater Management Program Effectiveness Monitoring Roadside Ditch Water Quality Treatment

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Certification

I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations.

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EXECUTIVE SUMMARY

This report presents the results from design, installation and monitoring of two road-side ditch water quality BMP studies and two stormwater flow control BMP studies implemented by King County Roads Maintenance in 2009 and 2010.

The results of the water quality studies were mixed; one study shows promise with meeting project goals of developing a low cost, low maintenance BMP that will work as an effective stormwater treatment within the confines of county owned road side ditches, while very little of this effect was measured at the other site. Water quality BMPs placed in ditch along 148th Avenue SE demonstrated a reduction in suspended solids (measured as total suspended solids or TSS) PAHs, dissolved zinc and chromium. Hardness, which provides a measure of the water's buffering capacity for mitigating the toxicity of dissolved metals increased at both project sites.

Both flow control projects show a reduction in downstream flows during dry-season storm events. At all sites the BMPs functioned to pool storm flows, reducing the scouring energy of high flows and allowing for some settling in addition to any filtering function the BMP may provide. This is thought to be one of the primary reasons for the reduction in TSS. The BMPs at all study sites survived high winter flows. To date the maintenance requirements have only included mowing excess vegetation and removing leaves at two sites.

Information gained from this first round of study was used to develop the second phase water quality and flow control BMP studies that were installed in 2010. The first round studies were instrumental in helping with second round study site selection, BMP design modifications and monitoring protocol, and included revising the water quality parameters include addition of total metals and total phosphorus and continuous monitoring during selected storm events for turbidity.

Although BMP monitoring has been suspended at the first year water quality BMPs study sites the BMPs have been left in place so that equipment could be moved to new study sites. The first year flow control BMP study projects have been incorporated into the second year projects with modified BMP designs and additional BMPs and treatment area.

1.0. INTRODUCTION

This report focuses on the permit requirements listed under Section 8, E, Targeted Stormwater Management Program Effectiveness Monitoring. The monitoring that is being conducted to fulfill this section of the permit is designed to answer two distinct questions:

1. Can road-side ditches in rural areas be retrofitted with stormwater BMP that will improve the water quality of the stormwater conveyed by these ditches.
2. Can road-side ditches in rural areas be retrofitted with stormwater BMPs that will improve the flow hydraulics of the stormwater conveyed by these ditches.

To answer these questions, King County has designed and implemented two separate studies. This report documents monitoring conducted to answer the first question. A companion report documents answers to the second question.

A portion of the stormwater draining to Puget Sound is runoff from rural, agricultural, and residential lands conveyed to receiving waters in road-side ditches. Runoff has been identified as a leading contributor of pollution, some of which is discharged untreated through roadside ditches into local surface water bodies. King County Department of Transportation (KCDOT) is responsible for maintaining over 1,800 miles of paved roadway throughout unincorporated King County. As the focus on stormwater regulatory programs for roadways increases, the King County Roads Maintenance Section (KCRMS) is responding by conducting research and developing affordable and effective Best Management Practice (BMP) designs to treat stormwater runoff within roadside ditches.

KCRMS is developing and testing road-side ditch stormwater treatment retrofit BMPs focusing on designs that are simple, low-cost, and low-maintenance. The BMPs tested here are intended to reduce or remove water quality contaminants. They are intended to fit within roadside ditches requiring no additional land purchase or impacts to adjacent lands. The designs are intended to be easily modified to on-site conditions such as soil type, ditch gradient, flow regime, and pollutant type(s). Providing research on low costs of design, installation, and maintenance of the cells will allow other public and private entities to retrofit multiple areas, retaining stormwater locally and creating an aggregate regional decrease in quality and quantity impacts from roadside ditch discharges.

This approach focuses on capturing most small storm events and “first flush” conditions from larger events primarily through retention, infiltration and providing water treatment via filter media. The road-side ditch stormwater treatment BMP research will study the costs for development, implementation, and maintenance and will evaluate pollutant removal.

2.0. GOALS AND OBJECTIVES

The goals and objectives for this study are to:

- Develop, install and test low-cost BMP designs intended to provide a measurable level of stormwater treatment to either reduce pollutant loads or attenuate storm peak hydrographs within existing road side ditches.
- Provide scientifically defensible and reproducible water quality and water quantity data above and below each BMP. The criteria for collecting and reviewing this data are presented in the Quality Assurance Project Plan (QAPP).
- Evaluate the level of effort and costs required in designing, installing and maintaining the roadside ditch BMPs.
- Making the results of this study available to the outside community through reports, journal articles and group presentations.

3.0. WATER QUALITY BMP STUDY DESIGN

The road-side Ditch BMP study reported here is designed to evaluate whether road-side ditch BMPs can improve water quality and reduce peak flows BMP project sites are being evaluated using data collected at monitoring stations placed upstream and downstream of each BMP. A total of four BMPs are being monitored to determine if water quality can be improved using these techniques.

Due to the expense of equipment and limitations in staffing the project is split into two phases. During the first phase two water quality and two flow control BMP projects were designed, installed and monitored. The water quality BMP sites have a sampling goal of analyzing samples collected from 12 storms events. These storms are intended to include both the wet season (Oct 1st through April 30th) and dry season (May 1st through September 30th) events. Information gained from the first set of studies has been used to guide development of the second set of studies. Monitoring of first set of two water quality and two flow control BMP projects took place in 2009 – 2010, and coincided closely with the 2010 water year (October 1st 2009 through September 2010).

Autosamplers, equipped with 15-liter glass sample carboys, and flow meters were installed upstream and downstream of each BMP and were placed in locked housings or utility boxes. The flow meters were used to measure stormflow and trigger the autosamplers to collect samples after a set amount of flow has passed the sampling site. The sampler delivered all aliquots directly to a single sample container. Analytical results from these composites are considered to be representative of the average pollutant concentration or event mean concentration (EMC) of the storm event. BMP efficiencies were calculated by measuring the differences in concentration between the upstream and downstream samples. More detail is provided in the project QAPP.

3.1 Project Locations

Two water quality BMP projects; 148th Ave SE and SE 136 St, were established in two separate ditches (study sites) during the 2009 water year. The location of these studies is shown in Figure 1 below.

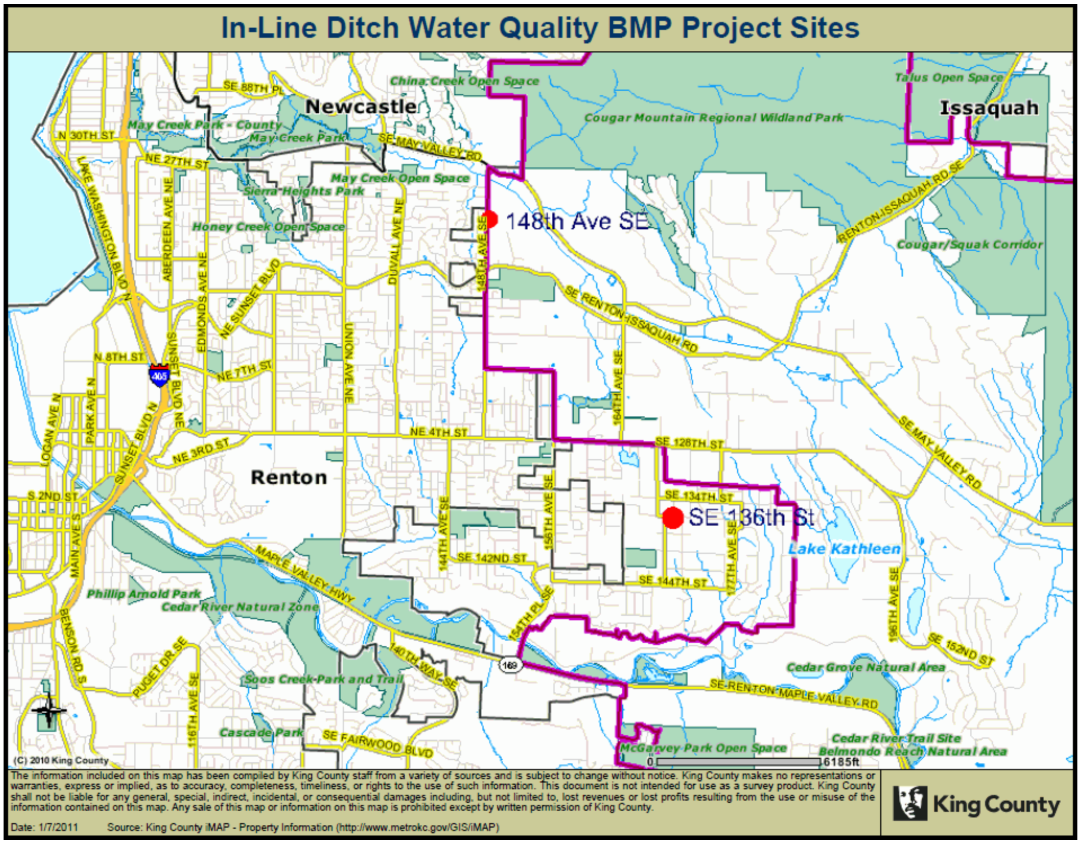


Figure 1 In-Line Ditch Water Quality BMP Project Sites in King County, WA

Study locations, monitoring station names and sample identifiers are provided in Table 4 below.

Table 1. Study Sites

Study Sites, Station Names and Sample Identifiers			
Location	**Station Location**	**Station Names**	**Sample Identifiers**
10222 148th Ave SE	Upstream	148UP	RSW1UP
	Downstream	148DN	RSW1DN
16918 SE 136th Street	Upstream	136UP	RSW8UP
	Downstream	136DN	RSW8DN

3.2 Engineering Designs

BMP design drawings at 90% completion were submitted to Ecology for review and approval prior to installation of each project. The engineering designs for the two water quality BMP projects studied during the 2010 water year are provided in Appendix F. The type, design and placement of the primary devices are included as part the engineering designs.

Both BMP designs are based on a modified rock check dams with an internal “treatment cell”. Commercially available compost based on a WSDOT specification as the treatment media. The compost was wrapped in a non-woven filter fabric secured inside the check dam as they were being constructed in the ditch.

3.3 Monitoring Parameters

Analytical parameters are listed in Table 1 (below). All BMP studies were monitored for continuous flow measured in gallons per minute (gpm).

Table 2 Analytical Parameters

Type of Monitoring	Parameter	Reporting Limit Criteria and Units
Storm Samples (Flow – Weighted Composite Samples)	Total suspended solids	1.0 mg/L
	Hardness as CaCO3	0.33 (mg/ $CaCO_3$/L)
	Total Kjeldahl nitrogen	0.2 mg/L
	Nitrate-nitrite (NO23)	0.02 mg/L
	Orthophosphate	0.005 mg/L
	Dissolved arsenic	0.5 ug/L
	Dissolved cadmium	0.25 µg/L
	Dissolved chromium	1.0 ug/L
	Dissolved copper	2.0 µg/L
	Dissolved lead	0.1 µg/L
	Dissolved nickel	0.5 ug/L
	Dissolved selenium	1.0 ug/L
	Dissolved tin	1.5 ug/L
	Dissolved zinc	2.5 µg/L
	PAH-SIM[1]	1.0 µg/L[2]

Storm Samples (Grabs)	TPH (NWTPH-Dx)	0.2 mg/L
	Fecal Coliform	1 cfu/100 ml

[1] Seventeen PAHs (Table 2) were analyzed from each storm sample. The results were summed and evaluated between upstream/downstream monitoring stations as Total PAH.

[2] The reporting limit for PAH-SIM compounds was revised to from 0.1 to 1.0 ug/L in the QAPP revision October 2010.

Table 3. Seventeen PAHs Analyzed from Flow Weighted Composite Samples

Acenaphthene	Dibenzo(a,h)anthracene
Acenaphthylene	2-Methylnaphthalene
Anthracene	Fluoranthene
Benzo(a)anthracene	Fluorene
Benzo(a)pyrene	Indeno(1,2,3-Cd)Pyrene
Benzo(b)fluoranthene	Naphthalene
Benzo(g,h,i)perylene	Phenanthrene
Benzo(k)fluoranthene	Pyrene
Chrysene	

Table 4. Field Parameters and Instrument Specifications

Type of Monitoring	Parameter	Instrument Resolution	Instrument Accuracy
Single Point Storm Water Quality Parameters[1]	Dissolved Oxygen	0.01mg/L	0 to 20 mg/L: +/- 2% of reading or 0.2 mg/L whichever is greater.
	pH	0.1 units	+/- 0.2 units
	Conductivity	0.001 to 0.1 mS/cm (range dependent)	+/-0.5 % of reading = 0.001 mS/cm
	Temperature	0.01°C	+/- 0.15°C
	Turbidity	0.1 NTU	+/-2% of reading or 0.3 NTU whichever is greater in YSI AMCO-AEPA Polymer Standards
Continuous Monitoring[2]	Temperature	0.02°C at 25°C	+/- 0.2 °C

[1] Single point field parameters were monitored using YSI Inc. 6920 sondes. Resolution and accuracy data from YSI.

[2] Continuous Monitoring Temperature collected using ONSET® Hobo Water Temp Pro V2 Loggers. Resolution and accuracy data from ONSET®.

3.4 Work Completed

Work completed on the first phase BMP projects since the project inception through September 30th 2010 (end of the 2010 water year) is listed below. Work done to start the second phase BMP projects is not included in this report.

- Completion of a Quality Assurance Project Plan (QAPP) (November 2008), revised October 2010.
- Information on selected monitoring sites was submitted to Ecology.
- Project designs for two water quality and two flow control BMP projects were submitted for Ecology Review and approval. Submitted final or as-built designs for the phase one projects.
- Installed the two phase one water quality BMPs projects at: 148th Ave SE and SE 136th St.
- Storm sampling:

- o 148th Ave SE. Collected 11 upstream/downstream stormwater flow composited samples and 10 grab samples.
- o SE 136th St. Collected 12 upstream/downstream stormwater flow composited samples and 8 grab samples.

- Flow monitoring through the water year at each project site (some short interruptions in the continuous flow record at the SE 136th St project are noted in the Quality Assurance review.
- Baseline flow monitoring. Some baseline flow monitoring data was collected prior to installation of BMPs at the two project sites.

3.5 Data Collection and Analysis

Storms targeted for sampling are listed in Tables 6 (148th Ave SE) and 14 (SE 136th St). Additional details on storm sampling are provided in this report's Appendix A, Tables A-1 and A-2. Individual storm summaries that include the storm flow hydrograph, rainfall, and timing of composite sample aliquots and grab sample collection are provided in Appendix C. Analytical results from each storm and the apparent BMP efficiency for each analyte are provided in this report's Appendix B, Tables B-1 and B-2 148th for the 148th Ave SE project and Tables B-3 and B-4 for the SE 136th St project). Flow response curves that plot stormflow vs. rainfall at each project site and are used to predict total stormflow and set sampler pacing are included in this report's Appendix D.

Storm sampling criteria and project goals for this program are described in the project QAPP. The QAPP defines two seasonal types of storms: Wet Season storms occur from October 1st through April 30th and require a 24 hour antecedent dry period before sampling. Dry season storms occur from May 1st through September 30th and require a 72 hour dry period prior to sampling. The storm sampling goal was to evaluate a mix of wet and dry season storms with about 60 percent collected during the wet season storms and about 40 percent during the dry season. Due to difficulties overall with storm sampling, particularly with dry season storms the resulting mix of storms evaluated in this report is weighted toward wet-season storms. Storm criteria required that the flow weighted composite samples each represent more than 50% of each storm flow hydrograph. Occasionally samples were analyzed from events that collected from less than 50% of the storm, usually due to excessive storm length or other factors, but were felt to represent the a significant portion of the front end or first flush portion of the storm. The rational for analyzing storm that did not meet strict criteria is included in the storm summaries.

Flow was measured using water level sensors (bubble meters) in conjunction with flumes and weirs installed above and below the BMP installations. The 148th Ave SE project used extra-large, 60° - V trapezoidal flumes installed in the ditch. Thel-Mar weirs installed in existing culverts were deployed at the SE 136th St project.

Level/flow measurement and field documentation is reviewed in more detail in section <u>Data Quality Review</u>.

Apparent BMP efficiency was evaluated by comparing monitoring results (This report's Appendix B Analytical Data, Tables B-1 and B-3) from flow weighted composite samples and grab samples at stations placed upstream and downstream of each BMP project during a series of storm events. Flow weighted composite samples were collected from targeted storm events by assigning a set sample volume or aliquot to be collected by an autosampler every time a specified, constant volume of stormflow was measured by the flow meter. The sampler delivered all aliquots directly to a single sample container. Analytical results from these composites are considered to be representative of the average pollutant concentration or event mean concentration (EMC) of the storm event. The pollutant removal efficiency of the ditch BMPs was calculated for each parameter analyzed during each targeted storm event using the formula:

$$\text{EMC Efficiency} = \frac{\text{EMCup} - \text{EMCdn}}{\text{EMCup}}$$

EMCup = EMC of the upstream sample
EMCdn = EMC of the downstream sample

Individual efficiencies from each storm event are provided in (This report's Appendix B Analytical Data, Tables B-2 and B-4). The overall efficiency of each BMP project was assessed as the median efficiency achieved for each parameter during the monitoring period. Efficiencies reported with negative values were found to have higher concentrations at the downstream stations than at the upstream stations.

Samples for Fecal Coliform and total petroleum hydrocarbons (TPH) were collected as discrete grab samples since sampling protocol for these parameters does not allow collection as a flow-weighted composite. Due to the lack of multiple grab samples during the storm, these results were evaluated using the efficiency equation (above).

4.0. RESULTS

4.1 148th Ave. SE

Project location: Ditch along the east side of 148th Ave. S.E. just south of S.E. 102nd St.

Drainage basin: This section of ditch drains 37.4 acres of low density residential neighborhood (zoned RA 5, one domestic unit per acre) as shown in Figure 1, with drainage to May Creek. This ditch has very limited road shoulder area and receives direct sheet flow storm runoff from 148th Ave SE.

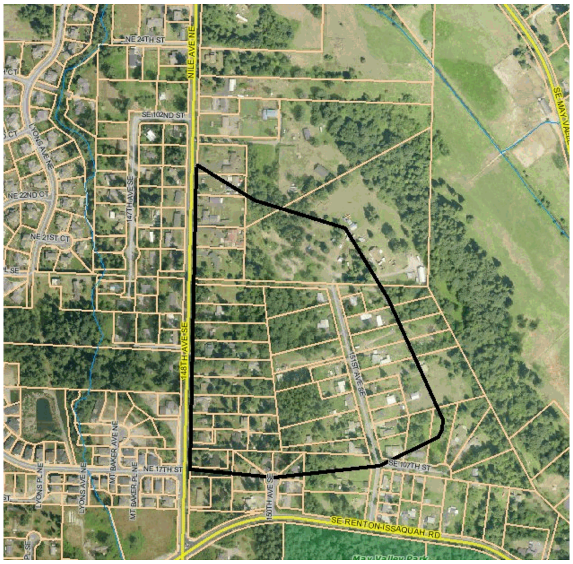
Traffic: Collector arterial with moderate [average daily traffic (ADT) volume of approximately 2,000 vehicles].

BMPs: Three BMPs were installed in a section of roadside ditch approximately 100' in length on June 4th 2009. Each BMP consisted of a "treatment cell" filled with compost media mixed with washed gravel and wrapped in filter fabric (Geotex 801) secured inside a rock check-dam. Compost was a commercially available product based on Washington State Department of Transportation (WSDOT) specification (EV Coarse) for use in stormwater treatment projects.

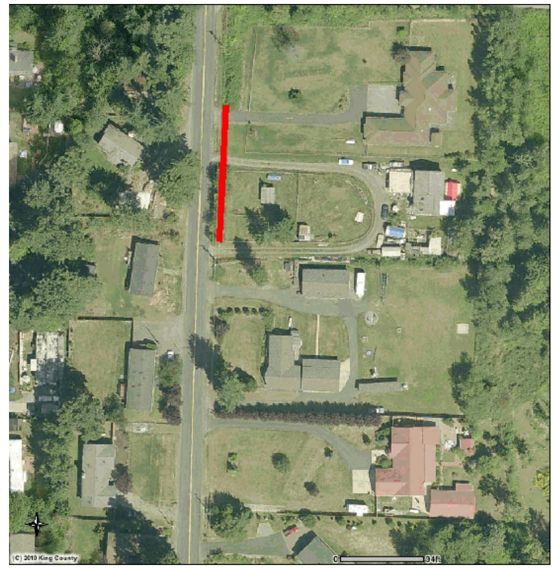
Installation: BMP installation was completed within one day by a King County Roads Maintenance division crew at a cost of just under $4000 including expenses. The crew consisted of a crew chief or lead, a heavy equipment operator, one truck driver, one utility working directly with the BMP installation and two flaggers. Equipment included one backhoe for prepping the ditch for the BMPs, one truck for removing soil and hauling the rock mix, a small trailer for hauling compost, and non-woven geotextile.

4.1.1 Targeted and Collected Storms

Monitoring stations at locations upstream and downstream of the installed BMPs were operated from June 17th 2009 through September 30th 2010. A total of 11 upstream/downstream flow composited storm sample sets were submitted for analysis from this project along with 10 grab sample sets. Monitoring activities included 14 failed attempts to collect simultaneous upstream/ downstream flow composite sample sets for a total of 25 sampling attempts (Table 5). Details from field monitoring activities including storm sampling, failed attempts and site visits to verify equipment operation are provided in this report's Appendix A, Table A-1; individual storm summaries are provided in Appendix C.



Watershed



Study Location (red line)

Figure 2 148th Ave SE Location

Table 5. Upstream/Downstream Storm Sampling Efforts 148th Ave SE

Storm Setup Date	**Flow Weighted Composite Sample Number and Failed Sampling Attempts**	**Antecedent Dry Period** ($\geq$ 0.2" precip 72 hours Dry Season, 24 hours Wet Season)	**Mid-Storm Dry Period (hours)**	**Rainfall (inches)**	**Comments**
9/3/10	No Composite Sample Analyzed	7	<6	1.35	Storm with intermittent rain and >6 hour dry periods over two days. Antecedent dry period not meet. High intensity rainfall on 9/6/09. Samplers overfilled. No samples submitted.
9/17/09	No Composite Sample Analyzed	45	<6	.33	Antecedent Dry period not met. No downstream aliquots collected.
9/28/09	No Composite Sample Analyzed	24	<6	.28	Antecedent Dry period not met. Insufficient sample upstream (about 250 mls total), no sample collected downstream.
Start of Wet Season October 1st					

10/8/09	No Composite Sample Analyzed	260	<6	0.88	Only 2 aliquots collected upstream, none downstream. Sample not analyzed.
Storm Setup Date	**Flow Weighted Composite Sample Number and Failed Sampling Attempts**	**Antecedent Dry Period (hours)** (≥ 0.2" precip 72 hours Dry Season, 24 hours Wet Season)	**Mid-Storm Dry Period (hours)**	**Rainfall (inches)**	**Comments**
10/16/09	1	31	<6	1.5	Composite sampling successful., grab samples collected.
10/22/10	No Composite Sample Analyzed	36	<6	0.5	Unable to complete composite sampling due to staffing issues.
10/28/09	2	41	<6	0.4	Both WQ Sites Collected. Grab samples collected
11/04/09	3	63	<6	0.84	Rainfall came in showers & less than predicted, sample volume limited. Grab samples collected.
12/14/09	No Composite Sample Analyzed	197	<6	0.44	Set pacing based on rainfall predictions of 0.7 to 0.8 inches of rain and wet –season flow response. Flows were significantly less than expected.
12/26/09	No Composite Sample Analyzed	--	--	0.03	Storm did not materialize, only 0.03 inches recorded.
1/10/10	4	39	<6	0.88	Composite sampling successful. No grabs collected.
1/22/10	No Composite Sample Analyzed	22	<6	0.42	Antecedent dry period not met. Samples missed a significant portion of leading edge of stormflow.
1/28/10	5	110	<6	0.4	Sample volume was lower than expected due to sampler intake placed partially out of water only collecting a partial aliquot. Sampled stormflow represents bulk of storm. No grabs collected.
2/4/10	6	25	<6	0.2	Both 148th samples collected successfully. Sample includes three aliquots collected before true start of stormflow. No grabs collected

2/23/10	7	180	<6	0.57	Composite sampling successful. No grabs collected.
Storm Setup Date	**Flow Weighted Composite Sample Number and Failed Sampling Attempts**	**Antecedent Dry Period (hours)** (≥ 0.2” precip 72 hours Dry Season, 24 hours Wet Season)	**Mid-Storm Dry Period (hours)**	**Rainfall (inches)**	**Comments**
3/5/10	No Composite Sample Analyzed	82	<6	0.1	Did not meet rain criteria. False start, all aliquots collected before start of stormflow.
3/19/10	8	76	<6	0.58	Collected less than 50% of leading edge of hydrograph. Sample kept. Grabs collected late in storm.
4/12/10	9	120	<6	0.14	Received rainfall from localized storm event. Grab samples collected.
4/19/10	10	72	<6	1.12	Storm not well forecasted. Sampling captured the leading storm edge but significantly less than 50%. Storm samples were analyzed. Grab samples collected.
4/26/10	No Composite Sample Analyzed	51	<6	0.35	Equipment failure at downstream station. Problem corrected after storm
6/14/10	No Composite Sample Analyzed	109	<6	0.46	Equipment failure at downstream station. Problem corrected after storm. Grab samples collected.
6/24/10	No Composite Sample Analyzed	271	<6	.34	No aliquots collected. Storm only produced 58 gallons of flow upstream, and less than 1 gallon downstream. Grabs collected from water pooled above flumes.
8/25/10	11	552	<6	.56	Storm resulted in to flow peaks separated by four hours with no flow. Second peak missed by samplers. Sample kept as representing first flush of dry season event. Grab samples collected.
9/14/10	No Composite Sample Analyzed	192	<6	.37	Only two gallons of stormflow measured downstream, with 1 aliquot collected. Sample not kept.

9/23/10	No Composite Sample Analyzed	24	<6	.25	No aliquots collected downstream due to small flow response. Grab samples collected.

4.1.2 Laboratory Water Quality Data

Complete analytical results from upstream/downstream monitoring at the 148th project site are listed in Table B-1 (Appendix B). The results from the upstream station are assumed to represent background conditions in the ditch, with the downstream data representing treated stormwater. The maximum, minimum, and median values for parameters tested at the 148th upstream monitoring station are listed in Table 6. below:

Table 6. Maximum, Minimum and Median Values for Background (Upstream of BMPs) and Downstream Stormwater 148th Ave SE

Parameter	Units	Upstream			Downstream		
		Max	**Min**	**Median**	**Max**	**Min**	**Median**
Conventionals							
Nitrite + Nitrate Nitrogen	mg/L	1.8	<MDL	0.865	2.16	<MDL	0.993
Orthophosphate Phosphorus	mg/L	0.173	0.00692	0.0216	0.264	0.0113	0.0278
Total Kjeldahl Nitrogen	mg/L	1.52	0.203	0.421	2.05	0.219	0.422
Total Suspended Solids	mg/L	74.1	5	14	48	2.53	6.6
Dissolved Metals							
Dissolved Arsenic	ug/L	0.567	0.17	0.23	1.59	0.28	0.42
Dissolved Cadmium	ug/L	0.052	<MDL	<MDL	0.07	<MDL	<MDL
Dissolved Chromium	ug/L	2.17	<MDL	0.56	2.19	<MDL	0.46
Dissolved Copper	ug/L	6.89	1.1	2	8.64	0.14	2.18
Dissolved Lead	ug/L	0.39	<MDL	<MDL	0.36	<MDL	0.15
Dissolved Nickel	ug/L	1.77	0.24	0.38	2.02	0.32	0.677
Dissolved Selenium	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dissolved Tin	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dissolved Zinc	ug/L	15.7	3.58	5.69	9.55	2.5	5.17
Hardness	ug/L	21.3	13.4	18.5	40.4	17.1	26
Polycyclic aromatic hydrocarbons (PAHs)							
2-Methylnaphthalene	ug/L	0.0076	<MDL	<MDL	0.0099	<MDL	<MDL
Acenapthene	ug/L	<MDL	<MDL	<MDL	0.0052	<MDL	<MDL
Acenaphthylene	ug/L	0.015	<MDL	<MDL	0.019	<MDL	<MDL
Anthracene	ug/L	0.014	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)anthracene	ug/L	0.219	<MDL	0.0946	0.0952	<MDL	0.031
Benzo(a)pyrene	ug/L	0.312	<MDL	0.138	0.168	<MDL	0.03905
Benzo(b)fluoranthene	ug/L	0.293	<MDL	0.1435	0.173	<MDL	0.037
Benzo(g,h,i)perylene	ug/L	0.201	<MDL	0.0694	0.0793	<MDL	0.0165
Benzo(k)fluoranthene	ug/L	0.308	<MDL	0.151	0.194	<MDL	0.032
Chrysene	ug/L	0.308	<MDL	0.117	0.0994	<MDL	0.0295
Dibenzo(a,h)anthracene	ug/L	0.0484	<MDL	<MDL	0.023	<MDL	<MDL
Fluoranthene	ug/L	0.485	<MDL	0.157	0.155	<MDL	0.024
Fluorene	ug/L	0.014	<MDL	<MDL	0.014	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	0.165	<MDL	0.0639	0.0667	<MDL	0.017
Naphthalene	ug/L	0.167	<MDL	0.016	0.0394	<MDL	0.017
Phenanthrene	ug/L	0.13	<MDL	0.0433	0.0545	<MDL	<MDL
Pyrene	ug/L	0.609	<MDL	0.1395	0.151	<MDL	0.02
Sum of PAHs	ug/L	2.7832	0.167	0.8918	1.2561	0.0447	0.1536
Total petroleum hydrocarbons (NWTPH-Dx)							
Diesel Range (>C12-C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Lube Oil Range (>C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fecal coliform bacteria	cfu/100 ml	6500	<MDL	740	7500	<MDL	1300

The figures below present a comparison of the upstream/downstream monitoring results from TSS, total PAH and dissolved zinc.

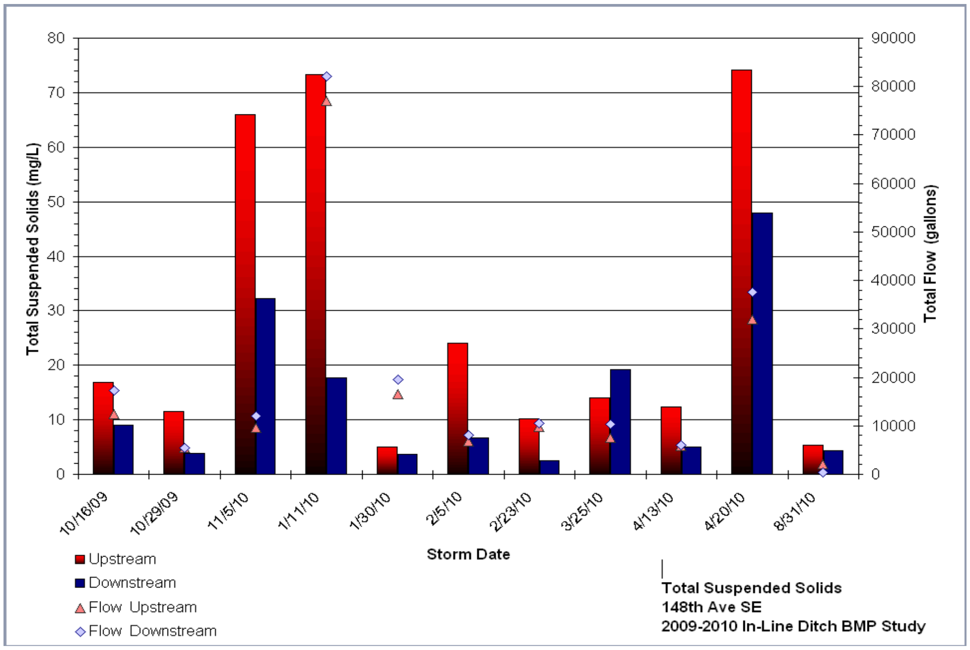


Figure 3. Upstream/Downstream Results for TSS, 148th Ave NE

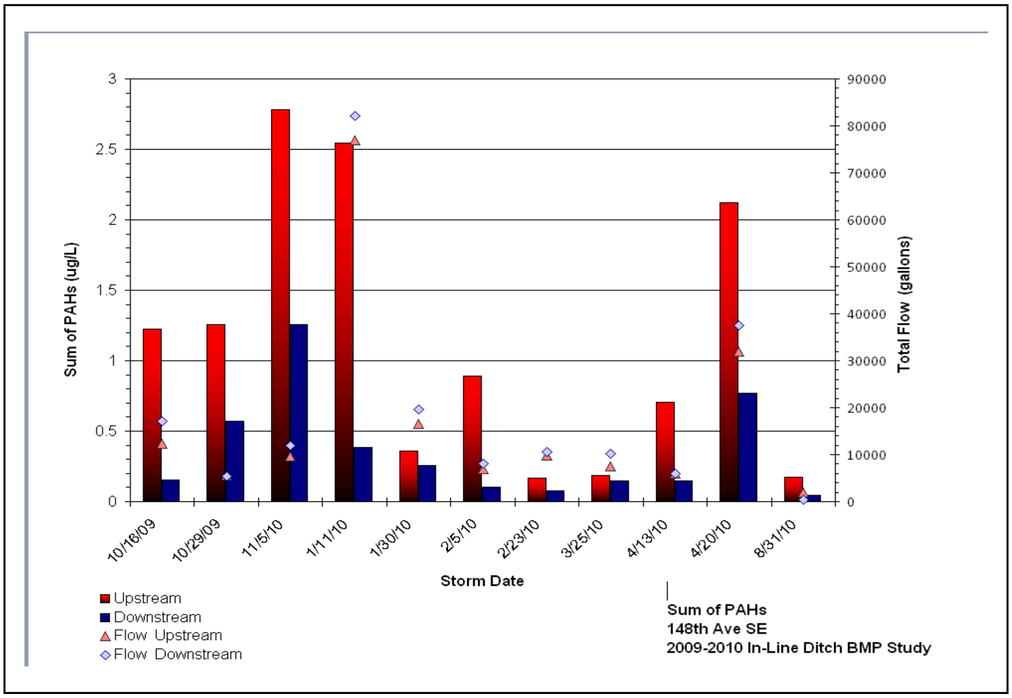


Figure 4. Upstream/Downstream Results for PAH, 148th Ave NE

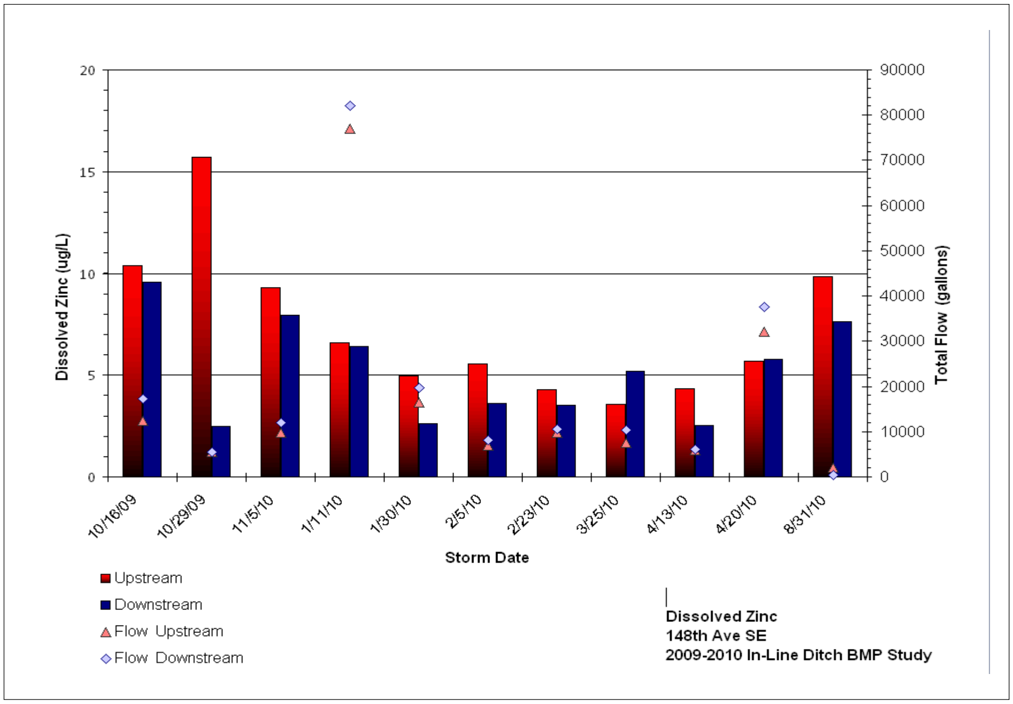


Figure 5. Upstream/Downstream Results for dissolved zinc, 148th

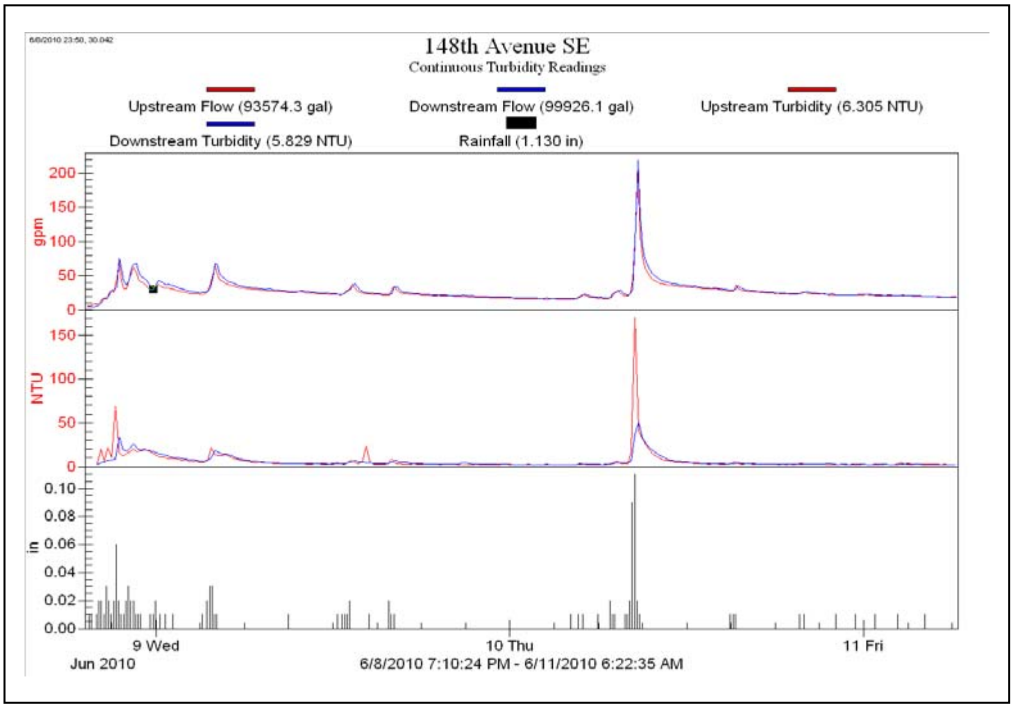


Figure 6. Results from Continous Monitoring of Flow, Turbidity and Rainfall June 8th through June 11th 2010. 148th Ave SE

4.1.3 Field Water Quality Data

Results from monitoring of water quality parameters as discrete measurements of dissolved oxygen (DO), pH, temperature, turbidity and specific conductivity are presented in Tables 7 through 11 below.

Table 7. Discrete Measurements of Dissolved Oxygen

Date M/D/Y	Upstream DO mg/L	Downstream DO mg/L	% Difference
10/16/2009	9.24	9.05	2.1
10/29/2009	11.8	11.43	3.1
11/5/2009	7.27	7.97	-9.6
3/25/2010	11.12	10.78	3.1
4/13/2010	11.64	11.05	5.1
4/21/2010	10.3	10.35	-0.5
6/16/2010	8.87	8.83	0.5
8/31/2010	8.69	8.47	2.5
Median	9.77	9.7	
Minimum	7.27	7.97	
Maximum	11.8	11.43	

Table 8. Discrete Measurements of pH

	Upstream	Downstream	
Date M/D/Y	**pH SU Units**	**pH SU Units**	**% Difference**
10/16/2009	6.52	7.82	-19.9
10/29/2009	7.02	7.33	-4.4
11/5/2009	6.17	6.37	-3.2
3/25/2010	7.18	7.32	-1.9
4/13/2010	6.9	7.11	-3.0
4/21/2010	6.42	6.56	-2.2
6/16/2010	6.86	6.99	-1.9
8/31/2010	7.16	7.3	-2.0
Median	6.88	7.205	
Minimum	6.17	6.37	
Maximum	7.18	7.82	

Table 9. Discrete Measurements of Temperature

	Upstream	Downstream	
Date M/D/Y	**Temp °C**	**Temp °C**	**% Difference**
10/16/2009	13.15	13.51	-2.7
10/29/2009	9.08	9.29	-2.3
11/5/2009	11.2	10.99	1.9
3/25/2010	9.1	8.97	1.4
4/13/2010	8.99	8.96	0.3
4/21/2010	9.48	9.58	-1.1
6/16/2010	12.68	12.53	1.2
8/31/2010	15.19	14.93	1.7
Median	9.77	9.7	
Minimum	7.27	7.97	
Maximum	11.8	11.43	

Table 10. Discrete Measurements of Turbidity

	Upstream	Downstream	
	Turbidity NTU	Turbidity NTU	% Difference
10/16/2009	9.8	13.9	-41.8
10/29/2009	5.2	7.2	-38.5
11/5/2009	18.3	7.8	57.4
3/25/2010	4.6	3.4	26.1
4/13/2010	3.4	4.5	-32.4
4/21/2010	12	16.1	-34.2
6/16/2010	6	6.4	-6.7
8/31/2010	5.1	5.4	-5.9
Median	5.6	6.8	
Minimum	3.4	3.4	
Maximum	18.3	16.1	

Table 11. Discrete Measurements of Conductivity

	Upstream	Downstream	
	SpCond mS/cm	SpCond mS/cm	% Difference
10/16/2009	0.085	0.08	5.9
10/29/2009	0.051	0.085	-66.7
11/5/2009	0.054	0.089	-64.8
3/25/2010	0.05	0.072	-44.0
4/13/2010	0.066	0.069	-4.5
4/21/2010	0.066	0.081	-22.7
6/16/2010	0.088	0.072	18.2
8/31/2010	0.045	0.101	-124.4
Median	0.06	0.0805	
Minimum	0.045	0.069	
Maximum	0.088	0.101	

In order to explore the effects of TSS reduction further, continuous recording turbidity sensors measuring turbidity in Nephelometric turbidity units (NTUs) were temporarily deployed at the upstream and downstream monitoring locations. The use of continuous monitoring instruments were done outside of work described in the project QAPP, however calibration followed SOP protocol established in the QAPP for sonde measurements.

Figure 6 shows continuous turbidity data collected from June 8th through June 11th 2010 at the 148th Ave SE project. On June 8th an upstream turbidity spike corresponding with a peak rainfall and flow event reached 47 NTUs, with a corresponding downstream spike of 24 NTUs, a reduction in turbidity of 49%. On June 10th and upstream turbidity peak reached 99 NTUs, the corresponding downstream peak measured 50 NTUs, representing a reduction of almost 50%.

Continuous temperature was recorded at upstream and downstream locations at both water quality BMP study sites. The intent of this monitoring was to determine the effects of the BMPs on increasing the temperature of water discharged from a treated section of ditch. Continuous temperature was measured through the use of independently recording temperature probes placed near the sampling stations at these sites, recording temperature in fifteen minute increments. Operation of the probes was check by conducting ice bath tests on a periodic basis.

4.1.4 BMP Efficiencies

Overall efficiencies, calculated for each analytical parameter tested from the eleven storms sampled for this project are provided in Table 12 below (negative values result from a higher EMC or analytical result for the downstream sample when compared to the upstream sample). Efficiencies were calculated from analytical data presented in Table B-1 (Appendix B).

Table 12. BMP Efficiencies 148th Ave SE

Parameter	Apparent BMP Efficiencies (Median Percent Decrease in Pollutant)
Total suspended solids	**51.2**
Total Kjeldahl nitrogen	-0.2
Nitrate-nitrite (NO23)	-8.8
Orthophosphate	-50.0
Hardness	-30.3
Dissolved arsenic	-65
Dissolved cadmium	0[3]
Dissolved chromium	0
Dissolved copper	-15.4
Dissolved lead	-120.0
Dissolved nickel	-9.6
Dissolved selenium	0[3]
Dissolved tin	0[3]
Dissolved zinc	**17.7**
PAH-SIM[1]	**63.8**
Total petroleum hydrocarbons (NWTPH-Dx)[2,3]	0[3]
Fecal Coliform[2]	-62.5

Note: a negative value indicates that the analyte concentration was higher downstream at the downstream station than the upstream.

[1] PAH value is calculated based on the sum of PAH's tested for each sample (see Appendix B, Table B-4).Analyte collected as a grab sample

[2] Sample collected as a grab sample

[3] Analyte not detected during any sampling events.

BMP efficiencies based on the median values of the efficiencies for each sampled parameter showed in reductions of TSS (51.2%), total PAH (63.8%), and dissolved zinc (17.7%). Hardness increased downstream by 30.3 % which is considered to be a benefit in increasing the buffering capacity of storm flow. Four parameters; dissolved cadmium, selenium, tin and total petroleum hydrocarbons were not detected in any samples. Dissolved chromium was found to have a net zero change in downstream concentration.

4.1.5 Flow

Flow was monitored from installation of the 148th Ave SE BMP project and has been included as electronic files to be submitted with this report's Appendix D.

These BMP designs function as weirs within the ditch, with the effect of pooling water and taking the scouring energy out of the stormflow. The BMPs are designed to allow stormwater flow-through, so the pooling is temporary. Lower flows are intended to filter through the BMP rock structure and treatment media. Higher flows are intended to overtop the BMPs, and flow into the next downstream pool with less scouring effect, leaving the BMPs intact and preventing scour in the ditch. The monitoring design measures total flow, not velocity. We can demonstrate a delay in flow and changes in total flow from the upstream to downstream monitoring stations, but since the monitoring equipment did not measure velocity directly, this study can not quantify the decrease in energy of the flow. However the pooling effect and lack of fast, scouring water between the BMPs is immediately evident during site visits and is documented in photos.

Figure 7. Stormflow Pooling above BMP Structures, 148th Ave SE

The ability of the 148th Ave SE BMPs to delay or decrease downstream flows varies with seasonal changes in storm volume, intensity, frequency, and soil saturation conditions in the watershed. Modification of storm flows tended to be measureable during the dry season with fewer, typically smaller storms and assumed lower soil moisture conditions, and the ditches tended to quickly dry out between storm events. During the wet season, as storms became more frequent and carried higher volumes, flows quickly overtopped the BMPs. The time required for surface soils to completely drain to the ditch extended so that flow typically remained in the ditch between storm events. The watershed contribution to stormflow along the length of the ditch was found to be significant and flows measured at the downstream monitoring station were typically higher than upstream flows during much the wet season. Table 13 presents upstream/downstream flow comparisons from selected storms monitored during both the dry and wet seasons. Figures 8 through 11 provide a graphical demonstration of flow during a few events.

Table 13. Upstream Downstream Flow Comparisons, 148th Ave SE

Date	Rain (inches)	Upstream Flow (gal)	Downstream Flow (gal	Flow Modification Percentage	Downstream Increase or Decrease in Flow
8/31/2009	0.56	1,989	1,065	46.4	Decrease
9/17/2009	0.56	1,154	999	13.4	Decrease
9/28/2009	0.28	588	94	84.0	Decrease
10/16/2009	1.5	12,400	17,203	-38.7%	Increase
10/28/2009	0.4	5,490	5,475	0.3%	Decrease
11/16/2009	1.52	116,625	129,188	-10.8	Increase
1/10/2010	0.8	76,960	82,141	-6.7%	Increase
1/28/2010	0.4	16,483	19,610	-19.0%	Increase
2/4/2010	0.21	6,830	8,122	-18.9%	Increase
2/23/2010	0.58	9,839	10,613	-7.9%	Increase
4/12/2010	1.4	5,877	6,019	-2.4%	Increase
5/17/2010	0..89	3317	2676	19.3	Decrease
8/31/2010	0.56	1,989	1,065	46.5%	Decrease
9/17/2010	0.33	1,154	999	13.4%	Decrease

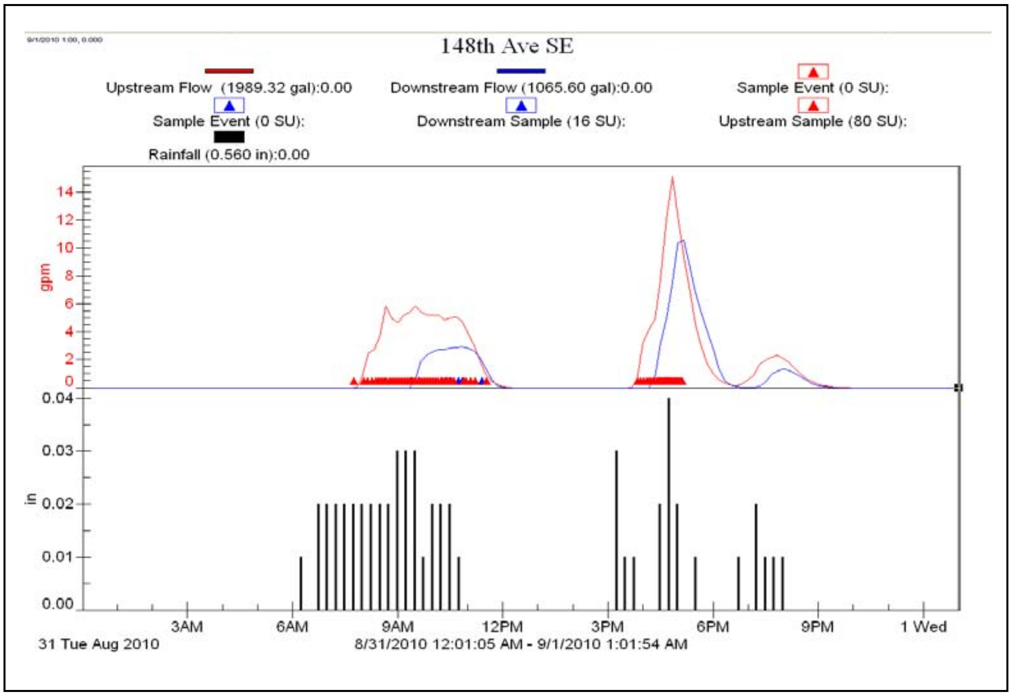


Figure 8. Upstream/downstream flow comparison, August 31 – September 1st 2010, 148th Av SE

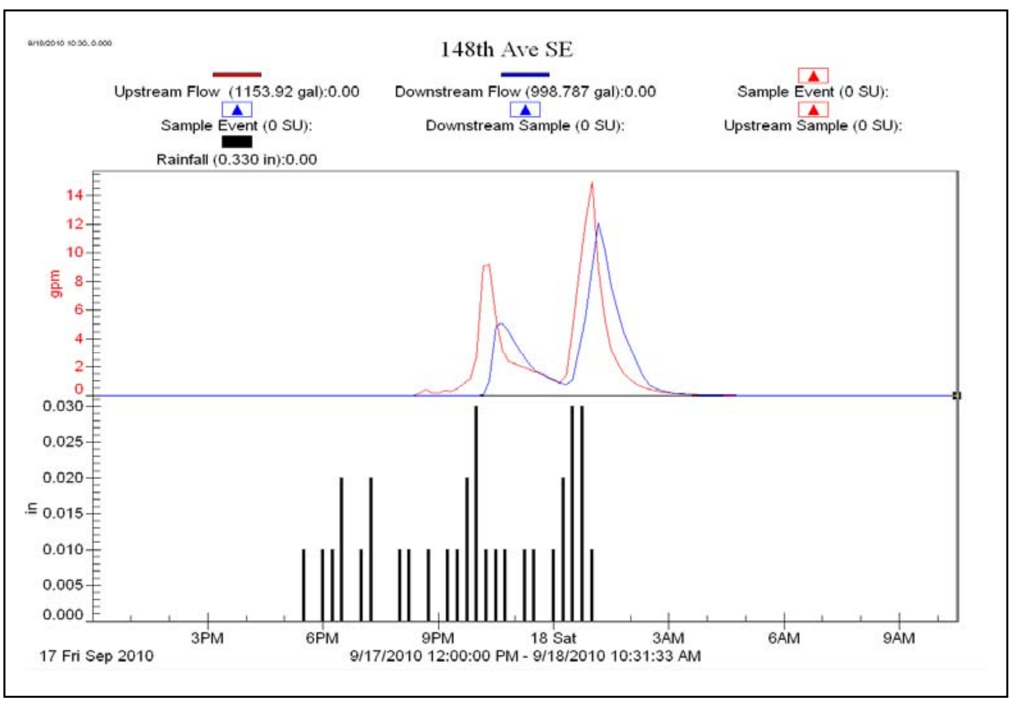


Figure 9. Upstream/downstream flow comparison, September 17th – 18th 2010, 148th Ave SE

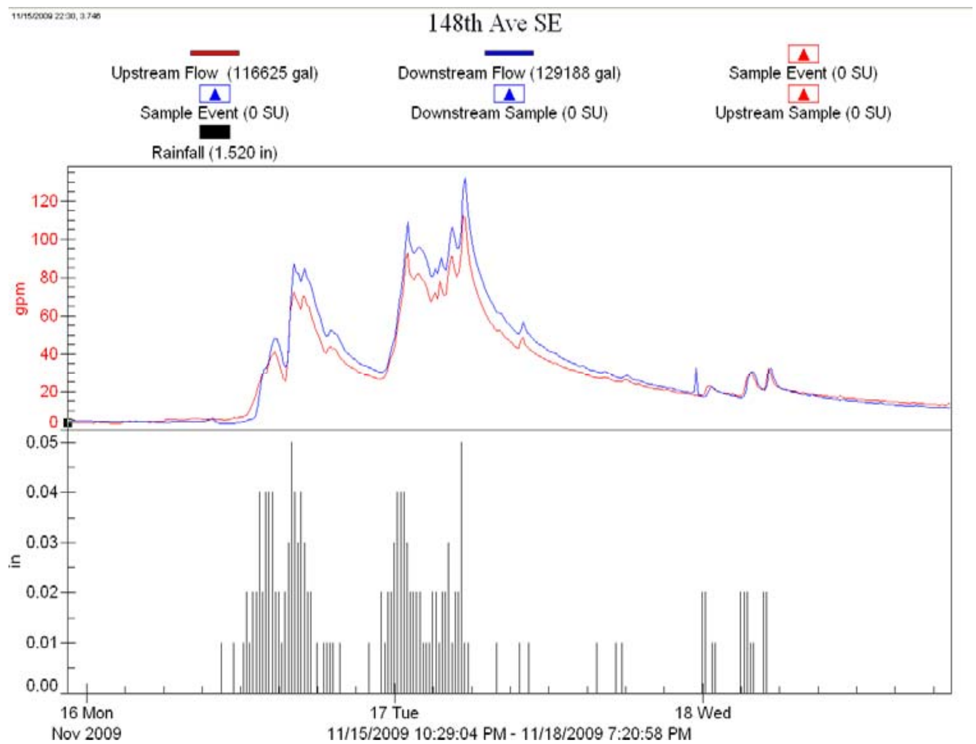


Figure 10. Upstream/downstream flow and rainfall, November 16 – 18, 2009, 148th Ave SE

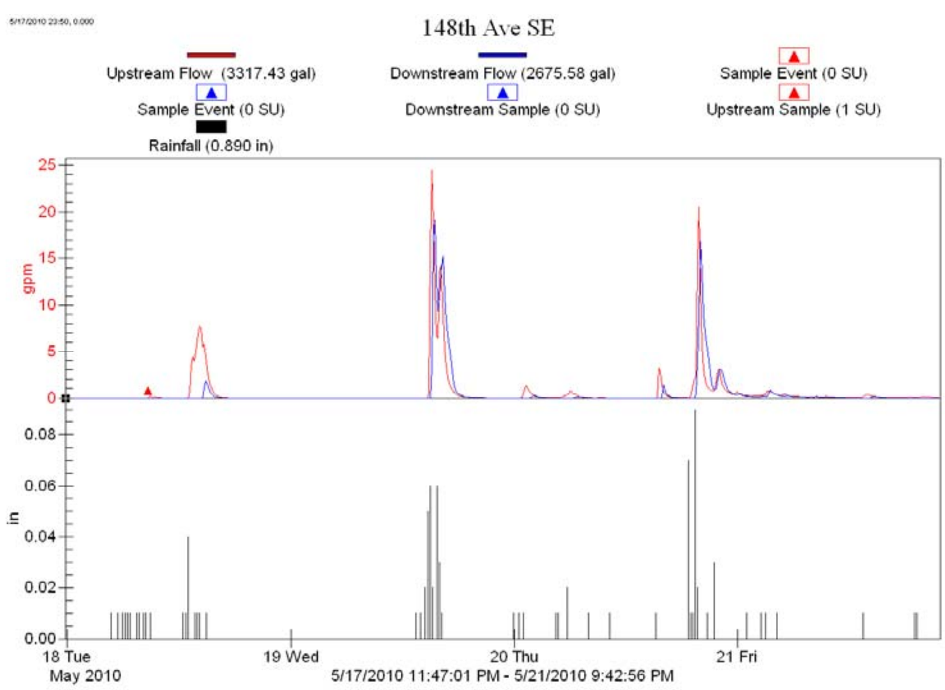


Figure 11. Upstream/downstream flow and rainfall May 18th – 21st 2010, 148th Ave SE

Baseline flow monitoring was initiated at some stations during the fall of 2008. This information was used to develop the methods and equipment that would be used during the BMP studies and to start developing rainfall – runoff relationships for use in composite sampling at each location. This baseline data are provided in an electronic file accompanying this document.

Baseline Flow data were collected at the following water quality monitoring stations:

- 148UP: October 30th 2008 through June 3rd 2009. A 1.0 foot HS flume was originally installed at this monitoring station in late October 2008. This flume was destroyed when a car ran off the road during a snow event on January 4t 2009. The HS flume was replaced with an extra – large 60° V trapezoidal flume on January 27th 2009. The trapezoidal flume was removed on June 3rd 2009 and moved about 10 feet closer to the upstream ditch culvert during BMP installation on June 4th 2009.

- 148DN: A trapezoidal flume was installed on February 19th 2009. A site visit on February 26th 2009 found that the meter was set two hours late and was adjusted (flow peaks for this time period are off by two hours). This flume was removed on June 3rd for installation of BMPs on June 4th. During BMP installation the far bank was re-built. During the baseline flow monitoring period, some flows were leaking around the flume on the far bank. The flume was replaced in the same location after BMP installation; the repaired ditch bank prevented the loss of flow around the flume.

4.2 SE 136th Street

Project Location: North shoulder of S.E. 136th St. between 169th Ave. S.E. and 170th Ave. S.E.

Drainage basin: This section of ditch drains 7.5 acres of residential neighborhood (zoned R4, four houses per acre) as shown in Figure 14. The study ditch receives ditched drainage directly from the ditch along the north shoulder SE 136th street to the east, the east shoulder of 170th Ave SE and a enclosed drainage pipe with catch basins on the west shoulder of 170th Ave SE. The ditch drains to an enclosed drainage pipe just below the BMP project.

Traffic: Moderate (average daily traffic (ADT) volume of approximately 1,521 vehicles). An elementary school is located one block north; and a high school is located one block south east of the study area – the neighborhood roads are busy with morning and early afternoon school traffic.

BMPs: Four BMPs were installed in a section of roadside ditch approximately 100' in length on June 11th 2009. Each BMP consisted of a “treatment cell” filled with compost media mixed with washed gravel and wrapped in filter fabric (Geotex 801) secured inside a rock check dam. Compost was a commercially available product based on Washington State Department of Transportation (WSDOT) specification (EV Coarse) for use in stormwater treatment projects.

Installation: BMP installation was completed within one day by a King County Roads Maintenance division crew at a cost of just under $2000 including expenses. The crew had completed the 148th Ave SE project installation and was familiar with the work required. They consisted of a crew chief or lead, a heavy equipment operator, one truck driver, one utility working directly with the BMP installation and a flagger. Work was completed in less than one day. Equipment included one backhoe for prepping the ditch for the BMPs, one truck for removing soil and hauling the rock mix, a small trailer for hauling compost, and non-woven filter fabric.

4.2.1 Storms Targeted and Collected

Monitoring stations at locations upstream and downstream of the installed BMPs were operated from June 17 2009 through September 30th 2010. A total of 12 upstream/downstream flow composited storm sample sets were submitted for analysis from this project along with 8 grab sample sets. Monitoring activities included 13 failed attempts to collect simultaneous upstream/ downstream flow composite sample sets for a total of 25 sampling attempts (Table 15). Details from field monitoring activities including storm sampling, failed attempts and site visits to verify equipment operation are summarized in this report's Appendix A, Table A-2; Individual storm summaries are provided in Appendix C.

Watershed

Study Site (red lines)

Figure 12. SE 136th St

Storm sampling activities including both events that resulted in composite samples submitted for analysis and failed storm sampling events are summarized in Table 15 below. Storm summary figures that graphically present the upstream and downstream stormflow hydrographs, rainfall and aliquot sampling along and summary details are provided in Appendix C. Detailed storm sampling information is provided in Table A-2 Appendix A.

Table 14. Upstream/Downstream Storm Sampling Efforts SE 136th St

Storm Setup Date	**Flow Weighted Composite Sample Number and Failed Sampling Attempts**	**Antecedent Dry Period** (≥ 0.2" 72hours- Dry Season, 24 hours- Wet Season)	**Mid-Storm Dry Period (hours)**	**Rainfall (inches)**	**Comments**
8/10/09	No Composite Sample Analyzed	648	<6	0.5	Equipment malfunction, no aliquots collected.
9/3/10	No Composite Sample Analyzed	7	>6	1.35	Storm with intermittent rain and >6 hour dry periods over two days. Antecedent dry period not meet. High intensity rainfall on 9/6/09. Samplers overfilled. No samples submitted.
9/17/09	No Composite Sample Analyzed	45	<6	.33	<72 hour dry period. No aliquots collected upstream, no downstream flow.
9/28/09	No Composite Sample Analyzed	24	<6	.28	<72 hour dry period. Upstream sampler failed no downstream flow.
Start of Dry Season October 1st					
10/8/09	No Composite Sample Analyzed	260	<6	0.88	Upstream sample failed.
10/16/09	1	31	<6	1.5	Composite sample successful, grab samples collected

10/22/09	No Composite Sample Analyzed	36	<6	0.5	Unable to complete sampling due to staffing issues.
10/28/09	2	41	<6	0.4	Composite sample successful. Grab samples collected.
11/4/09	3	63	<6	0.84	Rainfall less than predicted, sample volume limited. Grab samples collected.
12/14/09	4	197	<6	0.44	Composite sample submitted. No grabs collected.
1/10/10	5	39	<6	0.88	Upstream sample includes three aliquots of base flow, downstream sample includes flow after end of storm and start of next storm. Composite samples kept. No grabs collected.
1/22/10	No Composite Sample Analyzed	22	<6	0.42	Antecedent dry period not met.
1/28/10	No Composite Sample Analyzed	110	<6	0.4	Both 136 samplers had trigger levels set too high and missed first 24 hrs of storm.
2/3/10	No Composite Sample Analyzed	31	<6	0.26	Missed storm event due to faulty forecast
2/4/10	No Composite Sample Analyzed	25	<6	0.2	Upstream sampler did not trigger (incorrect setting) Samples not analyzed.
2/23/10	6	180	<6	0.57	Sampled light rain for 18 hours, samples were pulled before end of storm. Kept samples as representative of leading end of storm. No grabs collected.
3/5/10	No Composite Sample Analyzed	113	<6	0.1	Low rainfall amount. False upstream sampler start. Samples not kept.
3/19/10	7	76	<6	0.58	Sampled less than 50% of stormflow, but samples were kept as representative of the storm. Grab samples collected.

4/12/10	No Composite Sample Analyzed	120	<6	0.14	Low rainfall amount, sampler triggers set incorrectly. No aliquots collected.
4/19/10	8	72	<6	1.12	Storm not well forecasted. Sampling captured the leading storm edge but significantly less than 50%. Storm samples were analyzed. Grab samples collected.
4/26/10	9	51	<6	0.35	Upstream missed first 2 hours (12%) of storm flow due to trigger level above this early flow. Composite samples collected successfully. No grab samples collected.
Start of Dry Season May 1st					
5/14/10	No Composite Sample Analyzed	38	<6	.21	Samplers did not trigger. No composite sample collected.
6/14/10	10	109	<6	0.46	Composite samples included the two major storm peaks from this event, but the total % storm sample was <50% due to the long lag time of the hydrograph. Samples were analyzed. Grab samples collected late in storm.
6/24/10	11	271	<6	0.34	Composits collected successfully. Grab samples collected.
8/25/10	12	552	<6	.56	Downstream sample less than 50% of storm but collected well into storm peak. Samples analyzed as representative. Grab samples collected.

4.2.2 Laboratory Water Quality Data

Complete analytical results from upstream/downstream monitoring at the 136th project site are listed in Table B-2 (Appendix B). The results from the upstream station are assumed to represent background conditions in the ditch, with the downstream data representing treated stormwater. The maximum, minimum, and median values for parameters tested at the 136th upstream monitoring station are listed in Table 15 below:

Table 15. Maximum, Minimum and Median Values for Background (Upstream) Stormwater at SE 136th Street

Parameter	Units	Upstream			Downstream		
		Max	Min	Median	Max	Min	Median
Conventionals							
Nitrite + Nitrate Nitrogen	mg/L	1.8	<MDL	1.14	2.17	<MDL	1.16
Orthophosphate Phosphorus	mg/L	0.352	0.0039	0.0317	0.258	0.0125	0.05535
Total Kjeldahl Nitrogen	mg/L	2.81	0.223	0.601	3.42	0.27	0.5915
Total Suspended Solids	mg/L	34.6	2.31	11.2	44.2	5	11.4
Dissolved Metals							
Dissolved Arsenic	ug/L	1.04	0.27	0.42	1.21	0.22	0.45
Dissolved Cadmium	ug/L	0.06	<MDL	<MDL	0.081	<MDL	<MDL
Dissolved Chromium	ug/L	0.7	<MDL	0.325	2.19	<MDL	0.45
Dissolved Copper	ug/L	12.9	1.4	2.355	12.5	1.4	2.86
Dissolved Lead	ug/L	0.35	<MDL	0.18	0.45	<MDL	0.19
Dissolved Nickel	ug/L	2.08	0.34	0.46	2.7	0.28	0.485
Dissolved Selenium	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dissolved Tin	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Dissolved Zinc	ug/L	20.8	4.83	8.75	41.2	4.45	6.875
Hardness	ug/L	31.7	15	22.75	42.1	17.1	23.15
Polycyclic aromatic hydrocarbons (PAHs)							
2-Methylnaphthalene	ug/L	0.01	<MDL	<MDL	0.012	<MDL	<MDL
Acenapthene	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Acenaphthylene	ug/L	0.016	<MDL	<MDL	0.0602	<MDL	<MDL
Anthracene	ug/L	0.014	<MDL	<MDL	<MDL	<MDL	<MDL
Benzo(a)anthracene	ug/L	0.0803	<MDL	0.023	0.119	<MDL	0.0661
Benzo(a)pyrene	ug/L	0.142	<MDL	<MDL	0.146	<MDL	<MDL
Benzo(b)fluoranthene	ug/L	0.124	<MDL	<MDL	0.181	<MDL	<MDL
Benzo(g,h,i)perylene	ug/L	0.014	<MDL	<MDL	0.121	<MDL	<MDL
Benzo(k)fluoranthene	ug/L	0.164	<MDL	<MDL	0.168	<MDL	<MDL
Chrysene	ug/L	0.028	<MDL	0.018	0.196	<MDL	0.026
Dibenzo(a,h)anthracene	ug/L	<MDL	<MDL	<MDL	0.035	<MDL	<MDL
Fluoranthene	ug/L	0.014	<MDL	<MDL	0.371	<MDL	<MDL
Fluorene	ug/L	0.018	<MDL	<MDL	0.019	<MDL	<MDL
Indeno(1,2,3-Cd)Pyrene	ug/L	0.013	<MDL	<MDL	0.102	<MDL	<MDL
Naphthalene	ug/L	0.034	0.0064	0.014	0.034	0.0059	0.0125
Phenanthrene	ug/L	0.045	<MDL	0.022	0.0964	<MDL	<MDL
Pyrene	ug/L	0.013	<MDL	<MDL	0.31	<MDL	<MDL
Sum of PAHs	ug/L	0.6514	0.028	0.095	1.8084	0.0088	0.05115
Total petroleum hydrocarbons (NWTPH-Dx)							
Diesel Range (>C12-C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Lube Oil Range (>C24)	ug/L	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Fecal coliform bacteria	cfu/100 ml	4700	<MDL	855	5500	<MDL	1350

Upstream/ downstream monitoring results for TSS, total PAH and dissolved zinc are presented graphically in the figures below.

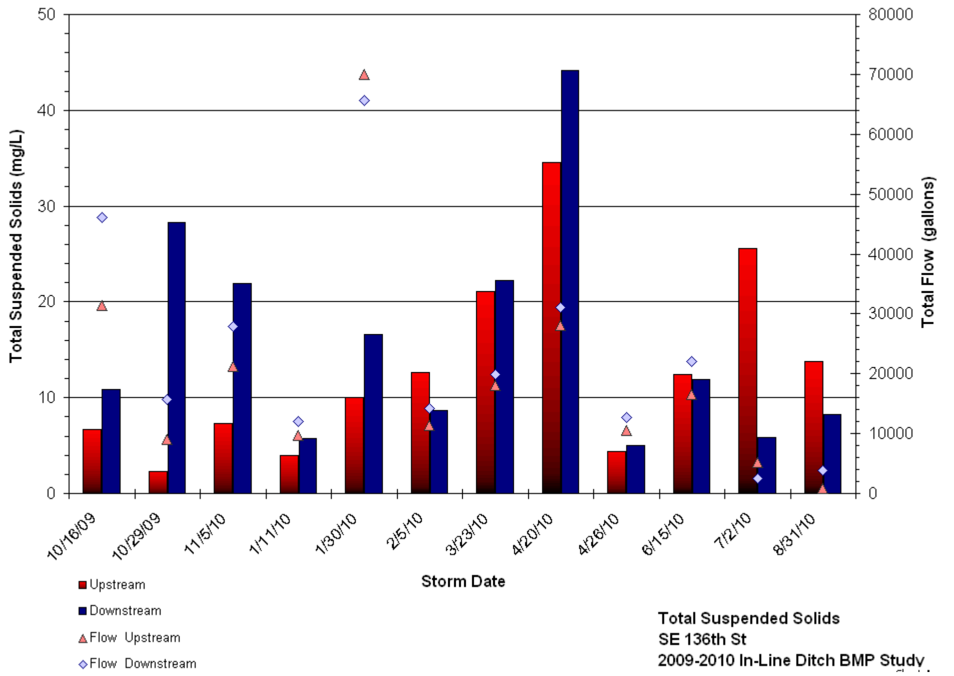


Figure 13 Upstream/Downstream Results for TSS at SE 136th Street

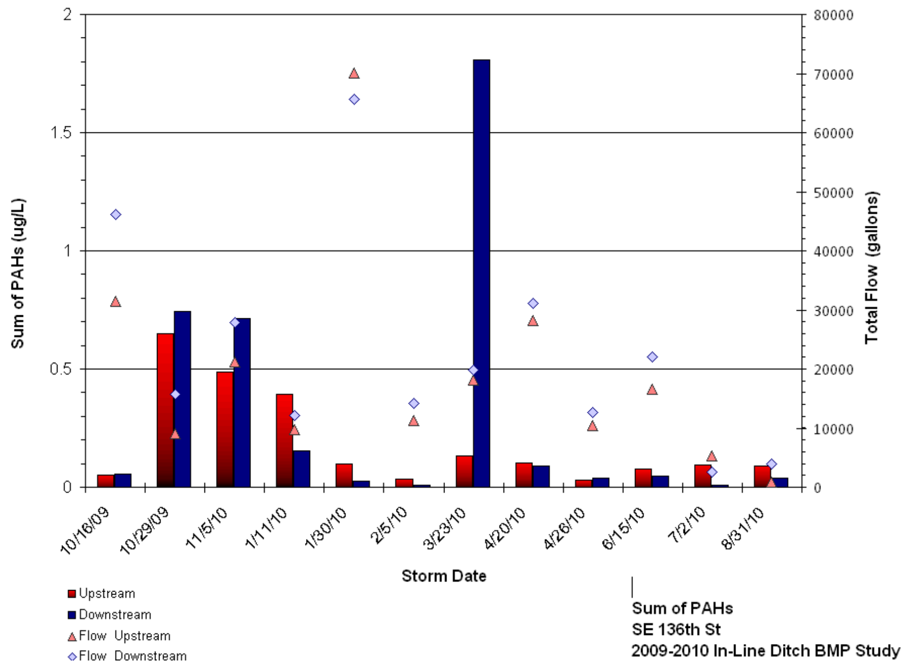


Figure 14 Upstream/Downstream Results for total PAH at SE 136th Street

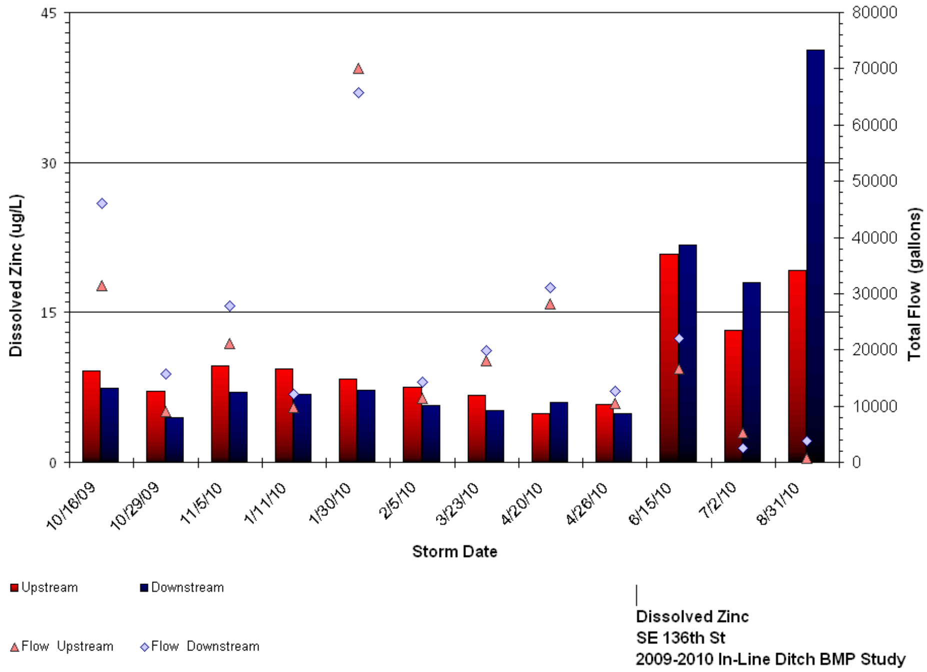


Figure 15 Upstream/Downstream Results for dissolved zinc at SE 136th Street

4.2.3 Flow Monitoring

Flow was monitored at the upstream and downstream station from the July 17th 2009 shortly after the BMPs were installed, through September 1st 2010. The flowmeters were removed on September 1st just after completing the 12th storm event for this project so they could be placed at one of the 2011 BMP project sites. These records are being submitted as electronic files accompanying this report.

While these BMP designs do function as those at the 148th project to pool stormwater and decrease the scouring energy out of the stormflow is observable in these photos from a January 2010 storm event. There is an apparent input of stormwater, measured as an increase in flow at the downstream monitoring station during most storm events except during very dry periods.

4.2.4 Field Water Quality Data

Results from monitoring of water quality parameters as discrete measurements of dissolved oxygen (DO), pH, temperature, turbidity and specific conductivity are presented in Tables 16 through 20 below.

Table 16. Discrete Measurements of Dissolved Oxygen SE 136th St

Date M/D/Y	Upstream DO Conc (mg/L)	Downstream DO Conc (mg/L)	% Difference
10/16/2009	12.16	8.05	33.8
10/29/2009	10.92	11.31	-3.6
11/5/2009	7.73	8.22	-6.3
3/25/2010	10.2	10.62	-4.1
4/21/2010	10.14	9.74	3.9
6/16/2010	7.98	8.47	-6.1
8/31/2010	7.51	7.97	-6.1
Median	9.5	9.2	
Minimum	7.5	8.0	
Maximum	12.2	11.3	

Table 17. Discrete Measurements of pH SE 136th St

Date M/D/Y	Upstream pH (SU units)	Downstream pH (SU units)	% Difference
10/16/2009	6.51	6.13	5.8
10/29/2009	7.07	6.95	1.7
11/5/2009	5.95	6.32	-6.2
3/25/2010	6.89	6.95	-0.9
4/21/2010	6.48	6.64	-2.5
6/16/2010	6.73	6.9	-2.5
8/31/2010	6.5	6.72	-3.4
Median	6.6	6.7	
Minimum	6.0	6.1	
Maximum	7.1	7.0	

Table 18. Discrete Measurements of Temperature SE 136th St

Date M/D/Y	Upstream Temp. (°C)	Downstream Temp. (°C)	% Difference
10/16/2009	13.15	13.33	-1.4
10/29/2009	9.39	9.26	1.4
11/5/2009	11.04	10.68	3.3
3/25/2010	9.49	9.33	1.7
4/21/2010	10.5	10.47	0.3
6/16/2010	13	13.06	-0.5
8/31/2010	15.3	15.12	1.2
Median	11.7	11.6	
Minimum	9.4	9.3	
Maximum	15.3	15.1	

Table 19. Discrete Measurements of Turbidity SE 136th St

Date M/D/Y	Upstream Turbidity (NTUs)	Downstream Turbidity (NTUs)	% Difference
10/16/2009	16.1	2.2	86.3
10/29/2009	11	8.2	25.5
11/5/2009	3.8	5.4	-42.1
3/25/2010	11.4	8.2	28.1
4/21/2010	8.9	9.9	-11.2
6/16/2010	2.8	3.4	-21.4
8/31/2010	9	8.5	5.6
Median	9.0	6.5	
Minimum	2.8	2.2	
Maximum	16.1	9.9	

Table 20. Discrete Measurements of Specific Conductivity SE 136th St

Date M/D/Y	Upstream Specific Conductivity mS/cm	Downstream Specific Conductivity mS/cm	% Difference
10/16/2009	16.1	2.2	86.3
10/29/2009	11	8.2	25.5
11/5/2009	3.8	5.4	-42.1
3/25/2010	11.4	8.2	28.1
4/21/2010	8.9	9.9	-11.2
6/16/2010	2.8	3.4	-21.4
8/31/2010	9	8.5	5.6
Median	9.0	6.5	
Minimum	2.8	2.2	
Maximum	16.1	9.9	

4.2.5 BMP Efficiencies

Analytical results and BMP efficiencies are presented in Appendix B Table B-3, and B-4. Storm summaries including the flow hydrograph, rainfall and sampling detail are provided Appendix C.

Overall efficiencies, calculated for each analytical parameter tested from the twelve storms sampled for this project are provided in Table 14 below (negative values result from an EMC or analytical result for the downstream sample that is higher than the result for the upstream sample).

The BMP efficiencies for reduction of TSS observed at the 148th Ave SE project were not repeated at this project site. With a few exceptions concentrations for all parameters increased at the downstream monitoring station. The reductions include dissolved zinc, which decreased by 11.3% and dissolved lead which decreased by 7.6%. Hardness was not intended to be evaluated as BMP efficiency; rather, the thought was that by retaining and retarding flow hardness values would increase creating a benefit to the buffering capacity of the stormwater discharge. The increase in hardness of 7.8% below the downstream BMP is still a positive outcome.

Table 21. 136th St BMP Efficiencies

Parameter	Apparent BMP Efficiencies (Median Percent Decrease in Pollutant)
Total suspended solids	-115.9
Total Kjeldahl nitrogen	-2.7
Nitrate-nitrite (NO2,3)	**1.9**
Orthophosphate	-35.4
Hardness	**-4.8**
Dissolved arsenic	-6.4
Dissolved cadmium	0.0
Dissolved chromium	0.0
Dissolved copper	-5.3
Dissolved lead	**2.6**
Dissolved nickel	-5.1
Dissolved selenium	0.0[3]
Dissolved tin	0.0[3]
Dissolved zinc	**17.6**
PAH-SIM[1]	**26.5**
TPH (NWTPH-Dx) [2,3]	0.0[3]
Fecal Coliform[1]	-79.2

Note: a negative value indicates that the analyte concentration was higher downstream at the downstream station than the upstream.

[1] PAH value is calculated based on the sum of PAH's tested for each sample (see Appendix B, Table B-4).Analyte collected as a grab sample

[2] collected as a grab sample

[3] Analyte not detected during any sampling events.

Parameters that showed decreases below the BMP project were total PAHs, dissolved zinc and lead, and nitrate-nitrite. Hardness was slightly increased (-4.8 percent) which is seen as a positive result to increasing the buffering capacity of the stormflow. TSS values were typically higher downstream than those measured upstream. Three parameters, dissolved selenium, tin, and TPH were not detected in any samples.

4.2.6 Flow

Figure 16 Stormflow Pooling above BMP Structures, SE 136th Street

Table 22 presents upstream/downstream flow comparisons from 12 storms from monitoring during both the dry and wet seasons.

Table 22 Upstream Downstream Flow Comparison

Date	Rain	Upstream	Downstream	Flow Modification Percentage	Downstream Increase or Decrease in Flow
9/19/09	0.33	58	0	100.0	Decrease
10/2/10	0.5	2677	1944	27.4	Decrease
11/1/09	0.33	12854	16274	-26.6	Increase
12/14/09	0.44	9750	12020	-23.3	Increase
1/11/10	0.42	64255	60119	6.4	Decrease
2/4/10	0.2	8749	10755	-22.9	Increase
3/25/10	0.58	20241	22401	-10.7	Increase
4/17/10	0.14	5276	8037	-52.3	Increase
5/18/10	0.21	3524	1935	45.1	Decrease
6/15/10	0.46	30887	44276	-43.3	Increase
7/2/10	0.34	5219	2493	52.2	Decrease
8/7/2010	0.39	881	0	100.0	Decrease

Variations in flow modification are presented graphically in Figures 17 to 20 below:

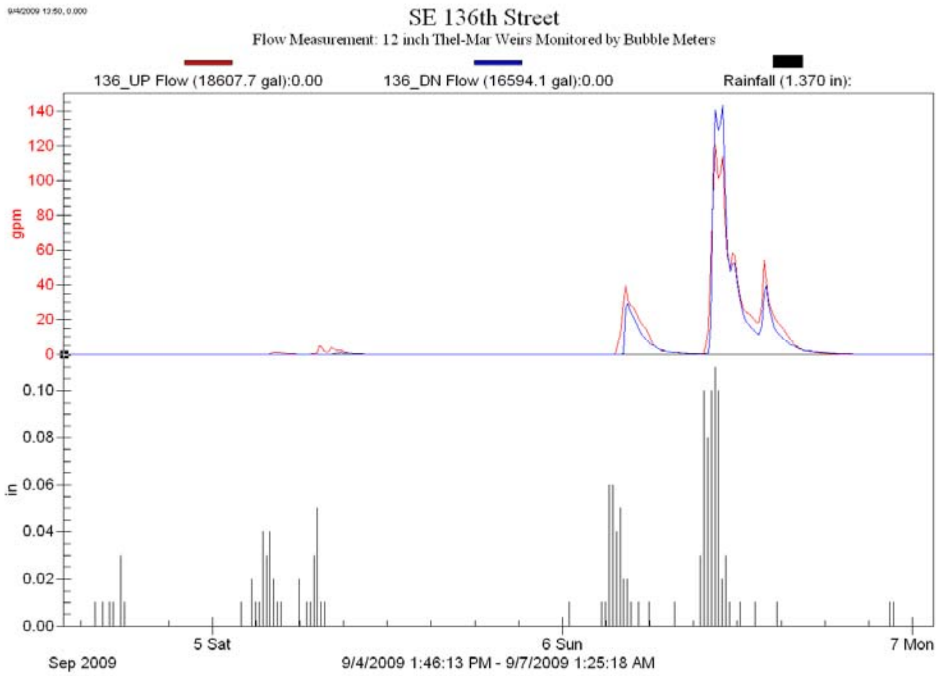
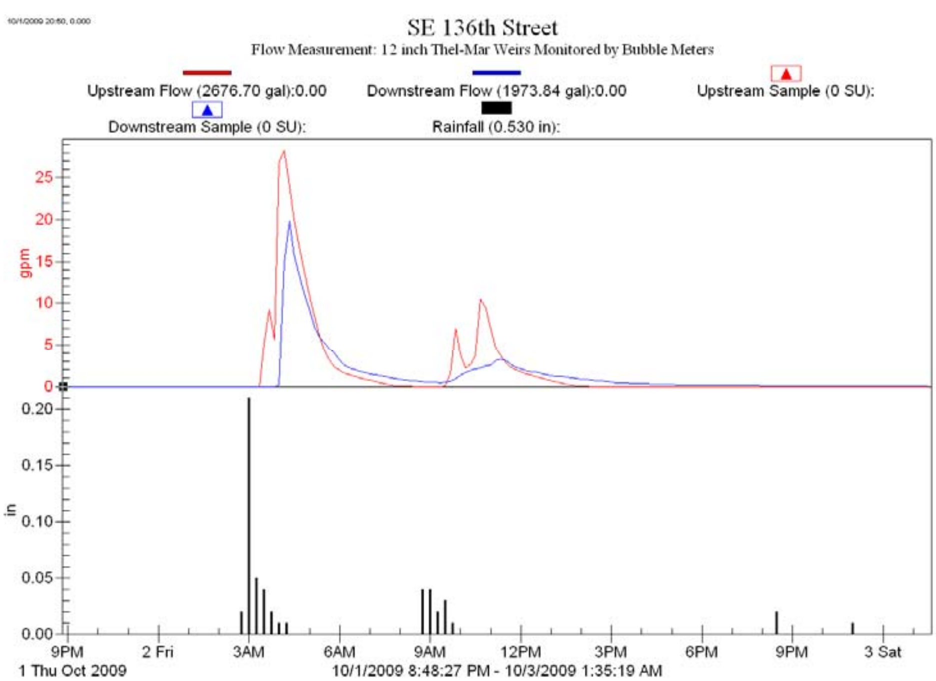


Figure 17 Flow and Rainfall September 5 -7 2009 SE 136th St

Figure 18 Flow and Rainfall October 2 2009 SE 136th St



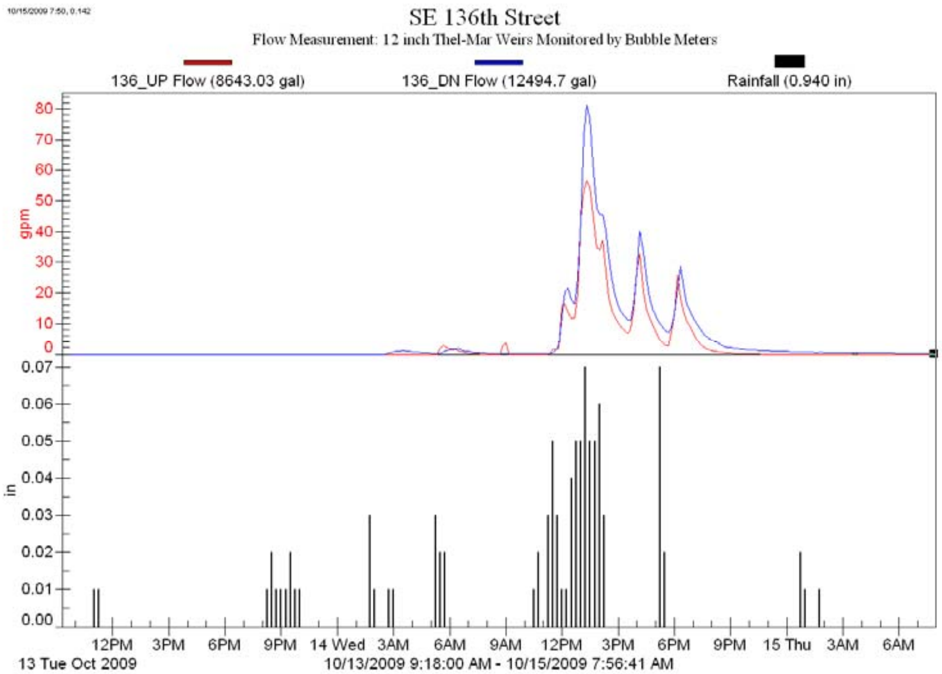


Figure 19 Flow and Rainfall October 13th – 15th 2009

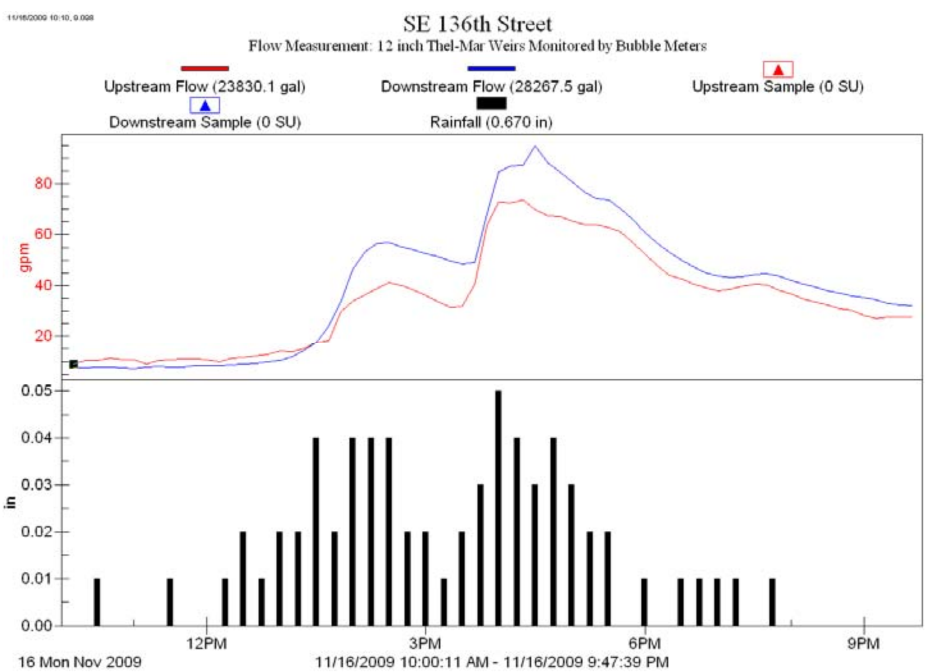


Figure 20 Flow and Rainfall November 16 2009 SE 136th St

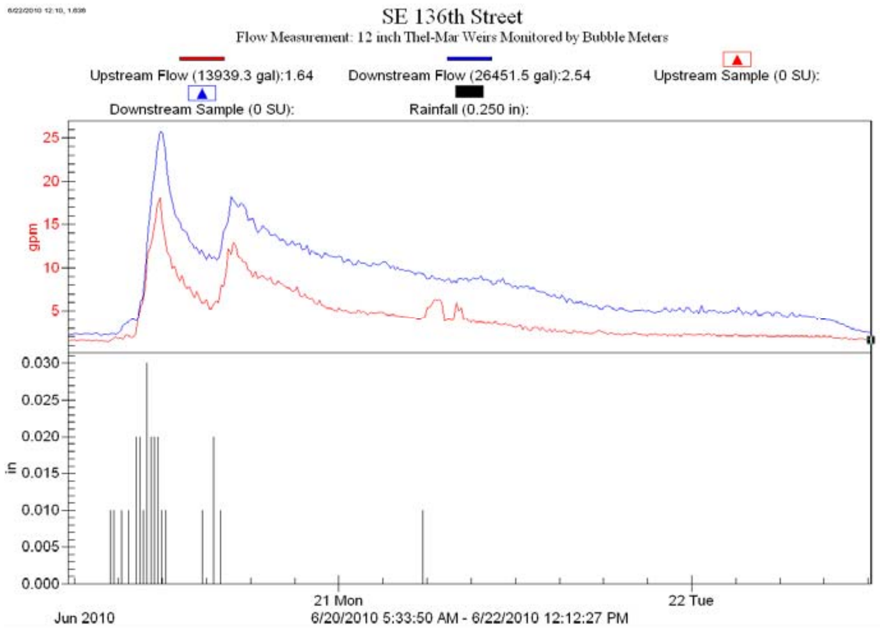


Figure 21 Flow and Rainfall June 21 - 22 2009 SE 136th St

Baseline flow monitoring was initiated at some stations during the fall of 2008. This information was used to develop the methods and equipment that would be used during the BMP studies and to start developing rainfall – relationships for use in composite sampling at each location. This baseline data are provided in an electronic file accompanying this document.

Baseline Flow data were collected at the following water quality monitoring stations:

- 136UP**:** Baseline flow data was collected using a Thel-Mar weir from March 3 2009 until BMPs were installed on June _
- 136DN: Baseline flow data was collected using a Thel-Mar weir from March 23 2009 until BMPs were installed on June _

5.0. DISCUSSION

5.1 148 Ave SE

The apparent BMP efficiencies in reducing levels of TSS is thought to result from the BMPs effect of pooling stormflow, reducing the scouring energy of the flows and allowing solids to settle. The reduction in PAH appears to track closely with the reduction in TSS. The relatively low cost of these BMPs, their ability to survive high winter flows and small maintenance requirements (to date), suggest that these BMPs successfully treat stormwater. Water quality improvements included median reductions in TSS (51%), total PAHs (64%) and dissolved zinc (18%). All other detected compounds were found at higher concentrations downstream than at the upstream monitoring station. The reason for the downstream increases is not known, but may be attributable to additional stormflow entering the ditch along its length. Three compounds; dissolved tin, dissolved selenium and TPH-Dx were not detected in any samples.

The percent reduction results suggest that a significant function of the BMPs is to slow and pool water flowing into and through the BMP treatment area, allowing solids along with their associated pollutants to settle out of the water column.

The ditch at 148th Avenue SE upstream from the BMP site has areas of bare soil and banks that are exposed and being washed by rainfall running off of the road and the surrounding watershed. This exposed soil provides the sediment source that is being captured in the storm monitoring samples.

Overall we feel that the BMP study at 148th Ave SE Water Quality BMP represents a successful study of a stormwater treatment BMP that can be low cost and effective in providing a level of stormwater treatment. The intent was to create a BMP that would primarily filter storm flows through a compost media. However, the large quantity of water that is carried in this ditch means much of the flow over-tops the BMP. Most of the beneficial effect is achieved through pooling storm flow upstream of each BMP, decreasing flow energy, which in turn decreases local scouring within the ditch, and allows particulates to settle. To avoid flooding, each BMP is limited in the amount of stormflow it can pool. It will be difficult to provide the amount of compost or other media necessary for a filtering treatment within the confines of a typical road-side ditch. We feel that the best application of this type of BMP is to maximize the length of ditch in which the BMPs are placed. We used this information to design our 2011 water year studies.

It should be noted that the correlation of flow to rainfall was low at both projects sites; this is most likely due to high number of unknowable and constantly changing variables such as soil moisture conditions and rainfall intensity.

Results from discrete measurements of water quality parameters show there are very little difference between upstream and downstream readings. Limitations of discrete water quality measurements in assessing stormflow are illustrated by a comparison to the limited use of continuous recording turbidity sondes. Figure 6 demonstrates how dynamic the suspended sediment loads in the ditch stormflow are. A comparison of discrete water quality measurements to these limited continuous measurements of turbidity suggest that the discrete water quality readings provide little useful information in evaluating the ditch BMPs.

5.2 SE 136th St

Results from the SE 136th St project did not mirror the apparent BMP efficiencies measured at the 148th street project. Several factors including the physical site features, the hydrology and topography of the site, how the pollutants of concern are transported through stormflow in this ditch contributed to this result. Flow monitoring results demonstrated that this ditch continues to transport stomflow runoff from storms well into the dry season. However the ditch, while most likely receiving runnoff from routine domestic contaminants such as lawn fertilizer and animal waste did not have upstream scouring and there was not a significant source of suspended solids entering the ditch. (One landowner informed us that the ditch was used for occasional disposal of fresh pet waste). In addition, the upstream monitoring station was located at the outlet from a catch basin which may have been working to limit the suspended sediment that was entering the system. Flow monitoring documented a fairly significant downstream increase in flows at almost all seasons with only a few exceptions. While sheet flow was observed to run directly off from the road into the lower portions of the study site, we feel that a significant portion of this flow is coming from the landscaped side of the ditch, and must seep into the ditch along much of its length. In spite of these factors, we still saw that these BMP designs provide a positive contribution to treatment of stormwater. These BMPs were observed to slow and pool water flowing into and through the ditch.

Overall we feel that the water quality BMP study at 136th Ave SE, while not demonstrating a reduction in pollutants did have positive outcomes. One of the primary outcomes is gaining an understanding of how our county ditches function, particularly in this common neighborhood setting. This study also demonstrates how much the site places a role in BMP function and the need to a good understanding of site criteria before placing this type of BMP.