
Snohomish County
Public Works
Surface Water Management

Prepared by:

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Little Bear Creek Basin Plan

August 2017

*A Final Watershed-Scale Stormwater Plan
Prepared in Fulfillment of Special Condition
S5.C.5.c.vi of the Phase I Municipal
Stormwater Permit*



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LITTLE BEAR CREEK BASIN PLAN

**A FINAL WATERSHED-SCALE STORMWATER PLAN
PREPARED IN FULFILLMENT OF SPECIAL CONDITION
S5.C.5.c.vi OF THE PHASE I MUNICIPAL
STORMWATER PERMIT**



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August 2017

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EXECUTIVE SUMMARY

I. Purpose and Background

This final watershed-scale stormwater plan for Little Bear Creek (“Basin Plan”) was developed in accordance with Special Condition S5.C.5.c of the 2013-2018 Phase I Municipal Stormwater Permit (“the Permit”). The Permit requires a data collection and modeling process and the development of a plan to meet future water quality standards for fecal coliform, temperature, dissolved copper, and dissolved zinc. Aquatic biologic health, as measured by B-IBI (benthic index of biotic integrity), must also be evaluated. The Permit requirements include the use of a calibrated continuous runoff model and the development of stormwater management strategies, cost estimates, and an implementation plan. The Little Bear Creek Basin Plan has been developed in fulfillment of these requirements using the methods prescribed by the Permit.

Study Area: Little Bear Creek drains more than fifteen square miles in south Snohomish County and northern King County and is one of four major tributaries to the Sammamish River. The Little Bear Creek watershed is an important resource for fish, recreation, and open space. Compared to other nearby Snohomish County watersheds undergoing urbanization, Little Bear Creek has relatively good water quality and stream habitat conditions. However, land development over time has affected water quality and flow patterns in the watershed. Even with increased stormwater treatment associated with redevelopment, Little Bear Creek will fall short of certain water quality standards and targets.

This Little Bear Creek Basin Plan addresses the upper 90 percent (about 8,550 acres or 13.4 square miles) of the basin within unincorporated Snohomish County. This study area is located east of the cities of Bothell and Mill Creek and north of the City of Woodinville. Small areas in Bothell and Woodinville drain into tributaries to Little Bear Creek at the county line (see Figure ES-1). These areas were included in the analysis of watershed conditions, but they were excluded from potential future actions to implement stormwater management strategies because they are outside county jurisdiction and the study area.

II. Technical Analysis

The County followed the Permit-specified methodology for evaluating dissolved copper, dissolved zinc, temperature, fecal coliform, and impacts of modified flow patterns on aquatic habitat in the study area.

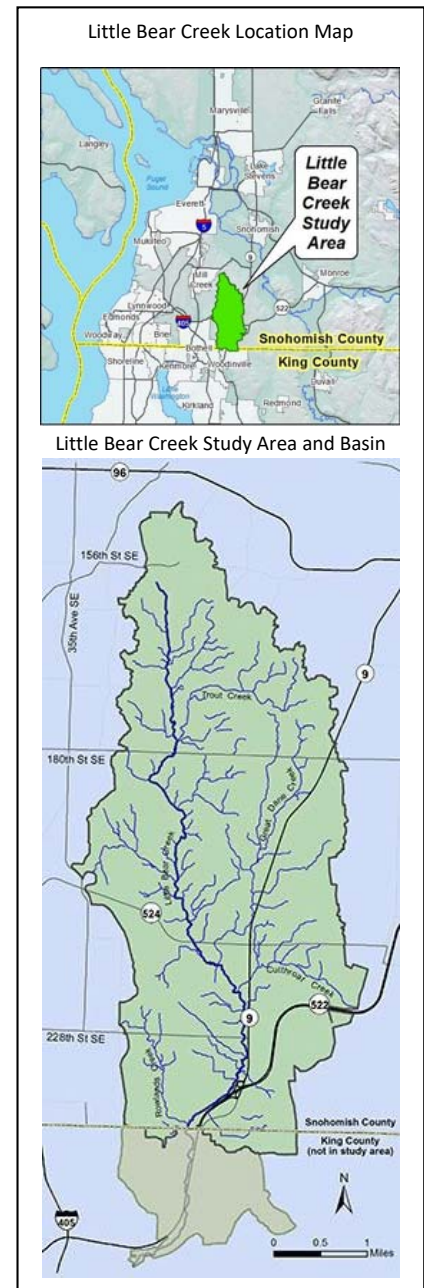


Figure ES-1: Study Area Location Map

Data collection: A Current Conditions Assessment of water quality and stream flow conditions in the study area was conducted, as described in detail in Appendix A to this Basin Plan. The County used a combination of existing and new data from a network of ambient water quality and long-term streamflow monitoring sites in the study area. From 2014 to 2015, the County collected additional flow and storm-related water quality data from four automated sampling sites installed for the purposes of this study. The County also used long-term B-IBI data (invertebrate species data) sampled between 2002 and 2015 at ten mainstem Little Bear Creek sites (two within King County). These were supplemented with new data collected for this study from 12 sites in 2014 and 16 sites in 2015. In addition, staff conducted fieldwork in portions of Little Bear Creek in the study area to determine stream and habitat-related health conditions. Lastly, many of the stormwater detention facilities were inspected and evaluated in the field. This information was used to evaluate current flow, water quality, and habitat conditions.

Modeling: A computer model was developed and calibrated to reflect existing conditions. That model was then used to predict future conditions under the County’s existing comprehensive plan (through 2035), as well as to assess the conditions that may have been present before any development in the watershed. More discussion of the computer modeling effort is given in the Watershed Modeling Report attached as Appendix B to this Basin Plan.

Results: The predicted future conditions, as determined by the computer model, were compared to water quality standards and targets. Water quality standards are set by the state for dissolved zinc, dissolved copper, and temperature, which if exceeded can be harmful to fish. Fecal coliform standards are also established to protect human health. The model showed that water quality standards for dissolved metals would be met, but water quality standards for temperature and fecal coliform would not be met. The study area would also fall short of the targeted 90 percent of forested values for B-IBI, which was estimated from the modeling using relationships to flow characteristics established by scientists in the Puget Sound region. The Permit requires the County to develop and evaluate stormwater management strategies (projects and actions) likely to improve water quality in the study area so that water quality standards and targets are met.

Table ES-1: Predicted Future Results

STANDARD	FUTURE BUILDOUT
Dissolved Zinc	✓
Dissolved Copper	✓
Temperature	●
Fecal Coliform	●
B-IBI (aquatic health)	●

III. Implementation Plan

A variety of stormwater management strategies were considered to meet standards for water quality and flow. Structural best management practices (BMPs), i.e. constructed stormwater facilities, were generally modeled in groups referred to as “BMP sequences.” The BMP sequences included traditional stormwater facilities such as detention, infiltration, and wet ponds, as well as Low Impact Development (LID) practices, such as filter strips, bioretention, permeable pavement, and rain gardens. Other strategies (riparian buffer restoration and water quality biofiltration) were modeled specifically to provide enhanced temperature or fecal coliform benefit. Optimization modeling was used to identify a

balance of efficient and effective improvements that would meet flow, temperature, and fecal coliform standards and targets.

Continuation and potential expansion of program activities that target reduction of fecal coliform sources—such as education and outreach, inspections, and maintenance—were considered but not explicitly modeled. The benefit provided by existing programs cannot be quantified but is reflected in the modeling through the data used for model calibration. Instream improvement strategies were also considered as allowed by the Permit (but not modeled), as a means of enhancing habitat and biological conditions. Both fecal reduction programs and instream projects may supplement or reduce the potential need for structural facilities, subject to further evaluation as proposed in the implementation plan.

Strategy Selection and Cost Estimates: The Permit requires that the Basin Plan include strategies to achieve water quality standards and targets, cost estimates, potential funding mechanisms, responsible parties, and schedule. Table ES-2 below summarizes the total amount and estimated cost of the various modeled strategies that would be needed to achieve water quality standards and targets, grouped by type of best management practice (BMP). The modeled BMP costs total about \$289 million.

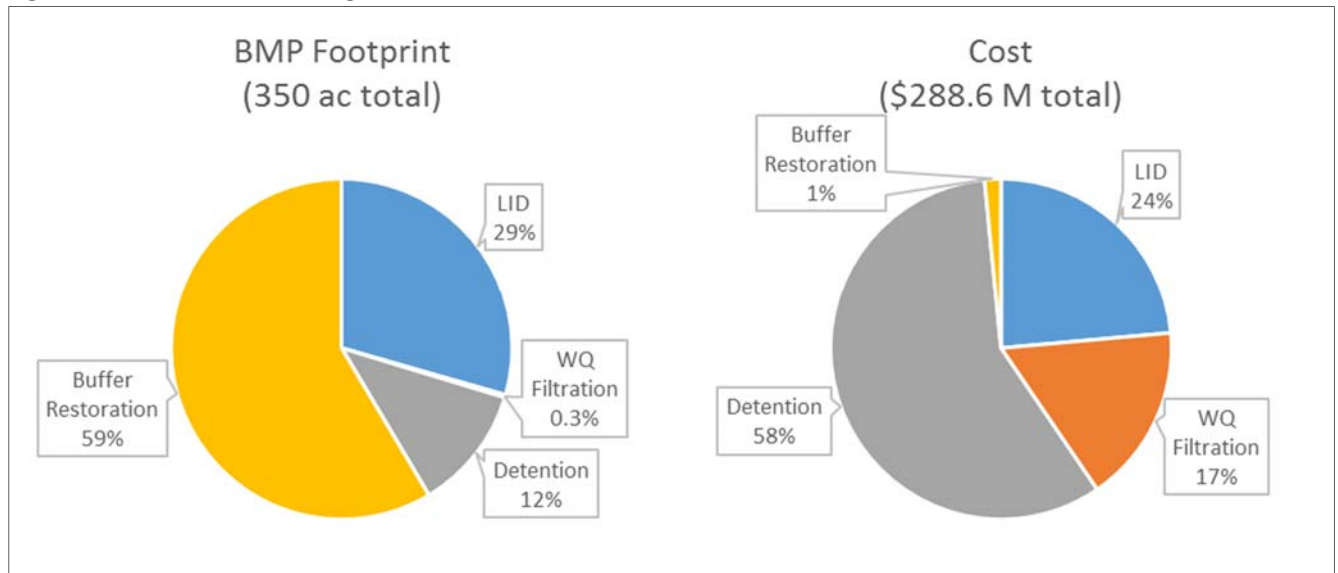
Table ES-2. Modeled Strategies

BMP TYPE	STRATEGY	TOTAL FOR STUDY AREA	COST
Low Impact Development (LID)	Filter Strip	64 miles	\$ 5.1 M
	Modified Ditches	30 miles	17.5 M
	Rain Gardens	7.4 acres	9.4 M
	Bioretention	6.1 acres	31.4 M
	Permeable Pavement	3.7 acres	4.6 M
WQ Filtration	Biofiltration	0.9 acres	48.7 M
Detention	Wet Pond	246 acre-feet	167.4 M
Buffer Restoration	Riparian Planting	204 acres	4.5 M
			288.6 M

Costs are planning level, in 2016 dollars (PV)

Figure ES-2 below illustrates the relative distribution of BMP types in terms of size (approximate footprint area, left) and cost (right). It is clear from the graphs that detention and filtration are more expensive strategies, relative to their footprint, compared to LID and voluntary buffer restoration (which has no associated land cost).

Figure ES-2. Modeled Strategies Distribution



Instream strategies—such as streambank stabilization, channel reconnection, and wetland restoration—are an optional component of the Permit and were not modeled as part of this study, with the exception of buffer restoration to provide stream shading and temperature reduction. Instream strategies could be implemented as supplemental projects, to be applied adaptively over the course of plan implementation, with the potential to offset some of the need for flow management from structural facilities.

Current program activities, such as fecal coliform source control and storm drain system maintenance, were not explicitly modeled but are assumed to provide some benefit. Ongoing costs for these and other support activities, as well as potential new costs for Plan administration and management, such as model refinement, fecal source study, monitoring and evaluation, are also included in the implementation of the Basin Plan. The additional costs for supplemental strategies and support activities total about \$20 million, and when added to the modeled cost, the total cost of the Basin Plan is about \$308 million.

Table ES-3. Basin Plan Estimated Costs

COMPONENT	NEW	ON-GOING	TOTAL
MODELED STRATEGIES	\$ 288.6 M		\$ 288.6 M
NON-MODELED STRATEGIES	\$ 13.5 M	\$ 2.5 M	\$ 16.0 M
SUPPORT	\$ 2.3 M	\$ 1.3 M	\$ 3.6 M
TOTAL			\$ 308.2 M

Costs are planning level, in 2016 dollars (PV)

Implementation Cost and Schedule: The Basin Plan recommends a variety of capital projects and non-capital maintenance, education and inspection programs, which are projected to cost approximately \$308 million (in 2016 dollars) over a 30-year period. This figure is an estimate and would be subject to

change as stormwater management strategies are adaptively managed, as proposed in the implementation plan. Implementation is proposed to occur in four phases over the 30-year period; however, actual timing and extent of work would depend on funding availability. There is currently no requirement in the Permit for the County to implement the Basin Plan.

Funding: The Basin Plan projects the need for significant additional projects and programs in order to meet state water quality standards and targets. While existing County programs are assumed to continue as long as existing local funding is available, funding for and timing of implementation of the remainder of the Basin Plan is projected to be dependent on grants.

IV. Public Process

The involvement of stakeholders, including Little Bear Creek residents, was integral to the development of the Basin Plan. Outreach began in 2015 with letters informing streamside property owners about the planning process and requesting permission to conduct stream walks to collect data. A public open house to introduce the basin planning study was held in April 2016. Between 2016 and early 2017, the County conducted three meetings and technical workshops for stakeholders and project partners to present progress and methodology, and to gather ideas and input on stormwater management strategies. In June 2017, the County held a public open house to present the draft Basin Plan to the community for comment.

V. Summary and Conclusions

This Basin Plan presents an overall blueprint for stormwater management activities in the Little Bear Creek study area to meet state water quality standards and targets. It proposes capital projects, maintenance and inspection programs, follow-up studies to target solutions, and outreach programs. It allows the flexibility to identify suitable project locations and to work with partners to implement specific projects or programs, incorporating principles of adaptive management.

Restoring water quality is an expensive, long-term process that carries with it elements of uncertainty, such as the limitations of current science and analysis, and limitations of available data. This Basin Plan was developed using the most robust methods, data and science available for the study.

This large effort in a limited geographic area presents unique challenges, and it will take participation and cooperation from federal, state and local agencies, as well as local residents, to meet projected water quality standards and targets.

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ACRONYMS AND ABBREVIATIONS

The following are the more commonly used acronyms and abbreviations in this report.

Ac	Acre
CWA	Clean Water Act
B-IBI	Benthic Index of Biotic Integrity (sometimes also called Benthic Index of Biological Integrity)
BMP	Best Management Practice
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
HSPF	Hydrological Simulation Program-FORTRAN
HPC	High Pulse Count
HPR	High Pulse Range
HRM	(WSDOT) Highway Runoff Manual
LID	Low Impact Development
M	Million
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PV	Present Value
QAMP	Quality Assurance Monitoring Plan
RBI	Richards-Baker (Flashiness) Index
RCW	Revised Code of Washington
SCD	Snohomish Conservation District
SHD	Snohomish Health District
SR	State Route
SUSTAIN	System for Urban Stormwater Treatment and Analysis INtegration
SWM	Surface Water Management Division
TMDL	Total Maximum Daily Load
UGA	Urban Growth Area
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WQ	Water Quality
WSDOT	Washington State Department of Transportation
7DADMax	7-Day Average Daily Maximum

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1 INTRODUCTION

1.1 Basin Plan Requirement

Special Condition S5.C.5.c of the Permit requires the County to conduct a watershed-scale stormwater planning effort on a selected watershed or portion thereof. The County selected the portion of the Little Bear Creek watershed in unincorporated Snohomish County, and Washington State Department of Ecology (Ecology) approved this selection.

Little Bear Creek is an important resource for fish, recreation, and aesthetic enjoyment. However, land development over time has affected water quality and flow patterns in the watershed, and conditions may worsen with potential future development. Portions of the creek system are currently considered to be impaired for bacteria, temperature, dissolved oxygen, and mercury (Howell Creek tributary only), based on comparison of basin water quality data to state standards. Some fish habitat conditions are also impaired relative to properly functioning conditions.

The objective of the watershed planning requirement is to:

Identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support “existing uses,” and “designated uses,” as those terms are defined in WAC 173-201A-020, throughout the stream system. (Permit, Special Condition S5.C.5.c.)

This Basin Plan documents the modeling, evaluation, and implementation plan development effort conducted by the County for the Little Bear Creek study area in fulfillment of Special Condition S5.C.5.c.vi.

1.2 Basin Plan Process and Methodology

This Basin Plan presents the culmination of extensive data collection, evaluation and analysis of the Little Bear Creek study area. The County prepared several supporting documents presenting specific analyses performed as part of the basin planning process. These analyses began with the assessment of current conditions in the study area, as required under Special Condition S5.C.5.c.iv (1). The *Little Bear Creek Basin Planning Current Conditions Assessment Report (Current Conditions Assessment Report)* (Snohomish County, 2016), included as Appendix A, evaluated existing hydrologic, water quality, and biologic conditions and the current status of the aquatic biological community in the study area. As part of that assessment, the County compiled and generated maps of the study area to identify the existing distribution of soil types, vegetative land cover, impervious land cover, and municipal separate storm sewer systems (MS4s), as required under Special Condition S5.C.5.c.iv (2).

As also required under Special Condition S5.C.5.c.iv (3), the County developed a continuous runoff model of the study area basin, using available and newly acquired monitoring data to calibrate the model to reflect the existing hydrologic, biologic, and water quality conditions. The County also used the calibrated model to estimate historic (forested) conditions, as well as future hydrologic, biologic, and water quality conditions at full build-out, as required in Special Condition S5.C.5.c.iv (4).

The County next used the calibrated model, and a supplementary optimization model, to evaluate stormwater management strategies to address those water quality conditions predicted to exceed water quality standards, as required under Special Condition S5.C.5.c.iv (5). The model was used to evaluate both structural and non-structural best management practices (BMPs). *The Little Bear Creek Basin Plan Watershed Modeling Report (Watershed Modeling Report)* (Snohomish County, 2017a), included as Appendix B, describes the modeling processes. The *Little Bear Creek Stormwater Strategies Report (Stormwater Strategies Report)* (Snohomish County, 2017b), included as Appendix C, documents the identification and analysis of stormwater management strategies to address predicted noncompliance with identified water quality standards.

In compliance with Special Condition S5.C.5.c.iv (6), the County developed an implementation plan and schedule, set forth in Chapter 6 of this Basin Plan.

Appendix D provides a detailed regulatory crosswalk for this planning effort, showing key Permit requirements, how those requirements were met, and where in this Basin Plan or the supplementary reports described above those requirements are addressed.

Involvement of Little Bear Creek stakeholders and the general public was also integral to the development of the Basin Plan. Appendix E provides a detailed summary of the public outreach effort conducted by the County under Special Condition S5.C.5.c.iv (7).

The Basin Plan assumes the continuation of the presently existing water quality facilities, programs and practices under the purview of local governmental agencies and special districts in the study area. These agencies and special districts are listed below, along with other agencies in the study area vicinity, by relative order of presence in the study area vicinity.

Agencies and Special Purpose Districts with Water Quality Programs in the vicinity of the Little Bear Creek Study Area:

- Snohomish County
- Washington State Department of Transportation (WSDOT)
- Snohomish Health District (SHD)
- Water and Wastewater Utility Districts:
 - Alderwood Water and Wastewater District
 - Cross Valley Water District
 - Silver Lake Water & Sewer District
 - Woodinville Water District
- City of Woodinville
- City of Bothell
- Snohomish Conservation District
- Washington State Department of Ecology (Ecology)
- Washington State Department of Fish and Wildlife (WDFW)
- Muckleshoot Indian Tribe

1.3 Modeling

Watershed-scale Continuous Modeling

Modeling of the Little Bear Creek study area was performed using a calibrated flow and water quality model developed in Hydrologic Simulation Program Fortran (HSPF, version 12.4). HSPF is a continuous simulation model developed by the United States Environmental Protection Agency (EPA) and is the accepted standard hydrologic model for stormwater analysis in western Washington. HSPF uses distinct site-specific combinations of soil type, land cover, and land use to characterize runoff response and pollutant loading from different areas within a basin. Land surface inputs are then routed through reach elements representing the drainage network, including stormwater facilities, pipes, ditches, and streams. Transport and decay processes for flow, sediment, temperature, and other water quality parameters are represented within each reach element.

The Little Bear Creek study area HSPF model includes 220 catchments¹ delineated to existing stormwater facilities, monitoring sites, stream confluences, and major road crossings. The catchments are aggregated into the nine major subbasins shown in Figure 1. Special Condition S5.C.5.c.iv (4) requires use of a calibrated continuous runoff model to evaluate dissolved copper, dissolved zinc, temperature, and fecal coliform bacteria, and also biologic conditions using a correlation of hydrologic metrics with benthic index of biological integrity (B-IBI) scores. The continuous runoff HSPF model developed for the Little Bear Creek basin planning project was calibrated to measured flow, temperature, metals and bacteria concentration data at multiple locations in the Little Bear Creek study area. Development and calibration of the Little Bear Creek study area HSPF model are documented in the *Watershed Modeling Report* (Appendix B).

Using the calibrated model parameters, forested and future build-out conditions HSPF models were developed by modifying the distribution of land use and land cover types within each catchment, as documented in the *Watershed Modeling Report* (Appendix B). The future build-out scenario represents the baseline condition for this Basin Plan. Stormwater management strategies were identified to meet water quality standards and biological conditions targets for this baseline condition.

Current Water Quality Programs

The modeling assumed the continuation of the presently existing water quality facilities, programs and practices under the purview of local governmental agencies and special districts in the study area. With the exception of existing facilities, as discussed in the *Watershed Modeling Report* (Appendix B), these programs are not explicitly represented in the models, but their effects are incorporated through calibration to recent water quality data. Additional practices or enhancement to these operations may occur over the course of the proposed implementation period of the Basin Plan.

¹ Catchments refer to smaller modeling units (draining to a specific facility or road crossing, for example) that comprise the nine major subbasins.

Stormwater Management Strategies Optimization

To evaluate potential stormwater management strategies, the County used an optimization model in combination with the calibrated Little Bear Creek HSPF model. EPA's SUSTAIN model (version 1.2) was used as a BMP optimization tool to determine cost-effective combinations of potential BMPs to meet stormwater management targets. The SUSTAIN model uses a two-tiered optimization approach to efficiently formulate large watershed-scale optimization analyses. Tier 1 involves developing a library of BMP cost-effectiveness curves that represent locally optimized solutions at the finer catchment scale. For Tier 2, the optimization algorithm uses the Tier 1 curves to identify combinations of solutions at the subbasin scale that are collectively optimal for achieving a management objective at downstream assessment points. Because the options are optimized Tier 1 solutions at the catchment level, Tier 2 solutions represent a potential cost-optimized layering of management strategies at the basin scale to achieve the basin stormwater management targets.

The SUSTAIN model defines potential BMP sequences for flow and pollutant runoff inputs from the soil, land cover and land use types simulated in the HSPF model. Through the optimization process, the most effective combinations of individual BMP types (in combination with potential land use and development code changes) are identified to meet the hydrologic metric targets (and associated biological targets) along the Little Bear Creek study area mainstem. SUSTAIN model development and optimization are documented in the SUSTAIN model documentation (Paradigm, 2017), included as an appendix to the *Stormwater Strategies Report* (Appendix C) developed as part of this basin planning project.

The SUSTAIN model lacks the more sophisticated water quality routines available for HSPF stream network routing reaches. Therefore, following the SUSTAIN optimization, runoff and water quality output from the SUSTAIN solution were routed through the stream network portion of the HSPF watershed model. Subsequently, supplemental temperature and bacteria reduction strategies were modeled using HSPF to address any remaining gap between the SUSTAIN solution and the water quality targets.

Model Limitations

As with any modeling study, results are subject to some inherent uncertainty. Model algorithms necessarily simplify the many complex physical processes occurring in the study area and cannot be expected to fully capture all of the processes and interactions occurring in the natural setting. Model parameters are estimated based on available data and adjusted to calibrate the model to observed data but cannot capture all of the spatial and temporal variability that affects runoff and pollutant generation within the study area. Likewise, optimization models utilize statistical algorithms that provide best estimates, but actual outcomes will vary.

Model selection and development utilized regionally-accepted methods and assumptions, and a robust calibration to observed data over multiple locations and time periods indicates that the model provides a reasonable tool for evaluating conditions and impacts for the planning study. Representation of modeled forested and future conditions are subject to somewhat greater uncertainty, due to the inability to observe or specifically calibrate to those conditions but provide the best estimate available. Model development and assumptions are discussed in greater detail in the *Watershed Modeling Report* (Appendix B).

2 BASIN SETTING

2.1 Introduction

Little Bear Creek drains more than 15 square miles in southern Snohomish County and northern King County and is one of four major tributaries to the Sammamish River. The Little Bear Creek Basin Plan focuses only on the upper 90 percent (about 8,550 acres or 13.4 square miles) of the basin within unincorporated Snohomish County. This study area is located east of the cities of Bothell and Mill Creek and north of the City of Woodinville. Small areas within Bothell (located within Snohomish County) and the City of Woodinville (located within King County) drain to tributaries to Little Bear Creek at the county line, as shown in Figure 1. These areas were included in watershed analyses but not for purposes of new stormwater management actions.

There are over 50 miles of mapped stream channels in the study area, with approximately 17.5 miles comprising mainstem Little Bear Creek and its major tributaries—Great Dane Creek, Cutthroat Creek, Trout Creek, and Rowlands Creek. Most of the major streams traverse rural or lightly developed residential areas. Long stretches of the mainstem of Little Bear Creek between 156th Street SE and Great Dane Creek are characterized by wetland areas influenced by beaver activity. Downstream of the Brightwater Wastewater Treatment Plant (Brightwater) located at the junction of Highway 9 and 228th Street SE, the character of the stream corridor changes into a predominantly commercial/industrial area.

Portions of the drainage system, which receives runoff from mixed land uses in unincorporated Snohomish County and the cities of Woodinville and Bothell, failed to meet water quality standards for bacteria and dissolved oxygen and have been listed under federal Clean Water Act (CWA) Section 303(d). Section 303(d) of the CWA addresses water bodies that have water quality data in exceedance of designated water quality standards. Such water bodies are deemed “impaired” and qualify for further analysis to estimate acceptable levels (or loads) specific to that water body to meet the standard. This load is termed the total maximum daily load (TMDL) and is set as the goal for the water body to meet the water quality standard. Specifically, Little Bear Creek is 303(d)-listed for dissolved oxygen, and has a TMDL for bacteria (measured by fecal coliform) (Ecology, 2012). The Little Bear Creek watershed supports anadromous runs of Chinook, sockeye, kokanee, and coho salmon and coastal cutthroat trout (Kerwin, 2001), as well as resident fish species.

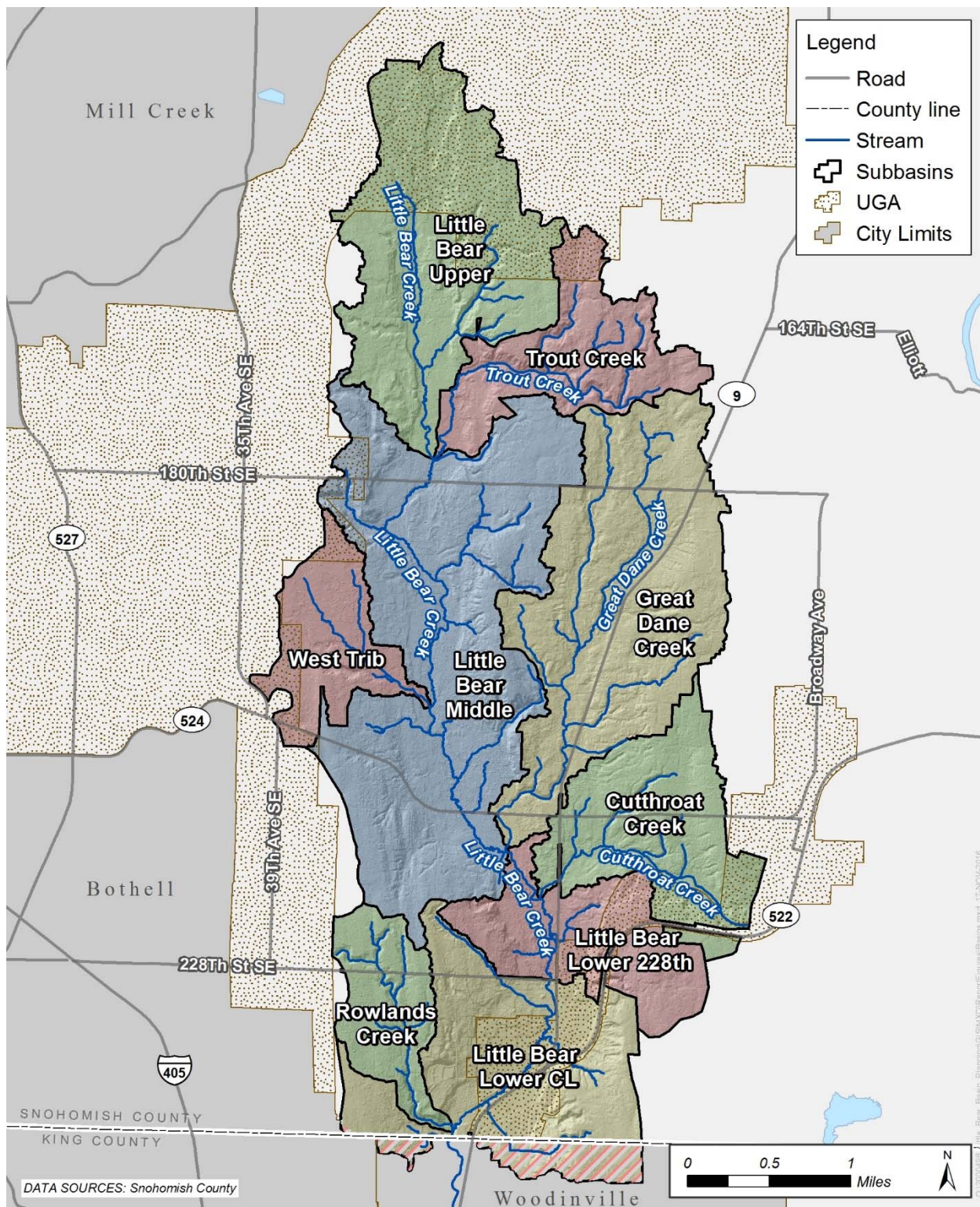


Figure 1. Little Bear Creek study area. Diagonal hatched areas are within city limits.

2.2 Subbasins and Drainage Systems

From its headwaters near 156th Street SE, the mainstem of Little Bear Creek flows predominantly north to south to the King County line at 244th Street SE. Five major (named) tributaries contribute to Little Bear Creek, adding drainage area from east and west of the Little Bear Creek valley. From upstream to downstream, those are Trout Creek (left bank [east] tributary at river mile [RM] 7.9); West Trib (right bank tributary at RM 5.8); Great Dane Creek (left bank tributary at RM 4.5); Cutthroat Creek (left bank tributary at RM 4); and Rowlands Creek (right bank tributary just upstream of the County Line at approximately RM 2). Drainage areas for these tributaries, as well as major segments of the Little Bear mainstem, are summarized in Table 1, and brief descriptions of each area follow. More detailed information for each of the basins is presented in the separately bound *Current Conditions Assessment Report*, found in Appendix A to this Basin Plan.

Table 1. Major Drainage Basins in the Little Bear Creek Study Area Basin

Drainage Basin	Area (acres)
Little Bear Upper (Upstream of Trout Creek)	1,275
Trout Creek	600
West Trib	432
Little Bear Middle (Trout Creek to Great Dane Creek)	2,095
Great Dane Creek	1,481
Cutthroat Creek	721
Little Bear Lower 228th (Great Dane Creek to 228 th St. SE)	627
Rowlands Creek	374
Little Bear Lower CL (228 th St. SE to County Line)	1,078

Little Bear Upper

The northern headwaters of Little Bear Creek lie within the Southwest County UGA and are dominated by the Silver Firs and Snohomish Cascade subdivisions. Stormwater from these developments goes through a series of pollution control and detention facilities constructed prior to current Ecology standards, based on the 2012 *Storm Water Management Manual for Western Washington*. Little Bear Creek emerges from a series of linked wet ponds (possibly former wetlands prior to development) north of 156th Street SE. The creek then flows south through a relatively undisturbed wetland area to its confluence with Trout Creek.

Trout Creek

Trout Creek joins Little Bear Creek from the east upstream of 180th Street SE. Its watershed is dominated by low-density residential development with minimal designed stormwater treatment, though forested buffers have been preserved along most of the upland stream network upstream of West Interurban Boulevard.

Little Bear Middle – Trout Creek to Great Dane Creek

Between Trout Creek and Great Dane Creek, the Little Bear Creek valley is an almost continuous forested wetland. Large undeveloped parcels remain in the local drainage area to this reach of the stream, primarily north of Maltby Road (SR-524). Development in this drainage basin is almost exclusively

residential—mainly at densities less than two units per acre—with very few designed stormwater treatment facilities. South of Maltby Road, development is somewhat denser.

West Trib

The West Trib joins Little Bear Creek from the northwest upstream of Little Bear Creek Road. The drainage area is still largely lower density residential with no stormwater treatment, but roughly a quarter of the West Trib basin lies within the Southwest County UGA, and adjacent areas in the North Creek basin to the west have been rapidly developing over the past several years.

Great Dane Creek

With nearly 1,500 acres of drainage area, Great Dane Creek is the largest tributary to Little Bear Creek. Starting from the headwaters near Trout Creek, the upper two thirds of the Great Dane Creek basin drains to two roughly parallel main channels west of SR-9. These channels converge to a single channel near 196th Street SE and continue in a south-southwest direction to the Little Bear Confluence south of Maltby Road (SR-524). SR-9 bisects the basin, with clusters of commercial areas along the highway that are unique to the upper Little Bear basin. Unlike the steeper Trout Creek, forested buffers along the two main channels are largely absent and there are frequent road crossings in the upland part of the basin (north of 188th Street SE).

Cutthroat Creek

Cutthroat Creek joins Little Bear Creek from the east approximately half a mile downstream of the Great Dane Creek confluence. The creek corridor itself is largely undisturbed with forest and wetland buffers, but the headwaters drain commercial and industrial areas in the SR-522 corridor (part of the Maltby UGA).

Little Bear Lower 228th – Great Dane Creek to 228th St SE

This is a transitional reach of Lower Bear Creek. Upstream of Great Dane Creek, the valley is characterized by large undeveloped areas and extensive wetlands. As the creek approaches SR-9 in this reach, it turns south to parallel the highway, and the stream corridor becomes confined between the highway and adjacent land uses. Much of the local drainage area is similar to the upper basin, with lower density residential land use and some open space, but land use is much more intense where the creek enters the UGA along the SR-9 corridor, including part of the Brightwater Wastewater Treatment Plant facility.

Rowlands Creek

Rowlands Creek is the smallest major tributary to Little Bear Creek and flows in from the northwest just upstream of the county line. For most of its length, Rowlands Creek traverses residential upland areas. About 3,000 feet upstream of its mouth, Rowlands Creek drops into a steep-sided ravine that emerges into a forested area extending to the Little Bear Creek confluence.

Little Bear Lower County Line – 228th St SE to County Line

From 228th Street SE to the Snohomish-King county line, Little Bear Creek parallels SR-9 then SR-522. For most of this reach, within the UGA, the creek is confined to a narrow (roughly 200-foot wide) corridor between the highways and adjacent commercial land uses. East of the UGA boundary, the Howell (aka Parsons) Creek and Vintage Creek tributaries drain a mixture of residential area and open space.

2.3 Climate

Climate in the Little Bear Creek study area is typical of the Puget Sound lowlands, with a maritime climate influenced by Puget Sound to the west and the Cascade Mountains to the east. The majority of precipitation occurs in the winter wet season, from approximately November through April, and summers are characteristically dry. Mean annual precipitation averages about 41 inches, ranging from 29 inches in a very dry year to more than 56 inches in a very wet year. Winter temperatures are moderate, so precipitation falls almost exclusively as rain. Lowland snow occurs occasionally, but significant accumulation is rare, and snow usually melts off within a day. Precipitation in the study area is discussed in further detail in the *Current Conditions Assessment Report* (Appendix A).

Evaluation of a climate change scenario was not required in the Little Bear Creek basin planning effort under Special Condition S5.C.5.c. The 60-year modeling period used to assess all scenarios covers an extensive range of meteorological conditions that encompasses much of the variability that would be expected from climate change projections over the 30-year planning horizon. Current projections for precipitation changes over the next 30 years generally indicate little change in annual volumes. Frequency of higher intensity storms, including atmospheric river events, is projected to increase (NCA, 2014; Neimann et al., 2011), though there are larger uncertainties in modeling small-scale, short-duration storm events compared to general climatic trends. Future temperature increases in the Puget lowlands region are expected with higher confidence, albeit at an uncertain pace and subject to inter-annual and inter-decadal variability. Temperatures have already increased across the Pacific Northwest region from 1895 to 2011 (NCA, 2014), the impacts of which are reflected in the temperature data over the modeling period.

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3 HYDROLOGY AND AQUATIC HABITAT

3.1 Introduction

The following sections describe the current understanding of hydrologic conditions in the Little Bear Creek study area, as related to impacts on biological conditions. Compared to many other urban and urbanizing streams in the region, Little Bear Creek has experienced fewer dramatic changes to several watershed characteristics strongly linked to hydrologic impacts of urbanization. Forest remains the predominant land cover outside of designated UGAs and dominates the riparian corridors of Little Bear, Trout, and Cutthroat Creeks. Preserved riparian wetlands in the Little Bear Creek valley also help to attenuate increased peak flows associated with impervious runoff.

Several regional studies (e.g. DeGasperi et al., 2009; King County, 2012; Horner, 2013; King County, 2015) have examined the relationship between hydrology—such as the magnitude and frequency of rapid changes in stream flow, or flashiness—and stream biology, as represented by the benthic index of biotic integrity (B-IBI). It has thus been posited that correlations between hydrologic metrics and B-IBI scores based on observed data can be used to estimate biological response (which cannot be directly modeled) from hydrologic response (which can be modeled) for different watershed conditions. Consistent with the requirement of Permit Special Condition S5.C.5.c.iv (4), the County used selected hydrologic metrics from DeGasperi et al., 2009, discussed in the following section, to estimate B-IBI scores for future build-out conditions and to analyze the effectiveness of stormwater management strategies in meeting flow-based B-IBI targets.

3.2 Relationship Between Hydrology and Biological Conditions

The County used hydrologic metrics computed from modeled streamflows to estimate B-IBI scores at sites along Little Bear Creek in the study area for development and stormwater management scenarios. The study used linear regressions between selected flow metrics and B-IBI scores developed from regional studies and data. B-IBI scores in the Little Bear Creek study area were significantly correlated with several hydrologic metrics previously identified at the regional scale (e.g. DeGasperi et al., 2009) for their correlation with the biological integrity of Puget Sound Lowland streams. The correlations using linear regression equations of selected hydrologic metrics with long-term average B-IBI scores at ten mainstem Little Bear Creek locations, generally conformed with B-IBI regressions using data from 26 sites in the Lake Washington/Cedar/Sammamish watershed included in the WRIA 8 Status and Trends report (King County, 2015).

Little Bear Creek B-IBI scores were best correlated with the average annual High Pulse Count (HPC), High Pulse Range (HPR), and Richards-Baker Index (RBI) metrics for the B-IBI data collection period (2002-2015). These metrics were also chosen because their model behavior was consistent and predictable for the forested and future build-out scenarios. Annual values of these metrics, computed from model-simulated flows, and the flow-B-IBI relationships established from the WRIA 8 dataset (King County, 2015) and specified in the equations below, were used to estimate best-fit predictions of B-IBI for mainstem sites on Little Bear Creek. The estimate of an average B-IBI score for a given scenario is based on the arithmetic mean of B-IBI scores computed for each of the three flow metrics.

High Pulse Count: $BIBI = -1.63 \times HPC + 50.3$ ($r = 0.87, r^2 = 0.75, p < 0.0001$)

High Pulse Range: $BIBI = -0.096 \times HPR + 50.9$ ($r = 0.74, r^2 = 0.54, p < 0.0001$)

Richards-Baker Index: $BIBI = -59.3 \times RBI + 47.2$ ($r = 0.87, r^2 = 0.75, p < 0.0001$)

B-IBI scores from Little Bear Creek tributaries were not well-correlated with the regional data and regressions, suggesting that factors other than hydrology play a larger role in biological conditions on these smaller streams. For this reason, hydrologically-based estimates of B-IBI were computed only for mainstem analysis points. Hydrologic metric and B-IBI correlations and analysis associated with the Little Bear Creek basin planning study are documented further in Appendix F.

3.3 B-IBI Targets

Washington State does not currently have a standard for biological conditions as represented by B-IBI. However, achievement of the basin planning objective of supporting designated uses for Little Bear Creek requires maintenance of aquatic habitat conditions supportive of salmonid use. For the purposes of this Special Condition S5.C.5.c planning effort, Ecology (2016) recommended that the target B-IBI score be the lower of:

- 38, or
- 90% of the forested conditions B-IBI score.

The Ecology guidance further recommends that the B-IBI score be computed as the arithmetic mean of B-IBI values estimated from individual hydrologic metrics. Since B-IBI scores—both observed and computed from hydrologic metrics—vary substantially from year to year, long-term averages computed over the 60-year HSPF simulation period were used for B-IBI assessment.

3.4 Flow/B-IBI Analysis

Existing, forested, and future build-out land use conditions in the Little Bear Creek study area were simulated using the HSPF flow and water quality model of the Little Bear Creek study area basin. Model development, calibration, and development of the future build-out condition are documented in the *Watershed Modeling Report* (Appendix B). The HSPF watershed model simulates land surface runoff and drainage system routing of flow, water temperature, total suspended solids (TSS), copper, zinc, and fecal coliform bacteria.

Hydrologic metric values and associated B-IBI scores were computed (as described in Section 3.2) for each land use condition for the four mainstem Little Bear Creek assessment points, located at the outlets of the Little Bear Upper, Little Bear Middle, Little Bear Lower 228th, and Little Bear Lower County Line subbasins (see Figure 1). B-IBI scores are shown in Table 2.

Table 2. Little Bear Creek Flow-Based B-IBI Results

Land Use Condition	Little Bear Lower CL	Little Bear Lower 228 th	Little Bear Middle	Little Bear Upper
Forested	40	40	40	38
Existing	29	31	34	31
Future Build-out	31	33	35	32
Target (90% Forested)	36	36	36	35

Both existing and future build-out scenarios fell short of the B-IBI targets at all four locations. Hence, under Special Condition S5.C.5.c.iv (5), the County is required to use the calibrated model to evaluate stormwater management strategies to meet the targets. The best conditions occurred in the Little Bear Middle subbasin, which is largely rural and characterized by extensive wetlands along the Little Bear Creek channel. In the more developed reaches, future build-out scores are slightly higher than existing conditions. This suggests that the hydrologic effects of development are being mitigated by the associated low impact development (LID) and flow control treatment included per current code requirements. Also, in redevelopment areas, replacement of impervious surface with little to no existing treatment with mitigated impervious surfaces appears to provide a small net benefit.

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4 WATER QUALITY

4.1 Introduction

The State of Washington’s water quality standards, listed in chapter 173-201A of the Washington Administrative Code (WAC), provide the metrics used to evaluate water quality constituents for waters of Washington State. The criteria vary depending on the designated uses for a receiving water. Little Bear Creek has the following designated uses:

- Aquatic Life Uses: Core Summer Salmonid Habitat (in addition to spawning, rearing, and migration outside the summer season)
- Recreation Uses: Extraordinary Primary Contact (waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas)
- Water Supply Uses: Domestic water, industrial water, agricultural water, and stock water
- Miscellaneous Uses: Wildlife habitat, harvesting, commerce/navigation, boating, and aesthetics

Little Bear Creek is subject to an additional temperature criterion based on the mapping included in Ecology publication 06-10-038 (Ecology, 2011b), which is designated as part of Chapter 173-201A of the WAC. The supplemental temperature criteria indicated in this publication for Little Bear Creek (13°C from September 15 through May 15) is colder than temperatures for the use-based criteria and thus takes precedence for that period.

Among the water quality parameters listed in Chapter 173-201A of the WAC, temperature, fecal coliform bacteria, dissolved copper, and dissolved zinc—listed in Table 3 below—are the constituents required for analysis under Special Condition S5.C.5.c. of the Permit and are the constituents targeted in this Basin Plan.

Table 3. Water Quality Standards for Permit-Mandated Constituents

Parameter	WAC Freshwater Water Quality Standard	Numeric Criteria
Fecal coliform bacteria	173-201A-200 (2)(b)	Extraordinary Primary Contact: geometric mean value < 50 colonies /100 mL, with ≤ 10 % exceeding 100 colonies /100 mL
Temperature¹	173-201A-200 (1)(c)	<ul style="list-style-type: none"> Supplemental temperature criteria (Sept 15-May 15): maximum 7-day average of the daily maximum temperature (7DADMax) is 13°C (55.4°F) Core Summer Salmonid Habitat criteria (June 15-Sept 14): maximum 7-DADMax of 16°C (60.8°F) Spawning, Rearing, Migration criteria (May 16-June 14): maximum 7-DADMax of 17.5°C (63.5°F)
Dissolved Copper (Cu)	173-201A-240	Acute ² $(0.960)(e^{(0.9422[\ln(\text{hardness})] - 1.464)})$ Chronic ³ $(0.960)(e^{(0.8545[\ln(\text{hardness})] - 1.465)})$
Dissolved Zinc (Zn)	173-201A-240	Acute ² $(0.978)(e^{(0.8473[\ln(\text{hardness})] + 0.8604)})$ Chronic ³ $(0.986)(e^{(0.8473[\ln(\text{hardness})] + 0.7614)})$
¹ Temperature (7DADMax) not to exceed the maximum of the criteria or forested temperature plus 0.3°C at a probability frequency of more than once every ten years on average. ² Acute criteria, 1-hour average concentration not to be exceeded more than once every three years on the average. ³ Chronic criteria, 4-day average concentration not to be exceeded more than once every three years on the average.		

4.2 Water Quality Analysis

The Permit requires evaluation of water quality conditions for existing, historic (forested), and future build-out land use conditions compared to state standards using a continuous water quality model. Development and calibration of the HSPF flow and water quality model for the Little Bear Creek study area basin, as well as documentation of the assumptions used to project historic and future land use conditions, are documented in the *Watershed Modeling Report* (Appendix B). For each land use condition, the HSPF watershed model was run to simulate flow, water temperature, dissolved copper and zinc, and fecal coliform bacteria (among other constituents) for a 60-year modeling period, using meteorological inputs from water years 1956 through 2015. Water quality results were analyzed and compared to the standards listed in Table 3 at each of the nine subbasin outlet points (Figure 1) for each land use condition.

The following sections document the modeled water quality results for each of the Permit-required constituents compared to state water quality standards. Results are presented in terms of exceedances of the corresponding standard, with compliance evaluated over the 60-year simulation. The stormwater management actions discussed in subsequent sections of this Basin Plan are targeted at meeting water quality standards under the future build-out condition.

Dissolved Metals

Copper and zinc are essential nutrients at low levels but can be toxic to aquatic organisms at higher concentrations. Studies in the last decade have also found that copper can affect sensory systems of juvenile salmonids at relatively low concentrations (e.g. Hecht et al, 2007). Metals toxicity and bioavailability is dependent on a number of factors, and the zinc and copper standards (Table 3) set exceedance thresholds based on hardness (which measures the amount of dissolved calcium and magnesium in water), which was also simulated in the HSPF model. The thresholds for both acute and chronic criteria are thus continuously varying with changes in flow and water chemistry.

The dissolved metal standards (see Table 3) allow for one exceedance every three years for each criterion, or an average of 0.33 exceedances per year over the modeling period. None of the modeled land use conditions violated the acute or chronic standards for dissolved copper or zinc, and in fact, there were no exceedances of any of the criteria simulated in the study area.

Temperature

Stream temperature standards in Washington are set to protect native fish and aquatic organisms and vary through the year depending on life cycle needs. Salmonids, which are the primary species of concern in Little Bear Creek, function best at temperatures between 10°C and 16°C (50°F and 60°F) (NMFS, 1996). Cool temperatures are particularly critical during spawning and incubation periods, which drives the supplemental temperature criteria applicable between September 15 and May 15.

The temperature standard sets exceedance criteria for the 7DADMax, which is a moving seven-day average of daily maximum temperatures. Any day with 7DADMax exceeding the applicable seasonal criteria was counted as an exceedance, so periods of extended high temperatures can produce multiple exceedances. The allowable exceedance frequency for the temperature criteria is one exceedance every ten years on average (less than or equal to 0.1 exceedances per year on an annual basis).

For the forested scenario, the 60-year time series of computed 7DADMax was compared to the seasonal temperature threshold listed for each temperature criteria (Table 3), based on the date, to assess natural conditions relative to the standard. Table 4 shows the average exceedances per year of each criterion under the temperature standard for the forested conditions scenario. Notably, the core summer salmonid habitat (June 15 through September 14) and supplemental temperature period (September 15 through May 15) criteria are exceeded well beyond the allowable rate.

Table 4. Forested Condition Average Number of Annual Temperature Exceedances of Numeric Criteria

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Core Summer	43	2	31	21	7	29	4	27	10
Supplemental	23	4	20	16	7	21	7	18	11
Spawning, Rearing, Migration	0	0	0	0	0	0	0	0	0

In cases where a water body's temperature exceeds the criteria thresholds listed in Table 3 due to natural conditions—as demonstrated by the forested results—the temperature standard allows for an increase of no more than 0.3°C above natural conditions (WAC 173-201A-200 (1)(c)(i)). Incorporating this natural conditions reference into the temperature analysis, the computed 7DADMax temperatures for the existing and future build-out scenarios were compared to the larger of the seasonal temperature threshold listed in Table 3 and the forested 7DADMax temperature plus 0.3°C to determine whether the standard was exceeded for a given day. Table 5 and Table 6 show the average number of exceedances per year for the existing and future build-out scenarios, relative to the thresholds and natural reference condition.

Table 5. Existing Condition Average Number of Annual Temperature Exceedances

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Core Summer	64	0.1	56	44	13	51	9	51	21
Supplemental	30	1	26	24	9	26	11	25	11
Spawning, Rearing, Migration	0.1	0	0	0	0	0	0	0	0

Table 6. Future Build-out Average Number of Annual Temperature Exceedances

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Core Summer	63	0.1	56	40	13	51	9	51	21
Supplemental	29	1	25	20	9	25	11	25	10
Spawning, Rearing, Migration	0.1	0	0	0	0	0	0	0	0

The modeling showed multiple exceedances per year of the core summer salmonid habitat (June 15 through September 14) and supplemental temperature period (September 15 through May 15)

thresholds in all subbasins except Rowlands Creek (which meets the core summer standard but not the supplemental temperature period). The results show very little change—slight reductions in some subbasins—between existing and future build-out land use conditions. This suggests that the stormwater treatment required by current regulations mitigated stream temperature impacts of the anticipated future development, preventing further degradation.

The information presented in Table 6 clearly shows that the temperature standard is not met under future build-out conditions, but provides no information about the size of the exceedances. The following discussion characterizes the magnitude of the exceedances—and how much temperature reduction is needed. Figure 2 shows the relative magnitude and frequency of temperature exceedances for all seasons over the 60-year modeling period for future build-out conditions. Values are displayed as the difference (or “residual”) between the simulated 7DADMax temperature and the applicable threshold—either the seasonal criteria or corresponding forested conditions 7DADMax plus 0.3°C. Any residual greater than zero indicates an exceedance of the temperature threshold. Using residuals thus simplifies comparison by eliminating the variability in the numeric thresholds. The histogram plots for each subbasin indicate the relative number of exceedances (red bars) compared to non-exceedances, as well as the difference from the applicable threshold.

Summary statistics for residuals of only the temperature exceedances (red bars in Figure 2) are presented in Figure 3. The shaded box represents the range of values between the 25th and 75th percentiles of the 60-year daily time series, with mean value indicated by an “x” and median by a line through the box. The “whiskers” extending from the box show the range of data (excluding statistical outliers, indicated by dots). The purpose of this figure is to illustrate the magnitude of the exceedances, i.e. how much temperature reduction is needed to meet the standard. While most exceedances are less than half a degree above the threshold, the figure shows that reductions of as much as one degree are needed in some subbasins to meet the standard. Figure 3 presents combined data for all exceedances; separate plots for core summer versus supplemental criteria seasons would show slight differences in distribution of the temperature residuals.

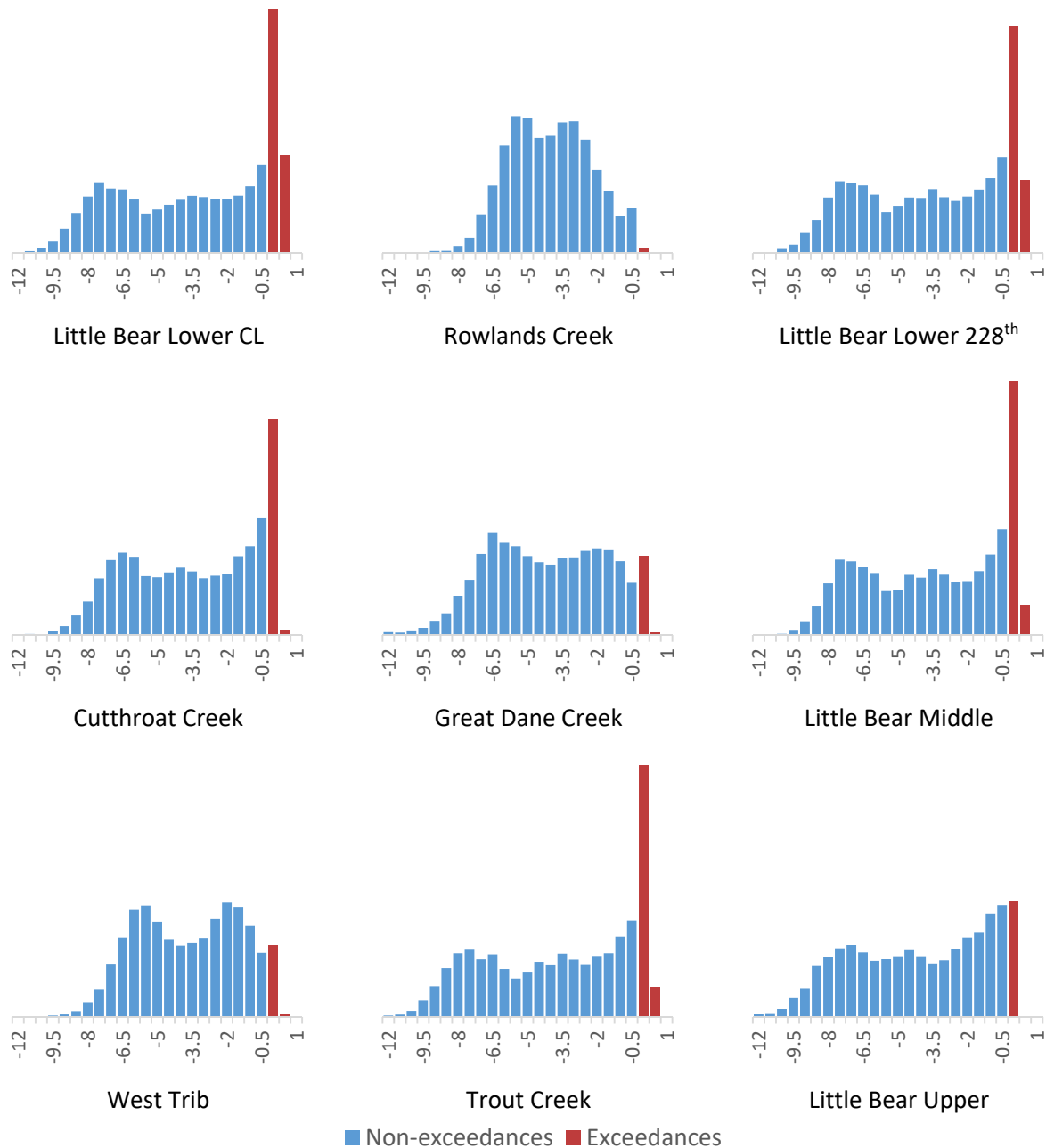


Figure 2. Distribution of residuals from temperature thresholds by subbasin. Bin lower limits shown on horizontal axis. Bins representing residuals greater than zero (red) indicate exceedances. The height of each bar indicates the number of samples with residuals within each range.

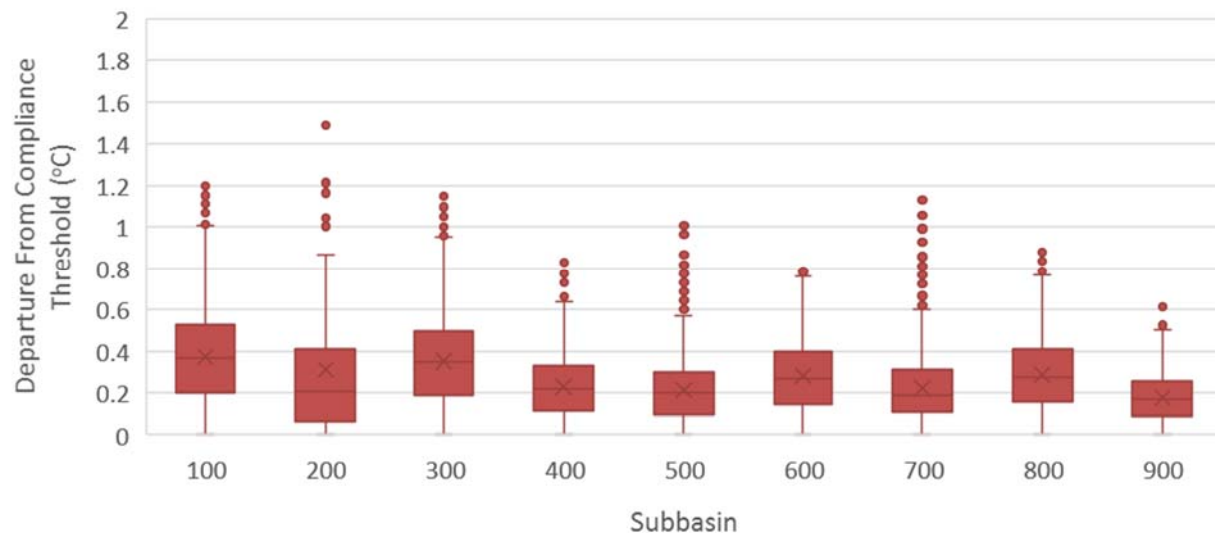


Figure 3. Summary statistics of temperature residuals for exceedances only by subbasin.

Fecal Coliform

Fecal coliform bacteria are present in the feces of humans and other warm-blooded animals; these bacteria can enter water bodies via surface wash-off, sewage discharge, or direct deposition (e.g. by water fowl and aquatic mammals). Although they are generally not harmful themselves, fecal coliform bacteria are indicators of the possible presence of pathogenic (disease-causing) bacteria that are difficult to measure directly. Unlike metals and temperature standards that target protection of fish and other aquatic organisms, bacteria standards target protection of people from contact with water-borne pathogens that can be transmitted through direct contact (e.g. wading or swimming) with or ingestion of aquatic organisms (e.g. shellfish) from contaminated waters. Snohomish County has already instituted programs targeting fecal coliform reduction under the Total Maximum Daily Load (TMDL) plan completed by Ecology in 2005. The TMDL is separate from the fecal standards required for assessment under Special Condition S5.C.5.c. of the Permit.

Fecal coliform is assessed for three seasons or periods on an annual (water year) basis: wet season (October through March), dry season (April through September), and annual (October through September). For each period and year, the geometric mean and the percent of samples exceeding the 100 colonies per 100 milliliters criteria (hereafter “10 percent” criteria) were computed. Table 7, Table 8 and Table 9 show the percent of years in the 60-year modeling period that fecal coliforms exceeded the water quality criteria for the forested, existing, and future build-out land use conditions, respectively. Any season or year with an exceedance of the geometric mean or 10 percent criteria was counted as exceeding the standard.

Table 7. Forested Condition Fecal Coliform % of Modeled Years Not Meeting Standard

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Annual									
Geo Mean	0%	0%	0%	0%	0%	0%	0%	0%	0%
10 Percent	2%	0%	2%	2%	0%	10%	0%	18%	25%
Wet Season									
Geo Mean	0%	0%	0%	0%	0%	0%	0%	0%	0%
10 Percent	7%	0%	13%	5%	3%	33%	0%	50%	72%
Dry Season									
Geo Mean	0%	0%	0%	0%	0%	0%	0%	0%	0%
10 Percent	2%	0%	3%	2%	2%	12%	0%	7%	8%
Geo Mean = geometric mean criteria; 10 Percent = 10% exceedance criteria									

Notably, the forested land use condition exceeds the 10 percent criteria in all subbasins except Rowlands Creek and West Trib, which are the two smallest subbasins in the study area. Fecal coliform bacteria are not necessarily anthropogenic in origin, and birds and other wildlife (e.g. beavers) can contribute significantly to fecal loading in streams. As documented in the *Watershed Modeling Report* (Appendix B), fecal coliform loadings in baseflows and pervious surface runoff assume a “natural” contribution from wildlife, which was based on scientific literature in the absence of local data for Little Bear Creek.

Table 8. Existing Condition Fecal Coliform % of Modeled Years Not Meeting Standard

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Annual									
Geo Mean	95%	68%	93%	100%	95%	75%	72%	95%	88%
10 Percent	100%	100%	100%	100%	100%	100%	100%	100%	100%
Wet Season									
Geo Mean	68%	32%	68%	87%	75%	35%	28%	72%	45%
10 Percent	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dry Season									
Geo Mean	97%	100%	97%	100%	98%	97%	100%	100%	100%
10 Percent	98%	95%	98%	98%	98%	97%	95%	100%	97%
Geo Mean = geometric mean criteria; 10 Percent = 10% exceedance criteria									

Table 9. Future Build-out Fecal Coliform % of Modeled Years Not Meeting Standard

Criteria	Little Bear Lower CL	Rowlands Creek	Little Bear Lower 228 th	Cutthroat Creek	Great Dane Creek	Little Bear Middle	West Trib	Trout Creek	Little Bear Upper
Annual									
Geo Mean	83%	83%	85%	93%	95%	77%	78%	97%	85%
10 Percent	100%	100%	100%	100%	100%	100%	100%	100%	100%
Wet Season									
Geo Mean	55%	40%	48%	47%	80%	35%	32%	75%	42%
10 Percent	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dry Season									
Geo Mean	97%	100%	97%	100%	100%	98%	100%	100%	100%
10 Percent	97%	95%	97%	97%	98%	97%	95%	100%	97%
Geo Mean = geometric mean criteria; 10 Percent = 10% exceedance criteria									

All subbasins regularly exceed both the geometric mean and 10 percent criteria for fecal coliform in the existing and future build-out scenarios. There is little difference in dry season geometric mean exceedances or exceedances of the 10 percent criteria (regardless of season) between existing conditions and future build-out. There are fluctuations in the percent of years exceeding the geometric mean during the wet season but no clear trend in direction.

The plots in Figure 4 and Figure 5 further illustrate the gap between simulated fecal coliform levels under future build-out conditions and the fecal coliform standards. The plots present summary statistics for each of the fecal criteria, based on the annual data. Similar plots for the wet season and dry season data would show some shifts in the positions of the boxes but provide a similar overall picture; i.e. that geometric mean consistently exceeds the criteria by a modest amount, while exceedances of the 10 percent criteria are much greater and almost universal. As in Figure 3, the shaded box represents the range of values between the 25th and 75th percentiles of the 60-year annual series, with mean value indicated by an “x” and median by a line through the box. The whiskers extending from the box show the data range (excluding statistical outliers indicated by dots).

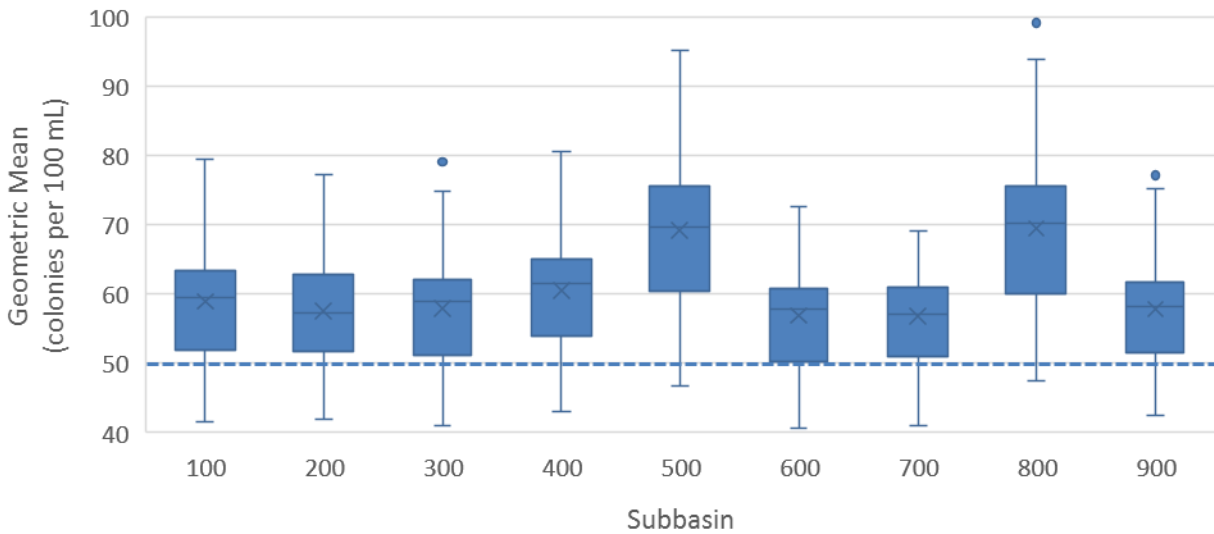


Figure 4. Summary statistics of annual fecal coliform geometric mean values relative to the 50 colonies per 100 mL threshold (dashed blue line) by subbasin.

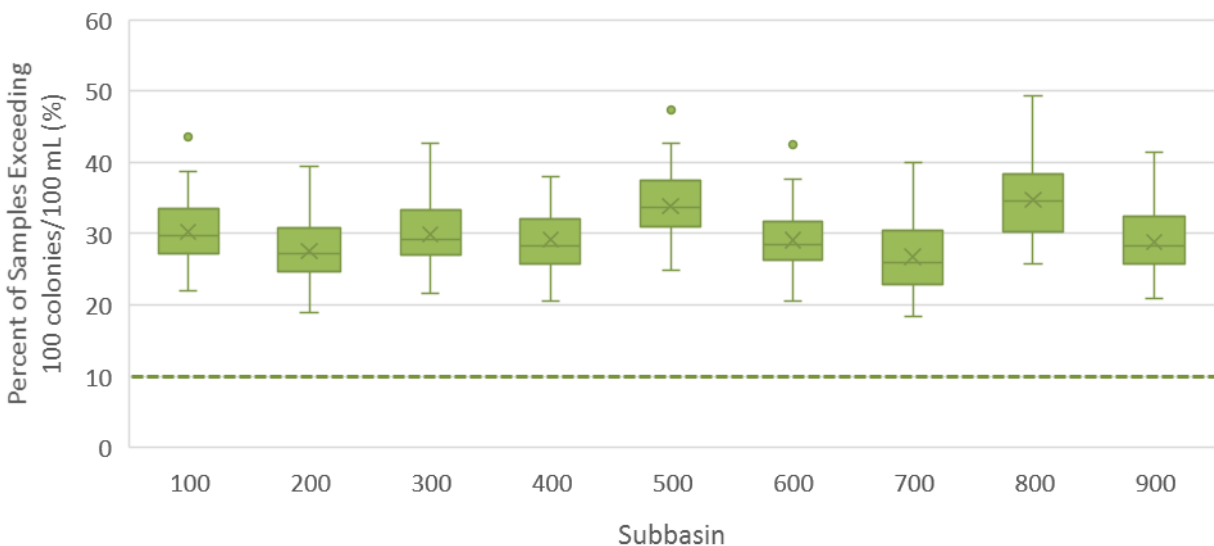


Figure 5. Summary statistics of annual fecal coliform exceedances of the 100 colonies per 100 mL threshold (dashed green line) by subbasin.

4.3 Summary of Key Findings

The modeling analysis indicated that the water quality standards for dissolved metals were met throughout the Little Bear Creek study area for all three land use conditions. However, temperature and fecal coliform bacteria standards were not met in the existing or future build-out land use conditions. One of the fecal coliform criteria was also not met under the forested land use condition.

With the exception of the Rowlands Creek subbasin, the core summer salmonid habitat and supplemental temperature criteria were exceeded hundreds of times more frequently than the standard allows. The higher Spawning/Rearing/Migration criteria (applicable May 16 through June 14) was met throughout the study area. The fecal coliform standard, particularly the 10 percent criteria, was also exceeded in most years throughout the study area. Hence, under Special Condition S5.C.5.c.iv (5), the County is required to use the calibrated model to evaluate stormwater management strategies that would enable the study area to meet the standards. Water quality results for the future build-out land use condition, which is the basis of the stormwater planning requirement, are summarized in Table 10.

Table 10. Water Quality Summary for Future Build-out Condition

Constituent	Criteria	Meets Criteria	Meets Standard
Dissolved Copper	Acute	✓	✓
	Chronic	✓	
Dissolved Zinc	Acute	✓	✓
	Chronic	✓	
Temperature	Core Summer	✗	✗
	Supplemental	✗	
	Spawning/Rearing/Migration	✓	
Fecal Coliform	Geometric Mean	✗	✗
	10 Percent Exceedance	✗	

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5 STRATEGY DEVELOPMENT

5.1 Strategies Considered

As described in Chapters 3 and 4, temperature, fecal coliform, and B-IBI fell short of applicable criteria in the study area. Accordingly, under Special Condition S5.C.5.c.iv (5), the County was required to use the calibrated model to evaluate stormwater management strategies to meet the standards for temperature and fecal coliform, and to evaluate biologic conditions using a correlation between hydrologic metrics and B-IBI.

Stormwater management strategies required to be evaluated under Special Condition S5.C.5.c.iv (5)(a) include:

- *Changes to development-related codes, rules, standards, and plans.*
- *Potential future structural stormwater control projects consistent with S5.C.6.a.*

Stormwater management strategies that may also be evaluated under Special Condition S5.C.5.c.iv (5)(b) include:

- *Basin-specific stormwater control requirements for new development and redevelopment as allowed by Section 7 of Appendix 1. (Note: the Section 7 and Appendix 1 references are with respect to the Phase I Municipal Stormwater Permit.)*
- *Strategies to encourage redevelopment and infill, and an assessment of options for efficient, effective runoff controls for redevelopment projects, such as regional facilities, in lieu of individual site requirements*

The County may also include an evaluation of strategies to preserve or improve other factors that support the existing and designated uses of the stream as described in Special Condition S5.C.5.c.v.

The County conducted a series of internal workshops on September 19 and 20, 2016, to gather ideas and input on stormwater management strategies to consider in the Little Bear Creek study area for fecal coliform reduction, temperature reduction, and flow control/B-IBI improvement. The individual internal workshops focused on the following groups of strategies:

- Structural
- Non-structural
- Instream

Structural strategies were defined as constructed stormwater BMPs, including both LID-type facilities, such as pervious pavement or bioretention systems, and more traditional facilities, such as stormwater detention and treatment. Structural strategies are most readily modeled and comprised the primary component of the SUSTAIN optimization model scenarios. The structural workshop considered types of BMPs, as well as sequencing of potential treatment opportunities for different land use types in the SUSTAIN model. The sequencing allows for assessment of combinations of BMPs to collectively meet treatment goals. Structural BMPs could be applied as retrofits in parts of the study area that will not

develop or redevelop or to provide enhanced stormwater treatment, beyond current code requirements, for future development.

Non-structural strategies encompass programs, actions, and code or policy changes that affect runoff and/or pollution generation and treatment. Non-structural strategies are not, in themselves, considered construction projects. Examples of non-structural strategies include increased maintenance of storm drainage systems, inspection of septic systems, changes to county codes to increase development requirements, and education/outreach to residents of the Little Bear Creek study area. The non-structural workshop identified potential actions targeted primarily at bacteria (fecal) reduction and temperature reduction, which are less likely to be fully achieved through structural BMPs. Non-structural strategies are generally more difficult to directly quantify, and, therefore, changes to development codes related to treatment and land cover were the only non-structural strategies evaluated in the modeling.

As specifically required under the Permit, the County considered the possibility of changes to the development code. Along with structural strategies, the SUSTAIN modeling included two possible code changes:

- (1) Additional treatment (beyond current code requirements) for development areas, and
- (2) An enhanced canopy requirement beyond the current code.

The former would be in the form of additional treatment facilities, or larger treatment facilities, to provide enhanced flow and water quality treatment, which could take the form of further detention, infiltration, filtration, or other treatment, beyond current code requirements. The latter was in the form of a 50 percent canopy requirement, to be applied to non-UGA developments outside of rural clustered subdivisions. Currently, a 30 percent canopy is required for development in UGA areas. In non-UGA areas, certain open space requirements apply to rural clustered subdivisions, providing some degree of pervious area retention and accomplishing some of the objectives of a canopy requirement. The enhanced canopy requirement would extend and increase canopy requirements to more development.

Instream strategies were defined as projects or actions within or near streams that have a more direct (usually local) impact on the stream itself. Instream strategies (often characterized as “stream restoration”) are generally targeted at improving physical habitat conditions at a stream reach scale, that is, particular to specific reaches of a stream. With the exception of temperature, the identified instream strategies generally do not directly address the Permit-targeted constituents (dissolved metals, fecal coliform, and B-IBI-related *flow* metrics). However, some of these actions would be expected to enhance local stream characteristics, and these stream characteristics have also been shown to relate to B-IBI and overall aquatic health.


To facilitate analysis, strategies identified at the workshops were grouped into four categories, listed below, reflecting their primary purpose or benefit relative to the stormwater management targets. Structural BMPs modeled in SUSTAIN provided the foundation for a modeled solution. “Supplemental strategies” were added as needed to the modeled scenarios to provide the complete water quality solution for the Little Bear Creek study area. Selected temperature and fecal coliform supplemental strategies that lent themselves to modeling, were modeled in HSPF, as a post-process using the SUSTAIN results.

Strategy Categories:

1. Structural BMPs and code changes (modeled in SUSTAIN with HSPF pre- and post-processing)
2. Supplemental temperature strategies (some modeled in HSPF)
3. Supplemental fecal strategies (some modeled in HSPF)
4. Supplemental habitat/B-IBI strategies (not modeled)

The SUSTAIN modeling provided combinations of BMPs needed to meet the flow-based B-IBI targets. A representation of the sequence of BMP options used in SUSTAIN is shown in Table 11. The BMP routing order shown is “Distributed/Onsite,” to “Conveyance,” and “End-of-pipe,” for each land use type. In addition to the structural BMPs listed, potential code changes (enhanced canopy and additional development BMPs) were also evaluated through the modeling, as discussed in Section 5.2.

Table 11. Structural BMPs and Sequencing for SUSTAIN Modeling



Land Use	Distributed/On-Site	Conveyance	End-of-pipe
Forest	None	None	None
Wetland	None	None	None
Agriculture	Filter strips	Modified ditches	None
Residential	Permeable pavement, Rain gardens	Modified ditches	Infiltration ponds/ Wet ponds ¹
Roads	Permeable pavement ² , Bioretention or Filter Strips	Modified ditches	Infiltration ponds/ Wet ponds ¹
Commercial	Permeable pavement, Bioretention		Infiltration ponds/ Wet ponds ¹

¹ Infiltration (with pre-treatment) in outwash areas, detention with treatment elsewhere.

² Permeable pavement applicable to sidewalks and low-traffic roads only.

As discussed in the next section, structural BMPs modeled in SUSTAIN provided some level of fecal coliform and temperature benefits but did not provide sufficient reductions to meet water quality standards. Other non-structural and instream strategies could provide additional temperature, fecal coliform, and habitat benefits, but were not as readily implementable within a modeling framework. These non-structural and in-stream strategies were classified as supplemental strategies and were grouped by their primary benefit, as shown in Table 12 through Table 14. Buffer restoration (Table 12) and stormwater planters (Table 13) were later modeled in HSPF to quantify temperature and fecal coliform reduction benefits, respectively, as part of the modeled solution for the Little Bear Creek study area. (This is discussed further in Section 5.2.)

Table 12. Supplemental Temperature Reduction Strategies

Strategy	Description	Temperature Benefit
1. Buffer restoration	Planting native trees along stream to achieve maximum shade potential	Increase shade to limit stream heating at stream-reach scale
2. Cold water supplementation	Supplemental flow at groundwater temperature pumped into stream at targeted locations	Offset heating at local to reach-scale by adding cold water (similar to springs)
3. Planting around ponds (stormwater and inline)	Planting native trees within 30ft of ponds to achieve maximum shade potential	Reduces heating of slow-moving surface water layer
4. Pool creation	Deeper pools in locations with groundwater inflow to stream cooler	Cool water refuges at local scale

Table 13. Supplemental Fecal Reduction Strategies

Strategy	Description	Fecal Benefit
1. Source Study	Study of fecal coliform source types, locations, and extents as practicable (land use, animal source(s), infrastructure, other) to target management actions	Efficient use of resources to ensure effective actions
2. Street sweeping/catch basin cleaning	Removes biofilm and accrued matter from road surfaces and drainage system	Removes accumulated bacteria and media, to reduce potential for further bacteria growth
3. Education and outreach: pet waste, septic systems, other	Social marketing targeting specific audiences, e.g. vet clinics, park users, homeowners	Education and behavior change to effect proper pet waste disposal, property septic maintenance, etc.
4. Septic inspection	Periodic inspection and maintenance as needed (other agency)	Agency inspection of septic system, and agency coordination and assistance with maintenance and repair.
5. Sanitary sewer inspection and repair	Part of capital infiltration and inflow program, to prevent overload of wastewater collection system with inflowing stormwater (which can cause wastewater overflow).	Reduces bacteria contributions that may come from sewer overflows or leaking systems.
6. Stormwater planters (e.g. Filterra®)	Small-scale bioretention cells providing infiltration and soil media treatment of local runoff. Could include special media inlets, mycofiltration, other new filtration technologies	Treat stormwater discharge with high efficiency filtration/treatment units
7. Fencing, animal exclusion	Animal barriers to prevent riparian entry	Reduces bacteria levels from animals that are close to creeks
8. Food inspections	Removes wildlife food source, control wildlife waste	Source reduction

Table 14. Supplemental Habitat/B-IBI Enhancement Strategies

Strategy	Description	Habitat/B-IBI Benefit
1. Increased roughness (e.g. large woody debris (LWD))	Increase stream channel roughness by placement of stream structure (e.g.; woody debris), to slow down flow, increase channel complexity	LWD and other measure to increase roughness help slow down flows, reduce erosion from flooding and high flows, keep stream bugs in place and stabilize habitat
2. Wetland/ stream restoration	Remove fill from wetlands and floodplain areas and restore natural stream form and flow pathways.	Increases flow storage that helps reduce peak flows, removal of fill increases potential for infiltration and groundwater recharge, helping to stabilize summer stream flows
3. Channel stabilization	Measures to limit significant channel erosion and/or channel head cutting. Includes bank erosion control and grade control measures.	Source control of streambank sediments reduces fine sediment input to streambed
4. Floodplain connection	Remove barriers (e.g. fill, berms, revetments) to natural floodplain area. Create side channel habitat and expanded flow pathways.	Spreading out flood flows over more of the floodplain, reduces concentrated flows in streams, reducing streambed and channel erosion. Barrier removal makes more habitat accessible.
5. Inline pond reduction	Return ponds with outflow control to free-flowing stream	Restores natural flow regime and stream processes

Strategy costs were developed following the workshops. Costs for non-structural and instream strategies were developed based on similar County programs, projects, and code development efforts. For structural strategies, unit BMP costs required as inputs for the SUSTAIN optimization were developed from regional and national databases, with total costs determined through modeling. Potential implementation costs are discussed further in Chapter 6 of this Basin Plan.

5.2 Modeled Solution

Potential strategies described in the previous section were evaluated using modeling to determine the type and distribution of actions needed to demonstrate compliance with the water quality targets and standards, as required by the Permit. The SUSTAIN model was used to determine the best combination of BMPs for flow control, which would also provide partial solutions for fecal coliform and temperature. The SUSTAIN scenarios used HSPF pollutant and runoff simulation and downstream routing, in conjunction with SUSTAIN providing cost effectiveness optimization of combinations of BMPs in the watershed, to achieve flow-based B-IBI targets. Supplemental strategies were evaluated using the HSPF watershed model to achieve required fecal coliform and temperature reductions.

SUSTAIN Scenarios

Four scenarios, representing combinations of structural BMPs and potential code changes, were modeled in SUSTAIN. The base component of each scenario was a suite of structural BMP options applied as retrofits (i.e. stormwater facilities constructed independently from land development) in areas of the Little Bear Creek study area not subject to future development. In Table 15 below, the base suite is given in the “Retrofit BMPs” column.

Two code change options—additional stormwater treatment and an enhanced canopy requirement—that would affect certain development and redevelopment projects were also evaluated in the SUSTAIN model. These are listed in Table 15 as “Additional Development BMPs” and “Canopy Requirement.” Various combinations of the retrofit BMPs and the two code change options comprise the four scenarios.

Table 15. SUSTAIN Model Scenarios

Scenario ID	Retrofit BMPs	Additional Development BMPs	Canopy Requirement
1	Yes	No	No
2	Yes	Yes	No
3	Yes	No	Yes
4	Yes	Yes	Yes

Modeling specifications for BMPs, such as size, factors that affect treatment capability, and unit costs were developed for structural BMPs from local experience and agency documentation and guidance (e.g. Department of Ecology, Puget Sound Partnership), supplemented by information from the International BMP database.

Thirty-year life-cycle costs including construction, design, and maintenance, and replacement, if expected life was less than 30 years, were estimated in present value (2016) dollars per unit of the structural BMPs included in SUSTAIN. Cost data were largely taken from the Puget Sound Stormwater BMP Cost Database (Herrera Environmental Consultants, 2012) with additional input from Snohomish County. Costs from the database were increased by 6 percent to account for inflation since the date the report was completed and an additional 25 percent to account for mobilization, temporary erosion control measures and traffic control, which were not accounted for in the reported unit costs. Life-cycle cost assumptions included a 3.8 percent annual bond interest rate and 2.5 percent annual inflation rate. Rates were based on input from the County and project team consultants and are considered in the acceptable range for public works infrastructure planning. Additional details about the data used to develop the estimated costs for each BMP are included in the *Stormwater Strategies Report* in Appendix C.

Space available for retrofit applications of each BMP type (i.e. BMP opportunity) was estimated at the catchment scale using screening criteria for characteristics such as slope, soil type, proximity to specific land uses, and parcel ownership. No BMP opportunity was included for catchments outside of Snohomish County jurisdiction, namely those areas located within the City of Woodinville or City of

Bothell. More detailed information about SUSTAIN model development, including assumptions regarding BMP sizing, performance, cost, and opportunity, is provided in the *Stormwater Strategies Report*, in Appendix C of this Basin Plan.

Scenario Selection

SUSTAIN optimization focused on flow control needed to achieve the flow-based B-IBI score targets at the four mainstem Little Bear Creek assessment points. All four SUSTAIN modeling scenarios provided the same level of performance, with scenario costs ranging from approximately \$170 million to \$230 million (all costs in 2016 dollars, present value (PV)). The County's NPDES Steering Committee, an interdepartmental committee formed to provide management coordination on County Permit requirements and implementation, selected a preferred scenario based on four criteria:

- Potential County cost
- Potential private cost
- Technical feasibility of implementation
- Flow and water quality performance

Flow and water quality performance was not a distinguishing characteristic between the SUSTAIN scenarios. All four met flow-based B-IBI targets—but not temperature or fecal standards—and produced very similar flow, stream temperature, and fecal coliform output. Scenario 1 had the highest potential public cost but low private cost and was expected to be the most straightforward to implement. The analysis for Scenario 1 provides a higher level of confidence than the other scenarios, since modeling of structural components is widely-used and well-documented, compared to modeling of code revisions or other non-structural components. This scenario is also expected to be the most straightforward to modify based on adaptive management. Finally, locations for projects in this scenario can be specifically identified and chosen to achieve the maximum improvement. The other scenarios depend on the vagaries of private development, and the development may not occur where the need for improvement is the highest. Consequently, Scenario 1, consisting of retrofit BMPs applied in parts of the study area not anticipated to develop or redevelop, was selected for purposes of development of an implementation plan and schedule in this Basin Plan.

Supplemental Strategies

Supplemental temperature and fecal coliform reduction strategies were evaluated using the HSPF model to address the gap between SUSTAIN scenario results and the water quality standards. The following paragraphs summarize the supplemental strategies analysis. Additional details about modeling approach and assumptions are provided in the *Stormwater Strategies Report* in Appendix C.

Temperature Reduction Strategies

One of the most significant factors in reducing temperatures in small streams is shading of the water surface provided by vegetation in the riparian corridor. Voluntary restoration of formerly forested buffer to enhance shading was identified as one of the most promising supplemental strategies for further temperature reduction. The County identified probable maximum extents of potential buffer restoration. With maximum buffer restoration added to the SUSTAIN flow control BMPs, modeling

results indicated that the temperature standard could be achieved in eight of the nine subbasins. Temperature exceedances in the West Trib were substantially reduced but did not meet the temperature criteria. Buffer restoration was less effective in the West Trib because approximately 30 percent of the subbasin area drains through a stream/ditch reach along the south side of 196th Street SE not identified for restoration.

In the West Trib subbasin, several of the remaining temperature exceedances were associated with early fall events that produced warm impervious surface runoff, compared to baseflow conditions in the reference forested condition. Thus, additional infiltration (beyond that included in the SUSTAIN solution) provides an effective means of further mitigating stream temperatures, by reducing warm runoff into the stream system.

Costs for voluntary buffer restoration of about 200 acres were estimated at approximately \$4.5 million based on previous experience within Snohomish County. This cost figure assumes buffer planting area would be provided voluntarily and does not include land acquisition. If land acquisition were included, such as for high priority locations, costs would be higher. Infiltration BMP costs are assumed to be the same as those used in the SUSTAIN model; bioretention in the right-of-way was assumed for purposes of supplemental cost estimation. Based on this assumption, supplemental infiltration in the West Trib subbasin would cost approximately \$6.3 million.

Fecal Coliform Reduction Strategies

The modeling results project a shortfall in meeting the fecal coliform water quality standard in the Little Bear Creek study area in the forested, existing, and future build-out conditions. “Natural” forested conditions notwithstanding, the Permit requires the County to develop a solution that fully meets the standard. Many of the proposed strategies use new technology or are non-structural in nature, and it is difficult to determine the in-field effectiveness of innovative and non-structural strategies. The County referred to current literature to develop these strategies. Given the uncertainties in characterizing and modeling fecal coliform sources and transport through the drainage network, and in the levels of fecal coliform attributable to natural sources, the proposed solution includes a study to better understand the sources of fecal coliform in Little Bear Creek and in order to more effectively target controls.

The flow-control BMPs derived from the SUSTAIN modeling provide a partial solution to reducing fecal coliform. The remaining gap in meeting the fecal coliform standard could be closed with BMPs specifically targeting fecal coliform reduction, which could be structural (using infiltration or filtration) or non-structural (using source reduction or control). The following paragraphs present a solution that meets the standard based on the modeling, as required by the Permit, but that may be difficult and very costly to implement. While there is limited current knowledge of field-based performance of some of the proposed strategies, the proposed solution encompasses the most current national and regional thinking on how to effectively remove fecal coliform from stormwater.

Source reduction programs are an important component of a community-based solution to fecal coliform and other water quality issues in Little Bear Creek. However, effectiveness of non-structural measures in reducing pollutants in the stream is difficult to quantify (Taylor et al., 2007), and there is very limited information regarding the effectiveness of public outreach and education programs at the

stream scale (Fore, 2013). In the Chesapeake Bay region, bacteria removal efficiencies have been defined for specific BMPs—including some of the identified source reduction programs—but application of these requires explicit definition of fecal loads by source, which is not consistent with the modeling for this study, nor is the source distribution in Little Bear Creek well understood. Based on the lack of available data, San Diego and Los Angeles have taken the approach of assuming a source reduction percentage representing collective effects of programs (on the order of 5 to 15 percent) for planning studies, then monitoring as programs are implemented. Given uncertainties in performance and the relatively modest reductions it seems reasonable to expect, source reduction benefits were not credited as providing measurable fecal coliform reductions for purposes of this Basin Plan.

Additional water quality treatment was modeled to make up the gap between treatment provided by the BMPs obtained by SUSTAIN modeling and the fecal coliform standards. Media filtration/bioretention type systems have generally been among the most effective BMPs for fecal coliform removal, and modeling assumptions were based on size, cost and performance of currently available filtration systems. Multiple studies have shown overall fecal removal² of 90 percent or higher for bioretention units (e.g. Galli, 1990; Davis, 1998, Davis et al., 2003). Lab studies and assessments of existing proprietary bioretention systems have reported non-bypass fecal coliform removal rates of 95 to 98 percent (e.g. Kelly and Hills, 2017; StormTreat, 2013; Rusciano and Obropta, 2007). Newer technologies, such as mycofiltration (using fungi to treat stormwater), have also shown promise for reducing bacteria in stormwater, in some cases with close to 100 percent removal (Stamets et al., 2013). For purposes of modeling, treatment was based on a high flow capacity filtration media with 95 percent fecal coliform removal effectiveness for non-bypass flow (zero removal for overflow). Cost estimates were based on unit costs for Filterra® bioretention units determined from recent local applications, with a 30-year life cycle cost of \$29,300 per unit. As water quality filtration technology continues to develop, similar performance may be achieved at lower cost with future treatment technology.

5.3 Proposed Strategies

Modeled Approach

This section summarizes the Permit-required modeled approach for the Little Bear Creek study area under Special Condition S5.C.5.c.iv (5). The approach is composed of:

- Structural BMP retrofits to provide additional flow and water quality treatment in parts of the Little Bear Creek study area;
- Buffer restoration and supplemental infiltration to provide additional temperature reduction; and
- Supplemental water quality treatment to provide additional fecal coliform reduction.

The distribution of stormwater management activities across the watershed is important in order to meet B-IBI targets and water quality standards throughout the study area. Factors affecting flow and water quality—including level of development, land use, existing treatment, and treatment

² Published facility effectiveness rates are often based on overall influent and effluent rates, which include untreated overflow. Removal effectiveness for non-bypass flow (i.e. flow through the filtration media) is typically higher.

opportunity—vary between the nine subbasins. Thus, proposed actions in this section are presented at the subbasin scale. Table 16 summarizes the potential actions modeled, by subbasin, to meet flow/B-IBI targets and temperature and fecal coliform standards throughout the study area. The BMPs included in Table 16 represent a planning level assessment of stormwater management needs.³ These treatments could be replaced by functionally equivalent BMPs depending on site-scale conditions and opportunities.

³ “Planning level” in engineering design usage typically means higher level assessment, solutions and estimates, based on generalized information, which may include modeled or calculated data, but not necessarily site-specific data.

Table 16. Modeled Stormwater Management Actions by Subbasin

Subbasin	Filter Strip Length, mi	Modified Ditches Length, mi	Rain Garden Area, sf	Bioretention Area, sf	Permeable Pavement Area, sf	Retention/ Detention Volume, ac-ft	WQ Filtration Area, sf	Buffer Restoration Area, ac	Subbasin Cost Rounded
Little Bear Upper	7.1	2.8	73,290	155,650	59,110	56	4,350	21	\$79 M
Trout Creek	7.1	3.5	29,300	1,450	4,170	10	2,580	19	\$14 M
West Trib	2.6	1.5	20,670	47,900	4,120	5	1,980	11	\$14 M
Little Bear Middle	10.5	5.5	70,520	100	31,900	30	9,080	43	\$36 M
Great Dane Cr	11.4	6.3	55,580	4,050	6,460	51	7,850	44	\$51 M
Cutthroat Cr	5.3	3.0	19,910	18,670	7,040	23	2,710	17	\$23 M
Little Bear Lower 228 th	9.1	4.6	16,700	1,000	7,860	26	1,730	11	\$23 M
Rowlands Cr	3.4	0.7	23,060	38,050	16,300	22	1,820	15	\$18 M
Little Bear Lower CL	7.0	2.4	14,190	70	22,150	23	6,860	23	\$29 M
Total Size (Rounded)	64	30	323,000	267,000	219,000	245	39,000	203	
Total Cost (Rounded)	\$5 M	\$18 M	\$9 M	\$31 M	\$5 M	\$167 M	\$49 M	\$4 M[†]	\$288 M

Costs are planning level 30-year life cycle costs in 2016 dollars (PV)

[†] Voluntary program, does not include land cost.

Table 17 groups the actions listed in Table 16 into more general functional categories—LID (filter strips, modified ditches, rain gardens, bioretention, and permeable pavement), water quality filtration, detention, and buffer restoration—and provides approximate surface area, as well as total subbasin cost, divided by subbasin area to facilitate comparison. Figure 6 illustrates the percent of the total BMP surface area (“footprint”) in the study area accounted for by each category, as well as the percent of subbasin cost. It is clear from the graphs that detention and filtration are relatively expensive strategies, compared to LID and buffer restoration (which has no associated land cost).

Table 17. Average Surface Area by BMP Type

Subbasin	LID sq ft/acre	WQ Filtration sq ft/acre	Detention sq ft/acre	Buffer sq ft/acre	Unit Cost \$M/acre
Little Bear Upper	530	3.4	320	720	0.06
Trout Creek	750	4.2	120	1360	0.02
West Trib	540	4.6	80	1110	0.03
Little Bear Middle	350	4.4	100	900	0.02
Great Dane Cr	520	5.3	250	1290	0.03
Cutthroat Cr	500	3.6	220	980	0.03
Little Bear Lower 228 th	970	3.0	320	820	0.04
Rowlands Cr	640	4.9	430	1750	0.05
Little Bear Lower CL	370	6.2	150	900	0.03
Study Area	510	4.5	210	1020	0.06

Planning level costs estimated in 2016 dollars (PV).

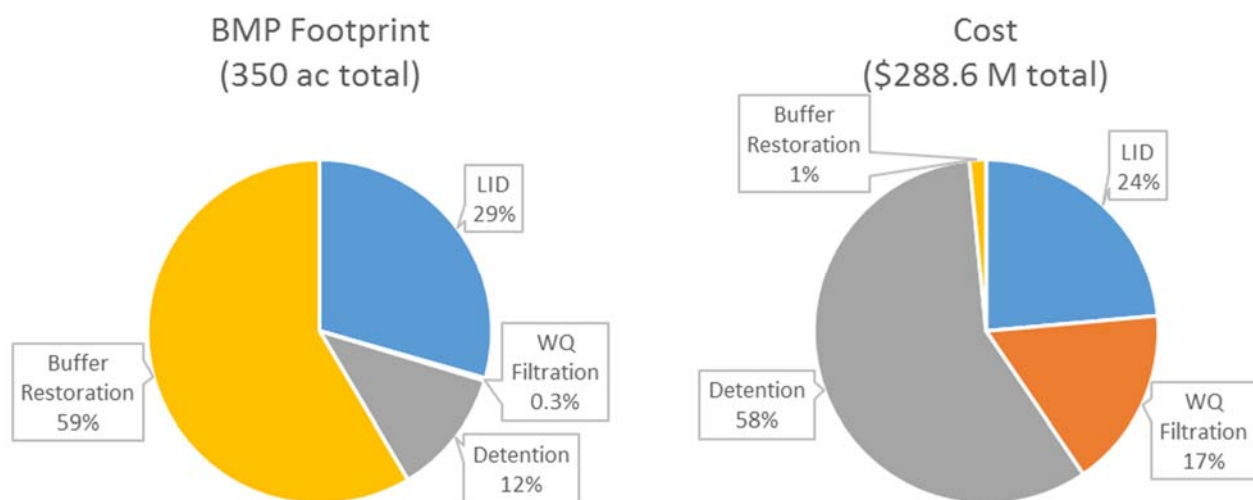


Figure 6. BMP footprint and cost distribution by type over study area

With all of the strategies discussed in this section included, modeling indicated that water quality standards and B-IBI targets would be met at all nine subbasin outlets. Summary results comparing the baseline future build-out condition with the modeled solution are presented in Table 18.

Table 18. Summary Water Quality Results

Constituent	Future Build-out under Current Code	Future Build-out with Plan
Dissolved Copper	✓	✓
Dissolved Zinc	✓	✓
Temperature	✗	✓
Fecal Coliform	✗	✓
B-IBI	✗	✓

Optional Programs

Due to the difficulty of quantifying benefits, fecal coliform source reduction programs were not credited as part of the modeled solution but are considered an important component of a comprehensive, community-based water quality program for the Little Bear Creek study area. Existing and potential future source reduction programs may include:

- Education and outreach, such as pet waste program
- Septic system inspection and maintenance
- Sanitary sewer inspection and repair
- Street sweeping and catch basin cleaning
- Riparian fencing and animal exclusion
- Food handling facility inspections
- Permit-required business inspection program
- Permit-required illicit discharge detection and elimination (IDDE) program

These strategies span diverse areas, including internal County programs, volunteer programs, and other agency programs or requirements. A fecal coliform source study would be a key initial action to determine the most significant types and locations of bacteria sources in the study area to best target reduction efforts. Costs associated with County source reduction activities were developed based on similar County programs and activities. This included start-up costs and staff support, based on routine activity levels, over a nominal 30-year timeframe. Costs were not developed for volunteer activities, or activities by non-County agencies.

Instream projects (optional under the Permit) are also incorporated into the Little Bear Creek Basin Plan as an option to provide diversified, multi-prong solutions to benefit habitat and stream biological conditions. Types and locations of instream projects will be identified based on geomorphic characteristics and habitat enhancement needs, as described in the process domain-based framework discussed in the *Stormwater Strategies Report* (Appendix C) and *Current Conditions Assessment Report* (Appendix A). The County proposes that implementation of instream projects should be adaptively managed. A rate of approximately one project per year was assumed for cost estimation purposes.

Monitoring and evaluation could be undertaken as projects are implemented over time to more accurately determine effectiveness of instream projects in elevating aquatic biological conditions. Quantifiable positive results for instream projects may relieve the need for more traditional stormwater improvements to improve aquatic biological health.

Cost Summary

The estimated cost for the full suite of proposed stormwater management actions is approximately \$308 million, as summarized in Table 19. In addition to costs of the strategies discussed in the previous sections, the total includes costs for additional programs and studies to support plan implementation (identified as Support Services in the table).

Table 19. Cost Summary for Proposed Stormwater Plan

Type of Strategy		Stormwater Management Target(s)			30-year Cost ¹
		Flow/B-IBI	Temperature	Fecal	
Modeled Strategies	Flow Control Facilities (LID & Detention)	✓	✓ ²	✓	\$ 235.4 M
	Buffer Restoration	--	✓	--	\$ 4.5 M
	WQ Filtration	--	--	✓	\$ 48.7 M
Non-Modeled Strategies	Fecal Source Control	--	--	✓	\$ 7.0 M
	Instream Projects	✓ ³	✓ ³	--	\$ 9.0 M
Support					\$ 3.6 M
Full Solution		✓	✓	✓	\$ 308.2 M

¹ Costs in 2016 dollars (PV), planning level.

² Temperature benefit from infiltration.

³ Primary target is habitat improvement. Some B-IBI and local temperature benefits expected.

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6 IMPLEMENTATION

This chapter describes the County’s proposed implementation actions, consistent with Permit Special Condition S5.c.5.c.iv (6), to achieve water quality standards and targets in the future, under the proposed Basin Plan. Permit Special Condition S5.C.5.c.iv (6) requires “an implementation plan and schedule that includes: potential future actions to implement the identified stormwater management strategies, responsible parties, estimated costs, and potential funding mechanisms.” The involvement of the public, partner jurisdictions, Tribes, agencies, and non-governmental organizations (NGOs) would be integral to the future implementation of this Basin Plan.

Section 6.1 describes an implementation plan and schedule for the Little Bear Creek study area. This includes potential future projects or programs to implement the identified stormwater management strategies, locations within the study area, schedule, and responsible parties. Section 6.2 describes cost estimates and potential funding mechanisms. Section 6.3 describes the County’s proposed application of adaptive management principles as part of the implementation plan to assess performance and to provide a basis for adjusting the implementation plan, as appropriate.

6.1 Potential Future Actions

General

The proposed strategies for stormwater management for the Little Bear Creek study area were described in Section 5.3. Implementation covers both capital projects and programmatic initiatives in the Little Bear Creek study area. Implementation is planned over 30 years, to coincide with 30-year life cycle costs, and is divided into four phases. Table 20 provides a phased schedule for implementation.

The County has identified structural BMPs needed in specific subbasins to improve water quality. Project prioritization and site selection are proposed as part of the implementation plan, during each phase of implementation. The implementation plan at this time does not identify specific projects and locations, allowing the necessary flexibility to identify suitable locations and to work with partners to install BMPs on public or private land. It also allows the flexibility of selecting suitable BMPs on the basis of factors such as costs, land availability, feasibility, and pollutant-removal efficiencies.

The ability to fully effect strategies identified in the implementation plan is contingent upon obtaining funding, as well as securing sites for retrofits. The estimated cost for this implementation plan exceeds the County’s current budget capacity and would require grant funding or funding from other as yet unidentified sources. This cost cannot be incorporated into the County’s budget without impacting other mandated responsibilities, as the study area comprises a small percentage of the entire County stormwater utility service area. Specific strategies in this plan that require funding would need to obtain approval through the County budgetary process. Funding is further discussed in Section 6.2.

The implementation plan is summarized in Table 21, located at the end of this section. This table follows the plan focus on achieving specific stormwater quality targets in the Little Bear Creek study area: enhancement of B-IBI (as represented by flow modification) and reduction of fecal coliform and

temperature. For each of the stormwater target areas, the table lists the proposed action (capital or programmatic), an estimated timeframe (indicated by the phase in which it is proposed), location, responsible parties, and estimated costs. The implementation plan schedule is shown in Table 20 and details the emphases of each phase of the plan.

Table 20. Implementation Plan Schedule

Phase	Period from Start of Implementation ¹	Phase Emphasis
1 - Set Up/Early Start	Years 1-6	<ul style="list-style-type: none"> • Maintain and enhance existing operational non-structural programs. • Source control study. • Modeling refinements. • Capital improvements as funding allows. • Monitor, evaluate, and adapt plan.
2 – Tier 1 Priority	Years 7-14	<ul style="list-style-type: none"> • Maintain and enhance operational non-structural programs. • Priority capital improvements as funding allows. (1st tier) • Monitor, evaluate, and adapt plan.
3 – Tier 2 Priority	Years 15-22	<ul style="list-style-type: none"> • Maintain and enhance operational non-structural programs. • Priority capital improvements as funding allows. (2nd tier) • Monitor, evaluate, and adapt plan.
4 - Completion	Years 23-30	<ul style="list-style-type: none"> • Maintain and enhance operational non-structural programs. • Capital improvements using new technology as funding allows. • Monitor, evaluate, and adapt plan.

¹Years are referenced to the start of implementation. For example, if implementation begins in 2018, year 1 is 2018, year 6 is 2025, and year 30 is 2047.

Flow/B-IBI

The Basin Plan identifies retrofit projects in specific subbasins of the Little Bear Creek study area that will help to reduce flashiness of stormwater runoff linked to deleterious effects on B-IBI. These are projects identified through SUSTAIN and HSPF modeling to provide flow control that reduces flashiness and increases B-IBI scores.

It is assumed that the County and WSDOT would be responsible for retrofit implementation within their respective jurisdictions. Actual County and WSDOT shares would be determined based on further evaluation of specific retrofit site opportunities and needs, as implementation is refined over time.

Instream projects, such as bank stabilization, wetland restoration, and channel reconnection, are also included as potential future actions to the extent practicable and could occur in any of the subbasins on larger reaches of tributaries or in the mainstem of Little Bear Creek. Instream projects are projected to be constructed at an average cost of about \$300 thousand per project, at a rate of one project per year for estimation purposes. These instream projects could be in addition to retrofit projects or could be implemented in lieu of certain retrofit projects, if found to provide the necessary B-IBI benefits.

Fecal Coliform

A number of projects or actions included in this plan are intended to reduce fecal coliform. Retrofit projects identified primarily for flow benefit (for B-IBI) are also anticipated to provide some fecal coliform reduction. Supplemental strategies include high flow capacity filtration or similar technology; these were added to the HSPF model to meet fecal coliform goals. Timing is preliminarily proposed for Phase 4, after the proposed implementation of other source controls and retrofit projects, to allow time for continued development and refinement of improved technologies. However, new and improved technologies could be implemented at any time, perhaps starting as pilot projects.

A fecal coliform source identification study is a non-structural activity proposed to be performed in advance of subsequent projects and targeted source control programs. A source identification study could identify specific point or non-point sources of fecal coliforms and would allow for more effective targeting of projects and programs. Cost estimates for this study are in the range of \$1 million to \$1.5 million.

Source controls could include continuation of current programs, program augmentation, or entirely new programs. Costs were estimated for continuation of programs at current levels. Some programs are grant funded. Source controls could also be revised within the framework of adaptive management, as described in more detail in Section 6.3. The following are current source control programs with activities that could be enhanced in the Little Bear Creek study area.

- The County operates a Business Inspection Program in which SWM inspects all businesses with the potential to produce stormwater runoff that may cause water quality degradation. This program could possibly be expanded to involve the Snohomish Health District, in a manner similar to Kitsap County's program, where there is collaborative work in a pilot program between the County and District to inspect and enforce for waste handling problems.
- The County conducts water quality investigations. These activities could potentially be expanded to involve the Snohomish Health District, similar to Kitsap County's program.
- The County has current education and outreach programs targeted at protection of water quality. These programs could be enhanced or expanded to focus more or provide more services related to fecal coliform control in the Little Bear Creek study area.
- State Agriculture Department assistance or regulatory support could be sought for farms that may be a source of fecal coliforms in the Little Bear Creek study area.

Infiltration and inflow control for sanitary sewers are activities typically performed by water and wastewater utility districts. The locations for such activities identified in this Basin Plan are in UGA

subbasins with sanitary sewer lines, which would primarily include the Little Bear Lower County Line, Little Bear Lower 228th, and Little Bear Upper subbasins, as well as parts of Cutthroat Creek, West Trib, and Trout Creek. Corrective efforts on any identified sewer system leaks could reduce bacteria from entering the storm drainage system through exfiltration.

Temperature

Capital projects and programs are proposed to reduce stream temperatures in the Little Bear Creek study area. Some retrofit projects identified in SUSTAIN modeling primarily for flow benefit (for B-IBI) are also anticipated to provide temperature reduction, particularly infiltration-based BMPs, and are not listed separately under this category. Costs associated with these projects are accounted for in the flow/B-IBI section. In addition to BMPs identified in the SUSTAIN modeling, supplemental infiltration BMPs are proposed for implementation in the West Trib subbasin to further mitigate late summer stream temperature exceedances. Supplemental infiltration may be implemented in Phase 2, 3 or 4. The cost estimated for supplemental infiltration is approximately \$6 million, based on an additional 1.1 acres of bioretention-type BMPs.

Buffer restoration offers potentially significant temperature benefits and is proposed as a capital program as part of this Basin Plan. Riparian buffer planting is proposed to be implemented on a voluntary basis, with the County working in cooperation with landowners by providing trees, support, and coordination. The goal of this action is to restore full shading of the streams by providing a forested buffer at least 30 feet wide on each side of the stream. The cost estimate is in the range of \$4 million for tree planting and weed control (knotweed, blackberry, ivy, etc.) over approximately 200 acres along Little Bear Creek and its tributaries.

Table 21. Implementation Plan and Phasing

Note: All actions are subject to funding availability.

Water Quality Target	Estimated Timeframe	Action Chosen	Location (Subbasin)	Responsible Parties ¹	Estimated Cost ² (rounded)
1. Flow/B-IBI	Retrofit: Capital Projects				
	Phase 1	a. Refine Little Bear modeling b. Evaluate, conduct additional study as needed, develop monitoring QAMP	All (100-900)	<ul style="list-style-type: none"> County: Project development and implementation 	\$1 M- \$2 M (to be further determined, depends on scope and extent)
	All Phases	c. Retrofit projects in Little Bear	All (100-900)	<ul style="list-style-type: none"> County: Project development and construction WSDOT: Project development and construction (when triggered by HRM) 	\$250k annually for Phase 1, balance of cost divided among Phases 2, 3, 4.
	In-Stream Supplemental Strategies:				
	All Phases	d. In-stream projects	Selected subbasins, depending on need, opportunity	<ul style="list-style-type: none"> County: Project development and construction WSDOT: Project development and construction 	\$300k each, assumed annually for estimation purposes, about \$ 9 M total, could replace retrofit project

Water Quality Target	Estimated Timeframe	Action Chosen	Location (Subbasin)	Responsible Parties ¹	Estimated Cost ² (rounded)
2. Fecal Coliform	Retrofit: Capital Projects:				
	All	a. Retrofit projects (potentially same projects as retrofits for flow/B-IBI)	All (100-900)	<ul style="list-style-type: none"> County: Project development and construction WSDOT: Project development and construction (when triggered by HRM) 	(Costs included in Flow/B-IBI retrofit projects)
	Structural Supplemental Strategies:				
	Phase 4 (after evaluation of Phase 3)	b. New technology: High Flow Capacity Media Filtration /Bioretention	All (100-900)	<ul style="list-style-type: none"> County: Project development and construction WSDOT: Project development and construction (when triggered by HRM) 	\$49M
	Non-Structural Supplemental Strategies/Additional BMPs:				
	Phase 1	c. Source Identification Study	All (100-900)	<ul style="list-style-type: none"> County: Project development and implementation 	Up to \$1.5M, depending on scope and extents
	All Phases	d. Savvy Septic	Non-UGA (200, 400-700)	<ul style="list-style-type: none"> County: Outreach Snohomish Health District: Outreach, inspection 	(Grant dependent)
	All Phases	e. Septic Inspection	Non-UGA (200, 400-700)	<ul style="list-style-type: none"> Snohomish Health District: inspection 	To be determined after source study

Water Quality Target	Estimated Timeframe	Action Chosen	Location (Subbasin)	Responsible Parties ¹	Estimated Cost ² (rounded)
	All Phases	f. Business Inspection	All (100-900)	<ul style="list-style-type: none"> County: County inspection program 	\$400k over 30 years
	All Phases	g. WQ Investigations, coordinated with Snohomish Health District	All (100-900)	<ul style="list-style-type: none"> County: County investigation program Snohomish Health District: Investigation co-visits (e.g. food waste handling) 	\$200k (County cost estimate only; SHD cost estimate to be determined after source study)
	All Phases	h. Education and Outreach	All (100-900)	<ul style="list-style-type: none"> County: Program development and implementation 	\$3M total. Phase 1 includes program development.
	All Phases	i. Catch basin cleaning and street sweeping ³	Selected subbasins for street sweeping, all for catch basin cleaning	<ul style="list-style-type: none"> County and WSDOT for respective facilities 	\$2M for County
	All Phases	j. Storm water treatment and flow control BMP maintenance	Selected subbasins	<ul style="list-style-type: none"> County and WSDOT for respective facilities 	\$300k for County

Water Quality Target	Estimated Timeframe	Action Chosen	Location (Subbasin)	Responsible Parties ¹	Estimated Cost ² (rounded)
	Supplemental Strategies/Additional BMPs by other Agencies:				
	Phase(s) 2, 3 or 4	k. Infiltration and Inflow Control	UGA (primarily 100, 300, 900, parts of 400, 700, 800)	<ul style="list-style-type: none"> Alderwood Water & Wastewater District Silver Lake Water & Sewer District Cross Valley Water District: Funding, Program development and implementation 	To Be Determined
	Phase(s) 2, 3 or 4	l. Business Inspection	All (100-900)	<ul style="list-style-type: none"> Snohomish Health District: Inspection co-visits (e.g. food waste handling) 	To Be Determined
	Phase(s) 2, 3 or 4	m. Farm Inspection	All (100-900)	<ul style="list-style-type: none"> State Dept. of Agriculture: Farm assistance, regulation 	To Be Determined
3. Temperature	Retrofit: additional/updated facilities				
	All phases	Retrofit projects (potentially same projects as retrofits for flow/B-IBI)	All (100-900)	<ul style="list-style-type: none"> County: Project development and construction WSDOT: Project development and construction (when triggered by HRM) 	(Costs included in Flow/B-IBI retrofit projects)
	Supplemental Strategies/Additional BMPs:				
	All Phases	n. Voluntary buffer planting	All (100-900)	<ul style="list-style-type: none"> County: Project development and implementation 	\$4.5M (assumes no land cost)

Water Quality Target	Estimated Timeframe	Action Chosen	Location (Subbasin)	Responsible Parties ¹	Estimated Cost ² (rounded)
	Phase 2,3 or 4	o. Supplemental infiltration	700	<ul style="list-style-type: none"> County: Project development and construction, funding WSDOT: Project development and construction (when triggered by HRM and deemed feasible) 	\$6M

¹ See Section 6.2 for discussion of responsible parties.

² Costs in 2016 dollars, present value, planning level.

³ WSDOT conducts sweeping operations to keep road surfaces clean and remove sediment, leaves, litter, and other debris before it enters the storm drain system or surface waters. Debris accumulation may require sweeping to occur as frequently as twice a month. The extent of debris accumulation and funding provided by the State Legislature dictates scheduling. (WSDOT's NPDES Municipal Stormwater Permit. Appendix 5 Stormwater Management Program Plan. 2014)

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Schedule

The implementation plan is designed to take place over 30 years in four phases. Table 22 presents a high level depiction of the schedule for implementation.

Table 22. Implementation Phasing Summary

Phase	Years	Est. Cost	Percent of Cost	
1. Set Up/Early Start	1-6	\$ 9 M	3%	
2. Tier 1 Priority	7-14	\$ 83 M		27%
3. Tier 2 Priority	15-22	\$ 83 M		27%
4. Completion	23-30	\$ 132 M		43%
TOTAL		\$ 308 M		100%

Planning level costs estimated in 2016 dollars (PV).

Phase 1 (years 1 through 6 of implementation), would be an initiation and early action phase. Phase 1 would include maintaining existing operational programs (and enhancing where appropriate), conducting a fecal coliform source identification study, continued monitoring, and further assessment and/or refinement of the basin models to improve their utility for project planning. This first phase is also proposed to include capital improvement project selection and prioritization, as well as seeking out funding sources to support the Basin Plan. Detailed scheduling would be developed for the implementation of subsequent phases.

The initial phase of the Little Bear Creek Basin Plan implementation is also proposed to include the development of a Quality Assurance Monitoring Plan (QAMP) for the study area. The QAMP will provide methodology and procedures for data collection to evaluate the efficacy of implementation efforts. The monitoring data will be utilized to evaluate implementation plan actions in comparison to water quality and flow targets accounting for natural variability, data collection procedures, and data interpretation thresholds. The monitoring results will inform the approach and decisions related to adaptive management. In general, B-IBI monitoring is proposed to be performed every year. Water quality monitoring (for temperature and fecal coliform) is anticipated to be performed within the last two years of each phase, including Phase 1. The Basin Plan would be evaluated and adapted as appropriate within the last two years of Phase 1, based on monitoring results. The estimated cost for this phase is approximately \$9 million. The extent of implementation within this timeframe would depend on the availability of funding.

Phase 2 of the Basin Plan implementation is proposed to occur in years 7 through 14, and include the first tier of high priority capital improvement projects, using established technologies. New treatment technologies could be considered and included if deemed appropriate. The implementation of the Basin Plan would be evaluated and adapted as appropriate within the last two years of Phase 2, based on monitoring results. The estimated cost for this phase is approximately \$83 million. The extent of implementation within this timeframe would depend on the availability of funding.

Phase 3 is proposed to occur in years 15 through 22, and is proposed to include the second tier of high priority capital improvement projects, using established technologies and potentially promising new treatment technologies. The Basin Plan would be re-evaluated and adapted as appropriate within the last two years of the phase, based on monitoring results. The estimated cost for this phase is approximately \$83 million. The extent of implementation within this timeframe would also depend on the availability of funding.

Phase 4, the last phase in years 23-30, is proposed to include projects that have a greater likelihood of being modified through adaptive management, depending of the effectiveness of the projects implemented in previous phases. The estimated cost for this phase is approximately \$132 million. The extent of implementation will depend on availability of funding.

6.2 Potential Funding Mechanisms

The total cost to implement the full suite of retrofit projects and non-structural programs is estimated at \$308 million, based on 30-year life cycle costs in 2016 dollars. This level of projects and programs, if implemented, would reflect an extraordinary increase in local government services and costs and require consideration of additional revenue sources beyond County government for implementation. The proposed County level of funding is estimated at \$3.2 million (in 2016 dollars), based on current programs and funding practices for activities in the Little Bear Creek study area. Additional revenue needed for the full implementation of the Basin Plan is estimated at about \$305 million (in 2016 dollars), and is projected to be largely grant dependent.

The Basin Plan concludes that the Little Bear Creek study area is not projected to meet certain water quality standards and targets at full build-out, but specific sources of deficiencies are not fully understood. With this uncertainty, the diversity and extent of governmental jurisdictions and potential funding mechanisms discussed in this section reflect overlapping interests and responsibilities for stormwater and water quality in the Little Bear Creek study area. The County is responsible for stormwater quality and management for discharges from its MS4. Other governmental agencies have responsibility for their respective stormwater discharges, facilities and operations, or for protecting water and environmental quality of those areas and waters that fall within their jurisdictions or interests. Therefore, this implementation plan proposes to seek mutual cooperation and coordination with other jurisdictions and special purpose districts to clarify responsibilities for funding as well as to leverage mutual efforts.

Major sources of funding for Snohomish County's surface water management projects and programs include service charge revenues collected under Snohomish County Code (SCC) Title 25, County Road Funds, Real Estate Excise Tax, and grant revenues from external agencies.

Other governments and special purpose districts with stormwater and/or water quality related jurisdiction, activities or operations in the Little Bear Creek study area, include but are not limited to:

- Washington State Department of Ecology (Ecology)
- Washington State Department of Fish and Wildlife (WDFW)
- Washington State Department of Transportation (WSDOT)
- Snohomish Health District

- Snohomish Conservation District
- Cross Valley Water District
- Alderwood Water and Wastewater District
- Silver Lake Water and Sewer District

The existing programmatic and jurisdictional practices of these agencies are expected to continue; however, changes, including additional practices or enhancements, may occur over the course of the implementation of this Basin Plan.

Governmental and public agencies that also have property, facilities, or other stormwater and water quality related interests in the Little Bear Creek study area include King County, Northshore School District, Everett School District, Snohomish School District, Snohomish County PUD No. 1, Snohomish County Fire District No. 7, Seattle City Light, University of Washington, and Bonneville Power Authority.

With particular respect to WSDOT responsibilities and funding, WSDOT's National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permit requires WSDOT to request adequate resources from the Legislature in order to maintain compliance with their permit and implement the stormwater management program. This funding is part of the State Transportation Budget. Highway construction and stand-alone stormwater retrofit funds are apportioned separately by the Legislature. In accordance with RCW 90.03.525, WSDOT has an existing stormwater utility fee program that is used to help compensate local jurisdictions for managing stormwater from state highways.

In the past, sources of grant revenue for stormwater and water quality projects and programs have included Ecology, the U.S. Environmental Protection Agency, State Department of Natural Resources, U.S. Army Corps of Engineers, Federal Emergency Management Agency, regional governmental grant clearinghouses, and other sources. The County anticipates the need to work in partnership with these and other contributing agencies if the proposed Basin Plan is to be implemented. Due to the large cost and scale of capital projects (including potential instream projects) and programs in the Little Bear Creek Basin Plan, the availability and timing of grants and other outside funding will largely determine the actual timeframe for implementation.

The County proposes to investigate and evaluate these and possibly other potential funding and collaborative options further, as a part of the implementation of the first phase of the Basin Plan. Future County funding for the Little Bear Creek study area is expected to continue approximately at current levels. A summary of existing County revenue sources is presented in Table 23. Potential grant funding sources are listed in Table 24.

Table 23. Summary of Existing County Revenue Sources

Existing Revenue Sources	Description
Surface Water Management (SWM) Service Charges	Revenues for much of the County Surface Water Management Utility District surface water management activities are collected under Snohomish County Code (SCC) Title 25, accounting for about \$19 million annually. The Little Bear Creek watershed surface water revenues are about \$1 million or nearly 5% of the service charge revenues, under the authority of RCW Chapter 36.89. (SCC Title 25).
Urban Growth Area (UGA) Service Charges	Under the authority of RCW 36.89, UGA service charge rates are specified in SCC Title 25. This is an additional surcharge to SWM service charges, in part to reflect a higher level of service in UGA areas.
Grants	Surface water programs in the County receive substantial competitive State and Federal funds from various grant programs. (Further grant source information in Table 24.).
Real Estate Excise Tax (REET)	Real estate excise tax on transactions that involve conveyance of property. The County collects this tax and allocates portions to various County departments in the annual budget process. In the past REET has been an important source of surface water capital funding.
Road Fund	The County Road Fund is used for the construction, maintenance and inspection of county roads, bridges, and other countywide public works projects.
General Fund	The County General Fund is the primary operating fund of the County and is used for funding services and operations of multiple county functions and departments.

Table 24. Potential Grant Sources

Grant Name	Funding Source (Agency)	Grant Description
Section 319 Grants	Washington Department of Ecology (Ecology)	Typical water quality projects include agricultural BMPs; education and stewardship; water quality monitoring; lake water quality monitoring; riparian and wetlands habitat restoration and enhancement; stream restoration; TMDL plan development and implementation; and wellhead protection.
Centennial Grants	Ecology	Provides grants for water quality infrastructure and nonpoint source pollution projects to improve and protect water quality. Eligible infrastructure projects are limited to wastewater treatment construction projects for financially distressed communities. Eligible nonpoint projects include stream restoration and buffers, on-site septic repair and replacement, education and outreach, and other eligible nonpoint activities.
Stormwater Financial Assistance	Ecology	Funds projects that address existing pollution problems and provide a high level of water quality benefit.
Watershed Planning Implementation and Flow Achievement Grants	Ecology	Funds projects that increase flows below the project site; improve instream and riparian zone conditions (such as enhancing fish passage or habitat); reorganizing or concentrating points of diversion; establishing water banks, water exchanges, or pursuing trust water opportunities; improving public water supply or irrigation district infrastructure that leads to water savings.
Salmon Recovery Grants	Washington State Recreation and Conservation Office (RCO) Salmon Recovery Funding Board	Projects that protect existing, high-quality habitats for salmon, and restore degraded habitat to increase overall habitat health and biological productivity. Typical projects include replacing fish barriers, replanting stream banks, removing dikes and levees, installing large woody debris to protect shorelines, and buying pristine habitat.
Puget Sound Acquisition and Restoration/Salmon Recovery Funding Program	RCO	Funds projects that protect existing, high-quality habitats for salmon, and that restore degraded habitat to increase overall habitat health and biological productivity. Projects may include the actual habitat used by salmon and the land and water that support ecosystem functions and processes important to salmon.
Land and Water Conservation Fund (LWCF)	RCO	Funding to preserve and develop outdoor recreation resources, including parks, trails, and wildlife lands. Typical LWCF projects include land acquisition and development or renovation, such as renovating community parks, building new parks and trails, protecting wildlife habitat, and building athletic fields.

Grant Name	Funding Source (Agency)	Grant Description
Washington Wildlife and Recreation Program	RCO	Funding for a range of land protection and outdoor recreation projects, including park acquisition and development, habitat conservation, farmland preservation, and construction of outdoor recreation facilities.
Estuary and Salmon Restoration Program (ESRP)	Washington State Department of Fish and Wildlife	ESRP was created to support the emerging priorities of the Puget Sound Nearshore Ecosystem Restoration Program. Typical projects include nearshore restoration and protection activities that restore natural ecosystem processes and functions, including protection of nearshore and wetland habitat, restoration of salmon habitat and estuaries, removing or breaching dikes, removing bulkheads, feasibility and design, and decommissioning roads and removing fill.
Landscape Scale Restoration	Washington State Department of Natural Resources	Funds projects that address priorities identified in Washington's Forest Action Plan and national themes of conserving working forests and enhancing public benefits from trees and forests, which include: clean air and water, fish and wildlife habitat, open space, outdoor recreation opportunities, and climate change buffering.
Trout and Salmon Foundation	Private funding and donations	Provides matching for an individual project that aids in the restoration or improvement of any trout stream, salmon fishery, and/or ambient stream conditions through research, education, publication, and physical stream restoration that will result in improved fish reproduction, fish growth and survival, or expansion of the trout/salmon fisheries.
Pre-Disaster Mitigation Grant	Federal Emergency Management Agency (FEMA)	This FEMA program assists applicants in implementing a sustained pre-disaster natural hazard mitigation program. Hazard mitigation is the effort to reduce loss of life and property by lessening the impact of disasters, most effective when implemented under a comprehensive, long-term mitigation plan.
Conservation Stewardship Program	US Department of Agriculture Natural Resources Conservation Service (USDA NRCS)	Assists agricultural and forest landowners build on existing conservation efforts while strengthening their operation. From improved grazing conditions, increased crop yields, to developing wildlife habitat, CSP can help. CSP offers annual incentive payments for installing these practices on your land.
Environmental Quality Incentives Program	USDA NRCS	Provides financial and technical assistance to agricultural producers to plan and implement conservation practices that improve soil, water, plant, animal, air, and related natural resources on agricultural land and non-industrial private forestland.
Regional Conservation Partnership Program	USDA NRCS	Partners (recipient of program funding) help producers and private landowners install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved.

Grant Name	Funding Source (Agency)	Grant Description
Agricultural Conservation Easement Program	USDA NRCS	Provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. Under the Agricultural Land Easements component, NRCS helps American Indian tribes, state and local governments, and non-governmental organizations protect working agricultural lands.
Community-based Coastal and Marine Habitat Restoration	National Oceanic and Atmospheric Administration U.S Department of Commerce	Seeks restoration projects that use a habitat-based approach to promote productive and sustainable fisheries, improve the recovery and conservation of protected resources, and promote healthy ecosystems and resilient communities.
Five Star & Urban Waters Restoration Programs	National Fish and Wildlife Foundation (NFWF) and others	Assists with projects focused on improving water quality, watersheds, and the species and habitats they support. Funding priorities for this program include on-the-ground wetland, riparian, in-stream, and/or coastal habitat restoration; education and training activities; measurable ecological, education, and community benefits; and partnerships to achieve ecological and educational outcomes.
Bring Back the Natives/ More Fish	NFWF	Funding priorities focus on projects that produce measurable outcomes for native fish species of conservation concern. Projects should focus on restoring habitat connectivity; restoring riparian, instream habitat, and water quality; invasive species management; and innovation and game changing research.
National Fish Passage Program	US Fish and Wildlife Service	Funds fish passage projects. A fish passage project is any activity that improves the ability of fish or other aquatic species to move by reconnecting habitat that has been fragmented by barriers.
Drinking Water Providers Partnership	Working Waters – Geos Institute	Partnership including USDA, Forest Service, Geos Institute, Oregon Department of Environmental Quality, Washington State Department of Health, EPA, U.S. Bureau of Land Management, and WildEarth Guardians, with goals of restoring and protecting the health of watersheds, which communities depend upon for drinking water, and benefitting aquatic and riparian ecosystems, including the fish that inhabit them, through successful implementation of projects.

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6.3 Adaptive Management

With the uncertainties that accompany such an expansive program in general, and rapidly changing stormwater management technologies in particular, flexibility to adjust the Plan to account for initial implementation results and new information and technologies is critical. As part of this implementation plan, the County proposes the application of principles of adaptive management throughout the phased approach, as explained below. In this way, the Basin Plan can allow for new technologies and methods to meet the difficult challenge of achieving water quality standards and targets throughout the study area for future build-out conditions.

The Basin Plan includes targets, strategies, and a proposed level of effort for action based on modeling of stormwater management scenarios. Other proposed actions do not derive from modeled scenarios, strategies or actions. Either way, and regardless of model accuracy or precision, there is sufficient uncertainty with respect to outcomes from implementation that monitoring the effectiveness of selected BMPs, as well as the status of flow, water quality and B-IBI conditions, is a necessary and appropriate part of implementation.

Adaptive management can be used to modify strategies, incorporate new information and new technologies, increase or decrease level of effort, or reduce plan implementation if targets and objectives have been reached, based on thresholds established for target attainment. In short, adaptive management can allow a more nimble response to new information and, long term, lead to a more efficient use of resources.

Any implementation plan should be adaptively managed over time for effectiveness. Five areas that may incorporate adaptive management include:

Model refinement. Refinement of the modeling used to project water quality conditions and effectiveness of proposed stormwater management strategies is proposed. The models employed were complex and large scale, incorporating many assumptions. The modeling methods used were developed for the purposes of the Little Bear Creek basin planning effort within resource and time parameters. Review and further refinement of the modeling beyond the current study effort could improve some assumptions and potentially reduce uncertainty in results. Improved results may then lead to modifications to the potential future actions needed to meet water quality standards and targets.

Action effectiveness. The selected structural and non-structural strategies, including capital improvements and operations and maintenance activities, represent presumptive solutions to projected water quality compliance needs and flow targets. Actual performance may vary upon implementation--positively or negatively—and lead to the need for adaptation.

Revisiting assumptions. The model and planning data used provided a best estimate of future build-out conditions. This included such major inputs as the current County Comprehensive Plan, development code and standards, existing and planned capital facilities, developable land evaluation, development suitability evaluation, and watershed conditions data. However, there is naturally some degree of uncertainty over actual future conditions, and changes may occur that were not anticipated in the

original modeling and evaluation. Such changes may result in water quality in the Little Bear Creek study area that is different from that projected, and would lead to the need for adaptations to the Basin Plan implementation.

New technology. In order to find solutions to future water quality needs and targets, the Little Bear Creek basin planning project needed to go beyond standard modeling methods and stormwater management practices. Advanced modeling and technology were used, including EPA SUSTAIN, customized optimization and data processing for HSPF, specialized GIS analysis of land cover and development suitability, and advanced stormwater treatment technology (particularly for fecal coliform). Further technological advances may also occur. This basin planning effort has provided the County with additional tools to evaluate future water quality conditions and strategies to protect water quality. As with all new technologies, application and experience will be invaluable to their improvement and refinement, leading back to the modeling refinement noted above, which would lead to adaptations to implementation.

Monitoring data. Assuming funds are available, monitoring is proposed to continue over time and track the status and trends of target indicators (water quality, B-IBI, temperature, flow). These indicators are projected to improve over time with implementation of the plan described in Section 6.1. Monitoring results could then indicate whether basin locations are all improving or whether there is uneven progress, which could suggest the need to alter the level of effort by location. Alternatively, if monitoring indicates that targets are attained sooner than expected, then plan adaptation could reflect a reduction in new capital construction and a greater emphasis on operations and maintenance, as well as stewardship and outreach.

Adaptive management is proposed to be developed and implemented within each phase of plan implementation with the recognition that for some plan targets and observed changes, confidence in results described by monitoring data may take years to determine. This can be particularly true where natural variability in stream ecosystems also influences the target conditions as much as—if not more than—the accumulation of plan actions.

7 REFERENCES

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Appendix A: Current Conditions Assessment Report

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Appendix B: Watershed Modeling Report

Report available under separate cover.

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Appendix C: Stormwater Strategies Report

Report available under separate cover.



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Appendix D: Permit Requirements Crosswalk

Permit Reference No.	Permit Requirement	How Addressed	Document Location
S5.C.5.c.iv.(1)	An assessment of existing hydrologic, biologic, and water quality conditions and an assessment of the current status of the aquatic community in the study area.	Snohomish County met this requirement with its review of data; stormwater quality sampling of base flows and storm flows; continuous flow monitoring, macroinvertebrate data collection for the purposes of estimated current Benthic Index of Biotic Integrity (B-IBI) scores, and assessed the aquatic community conditions. The analysis was documented in the Current Conditions Assessment (CCA) Report.	Appendix A
S5.C.5.c.iv.(2)	A compilation and/or generation of maps of the study area to identify the existing distribution and totals of general soil types, vegetative land cover, impervious land covers, MS4s and non-regulated public stormwater systems (if applicable). Maps shall be sufficient to allow construction of a rainfall/runoff model representation of the study area. Maps must also identify areas within the study area appropriate for special attention in regard to hydrologic and water quality impacts.	Snohomish County met this requirement with its development and/or updating of existing maps to support hydrologic/hydraulic and water quality modeling of the study area. Map figures are included in the CCA (Appendix A) and Watershed Modeling Report (Appendix B). GIS data sources are listed in in Appendix A to the CCA. Several of the maps were used as the basis for development of a continuous runoff model of the study area.	Appendix A and Appendix B. The following is a partial shapefile listing corresponding to the listed map types in S5.C.5.c.iv.(2); additional shapefiles are also listed in Appendix A to the CCA: General soil types: SSURGO_BasinSoils; Vegetative land cover: landcover_NAIP2013_v4; Impervious land covers: App. A, landcover_NAIP2013_v4; MS4s: Snohomish County: drainage_facilities_pnts, utilities_drainage_catchbas, utilities_drainage_drainpnt, utilities_drainage_network, utilities_drainage_xs;

Permit Reference No.	Permit Requirement	How Addressed	Document Location
			<p>Bothell:</p> <p>Bothell_Berms_PondSwale, Bothell_BioSwales, Bothell_catchbas, Bothell_culverts, Bothell_dams, Bothell_DetentionPonds, Bothell_ditches, Bothell_OpenChannels, Bothell_Pipes, Bothell_Pipes_Detention, Bothell_Vaults, Bothell_Wetlands;</p> <p>Woodinville:</p> <p>Commercial_detention, Woodinville_facility, Woodinville_residential_detention, Woodinville_structure_VaultLid, swfacility, sw_inlet_outlet, sw_openchannel, sw_pipe, sw_structure</p> <p>Special attention:</p> <p>CAR_Aquifer_usgs_sensitivity, LBC_wetlands_CAR2007, LBCWetland_NWI, LBC_Wetlands_PDS; Bothell_Wetlands</p>
S5.C.5.c.iv.(3)	Permittee shall use the existing conditions assessment in S5.C.5.c.iv.(1) and the maps described in S5.C.5.c.iv.(2), and calibrate a continuous runoff model to reflect the existing hydrologic, water quality, and	Snohomish County met this requirement with its development of a HSPF continuous hydrologic model that was calibrated to existing conditions.	Summarized in Section 1.3 of this Basin Plan. Detailed documentation of model development and calibration included in Appendix B.

Permit Reference No.	Permit Requirement	How Addressed	Document Location
	biologic (as represented by B-IBI score) conditions.		
S5.C.5.c.iv.(4)	Permittee shall use the calibrated model to estimate hydrologic changes from the historic condition; predict the future hydrologic, biologic, and water quality conditions at full build-out under the existing comprehensive land use management plan for the study area.	Snohomish County met this requirement with its use of the calibrated HSPF model to estimate changes in hydrologic conditions, B-IBI scores, and water quality concentrations of the pollutant parameters listed in the Permit between historical forested conditions and future land use conditions. Future land use development was assumed to include stormwater mitigation BMPs meeting current standards. B-IBI correlation evaluation was conducted and DeGasperi metrics were used based on WRIA dataset, as documented in the County's memo response to Ecology dated February 3, 2017.	Modeling results were summarized in Key Findings subsections of Chapters 3 and 4 of this Basin Plan. Further detail is provided in Appendix B.
S5.C.5.c.iv.(5)	If the estimation in S5.C.5.c.iv.(4) predicts water quality standards will not be met, the Permittee shall use the calibrated watershed model to evaluate stormwater management strategies to meet the standards.	Snohomish County met this requirement with its use of the calibrated HSPF model in combination with a SUSTAIN model, to evaluate a combination of structural and non-structural measures that if implemented were projected to fully meet water quality standards.	This is summarized in Chapter 5 of this Basin Plan. Additional information is provided in Appendix C (Stormwater Strategies Report).
S5.C.5.c.iv.(5) continued	Stormwater Strategies to be evaluated must include: <ul style="list-style-type: none"> Changes to development-related codes, rules, standards, and plans. 	Snohomish County met this requirement with its evaluation of strategies for implementing changes to development requirements. SUSTAIN	Non-structural strategies evaluated are discussed in Section 5 of this Basin Plan. Further detail is provided in Appendix C.

Permit Reference No.	Permit Requirement	How Addressed	Document Location
		was used in combination with the calibrated HSPF model to optimize combinations of code change impacts with structural projects.	
S5.C.5.c.iv.(5) continued	<p>Stormwater Strategies to be evaluated must include:</p> <ul style="list-style-type: none"> Potential future structural stormwater control projects 	<p>Snohomish County met this requirement with its evaluation of strategies for implementing potential future structural control projects. SUSTAIN was used in combination with the calibrated HSPF model to optimize combinations of structural projects.</p>	<p>Structural strategies evaluated are discussed in Section 5 of this Basin Plan. Further detail is provided in Appendix C.</p>
S5.C.5.c.iv.(6)	<p>An implementation plan and schedule, including: potential future actions to implement the identified stormwater management strategies, responsible parties, estimated costs, and potential funding mechanisms.</p>	<p>Snohomish County met this requirement in this Basin Plan, which includes an implementation plan and schedule with the required elements: potential future actions to implement the identified stormwater management strategies, responsible parties, estimated costs, and potential funding mechanisms. Also an adaptive management strategy is defined to guide implementation of the potential future actions under this proposed implementation plan.</p>	<p>Chapter 6 of this Basin Plan describes these required elements as well as the recommended adaptive management approach.</p>
S5.C.5.c.iv.(7)	<p>A public review and comment process, at a minimum, focused on the draft watershed-scale stormwater plan. The public review must allow for public comment from all governmental entities with jurisdiction within the study area.</p>	<p>Snohomish County met this requirement with its planning process, which has included ongoing coordination with a technical stakeholder group that includes all governmental agencies with jurisdiction in the study area as well as a public</p>	<p>The public outreach process is summarized in Section 1.2. More information on public outreach is provided in Appendix E.</p>

Permit Reference No.	Permit Requirement	How Addressed	Document Location
		meeting on June 21, 2017, to receive comments on the Basin Plan.	
S5.C.5.c.v	The watershed-scale stormwater planning process, as documented in the scope of work and schedule, may include an evaluation of strategies to preserve or improve other factors that influence maintenance of the existing and designated uses of the stream.	Snohomish County has included this option in its planning process. Snohomish County has conducted an evaluation of study area conditions and development of a process-domain based method for evaluation and selection of instream strategies to preserve or improve other factors that influence maintenance of the existing and designated uses of the stream.	Instream strategies are discussed in Chapter 5 of this Basin Plan. Further detail is provided in Appendix C.

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Appendix E: Public Outreach Summary

Overall, the County aimed to exceed the minimum Permit requirement for public review in Special Condition S5.C.5.c.iv (7).

In spring 2015, prior to the beginning of the public outreach effort, the County established project webpages devoted to the Little Bear Creek planning effort, www.littlebearcreek.surfacewater.info. The webpage initially included the background, project scope, timeline and project manager's contact information. It was expanded over the life of the project to include relevant resources, studies and reports associated with the project, meeting information and handouts, and the draft plan and appendices. Interested parties were able to sign up to receive an email notice when the new information was posted.

The County's initial project outreach effort occurred in spring, 2015, when the County sent a mailer to over 700 streamside property owners to introduce the Little Bear Creek water quality study as preparation for a watershed-scale plan for water quality improvements. The mailer noted that County staff would be gathering stream data on habitat conditions, stream temperature and pollution levels, and requested permission to access Little Bear Creek through their private property. Approximately 30% of the property owners responded positively to the mailing, which provided county staff with good access for data collection.

The project team held meetings for the public and stakeholders at key points in the project at the Brightwater Center in Woodinville. The meetings were documented on the project meeting page, <http://snohomishcountywa.gov/3736/Little-Bear-Creek-Meetings>. This page includes direct links to agendas, PowerPoint presentations, and other relevant information presented at each of the five public meetings. The timing and purpose of these meetings was as follows:

- **March 23, 2016 Stakeholder Workshop;** held to introduce the project to stakeholders
- **April 19, 2016 Public Open House;** held to introduce the project to the community at large
- **November 2, 2016 Technical Workshop #1;** held to present the results of the water quality data and analysis and introduce the modeling approach and strategy to stakeholders and other technical experts
- **February 14, 2017 Technical Workshop #2;** held to present the modeling results and receive input on strategies for plan to stakeholders and other technical experts
- **June 21, 2017 Public Open House;** held to present the Draft Little Bear Creek Basin Plan to the community at large

Meeting announcements for the Stakeholder/Technical Workshops were sent via email to representatives of non-governmental organizations and governmental entities with jurisdiction within the Little Bear Creek study area and publicized on the Little Bear Creek project website. Meeting announcements for the Public Meetings were publicized via (1) postcards and letters to all property owners within the Little Bear Creek study area, (2) email notices sent to representatives of non-governmental organizations and governmental entities with jurisdiction or interest in the Little Bear Creek study area, (3) media alerts sent to the Everett Herald and other local newspapers, (4) social

media, (5) notice on the Little Bear Creek project website. Notice of the June 21, 2017 meeting included a newspaper ad in the Everett Herald, and newspaper web notice.

All the meetings were well-attended. The final June 21, 2017 open house to present the draft plan attracted 66 area residents, who participated actively in the question and answer session and in completing comment cards. Comments were due on July 6th. Some minor revisions to the Modeling Report were made and posted to the project website after the June 21st meeting. Email notices of the Modeling Report posting were sent to those who had provided email addresses for website or project updates, and governmental entities with jurisdiction or interest in the Little Bear Creek study area. The comment period for these revisions was extended to July 14th. An overview of the input received at the meeting and via email afterward was added to the meeting record online.

Comments received on the draft Little Bear Creek Basin Plan were considered in completing the final Basin Plan.

Table 1 below lists governmental entities that were contacted and invited to comment on the Little Bear Creek Basin Plan.

Table 1
Governmental Entities Contacted and Invited to Comment on Little Bear Creek Basin Plan

Alderwood Water & Wastewater District	Snohomish Conservation District
Bonneville Power Administration	Snohomish County
City of Bothell	Snohomish County Agricultural Advisory Board
City of Mill Creek	Snohomish County PUD No. 1
City of Woodinville	Snohomish County Fire District #7
Cross Valley Water District	Snohomish Health District
Environmental Protection Agency	Snohomish School District 201
Everett School District	University of Washington
King County	Washington Department of Fish & Wildlife
King County (Brightwater)	Washington Department of Natural Resources
King County (WRIA 8 Salmon Recovery)	Washington State Department of Commerce
Muckleshoot Indian Tribe	Washington State Department of Ecology
Northshore School District	Washington State Department of Transportation
Seattle City Light	Woodinville Water District
Silver Lake Water & Sewer District	

**Appendix F: Memo to Ecology – Selected Regional Regressions of Flow
Metrics and B-IBI for Little Bear Creek**

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Snohomish County NPDES Watershed Planning

Memorandum Response Documenting Selected Regional Regressions of Flow Metrics and Benthic Index of Biotic Integrity-BIBI for Little Bear Creek

This document describes Snohomish County's approach to selecting regional regressions characterizing flow and BIBI response applicable to Little Bear Creek (LBC) Watershed Planning under Special Condition S5.C.5.c of the County's Phase I Permit. Selection of Flow-BIBI correlations applicable to LBC are used for prediction of future biologic conditions and implements Special Condition S5.C.5.c.iv(4). Based on email communication (Appendix A) from the Washington State Department of Ecology, the required elements to document and support the County's approach are as follows:

1. Rationale for why the new dataset and regressions are being considered.
2. Comparison between the methods of the DeGasperi paper, WRIA 9 and Juanita Creek Studies and the methods used to determine the WRIA 8 study.
3. Discussion on the determination of which data was selected from the WRIA 8 study to use in the regression analysis.
4. Best fit analysis for all hydrologic metrics presented in the WRIA 8 study using linear, log and exponential correlation assumptions.
5. Comparison of simulated B-IBI and measured B-IBI within the WRIA 8 study.
6. Discussion of the metrics selected for use in the Little Bear Creek Watershed-Scale Stormwater Plan
7. Statistical fit analysis between the Little Bear Creek data and the regression equations from Juanita Creek, WRIA 9 and WRIA 8.

Element 6 is addressed out of order at the end of this document, but the document responds to each element, point by point.

Summary

Snohomish County will use linear regressions between flow metrics and BIBI scores that use flow metrics in DeGasperi et al. (2009) and are based on the WRIA 8 Status and Trends Monitoring dataset (King County 2015). These analyses will be used to interpret the alignment and fit of existing Little Bear Creek BIBI scores to a regional representation of flow and biological response and estimate BIBI scores from modeled flow scenarios (i.e. fully forested and future developed).

Although the Permit references the application of DeGasperi et al. "correlations," the DeGasperi et al. 2009 publication does not actually contain correlations that specify the parameterization (the coefficient/constant or slope/intercept) of the linear relationships reported. Hence, there is no direct application of results presented in DeGasperi et al. that would support the Permit directive that the Special Condition S5.C.5.c.iv(4) language implies is feasible. Importantly, the DeGasperi et al. results do provide valuable guidance for considering the applicability and strength of selected flow-BIBI relationships, and thus provides for future testing and selection of a focused set of flow metrics, as was explored by Horner (2013).

This memo describes the consideration of DeGasperi et al. flow metrics and the comparison of regression analyses from two regional datasets that ultimately inform the selection of flow-biological response

relationships applicable to Little Bear Creek Watershed Planning. This examination of Little Bear Creek BIBI scores relies heavily on the analyses and reporting in DeGasperi et al. 2009, King County 2012 (the Juanita Report), Horner 2013 (the WRIA 9 report), and King County 2015 (the WRIA 8 Status and Trends Report) as sources of analytical approaches and examples of important findings on the relationships between flow metrics and biotic integrity.

BIBI scores in the Little Bear Creek (LBC) subbasin were significantly correlated with several hydrologic metrics previously identified at the regional scale for their correlation with the biological integrity of Puget Sound Lowland streams. Linear regression equations of long-term (2002-2015) averaged BIBI scores at ten mainstem LBC locations on selected hydrologic metrics generally conformed (similar slope and intercept) with BIBI regressions using data (2010-2013) from 26 out of 28 WRIA 8 Status and Trend study sites presented in King County 2015. BIBI scores at ten mainstem LBC locations did not convincingly conform to the data sources from DeGasperi et al. (2009), published as the “Juanita” regressions (King County 2012) based on those 16 sites. The long-term (2002-2015) average BIBI scores among sites were best correlated with the average annual simulated High Pulse Count (HPC), High Pulse Range (HPR), and Richards-Baker Index (RBI) for the BIBI data collection period, as well as Flow Reversals, and two new metrics, HPC2 and HPR2 (High Pulse Count and High Pulse Range based on flow thresholds coincident with expected streambed mobilization using Little Bear Creek channel- and site-specific data). These two new metrics, HPC2 and HPR2, have not been evaluated as part of a regional study and only have applicability to Little Bear Creek BIBI score evaluation. These two metrics do support the hypothesis that both pulse frequency and range influence biotic integrity. Similar metrics that represent stream power or hydraulic influence have been considered in other studies (Cassin et al. 2005).

For this analysis, the WRIA 8 dataset was chosen for comparison to Little Bear Creek BIBI scores and for estimating BIBI scores using simulated flow (61 years) for fully forested watershed conditions and future development. Hydrologic simulation for different watershed scenarios is accomplished using an HSPF flow model calibrated to the available stream gauging record and subsequently extended to the available precipitation record. This document provides the support for using the HPC, HPR and RBI flow metrics based on the applicability of the WRIA 8 dataset to Little Bear Creek. These metrics, and each of the flow-BIBI relationships specified below for HPC, HPR, and RBI are used to estimate the best-fit line predictions of BIBI. In the case of the fully forested natural land use scenario, the estimate of a historical BIBI score is based on the arithmetic mean of the fully forested BIBI estimated from each of the three flow metrics.

$$\text{Eq. 1: High Pulse Count (HPC)} \quad \text{BIBI} = -1.63 * (\text{HPC}) + 50.3 \quad (r=-0.87; r^2 = 0.75, p<0.0001)$$

$$\text{Eq. 2: High Pulse Range (HPR)} \quad \text{BIBI} = -0.096 * (\text{HPR}) + 50.9 \quad (r=-0.74; r^2 = 0.54; p<0.0001)$$

$$\text{Eq. 3: Richards-Baker Index (RBI)} \quad \text{BIBI} = -59.3 * (\text{RBI}) + 47.2 \quad (r=-0.87; r^2=0.75; p<0.0001)$$

Discussion Points 1-7

1. Rationale for why the new (WRIA 8) dataset and regressions are being considered.

Snohomish County considered the potential applicability of the WRIA 8 Status and Trends dataset (hereafter “WRIA8” or “WRIA8 dataset”) after recognizing the lack of data alignment between the DeGasperi et al. dataset (obtained from the Journal of American Water Resources Association) and average BIBI scores in Little Bear Creek (2002-2015) using 10 mainstem stream locations.

For both regional studies, the DeGasperi et al. (2009) study and the WRIA 8 Status and Trends monitoring (King County 2015), the hydrologic metrics used were nearly identical as highlighted in Table 1, which also includes metrics from WRIA 9 (Horner 2013), Juanita Creek (King County 2012), and this Little Bear Creek Watershed Planning Project. The DeGasperi et al. (2009) study, WRIA 9 (Horner 2013), and Juanita Creek study (King County 2012) use the same underlying dataset of 16 sites – the BIBI scores and flow metric values.

Table 1. Flow metrics included in study evaluations of BIBI and Flow. Bolded study names used HSPF simulated flows. Shaded cells correspond to the study where the flow metric definition is found. Open circles represent use of log-transformed flow metric values.

Flow Metric	DeGasperi et al. (2009)	WRIA9 (Horner 2013)	Juanita Creek (King County 2012)	WRIA8 (King County 2015)	Little Bear Watershed Planning Project
High Pulse Count	○	● vs. Ln BIBI	○	●	● ○
High Pulse Duration	○		○	●	● ○
High Pulse Range	●	● vs. Ln BIBI	●	●	●
Low Pulse Count	○		○	●	● ○
Low Pulse Duration	○		○	●	● ○
Low Pulse Range	●				●
Flow Reversals	●		●	●	●
TQmean	●		●	●	●
R-B Index	●		●	●	●
Julian date of minimum flow	●			●	
30dayminflow				●	
7dayminflow	●			●	●
Qmax:Qmean				●	
Fall Count	●				
Rise Count	●				
Fall Rate	○				●
Rise Rate	○				●
2YRPEAK:BASE		●	●		
HPC2					●
HPD2					●
HPR2					●
Theta					●

The simple plots of four flow metrics are shown in Figures 1-4, where each plot includes the 2002-2015 Little Bear Creek mainstem location average BIBI scores (black squares), the DeGasperi et al. data (labeled as “Juanita Corr” in the figure legends), and the WRIA8 dataset. Note that the definitions of flow metrics and calculation of metric values were the same between studies.

The flow values (x-axis) for DeGasperi et al. data points are derived from gauging data from at least one complete year of flow (the BIBI water year) or up to 3 years of flow prior to and including the one BIBI sample year. The flow values (x-axis) for WRIA8 data points are derived from gauging data from at least one complete year of flow (and up to 4 years of averaged flow metrics overlapping the four averaged BIBI sample years). Little Bear Creek flow values (same x-axis) are derived from averaging annual flow metrics using HSPF daily flow simulation covering the same period (2002-2015) as BIBI data years. In some cases, not only do the Little Bear Creek sites plot in better alignment with the WRIA 8 dataset, but the WRIA 8 dataset demonstrates a tighter coefficient of determination (r^2 value) between flow metrics and BIBI scores that explains more of the variability in BIBI scores attributable to the flow metric. This may be due to a variety of factors including several discussed in Table 2, an examination of study differences between WRIA 8 (King County 2015) and DeGasperi et al. (2009). For example, using multi-year averaged BIBI scores as well as longer-term averaged flow metrics should deliver more representative BIBI scores and flow metric values for correlation. This is based on observations that Little Bear Creek BIBI scores, by site, can change by 10-12 points per year. Using only one BIBI score could increase the possibility that the selected year was less representative than an average would be, particularly if and where no other site-year scores were known. Other examples of DeGasperi et al. and WRIA 8 study differences are included in Table 2.

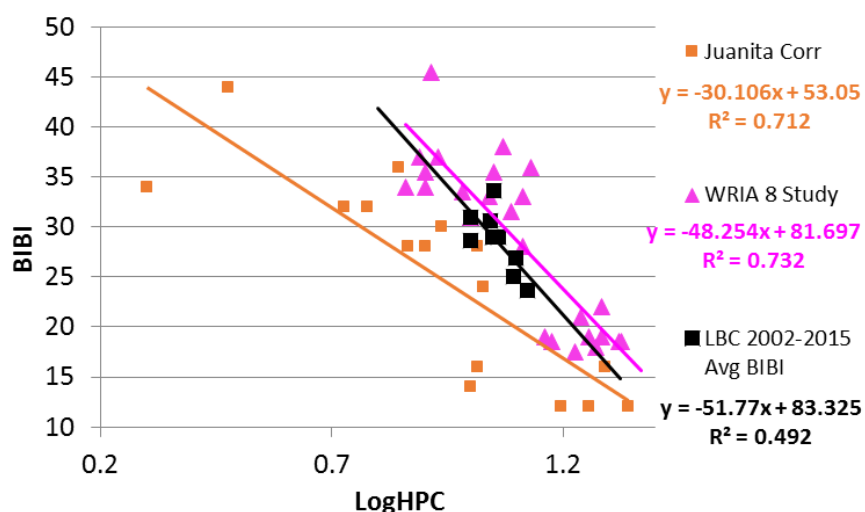


Figure 1. Log HPC and BIBI plot of Juanita Creek correlation and plots of WRIA 8 study dataset and 10 LBC mainstem locations averaged for year 2002-2015.

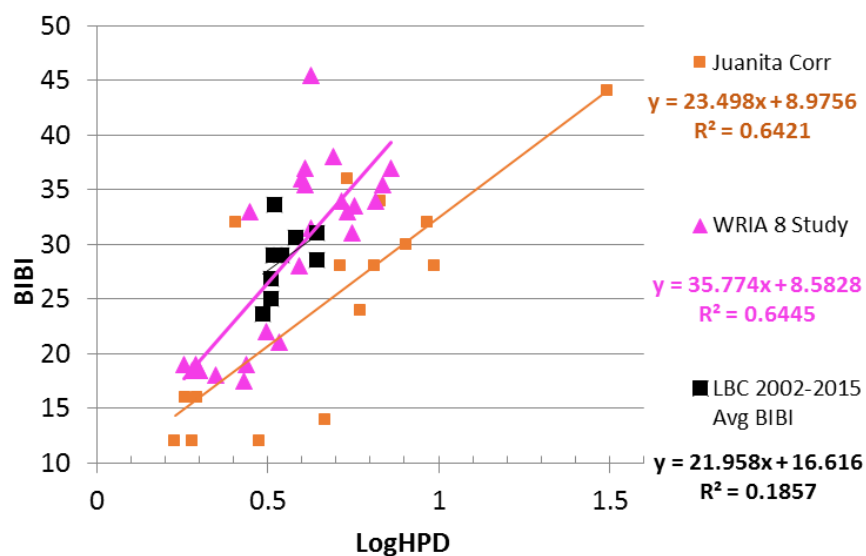


Figure 2. Log HPD and BIBI plot of Juanita Creek correlation and plots of WRIA 8 study dataset and 10 LBC mainstem locations averaged for year 2002-2015.

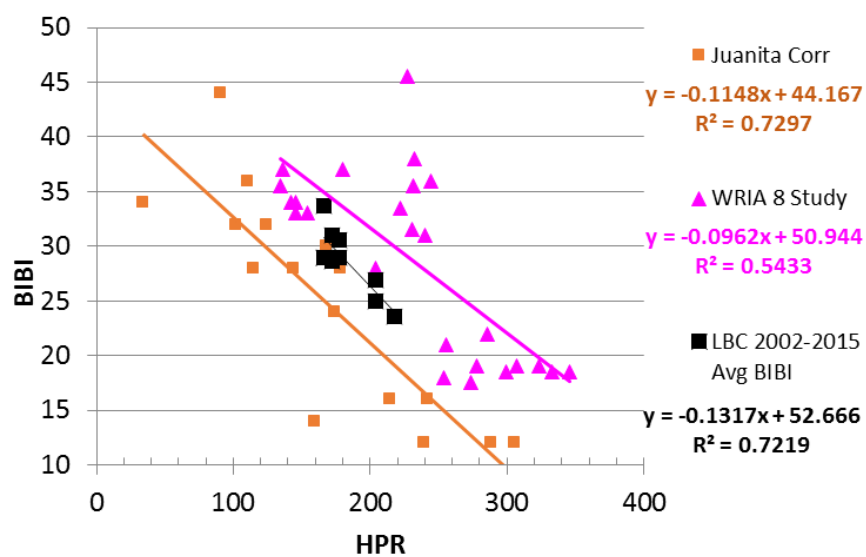


Figure 3. HPR and BIBI plot of Juanita Creek correlation and plots of WRIA 8 study dataset and 10 LBC mainstem locations averaged for year 2002-2015.

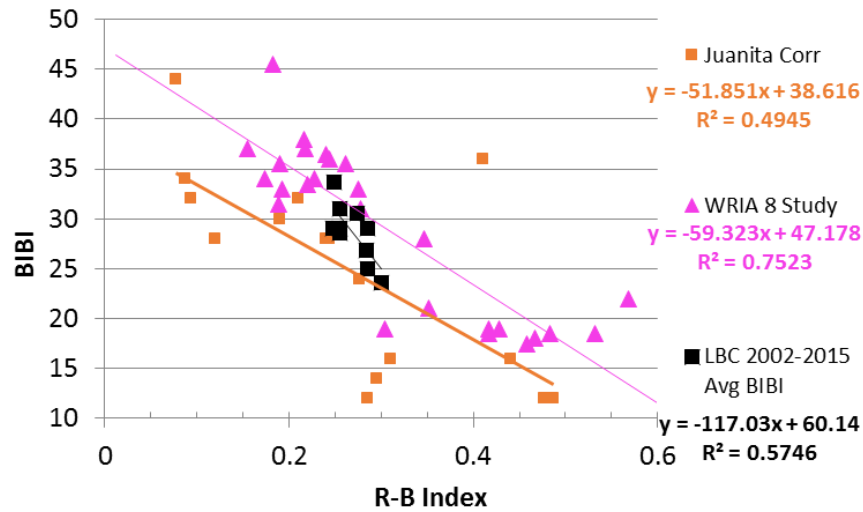


Figure 4. RBI and BIBI plot of Juanita Creek correlation and plots of WRIA 8 study dataset and 10 LBC mainstem locations averaged for year 2002-2015.

In addition to Figures 1-4, Figure 5 shows a plot of the natural log of the percent of maximum BIBI against HPC that replicates the examination of BIBI scores completed by Horner (2013) in support of the WRIA 9 study. As in the figures above, BIBI scores in Little Bear Creek plot in alignment with the WRIA 8 dataset. This plot also suggests strongly that the biological response curve (the linear slope) across the x-axis range is consistent between the plots, but that the Little Bear Creek data have a better statistical fit with the WRIA 8 dataset. This result could imply that real differences exist between mid-1990 and later 2010-era BIBI scores, or that meteorological conditions have led to flow metric changes without BIBI score reduction. Alternatively, other sources of error and uncertainty could derive from the use of mixed single year BIBI scores versus averaged BIBI scores, changes in BIBI sampling methods over time, and BIBI score computation changes from revised taxa lists) that leaves the older DeGasperi et al. dataset and scores outdated relative to more recent WRIA 8 and LBC dataset and scores.

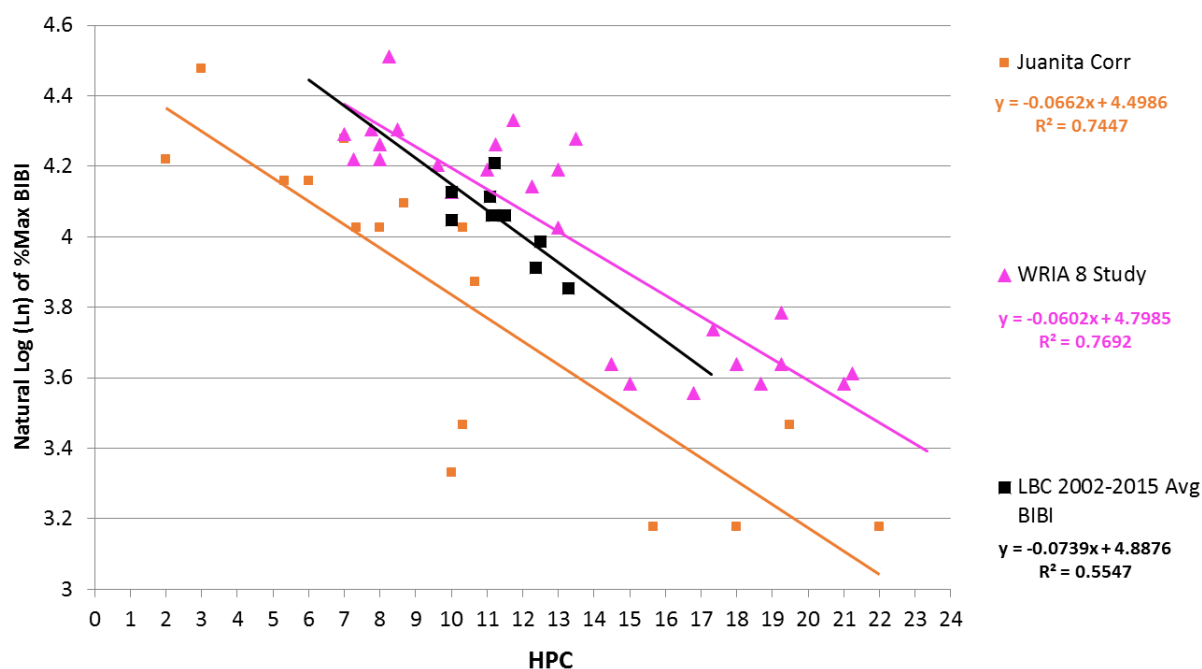


Figure 5. High Pulse Counts versus the natural log of the percent maximum BIBI score based on analyses by Horner (2013). The normalized y-axis metric was necessary for Horner's comparison of DeGasperi et al. (2009) BIBI scores to scores from an older study (Cooper 1996) that used a maximum BIBI score of 45.

In addition to the visual examination of BIBI score fit to the WRIA 8 dataset, Table 2 below describes some categories of study differences, an interpretation of the study differences, and support for WRIA 8 data applicability to the Little Bear Creek Watershed Planning project.

Table 2. Examination of study differences between DeGasperi et al. (2009) and WRIA 8 (King County 2015) and interpretation of WRIA 8 data applicability and support for use in Little Bear Creek.

Categories of Study Differences and Uncertainty	DeGasperi et al. (2009)	WRIA 8 Study - King County (2015)	Support for WRIA 8 data applicability
Number of sites	16	26 (2 outlier data points were removed see-below)	More sites.
Area	King County	WRIA 8 + EPA Puget Lowland sentinel sites	Similar geography.
Forest-to-urban conditions gradient	Total Impervious Area Range – 10 to 59%; Forest Range – 5 to 81%;	TIA Range – 0 to 50%; Forest Range – 6 to 96%;	Similar range in Forest-Urban conditions continuum.

Table 2, continued

Categories of Study Differences and Uncertainty	DeGasperi et al. (2009)	WRIA 8 Study - King County (2015)	Support for WRIA 8 data applicability
Number BIBI years per site	1 year per site from 5 different years – 16 BIBI scores used	4 years averaged per site for same year range – 104 BIBI scores used	Averaged WRIA 8 scores minimizes unknown error from using only one BIBI year – note that BIBI scores changed by up to 12 BIBI points in consecutive years in Little Bear Cr.
BIBI sampling method/ Taxa analysis	3 square feet composited from one riffle/ (3 replicates averaged from same riffle)/Karr 1998 analysis	1- 8 square foot sample composited from up to 8 riffles per site/ Wisseman 1998 analysis	Eight square feet was used in Little Bear Creek from 2009. Puget Sound Benthos database BIBI calculations are the same for WRIA 8 and LBC.
Years	Separate 1995, 1996, 1997, 1998, or 1999 BIBI scores by site	2010-2013 for each site	More recent WRIA 8 dataset overlaps Little Bear Creek BIBI data range and analysis years.
Hydrology – years used for flow metric calculation	Average of 3 years prior to BIBI year, but as few as 1 year	Average of up to 4 years; same as BIBI years; some flow years missing	Uses same year range for estimating hydrologic metrics instead of different three year ranges among sites.
Hydrologic metric range in x-axes	Greater range from using individual years with wide ranging flow differences among years 1993-1999	Narrower range from averaging metrics over 4 years; some flow years missing	The range in 1993-1999 flow metric values was approx. 2-times the 2010-2013 range based on Little Bear Creek flow simulation.
BIBI correlation with % Total Impervious Area	$r^2 = 0.51$ Vs. Arcsin (square root %TIA)	$r^2 = 0.72$ Vs. %TIA	Better correlation with contributing impervious area.
Best fit Hydrologic metrics by r^2 value in order	HPR-LnBIBI and HPC-LnBIBI (Horner), HPR, Log HPC, Log HPD, Log LPD, RBI (<i>LnBIBI is natural log of % of maximum BIBI</i>)	HPC-LnBIBI, RBI, HPC, Log HPC, HPR, Log HPD, HPR-LnBIBI, HPD, HPR, Log LPC, Reversals, LPC, Log LPD	WRIA 8 metric list is consistent with DeGasperi et al. (2009) and Horner (2013) metric lists. HPD and TQmean were ruled out for LBC prediction purposes (see below).
Slopes for Hydrologic metrics	High r^2 values and significance	High r^2 values and significance	Similar slopes (but not intercepts) indicate BIBI response is similar over x-axis range.
Y-Intercepts (at Zero value in x-axis or lowest hydrologic metric values)	Intercept is approximately 40 BIBI pts for negative slope coefficients	Intercept is approximately 45-50 BIBI pts for negative slope coefficients	45-50 BIBI intercept reflects scores closer to maximum potential BIBI for zero x-axis or lowest modeled hydrologic metric values.
Fully Forested flow simulation BIBI prediction	BIBI prediction is lower than upper bound of current forested locations in Puget Lowlands.	BIBI prediction is similar to many forested locations in Puget Lowlands.	Forested BIBI prediction is more consistent with upper bound of forested sites.

2. Comparison between the methods of the DeGasperi paper, WRIA 9 and Juanita Creek Studies and the methods used to determine the WRIA 8 study.

The methods for the DeGasperi et al. (2009), WRIA 9 study (Horner 2013) and Juanita Creek (King County 2012) studies are overlapping in terms of exploratory analysis of hydrologic flow metrics and BIBI scores mostly due to the use of the same underlying dataset of 16 BIBI scores for 16 sampled locations (1995-1999). The WRIA 9 and Juanita Creek studies did not explore or develop any other regional dataset. Many elements of the study methods are noted in Table 2.

The DeGasperi et al. (2009) analyses use one BIBI score from one year depending on availability among 5 different years (1995, 1996, 1997, 1998, and 1999) for 16 sites in King County. The flow data used to evaluate BIBI scores represents one to three years averaged flow metrics preceding the BIBI sample year, which suggests that the various flow years used were from 1993-1999. Flow gauging locations were within two kilometers of selected BIBI sites where flow data could be summarized. Various hydrologic metrics indicating annual flow magnitude, duration, frequency, timing, or pattern (e.g., flashiness) were calculated. The BIBI scores were regressed against the computed or transformed flow metrics to evaluate the strength of correlation. The DeGasperi et al. (2009) study did not include the use of flow data simulated by a hydrologic model for calculating hydrologic metrics, although the Juanita Creek study did.

For the WRIA 8 Study (2015), King County used four years (2010-2013) of channel, habitat, riparian buffer, and BIBI score data at WRIA 8 locations and EPA “Sentinel” sites that spanned a large range of land cover conditions in the Puget Lowland ecoregion. For 28 of these sites, stream hydrology data from nearby locations were matched to the stream survey site to implement the analyses described in the study. For some locations, as few as one year of flow data were available or useable, as was the case for the DeGasperi et al. (2009) study. For other sites, more than 10 years of flow data were available. The WRIA 8 study did not employ a hydrologic model to simulate flow data used in metric calculation. The full dataset for these 28 sites was obtained from King County and was used to compute univariate correlation analyses for the Little Bear Creek Watershed Planning project. For their part, King County evaluated stressor-response relationships using a Boosted Regression Tree non-parametric analysis approach to evaluate the relative contribution of multiple independent parameters by category (Land cover, Hydrology, Habitat, Temperature). Relatively weak relationships with BIBI were found for habitat metrics, with the exception of a descriptor of riparian buffer development. Where hydrology was tested, High Pulse Duration, High Pulse Count, and the R-B index (RBI) were the most important contributors to BIBI model value. Unlike the DeGasperi et al. (2009) study, and somewhat unexpectedly, BIBI scores did not strongly correlate with individual flow metrics, though the univariate Pearson’s r values are not reported.

For the WRIA 9 Stormwater Management Project, Horner (2013) used the DeGasperi et al. dataset of 16 subbasins and applied various suitability criteria (similar to Cassin et al. 2005) to 20 hydrologic metrics based on their correlation to urbanization, findings of other investigators, demonstrated relevance to biotic integrity, the correspondence between flow simulation and gaged data, relative independence from confounding variables (such as basin area), replication or redundancy with other metrics, and the ability to obtain SUSTAIN model output for the metric (Horner 2013). As a result of this inquiry, Horner reduced his analysis to include only three metrics, HPC, HPR and 2-Year Peak to Winter Base Flow Ratio. Although Horner indicates this last metric demonstrates a “strong match with criteria 1 [and] 2,” somewhat inexplicably the combined numerical rank score for criteria 1 and 2 is last among the 8 metrics ranked. HPR and HPC are ranked first and second, respectively, which indicates their strong relevance. RBI was ranked third, but was

not selected because of confounding correlation with drainage area (9.6 – 53.5 km²). In contrast, for Little Bear Creek, average RBI (13 years) among 13 locations was not correlated with drainage area (2.9-32.7 km²).

Unlike DeGasperi et al. (2009), Horner (2013) did not log-transform HPC for analysis. Instead, the natural log of the percent-of-maximum-BIBI score was computed even though the need for transformation (e.g.; non-linearity, non-constancy of error terms, non-normality of errors) was not discussed. Horner used the percent-of-maximum-BIBI score for the three metrics evaluated to normalize scores because the 2-Year Peak to Winter Base Flow Ratio correlation with BIBI was based on a 45 point scale, which predated the 50-point scale used for metrics included in DeGasperi et al. (2009). The log-transformation of the dependent variable, the BIBI, resulted in an improved correlation coefficient for both HPC and HPR compared to results reported by DeGasperi et al. (2009). Horner used these results to develop prediction analyses and confidence limits based on the best fit regression equations for HPR and HPC and confidence intervals about the coefficients and constants (slopes and intercepts). It should be noted that the regression relationship between BIBI and the 2-Year Peak to Winter Base Flow Ratio was relatively weak ($r^2=0.23$ for a power function), and Horner concluded its value to be secondary to HPC and HPR for BIBI prediction. This obviates the need to normalize BIBI scores for any new analyses (i.e., the following tables), but these are shown for illustrative purposes.

The Juanita Creek study (King County 2012) used the DeGasperi et al. dataset to calculate and apply the best regression correlations between BIBI and nine hydrologic metrics for prediction purposes. For each metric, a linear, log-linear, or exponential function describing the best line fit was applied to 12 flow simulation scenarios for 30 locations within the Juanita Creek subbasin. The flow simulation scenarios included a historical forested condition, a current condition, a future unmitigated condition and future conditions where flow was mitigated using various best management schemes applied in the flow modeling environment. For the existing condition, actual average BIBI scores for 3-6 years (2002-2008) at 5 locations in Juanita Creek were compared to simulated BIBI scores, which were based on the correlation equations and modeled flow values representing the nine BIBI-Flow metric regressions. The relative percent difference, or error, between observed and predicted BIBI scores was 18.6%, with predicted BIBI scores greater than the observed scores. Under the fully forested historical condition, simulated BIBI scores based on each of the nine metrics ranged from 33-43, with a resulting average score of 38.

The Juanita Creek study best represents the approach being taken for the Little Bear Creek Watershed Planning Project. Although simulated BIBI scores can be calculated based on BIBI-Flow metric relationships for any number of metrics, some of these correlations are stronger than others and have greater applicability for use based on criteria discussed by Horner (2013) and Cassin et al. (2005). Therefore the Little Bear Creek study will focus on the selection of certain hydrologic metrics for BIBI calculation and prediction.

For the Little Bear Creek Watershed Planning project, a calibrated HSPF flow model was developed and generated hourly flows over a 61-year record for gaged and non-gaged locations within Little Bear Creek. Snohomish County identified 5 tributaries and 10 mainstem locations for BIBI sampling in 2014 and 2015. These new BIBI results were combined with historical BIBI scores, as feasible. As such, the analyses in this report rely on sites with 2 to 13 years of BIBI data. The greatest number of sites were sampled in 2014 and 2015. All BIBI sites, scores, summary statistics, interannual score changes, and trends analysis are included in the Little Bear Creek Current Conditions Report (NHC and Snohomish County 2016).

3. Discussion on the determination of which data was selected from the WRIA 8 study to use in the regression analysis.

WRIA 8 study data were obtained directly from King County for the hydrologic metrics and from the Puget Sound Stream Benthos website for BIBI (maintained by King County). Obtaining BIBI data from the website ensured that BIBI score calculation (10-50 point scale) methods were the same as BIBI score calculations for Little Bear Creek data (2002-2015). For the WRIA 8 study, King County (2015) followed a similar data collection and analytical approach as past studies, but with some key differences.

For the WRIA 8 study dataset, four consecutive years of BIBI data were averaged for the 28 locations for which flow metric values were also estimated. The flow gauging in many instances was not co-located with BIBI sample sites, and this was also the case for the DeGasperi et al. (2009) dataset. In some cases flow data were not available for each flow year overlapping the BIBI years, and in some cases, only one year was available (as highlighted in Table 4 of King County 2015). Additional years of antecedent flow data were not included prior to 2010, though for some sites many more years of antecedent flow data are available. Inevitably, there is not perfect alignment of BIBI scores and flow data by years or co-location. For example, in the case of the DeGasperi et al. data, half of the 16 BIBI sites were located farther than 900 meters away from the flow gauging location. Although the supposition that the distance between a BIBI sample site and a flow gauging location is not problematic for assigning flow metric values to the different BIBI site, it is nevertheless the case that stream channel characteristics and BIBI scores can be quite different between sites separated by relatively short distances (even given similar upstream land cover) as they may be affected by differences in stream gradient, sediment content, buffer condition, or other differences between sites that may not be related to all upstream land cover and land uses that would otherwise lead to similar flow statistics between sites separated by these distances. For these reasons, some BIBI sample sites (and their scores) may not conform to a biological response pattern observed for many other BIBI sites where all are assumed to be part of a similar population of Puget Lowland sites. For prediction value, sites where BIBI scores do not behave or respond characteristically alongside the majority population could be considered outliers to the “model” population.

King County (2015) noted in their WRIA 8 Status and Trends report that the correlations between most flow metric values and BIBI scores were lower than those indicated by the earlier DeGasperi et al. (2009) data set. High Pulse Duration, High Pulse Count, RBI, and High Pulse Range were all cited in their stressor-response relationships but were not compelling compared to results described in DeGasperi et al. (2009). However, the low correlation values (in comparison to DeGasperi et al. (2009)) were generally the result of two (out of 28) “outlier” values. The 28 average BIBI scores and their correlation (equation coefficient, constant and r^2 value) to HPC values is shown in Figure 6 and labeled “WRIA 8 with outliers.” The 26 BIBI scores and their correlation (equation coefficient, constant and r^2 value) to HPC values is shown and labeled “WRIA 8 Study.” The long-term average LBC BIBI scores are also plotted (as shown previously) to highlight the alignment and linear response of these sites to the restricted WRIA 8 dataset (26) that supports the interpretation of expected BIBI performance based on conformity to this population of sites.

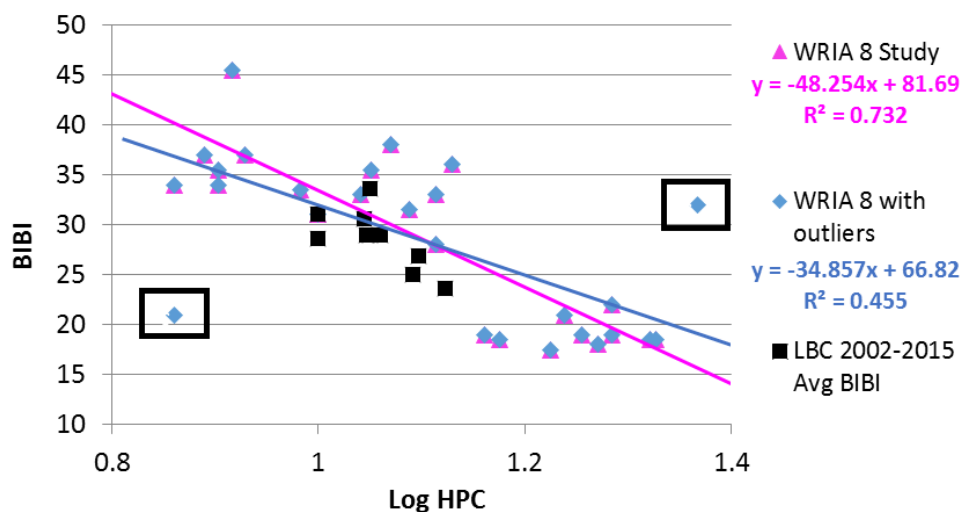


Figure 6. Comparison plot of WRIA 8 Study data for HPC and BIBI showing 28 data points for WRIA 8 with outliers (boxed) and WRIA 8 Study sites (26 data points) used for this analysis.

Conservative removal of outliers based on the uniqueness of site characteristics, if known, or remedial measures in regression analysis, such as review of standardized residual values were considered. The two locations in question are Venema Creek in the City of Seattle and North Creek in Snohomish County. In the case of Venema Creek the contributing basin area is tiny, the smallest of all drainage areas among the WRIA 8, DeGasperi and LBC sites. Based on project team familiarity with the site, there is limited stream length upstream of the sampled site - mainly pipes and ditches - which may affect benthic invertebrate colonization of the sampled site. The Venema site is also problematic because there are cross-culverts that link to adjacent basins, so flow response is not consistent from storm to storm, and high pulses may get diverted out of basin leading to reduced high pulse metric values. For these reasons, it does not belong in the same population of sites. And, if the creek is benefitting from more directed stormwater management (such as storm flow bypass compared to larger subbasins), it could be considered a “treated” subbasin, which would, again, differentiate it from the other population of sites.

For North Creek, the apparent resiliency of elevated BIBI scores given the higher level of development and highest average HPC value in the WRIA 8 dataset is more difficult to explain for designating the site as an outlier based on site characteristics. The relatively higher BIBI scores were observed in most of the averaged years, so the average score was not due to any single anomalous year score. Also, two adjacent BIBI sites not included in the WRIA 8 study, and sampled in the same years, demonstrate similar scores. This North Creek site is located in Snohomish County and is familiar. This site lies downstream of a very large (for an urban setting) protected wetland with wide buffers. The WRIA 8 study dataset of landscape characteristics shows that this site has very low channel slope, low road crossing density, and relatively higher forest cover retention given the extent of urbanization present. Although the calculated impervious area (42%) is 4th highest among 28 sites and average HPC is highest, wetland area (5%) is 7th highest, and road crossing frequency is 3rd lowest. Another possible source of uncertainty and error between flow and BIBI correlation would be with respect to the gage location. The gage is located approximately 700 meters downstream from the BIBI sample site, but this distance also incorporates drainage from the City of Mill Creek town center.

Thus, the gaged flow may not be representative of the BIBI sampled site. Alternatively, or additively, the landscape characteristics mentioned above may be relatively unique (certainly in North Creek) in so far as providing mitigative functions that maintain higher BIBI scores in this anomalous setting. These conditions and resulting BIBI scores may mask the characteristic BIBI score response to hydrology that is evident in the rest of the population of sites, making the BIBI response (not the hydrologic metrics) the source of its outlier status. Given the absence of characteristic (and therefore predictable) response to hydrologic metrics and the conformity of the LBC mainstem sites to the remaining 26 sites, the flow-BIBI response relationship described by the 26 sites better represents the anticipated flow-BIBI relationship and response in the planning subbasin.

Additionally, for these two sites, the standardized residual scores were greater than two standard deviations and fall outside of the 95% prediction interval of the data distribution. For “prediction” purposes, an objective is to reduce the “model” used for BIBI prediction to the BIBI population that best describes the characteristic (and expected) response of the target locations. Of note, in the DeGasperi et al. dataset, Little Soos Creek and Soosette Creek routinely display high residual error for multiple hydrologic metrics. These results suggest not all subbasins (sites) behave similarly in terms of biological response to hydrologic characteristics. And the observation of outlier values also suggests that sensitivity of the biological response to hydrologic alteration may not be the same among subbasins (sites).

Reducing the model population by eliminating outliers leads to a narrower linear regression confidence interval and therefore prediction interval. Figure 7 highlights the increase in the r^2 value with removal of the two outlier values. For illustrative purposes, Figure 7 also shows the diminished increase in subsequent r^2 value from removal of two additional data points based on the next largest standardized residuals.



Figure 7. Change in r^2 value based on removal of outlier sites.

4. Best fit analysis for all hydrologic metrics presented in the WRIA 8 study using linear, log and exponential correlation assumptions.

The WRIA 8 study included various flow metrics as shown in Table 1 (and on page 23 of King County 2015). The WRIA 8 report did not actually provide the simple linear, logarithmic, or exponential correlations to fit relationships between flow metrics and BIBI scores. However, with the dataset available, this effort was completed as part of considering the applicability of regional datasets. For example, Figure 8 shows three correlations based on different line fit assumptions for High Pulse Count and BIBI for the WRIA 8 study.

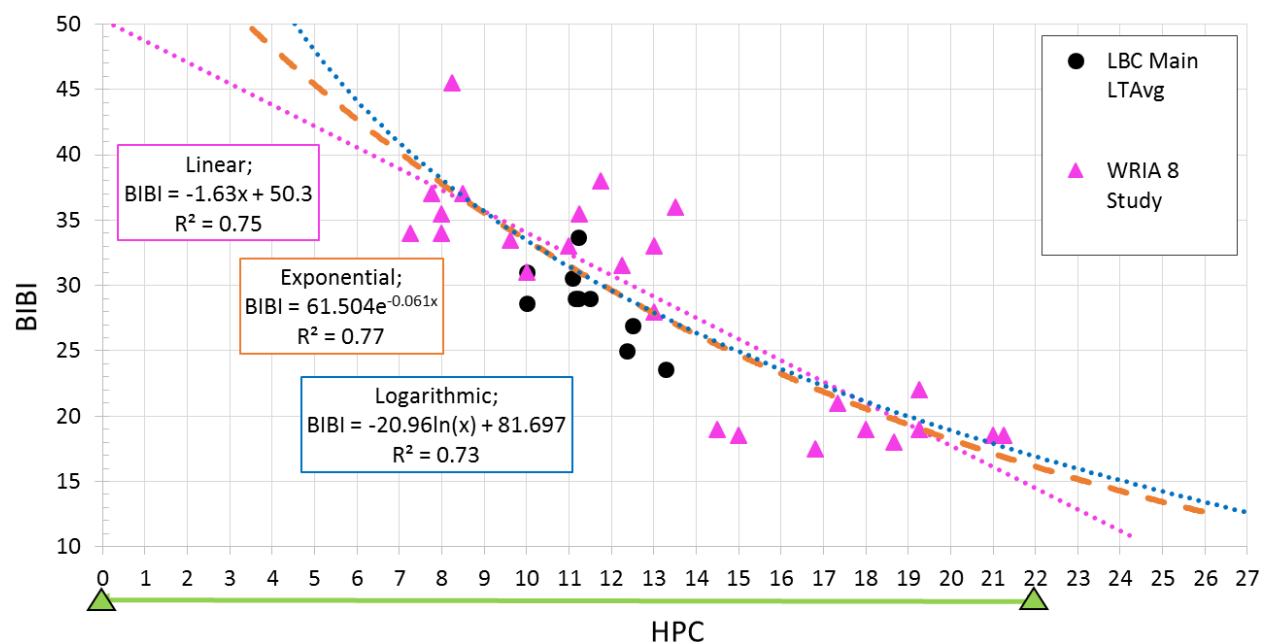


Figure 8. Plots of HPC versus BIBI applying different line fit assumptions. Also shown are mainstem LBC sites versus average BIBI. The range of HPC values shown between triangles at the HPC axis is for mainstem LBC sites for the fully forested HSPF simulation (61 years).

BIBI scores range, of course, from 10-50 points. Although the exponential line fit has the highest r^2 value, HPC values <4 would “predict” a BIBI score of 50, though the y-intercept of the exponential line fit is 61 points. Unfortunately, it’s simply not known whether average HPC values less than 4 would lead consistently to scores of 50 BIBI points. However, a hallmark of larger datasets of BIBI scores (e.g., the Puget Sound Benthos Database), is that greater score variability, including low scores, are observed in locations with very low (or no) urbanization (as shown in Figure 3 in King County 2014). This suggests that usually scores are less than 50 and that median values among sites/years in locations with low or no urbanization would likely be in the mid-40 range.

A better line fit for prediction estimation at the low range of HPC is the linear line fit which has slightly lower r^2 value but intercepts the y-axis at approximately 50 BIBI points, the index maximum. At the same time, under the future flow simulation scenario only 0.5% of all years (less than one year out of 61 simulation years) exceed 24 HPC per year, the HPC value where BIBI would be predicted to be less than 10 based on the

linear correlation, and fall outside the plausible response range of the BIBI index. Therefore, although the logarithmic and exponential line fit assumptions are asymptotic toward the low score of 10 (and not below it), the applicability of the linear line fit is greater due to the BIBI prediction at low values of HPC. This discussion highlights the need to evaluate not only the line fit in terms of r^2 value and significance, but also the fit of the correlation analysis to the boundaries and limitations of the BIBI index range. In reality, the biological response and index scores for flow metric values less than or greater than observed range limits in regional or local datasets leaves remaining uncertainty as to the selection of an appropriate biological response curve for extended x-axis values (i.e., linear, logarithmic, , exponential, threshold-based, compound, etc.).

Table 3 shows the r^2 values and y-intercept values (in parentheses) for WRIA 8 data. As mentioned above, in some cases y-intercept values may be too high or too low to represent plausible BIBI scores for the simulated flow ranges, even though the explanatory power (r^2) for the data available is high. As King County (2015) reported, the variability in BIBI scores explained by flow metrics using the full WRIA 8 dataset ($n=28$, all sites linear model) was relatively weak (low r^2 values) compared to DeGasperi et al. (2009). The selected dataset ($n=26$, with 2 outliers removed) was explored using linear, logarithmic, and exponential line fit assumptions. In many cases, either an implausible line fit or low r^2 value was found. Relatively high correlation and good line fit was observed for the linear representation of HPC, HPR, and RBI, in particular, which are highlighted in boxes. In the absence of knowing a non-linear or discontinuous type of line fit is representative of biological response, the linear line fits are acceptable and are consistent with the vast majority of response relationships depicted in the scientific literature.

Table 3. Coefficient of determination values (r^2) for WRIA 8 flow metrics and BIBI correlation for different line fit assumptions applied to 28 sites and 26 sites, with 2 outliers removed. Significance at $\alpha=0.05$ is denoted by red font and italics. Parentheses contain model y-intercept values.

Hydrologic Metrics	BIBI Years 2010-2013			
	n=28 all sites	n=26; 2 outliers removed		
Flow Years (2010-2013)	Linear r^2	Linear r^2	Logarithmic r^2	Exponential r^2
High Pulse Count	<i>0.44 (47)</i>	<i>0.75 (50)</i>	<i>0.73 (82)</i>	<i>0.77 (61.5)</i>
Log HPC	<i>0.47 (66)</i>	<i>0.73 (81)</i>	<i>0.71 (189)</i>	<i>0.74 (181)</i>
High Pulse Range ¹	<i>0.32 (46)</i>	<i>0.54 (51)</i>	<i>0.49 (135)</i>	<i>0.59 (65)</i>
Low Pulse Count	<i>0.25 (34)</i>	<i>0.38 (36)</i>	<i>0.45 (51)</i>	<i>0.4 (37)</i>
Log LPC	<i>0.06</i>	<i>0.44 (50)</i>	<i>0.47 (62)</i>	<i>0.41 (74)</i>
Low Pulse Duration	<i>0.20</i>	<i>0.19 (60)</i>	<i>0.36 (46)</i>	<i>0.2 (90)</i>
Log LPD	<i>0.34</i>	<i>0.36 (47)</i>	<i>0.37 (42)</i>	<i>0.38 (54)</i>
Flow Reversals ²	<i>0.38</i>	<i>0.42 (40-50)</i>	<i>0.43 (40-50)</i>	<i>0.43 (40-50)</i>
R-B Index	<i>0.50</i>	<i>0.75 (47)</i>	<i>0.78 (66)</i>	<i>0.77 (51)</i>
Julian date of minimum flow	<i>0.06</i>	<i>0.06</i>	<i>0.07</i>	<i>0.07</i>
Qmax:Qmean	<i>0.01</i>	<i>0.04</i>	<i>0.06</i>	<i>0.03</i>
HPC- LN (%Max BIBI)	<i>0.48</i>	<i>0.77 (62)</i>		
HPR – LN (%Max BIBI)	<i>0.48 (59)</i>	<i>0.59 (65)</i>		

1 – for HPR one additional site was removed from the analysis; n=25

2 – For flow reversals, LBC metric values did not match other regional datasets.

In Table 3, results for HPD, TQmean, and 7daymin are excluded as these metrics were deemed infeasible for use in the Little Bear Creek study due to the unexpected flow simulation response (and metric calculations) among subbasins under the fully forested flow simulation regime. For these metrics, the flow response (or calculated metric value) was opposite from what was expected under a fully forested flow regime for some subbasins within the HSPF model. For example, for HPD, values would be expected to increase under a fully forested condition, but decreased for some locations. Also, the 30daymin, Rise Rate, Fall Rate and Qmean are excluded due to their strong correlation with drainage area.

5. Comparison of simulated B-IBI and measured B-IBI within the WRIA 8 study.

AND

7. Statistical fit analysis between the Little Bear Creek data and the regression equations from Juanita Creek, WRIA 9 and WRIA 8.

Comparison of simulated BIBI and measured BIBI for the WRIA 8 study describes the error (variability or confidence interval) around the best line fit and establishes the values for a statistical fit analysis between the Little Bear Creek data and the regression equations from Juanita Creek, WRIA 9 and WRIA 8. Thus, Discussion points 5 and 7 are included together.

For the WRIA 8 dataset, computed BIBI scores for a given flow metric value are based on the best line fit (slope and y-intercept) for each flow metric. For several flow metrics, simulated BIBI scores and measured BIBI scores were compared and summarized in terms of relative percent difference (RPD in Table 4). The RPD is represented by the BIBI score difference for individual points between the observed BIBI score and the computed BIBI score based on the best line fit. For additional comparison, RPD values were calculated for simulated BIBI scores using the Juanita regressions compared to the observed scores for the 16 sites included in that study (column 1 in Table 4). The RPD values for the WRIA 8 dataset (Column 2 in Table 4) generally were lower than for the DeGasperi et al. dataset, suggesting that generally there was less variance (error) between the observed scores and simulated scores for the WRIA 8 dataset. Next, the 10 mainstem Little Bear Creek averaged BIBI scores (2002-2015) were compared for their relative percent difference from the Juanita and WRIA 8 regressions (Column 3 and Column 4, respectively) to determine which regional dataset the Little Bear Creek scores were most similar to for several flow metrics. The linear regressions from the WRIA 8 study produced the lowest relative percent difference values between the observed and expected (predicted) scores.

For illustrative purposes, the graphical depiction of the differences between the DeGasperi et al. data and the WRIA 8 study data are shown in Figure 9. The long-term average BIBI scores for 10 mainstem locations in Little Bear Creek are also shown (2002-2015 average BIBI by site). Arrows, color-coded to the legend, illustrate the relative percent difference (distance) between the observed BIBI scores and the best line fit for BIBI simulation. For the Little Bear Creek BIBI scores (filled squares), arrows depict the distance and, therefore, relative percent difference between the LBC scores and the WRIA 8 study data and DeGasperi et al. datasets, respectively. In Figure 9, the average RPDs for Little Bear Creek scores are 10.6% and 23.8% for WRIA 8 and DeGasperi datasets respectively (as also reported in Table 4).

Table 4. Relative Percent Differences (RPD) between observed and simulated scores for DeGasperi et al. (2009) data and the WRIA 8 dataset. RPD for mainstem Little Bear Creek observed data to the Juanita and WRIA 8 regressions, Column 3 and 4, respectively.

Selected Flow Metrics	Column 1 DeGasperi Observed to Simulated BIBI RPD	Column 2 WRIA 8 Observed to Simulated BIBI RPD	Column 3 RPD of observed LBC BIBI to Juanita correlations	Column 4 RPD of observed LBC BIBI to WRIA 8 correlations
HPC / Log HPC	19.2% / 17.5%	12% / 11.8%	23.8%	10.6%
HPD / Log HPD	26.2% / 18.4%	16.3% / 13.6%	39.7%	9.3%
HPR	15.8%	15.7%	23.4%	14.3%
RBI	20.8%	12.6%	16%	8.6%
LPC / Log LPC	24.8% / 24.2%	20.9% / 18.3%	22.8%	9.8%
LPD / Log LPD	27.9% / 23.1%	24% / 20.1%	34.9%	10%
HPC (Horner - Ln %Max BIBI)	4.7%	2.9%	8%	2.2%
HPR (Horner - Ln %Max BIBI)	4.3%	4.0%	8.1%	3.3%

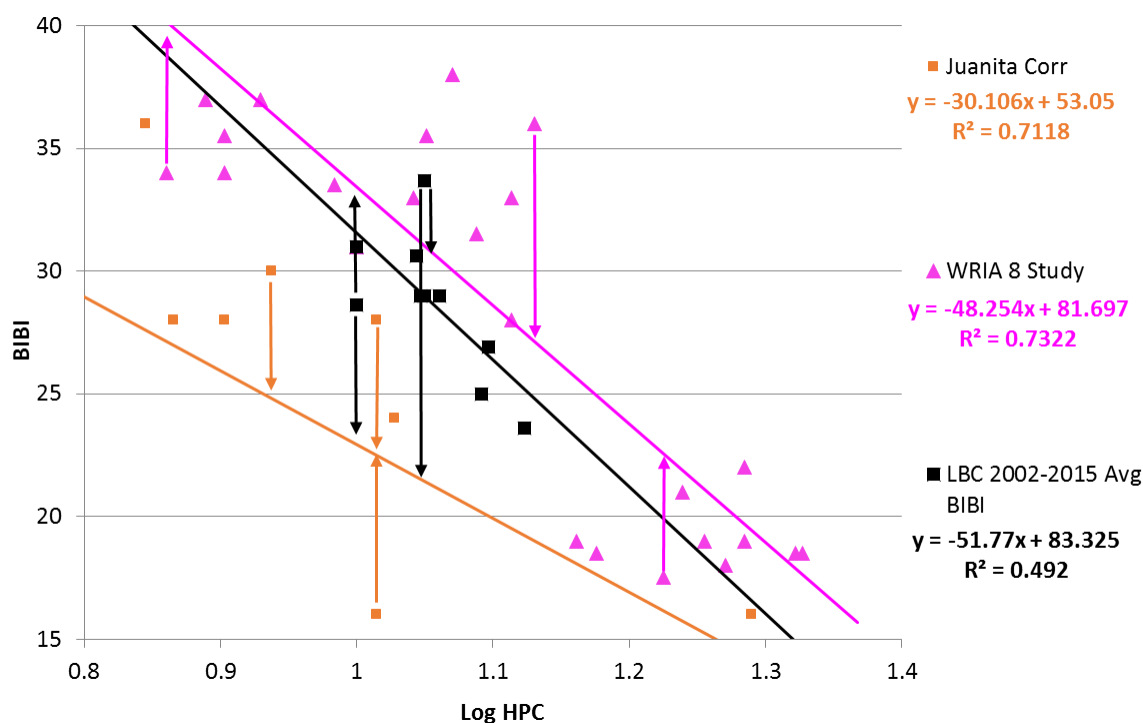


Figure 9. Log HPC and BIBI relationships showing the residual difference (arrow distance for selected points) of observed BIBI scores from the simulated flow-BIBI response relationship (linear regression lines). For LBC scores (in black), the closer distance to the WRIA 8 study flow-BIBI response relationship equates to a lower average RPD (Column 4 in Table 4) compared to RPD for DeGasperi et al. linear regressions (Column 3 in Table 4).

6. Discussion of the metrics selected for use in the Little Bear Creek Watershed-Scale Stormwater Plan

Table 5 shows the statistical fit analysis for the Juanita regressions, WRIA 9, WRIA 8, all mainstem Little Bear Creek sites, and a subset of the 5 Little Bear Creek sites with 13 years of BIBI scores. For this exercise, only linear regression relationships were computed. Significant correlations are marked with red font. The objective was to determine which flow metrics ranked highest based on the sum of correlations among regional studies and local data. WRIA 8, Juanita, and Little Bear Creek results were weighted equally. HPC, HPR, and RBI were the best ranked metrics as shown in the final column. Log HPC was redundant with HPC and is not highlighted.

Table 5 also includes an evaluation of annual BIBI scores and annual changes in BIBI scores from one year to the next in Little Bear Creek (labeled inter-annual correlations). The controlling mechanisms for BIBI scores have generally been attributed to longer term changes in the extent of development across sites reflecting the range of forest-to-urban conditions that are generally manifest over decades. BIBI score changes from year-to-year and the potential influence of annually changing factors (flow, sediment, and temperature) have not been explored to the same degree. As BIBI has been observed to change annually at a site by up to 12 BIBI points, the potential that these score changes relate to annually variable flow characteristics was investigated.

Annual BIBI scores and flow metric values were averaged for the five long-term mainstem sites (13 years). Average BIBI scores were regressed against average annual flow metrics. Figure 10 highlights how simulated HPC values change over time relative to BIBI scores as averaged for 5 sites. During this time, average annual HPC values have significantly increased (even more so if 2002 is excluded). Whereas lower BIBI scores are expected to result from higher HPC values, and results in Figure 10 suggest an inverse relationship between increasing HPC and decreasing BIBI scores, this trend is non-significant ($\alpha=0.05$). Figure 11 includes the same point values as Figure 10 and shows that average BIBI score by year was strongly correlated with average HPC in the same water year (average HPC for 5 sites shown as red diamonds in Figure 11), suggesting there was a mechanistic response in the type of change (positive or negative) if not in magnitude. An even better correlation with annual average BIBI was obtained by using the 2-year average HPC value ($r^2 = 0.6$; $p=0.003$). The analysis of all 82 year-site BIBI point values for 5 sites and 14 years were also significantly correlated with year-site HPC values (also shown in Figure 11). This plot uses the 4-year average of annual simulated HPC values in comparison to annual BIBI, as the 4-year average of antecedent HPC values was most strongly correlated with annual BIBI.

Table 5. Pearson's (*r*) values for flow metric linear correlations (except as noted) with BIBI scores for various datasets, and time considerations. Final ranks represent equal weighting of Juanita, WRIA 8, and LBC data analyses for decision support of final flow metric selection for prediction. Log HPC is redundant with HPC. HPD, Rise rate, Fall Rate, TQmean, 7-day min, 30-day min, and Qmean are not included in this table for reasons already discussed.

BIBI Dataset (sites)	Juanita (WRIA 9); (16)	WRIA 8 (26,25)	LBC Mainstem (10)		LBC long-term mainstem (5)		Inter-annual correlations		Weighting	Rank
Flow Metric	1 yr. BIBI vs. 1-3 yrs. avg. flow data	4 yr. avg. BIBI vs. 1-4 yrs. avg. flow data (2010-2013)	2-13 yrs. avg. BIBI vs. 13 yrs. avg. flow (HSPF)	2014/2015 2 yr. avg. BIBI vs. 2 yr. avg. flow data	13 yrs. avg. BIBI vs 13 yrs. avg. Flow (HSPF)	2014/2015 2 yr. avg. BIBI vs. 2 yr. avg. flow data	Avg. BIBI vs. annual avg. flow for 5 sites for 2003-2015 (13 yrs.)	5 site avg. yr.-yr. BIBI change vs. avg. yr.-yr. flow change, (11 yrs.)	Avg. correlation $r = (LBC\ main\ r + Juanita\ r + WRIA8\ r)/3$	
HPC	-0.852	-0.866	-0.722	-0.555	-0.664	-0.497	-0.591	-0.585	0.773	1
Log HPC	-0.844	-0.856	-0.701	-0.553	-0.635	-0.488	-0.471	-0.594	0.758	3
HPC-LN BIBI	-0.863	-0.874								
HPC2			-0.858	-0.565	-0.881	-0.722	-0.578	-0.669	0.680	5
HPR	-0.854	-0.737	-0.850	-0.740	-0.914	-0.948	-0.043	-0.153	0.733	4
HPR-LN BIBI	-0.869	-0.768								
HPR2			-0.838	-0.414	-0.911	-0.708	0.096	0.054	0.470	11
LPC	-0.612	-0.610	-0.094	-0.314	-0.295	-0.689	0.197	-0.269	0.489	9
Log LPC	-0.664	-0.666	-0.134	-0.312	-0.345	-0.683			0.566	8
LPD	0.673	0.446	0.154	0.328	0.385	0.759	-0.047	0.367	0.481	10
Log LPD	0.766	0.601	0.134	0.364	0.357	0.760			0.590	6
LPR	-0.036		0.148	-0.146	-0.055	-0.509	0.197	0.335	0.021	13
Fall Count	-0.42									
Rise Count	-0.529									
REVERSE	-0.652	-0.633	-0.678	-0.565	-0.575	-0.502	-0.055	-0.406	0.583	7
R-B Index	-0.703	-0.867	-0.758	-0.763	-0.868	-0.932	-0.162	-0.856	0.764	2
Date min flow	0.475	0.207								
Theta			-0.624	-0.207	-0.860	-0.522	-0.244	-0.446	0.450	12
Qmax:Qmean		-0.335								
2YPK:BASE	-0.469; -0.479 (power function)									

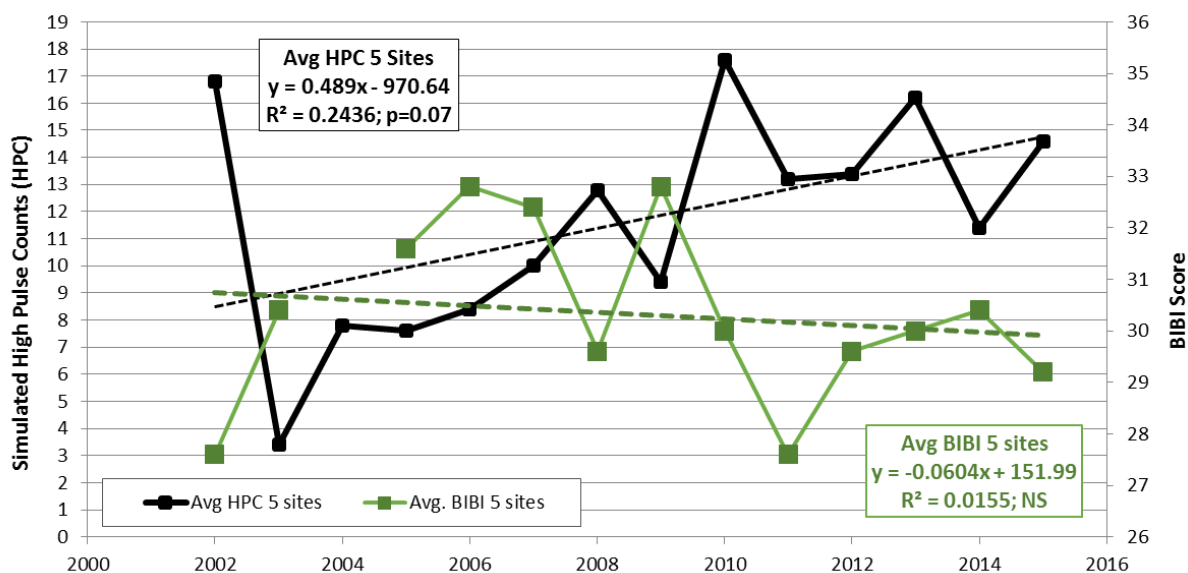


Figure 10. Annual average HPC for 5 LBC mainstem sites compared to annual average BIBI score for 5 sites. Whereas HPC was strongly increasing due to meteorological conditions, BIBI scores were weakly decreasing.

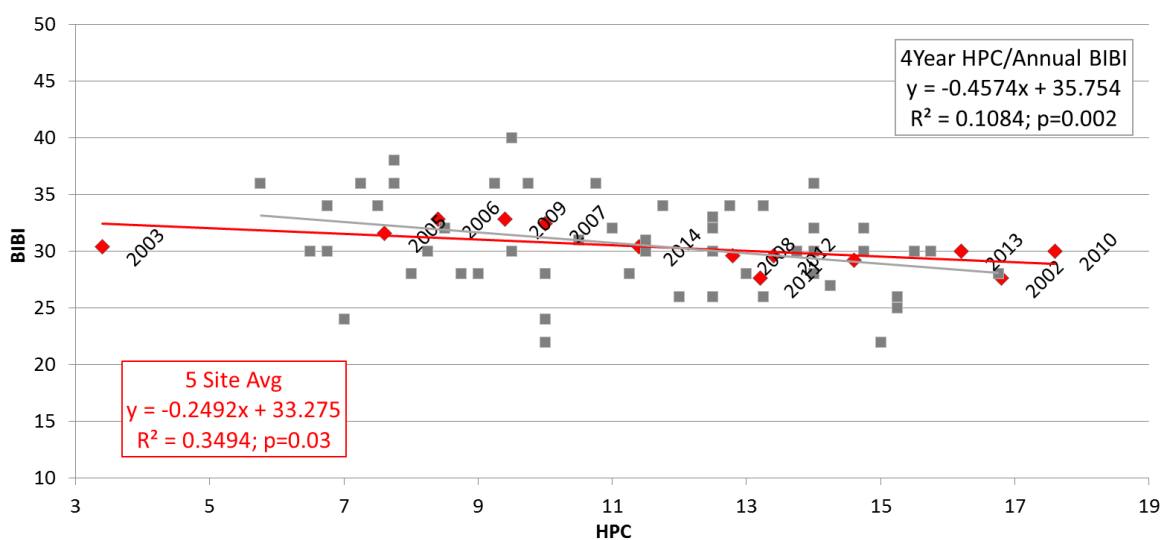


Figure 11. Linear regression of HPC and BIBI scores for 5 long-term sites. The correlation among years is much stronger when 2003 is averaged with 2002.

Other flow metrics did not demonstrate significant correlation by year based on averages for these 5 sites. Correlation coefficients are included in Table 5. In addition, the year-to-year change (difference) in BIBI scores (increasing or decreasing) relative to the year-to-year difference in hydrologic metrics was explored.

For example, for HPC, Figure 12 shows the year-to-year positive or negative change in average BIBI score versus the positive or negative change in HPC (non-significant). As in the example above, an even better correlation was found by using the year-to-year difference between the 2-year averaged HPC and year-to-year difference in BIBI scores ($r^2=0.5$, $p=0.02$)

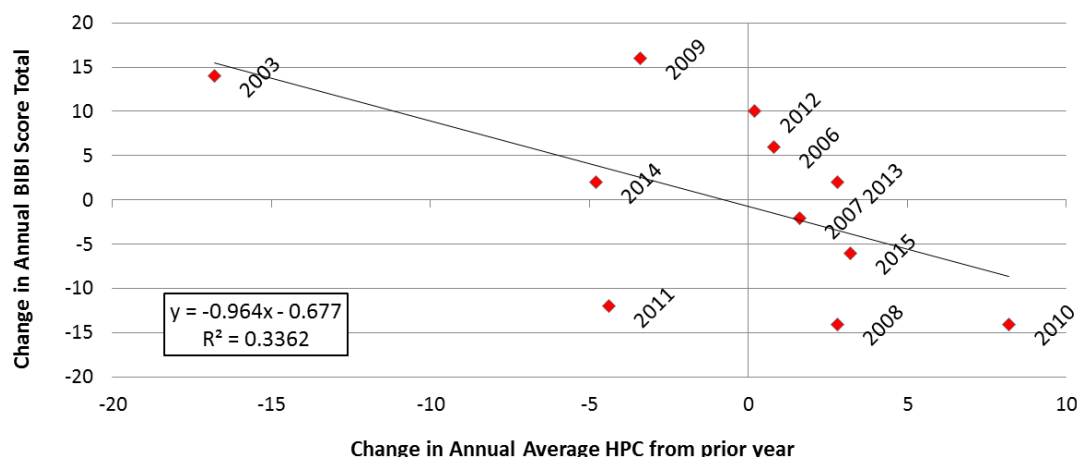


Figure 12. Inter-annual change in BIBI scores versus the change in HPC from the prior year. Increasing HPC from the prior year tends to be associated with decreasing BIBI.

A more compelling relationship was observed between the annual change in BIBI scores and the annual change in RBI. Figure 13 not only shows the strong correlation between the change in flashiness from the prior year for the 5 long-term sites and the correlation to BIBI score change, but also shows that the underlying data from each site-year, though variable, supports the same conclusion, though with much more site-year variability. Figure 14 shows the same data in a different plot that highlights the inverse nature of the change in BIBI response relative to the change in flashiness from the prior year. These results, if real, suggest that flow variability at annual time scales represented by certain flow metric characteristics (pulse frequency, flashiness) may have a mechanistic effect on biological response that improves the confidence in, if not understanding of, the applicability of certain flow metrics to guide development of management strategies and test outcomes through monitoring.

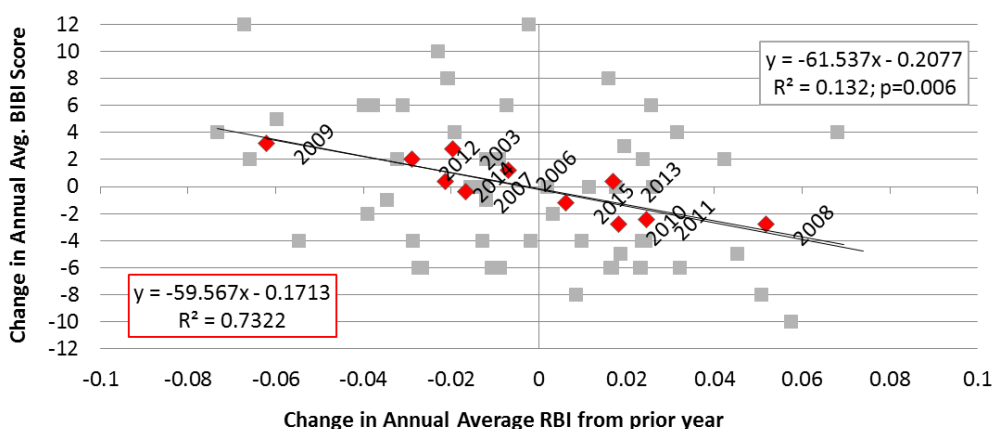


Figure 13. Inter-annual change in BIBI scores versus the change in RBI from the prior year. Increasing RBI from the prior year tends to be associated with decreasing BIBI.

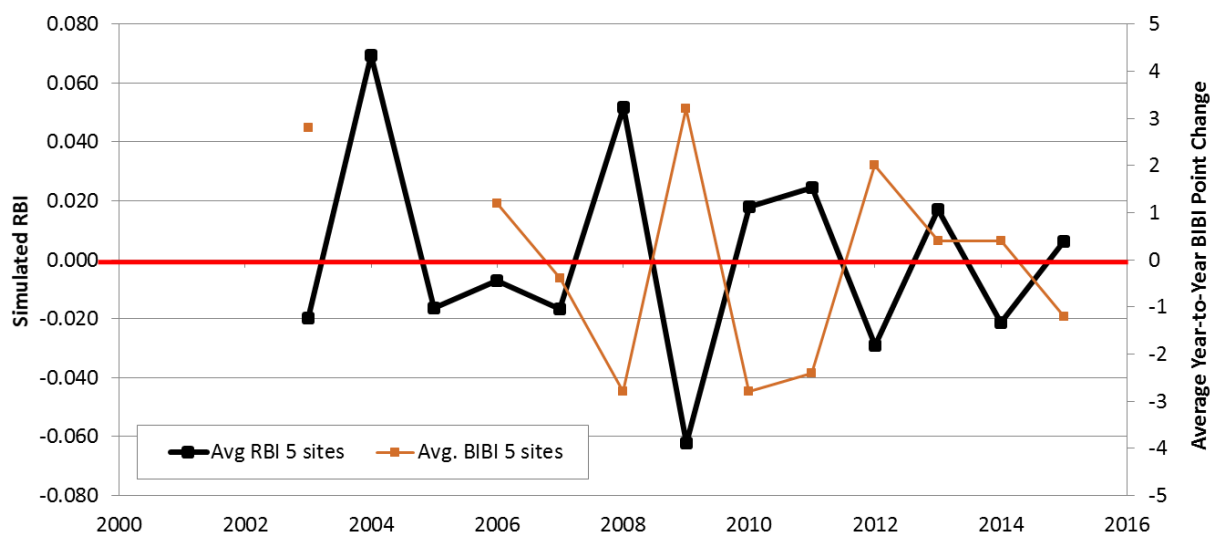


Figure 14. Annual plot of average RBI and average BIBI scores for 5 sites. Years with greater directional change appear to lead to greater BIBI score change.

Lastly, although 5 sites were averaged to compute annual flow metrics and BIBI scores for year-to-year analyses, the annual BIBI scores for the 5 separate sites were compared for the years representing the highest antecedent 4-year average HPC (2010-2013) versus the years representing the lowest antecedent 4-year average HPC (2003-2006). That comparison is shown in Figure 15, where each of the 5 sites is shown separately. The 4-year antecedent period was selected based on the strength of correlation in Figure 11. Of note, the three most downstream locations (2692, LBLD, and LB58) demonstrated the largest difference in BIBI scores between the years with the highest and lowest 4-year average HPC. The difference between

average BIBI between the years with highest and lowest 4-year average HPC is significant using a simple Student's t-test (one-tailed test, $t=2.06$, $d.f.=8$, $p=0.03$), but is less so using a matched pairs test ($t=1.72$, $d.f.=4$, $p=0.08$). This lower level of significance is potentially due to the smaller difference between the highest and lowest HPC years for sites 2603 and 2602 compared to the three downstream locations. Regardless of whether the BIBI response is site specific or whether it can be generalized among sites (i.e., by averaging results from 5 sites), the results strongly suggest that BIBI scores are responsive to flow effects over shorter time scales when more widespread changes in land cover or riparian buffer characteristics would not be expected to change significantly and not in ways that leads to both increasing and decreasing BIBI score changes.

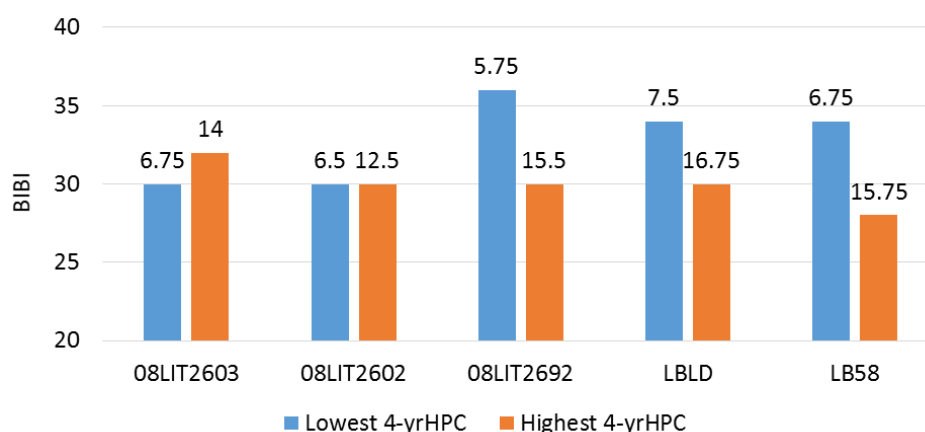


Figure 15. A comparison of BIBI scores among 5 long-term sites for years with the highest (2010-2013) and lowest (2003-2006) 4-year average HPC value antecedent to these BIBI sample years (2006 and 2013). Bar-chart values are the 4-year average annual HPC values by site.

Conclusion

For Little Bear Creek, the analyses described above support the use of the WRIA 8 dataset for flow-BIBI response relationships for application to this watershed planning project. More specifically, the flow-BIBI response for HPC, HPR, and RBI can each be used to estimate BIBI with tighter confidence based on the strength of correlation and plausible prediction values over the range of simulated flows. These three metrics fall into three functional metric categories of flow frequency (HPC), range of seasonal occurrence within the water year (HPR), and flow oscillation pattern (RBI). The equations are shown below.

Eq. 1:	High Pulse Count (HPC)	$BIBI = -1.63 * (HPC) + 50.3$	$(r=-0.87; r^2 = 0.75, p<0.0001)$
Eq. 2:	High Pulse Range (HPR)	$BIBI = -0.096 * (HPR) + 50.9$	$(r=-0.74; r^2 = 0.54; p<0.0001)$
Eq. 3:	Richards-Baker Index (RBI)	$BIBI = -59.3 * (RBI) + 47.2$	$(r=-0.87; r^2=0.75; p<0.0001)$

The HPC metric consistently demonstrates the best correlation with BIBI scores, which was true for HPC, Log HPC, and HPC2. HPC2 demonstrated strong correlation with BIBI scores in Little Bear Creek and reflects pulses based on estimated flow thresholds for streambed mobilization, but has not been applied elsewhere to establish regional regressions. However, that BIBI scores in Little Bear are well correlated with HPC2 adds additional support to understanding the influence of flow pulses on BIBI as a causal mechanism (streambed mobilization) of change that could have management implications. Other flow metrics, including low pulse count (LPC) and low pulse duration (LPD), did not demonstrate strong or compelling correlation with BIBI scores in Little Bear Creek, nor had they previously been identified as strong candidate metrics by Horner (2013).

In support of the Little Bear Creek Watershed Planning Project, the flow-BIBI response relationships for HPC, HPR and RBI are applied using flow simulation (HSPF model) outputs that reflect a fully forested watershed, a future development scenario based on the currently adopted Snohomish County Comprehensive Plan, and future “mitigated” scenarios identified through application of the SUSTAIN model. For each flow metric, the forested flow simulation results by year are used to estimate forested BIBI scores. The results establish the average forested BIBI score for multiple mainstem locations for each flow metric. Predicted BIBI scores for each of the three flow metrics average to identify the fully forested BIBI score, which is used to develop management targets and objectives for this project.

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- Puget Sound Stream Benthos. Benthic Taxa Attributes. King County, n.d. Web. 25 Jan. 2017. <<http://pugetsoundstreambenthos.org/Taxa-Attributes.aspx>>. Wisseman, 1998 (recommended for 10-50 B-IBI) attribute list was compiled by taxonomist Bob Wisseman based on his best professional judgment for predator, long-lived, tolerant, and intolerant classifications and based on the habit designation in Merritt and Cummins 1996 for clinger. <http://pugetsoundstreambenthos.org/Taxa-Attributes.aspx>

APPENDIX A

Washington Department of Ecology email from Rachel McCrea to Arthur Lee, dated Tuesday 11/1/2016 3:23 PM

Hello Arthur and Team –

As per the action item from our meeting 10/19, Ecology's response is provided below. Thanks for meeting with us and discussing the progress on your Watershed-scale Stormwater Plan.

We understand your interest in using some correlations derived from WRIA 8 data (WRIA 8 correlations). The WRIA 8 correlations differ from the cited data and corresponding correlations at Special Condition S5C5c.iv (4) of the Phase I Municipal Stormwater Permit (Permit). Thus, consistent with the existing record, including Ecology's June 30, 2015 approval letter for Snohomish County's Little Bear Creek Scope of Work, Ecology considers use of the WRIA 8 correlations an "alternative correlation" that requires Ecology's review and approval. Refer also to Ecology's March 29, 2016 guidance memo, Section 3. We believe you have 2 options that would allow you to use the WRIA 8 correlations and remain in compliance with the applicable Permit requirement:

1. Use the WRIA 8 correlations as a supplement to the cited *Puget Sound Lowland Stream* correlations. No further approval from Ecology is required.
2. Prepare and submit to Ecology a memo detailing how the WRIA 8 correlations (e.g., data and derived regression equations) are at least equally valid. Ecology can then base our approval of use of the WRIA 8 correlations on this memo.

Ecology performed a preliminary review of the WRIA 8 data that was sourced from the "Monitoring for Adaptive Management: Status and Trends of Aquatic and Riparian Habitats in Lake Washington/Cedar/Sammamish Watershed (WRIA 8)" April 2015 report (<http://your.kingcounty.gov/dnrp/library/2015/kcr2671.pdf>) and your October 19, 2016 presentation that discussed the derived correlations. Information in your presentation was helpful, but is insufficient on its own to justify use of the alternative. We do believe the WRIA 8 equations are approvable with sufficient analysis. The WRIA 8 study appears to have similar objectives and sampling rationale when compared to the DeGasperi paper. The sample set was meant to describe a wide geographic and land use spread so that trends could be derived.

If you choose option 2, above, Ecology expects the same level of analysis on the derivation of the WRIA 8 regression equations to the DeGasperi et al. 2009 (<http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/normative-flow/0904-lowland-streams-hydrology-biology.pdf>), WRIA 9 (<http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/green-duwamish/stormwaterretrofit-project/stormwater-mitigation-projected-by-2040-wria-9.pdf>) and Juanita Creek (<http://your.kingcounty.gov/dnrp/library/water-andland/stormwater/juanita-retrofit/main-document.pdf>) studies. At a minimum, Snohomish County's memo detailing the proposed use of WRIA 8 correlations must include:

1. Rationale for why the new dataset and regressions are being considered.
2. Comparison between the methods of the DeGasperi paper, WRIA 9 and Juanita Creek Studies and the methods used to determine the WRIA 8 study.
3. Discussion on the determination of which data was selected from the WRIA 8 study to use in the regression analysis.

4. Best fit analysis for all hydrologic metrics presented in the WRIA 8 study using linear, log and exponential correlation assumptions.
5. Comparison of simulated B-IBI and measured B-IBI within the WRIA 8 study.
6. Discussion of the metrics selected for use in the Little Bear Creek Watershed-Scale Stormwater Plan
7. Statistical fit analysis between the Little Bear Creek data and the regression equations from Juanita Creek, WRIA 9 and WRIA 8.

Please reach out to Dan (360-407-6470) to arrange a discussion about the memo with your team. This way you can clear up any questions or confusion before you initiate the memo (should you choose option 2). Please let me know if you have general questions. And certainly let us know if you choose option 1.

Good luck with tomorrow's workshop. I believe Dan will be in attendance.

Best,
Rachel

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