Stream Benthos and Hydrologic Data Evaluation for the City of Bainbridge Island

December 2015

King County

Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section
King Street Center, KSC-NR-0600
201 South Jackson Street, Suite 600
Seattle, WA 98104
206-477-4800 TTY Relay: 711
www.kingcounty.gov/EnvironmentalScience

Alternate Formats Available

Stream Benthos and Hydrologic Data Evaluation for the City of Bainbridge Island

Prepared for:

City of Bainbridge Island Public Works
City of Bainbridge Island, Washington

Submitted by:

Curtis DeGasperi and Chris Gregersen
King County Water and Land Resources Division
Department of Natural Resources and Parks

Funded by:

Interagency agreement with the City of Bainbridge Island (#21500011)

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

Acknowledgements

Special thanks to Ken Rauscher (King County Information Technology Geographic Information Analyst) for providing the land cover data for the Puget Sound basins. Thanks also to Cami Apfelbeck (City of Bainbridge Island, Water Quality and Flow Monitoring Program Manager) for initiating the agreement for this study and guiding the work as it unfolded.

Citation

King County. 2015. Stream Benthos and Hydrologic Data Evaluation for the City of Bainbridge Island. Prepared by Curtis DeGasperi and Chris Gregersen, Water and Land Resources Division. Seattle, Washington.

Table of Contents

Figures

Tables

Appendices

EXECUTIVE SUMMARY

In complex environmental systems, change resulting from human activity and management actions may be subtle and slow to emerge. Long-term monitoring data provide a means of identifying important patterns, including trends, natural cycles and rare events. It is widely recognized that consistent, long-term environmental monitoring data are essential for effective watershed management and decision-making. The current City of Bainbridge Island monitoring program provides a good foundation for such a monitoring effort.

This study serves as an initial review of available hydrologic and stream benthos monitoring data collected by the City of Bainbridge Island. Since 2004, between three and ten years of continuous flow measurements have been made in three streams and one stormwater conveyance system. Stream benthos sampling has occurred between two and six times since 2008 at eight stream sites and three of these sites include continuous flow measurements. The study streams are located in watersheds that span a range of development and forest cover and have substantially varying contributing watershed areas. Given the limited number of years of data, the variability between years, and the inconsistent periods of records, this initial data analysis was conducted to glean any available information to date, to identify any obvious changes in environmental conditions, and to make recommendations for future efforts.

The flow data analysis showed that stream flows increase more quickly following rain events and generally have higher peaks than would be expected under forested conditions (i.e., the flows are “flashier” than natural conditions). These results were generally consistent with increasing levels of urbanization upstream of each gauge and consistent with other data collected in other Puget Sound watersheds, with the stormwater system being the flashiest monitored system. This analysis used several hydrologic flashiness metrics, including High Pulse Count, TQmean and R-B Index that are widely recognized as being sensitive to urbanization. Integrated flow management approaches that include low impact development techniques have been demonstrated to limit stream flashiness in urban areas.

The health of the stream benthos community was assessed by calculating the Benthic Index of Biotic Integrity (B-IBI) and three other diagnostic metrics (for organic pollution, fine sediment and metals), by analyzing trends over time, and by comparing results to other locations in Puget Sound. The average B-IBI scores spanning all of the years of data were very poor for Ravine Creek; poor for Issei, Murden, and Whiskey Creeks; and fair for Cooper, Manzanita, Springbrook, and Woodward Creeks. None of the eight sites investigated had average scores that showed good or excellent stream benthic communities, although two sites (Cooper Creek and Springbrook Creek) did have individual sampling years that had good scores. These data were generally consistent with the level of development in the study watersheds and consistent with B-IBI data collected in other Puget Sound lowland watersheds. However, the Bainbridge Island B-IBI scores were typically lower than B-IBI scores from a tentative list of presumed least disturbed reference sites distributed across Puget Sound.

The Fine Sediment Sensitivity Index was generally lower at all Bainbridge sites relative to the reference sites, suggesting that fine sediment inputs may be a factor in benthic impairment in these streams. If confirmed through evaluation of sediment conditions at these sites, the cause is unlikely related exclusively to development as some of these stream basins are relatively undeveloped. It is possible that at least in some instances, past land use (e.g., historical logging and farming activities) is a factor in causing excess sediment to be (or to have been) delivered to these streams. Any development within these basins may also be a contributing factor as well; potentially delivering fine sediment through construction and land clearing activities and through stream bank erosion resulting from increased peak flows.

All three diagnostic metrics and the flashiness hydrologic metrics indicate that Ravine Creek, the most developed watershed that includes a portion of the former City of Winslow, is suffering from multiple stressors that potentially include organic and metal pollution, geomorphic alteration and flashier flows. The occurrence of multiple stressors in developed stream basins has been termed the "urban stream syndrome." The real challenge in the future may be testing the hypothesis that effective application of management practices at the catchment scale can maintain and/or improve habitat conditions and water quality and ultimately improve B-IBI scores.

This report suggests some potential refinements for the City of Bainbridge Island to make in refining its long term monitoring program to assist in watershed management. Recommended future actions include discontinuing the collection of three separate stream benthos samples from each site for taxonomic analysis and instead combining the samples in the field and having the lab analyze a single sample from each site each year. If that change is made, then it is recommended that a stream benthos field replicate sample be collected from a randomly selected site each year to allow incorporation of within site variance in trend analyses. This would result in a cost savings to the program (cost of analyzing 9 rather than 24 samples each year).

It is also recommended that an investigation of the stream sediment character at all stream benthos sampling sites be conducted with an emphasis on measuring fine sediment. Further studies may be warranted based on the results of the initial study (e.g., installation of continuous turbidity sensors).

1.0 INTRODUCTION

An interagency agreement was made between the City of Bainbridge Island and King County Water and Land Resources Division to evaluate City of Bainbridge Island stream flow and stream benthic invertebrate data collected through the end of 2014. The goal of this agreement was to analyze City of Bainbridge Island benthic macroinvertebrate data from eight locations sampled annually and continuous hydrologic data from four locations. Land cover data for the watershed area above the sampling sites were also compiled for comparison to benthic community metrics at the eight sampling locations.

Flow data were collected at three of the eight stream benthos sampling locations and the other flow gauge was located in a stormwater conveyance channel. Hydrologic metrics derived from the flow data from the three co-located stream gauges were compared to the stream benthic community metrics. Hydrologic metrics derived from the flow data from the stormwater conveyance site were compared to the metrics derived from the tributary streams. In addition, City of Bainbridge Island benthic community and hydrologic metric data were compared to data from other areas across the Puget Sound lowlands and to a set of potential reference sites to provide a larger context for the island's data.

This document provides a summary of the data, methods and analyses conducted under this agreement and presents and discusses the results of the analyses. The report also provides conclusions based on the results and recommendations are provided for strengthening the ongoing monitoring program.

1.1 Background[1]

City of Bainbridge Island encompasses all 27.5 mi^2 of Bainbridge Island (Figure 1). The City of Bainbridge Island was formed in 1991 as the result of the annexation by the former City of Winslow of the rest of the island. The City of Bainbridge Island, with a 2010 population estimated at 22,958 is the second largest city in Kitsap County. The island is located on the west side of the main basin of Puget Sound and is separated on the west side from the Kitsap Peninsula by Port Orchard.

The land surface is gently rolling with elevations ranging from sea level to a little over 400 ft above sea level. The geology of the island is a complex mix of unconsolidated glacial and nonglacial material. Higher elevation areas are predominantly capped by a layer of glacial till with relatively low permeability. More permeable surficial deposits of advance and recessional outwash also occur across the island. Post glacial erosion has also created alluvial deposits of sands and gravels in valleys. Bedrock outcrops of sandstone, siltstone, claystone and conglomerate are found on the southern end of the island.

---

[1] Sources for background information on Bainbridge Island included Dion et al. (1987), Frans et al. (2011) and Wikipedia Bainbridge Island, Washington (https://en.wikipedia.org/wiki/Bainbridge_Island,_Washington).

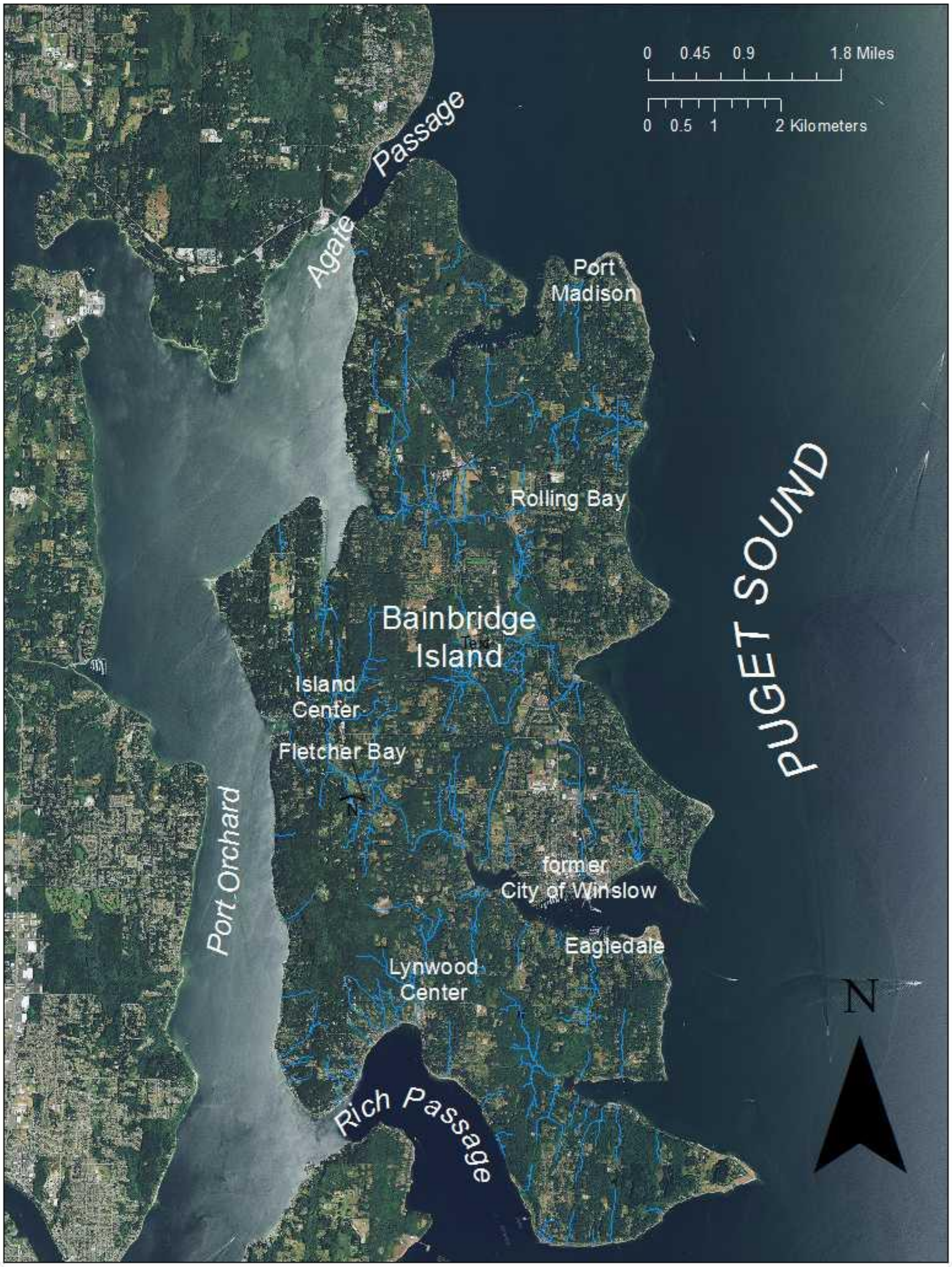

Figure 1. Aerial photo illustrating the location of Bainbridge Island in the main basin of Puget Sound with primary population centers identified.

The post-glacial forest covering the island included huge cedars that were ideal for ship's masts, which led to the establishment of logging and ship building enterprises beginning in the mid-1800s. At the same time, the island was used as a summer resort for Seattle residents and as land was cleared of timber, farms (primarily for berries) were established. Over time, the island has developed primarily into a community of year-round residents, many of whom work at nearby Naval Base Kitsap or commute by ferry to work in Seattle or other nearby metropolitan areas on the east side of Puget Sound.

The population of the island has increased more than 13 percent since 2000 and is expected to increase by more than 31 percent between 2010, and 2030 to about 30,000 people. The present population is spread fairly evenly across the island, with the highest population density in the area of the former City of Winslow. Other areas of concentrated development include Eagledale, Fletcher Bay, Island Center, Lynwood Center, Port Madison, and Rolling Bay, although most of these are located along the marine shoreline (Figure 1). There are also agricultural and light commercial endeavors scattered across the island.

1.2 Report Organization

The report is organized into an introduction (this section), sections describing the data and analysis methods used (Methods), and a section summarizing the results of the analyses (Results and Discussion). The Methods section provides an overview of the study basins, a description of the methods used to compile and process the stream flow, stream benthos and land cover data and a description of the analysis methods. The Results and Discussion section presents analysis results for stream flow, stream benthos, relationships between stream benthos and hydrologic data, land cover data and relationships between stream benthos and land cover data. The final Conclusion and Recommendations section summarizes the key findings of this study and provides some recommendations for strengthening the current monitoring program.

2.0 METHODS

The City of Bainbridge Island has collected stream flow data in three streams and one stormwater conveyance system and macroinvertebrate data has been collected in eight stream basins (Figure 2). These locations represent relatively undeveloped forested conditions (e.g., Cooper Creek) to highly developed basins (e.g., Ravine Creek). This section describes the study drainage basins, the compilation of available data through 2014 and the data analysis methods used in the study.

2.1 Study Basins

The eight creek basins sampled as part of the City of Bainbridge Island's monitoring program are describe below, including information regarding the years of available monitoring data at each site. The study basin information presented below is summarized in Table 1.

Table 1. Summary of study basin characteristics and available flow and stream benthos data used in this study.

Stream Basin	Watershed Area (acres)	Percent Developed [c]	Flow Data	Stream Benthos Data
Tributary basin [a]				
Cooper Creek	230	10	5/22/2010 - 12/31/2014	2008, 2010-2014
Issei Creek	514	4	-	2008, 2010-2013
Manzanita Creek	787	22	-	2008, 2010-2013
Murden Creek	1,342	12	-	2008, 2010-2014
Ravine Creek	331	46	10/17/2011 - 12/31/2014	2008, 2010-2013
Springbrook Creek	842	12	3/31/2004 - 12/31/2014	2008, 2010-2013
Whiskey Creek	302	9	-	2012-2013
Woodward Creek [b]	629	10	-	2013-2014
Stormwater basin				
Stormwater Conveyance OFL169	-	-	6/17/2010 - 12/31/2014	-

[a] Stream Benthos Site Codes for the tributary basins are CoopBain, IssBain, ManzBain, MurdBain, RavBain, SpringBain, WhisBain and WoodBain, respectively.
[b] Woodward Creek is a subbasin (i.e., nested catchment) of Murden Creek
[c] Percent developed based on 2011 National Land Cover Database (see Section 2.2.3 for details).
'-' = The stormwater conveyance watershed was not delineated in this study. The flow data from this station was compiled for comparison to tributary flow data only.

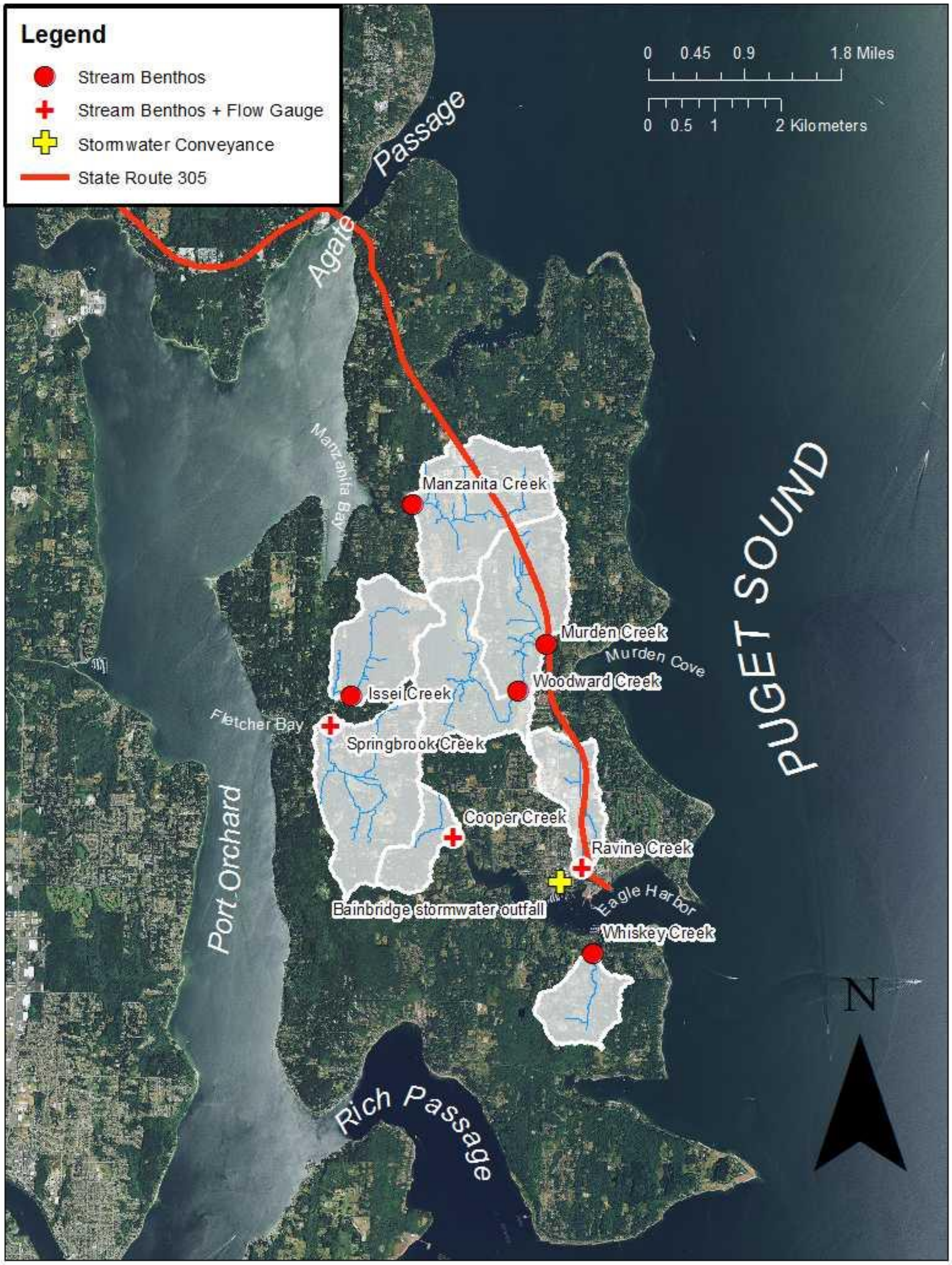

Figure 2. Locations of the stream benthos and flow gauging sites on Bainbridge Island.

Note: Woodward Creek is a subbasin (i.e., nested within) the Murden Creek watershed.

2.1.1 Cooper Creek

The 230-acre Cooper Creek watershed above the sampling station is the smallest watershed in this study and is relatively undeveloped. The Cooper Creek sampling station (Benthos Site Code: CoopBain) is about 20 ft above sea level, and the creek discharges to the head of Eagle Harbor about 600 ft downstream of the station. Stream gauging at this site began on May 22, 2010. Stream benthos samples have been collected six times between 2008 and 2014, with sampling dates occurring between August 12 and September 3 of each year. No stream benthos data were collected in 2009 at this site.

2.1.2 Issei Creek

The 514-acre Issei Creek watershed above the sampling station is the least developed of the eight study basins. The Issei Creek sampling station (Benthos Site Code: IssBain) is about 40 ft above sea level and the creek ultimately discharges to Fletcher Bay on the west side of the island. Currently, there is no stream flow gauge at this station. The Issei Creek station has been sampled for stream benthos five times between 2008 and 2013, with sampling dates occurring between August 16 and September 17 of each year. No stream benthos data were collected in 2009 or 2014 at this site.

2.1.3 Manzanita Creek

The 787-acre Manzanita Creek watershed above the Manzanita Creek station is relatively developed and is crossed by State Route (SR) 305. The Manzanita Creek station (Benthos Site Code: ManzBain) is located at an elevation of about 30 ft and ultimately drains to Manzanita Bay on the west side of the island. Currently, there is no stream flow gauge at the Manzanita Creek site. The site has been sampled for stream benthos five times between 2008 and 2013, with sampling dates occurring between August 16 and September 4 of each year. No stream benthos data were collected in 2009 or 2014 at this site.

2.1.4 Murden Creek

The 1,342-acre Murden Creek watershed above the sampling station is relatively developed and is also crossed by State Highway 305 NE. This is also the largest watershed in the study. The Murden Creek sampling site (Benthos Site Code: MurdBain) is actually located where State Highway 305 NE crosses the creek. The station is about 16 ft above sea level and ultimately discharges to Murden Cove on the east side of the island. Currently, there is no stream flow gauge at the site. This site has been sampled six times for stream benthos between 2008 and 2014, with sampling dates occurring between August 12 and September 3 of each year. No stream benthos data were collected in 2009 at this site.

2.1.5 Ravine Creek

The 331-acre Ravine Creek watershed above the sampling site is the most developed of the study basins as it drains a portion of the former City of Winslow and is also crossed by SR 305. The Ravine Creek sampling site (Benthos Site Code: RavBain) is about 20 ft above sea level and discharges to Eagle Harbor about 750 ft downstream of the sampling site. Stream gauging at this site began on October 17, 2011. This site has been sampled for stream benthos five times between 2008 and 2013, with sampling dates occurring between August 16 and September 2 of each year. No stream benthos data were collected in 2009 or 2014 at this site.

2.1.6 Springbrook Creek

The 842-acre Springbrook Creek watershed above the sampling station is relatively developed. The Springbrook Creek sampling site (Benthos Site Code: SpringBain) is located at an elevation of about 20 ft and the creek ultimately drains to Fletcher Bay on the west side of the island. Stream gauging at this site began on March 31, 2004. The site has been sampled for stream benthos five times between 2008 and 2013, with sampling dates occurring between August 16 and September 2 of each year. No stream benthos data were collected in 2009 or 2014 at this site.

2.1.7 Whiskey Creek

The 302-acre Whiskey Creek watershed above the sampling site is relatively developed. The Whiskey Creek sampling site (Benthos Site Code: WhisBain) is located at an elevation of about 16 ft, and the creek discharges to Eagle Harbor a little over 400 ft downstream of the sampling station. Currently, there is no stream flow gauge at this site. This site has been sampled for stream benthos twice, once on August 20, 2012, and again on August 19, 2013. No stream benthos data were collected in 2014 at this site.

2.1.8 Woodward Creek

The 629-acre Woodward Creek watershed above the sampling site (Benthos Site Code: WoodBain) is relatively undeveloped. The Woodward Creek basin is a subbasin of Murden Creek (i.e., a nested basin within the greater Murden Creek watershed). Currently, there is no stream flow gauge at this site. This site has been sampled for stream benthos twice, once on August 20 2013, and again on August 12 2014.

2.1.9 Stormwater Conveyance Site OFL169

To provide some perspective for the stream flow gauging data, flow data for a stormwater conveyance facility located in the former City of Winslow (Station OFL169) were also included in the hydrologic analysis. Flow gauging at this site began on June 17, 2010.

2.2 Compilation of Data

In addition to compiling City of Bainbridge Island stream flow and benthos data, we also compiled and analyzed land cover data that were used in the analysis of stream benthos data. The compilation process for these data sets: stream flow, stream benthos and land cover is described below.

2.2.1 Stream Flow

Stream flow data used in this report were obtained from the City of Bainbridge Island in the form of comma-delimited continuous (typically between 5 and 15 minute sampling intervals) stage and flow time series files for each station gauge and year. Included with the continuous flow records was an Excel worksheet that contained QA/QC logs for each data file that identified missing data time periods or periods of anomalous data.

The comma-delimited files were imported into an Access database and qualifier flags were added to the appropriate gauge time stamps for the anomalous data periods identified in the QA/QC log file. Database queries were then created so that data without any qualifier flags were used to calculate daily average flow for each gauge record and the number of usable records each day was tabulated so that days with incomplete data could be excluded from the analysis. An attempt was made to fill in missing data records using the fillMiss function in the R package waterData (Ryberg and Vecchia 2014), but the gaps were too large (more than 30 contiguous days were missing from each station's flow record).

The daily average flow data were then used to calculate eight hydrologic "flashiness" metrics that have been correlated with land cover (%Forest and %Urban land cover) and B-IBI scores (DeGasperi et al. 2009). These "flashiness" metrics are High Pulse Count, High Pulse Duration, High Pulse Range, Flow Reversals, TQmean, R-B Index, Low Pulse Count and Low Pulse Duration (see Table 2). Technically, flashiness is measured by the rate of change of flow and the duration of high flow during a storm event best represented by the R-B Index. However, these eight metrics have been shown to be highly correlated with each other (DeGasperi et al. 2009) and are therefore hereafter generally referred to as flashiness metrics. Flow flashiness generally results from increases in the rate of runoff resulting from development and increasing connectedness of stormwater infrastructure.

In addition to these "flashiness" metrics, two other stormwater-related metrics were evaluated (Qmax and Qmax:Qmean). These are also defined in Table 2. Two low flow metrics were included as well (summer 7-day low flow and summer 30-day low flow) and are defined in Table 2.

To put the Bainbridge Island flashiness metrics calculated from the tributary stream flow records into perspective, the results from the tributary streams were compared to the flow data from the stormwater conveyance site. The general expectation is that the magnitude of these metrics will increase (or decrease) for stream gauging locations representing low levels of development to higher levels of development and reach maximum (or minimum) levels in a catchment representing a very high level of development (i.e., Station OFL169).

Table 2. Description of hydrologic metrics evaluated in this study.

Metric Name	Abbreviated Name	units	Description	Expected Response to Urbanization	Basis
30-day summer low flow	summer 30-day low	cfs	30-day summer (Jul-Oct) low flow.	Indeterminate. [a]	Summer
7-day summer minimum flow	summer 7-day low	cfs	7-day summer (Jul-Oct) minimum flow.	Indeterminate. [a]	Summer
Flow Reversals	Flow Reversals	#	The number of times that the flow rate changed from an increase to a decrease or vice versa during a water year. Flow changes of less than 2 percent are not considered.	Increase.	WY
High Pulse Count	HPC	#	Numbers of times each water year that discrete high flow pulses occur.	Increase.	WY
High Pulse Duration	HPD	days	Annual average duration of high flow pulses during a water year.	Decrease.	WY
High Pulse Range	HPR	days	Range in days between the start of the first high flow pulse and the end of the last high flow pulse during a water year.	Increase.	WY
Low Pulse Count	LPC	#	Number of times each calendar year that discrete low flow pulses occurred.	Increase.	CY
Low Pulse Duration	LPD	days	Annual average duration of low flow pulses during a calendar year.	Decrease.	CY
Qmax	WY Q max	cfs	Annual water year maximum daily average flow.	Increase.	WY
Qmax:Qmean	WY Qmax:Qmean	unitless	Ratio of annual maximum daily flow to long-term mean annual flow.	Increase.	WY
Qmean	WY mean Q	cfs	Annual water year mean flow.	Indeterminate. [a]	WY
R-B Index	R-B Index	unitless	Richards-Baker Flashiness Index – A dimensionless index of flow oscillations relative to total flow based on daily average discharge measured during a water year.	Increase.	WY
TQmean	TQmean	fraction	The fraction of time during a water year that the daily average flow rate is greater than the annual average flow rate of that year.	Decrease.	WY

[a] *Although winter low flow has been shown to consistently decrease in response to urbanization, a similar consistent response in summer low flow has not been demonstrated (Konrad and Booth 2002, Konrad and Booth 2005). This may be due in part to confounding effects of water management activities – in particular to net import (export) of water into (out of) a particular stream basin (King County 2010). Examples of water management activities include surface water and groundwater withdrawals, wastewater exports and potable water imports and exports.*

2.2.2 Stream Benthos

Stream benthos (macroinvertebrate) data used in this report were obtained through the Puget Sound Stream Benthos (PSSB) database maintained by King County.[2] This regional database was developed as a data repository and analysis tool for macroinvertebrate data collected throughout the Puget Sound region, allowing for consistent comparisons among sites and monitoring programs over time.

Data were downloaded directly from the PSSB for all eight sites sampled by the City of Bainbridge Island. B-IBI analysis and component metrics were calculated with the 10–50 B-IBI scoring system using Wisseman (1998) taxa attributes, as well as the recently developed 0-100 B-IBI scoring system using Fore and Wisseman (2012) taxa attributes. Both methods were calculated using the fine taxonomic resolution as provided by the taxonomic lab. The purpose of calculating 10-50 and 0-100 B-IBI scores was to compare the earlier scoring system (10-50) with the recently developed 0-100 system (King County 2014). Scores between the two systems are different due to the updated species specific taxa attributes used (Wisseman 1998 vs Fore and Wisseman 2012), as well as the new 0-100 scoring system that has a wider range of potential values.

Macroinvertebrate samples were collected using three replicates of 3 square feet at each sampling location. For our analysis, we composited the replicate samples into one sample totaling 9 ft^2. A target 500-count subsample was used to calculate component metric and overall B-IBI scores. Replicate samples are typically composited for analysis primarily because taxa counts for individual samples are not always high enough to accurately quantify B-IBI as was the case with most of the Bainbridge Island replicate samples. Also, the majority of samples throughout the Puget Sound region do not have replicate data, therefore compositing these sites is the best way to compare scores across other sites and projects in the Puget Sound region.

In general, B-IBI is a quantitative method for determining the biological condition (i.e., health) of streams and comparing the condition of different streams or locations along a stream. However, B-IBI scores do not provide any diagnostic information on the causes of low B-IBI scores (i.e., poor biological condition or stream health). Three diagnostic metrics have now been incorporated into the Puget Sound Stream Benthos system. These diagnostic metrics may provide tools for identifying the causes of impairment of stream health. These three diagnostic metrics are:

- Hilsenhoff Biotic Tolerance Index
- Fine Sediment Sensitivity Index
- Metals Tolerance Index

These diagnostic metrics were developed to identify specific stressors or causes of poor biological condition. The stressors evaluated by these metrics include the input of excessive

[2] Puget Sound Stream Benthos (http://www.pugetsoundstreambenthos.org)

labile organic matter (i.e., animal waste including waste from humans), fine sediment (due to natural or human factors) and metal pollution (typically due to human influences).

The Hilsenhoff Biotic Tolerance Index estimates the overall tolerance of the sampled benthic community based on taxa tolerance scores related to sensitivity to labile organic matter pollution (Hilsenhoff 1988). The Hilsenhoff Biotic Tolerance Index is on a scale from 0 to 10 with higher values indicating the presence of more organic pollution tolerant organisms.

The Fine Sediment Sensitivity Index (Relyea et al. 2012) is used to identify samples with a high number of taxa sensitive to fine sediment. This index is not scaled from 0 to 10 but rather ranges from 0 to 200 or more in a few Puget Sound streams. Higher values of this index indicate the presence of more sensitive taxa. Lower values indicate that fewer of these taxa are present (a score of 0 means that no fine sediment sensitive taxa are present) and indicate that fine sediment may be a significant stressor at a particular site.

The Metals Tolerance Index was developed by McGuire (1999) and is used to identify samples with a high number of organisms that are tolerant of metals. The index ranges from 0 to 10 with higher values indicating the presence of more tolerant organisms and potentially elevated stream metals levels.

2.2.3 Land Cover

Land Cover data were compiled from the National Land Cover Database (NLCD) for the years 2006 and 2011. The land cover classes for developed and forested land were aggregated to %Developed (sum of high, medium and low intensity development categories) and %Forest (sum of deciduous, mixed and evergreen forest categories) within each delineated basin at three different spatial scales following the approach outlined by Wilhelm et al. (2011). The %Developed and %Forest aggregations were chosen for use in comparisons to stream benthos metrics because they have been shown to be correlated with B-IBI scores and several hydrologic metrics in previous studies (e.g., DeGasperi et al. 2009). The three different spatial scales assessed were:

- Whole contributing watershed above the sampling point.
- 90-m buffer along the delineated stream course.
- 1-km radius of the contributing watershed above the sampling point.

Initial basin delineations were determined using geographic information system (GIS) digital elevation models and tools in ArcMap GIS. Initial delineations were checked and revised in locations where on-the-ground experience indicated errors in the initial delineation.

2.3 Data Analysis

A number of analyses were conducted, but they generally fell into trend analyses of stream benthos metrics and correlation analyses and graphical evaluations of relationships between stream benthos metrics and land cover and stream benthos metrics and hydrologic metrics. The data analysis methods are described in more detail below.

2.3.1 Trends in Stream Benthos Metrics

Stream Benthos data were evaluated for trends at each site by performing a non-parametric Mann-Kendall trend test for the overall B-IBI scores (10-50 and 0-100 scale) and the ten component metrics associated with the two scales and the three diagnostic metrics. The Mann-Kendall test does not require that the data be normally distributed, so it is well suited to evaluating trends in environmental data that rarely ever meet the requirements of parametric statistical testing (Helsel and Hirsch 2002). The rkt package in R was used to perform the Mann-Kendall trend test (Marchetto 2014). [3,4]

The output from the test includes tau, which measures the strength of the monotonic relationship between time and the tested metric. “Strong” parametric correlations of 0.9 or above correspond to tau values of about 0.7 or above (Helsel and Hirsch 2002). The test also calculates a p-value, which is the probability of observing a trend given the hypothesis that no trend exists (the null hypothesis). A p-value of less than 0.05 is a standard threshold for rejecting the null hypothesis and accepting that there is a trend. Note that not rejecting the null hypothesis (i.e., p-value >=0.05) does not prove that there is not a trend, only that there is insufficient evidence to prove otherwise.

Generally, the ability to detect statistically significant trends in environmental data increases with the length of the data set and is reduced by data gaps. A rule of thumb is that a minimum of 10 years of complete data are needed to reliably detect a trend (if present) with more or fewer years required depending on variety of factors. These factors include the desired amount of change one wants to detect and the amount of sampling variation, including random sampling error and the amount of natural variability from one year to the next.

2.3.2 Comparison of Stream Benthos Diagnostic Metrics to Reference Site Data

To evaluate whether or not these diagnostic metrics might provide some indication of the relative importance of specific stressors as explanatory factors for low B-IBI scores observed in some Bainbridge Island streams, a preliminary set of ten presumed reference

[3] R Core Team. 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna Austria, http://www.R-project.org.

[4] Note that as a result of a large numbers of ties (equal values) in these relatively short records, the reported slope was occasionally reported as zero or near zero and assigned an improbable p-value of 1.00. Methods for adjusting slopes and p-values have been recommended by McBride (2002), but have not been implemented in the R package used in these analyses.

sites was identified for use in analyses being conducted for the Soos Creek Total Maximum Daily Load Study (Larson, Chad, personal communication, October 15, 2015). The distribution of these sites across the lowlands of Puget Sound is illustrated in Figure 3. This list of sites based on best professional judgment should be considered a starting point for evaluating the potential utility of these diagnostics metrics. For example, the list could be refined based on additional data and evaluations of the type conducted by Wilmoth et al. (2015).

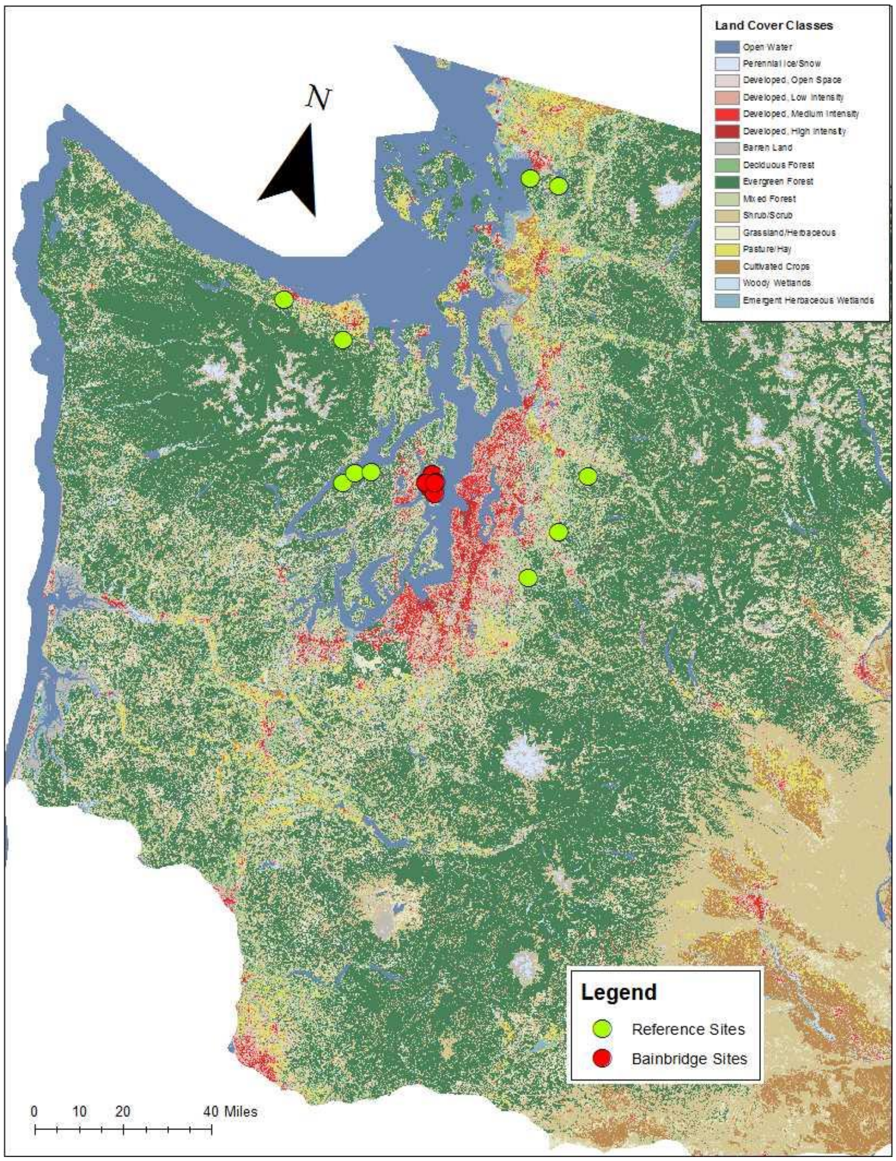

Figure 3. Map showing locations of presumed lowland Puget Sound reference sites in relation to City of Bainbridge Island stream benthos sampling sites.

Note: Map colors are based on the internal color template of the 2011 National Land Cover Database (see descriptions at top right of figure above).

2.3.3 Evaluate Relationship between Stream Benthos Metrics and Land Cover Data

Analyses were conducted to evaluate relationships between stream benthos metrics and land cover. Stream benthos metrics were compared to land cover data both graphically and through Pearson correlation analysis.

2.3.4 Evaluate Relationship between Stream Benthos Metrics and Hydrologic Metrics

Analyses were conducted to evaluate relationships between stream benthos metrics and hydrologic metrics. Because there were only three co-located stream flow gauging locations, comparisons of stream benthos metrics to hydrologic metrics was limited to graphical analysis.

2.3.5 Comparisons to Other Puget Sound Data

To begin to place the data for Bainbridge Island in the larger context of Puget Sound, comparisons were made for hydrologic and stream benthos metrics.

2.3.5.1 Stream Benthos and Hydrologic Metrics

To put the Bainbridge Island stream benthos data and hydrologic metric data into a regional perspective, B-IBI and hydrologic metric data for sites across WRIA 8 were compared to the Bainbridge Island data. The WRIA 8 data were generated as part of a four-year Status and Trends study of benthos and stream habitat at over 50 sites in WRIA 8 (King County 2015). A subset of these sampling locations an four additional Sentinel monitoring locations were identified as having a nearly co-located continuous stream gauge that could be used to develop paired B-IBI and hydrologic indictor values. A total of 28 co-located sites were considered to have sufficient data for use in making comparisons. This is currently the most extensive paired B-IBI – hydrologic metric data set currently available for Puget Sound lowland basins.

2.3.5.2 Stream Benthos Metrics and Land Cover Data

To put the Bainbridge Island stream benthos data into a regional perspective, B-IBI and 2011 National Land Cover Database (NLCD) data for sites throughout Puget Sound were compared to the Bainbridge Island B-IBI and land cover data. The Puget Sound data were generated as part of the Puget Lowland Benthic Index of Biotic Integrity (B-IBI) Recalibration Study.[5] The distribution of these sites across the Puget Sound basin is illustrated in Figure 4.

[5] B-IBI Recalibration Study: http://www.pugetsoundstreambenthos.org/Projects/BIBI-Recalibration-Documentation.aspx#group-1822795684

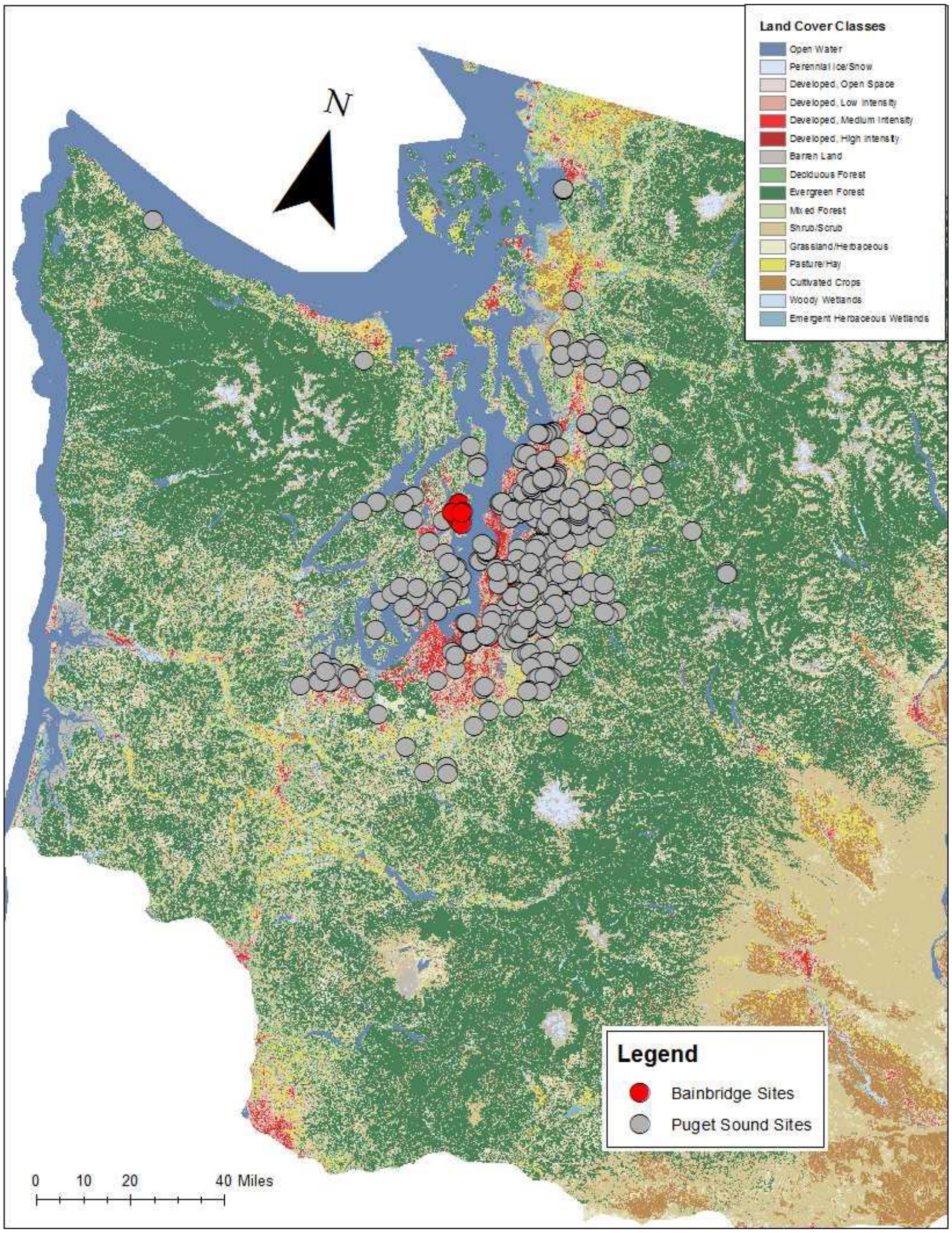

Figure 4. Map showing locations of Puget Sound lowland comparison sites in relation to City of Bainbridge Island stream benthos sampling sites.

Note: Map colors are based on the internal color template of the 2011 National Land Cover Database (see descriptions at top right of figure above).

3.0 RESULTS AND DISCUSSION

As noted above, this section is organized in the following sequence: Stream Flow, Stream Benthos, Relationships Between B-IBI scores and Hydrologic Metrics, Land Cover Data and Relationships between Stream Benthos Metrics and Land Cover Data.

3.1 Stream Flow

The hydrologic metrics calculated from the three stream and one stormwater conveyance flow records are summarized in Appendix A. The discharge (i.e., flow) data from each gauge is presented below followed by a comparison of flashiness metrics for the tributary streams to the stormwater conveyance monitoring site.

3.1.1 Cooper Creek

Continuous stream flow measurements have been made at Station SE62 on Cooper Creek since May 22, 2010. Daily mean discharge based on these continuous records is presented in Figure 5.

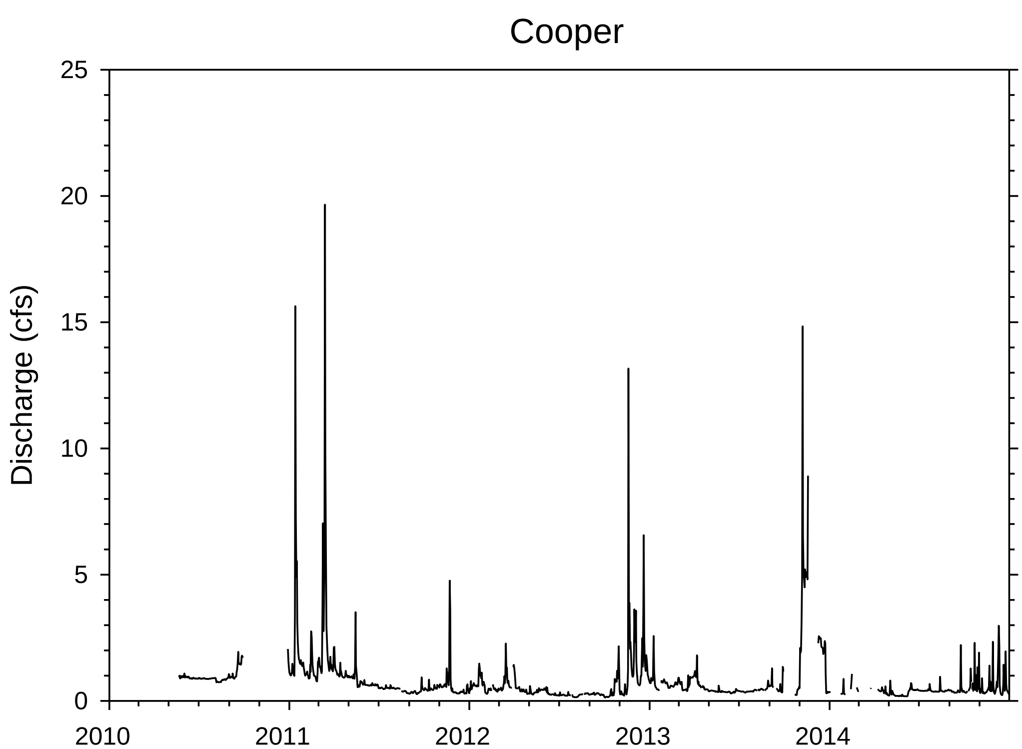

Figure 5. Daily mean discharge record for Cooper Creek Station SE62.

3.1.2 Ravine Creek

Continuous stream flow measurements have been made at Station SE1A on Ravine Creek since October 17, 2010. Daily mean discharge based on these continuous records is presented in Figure 6.

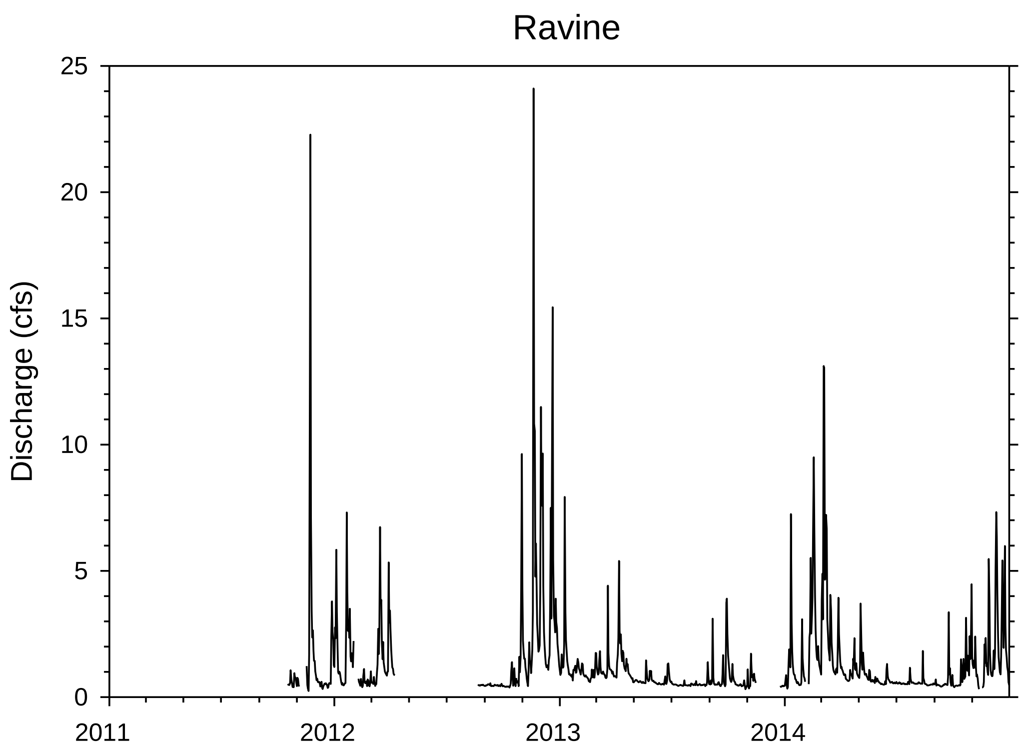

Figure 6. Daily mean discharge record for Ravine Creek Station SE1A.

3.1.3 Springbrook Creek

Continuous stream flow measurements have been made at Station SE35 on Springbrook Creek since March 31, 2004. Daily mean discharge based on these continuous records is presented in Figure 7.

3.1.4 Stormwater Conveyance Site OFL169

Continuous flow measurements have been made at the stormwater conveyance location OFL169 since June 17, 2010. Daily mean discharge based on these continuous records is presented in Figure 8.

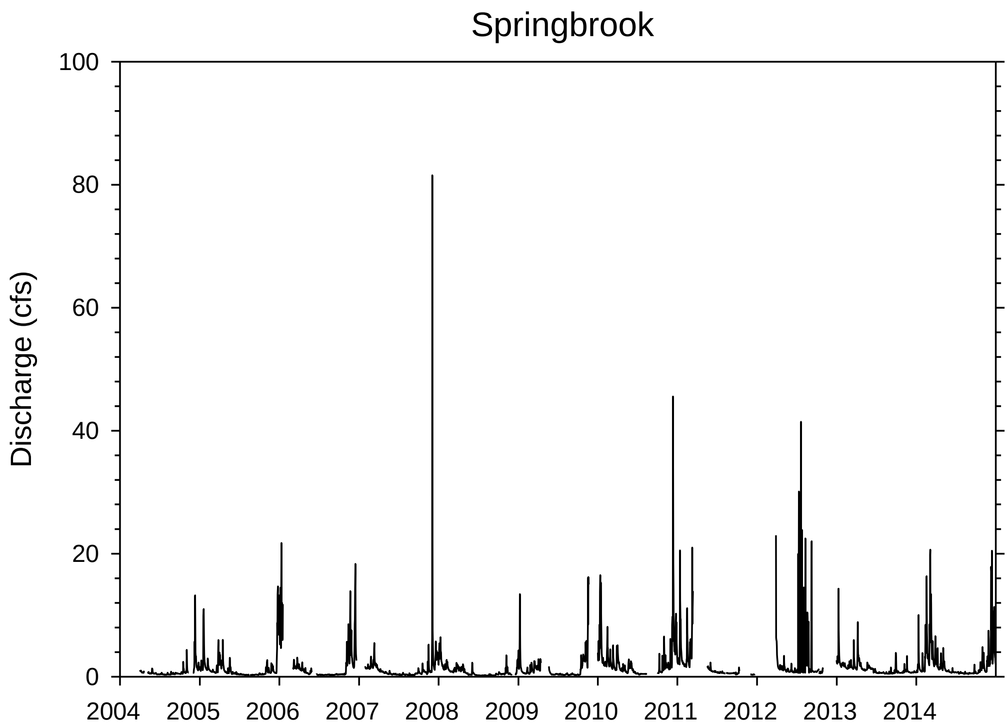

Figure 7. Daily mean discharge record for Springbrook Creek Station SE35.

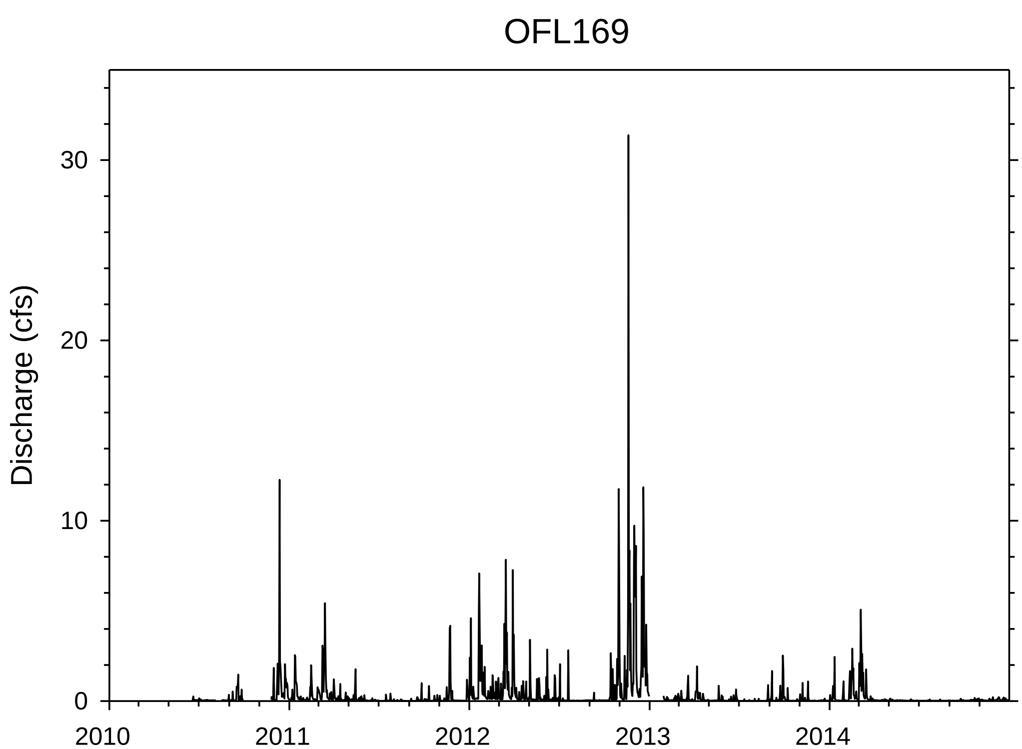

Figure 8. Daily mean discharge record for stormwater conveyance Station OFL169.

3.1.5 Tributary Stream and Stormwater Conveyance Flashiness

Figure 9 provides a set of bar charts comparing the arithmetic mean of the eight "flashiness" metrics between the stormwater conveyance station OFL169 in the former city of Winslow to the metrics calculated from the three tributary stream flow gauges. The bars were ordered from left to right in each chart to capture the development gradient from least (left) to most (right) developed with the most developed location represented by Station OFL169. The expectation is that the values for any particular metric would increase (or decrease depending on the metric) monotonically from left to right. However, there is a substantial amount of variation expected for basins with similar levels of development due to factors such as differences in surficial geology, in particular the amount of surficial bedrock (DeGasperi et al. 2009). The metric values also vary from year to year in response to variation in seasonal precipitation distribution and magnitude (King County 2011 and 2013). Therefore, it is not expected that all of these metrics follow this exact pattern, but those that do might be suggestive of their superiority for monitoring change over time in relation to future development and/or management actions.

The flashiness metrics that clearly follow the expected pattern are High Pulse Count, TQmean and R-B Index. Even though the limited data available for Ravine Creek precluded the reliable estimation of Low Pulse Count and Low Pulse Duration at this time, it is still possible to evaluate the Low Pulse Duration metric because it was highest at one of the least developed watersheds (Springbrook) and at OFL169 so it does not appear to strictly follow the expected pattern. The utility of Low Pulse Count is less clear. Low Pulse Count was lower for the less developed Cooper and Springbrook watersheds relative to OFL169.

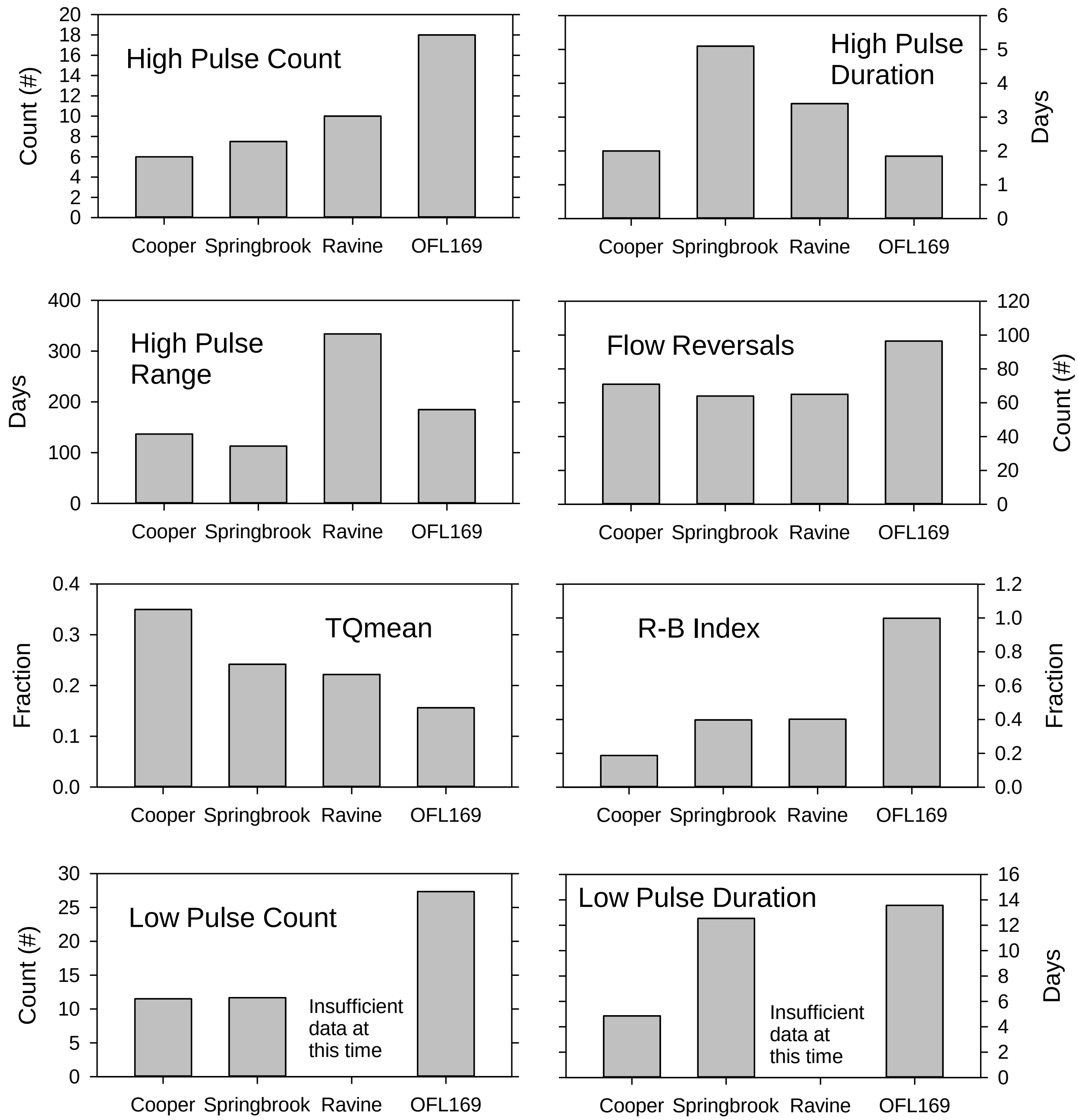

Figure 9. Bar charts comparing the arithmetic mean of eight "flashiness" metrics for Stormwater Conveyance OFL169 to the three tributary stream gauging sites.

3.2 Stream Benthos

The B-IBI data from each site is summarized below. The B-IBI summary is followed by the results of the trend analysis and the comparisons to data from Puget Sound reference sites. As discussed below, the newer 0-100 scale B-IBI has greater precision and is therefore the focus of the overall B-IBI summary. The 0-100 scale B-IBI scores are also used in the comparisons to hydrologic metrics, land cover data and to B-IBI data from other locations across Puget Sound that are presented in subsequent sections.

3.2.1 B-IBI Summary

The average 0-100 scale B-IBI scores spanning all of the years of data (2008-2014) were very poor for Ravine Creek; poor for Issei, Murden, and Whiskey creeks; and fair for Cooper, Manzanita, Springbrook, and Woodward creeks (Table 3). None of the eight sites investigated had average scores that showed good or excellent stream benthic communities, although two sites (Cooper Creek and Springbrook Creek) did have individual sampling years that had good scores. Figures illustrating the variation over time in 0-100 scale and 10-50 scale B-IBI scores at the eight monitoring locations are presented in Appendix B.

3.2.2 Trend Analysis

Trend analysis results for B-IBI 0–100 and B-IBI 10–50 scale scores and associated component metrics are presented in Appendix B. The results for B-IBI 0–100 and 10–50 scale scores are presented in Table 4 below.

A statistically significant ($p<0.05$) trend in B-IBI scores was detected at only one site (downward trend for the Murden Creek site) and only for B-IBI based on the updated 0–100 scale (Figure 10) . In general, it is expected that more statistically significant trends will be identified using the B-IBI 0-100 scale, because this updated version has been shown to have less relative error or noise compared to B-IBI calculated on the 10–50 scale (King County 2014, King County 2015).

More statistically significant B-IBI 0-100 scale component metric trends were also detected, consistent with the presumed greater trend detection power for the updated version of B-IBI (see Appendix B, Tables B1 and B2). Five statistically significant B-IBI 0-100 component metric trends were identified in four creek sites including two Murden Creek site component metrics which showed a downward trend in Ephemeroptera Richness and upward trend in Percent Dominance consistent with an overall downward trend in B-IBI 0–100 scale score at the Murden Creek site. Manzanita Creek's site showed an upward trend in Clinger Richness and both Issei Creek's site and Cooper Creek's site showed a downward trend in Tolerant Percent.

Only three component metric trends were identified as statistically significant based on B-IBI 10–50 scale component metrics, including the same single Cooper Creek site component

Table 3. Summary of 0-100 scale B-IBI scores, 2008-2014.

Stream	Site Code	2008	2009	2010	2011	2012	2013	2014	Mean
Cooper Creek	CoopBain	41.6		59.7	40.4	65.9	62.1	36.5	51.0
Issei Creek	IssBain	38.8		58.0	20.9	14.2	20.8		30.5
Manzanita Creek	ManzBain	34.9		56.3	38.9	44.3	55.3		45.9
Murden Creek	MurdBain	43.0		28.9	34.2	25.6	22.8	21.6	29.4
Ravine Creek	RavBain	8.7		23.7	6.5	15.3	10.0		12.8
Springbrook Creek	SpringBain	55.0		75.1	59.9	52.6	51.5		58.8
Whiskey Creek	WhisBain					21.9	22.2		22.1
Woodward Creek	WoodBain						49.7	59.9	54.8

Legend	Excellent	Good	Fair	Poor	Very Poor
	≥80 to 100	≥60 and <80	≥40 and <60	≥20 and <40	≥0 and <20

metric and two Murden Creek site component metrics identified based on B-IBI 0–100 scale.

Table 4. Summary of trend test results for B-IBI 0-100 and 10-50 scale scores.

Note: Mann-Kendall tau (strength and direction of trend) with statistical significance (p) in parentheses.

Stream	Period of Record	B-IBI (0-100)	B-IBI (10-50)
Cooper Creek [a]	2008-2014 (n=6)	-0.067 (1.00)	0.267 (0.566)
Issei Creek [b]	2008-2013 (n=5)	-0.600 (0.221)	-0.700 (0.130)
Manzanita Creek [c]	2008-2013 (n=5)	0.400 (0.462)	0.600 (0.192)
Murden Creek [d]	2008-2014 (n=6)	***-0.867 (0.024)***	-0.067 (1.00)
Ravine Creek [e]	2008-2013 (n=5)	0.000 (1.00)	-0.300 (0.613)
Springbrook Creek [f]	2008-2013 (n=5)	-0.600 (0.221)	-0.500 (0.312)
Whiskey Creek [g]	2012-2013 (n=2)	-	-
Woodward Creek	2013-2014 (n=2)	-	-

Note: Statistically significant (p<0.05) trends in bold italics. "n" indicates number of observations over period of record. "-" indicates stations where data were insufficient to evaluate trends.

[a] Cooper Creek missing data for 2009
[b] Issei Creek missing data for 2009 and 2014
[c] Manzanita Creek missing data for 2009 and 2014
[d] Murden Creek missing data for 2009
[e] Ravine Creek missing data for 2009 and 2014
[f] Springbrook Creek missing data for 2009 and 2014
[g] Whiskey Creek missing data for 2014

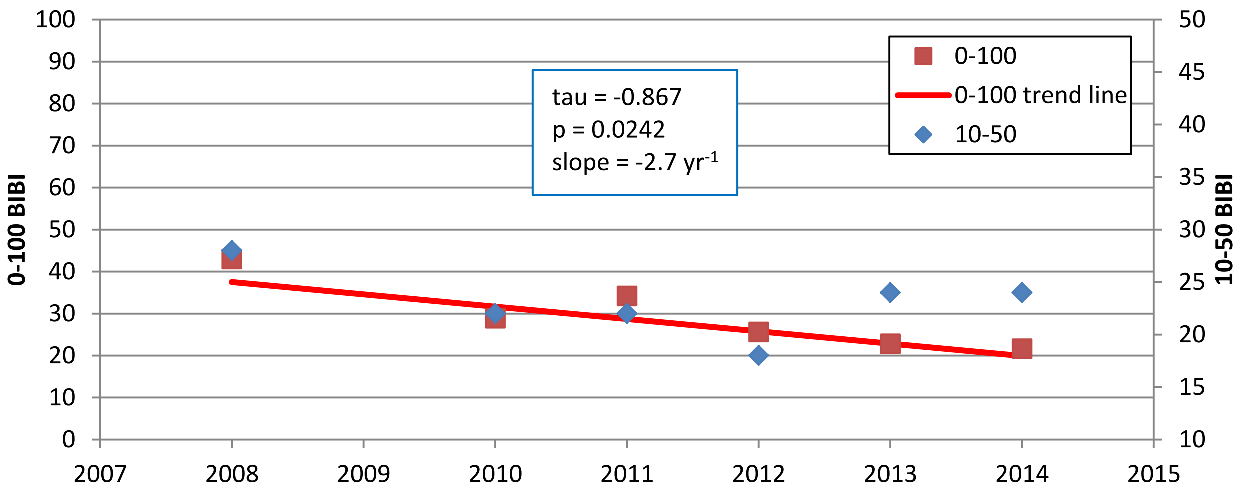

Figure 10. Murden Creek (MurdBain) B-IBI scores for the 0-100 and the 10-50 scoring system, including the trend line for the statistically significant downward trend in 0-100 Scale B-IBI.

It should be noted that statistically significant trends, especially derived from data records of fewer than 10 years can occur as a result of natural variability (Mazor et al. 2009). For example, a statistically significant trend in B-IBI scores was observed in the Cedar-Sammamish watershed (WRIA 8) over the period 2010–2013, but a qualitative evaluation of a longer King County dataset suggested that this short term trend may have been part of longer upward and downward fluctuations in B-IBI scores over the last decade and a half (King County 2015; Figure 11).

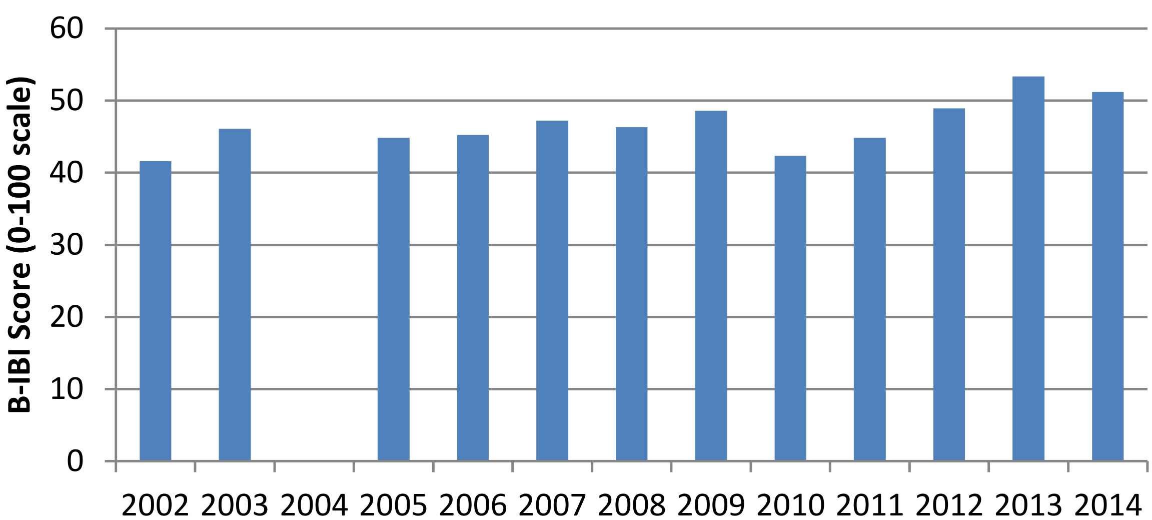

Figure 11. Arithmetic mean B-IBI scores from King County's Ambient Monitoring Program, 2002-2014.

Source: King County (2015)

In complex systems, change resulting from management actions may be subtle and slow to emerge. Long-term monitoring data provide a means of identifying important patterns, including trends, natural cycles and rare events. It is widely recognized that consistent, long-term environmental monitoring data are essential for effective watershed management and decision-making (e.g., Lovett et al., 2007; Lindenmayer and Likens, 2009; Burt et al., 2014). The current City of Bainbridge Island monitoring program appears to provide a good foundation for such a monitoring effort.

With the exception of a negative trend in the Metals Tolerance Index for Issei Creek, there were no significant upward or downward trends in any other diagnostic metric (Table 5).

Table 5. Summary of trend test results for stream benthos diagnostic metrics.

Note: Mann-Kendall tau (strength and direction of trend) with statistical significance (p) in parentheses.

Stream	Period of Record	Hilsenhoff Biotic Tolerance Index	Fine Sediment Index	Metals Tolerance Index
Cooper Creek [a]	2008-2014 (n=6)	-0.267 (0.566)	0.200 (0.681)	-0.600 (0.133)
Issei Creek [b]	2008-2013 (n=5)	-0.400 (0.462)	0.100 (1)	**-0.900 (0.043)**
Manzanita Creek [c]	2008-2013 (n=5)	-0.200 (0.806)	-0.300 (0.579)	-0.400 (0.462)
Murden Creek [d]	2008-2014 (n=6)	0.333 (0.452)	0.267 (0.566)	0.600 (0.133)
Ravine Creek [e]	2008-2013 (n=5)	0.300 (0.613)	0.000 (1)	-0.200 (0.794)
Springbrook Creek [f]	2008-2013 (n=5)	0.100 (1)	-0.300 (0.613)	0.200 (0.794)
Whiskey Creek [g]	2012-2013 (n=2)	-		-
Woodward Creek	2013-2014 (n=2)	-		-

Note: Statistically significant (p<0.05) trends in bold italics. "n" indicates number of observations over period of record. "-" indicates stations where data were insufficient to evaluate trends.

[a] Cooper Creek missing data for 2009
[b] Issei Creek missing data for 2009 and 2014
[c] Manzanita Creek missing data for 2009 and 2014
[d] Murden Creek missing data for 2009
[e] Ravine Creek missing data for 2009 and 2014
[f] Springbrook Creek missing data for 2009 and 2014
[g] Whiskey Creek missing data for 2014

The statistically significant downward trend in the Metals Tolerance Index appears to be due to a step change between 2011 and 2012 (Figure 12). Although there were no statistically significant trends in the 0–100 or 10-50 scale B-IBI score at this site, there was a somewhat similar step change in B-IBI scores (see Appendix B, Figure 2B), but between 2010 and 2011 rather than between 2011 and 2012, as suggested below.

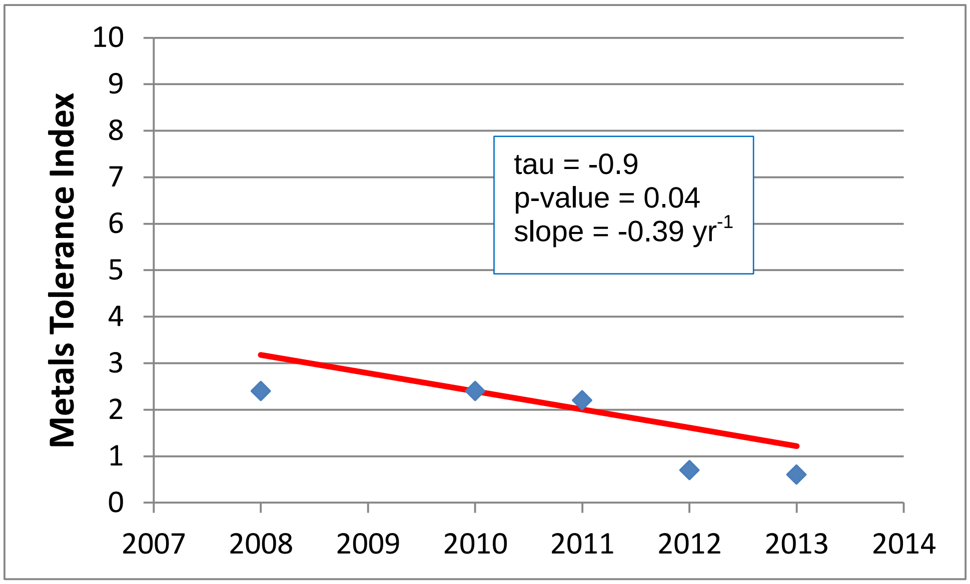

Figure 12. Metals Tolerance Index values for Issei Creek, including the trend line for the statistically significant downward trend.

Note: No stream benthos data collected at this station in 2009 or 2014.

3.2.3 Comparison of Stream Benthos Metrics to Reference Sites

Due to the preliminary nature of the reference sites chosen for this study and the lack of complete data for all sites between 2008 and 2014, comparisons were based on a qualitative comparison of box plots of the data compiled from all of the reference sites and the box (and whisker) plots of data from each Bainbridge Island site. Box plots are a convenient way of illustrating the distribution of sample data and making comparisons to other data sets. The upper and lower bounds of the box are defined by the first (25th percentile) and third (75th percentile) quartile (Q1 and Q3) of the data and the line through the box represents the median (or 50th percentile). The whiskers represent the limits of a simple outlier test based on the 1.5 times the interquartile range (IQR = Q3 – Q1; Q1 – 1.5xIQR and Q3 + 1.5xIQR) and the point symbols above and below the whiskers represent data outside of this range. Generally, if two boxes do not overlap, the data represented by the boxes are very likely to be significantly (statistically) different. Below, statements about sites with higher or lower index values are based on the lack of overlap between the reference sites and Bainbridge site boxes.

Figure 13A indicates that all City of Bainbridge Island sites typically have B-IBI scores that are lower than the majority of the scores from the presumed reference sites. This suggests that there may be sources of impairment at all of the sampling locations.

Figure 13B indicates that, with the exception of the Ravine Creek site, all City of Bainbridge Island sites typically have Hilsenhoff Biotic Tolerance Index scores that are similar to the scores from the presumed reference sites. This suggests that organic pollution may be a source of impairment at the Ravine Creek sampling location.

Figure 13C indicates that all City of Bainbridge Island sites typically have lower Fine Sediment Sensitivity Index scores than the presumed reference sites. This suggests that fine sediment may be a source of impairment at all City of Bainbridge Island stream sampling locations, with the Ravine Creek site having the lowest Fine Sediment Sensitivity Index score.

Figure 13D suggests that two City of Bainbridge Island sites typically have higher Metals Tolerance Index scores than the presumed reference sites; Cooper Creek and Ravine Creek. The Ravine Creek site has the highest values of the Metals Tolerance Index among City of Bainbridge Island stream benthos sampling sites, suggesting that metal pollution may be a source of impairment at the Ravine Creek site.

That seven of the eight stream benthos monitoring locations have B-IBI scores that are generally lower than the reference sites might not be a complete surprise given that studies have shown that even low levels of watershed development can have ecologically relevant effects on stream geomorphology (Vietz et al. 2014). However, legacy land uses (e.g., historical timber harvest and agriculture) have also potentially played a role in increasing the delivery of fine sediment to these streams. Such legacy land use effects have been recognized in other studies (e.g., Harding et al. 1998, Maloney and Weller 2011) and have been acknowledged in a recently developed framework for rapidly assessing stream susceptibility to alteration of stream flow and sediment patterns (Bledsoe et al. 2012). For example, historical logging practices resulted in removal of large woody debris from many stream channels resulting in greater sediment yields, more rapid bank erosion and incision and loss of variation in bed morphology (Booth et al. 1997). Investigation of the sediment character of these streams may be warranted. Pending the results of such a study, further geomorphic investigations could be conducted to identify sediment sources and assess the transport capacity of these stream systems. Continuous turbidity monitoring may also be warranted.

That organic and metal pollution diagnostic metrics for almost all of the creek sites (Cooper Creek appears to have a slightly elevated Metals Tolerance Index), except Ravine Creek, are similar to the reference sites would seem consistent with their relatively undeveloped condition and absence of significant untreated wastewater inputs. On the other hand, the diagnostic metrics for Ravine Creek suggest problems associated with organic pollution, metals and fine sediment which are not surprising given the relatively high level of development in the Ravine Creek watershed which includes portions of the former city of Winslow. Overall, Ravine Creek appears to suffer from the “urban stream syndrome” that includes flashier flows, elevated inputs of contaminants, and altered channel morphology resulting in reduced benthic species richness and an increased dominance of tolerant species (Walsh et al. 2005).

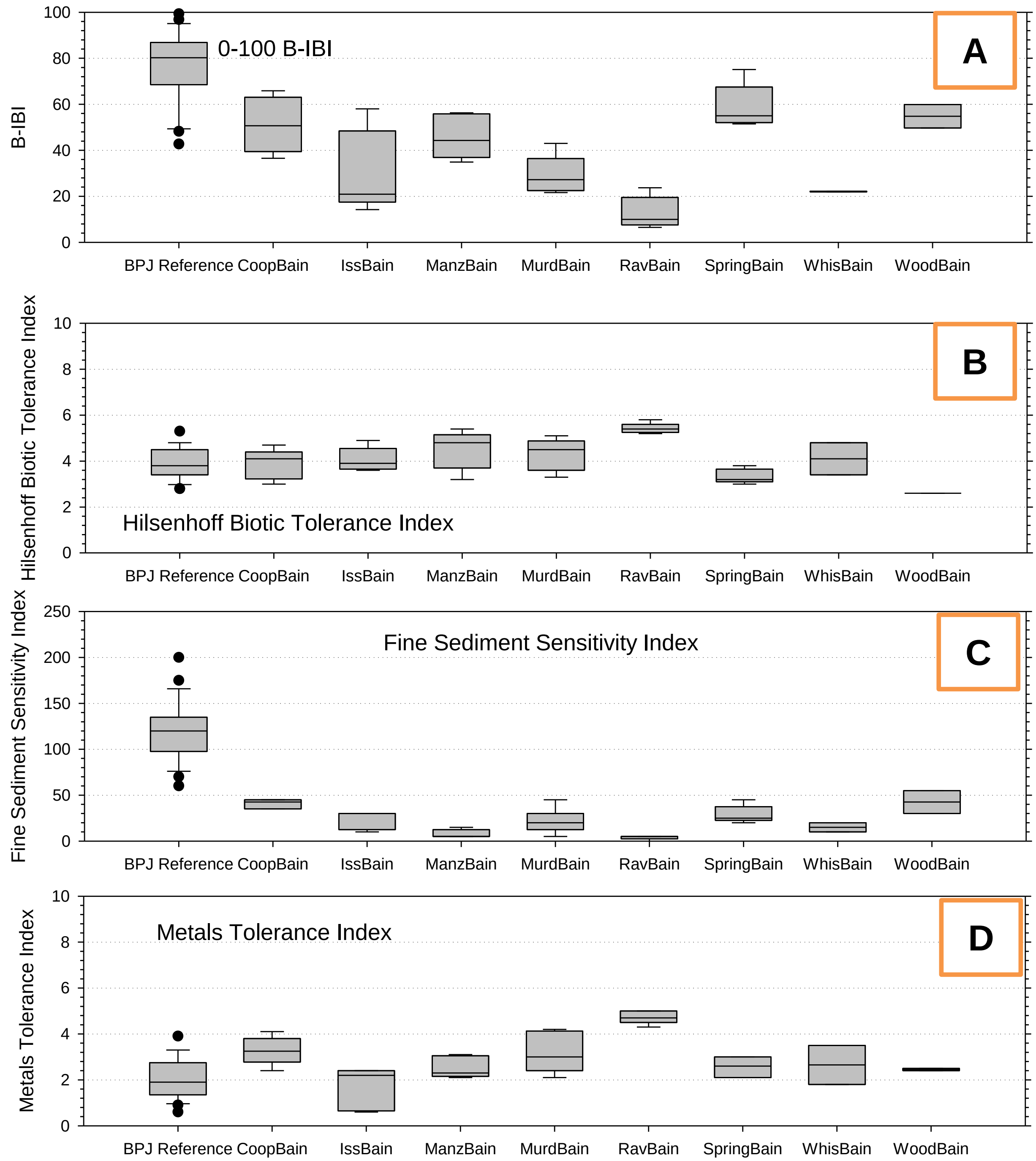

Figure 13. Box plots comparing diagnostic metrics between Puget Sound reference sites and Bainbridge Island sites: (A) B-IBI, (B) Hilsenhoff, (C) Fine Sediment Sensitivity Index, and (D) Metals Tolerance Index.

3.3 Relationships between B-IBI Scores and Hydrologic Metrics

Because stream flow is only measured at three of the eight B-IBI sampling locations, meaningful statistical comparisons are not possible. However, scatter plots comparing mean 0–100 scale B-IBI scores to mean values of hydrologic metrics were prepared and are presented in Figure 14 and Figure 15. Likely due to the limited number of comparisons[6], the limited duration of continuous flow measurements and the inherent variability of Puget Sound lowland streams, not all patterns were clearly consistent with expectations based on previous research (e.g., DeGasperi et al., 2009). However, the pattern of higher numbers of high pulses (High Pulse Count) being associated with lower B-IBI scores was evident and the association of the highest High Pulse Count with the most developed basin (Ravine Creek) was also consistent with findings of previous research (see Figure 14). The expected association of longer High Pulse Range with lower B-IBI scores was also evident and Ravine Creek had the highest High Pulse Range (see Figure 14).

A relationship between mean B-IBI and summer 7-day and 30-day low flow (normalized to basin area) across the three basins was evident, although the relationship was counterintuitive with higher low summer flows associated with lower B-IBI scores (see Figure 15). It appears that this finding is driven by a relatively high annual average water yield for Ravine Creek (approximately 37 inches of runoff per year). The high annual water yield of Ravine Creek is due to contributions from groundwater and possibly via enhanced groundwater collection and delivery through the urban subsurface stormwater conveyance system (Apfelbeck, C., email, 19 August 2015).

To put the Bainbridge Island stream benthos data and hydrologic metric data into a regional perspective, B-IBI and hydrologic metric data for sites across WRIA 8 were compared to the Bainbridge Island data (see Figure 14 and Figure 15). The WRIA 8 data were generated as part of a four year status and trends study of benthos and stream habitat at over 50 sites in WRIA 8 and 5 control sites located in the Puget Sound lowlands (King County 2015). A subset of these sampling locations were identified as having a nearly co-located continuous stream gauge that could be used to develop paired B-IBI and hydrologic indictor values. A total of 28 co-located sites were considered to have sufficient data for use in making comparisons. This is currently the most extensive paired B-IBI – hydrologic metric data set currently available for Puget Sound lowland basins.

Generally, hydrologic metrics calculated from the three City of Bainbridge Island flow gauging records are consistent with the larger WRIA 8 data set, with the possible exception of High Pulse Count. High Pulse Count at the City of Bainbridge Island sites was typically a bit lower than expected for the associated 0–100 B-IBI score relative to the WRIA 8 data

[6] Only three B-IBI monitoring sites have continuous flow gages and only two of these sites had usable Low Pulse Count and Low Pulse Duration values due to the relatively large calendar year gaps in the Ravine Creek flow records.

set, although the King County (2015) data set also included one site on Venema Creek that had a relatively low High Pulse Count associated with a relatively low B-IBI score.

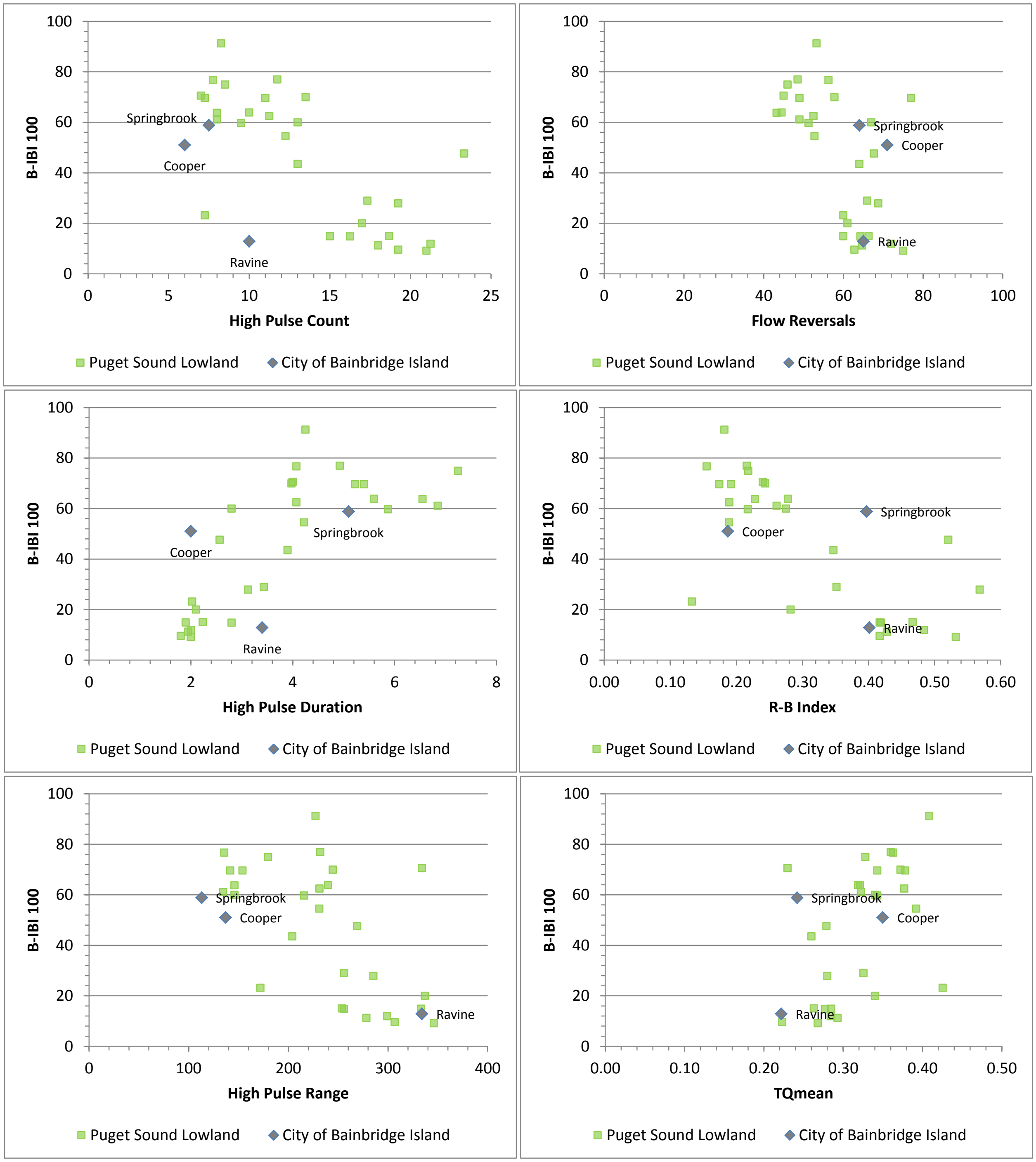

Figure 14. Scatterplots of 0-100 B-IBI scores vs. a) High Pulse Count, b) Flow Reversals, c) High Pulse Duration, d) R-B Index, e) High Pulse Range and f) TQmean.

Note: Data for the same metrics from the WRIA 8 Status and Trends study also plotted to provide context (King County, 2015)

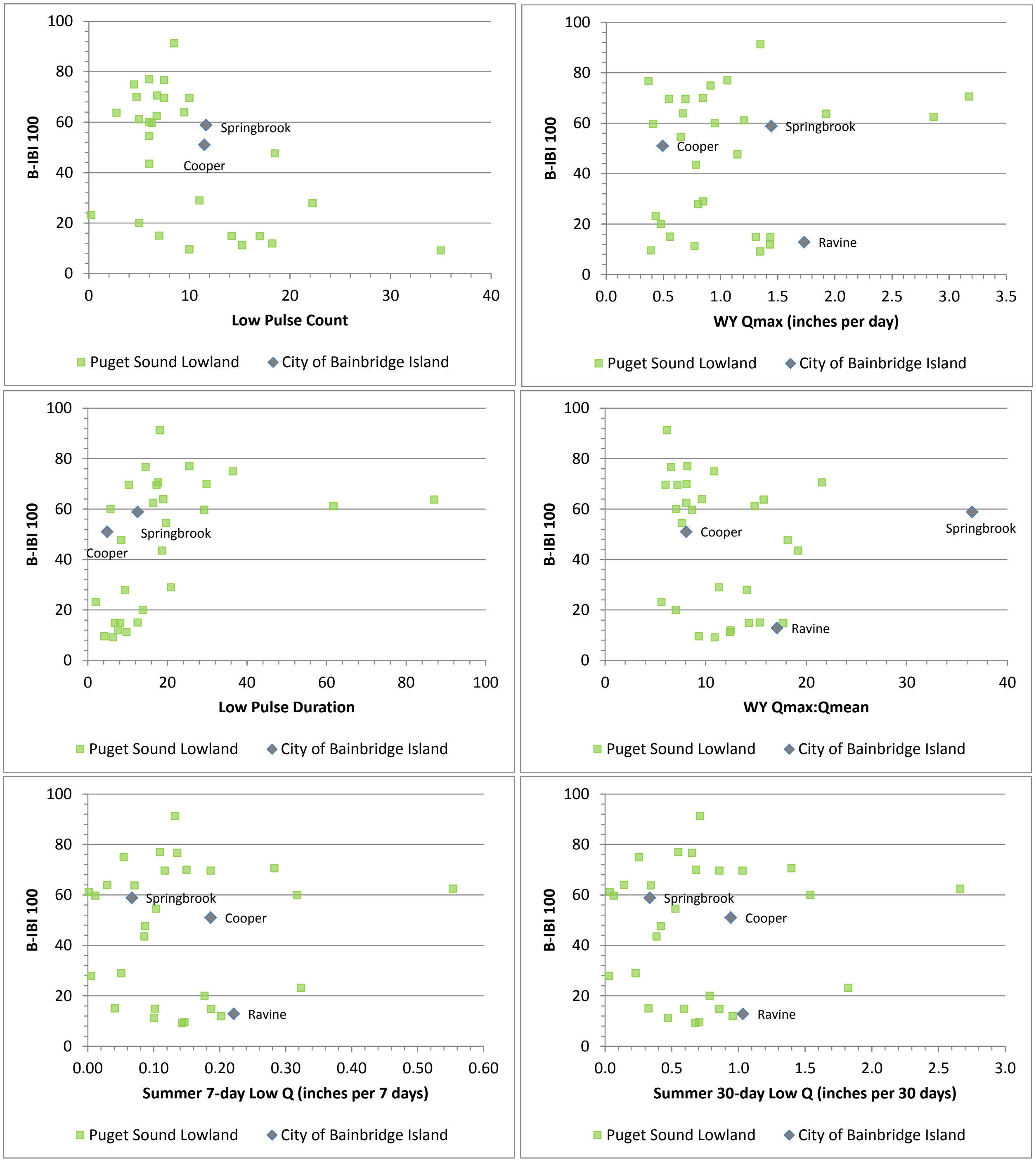

Figure 15. Scatterplots of 0-100 B-IBI scores vs. a) Low Pulse Count, b) Qmax, c) Low Pulse Duration, d) Qmax:Qmean, e) Summer 7-day low Q and f) summer 30-day low Q.

Note: Data for the same metrics from the WRIA 8 Status and Trends study also plotted to provide context (King County, 2015)

3.4 Land Cover Data

Based on the analysis of the 2006 and 2011 NLCD data, very little (<0.1 percent) developed land cover change occurred between 2006 and 2011 at any of the three scales of analysis (Table 6 and Appendix C). Somewhat more change appears to have occurred in the amount of forest land cover. Watershed scale changes in %Forest ranged from about ±1 percent or less (Cooper, Issei and Woodward watersheds) to losses of between 2.2 and 5.3 percent, with the largest losses measured in the Ravine and Murden watersheds. Estimated losses at the 90-m buffer and 1 km basin scale were typically higher than at the watershed scale. The greatest losses were measured in the 90 m buffer and were greatest in Ravine Creek (-15.1 percent), Murden Creek (-12.8 percent) and Woodward Creek (-11.2 percent).

A detailed land cover change analysis is beyond the scope of this study, but forest loss in the Murden Creek watershed, particularly within the 90-m stream buffer might be a factor in the observed decline in 0-100 scale B-IBI scores at the Murden Creek stream benthos monitoring location. However, it should be noted that using remote sensing data alone in detecting land cover changes is not without error (Jin et al. 2013). It is recommended that the changes measured here using the 2006 and 2011 NLCD data be critically evaluated, possibly including the investigation of other land use change detection methods (e.g., Pierce 2011). Routine evaluation of the stream benthos data from the Murden Creek site will also be useful in assessing whether the trend is spurious (i.e., due to natural variability) or is sustained in the future.

Table 6. Summary of the percent change between 2006 and 2011 in %Developed and %Forest land cover in the eight Bainbridge Island study basins at three different spatial scales.

Note: See text for details regarding the three spatial scales and data sources.

Creek	Basin Area (ac)	Watershed		90 m Buffer		1 km Basin	
		%Developed	%Forest	%Developed	%Forest	%Developed	%Forest
Cooper	230	0.0%	0.5%	0.0%	2.0%	0.0%	0.6%
Issei	514	0.0%	1.0%	0.0%	0.4%	0.0%	3.4%
Manzanita	787	0.0%	-2.2%	0.0%	-5.8%	0.0%	-3.4%
Murden	1342	0.0%	-4.5%	0.0%	-12.8%	0.0%	-8.5%
Ravine	331	0.0%	-5.3%	0.0%	-15.1%	0.0%	-8.0%
Springbrook	842	0.0%	-3.2%	0.0%	-7.2%	0.0%	-3.3%
Whiskey	302	0.0%	-0.4%	0.0%	-1.9%	0.0%	-1.2%
Woodward[a]	629	0.0%	-3.8%	0.0%	-11.2%	0.0%	-5.7%

[a] *Woodward Creek is a subbasin of Murden Creek*

Note: Positive values indicate an increase between 2006 and 2011 and negative values indicate a decrease.

The remainder of the analyses in this report focused on the 2011 land cover data, specifically %Developed and %Forest at the three spatial scales described in the Methods section (whole contributing watershed above the sampling point, 90-m buffer along delineated stream course, and a 1-km radius of the contributing watershed above the sampling point).

In general, the amount of development or forest cover was very similar regardless of the spatial scale (Table 7). This is consistent with other studies that have found a high degree of correlation between riparian buffer and watershed scale land cover (e.g., Alberti et al. 2007). Ravine Creek is the most developed watershed (46 percent developed at the watershed scale), while Issei Creek is the least developed (4 percent developed at the watershed scale). The Manzanita watershed has an intermediate level of development (22 percent). While Whiskey, Cooper, Springbrook, Woodward and Murden watersheds have relatively low levels of development (9 to 12 percent at the watershed scale).

A somewhat similar picture emerges based on %Forest land cover, with Ravine Creek having the lowest forest cover (35 percent at the watershed scale) and Issei Creek having the highest forest cover (90 percent at the watershed scale). However, the Cooper Creek watershed stands out as having relatively high forest cover (84 percent) for the amount of development in the watershed– almost as much forest cover as Issei Creek (see Table 7).

Table 7. Summary of 2011 %Developed and %Forest land cover in the eight Bainbridge Island study basins at three different spatial scales.

Note: See text for details regarding the three spatial scales and data sources.

	Basin Area	Watershed		90 m Buffer		1 km Basin	
Creek	**(ac)**	**%Developed**	**%Forest**	**%Developed**	**%Forest**	**%Developed**	**%Forest**
Cooper	230	10%	84%	3%	92%	9%	86%
Issei	514	4%	90%	1%	96%	1%	96%
Manzanita	787	22%	49%	16%	45%	18%	48%
Murden	1342	12%	65%	6%	57%	11%	58%
Ravine	331	46%	35%	31%	47%	48%	39%
Springbrook	842	12%	67%	8%	62%	13%	60%
Whiskey	302	9%	63%	9%	53%	11%	59%
Woodward[a]	629	10%	70%	4%	66%	14%	71%

[a] *Woodward Creek is a subbasin of Murden Creek*

Note: %Developed = Sum of Low, Medium and High Intensity Development. %Forest = Sum of Deciduous, Mixed and Evergreen Forest. Detailed land cover data provided in Appendix C.

3.5 Relationships between Stream Benthos Metrics and Land Cover Data

Figure 16 shows relationships between mean 0-100 scale B-IBI scores with %Developed and %Forest land cover estimated in 2011 at the three different scales. None of these relationships are statistically significant ($p<0.05$; see table below), but they are all in a direction consistent with the understanding that B-IBI is negatively correlated with %Developed and positively correlated with %Forest.

Table 8 provides Pearson correlation coefficient (R) and p-values for mean 0–100 scale B-IBI vs. %Developed and %Forest cover in 2011 at three different spatial scales (see above for description of the three different scales).

Table 8. Summary of Pearson correlations between 0-100 B-IBI scores and 2011 land cover metrics.

2011 Land Cover Metrics	R	p
Watershed Developed	-0.486	0.222
Buffer Developed	-0.551	0.157
1km Developed	-0.484	0.224
Watershed Forest	0.411	0.311
Buffer Forest	0.292	0.483
1km Forest	0.350	0.396

Figure 16 also shows relationships between mean 0-100 scale B-IBI scores and 2011 %Developed and %Forest land cover at three spatial scales in relation to 495 sites sampled across the lowlands of Puget Sound. The Puget Sound B-IBI values are means of measurements made at these sites between 2008 and 2014; the same span of sampling conducted on Bainbridge Island. Generally, the relationships between 0–100 B-IBI scores and %Developed and %Forest land cover are consistent with the larger Puget Sound lowlands data set.

Because of the highly correlated nature of land cover at various scales from local buffer to whole watersheds (noted above), it is not surprising that no clear patterns emerge in the comparisons of B-IBI vs %Developed or %Forest cover at the various landscape scales. Although the importance of forested riparian buffers is recognized for filtering pollutant inputs, providing shade and protecting streams from temperature extremes, stabilizing banks, delivering woody debris and leaf litter, etc., studies attempting to tease out the importance of intact riparian buffers to benthic biotic integrity have typically concluded that watershed scale urbanization is the overriding factor (e.g., Walsh et al. 2007, Wahl et al. 2013). However, intermittent intact riparian corridors have been suggested as the cause of improvement in local B-IBI scores in a degraded stream in at least one Puget Sound study (Booth et al. 2004).

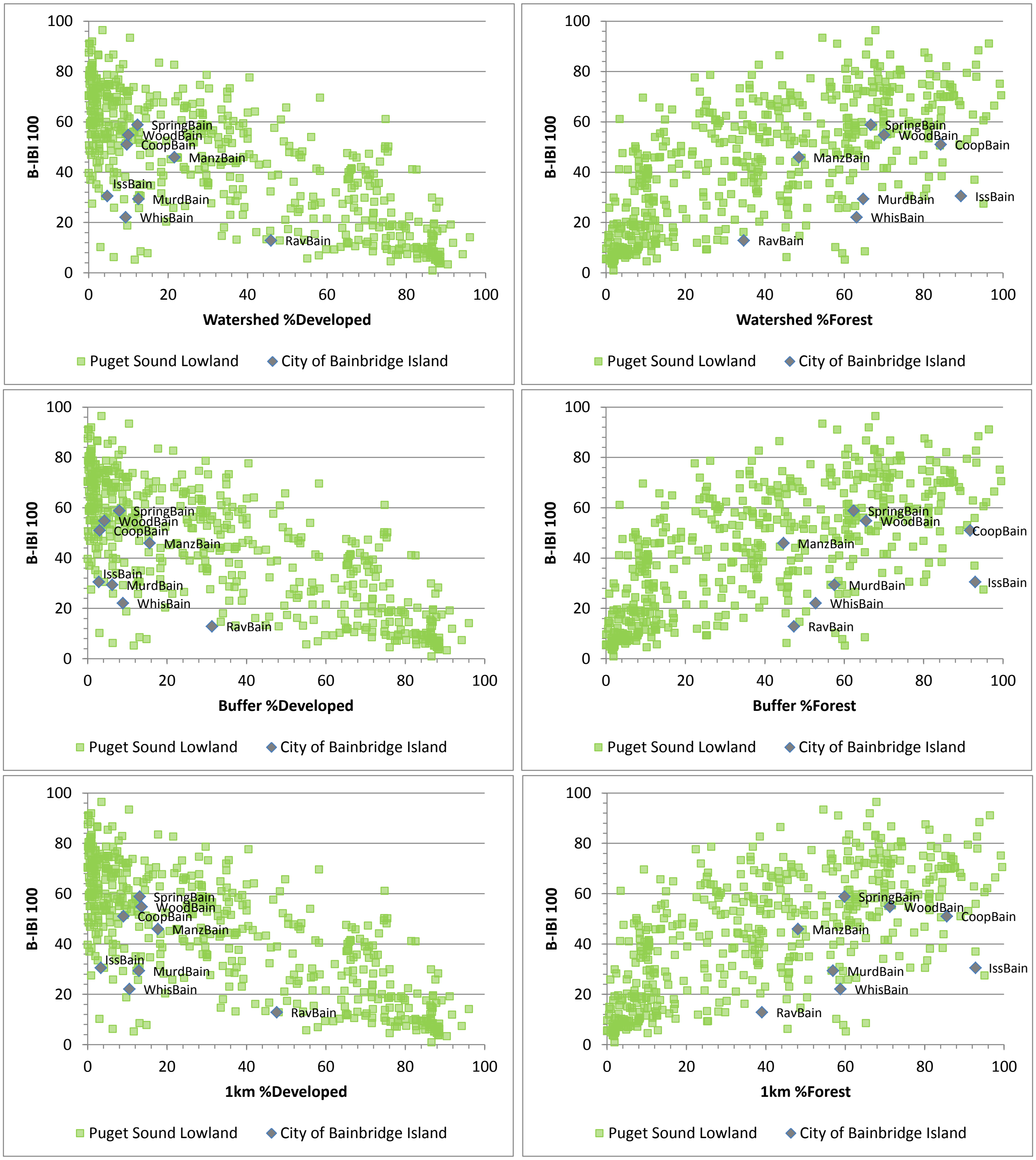

Figure 16. Scatterplots of 0-100 B-IBI scores vs. a) Watershed %Developed, b) Watershed %Forest, c) Buffer %Developed, d) Buffer %Forest, e) 1 km %Developed and f) 1 km %Forest.

Note: Data for the same metrics from the Puget Sound Stream Benthos Database to provide context

4.0 CONCLUSIONS AND RECOMMENDATIONS

In complex systems, change resulting from human activity and management actions may be subtle and slow to emerge. Long-term monitoring data provide a means of identifying important patterns, including trends, natural cycles and rare events. It is widely recognized that consistent, long-term environmental monitoring data are essential for effective watershed management and decision-making (e.g., Lovett et al., 2007; Lindenmayer and Likens, 2009; Burt et al., 2014). The current City of Bainbridge Island monitoring program appears to provide a good foundation for such a monitoring effort.

This study serves as an initial review of available data and provides documentation that will be useful for future evaluations. The data that are presented is variable and can be difficult to use for comparisons due to the difference in number of years and inconsistent periods of complete data. The City of Bainbridge Island has already taken measures in 2015 to improve the quality, completeness and management of the stream gauging data, including replacing battery with solar power (batteries require frequent replacement and can fail unpredictably) and data telemetry(which provides a means of detecting problems in near real time).

The study streams are located in watersheds that span a range of development and forest cover and have substantially varying contributing watershed areas. Watershed drainage area has a strong influence on flow statistics/metrics such as mean annual flow, summer low flow, TQmean and R-B Index. The low flow metrics (both 7- and 30-Day Low Flow) are dependent on contributing watershed size and stream type, but may be an important indicator of summer aquatic habitat and fish productivity. Watershed drainage area has no discernable effect on B-IBI scores (King County 2015).

The calculated hydrologic flashiness metrics High Pulse Count, TQmean and R-B Index were generally consistent with increasing levels of urbanization upstream of each gauge and consistent with other data collected in other Puget Sound watersheds. Increasing urbanization without adequate stormwater controls can lead to increased numbers of High Pulse Counts, higher R-B Index and lower TQmean (Baker et al. 2004, Booth et al. 2004, DeGasperi et al. 2009). In a recent hydrologic modeling study by Wu et al., (2015), High Pulse Count and R-B Index were consistently sensitive to change resulting from development and were also consistently sensitive (i.e., manageable) to integrated flow management approaches that included low impact development techniques. Unfortunately, TQmean was not included in that study.

The stream benthos data as represented by the 0-100 scale B-IBI score were also generally consistent with the level of development in the study watersheds and consistent with B-IBI data collected in other Puget Sound watersheds. However, all of the Bainbridge Island B-IBI scores were typically lower than B-IBI scores from a set of presumed reference sites distributed across Puget Sound.

Stream benthos diagnostic metric results provided a potential explanation for the relatively low B-IBI scores compared to reference conditions. The Fine Sediment Sensitivity Index was generally lower at all Bainbridge sites relative to the reference sites, suggesting that fine sediment inputs may be a factor in benthic impairment in these streams. If confirmed through evaluation of sediment conditions at these sites, the cause is unlikely related exclusively to development as some of these streams are relatively undeveloped. It is possible that at least in some instances, past land use (e.g., forest clearing and/or agriculture) is a factor in causing excess sediment to be (or to have been) delivered to these streams. Any development within these basins may also be a contributing factor as well; potentially delivering fine sediment through construction and land clearing activities and through stream bank erosion resulting from increased peak flows.

All three diagnostic metrics and the flashiness hydrologic metrics indicate that Ravine Creek, the most developed watershed that includes a portion of the former city of Winslow, is suffering from multiple stressors that potentially include organic and metal pollution, geomorphic alteration and flashier flows. The occurrence of multiple stressors in developed stream basins has been termed the "urban stream syndrome" (Walsh et al. 2005). The real challenge in the future may be testing the hypothesis that effective application of management practices at the catchment scale can maintain and/or improve habitat conditions and water quality and ultimately improve B-IBI scores (Scheuler et al. 2009).

Recommended future actions include discontinuing the collection of three separate stream benthos samples from each site for taxonomic analysis and instead compositing the samples in the field and having the contract laboratory analyze a single sample from each site each year. If that change is made, then it is recommended that a stream benthos field replicate sample be collected from a randomly selected site each year to allow incorporation of within site variance in trend analyses. This would result in a cost savings to the program (cost of analyzing 9 rather than 24 samples each year).

It is also recommended that an investigation of the stream sediment character at all stream benthos sampling sites be conducted with an emphasis on measuring fine sediment. Further studies may be warranted based on the results of the initial study (e.g., installation of continuous turbidity sensors).

5.0 REFERENCES

Alberti, M., D. Booth, K. Hill, B. Coburn, C. Avolio, S. Coe and D. Spirandelli. 2007. The impact of urban patterns on aquatic ecosystems: An empirical analysis in Puget lowland sub-basins. Landscape and Urban Planning 80:345-361.

Bledsoe, B.P., E.D. Stein, R.J. Hawley, and D. Booth. 2012. Framework and tool for rapid assessment of stream susceptibility to hydromodification. Journal of the American Water Resources Association (JAWRA) 48:788-808.

Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. 2004. Reviving urban streams: Land use, hydrology, biology, and human behavior. Journal of the American Water Resources Association (JAWRA) 40:1351-1364.

Booth, D.B., Montgomery, D.R., Bethel, J., 1997. Large woody debris in urban streams of Pacific Northwest. In Proceedings of the Conference on Effects of Watershed Development and Management on Aquatic Ecosystems, American Society of Civil Engineers, pp. 179–197.

Burt, T. P., N. J. K. Howden, and F. Worrall. 2014. On the importance of very long-term water quality records. WIREs Water 1:41-48.

Fore, L. and R. Wisseman. 2012. Pacific Northwest benthic invertebrate taxa attribute list. [Maintained as part of the Puget Sound Stream Benthos Database: http://pugetsoundstreambenthos.org/Default.aspx]

Harding, J.S., E.F. Benfield, P.V. Bolstad, G.S. Helfman, and E.B.D Jones, III. 1998. Stream biodiversity: The ghost of land use past. Proc. Natl. Acad. Sci. USA 95:14843-14847.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical Methods in Water Resources. U.S. Geological Survey, Techniques of Water-Resources Investigations Book 4, Chapter A3. http://pubs.usgs.gov/twri/twri4a3/

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7:65-68.

Jin, S., L. Yang, P. Danielson, C. Homer and J. Fry. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment 132:159-175.

King County. 2011. Existing Data Review for the Development of a Stormwater Retrofit Plan for Water Resource Inventory Area (WRIA) 9: Historical Flow, Total Suspended

Solids, and Turbidity Data. Prepared by Chris Knutson. King County Water and Land Resources Division, Seattle, Washington. http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/green-duwamish/stormwater-retrofit-project/update-existing-data-review.pdf

King County. 2013. Kitsap County Stream Flow Report. Prepared by Chris Knutson and Curtis DeGasperi for Kitsap County Public Works. King County Water and Land Resources Division, Seattle, Washington. http://www.kitsapgov.com/sswm/pdf/Kitsap-Stream-Flow-3-4-13.pdf

King County. 2014. Updating the Benthic Index of Biotic Integrity (B IBI): Outcomes and Key Findings. Prepared by Elene Dorfmeier (King County WLRD), Leska Fore (Statistical Design), Jo Wilhelm and Deb Lester (King County WLRD). King County Water and Land Resources Division, Seattle, Washington. http://www.pugetsoundstreambenthos.org/Projects/EPA_Grant_2010/TechDocs/Final/BIBI_Update_OutcomesAndKeyFindings.pdf

King County. 2015. Monitoring for Adaptive Management: Status and Trends of Aquatic and Riparian Habitats in the Lake Washington/Cedar/Sammamish Watershed (WRIA 8). Water and Land Resources Division, Seattle, WA. http://www.kingcounty.gov/depts/dnrp/wlr/sections-programs/science-section/doing-science/wadeable-streams.aspx

Lindenmayer, D.B. and G.E. Likens. 2009. Adaptive monitoring: a new paradigm for long-term research and monitoring. Trends in Ecology and Evolution 24:482-486.

Lovett, G. M., D. A. Burns, C. T. Driscoll, J. C. Jenkins, M. J. Mitchell, L. Rustad, J. B. Shanley, G. E. Likens, and R. Haeuber. 2007. Who needs environmental monitoring? Frontiers in Ecology and the Environment 5:253-260.

Maloney, K.O. and D.E. Weller. 2011. Anthropogenic disturbance and streams: land use and land-use change affect stream ecosystems via multiple pathways. Freshwater Biology 56:611-626.

Marchetto, A. 2014. rkt: Mann-Kendall test, Seasonal and Regional Kendall Tests. R package version 1.3. http://CRAN.R-project.org/package=rkt

Mazor, R.D, A.H. Purcell, and V.H. Resh. 2009. Long-term variability in bioassessments: A twenty-year study from two Northern California streams. Environmental Management 43:1269-1268.

McGuire, D.L. 1999. Clark Fork River Macroinvertebrate Community Biointegrity: 1997 and 1998 Assessments. Prepared for Montana Department of Environmental Quality, Planning, Prevention and Assistance Division. June.

Pierce, K. 2011. Final Report on High Resolution Change Detection Project. Washington Department of Fish and Wildlife, Olympia, WA http://wdfw.wa.gov/conservation/research/projects/aerial_imagery/index.html

Relyea, C.D., G.W. Minshall and R.J. Danehy. 2012. Development and validation of an aquatic Fine Sediment Biotic Index. Environmental Management 49:242-252.

Ryberg, K.R and A.V. Vecchia. 2014. waterData: An R Package for Retrieval, Analysis, and Anomaly Calculation of Daily Hydrologic Time Series Data. R package version 1.0.4. http://CRAN.R-project.org/package=waterData

Scheuler, T.R., L. F-M., and K. Cappiella. 2009. Is impervious cover still important? Review of recent research. Journal of Hydrologic Engineering 14:309-315. http://clear.uconn.edu/projects/tmdl/library/papers/Schueler-etal_2009.pdf

Vietz, G.J., M.J. Sammonds, C.J. Walsh, T.D. Fletcher, I.D. Rutherfurd, and M.J. Stewardson. 2014. Ecologically relevant geomorphic attributes of streams are impaired by even low levels of watershed effective imperviousness. Geomorphology 206:67-78.

Wahl, C.M., A. Neils, and D. Hooper. 2013. Impacts of land use at the catchment scale constrain the habitat benefits of stream riparian buffers. Freshwater Biology 58:2310-2324.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman and R.P. Morgan. 2005. The urban stream syndrome: current knowledge and the search for a cure. J. N. Amer. Benthol. Soc. 24:706-723.

Walsh, C.J., K.A. Waller, J.Gehling, and R. Mac Nally. 2007. Rivering invertebrate assemblages are degraded more by catchment urbanization than riparian deforestation. Freshwater Biology 52:574-587.

Wilhelm, J.O. P. Leinebach, L. Fore, D. Lester, K. Adams and G. Hayslip. 2013. Memorandum: Watershed Delineation and Land Cover Calculations for Puget Sound Stream Basins. http://pugetsoundstreambenthos.org/Projects/EPA_Grant_2010/Data/GIS_Memo.pdf

Wilmoth, S.K., K.M. Irvine and C.A. Larson. 2015. Evaluating Physical Habitat and Water Chemistry Data from Statewide Stream Monitoring Programs to Establish Least-

Impacted Conditions in Washington State. U.S. Geological Survey, Bozeman, MT and Washington Department of Ecology, Olympia, WA. Ecology Publication No. 15-03-011. https://fortress.wa.gov/ecy/publications/SummaryPages/1503011.html

Wisseman, R. 1998, Common Pacific Northwest benthic invertebrate taxa, draft. Aquatic Biology Associates, Corvallis, OR. [Benthic taxa attribute list maintained as part of the Puget Sound Stream Benthos Database: http://pugetsoundstreambenthos.org/Default.aspx]

Wu, H., J.P. Bolte, D. Hulse and B.R. Johnson. 2015. A scenario-based approach to integrating flow-ecology research with watershed development planning. Landscape and Urban Planning 74-89.

Appendix A: Hydrologic Metric Data

Table A1 Summary of Hydrologic metrics calculated from City of Bainbridge Island gauging records.

Basin	Gauge	Metric	Units	Years		# Years	Mean	Std Dev
Summer Metrics								
Cooper	SE62_Cooper	summer 30-day low	cfs	2011	2014	3	0.30	0.09
Cooper	SE62_Cooper	summer 7-day low	cfs	2011	2014	3	0.26	0.09
OFL169	OFL169	summer 30-day low	cfs	2011	2014	4	0.02	0.01
OFL169	OFL169	summer 7-day low	cfs	2011	2014	4	0.01	0.01
Ravine	SE1A_Ravine	summer 30-day low	cfs	2013	2014	2	0.48	0.00
Ravine	SE1A_Ravine	summer 7-day low	cfs	2013	2014	2	0.44	0.01
Springbrook	SE35_Springbrook	summer 30-day low	cfs	2005	2014	8	0.40	0.20
Springbrook	SE35_Springbrook	summer 7-day low	cfs	2005	2014	8	0.34	0.16
Water Year Metrics								
Cooper	SE62_Cooper	Flow Reversals	#	2012	2012	1	71.0	-
Cooper	SE62_Cooper	HPC	#	2012	2012	1	6.0	-
Cooper	SE62_Cooper	HPD	days	2012	2012	1	2.0	-
Cooper	SE62_Cooper	HPR	days	2012	2012	1	137	-
Cooper	SE62_Cooper	R-B Index	unitless	2012	2012	1	0.19	-
Cooper	SE62_Cooper	TQmean	fraction	2012	2012	1	0.35	-
Cooper	SE62_Cooper	WY mean Q	cfs	2012	2012	1	0.46	-
Cooper	SE62_Cooper	WY Q max	cfs	2012	2012	1	4.8	-
Cooper	SE62_Cooper	WY Qmax:Qmean	unitless	2012	2012	1	8.1	-
OFL169	OFL169	Flow Reversals	#	2012	2014	2	96.5	2.12
OFL169	OFL169	HPC	#	2012	2014	2	18	11.3
OFL169	OFL169	HPD	days	2012	2014	2	1.9	0.07
OFL169	OFL169	HPR	days	2012	2014	2	185	79.2
OFL169	OFL169	R-B Index	unitless	2012	2014	2	1.00	0.10
OFL169	OFL169	TQmean	fraction	2012	2014	2	0.16	0.05
OFL169	OFL169	WY mean Q	cfs	2012	2014	2	0.29	0.19
OFL169	OFL169	WY Q max	cfs	2012	2014	2	6.5	2.0
OFL169	OFL169	WY Qmax:Qmean	unitless	2012	2014	2	15.4	4.7
Ravine	SE1A_Ravine	Flow Reversals	#	2013	2013	1	65	-
Ravine	SE1A_Ravine	HPC	#	2013	2013	1	10	-

Basin	Gauge	Metric	Units	Years		# Years	Mean	Std Dev
Ravine	SE1A_Ravine	HPD	days	2013	2013	1	3.4	-
Ravine	SE1A_Ravine	HPR	days	2013	2013	1	334	-
Ravine	SE1A_Ravine	R-B Index	unitless	2013	2013	1	0.40	-
Ravine	SE1A_Ravine	TQmean	fraction	2013	2013	1	0.22	-
Ravine	SE1A_Ravine	WY mean Q	cfs	2013	2013	1	1.4	-
Ravine	SE1A_Ravine	WY Q max	cfs	2013	2013	1	24.1	-
Ravine	SE1A_Ravine	WY Qmax:Qmean	unitless	2013	2013	1	17.1	-
Springbrook	SE35_Springbrook	Flow Reversals	#	2008	2014	2	64	14.1
Springbrook	SE35_Springbrook	HPC	#	2008	2014	2	7.5	2.12
Springbrook	SE35_Springbrook	HPD	days	2008	2014	2	5.1	0.14
Springbrook	SE35_Springbrook	HPR	days	2008	2014	2	113	76.4
Springbrook	SE35_Springbrook	R-B Index	unitless	2008	2014	2	0.40	0.13
Springbrook	SE35_Springbrook	TQmean	fraction	2008	2014	2	0.24	0.02
Springbrook	SE35_Springbrook	WY mean Q	cfs	2008	2014	2	1.49	0.19
Springbrook	SE35_Springbrook	WY Q max	cfs	2008	2014	2	51.1	43.06
Springbrook	SE35_Springbrook	WY Qmax:Qmean	unitless	2008	2014	2	36.5	30.76

Calendar Year Metrics								
Cooper	SE62_Cooper	7-day low	cfs	2011	2012	2	0.22	0.1
Cooper	SE62_Cooper	LPC	#	2011	2012	2	11.5	9.2
Cooper	SE62_Cooper	LPD	days	2011	2012	2	4.9	4.0
OFL169	OFL169	7-day low	cfs	2011	2014	3	1E-02	0.0
OFL169	OFL169	LPC	#	2011	2014	3	27.3	12.7
OFL169	OFL169	LPD	days	2011	2014	3	13.6	10.4
Springbrook	SE35_Springbrook	7-day low	cfs	2005	2014	3	0.40	0.13
Springbrook	SE35_Springbrook	LPC	#	2005	2014	3	11.7	2.9
Springbrook	SE35_Springbrook	LPD	days	2005	2014	3	12.5	6.2

Appendix B: Stream Benthos Data: B-IBI Figures and Trend Analysis Results

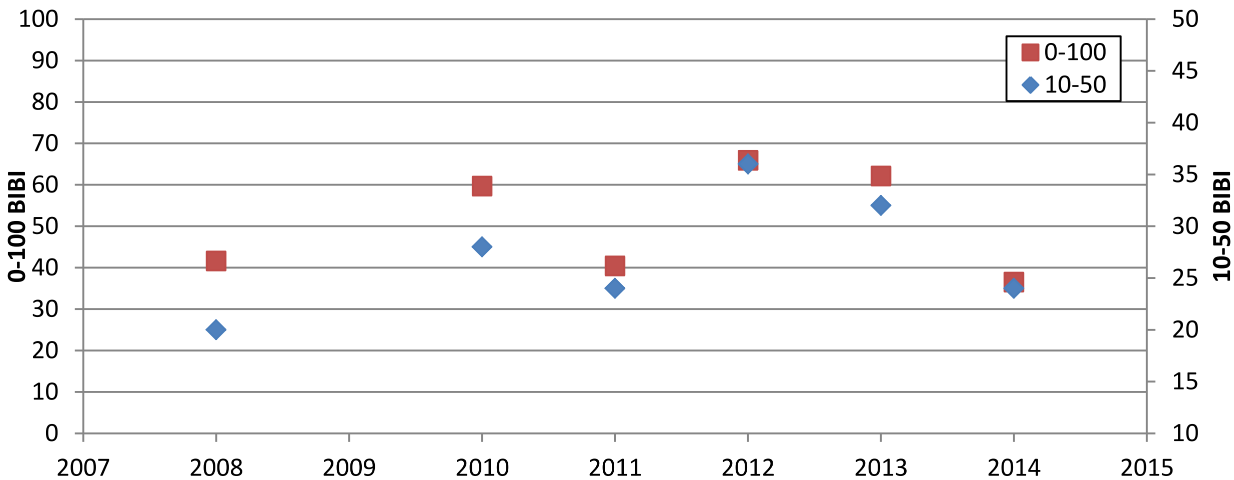

Figure B1. Cooper Creek (CoopBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

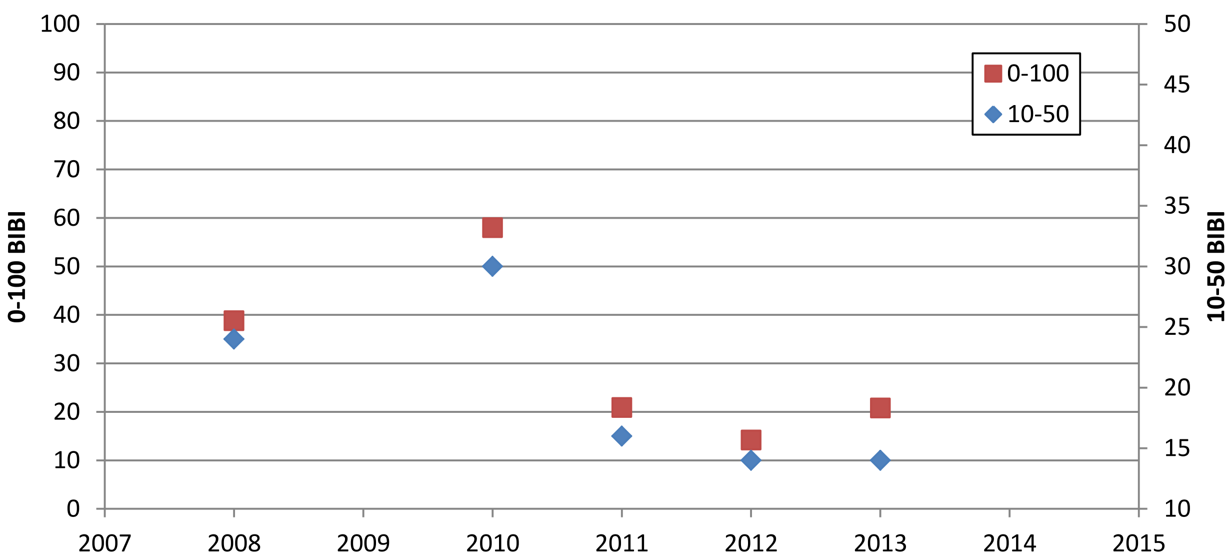

Figure B2. Issei Creek (IssBain B-IBI scores for the 0-100 and the 10-50 scoring system.

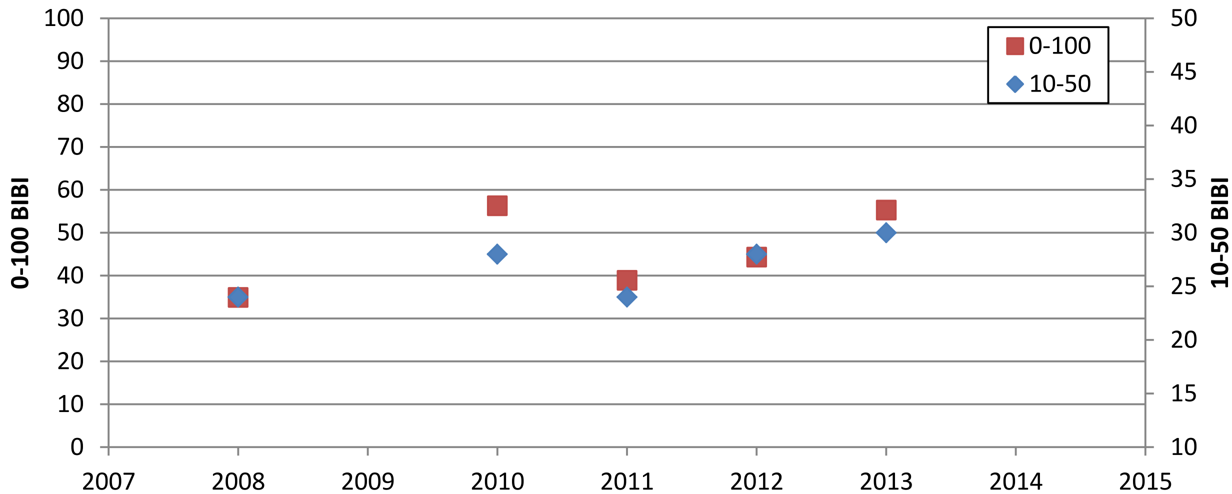

Figure B3. Manzanita Creek (ManzBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

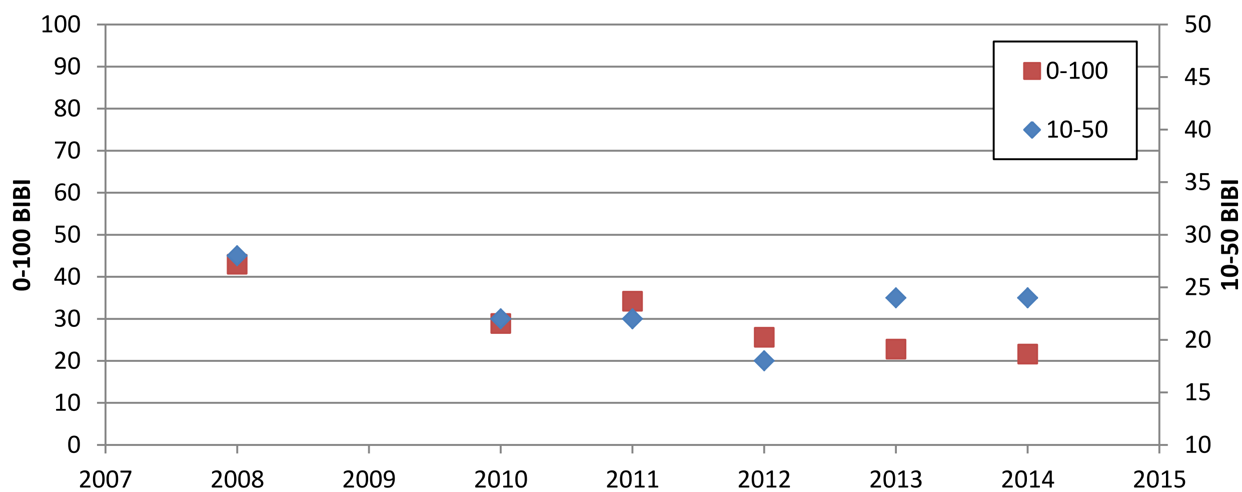

Figure B4. Murden Creek (MurdBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

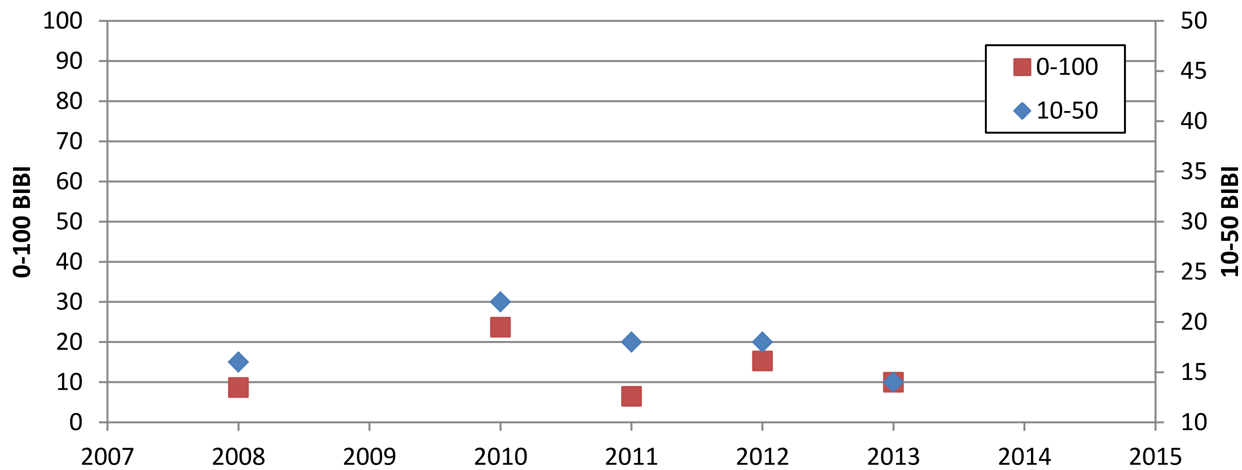

Figure B5. Ravine Creek (RavBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

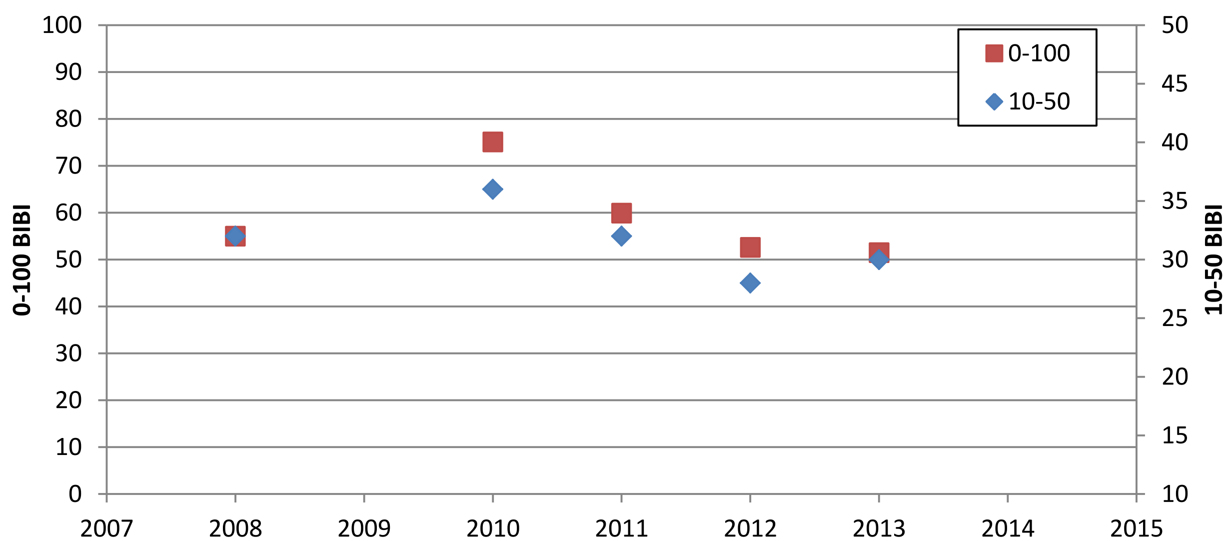

Figure B6. Springbrook Creek (SpringBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

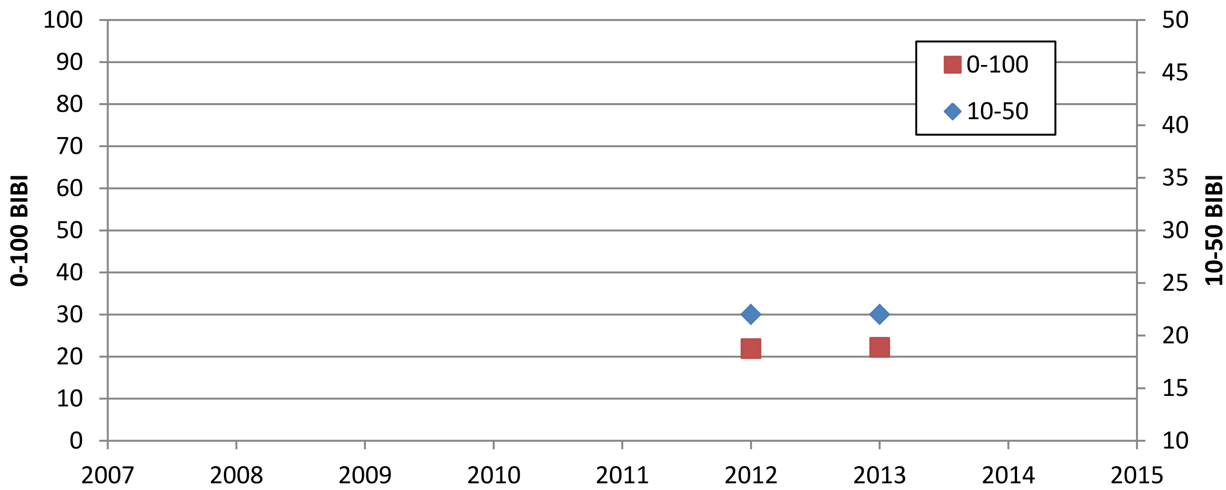

Figure B7. Whiskey Creek (WhisBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

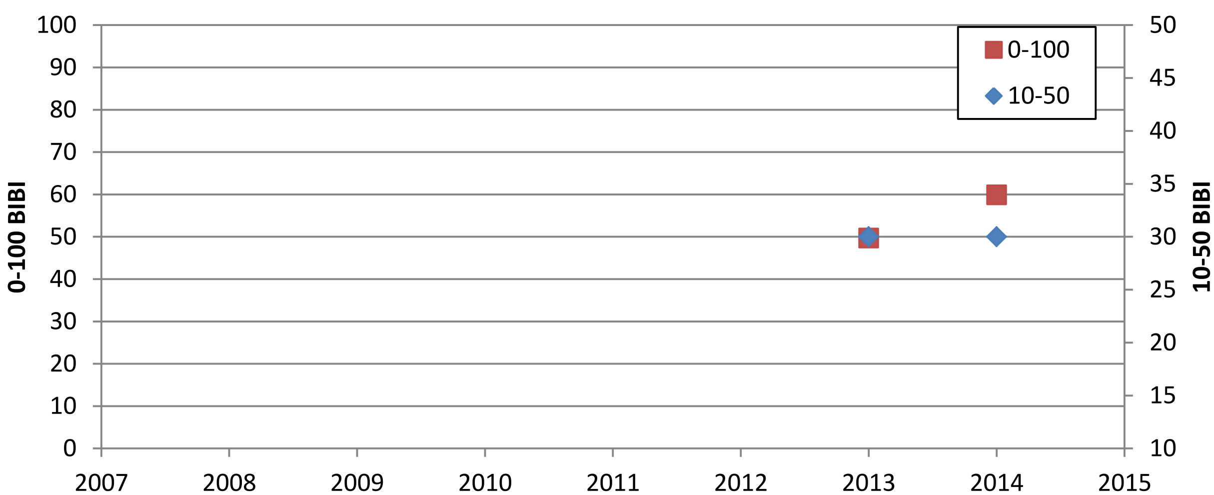

Figure B8. Woodward Creek (WoodBain) B-IBI scores for the 0-100 and the 10-50 scoring system.

Table B1. Summary of trend test results for B-IBI 0-100 scores and the ten component metric scores. Mann-Kendall tau (strength and direction of trend) with statistical significance (*p*) in parentheses.

Stream	Period of Record	B-IBI (0-100)	Taxa Richness	Ephem. Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long_Lived Richness	Intolerant Richness	Percent Dominant	Predator Percent	Tolerant Percent
Cooper Creek [a]	2008-2014 (n=6)	-0.067 (1.00)	0.067 (1.00)	-0.467 (0.242)	-0.333 (0.436)	0.333 (0.452)	0.000 (1.00)	0.067 (1.00)	0.067 (1.00)	0.200 (0.707)	0.467 (0.260)	***-0.867 (0.024)***
Issei Creek [b]	2008-2013 (n=5)	-0.600 (0.221)	-0.400 (0.462)	-0.400 (0.433)	-0.200 (0.794)	-0.600 (0.192)	-0.400 (0.462)	-0.400 (0.433)	-0.300 (0.579)	0.800 (0.086)	-0.200 (0.806)	***-1.00 (0.027)***
Manzanita Creek [c]	2008-2013 (n=5)	0.400 (0.462)	0.700 (0.130)	0.600 (0.149)	0.300 (0.613)	-0.500 (0.267)	***0.900 (0.043)***	0.300 (0.613)	-0.200 (0.724)	-0.600 (0.221)	0.400 (0.462)	-0.300 (0.613)
Murden Creek [d]	2008-2014 (n=6)	***-0.867 (0.024)***	-0.200 (0.707)	***-0.733 (0.04)***	0.000 (1.00)	-0.400 (0.314)	-0.200 (0.697)	0.333 (0.411)	0.067 (1.00)	***1.00 (0.009)***	-0.067 (1.00)	0.600 (0.133)
Ravine Creek [e]	2008-2013 (n=5)	0.000 (1.00)	0.400 (0.462)	-0.200 (0.794)	-0.200 (0.724)	0.200 (0.724)	-0.300 (0.613)	0.500 (0.312)	0.000 (1.00)	0.000 (1.00)	-0.400 (0.462)	0.000 (1.00)
Springbrook Creek [f]	2008-2013 (n=5)	-0.6 (0.221)	0.000 (1.00)	-0.600 (0.221)	-0.200 (0.724)	-0.500 (0.312)	-0.300 (0.613)	0.700 (0.130)	-0.100 (1.00)	0.600 (0.221)	0.200 (0.806)	0.000 (1.00)
Whiskey Creek [g]	2012-2013 (n=2)	-	-	-	-	-	-	-	-	-	-	-
Woodward Creek	2013-2014 (n=2)	-	-	-	-	-	-	-	-	-	-	-

Note: Statistically significant (p<0.05) trends in bold italics. "n" indicates number of observations over period of record. "-" indicates stations where data were insufficient to evaluate trends. Ephem. Is an abbreviation for Ephemeroptera.

[a] Cooper Creek missing data for 2009
[b] Issei Creek missing data for 2009 and 2014
[c] Manzanita Creek missing data for 2009 and 2014
[d] Murden Creek missing data for 2009
[e] Ravine Creek missing data for 2009 and 2014
[f] Springbrook Creek missing data for 2009 and 2014
[g] Whiskey Creek missing data for 2014

Table B2. Summary of trend test results for B-IBI 10-50 scores and the ten component metric scores. Mann-Kendall tau (strength and direction of trend) with statistical significance (*p*) in parentheses.

Stream	Period of Record	B-IBI (10-50)	Taxa Richness	Ephem. Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long_Lived Richness	Intolerant Richness	Percent Dominant	Predator Percent	Tolerant Percent
Cooper Creek [a]	2008-2014 (n=6)	0.267 (0.566)	0.067 (1.00)	-0.467 (0.242)	-0.333 (0.436)	0.333 (0.452)	-0.067 (1.00)	0.333 (0.242)	-0.133 (0.840)	0.200 (0.707)	0.467 (0.260)	***-1.00 (0.009)***
Issei Creek [b]	2008-2013 (n=5)	-0.700 (0.130)	-0.400 (0.462)	-0.400 (0.433)	-0.200 (0.794)	-0.600 (0.192)	-0.400 (0.462)	-0.500 (0.267)	-0.500 (0.312)	0.800 (0.086)	-0.300 (0.613)	0.800 (0.086)
Manzanita Creek [c]	2008-2013 (n=5)	0.600 (0.192)	0.700 (0.130)	0.600 (0.149)	0.300 (0.613)	-0.500 (0.267)	0.700 (0.096)	0.100 (1.00)	0.600 (0.192)	-0.600 (0.221)	0.400 (0.462)	0.800 (0.086)
Murden Creek [d]	2008-2014 (n=6)	-0.067 (1.00)	-0.200 (0.707)	***-0.733 (0.04)***	0.000 (1.00)	-0.400 (0.314)	-0.267 (0.546)	0.533 (0.164)	-0.600 (0.071)	***1.00 (0.009)***	0.067 (1.00)	-0.200 (0.707)
Ravine Creek [e]	2008-2013 (n=5)	-0.300 (0.613)	0.400 (0.462)	-0.200 (0.794)	-0.200 (0.724)	0.200 (0.724)	-0.300 (0.613)	0.300 (0.579)	-0.100 (1.00)	0.000 (1.00)	-0.400 (0.462)	0.400 (0.462)
Springbrook Creek [f]	2008-2013 (n=5)	-0.500 (0.312)	0.000 (1.00)	-0.600 (0.221)	-0.200 (0.724)	-0.500 (0.312)	-0.100 (1.00)	0.000 (1.00)	-0.100 (1.00)	0.600 (0.221)	0.200 (0.806)	-0.400 (0.462)
Whiskey Creek [g]	2012-2013 (n=2)	-	-	-	-	-	-	-	-	-	-	-
Woodward Creek	2013-2014 (n=2)	-	-	-	-	-	-	-	-	-	-	-

Note: Statistically significant (p<0.05) trends in bold italics. "n" indicates number of observations over period of record. "-" indicates stations where data were insufficient to evaluate trends. Ephem. Is an abbreviation for Ephemeroptera.

[a] Cooper Creek missing data for 2009
[b] Issei Creek missing data for 2009 and 2014
[c] Manzanita Creek missing data for 2009 and 2014
[d] Murden Creek missing data for 2009
[e] Ravine Creek missing data for 2009 and 2014
[f] Springbrook Creek missing data for 2009 and 2014
[g] Whiskey Creek missing data for 2014

Appendix C: Land Cover Data

Table C-1 Summary of watershed scale land cover data for City of Bainbridge Island study watersheds: (A) 2006, (B) 2011 and (C) Difference between 2011 and 2006

A - 2006 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_solidated Shore	Bare Land	Water
RavBain	331.4	8.0%	14.9%	23.0%	10.7%		2.1%	16.8%	7.4%	15.8%	0.6%	0.5%	0.1%	0.1%		0.1%	
SpringBain	842.1	0.1%	1.4%	10.8%	9.9%	0.2%	4.0%	10.8%	36.8%	22.2%	1.2%	0.4%	1.0%	1.1%		0.1%	0.0%
MurdBain	1342.2	0.5%	1.0%	11.0%	10.5%	0.2%	3.2%	18.5%	28.9%	21.9%	1.2%	1.2%	1.1%	0.9%	0.0%		
CoopBain	229.5		1.0%	8.6%	1.8%		1.1%	0.8%	59.1%	23.9%	1.3%	1.0%	1.3%	0.3%			
ManzBain	786.8	0.8%	2.5%	18.3%	13.5%	0.5%	9.0%	12.4%	18.4%	20.0%	3.3%	0.1%	0.4%	0.9%		0.0%	
IssBain	514.0		0.2%	4.1%	2.1%	0.6%	1.8%	4.5%	60.2%	24.0%	0.5%	1.5%	0.7%				
WhisBain	301.8			9.3%	23.5%	0.1%	1.0%	14.5%	21.4%	27.7%	1.2%	0.8%	0.4%	0.1%			
WoodBain	628.5	0.6%	1.0%	8.4%	12.3%	0.4%	2.0%	13.0%	39.2%	21.6%	1.0%	0.1%	0.3%	0.1%	0.0%		

B - 2011 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_solidated Shore	Bare Land	Water
RavBain	331.4	8.0%	14.9%	23.0%	10.7%		2.1%	13.8%	7.3%	13.6%	0.7%	5.6%				0.3%	
SpringBain	842.1	0.1%	1.4%	10.8%	9.9%	0.2%	4.5%	8.8%	36.7%	21.2%	1.4%	3.6%	0.7%	0.6%		0.1%	0.0%
MurdBain	1342.2	0.5%	1.0%	11.0%	10.6%	0.2%	2.8%	15.7%	28.5%	20.6%	1.6%	5.7%	0.6%	1.3%			
CoopBain	229.5		1.0%	8.6%	1.8%		1.4%	0.8%	59.4%	24.1%	2.1%	0.5%	0.5%				
ManzBain	786.8	0.8%	2.5%	18.3%	13.4%	0.5%	8.9%	11.8%	17.9%	18.9%	3.7%	2.3%	0.1%	1.0%		0.0%	
IssBain	514.0		0.2%	4.1%	2.1%	0.6%	1.8%	4.5%	59.9%	25.2%	1.2%	0.5%					
WhisBain	301.8		0.0%	9.3%	23.6%	0.2%	1.0%	14.1%	21.4%	27.6%	1.4%	1.3%	0.1%				
WoodBain	628.5	0.6%	1.0%	8.4%	12.3%	0.4%	1.9%	11.0%	38.8%	20.3%	1.1%	3.9%	0.2%	0.3%			

C 2011 – 2006 Site ID		High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_solidated Shore	Bare Land	Water
RavBain		0.00%	0.00%	0.00%	0.07%	0.00%	0.00%	-3.02%	-0.07%	-2.22%	0.07%	5.10%	-0.07%	-0.07%	0.00%	0.20%	0.00%
SpringBain		0.00%	0.00%	0.00%	0.05%	0.00%	0.45%	-2.03%	-0.16%	-1.00%	0.25%	3.19%	-0.25%	-0.50%	0.00%	0.00%	0.00%
MurdBain		0.00%	0.00%	0.00%	0.03%	-0.02%	-0.43%	-2.80%	-0.38%	-1.29%	0.43%	4.47%	-0.43%	0.43%	-0.02%	0.00%	0.00%
CoopBain		0.00%	0.00%	0.00%	0.00%	0.00%	0.29%	0.00%	0.30%	0.19%	0.83%	-0.48%	-0.83%	-0.29%	0.00%	0.00%	0.00%
ManzBain		0.00%	0.00%	0.00%	-0.08%	0.00%	-0.14%	-0.62%	-0.54%	-1.07%	0.40%	2.23%	-0.28%	0.11%	0.00%	0.00%	0.00%
IssBain		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	-0.26%	1.21%	0.69%	-1.00%	-0.69%	0.00%	0.00%	0.00%	0.00%
WhisBain		0.00%	0.00%	0.00%	0.07%	0.07%	0.00%	-0.37%	0.07%	-0.15%	0.22%	0.44%	-0.22%	-0.15%	0.00%	0.00%	0.00%
WoodBain		0.00%	0.00%	0.00%	0.03%	0.00%	-0.11%	-2.05%	-0.46%	-1.31%	0.07%	3.82%	-0.07%	0.11%	-0.04%	0.00%	0.00%

Table C-2 Summary of 90 m buffer scale land cover data for City of Bainbridge Island study watersheds: (A) 2006, (B) 2011 and (C) Difference between 2011 and 2006

A - 2006 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain	115.9	5.3%	8.9%	17.0%	3.9%		0.8%	33.2%	5.6%	23.6%	0.6%	1.3%					
SpringBain	256.6		0.5%	7.5%	8.4%	0.6%	5.6%	17.1%	24.1%	28.3%	1.8%	1.0%	2.4%	2.7%		0.1%	0.1%
MurdBain	423.0		0.4%	5.8%	9.3%	0.4%	4.3%	29.3%	12.3%	28.6%	1.3%	2.8%	2.7%	2.8%			
CoopBain	58.8			3.1%				0.6%	49.4%	39.6%		3.7%	3.6%				
ManzBain	242.2	0.4%	2.2%	13.0%	12.1%	0.0%	15.9%	12.9%	13.3%	24.2%	2.3%	0.3%	0.9%	2.5%			
IssBain	157.4		0.2%	1.3%	0.8%		0.2%	4.8%	64.2%	26.2%	0.2%	1.7%	0.4%				
WhisBain	74.7			8.9%	31.0%	0.3%	0.6%	13.3%	23.6%	17.9%	0.5%	2.8%	0.6%	0.4%			
WoodBain	199.4		0.2%	4.0%	13.8%	0.2%	2.9%	22.8%	19.8%	34.1%	1.3%	0.2%	0.4%	0.5%			

B - 2011 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain	115.9	5.3%	8.9%	17.1%	3.9%		0.8%	24.4%	5.4%	17.5%	0.6%	16.1%				0.2%	
SpringBain	256.6		0.5%	7.5%	8.4%	0.6%	6.5%	13.0%	24.0%	25.4%	1.9%	8.1%	2.3%	1.7%		0.1%	0.1%
MurdBain	423.0		0.4%	5.8%	9.3%	0.3%	3.2%	21.3%	11.3%	24.9%	2.3%	15.6%	1.6%	3.9%			
CoopBain	58.8			3.1%				0.6%	50.5%	40.4%	1.7%	1.8%	1.9%				
ManzBain	242.2	0.4%	2.2%	13.0%	11.4%	0.0%	15.2%	11.7%	11.9%	21.1%	3.6%	6.0%	0.3%	3.2%			
IssBain	157.4		0.2%	1.3%	0.8%		0.2%	4.9%	63.4%	27.3%	0.6%	1.3%					
WhisBain	74.7			8.9%	31.2%	0.6%	0.6%	12.1%	23.7%	17.0%	0.5%	4.8%	0.6%				
WoodBain	199.4	0.2%	4.0%	13.8%	0.2%	2.6%	16.8%	18.6%	0.0%	30.1%	1.1%	11.4%	0.5%	0.8%			

C 2011 – 2006 Site ID		High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc-Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-8.78%	-0.19%	-6.11%	0.00%	14.86%	0.00%	0.00%		0.21%	0.00%
SpringBain		0.00%	0.00%	0.00%	0.08%	0.00%	0.92%	-4.09%	-0.17%	-2.90%	0.05%	7.17%	-0.05%	-1.01%		0.09%	-0.02%
MurdBain		0.00%	0.00%	0.00%	0.05%	-0.05%	-1.14%	-8.00%	-1.06%	-3.73%	1.08%	12.79%	-1.08%	1.14%		0.00%	0.00%
CoopBain		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.13%	0.84%	1.71%	-1.97%	-1.71%	0.00%		0.00%	0.00%
ManzBain		0.00%	0.00%	0.00%	-0.64%	0.00%	-0.63%	-1.23%	-1.46%	-3.08%	1.27%	5.68%	-0.64%	0.73%		0.00%	0.00%
IssBain		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.12%	-0.78%	1.08%	0.41%	-0.42%	-0.41%	0.00%		0.00%	0.00%
WhisBain		0.00%	0.00%	0.00%	0.14%	0.30%	0.00%	-1.19%	0.17%	-0.90%	0.00%	1.92%	0.00%	-0.44%		0.00%	0.00%
WoodBain		0.00%	0.00%	-0.01%	-0.01%	0.00%	-0.33%	-5.95%	-1.19%	-4.08%	-0.18%	11.22%	0.18%	0.33%		0.00%	0.00%

Table C-3 Summary of 1 km radius of the contributing area scale land cover data for City of Bainbridge Island study watersheds: (A) 2006, (B) 2011 and (C) Difference between 2011 and 2006

A - 2006 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc- Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain	113.6	2.4%	12.9%	32.3%	4.5%		0.2%	13.9%	8.2%	24.9%	0.6%					0.2%	
SpringBain	277.1	0.3%	1.6%	11.2%	11.3%	0.6%	5.2%	10.5%	28.5%	24.0%	1.0%	0.8%	2.4%	2.3%		0.1%	0.1%
MurdBain	464.3	0.5%	0.8%	9.7%	6.9%		5.1%	29.4%	14.7%	21.9%	1.9%	3.4%	3.1%	2.6%			
CoopBain	188.4		0.7%	8.4%	1.1%		0.6%	0.7%	59.2%	25.0%	1.1%	1.2%	1.6%	0.4%			
ManzBain	317.5	1.4%	3.6%	12.8%	17.0%		9.5%	11.9%	20.9%	18.4%	1.8%	0.1%	0.6%	2.1%			
IssBain	203.1			1.1%			1.6%	7.3%	48.4%	37.0%	0.1%	3.4%	1.0%				
WhisBain	190.0			10.5%	26.2%	0.2%	0.7%	11.4%	25.5%	23.0%	1.6%	0.1%	0.6%	0.1%			
WoodBain	254.6	1.6%	2.2%	9.9%	5.5%	0.0%	2.6%	16.6%	24.7%	35.6%	1.3%	0.0%	0.1%	0.0%	0.1%		

B - 2011 Site ID	Area (acres)	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc- Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain	113.6	2.4%	12.9%	32.3%	4.5%		0.2%	10.4%	8.2%	20.4%	0.6%	7.4%				0.8%	
SpringBain	277.3	0.3%	1.6%	11.2%	11.5%	0.6%	5.8%	8.7%	28.4%	22.5%	1.3%	4.2%	2.1%	1.5%		0.1%	0.1%
MurdBain	464.3	0.5%	0.8%	9.7%	6.9%		3.7%	23.2%	14.5%	19.9%	3.2%	11.9%	1.8%	4.0%			
CoopBain	188.4		0.7%	8.4%	1.1%		1.0%	0.7%	59.6%	25.3%	2.1%	0.6%	0.6%				
ManzBain	317.5	1.4%	3.6%	12.8%	16.6%		9.5%	11.0%	20.2%	16.7%	2.0%	3.5%	0.2%	2.5%			
IssBain	203.1			1.1%			1.6%	7.6%	48.5%	40.0%	1.2%						
WhisBain	190.0			10.5%	26.2%	0.4%	0.7%	10.4%	25.5%	22.8%	2.0%	1.3%	0.2%				
WoodBain	254.6	1.6%	2.2%	9.9%	5.6%	0.0%	2.3%	13.5%	24.4%	33.3%	1.2%	5.7%	0.2%	0.3%			

C 2011 – 2006 Site ID	High Intensity Develop.	Medium Intensity Develop.	Low Intensity Develop.	Develop. Open Space	Pasture /Hay	Grassland	Decid_ uous Forest	Evergreen Forest	Mixed Forest	Scrub /Shrub (Sh/Sc)	Palustrine Forested Wetland	Palustrine Sh/Sc- Wetland	Palustrine Emergent Wetland	Uncon_ solidated Shore	Bare Land	Water
RavBain	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-3.5%	0.0%	-4.5%	0.0%	7.4%	0.0%	0.0%	0.0%	0.6%	0.0%
SpringBain	0.0%	0.0%	0.0%	0.2%	0.0%	0.6%	-1.8%	-0.1%	-1.5%	0.3%	3.3%	-0.3%	-0.8%	0.0%	0.0%	0.0%
MurdBain	0.0%	0.0%	0.0%	0.0%	0.0%	-1.4%	-6.2%	-0.3%	-2.0%	1.3%	8.5%	-1.3%	1.4%	0.0%	0.0%	0.0%
CoopBain	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.4%	0.2%	1.0%	-0.6%	-1.0%	-0.4%	0.0%	0.0%	0.0%
ManzBain	0.0%	0.0%	0.0%	-0.4%	0.0%	0.0%	-1.0%	-0.7%	-1.7%	0.2%	3.4%	-0.4%	0.4%	0.0%	0.0%	0.0%
IssBain	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	3.1%	1.0%	-3.4%	-1.0%	0.0%	0.0%	0.0%	0.0%
WhisBain	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	-1.1%	0.0%	-0.1%	0.4%	1.2%	-0.4%	-0.1%	0.0%	0.0%	0.0%
WoodBain	0.0%	0.0%	0.0%	0.1%	0.0%	-0.3%	-3.1%	-0.4%	-2.3%	-0.1%	5.7%	0.1%	0.3%	-0.1%	0.0%	0.0%