Whatcom Creek Restoration Project: Final Monitoring Report

Developed for the June 10, 1999
Olympic Pipeline Gasoline Spill

December 2020

City of Bellingham
Department of Public Works
Natural Resources Division
Bellingham, WA

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EXECUTIVE SUMMARY

The purpose of this *Whatcom Creek Restoration Project Final Monitoring Report* is to summarize results from the ten years of monitoring conducted on restoration sites associated with the June 10, 1999 Olympic Pipeline incident as required in the *Monitoring and Maintenance Plan Associated with the Whatcom Creek Restoration Plan Developed for the June 10, 1999 Olympic Pipe Line Gasoline Spill* (City of Bellingham 2006). The Cemetery Creek and Salmon Park restoration projects were constructed in 2006 as part of the mitigation for damages caused by this incident. Monitoring at these sites was initiated by City staff following project construction in 2007 and was continued through 2016 for a 10-year monitoring period.

The goals of the *Monitoring and Maintenance Plan* are to ensure that restoration projects implemented under the restoration plan function as designed and are maintained as necessary. Appendix B of the *Monitoring and Maintenance Plan* identified the following biological and physical monitoring elements for *restoration project monitoring* of the Cemetery Creek and Salmon Park habitat restoration projects. The purpose of the monitoring was to evaluate the effectiveness of restoration projects and maintenance activities:

1) Biological Monitoring
    - Vegetation
    - Fish community
    - Aquatic macroinvertebrates
    - Riparian and terrestrial wildlife community

2) Physical Monitoring
    - Pond Habitat
    - Stream habitat
    - Water quality
    - Photodocumentation

This *Monitoring and Maintenance Plan* (COB 2006) articulated specific objectives and success criteria associated with each of the monitoring elements. Success criteria and results are summarized in Table 0-1 below, as well as reproduced within the gray-shaded boxes included in each section of this report. **Green font indicates success criteria that were met**, **red font indicates success criteria that were not met**, and **blue font indicates that success criteria could not be evaluated or were partially met**.

Overall, most success criteria were achieved by the end of the 10-year monitoring period, indicating that restoration and maintenance activities have been effective. Criteria that were not met were a result of influences beyond the control of this restoration effort. Recommendations related to each monitoring element are included throughout the report at the end of each section.

Table 0-1 Table of monitoring elements, objectives, success criteria & results

	Monitoring Element	Monitoring Type	Objective	Success Criteria & Results
Biological Monitoring	1. Vegetation	Vegetation Surveys	To document establishment and success of native riparian species, while ensuring that invasive species are not interfering with native plants.	Native tree and shrub species composition should not consist of greater than 10% (by area) of non-native/invasive plant species at the end of 10 years. Criterion met for trees and shrubs. Survival of plantings should be at least 75% at the end of three years and through the lifetime of the monitoring plan. Criterion met. Total numbers of native trees/shrubs increased by 150% by the end of the monitoring period.
	2. Fish community	Adult Spawner Surveys	Confirm that habitat within the restoration area is being used for salmonid spawning.	Resident and anadromous fish utilize all features of the restoration site for migration, spawning and rearing. Spawner survey and smolt trap results confirm that resident and anadromous fish used the restoration site for migration, spawning and rearing.
		Smolt trap (Juvenile rearing)	Document seasonal use of constructed habitats by juvenile salmonids.	
	3. Aquatic macroinvertebrates	Macroinvertebrate surveys	To document colonization and survivorship by macroinvertebrate community in ponds and reconstructed channels in the restoration site.	Trends in community composition and structure, functional feeding groups, taxa abundance, species richness, and other indices should show improvement or remain stable over a 10-year post-construction period as compared to baseline population information. Macroinvertebrate indices remained stable over the 10-year period and did not change compared with baseline data.
	4. Riparian & Terrestrial Wildlife	Amphibian surveys	To document successful re-colonization of the restoration sites by amphibians.	Presence and habitat utilization by native amphibian species at the restoration sites over the 10-year period following restoration construction. Criterion met. Native amphibians were detected at the restoration sites over the 10-year monitoring period. Absence of non-native species (i.e. bull frog) within the restoration site over the monitoring period. Criterion not met. Non-native bullfrog(s) detected in all monitoring years.
		Avian surveys	To document avian use of the restoration areas.	Presence and persistent habitat utilization by native avian species at the restoration sites over the 10-year period following restoration construction. Criterion met. Native species were observed using the restoration sites over the 10-year monitoring period. Absence or continued low levels of non-native, invasive species (eg. European starling, house sparrow, brown-headed cowbird, Canada goose). Criterion met. Only four non-native bird species were observed at the sites and in low numbers across all years (5% of the total birds observed during surveys).
		Mammal observations	Document use of the restoration area by mammals.	Presence and habitat utilization by native mammal species at the restoration sites over the 10-year period following restoration construction. Criterion met. Native mammals were observed using the restoration sites over the 10 year monitoring period. Absence of major site damage from mammals throughout the monitoring period. Criterion met. No major site damage from mammals.
Physical Monitoring	5. Pond Hydrology	Bathymetry surveys Large woody debris	Document that ponds maintain designed depth, and volume characteristics for the duration of the monitoring period	Created ponds maintain designed hydrologic and habitat forming functions such as seasonal wetted area, adequate cover, and structural stability. Criterion not met-- all transects experienced a net loss of depth and volume. Seasonal wetted area, adequate cover and structural stability were not assessed. Pond LWD loading remains constant or increase over the 10-year monitoring period. Criterion met.
	6. Stream Habitat	Cross section surveys Habitat surveys Large woody debris Spawning gravel	To document that reconstructed stream channels are functioning as designed and provide suitable habitat for salmonids.	Restored stream channels habitat features will maintain designed hydrologic and habitat forming functions such as pools, LWD loading, suitable spawning areas, and stable banks. This criterion was met with respect to maintenance of hydrologic and habitat forming functions such as LWD loading and stable banks, partially met with respect to pool habitat, and not met with respect to suitable spawning areas.
	7. Water Quality	Pond surveys	Document that ponds provide suitable year round habitat conditions for native salmonids.	Water temperature, pH, and dissolved oxygen in restoration sites will meet current Washington state water quality standards during the 10-year monitoring period. These criteria have not been met for dissolved oxygen or temperature. However, the criterion for pH was met. Fecal coliform and conductivity were also measured, but no success criteria were identified.
		Stream surveys	To ensure reconstructed streams meet minimum water quality criteria for Class A standards and create temporal documentation of water quality data.	

Over the long term, the restoration area is on track to mature into a saturated wetland mosaic, an evolution supported by the influence of ongoing beaver activity. Both dissolved oxygen and temperature profiles will continue to improve at the site as beaver activity increases seasonal water storage in the landscape and provided routine vegetation maintenance continues with a focus on shading the stream channels and ponds. As the site evolves, the Cemetery Creek project area may be best suited to juvenile coho (*Oncorhynchus kisutch)* rearing as well as year-round habitat for resident western brook lamprey (*Lampetra richardsoni*). The entire restoration area also provides excellent avian foraging, rearing and nesting habitat. Additionally, the backwater habitat at Salmon Park has functioned as intended, increasing habitat complexity for all life stages of salmonids in Whatcom Creek.

1. INTRODUCTION

The purpose of this *Whatcom Creek Restoration Project Final Monitoring Report* is to summarize results from the ten years of monitoring conducted on restoration sites associated with the June 10, 1999 Olympic Pipeline incident as required in the *Monitoring and Maintenance Plan Associated with the Whatcom Creek Restoration Plan Developed for the June 10, 1999 Olympic Pipe Line Gasoline Spill* (City of Bellingham 2006). The Cemetery Creek and Salmon Park restoration projects were constructed in 2006 as part of the mitigation for damages caused by this incident. Monitoring at these sites was initiated by City staff following project construction in 2007 and was continued through 2016 for a 10-year monitoring period.

The goals of the *Monitoring and Maintenance Plan* are to ensure that restoration projects implemented under the restoration plan function as designed and are maintained as necessary. Appendix B of the *Monitoring and Maintenance Plan* identified the following biological and physical monitoring elements for *restoration project monitoring* of the Cemetery Creek and Salmon Park habitat restoration projects. The purpose of the monitoring was to evaluate the effectiveness of restoration projects and maintenance activities:

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This *Monitoring and Maintenance Plan* (COB 2006) articulated specific objectives and success criteria associated with each of the monitoring elements. Success criteria and results are summarized in Table 0-1 below, as well as reproduced within the gray-shaded boxes included in each section of this report. **Green font indicates success criteria that were met**, **red font indicates success criteria that were not met**, and **blue font indicates that success criteria could not be evaluated or were partially met**.

2. BACKGROUND

On June 10, 1999 an underground pipeline ruptured in Bellingham, Washington, releasing approximately 277,200 gallons of unleaded gasoline into Hannah and Whatcom Creeks. The gasoline was subsequently ignited, resulting in a fire which burned approximately 25 acres of riparian vegetation along the Whatcom Creek corridor (**Figure 2-1**). During this event, the fishery and aquatic resources of Whatcom Creek were severely impacted. A long-term restoration plan was designed to determine the impacts of the spill on natural resources and identify measures that would be implemented to restore and improve those injured resources. The goals for rehabilitation and enhancement centered on mitigating damages by creating and improving salmonid habitat associated with Whatcom Creek. As stated in the 2006 *Monitoring and Maintenance Plan*, specific habitat objectives implemented in the projects included: increased salmonid summer rearing habitat by creating off-channel pools in Cemetery Creek; increased salmonid winter rearing habitat by creating backwater habitats during frequent floods in Salmon Park and Cemetery Creek; improved habitat complexity for all life stages of salmonids in the lower portion of Cemetery Creek; reduced erosion in the lower portion of Cemetery Creek; removal of human-placed gravel berms, where appropriate, to restore geomorphic function of stream processes within the confines of Salmon Park and Whatcom Creek; and provide enhanced habitat conditions, while minimizing impacts to surrounding vegetation and ground surfaces.

Monitoring protocols and restoration actions associated with the long-term restoration plan were outlined in the following plan:

- *Monitoring and Maintenance Plan: Associated with the Whatcom Creek Restoration Plan Developed for the June 10, 1999 Olympic Pipe Line Gasoline Spill* (City of Bellingham 2006). This report specifies monitoring protocols and restoration actions for the burn zone and associated restoration sites.

The City of Bellingham was tasked with implementing this monitoring and maintenance plan with oversight by the Natural Resource Trustees (Trustees) for the Olympic Pipeline incident. The Trustees are: the United States Department of Commerce as represented by the National Oceanic and Atmospheric Administration; the United States Department of the Interior as represented by the United

States Fish and Wildlife Service; the State of Washington as represented by the Department of Ecology; the City of Bellingham; the Lummi Nation of Washington; and the Nooksack Tribe of Washington. The Trustees and the Olympic Pipeline Company established a fund of $500,000 from which all long-term monitoring and maintenance activities related to this incident have been supported.

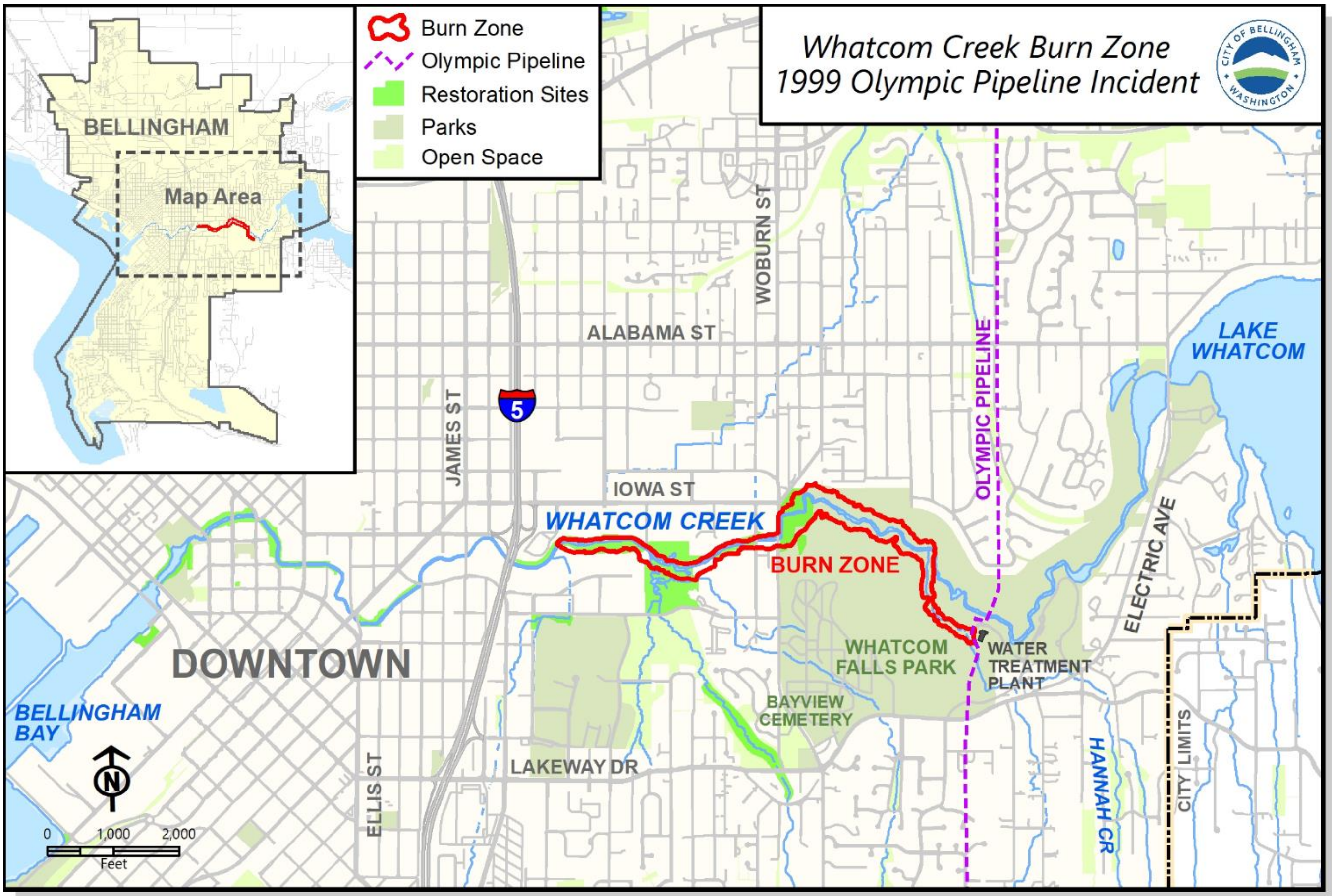


Figure 2-1 Whatcom Creek 1999 Olympic Pipeline burn zone vicinity map.

Monitoring and restoration occurred in two areas: the burn zone and associated restoration projects (**Figure 2-2**). Evaluation of recovery in the burn zone was completed in 2009; results and analyses are presented in two companion reports:

- *Whatcom Creek Post-Fire Evaluation: Ten Years After* (Madsen and Nightengale 2009). This final report details scientific monitoring results and restoration effectiveness in the burn zone along Whatcom and Hannah Creeks from 1999-2009.

- *Whatcom Creek – Ten Years After: Summary Report* (Madsen 2009). This final report summarizes monitoring results and restoration effectiveness in the burn zone and associated restoration sites in the ten years since the incident.

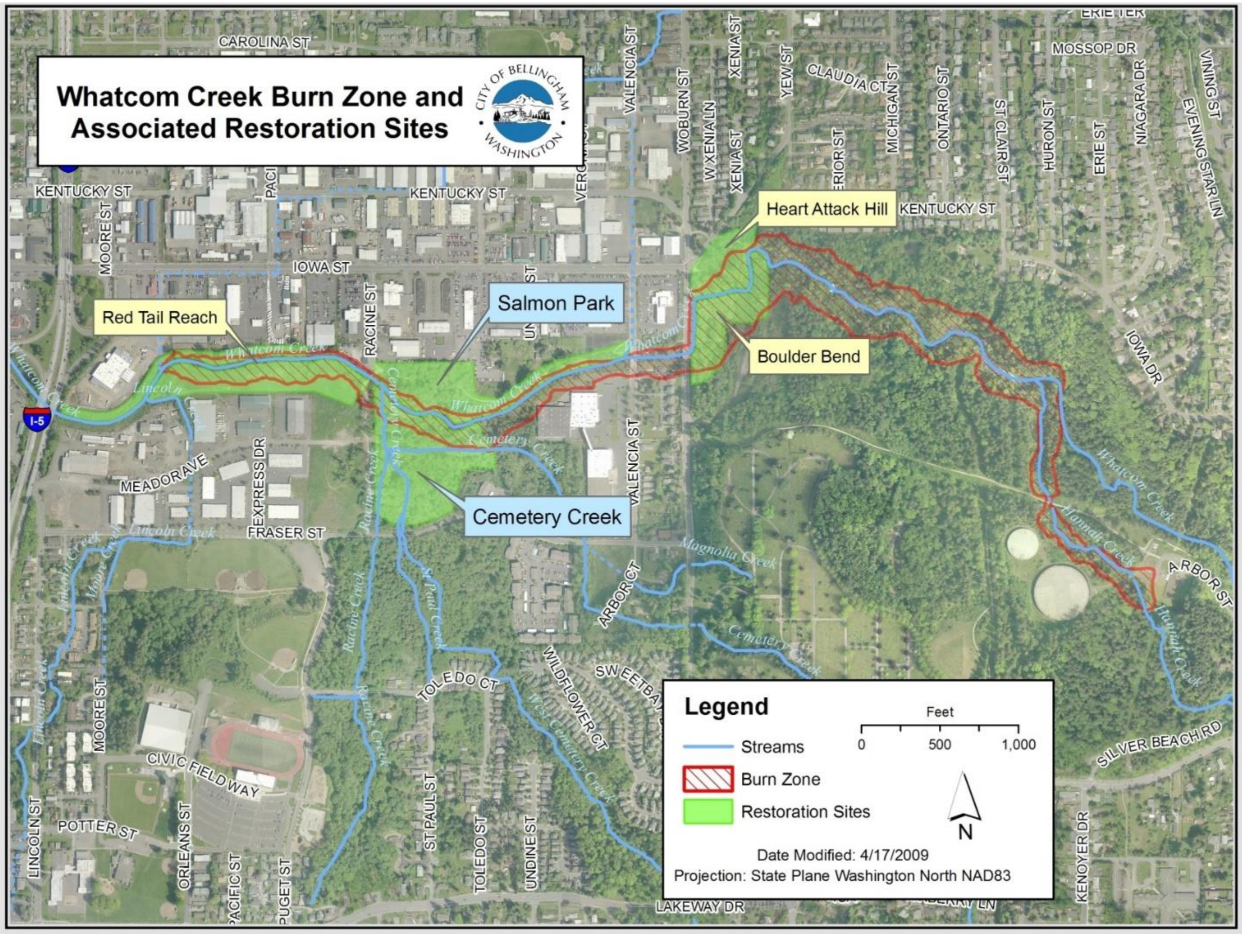


Figure 2-2 Map of Whatcom and Hannah Creek Burn Zone and associated restoration sites. Monitoring presented in this report was conducted at the Salmon Park and Cemetery Creek Restoration Sites.

The Cemetery Creek and Salmon Park restoration projects (**Figure 2-2**) were constructed in 2006 as part of the mitigation for damages caused by the fuel spill and fire. Monitoring at these sites was initiated by City staff following project construction in 2007 and was continued through 2016 for a 10-year monitoring period. See **3. OVERVIEW**, below, for additional detail on monitoring schedule, parameters, and objectives.

Initial monitoring results for the years 2007-2009 at the Cemetery Creek and Salmon Park restoration sites are summarized in the following reports:

- *Whatcom Creek Restoration Project Report: 2007-2008* (Forester 2009). This report details monitoring results from 2007-2008 in the Cemetery Creek and Salmon Park restoration sites.
- *Whatcom Creek Restoration Project Report: 2009* (Forester 2010). This report details

monitoring results from 2009 in the Cemetery Creek and Salmon Park restoration sites.

The current report provides a comprehensive summary of results from all monitoring conducted at the Cemetery Creek and Salmon Park restoration sites in all 10 monitoring years (Figure 3 5). Therefore, this report includes all data presented in the companion reports listed above (Forester 2009 and 2010) in addition to monitoring conducted in subsequent years.

3. OVERVIEW

The Cemetery Creek and Salmon Park restoration sites are located near the confluence of Cemetery Creek and Whatcom Creek. The Salmon Park project covers over 300 feet of the Whatcom Creek stream bank to the north of the creek, while Cemetery Creek encompasses approximately 250 feet along the south bank of Whatcom Creek and over 1,300 feet along Cemetery Creek and West Cemetery Creek. Only a portion of these restoration areas overlap with the primary burn zone along Whatcom Creek (**Figure 2-2**).

Restoration goals at the Cemetery Creek and Salmon Park sites were aimed at mitigating damages from the oil spill and fire by creating and improving salmonid habitat associated with Whatcom Creek. Goals included increasing salmonid rearing habitat by creating off-channel pools in Cemetery Creek; increasing salmonid winter rearing habitat by creating backwater habitats along Whatcom Creek that fill during floods; improving habitat complexity for all life stages of salmonids in the lower portion of Cemetery Creek; reducing erosion in the lower portion of Cemetery Creek; removing human-placed gravel berms, where appropriate; restoring geomorphic function and stream processes within the confines of Salmon Park and the Whatcom Creek floodplain; and providing enhanced habitat conditions, while minimizing impacts to surrounding vegetation and ground surfaces.

Aerial photos of the Cemetery Creek and Salmon Park restoration sites pre- and post-fire are presented in **Figure 3-1** and **Figure 3-2**. Aerial photos of the sites pre- and post-restoration are presented in Figure **3-3** and **Figure 3-4**. The three pre-restoration aerials (**Figure 3-1, Figure 3-2** and **Figure 3-3**) illustrate the channelized nature of Whatcom, Cemetery and West Cemetery Creeks as well as an overall lack of large woody debris and habitat complexity. The post-restoration aerial (**Figure 3-4**) shows some of the implemented restoration actions, including: removal of gravel berms and creation of backwater habitats in Salmon Park; creation of an additional backwater swale habitat upstream and opposite of Salmon Park; and creation of ponds and backwater habitats along Cemetery and West Cemetery Creeks. The Salmon Park island, which divides the flow of Whatcom Creek, is also evident in the post-restoration aerial.

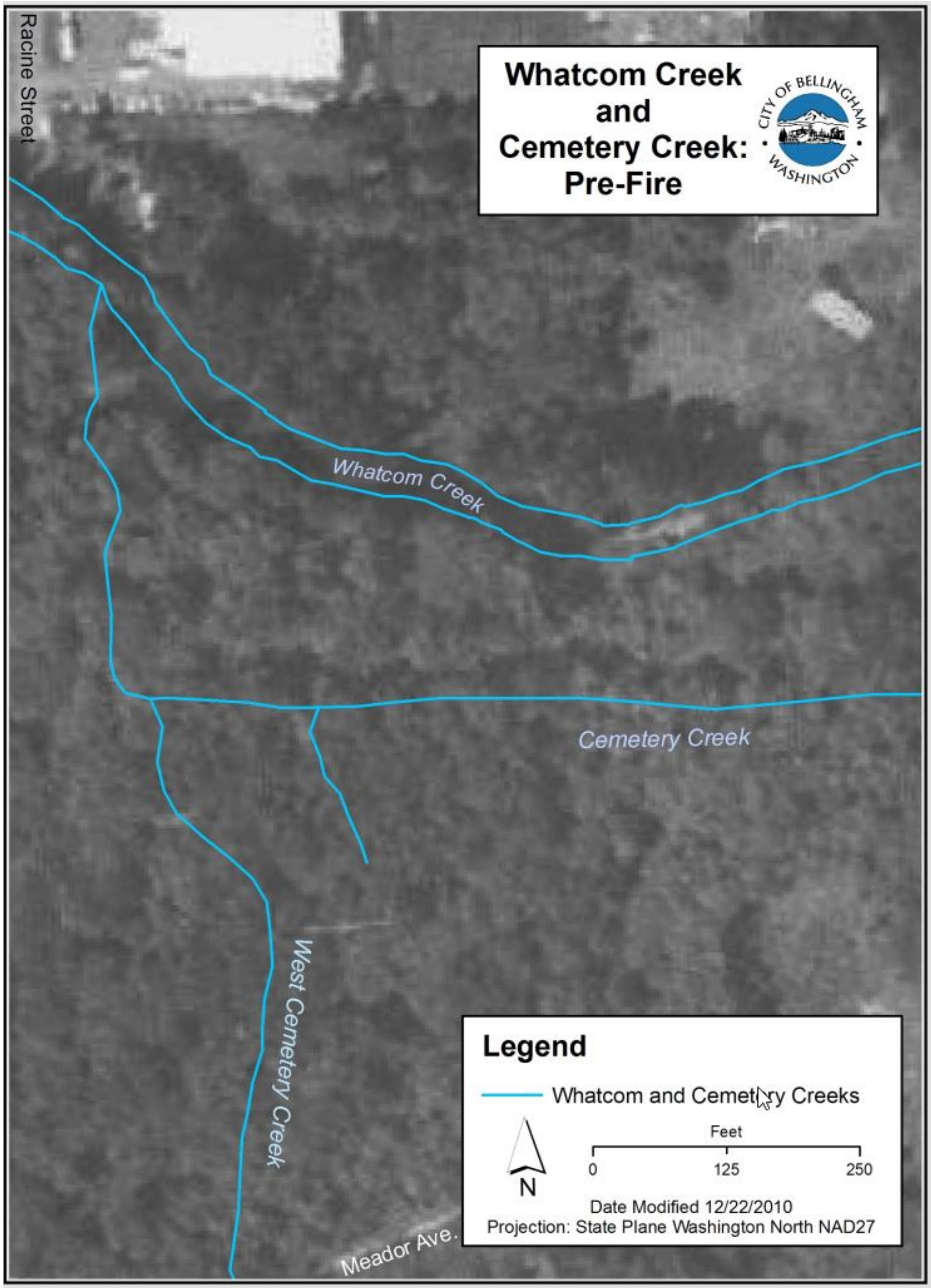


Figure 3-1 Aerial photo (2006) of Cemetery Creek and Salmon Park restoration sites prior to restoration.

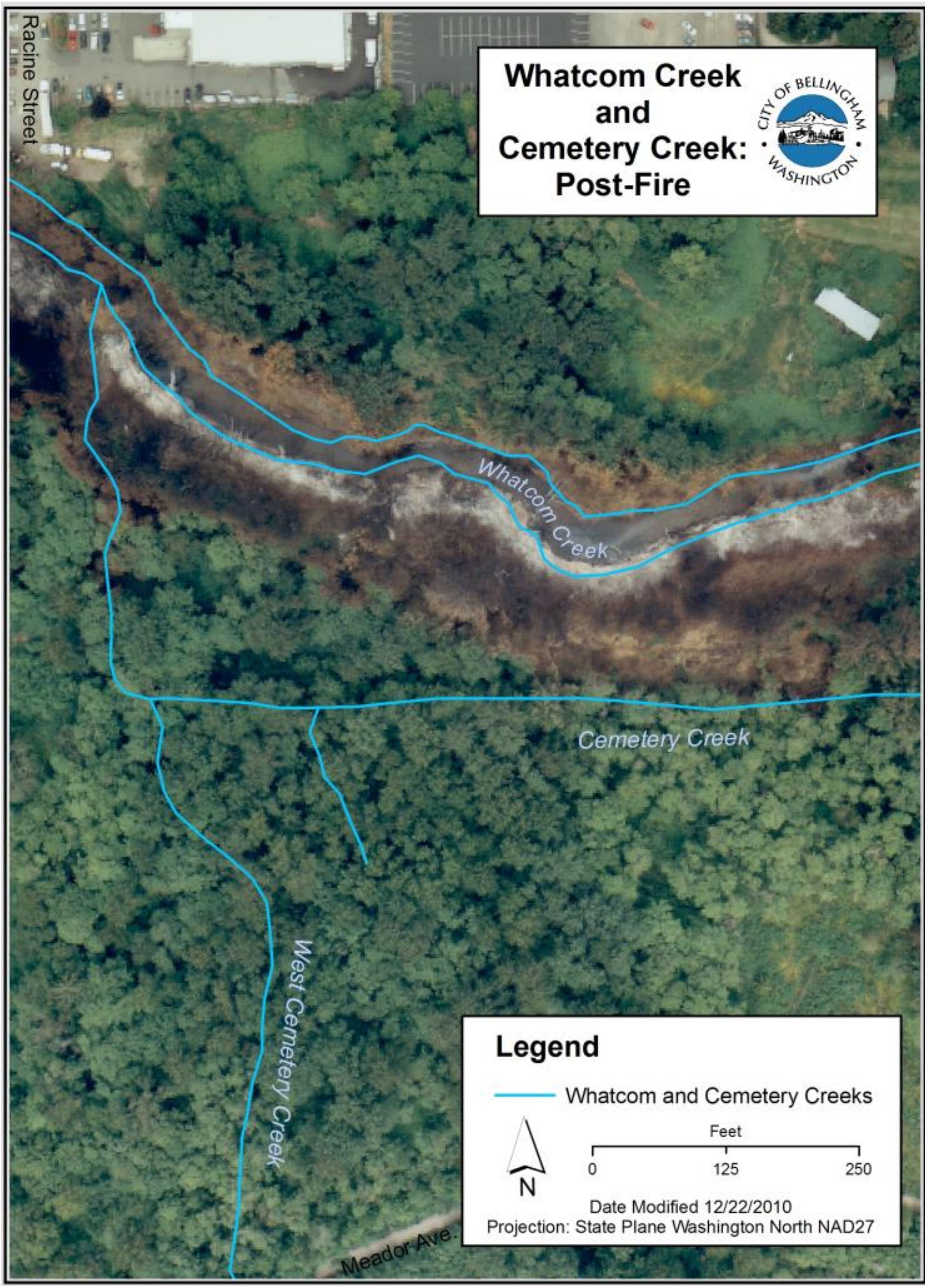


Figure 3-2 Aerial photo (June 16, 1999) of Whatcom and Cemetery Creeks six days after the fire.

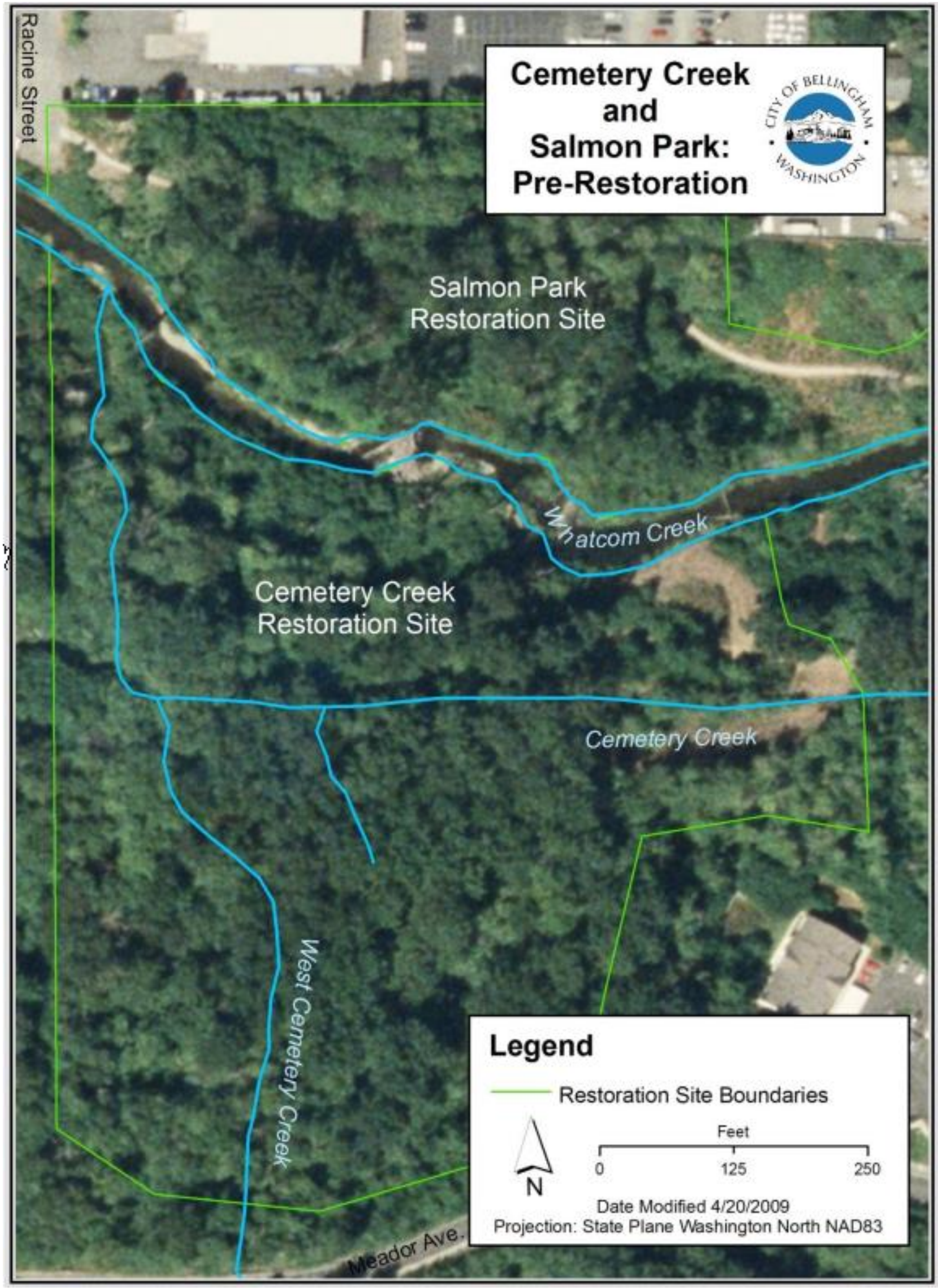


Figure 3-3 Aerial photo (2006) of Cemetery Creek and Salmon Park restoration sites prior to restoration.

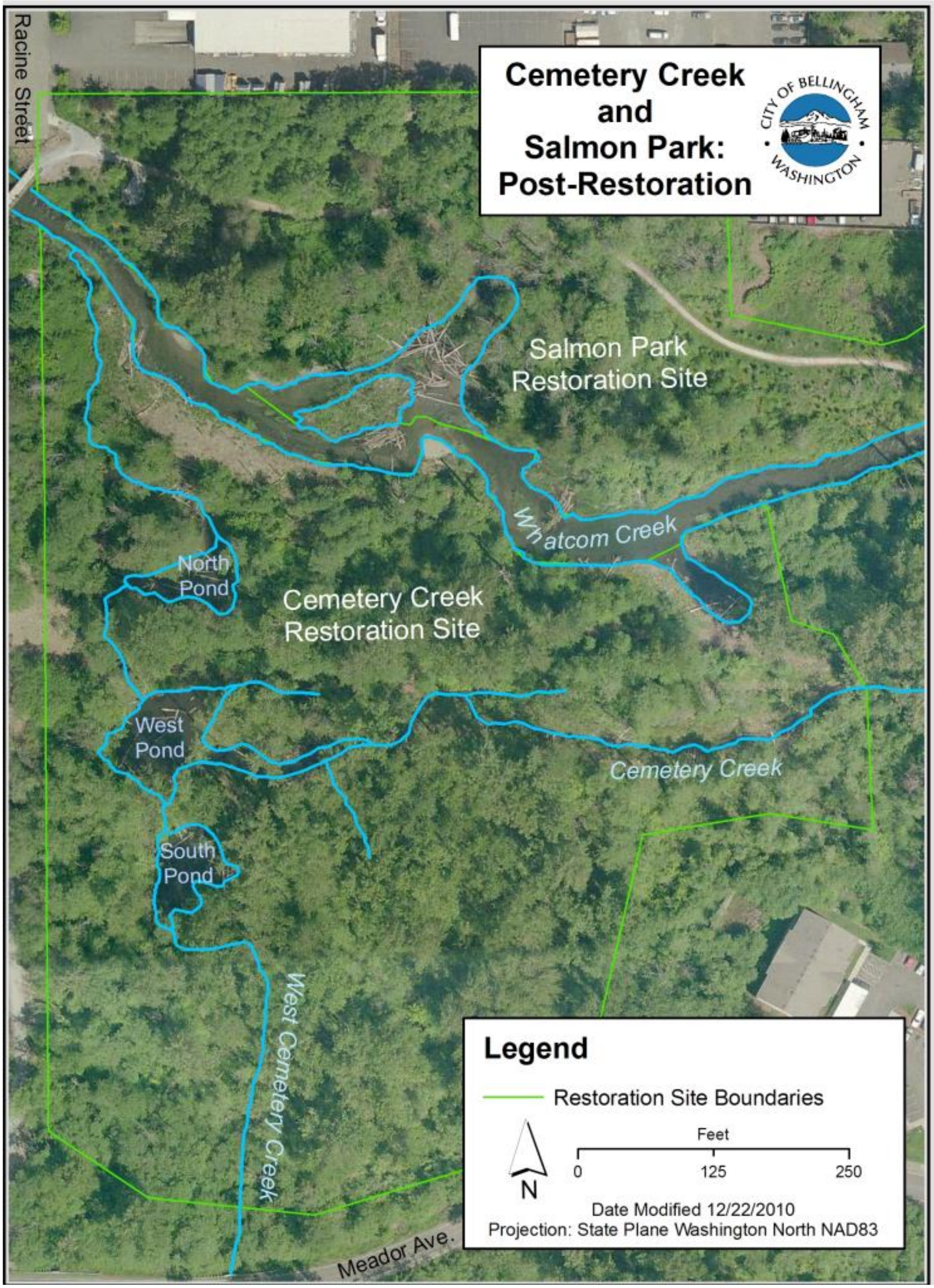


Figure 3-4 Aerial photo (2008) of Cemetery Creek and Salmon Park restoration sites after restoration.

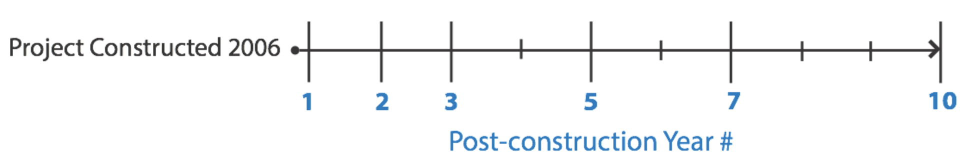
Monitoring of the Cemetery Creek and Salmon Park restoration sites was completed by qualified and trained City of Bellingham staff and Washington Conservation Corps crewmembers. Monitoring activities focused on both biological and physical elements:

1) Biological Monitoring
    - Vegetation
    - Fish community
    - Aquatic macroinvertebrates
    - Riparian and terrestrial wildlife community

2) Physical Monitoring
    - Pond hydrology
    - Stream habitat
    - Water quality
    - Photodocumentation

The *Monitoring and Maintenance Plan* (COB 2006) specified that monitoring of the restoration sites should occur in post-construction years 1, 2, 3, 5, 7 and 10 corresponding to years 2007, 2008, 2009, 2011, 2013 and 2016, respectively[1] (**Figure 3-5**). The *Monitoring and Maintenance Plan* (COB 2006) also articulated specific objectives and success criteria associated with each of the monitoring elements Table 3-1). Success criteria are reproduced within the gray-shaded boxes included in each section of this report, along with summary statements describing whether these criteria were met by the end of the monitoring period.

Figure 3-5 Restoration project monitoring began in 2007 and continued through 2016 with monitoring occurring in post-construction years 1, 2, 3, 5, 7 and 10.



[1] Monitoring of adult and juvenile salmonids are the only monitoring components following a different schedule; see Appendix A.

Table 3-1 Monitoring elements, parameters and objectives.

	Monitoring Element	Monitoring Type	Parameters Measured	Objective
Biological Monitoring	**1. Vegetation**	Vegetation Surveys	Vegetation community type	To document establishment and success of native riparian species, while ensuring that invasive species are not interfering with native plants.
			Species	
			Condition	
			Height class	
			Invasive (% cover)	
	2. Fish community	Adult Spawner Surveys	Number of live fish	Confirm that habitat within the restoration area is being used for salmonid spawning.
			Number of carcasses	
			Number of redds	
		Smolt trap (Juvenile rearing)	Species	Document seasonal use of constructed habitats by juvenile salmonids.
			Size class	
			Cemetery Creek flow	
	3. Aquatic macroinvertebrates	Macroinvertebrate surveys	Community composition	To document colonization and survivorship by the macroinvertebrate community in ponds and reconstructed channels in the restoration site.
			Functional feeding groups	
			Taxa abundance	
			Species richness and abundance	
	4. Riparian & Terrestrial Wildlife	Amphibian surveys	Species composition	To document successful re-colonization of the restoration sites by amphibians.
			Habitat characterization use	
		Avian surveys	Species composition	To document avian use of the restoration areas.
			Species abundance	
		Mammal observations	Species composition	Document use of the restoration area by mammals.
Physical Monitoring	**5. Pond Hydrology**	Bathymetry surveys	Pond water surface elevation	Document that ponds and back water habitats maintain designed depth, and volume
		Large woody debris	LWD	
	6. Stream Habitat	Cross section surveys	Channel cross section	To document that reconstructed stream channels are functioning as designed and provide suitable habitat for salmonids.
		Habitat surveys	Habitat Units (pool/riffle ratio)	
		Large woody debris	LWD	
		Spawning gravel	Spawning gravels/ Substrate size distribution	
	7. Water Quality	Pond surveys	Water Temperature	Document that ponds provide suitable year round habitat conditions for native salmonids.
			pH	
			Dissolved Oxygen	
			Conductivity	
		Stream surveys	Water Temperature	To ensure reconstructed streams meet minimum water quality criteria for Class A standards and create temporal documentation of water quality data.
			pH	
			Dissolved Oxygen	
			Conductivity	
			Fecal coliform	
	8. Photodocumentation	Photopoint surveys	Temporal sequence of photos	Provide a visual record of habitat recovery within the restoration sites.

BIOLOGICAL MONITORING

3.1 VEGETATION SURVEYS

3.1.1 Introduction

Construction at the restoration sites in July and August 2006 created ponds, reconfigured streambanks, and removed non-native vegetation. Surrounding habitat consisted of deciduous mid-successional forest and deciduous riparian vegetation. Care was taken to preserve as much of the pre-existing native riparian forest as possible. Cleared areas were planted with native shrubs and trees the following winter, between November 2006 and February 2007 (**Figure 3-6**). Sedges were planted in swales and along stream margins in April 2007.

Figure 3-6 Photo showing recently constructed stream channel in Cemetery Creek, with newly planted conifers, willow stakes and deciduous shrubs; March 6, 2007.

Infill planting and installation of additional willow cuttings occurred the following winter (2007). Supplementary infill planting and weed maintenance continues to the present.

3.1.2 Objective

The objective of vegetation surveys was to document establishment and success of native riparian species while ensuring that invasive species are not interfering with native plant growth and survival. As specified in the *Monitoring and Maintenance Plan* (COB 2006), vegetation survey results have been compared against the following criteria for success:

Success Criteria:

- Non-native/invasive plants: Native tree and shrub species composition should not consist of greater than 10% (by area) of non-native/invasive plant species at the end of 10 years.
- Plant survival: Survival of plantings should be at least 75% at the end of three years and through the lifetime of the monitoring plan.

The *Monitoring and Maintenance Plan* (COB 2006) also prescribed assessment of "ground cover by species… in lieu of information on individual plants" for the emergent wetland communities. City staff therefore decided to monitor this ground cover component at all vegetation transects, even though it is not relevant to the vegetation success criteria. Similarly, several vegetation parameters listed in the *Monitoring and Maintenance Plan* (COB 2006) could not be used to assess the above success criteria: vegetation community type, species, condition, height class and plant origin (planted/natural). In addition, subsequent monitoring reports (Forester 2009 & 2010) added new parameters to the vegetation surveys such as canopy cover and aquatic plants. Although these supplementary measures could not be used to assess the original success criteria, they have been succinctly described in this report.

3.1.3 Methods

Riparian vegetation surveys were conducted in the summer, within cleared and re-planted areas at the Cemetery Creek and Salmon Park restoration sites. Twenty-three transects were established perpendicular to the stream throughout the restoration site (**Figure 3-77**). The ends of each transect were marked with wooden stakes or tags in established trees. Transects were 30 feet wide and extended from the stake/tag to the water's edge. Vegetation surveys were conducted during the summer in post-construction years 1, 2, 3, 5, 7, and 10, corresponding to years 2007, 2008, 2009, 2011, 2013, and 2016.

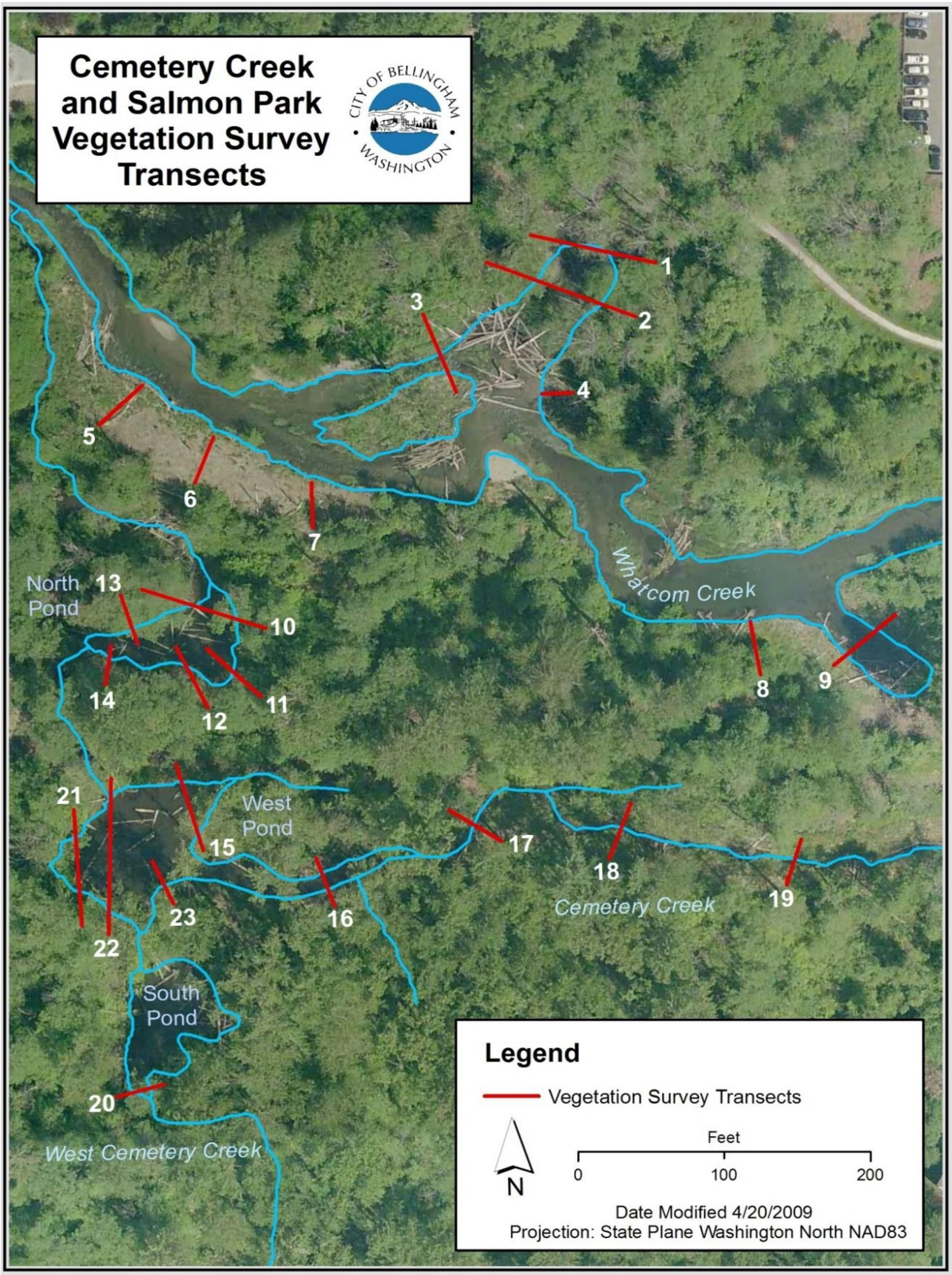


Figure 3-7 Map of vegetation survey transects.

Within the transect, all trees, woody shrubs and ferns greater than 1- foot tall were identified to species, counted, and characterized by condition (good/fair/poor/dead) and height class (1-5 feet/5-15 feet/15+ feet). Trees were defined as single-stemmed, woody plants greater than 30 feet in height when mature (Pojar and Mackinnon 2004). Percent cover in the ground layer (vegetation < 12 inches high) was visually estimated for each transect by vegetation type: sedges/native grasses, native forb/fern, and invasive species. Canopy cover estimates were determined using a spherical concave densiometer. Four readings were taken while standing on the mid-line of the transect at the bank's edge: facing the bank, facing left, facing the stream, and facing right. (Transects 5, 6, and 7 have only one densiometer station: standing on the mid-line of the transect at the center of the plot.) Aquatic plants were also surveyed to monitor the recolonization of constructed stream channels and ponds by aquatic plants. Aquatic plants provide important habitat for fish, amphibians, insects and macroinvertebrates. Aquatic plant surveys were conducted within the transect area to a water depth of three feet. Plants were classified to the most practical level (family, genus and/or species) and percent cover was estimated.

Ground cover data collected in 2007 followed a different protocol than subsequent years and have therefore been excluded from this analysis. Additionally, the origin of trees and shrubs (installed plant vs. natural recruit) was determined during 2007 surveys, however this component of the monitoring was eliminated in 2008 as it became increasingly intractable to differentiate between volunteer recruits and installed plants, a distinction that was further confounded by infill plantings introduced as part of ongoing maintenance at the site. Therefore, all trees and shrubs present within each transect were counted regardless of origin, and percent survival is estimated by comparing the number of original plantings to the number of existing native trees and shrubs counted in each monitoring year.

3.1.4 Results

Non-native/invasive plants: Non-native/invasive trees and shrubs have consistently represented less than 10% overall of the tree and shrub plant community during all monitoring years from 2007-2016. Eighty percent of the total tree and shrub transects surveyed to date (i.e. 107 out of 135 independent transects) have met the prescribed success criterion of less than 10% non-native/invasive plant community composition (Table 3-2). Overall, the average percentage of non-native/invasive trees and shrubs at all transects during all survey years has ranged between 2.5% and 10.0% (Figure 3-8) meeting and/or exceeding the aforementioned criterion. Non-native/invasive tree and shrub species are dominated by Himalayan blackberry (*Rubus armeniacus*), but also include, English Holly (*Ilex aquifolium*), Knotweed (*Polygonum sp*.), and one Rowan tree (*Sorbus aucuparia*) which was found in 2013 at Transect 1.

Table 3-2 Percent non-native/invasive tree and shrub species by transect, 2007 to 2016. Red font indicates where success criteria were not met.

Transect	Invasive Trees and Shrubs					
	2007	2008	2009	2011	2013	2016
1	11.0%	4.6%	5.4%	7.1%	3.8%	3.4%
2	5.6%	1.7%	3.0%	8.8%	2.3%	2.6%
3	7.6%	7.4%	--[1]	32.1%	23.0%	--[3]
4	14.9%	11.8%	10.7%	15.4%	0.0%	8.0%
5	26.7%	4.8%	3.5%	10.1%	2.3%	5.4%
6	0.0%	0.6%	3.6%	--[2]	2.7%	2.2%
7	13.5%	3.0%	2.5%	7.4%	3.8%	11.1%
8	3.9%	0.0%	1.1%	13.5%	5.4%	8.2%
9	1.1%	2.8%	1.6%	3.5%	3.2%	12.4%
10	3.5%	0.0%	4.9%	0.0%	1.8%	8.9%
11	6.7%	0.0%	4.1%	0.6%	1.7%	5.8%
12	0.0%	0.0%	3.6%	4.6%	0.0%	6.3%
13	3.9%	4.2%	15.7%	18.5%	7.1%	16.3%
14	4.1%	0.0%	4.1%	20.2%	0.0%	3.6%
15	6.2%	1.3%	15.3%	18.1%	7.2%	16.7%
16	1.8%	2.8%	1.2%	10.6%	2.7%	5.6%
17	4.7%	0.0%	5.4%	6.5%	3.1%	8.7%
18	7.0%	2.0%	4.3%	5.6%	4.1%	0.0%
19	6.8%	3.0%	4.2%	13.2%	10.5%	26.7%
20	2.4%	5.8%	2.3%	9.3%	14.4%	1.1%
21	6.5%	0.5%	5.3%	7.0%	3.6%	13.3%
22	15.4%	2.1%	7.1%	4.9%	0.0%	18.2%
23	0.0%	0.0%	1.6%	4.1%	1.3%	1.9%
Arithmetic Mean	6.7%	2.5%	5.0%	10.0%	4.5%	8.5%
Standard Deviation	0.06	0.03	0.04	0.07	0.05	0.07

[1] Transect 3 was not surveyed in 2009.

[2] Transect 6 was not surveyed in 2011.

[3] Transect 3 was not surveyed in 2016.

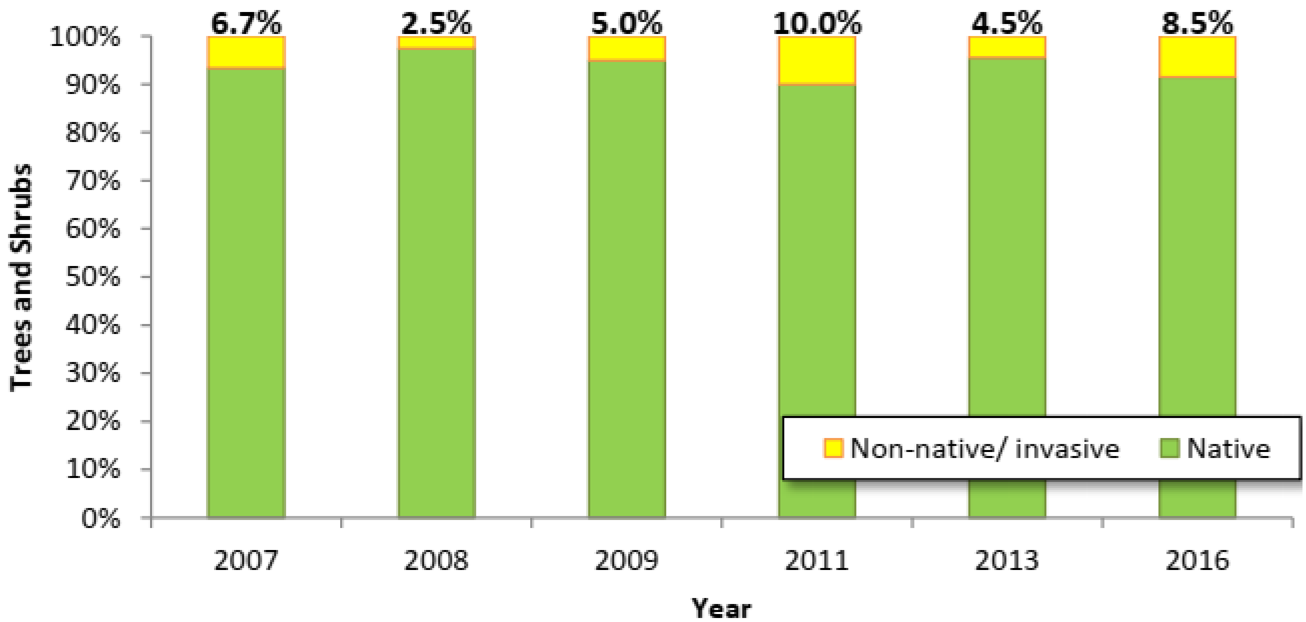
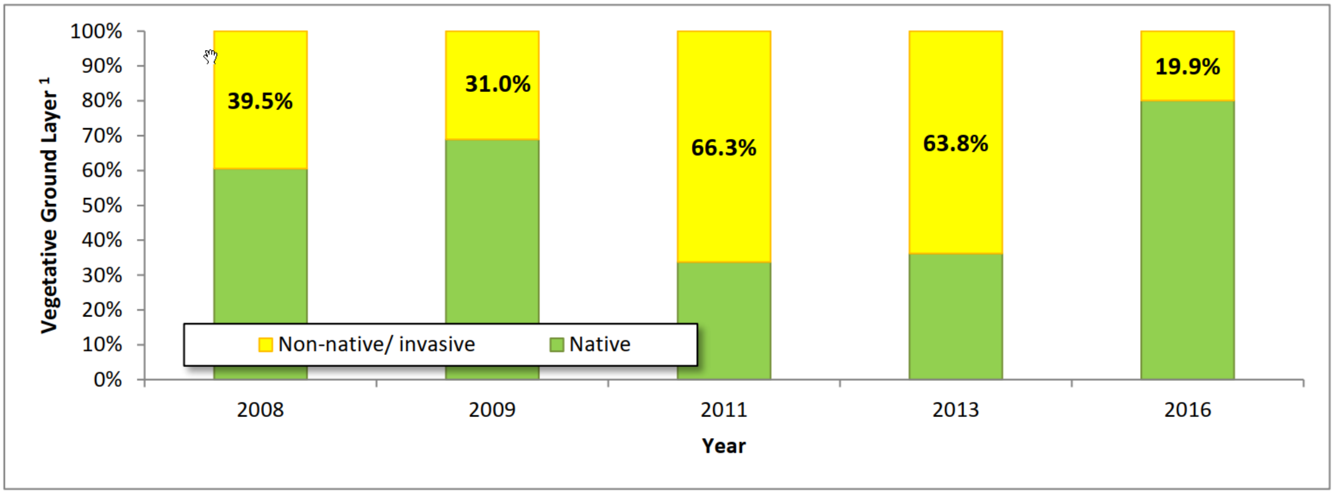


Figure 3-8 Relative percent of non-native/invasive tree and shrub species compared with native species averaged across all transects by year.

As per the *Monitoring and Maintenance Plan* (COB 2006) and subsequent monitoring reports (Forester 2009 & 2010), the proportion of non-native/invasive species in the herbaceous ground layer was also assessed. Overall, the average proportion of herbaceous non-native/invasive species at all transects has decreased from 39.5% in 2008 to 19.9% in 2016 (**Figure 3-9**). Persistence of some non-native/invasive plants in the ground layer is expected as herbaceous invasive species often colonize disturbed sites and are common in early restoration successional stage(s). The proportion of non-native/invasive species observed in the ground layer at the restoration site has been acceptable and has not impacted successful establishment of native trees and shrubs in this study. Non-native/invasive ground cover species include creeping buttercup (*Ranunculus repens*), reed canary grass (*Phalaris arundinacea*), herb-Robert (*Geranium robertianum*), and seedling Himalayan blackberry (*Rubus armeniacus*). It is anticipated that invasive ground cover, especially reed canary grass, will decrease as native trees and shrubs continue to grow and increase shade at the site.



[1] Vegetative ground layer percentages represent the proportion of the vegetated ground surface covered by either non-native/invasive or native plant cover; does not account for portion of ground that is bare or covered by duff.

Figure 3-9 Relative percent of non-native/invasive species compared with native species in the vegetative ground layer averaged across all transects by year.

Plant survival: In the initial years of monitoring (2007-2009), "survival" of plantings was assessed based on the percentage of surveyed plants characterized as having "Good" or "Fair" condition as compared with "Poor" or "Dead" plants. Under this schema, the average percentage of "Good" and "Fair" plantings per year ranged between 93% and 99% and the project was thus determined to meet the second vegetation success criterion: "*Survival of plantings should be at least 75% at the end of three years and through the lifetime of the monitoring plan*" (COB 2006). However, natural recruitment quickly made it impossible to differentiate volunteer plants from restoration plantings. While it was not possible to assess this success criterion as originally written in the *Monitoring and Maintenance Plan* (COB 2006), a surrogate measure of percent survival is estimated here by comparing the number of original plantings to the number of existing native trees and shrubs counted in each subsequent monitoring year. Over the ten-year monitoring period, an increase in total numbers of native trees and shrubs from 1,744 stems in Year 1 to 2,594 stems by Year 10 was observed (**Figure 3-10**). This represents a 150% increase in native trees and shrubs over the 10-year period, exceeding the survival criterion of 75% survival.

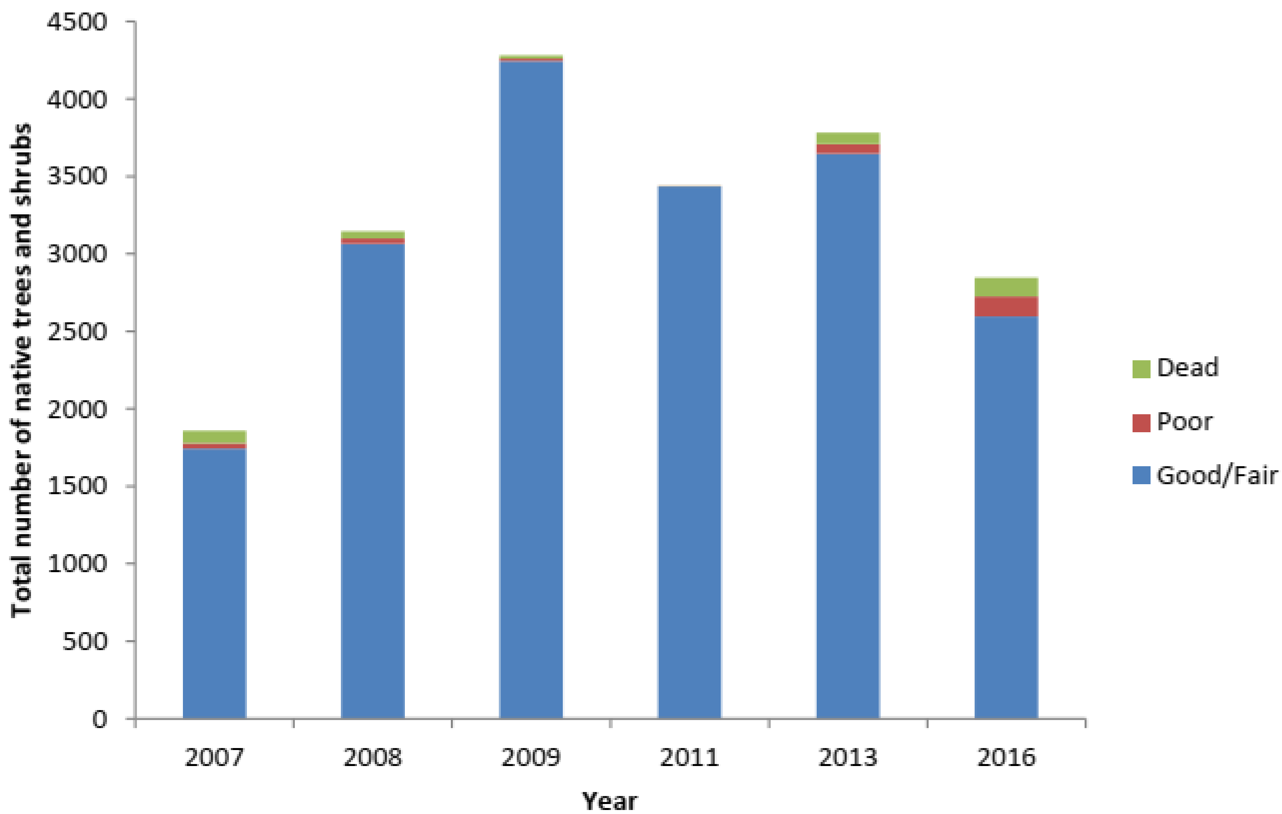


Figure 3-10 Total number of trees and shrubs in Good/Fair, Poor and Dead condition counted during vegetation surveys 2007 to 2013.

Tree height: As per the *Monitoring and Maintenance Plan* (COB 2006) and subsequent monitoring reports (Forester 2009 & 2010), tree height class was monitored. The following tree species have been documented at the restoration sites: western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*), western redcedar (*Thuja plicata*), red alder (*Alnus rubra*), Sitka alder (*Alnus viridis* ssp. *sinuata*), bigleaf maple (*Acer macrophyllum*), Douglas maple (*Acer glabrum*), black cottonwood (*Populus trichocarpa*), paper birch (*Betula papyrifera*), Pacific crabapple (*Malus fusca*), and Oregon Ash (*Fraxinus latifolia*). Red alder is the predominant tree species, with black cottonwood and western red cedar being the second and third most abundant, respectively. In 2007, following initial construction and plant installation, smaller trees (280 total) from 1-5 ft in height dominated the site, with 43 trees in the intermediate (5-15 ft) size class, and only 17 pre-existing trees in the tallest (15+ ft) size class category. However, by 2016 (ten years after project construction) trees in the intermediate and tallest size classes dominated the restoration area with counts of 237 and 248 stems, respectively (Table 3-3). Overall, between 2007 and 2016 the project area has seen an 8-fold increase in the intermediate and tallest tree sizes.

Table 3-3 Size class of live trees in all vegetation transects from 2007 to 2016.

Year	2007	2008	2009 [1]	2011 [2]	2013	2016 [3]	Change 2007-2016	Percent Increase 2007-2016
Total # Live Trees	340	1030	1360	1012	835	586	246	72%
1-5 feet	280	900	920	303	211	101	-179	-64%
5-15 feet	43	111	411	664	492	237	194	451%
15+ feet	17	19	29	45	132	248	231	1359%

[1] Transect 3 was not surveyed in 2009.

[2] Transect 6 was not surveyed in 2011.

[3] Transect 3 was not surveyed in 2016.

This pattern of tree height development conforms well to a classic model of forest succession, with the tree community passing through multiple seral stages as it matures. **Figure 3-11** illustrate this pattern, showing a peak in the number of smaller trees (as well as the total number of trees) in 2009, followed by a peak in the number of intermediate size trees in 2011, all while the number of trees in the tallest size class has continued a steady uptick across all monitoring years. Similarly, red alder and black cottonwood, the two dominant pioneer tree species, show a peak in 2009 while western redcedar, often associated with secondary seral stages, shows a peak later in 2011 (**Figure 3-12**).

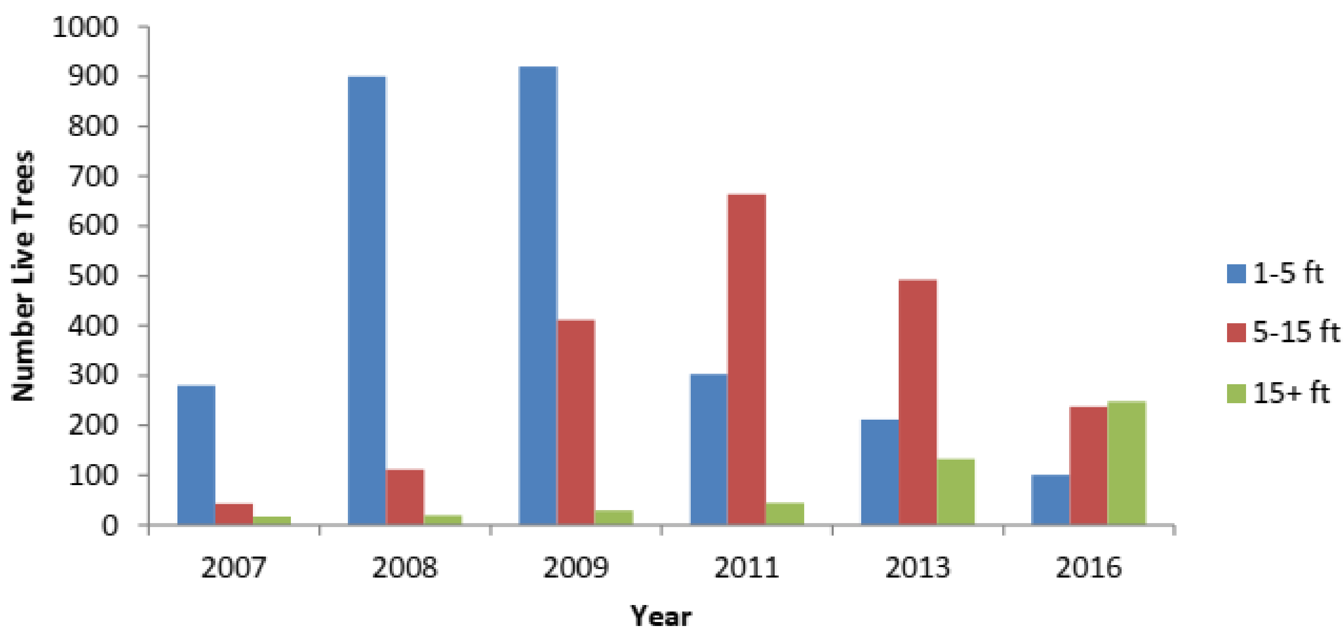


Figure 3-11 Total number of live trees in each size class category from 2007 to 2016.

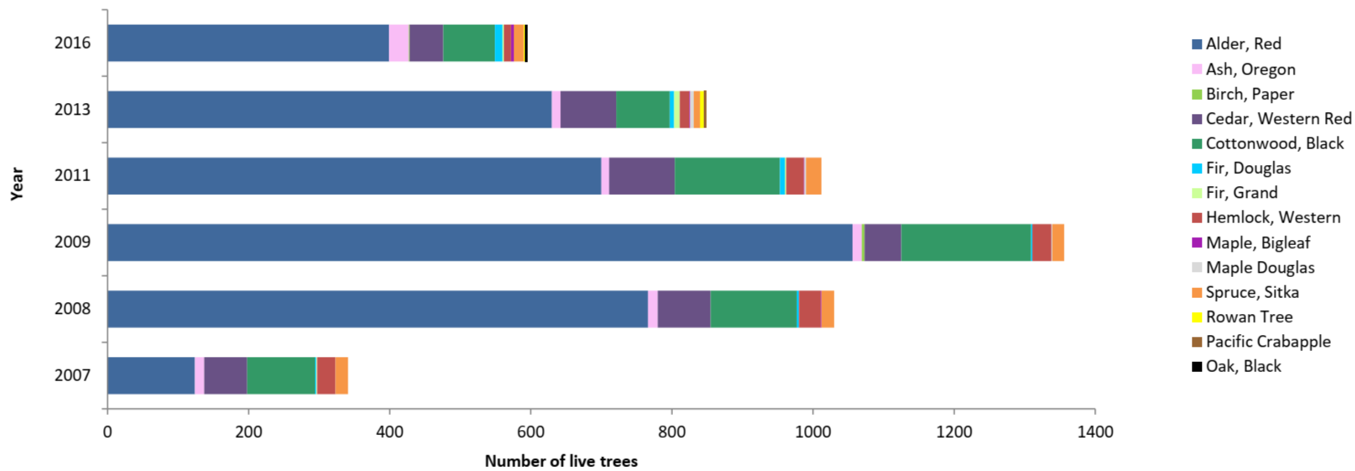


Figure 3-12 Red alder and black cottonwood dominate , followed by western redcedar. Total number of live trees peaks in 2011.

Canopy Cover: As per the *Whatcom Creek Restoration Project Report: 2007-2008* (Forester 2009) a spherical concave densiometer was used to quantify canopy cover at each of the vegetation transects starting in 2008. Results presented in Table 3-4 show that, with the exception of transects 21 and 23, canopy cover increased at all vegetation transects between 2008 and 2016. The drop in cover at transects 21 and 23 may be attributable to the loss of some willow trees due to vandalism, or to loss of overhead branches during winter wind storms. Overall, canopy cover has increased since monitoring began in 2008, peaking in 2011, and exhibiting a progressively tighter distribution over the years indicating that canopy is becoming better established and more uniform across the project area (**Figure 3-13**).

Table 3-4 Percent canopy cover measured at each vegetation transect, plus the net change between 2008 and 2016.

Transect	2008	2009 [1]	2011 [2]	2013	2016	Δ 2008 to 2016	↑ Increase ↓ Decrease
1	36.8%	50.0%	78.8%	91.5%	90.0%	53.2%	↑
2	63.5%	61.8%	78.8%	75.9%	65.6%	2.1%	↑
3	45.0%	--[1]	42.1%	68.5%	--[3]	--[3]	↑
4	5.9%	7.6%	51.8%	37.1%	19.4%	13.5%	↑
5	4.7%	4.7%	95.9%	100.0%	82.4%	77.6%	↑
6	1.8%	7.6%	--[2]	98.8%	97.1%	95.3%	↑
7	1.8%	63.5%	97.1%	84.1%	92.9%	91.2%	↑
8	0.0%	4.7%	60.6%	73.5%	66.5%	66.5%	↑
9	1.8%	1.8%	49.4%	44.4%	52.4%	50.6%	↑
10	70.9%	67.1%	80.3%	86.2%	80.3%	9.4%	↑
11	61.8%	75.3%	84.1%	85.3%	92.4%	30.6%	↑
12	50.0%	78.2%	100.0%	70.6%	76.5%	26.5%	↑
13	58.8%	76.5%	97.1%	78.2%	67.6%	8.8%	↑
14	57.6%	82.4%	100.0%	75.3%	98.8%	41.2%	↑
15	44.4%	40.6%	73.8%	50.9%	70.0%	25.6%	↑
16	61.8%	66.5%	81.2%	78.8%	92.6%	30.9%	↑
17	61.2%	70.0%	95.6%	97.9%	83.2%	22.1%	↑
18	40.6%	85.6%	100.0%	78.8%	67.1%	26.5%	↑
19	37.1%	82.6%	98.5%	53.8%	84.1%	47.1%	↑
20	65.6%	69.1%	80.3%	72.1%	70.0%	4.4%	↑
21	76.5%	75.3%	90.6%	72.9%	58.2%	-18.2%	↓
22	65.6%	79.4%	82.4%	74.4%	70.0%	4.4%	↑
23	45.9%	51.8%	45.9%	76.5%	31.2%	-14.7%	↓
Arithmetic Mean	41.7%	54.6%	80.2%	75.0%	73.1%	31.4%	↑
Standard Deviation	0.26	0.30	0.19	0.16	0.20	NA	NA

[1] Transect 3 was not surveyed in 2009.

[2] Transect 6 was not surveyed in 2011.

[3] Transect 3 was not surveyed in 2016.

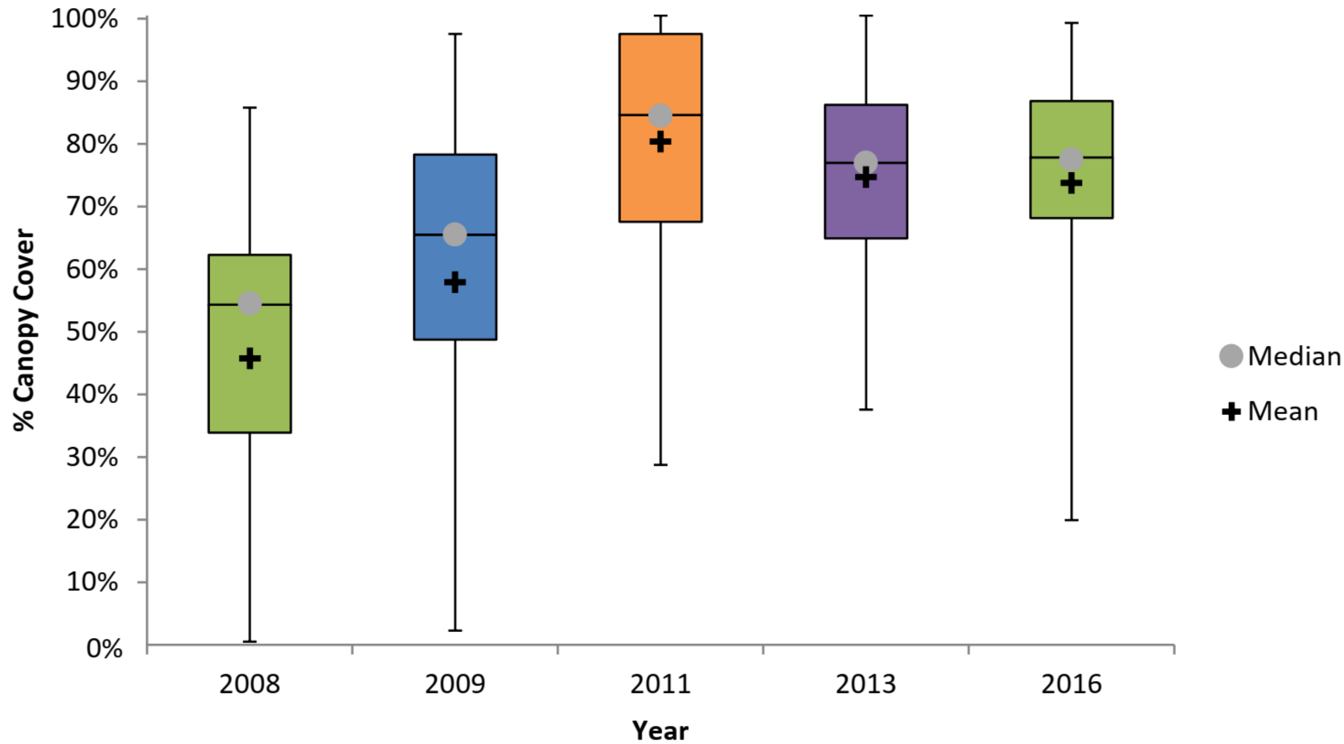


Figure 3-13 Box plot showing percent canopy cover from 2008 to 2016. Gray dot shows the median, black plus sign shows the mean.

While most transects retained some pre-existing, naturally occurring canopy cover through project construction, those transects along Whatcom Creek (Transects 4-9;Table 3-4) started with very little cover in 2008 followed by dramatic increases in canopy cover in 2011 through 2016. From 2011 to 2016 the canopy opened up slightly but closure remained high overall, with overall mean canopy cover shifting from 80.2% down to 73.1% (Figure 3-13).

Aquatic plants: As per the *Whatcom Creek Restoration Project Report: 2007-2008* (Forester 2009) aquatic plants were monitored starting in 2008. Monitoring of aquatic plants was added to the monitoring plan in 2008 to document the recolonization of constructed stream channels and ponds by aquatic plants. Data on the establishment and spread of aquatic plants can be used as an indicator of habitat quality for fish, amphibians, insects and macroinvertebrates, all of which rely on aquatic plants in some way. Overall, average percent cover has increased from 5% in 2008 to 17% in 2016 (Table 3-5).

Table 3-5 Percent cover of aquatic plants at all transects, 2008-2016.

Transect	Total Aquatic Vegetation Cover				
	2008	2009	2011	2013	2016
1					
2	5%		23%		
3	0%	Not surveyed	0%	0%	Not surveyed
4				0%	2%
5				0%	
6			Not surveyed	0%	
7				93%	18%
8				22%	23%
9	50%	70%	85%	87%	100%
10	5%	20%	12%	22%	4%
11	5%	6%	4%	21%	8%
12	1%	2%	11%	16%	14%
13	2%	3%	8%	52%	2%
14	1%	1%	1%	45%	1%
15	2%	8%	29%	34%	2%
16	5%	5%	5%	30%	1%
17	5%				
18	1%	1%	1%	1%	
19	1%	0%	0%	1%	
20	0%	0%	19%	0%	1%
21	2%	11%	2%	1%	21%
22	1%	2%	21%	33%	49%
23	5%	3%	1%	3%	13%
Arithmetic Mean	5%	9%	14%	23%	17%
Standard Deviation	0.12	0.18	0.21	0.28	0.26

* Transects highlighted in grey contained no wetted area at time of survey.

Note: Where "<1%" is written into the field sheets, data has been tallied and entered as if this were an entire "1%."

The non-native/invasive starwort (*Callitriche stagnalis*) continues to be the most common aquatic plant in surveyed transects, accompanied by the following native aquatic plants: american waterweed (*Elodea canadensis*), giant duckweed (*Spirodela polyrrhiza*), blue skullcap (*Scutelleria lateriflora*), lesser duckweed (*Lemna minor*), water purslane (*Ludwigia palustris*), water speedwell (*Veronica anagallis-aquatica*), and narrow-leaf burr reed[2] (*Sparganium angustifolium*). Plant identification is taken to the lowest practical level; pondweed (*Potamogeton sp.*) and *Nitella sp.* (a plant-like algae) both occur at the site but require microscopic examination to distinguish between species. Without species-level

[2] Narrow-leaf burr reed (*Sparganium angustifolium*) in North Pond was most likely mis-identified as tapegrass (*Vallisneria americana*) in previous survey years.

identification, it is uncertain if these specimens are of native or non-native phylogeny. However, Nitellas are generally considered desirable in Washington state, while the only *Potamogeton* that is widely considered invasive and problematic is curly-leaf pondweed (*Potamogeton crispus*) which is identifiable in hand sample and has not been observed at the site to date. Additionally, neither Brazilian elodea (*Egeria densa*) nor hydrilla (*Hydrilla verticillata*)-- two highly problematic invasive aquatic plants-- have been observed at the restoration site.

3.1.5 Discussion

Figure 3-14 Left photo taken in 2007 shows the newly constructed stream channel in Cemetery Creek; right photo is a repeat photo taken in 2014 at the same location.

The first criterion for "successful" establishment of vegetation states that: "*Native tree and shrub species composition should not consist of greater than 10% (by area) of non-native/invasive plant species at the end of 10 years"* (COB 2006). Overall, the average percentage of non-native/invasive trees and shrubs at all transects during all survey years has ranged between 2.5% and 10.0% (**Figure 3-8**) meeting and/or exceeding this criterion.

The second criterion for "successful" establishment of vegetation states that: *"Survival of plantings should be at least 75% at the end of three years and through the lifetime of the monitoring plan*" (COB 2006). Natural recruitment preventeds us from generating a survivability metric as originally intended. Instead, percent survival is estimated here by comparing the number of original plantings to the number of existing native trees and shrubs counted at each monitoring event. Over the ten-year monitoring period, an increase in total numbers of native trees and shrubs from 1,744 stems in Year 1 to 2,594 stems by Year 10 was observed. This represents a 150% increase in native trees and shrubs over the 10-year period, exceeding the survival criterion of 75% survival.

Success Criteria:

- **Non-native/invasive plants:** Native tree and shrub species composition should not consist of greater than 10% (by area) of non-native/invasive plant species at the end of 10 years. **Criterion met for trees and shrubs.**
- **Plant survival**: Survival of plantings should be at least 75% at the end of three years and through the lifetime of the monitoring plan. **Criterion met. Total numbers of native trees/shrubs increased by 150% by the end of the monitoring period.**

As the project continues to mature and space for naturally recruiting seedlings declines, it is anticipated that overall plant numbers will gradually decrease (**Figure 3-10**). The average proportion of herbaceous non-native/invasive species in the ground layer has decreased over the course of the monitoring period (**Figure 3-9**) and is expected to continue to decline as the site matures. For example, reed canary grass (established throughout the restoration area) will be progressively shaded-out as native plants grow.

3.1.6 Recommendations

Continue maintenance at the restoration sites as needed for management of noxious weeds such as reed canary grass, Himalayan blackberry, knotweed, yellow flag iris and English holly.

3.2 FISH COMMUNITY

3.2.1 Spawner Surveys

3.2.1.1 Introduction

Whatcom Creek currently supports six species of anadromous salmonids: fall Chinook, coho, chum, pink salmon, winter steelhead and coastal sea-run cutthroat trout. Resident forms of rainbow and cutthroat trout are also present. For more information on historic and recent use of Whatcom Creek by salmonids and other fish species, see the *Whatcom Creek Post-Fire Evaluation* (Madsen and Nightengale 2009). As a small tributary, Cemetery Creek was expected to provide suitable spawning habitat for smaller bodied salmonids such as coho (**Figure 3-15**), sea-run cutthroat and resident trout. However, larger salmonids such as steelhead, Chinook and chum have also been observed in the stream (**Figure 3-16**). Spawner surveys were conducted to determine whether anadromous salmonids were spawning in the reconstructed stream channels of Cemetery Creek and West Cemetery Creek.

Figure 3-15 Adult male coho observed in Cemetery Creek on November 9, 2011.

Figure 3-16 Female Chinook observed in Cemetery Creek on October 21, 2010.

3.2.1.2 Objective

The objective of spawner surveys is to confirm that habitat within the restoration area is being used for salmonid spawning. Spawner survey results, in tandem with smolt trap results, are used to assess the following criteria for success, as specified in the *Monitoring and Maintenance Plan* (COB 2006):

3.2.1.3 Methods

Salmon begin to return to small streams in Puget Sound, including those in the City of Bellingham, during the late summer (**Appendix B**). Salmon returns often coincide with the onset of fall rains that increase water levels in smaller tributary streams. In many Bellingham streams salmon begin upstream migration around the beginning of October, however certain species will run earlier given sufficient flows (eg, Pink in mid-August, Chinook in early September). Therefore, spawner surveys in Cemetery Creek were initiated in early September and continued through the spawning season with the goal of capturing at least one null or "zero" survey. A null survey (completed before fish are expected to enter the system) helps to confirm that our survey season has not missed any early returning fish. Survey frequency was typically 7-10 days, with no more than two weeks between surveys. Surveyors avoided high water and turbid conditions to minimize the chance of accidental redd trampling or fish stress. Spawner surveys were conducted in all post-construction years (except the 2009-2010 run year; **Appendix A**)[3]. Survey reaches covered all 1450 ft of restored stream length (**Figure 3-17**).

Success Criteria:

- Resident and anadromous fish utilize all features of the restoration site for migration, spawning and rearing.

[3] The original *Monitoring and Maintenance Plan* schedule (City of Bellingham, 2006) specified that all monitoring of the restoration sites should occur in post-construction years 1, 2, 3, 5, 7, and 10 with the exception of juvenile salmonid monitoring using a smolt trap in years 1, 3, 6, and 10. However, in 2011 (Year 5) the frequency of both spawner surveys and smolt traps was increased to better correlate spawners with outmigrants. Please see **Appendix A** for details.

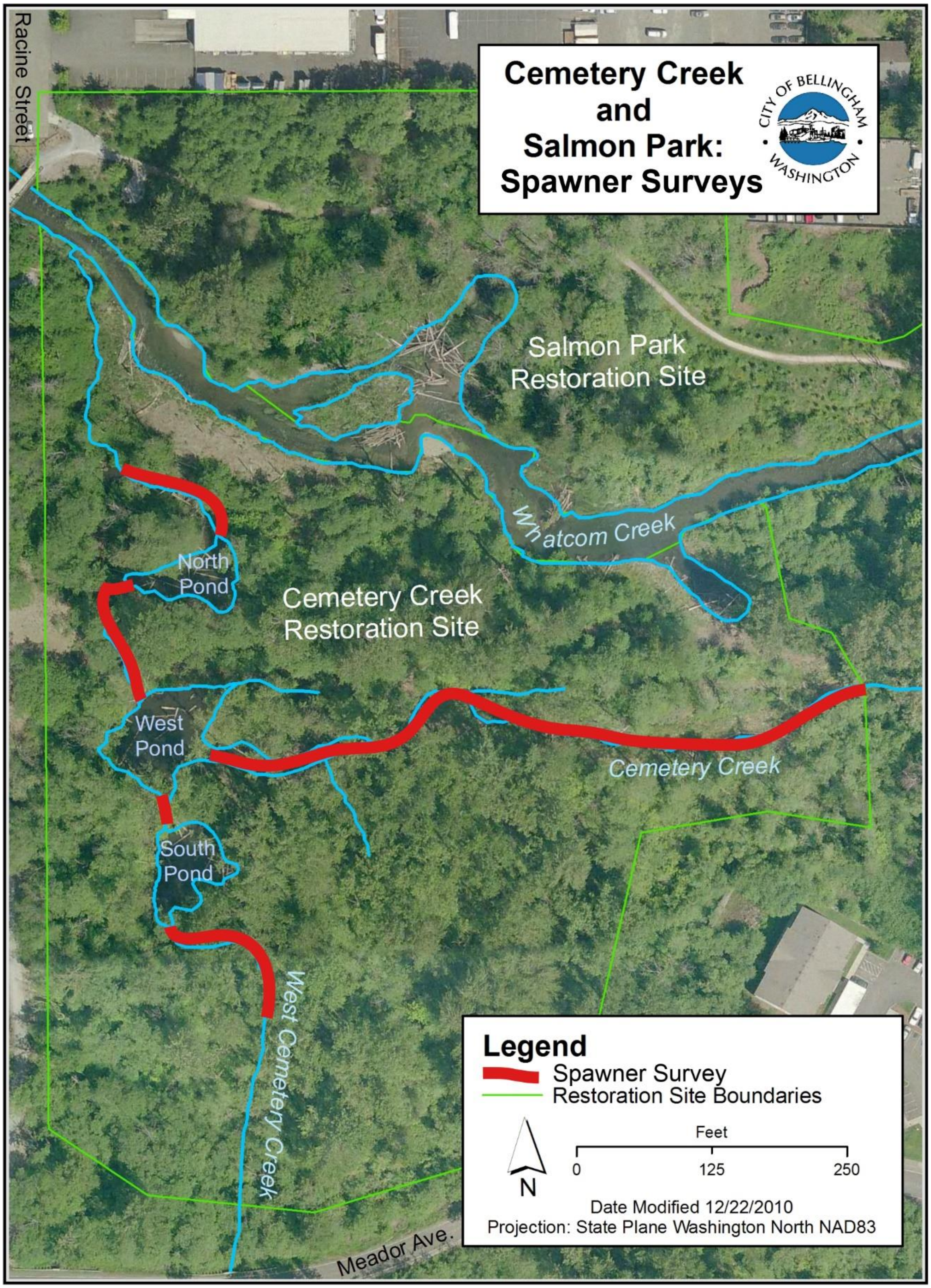


Figure 3-17 Map of spawner survey reaches on restored stream channels of Cemetery and West Cemetery Creeks.

Spawner surveys followed Washington Department of Fish and Wildlife (WDFW) protocols (WDFW 2008). Starting at the downstream end of the project area, surveyors counted the number of live fish, carcasses and redds as they walked upstream. Live fish were identified to species (if possible) and observed to determine if they were building or guarding a redd. Redds were associated with a species (if possible) and marked with flagging denoting the survey date and location (**Figure 3-18**). The caudal fin was then cut off to indicate that the carcass had been counted. A qualitative estimate of visibility (percentage of the stream reach visible) was also assessed.

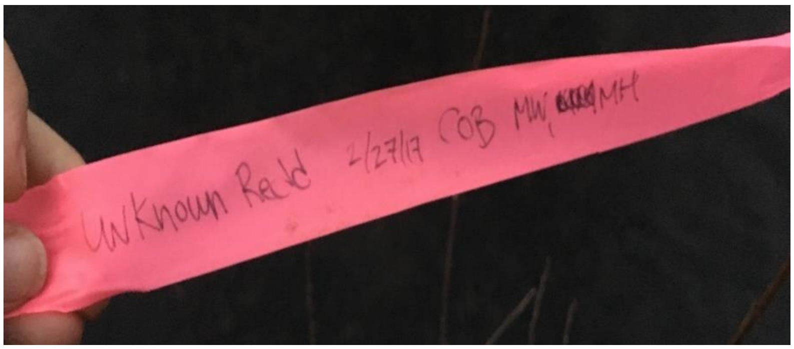


Figure 3-18 All observed redds were marked with flagging.

3.2.1.4 Results

A total of 215 walking surveys were performed along the restored stream reaches of Cemetery and West Cemetery Creeks between 2006 and 2016 (**Table 3-6**).

Table 3-6 Spawner survey summary statistics for all monitored years.

Survey year	2006-2007	2007-2008	2008-2009	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	Totals
Number of surveys	8	18	20	29	30	30	29	27	24	215
Number of surveys with ≥ 80% visibility	7	14	14	20	17	13	15	11	10	121
Number of live fish	-	1	-	10	5	2	-	1	-	19
Number of dead fish	-	5	-	5	2	1	1	3	-	17
Number of redds	-	2	2	1	3	3	2	5	-	18

For three of these survey years (2006-2007, 2008-2009, and 2015-2016), no anadromous fish were observed. Over the course of the remaining survey years, 36 total spawning salmonids were observed: 13 Chinook, 11 coho, 1 steelhead and 11 unknown spawners which could not be identified to species due to decomposition or poor visibility (**Table 3-7**).

Table 3-7 Spawner survey fish counts (live + dead counts) by species for all monitored years

Common Name	Species	2006-2007	2007-2008	2008-2009	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	Total by Species
Chinook	*Oncorhynchus tshawytscha*	-	1	-	11	-	-	-	1	-	13
Coho	*Onchorynchus kisutch*	-	2	-	1	4	1	1	2	-	11
Chum	*Oncorhynchus keta*	-	-	-	-	-	-	-	-	-	0
Pink	*Oncorhynchus gorbuscha*	-	-	-	-	-	-	-	-	-	0
Cutthroat	*Oncorhynchus clarkii*	-	-	-	-	-	-	-	-	-	0
Steelhead/Rainbow	*Oncorhynchus mykiss*	-	-	-	-	1	-	-	-	-	1
Unknown Salmonid	*Oncorhynchus sp.*	-	3	-	3	2	2	-	1	-	11
	Total by Year	**0**	**6**	**0**	**15**	**7**	**3**	**1**	**4**	**0**	**36**

Between 2006 and 2016 (minus 2009-2010), an average of 2 redds were observed per year within the 1450 ft of restored stream length on Cemetery and West Cemetery Creeks. Out of the 18 total redds observed, two-thirds were dug by unknown salmonids, but the remaining one-third of redds were positively identified as coho redds (**Table 3-8**).

Table 3-8 Spawner survey redd counts by species for all monitored years

Common Name	Species	2006-2007	2007-2008	2008-2009	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	Total Redds
Chinook	*Oncorhynchus tshawytscha*	-	-	-	-	-	-	-	-	-	-
Coho	*Onchorynchus kisutch*	-	1	-	-	2	1	-	2	-	6
Chum	*Oncorhynchus keta*	-	-	-	-	-	-	-	-	-	-
Pink	*Oncorhynchus gorbuscha*	-	-	-	-	-	-	-	-	-	-
Cutthroat	*Oncorhynchus clarkii*	-	-	-	-	-	-	-	-	-	-
Steelhead/Rainbow	*Oncorhynchus mykiss*	-	-	-	-	-	-	-	-	-	-
Unknown Salmonid	*Oncorhynchus sp.*	-	1	2	1	1	2	2	3	-	12
	Total by Year	**0**	**2**	**2**	**1**	**3**	**3**	**2**	**5**	**0**	**18**

Most of the adult Chinook observations in Cemetery Creek (85%; 11 out of 13) were found during the 2010-2011 season while spawning coho were observed in smaller numbers more consistently across the years. Pre-spawn mortality was documented in both Chinook and coho carcasses, when carcasses were found with either intact egg skeins or substantial milt (**Figure 3-19**). Appendices C and D contain tables and charts documenting detailed results from each monitoring year.

Figure 3-19 Unspawned Chinook at Cemetery Creek. Female observed on October 29, 2010 (left) and male observed on November 1, 2007 (right).

Although spawner surveys did not target lamprey, field staff made incidental observations of spawning Western brook lamprey (*Lampetra richardsoni*) in the Cemetery Creek channel in June 2009 (**Figure 3-20**). Three adult lamprey were first noted on June 3, 2009 in the area of fine gravel just upstream of the North Pond. On June 8, other spawning groups were located in the mainstem of Cemetery Creek, upstream of the West Pond.

Figure 3-20 Western brook lamprey spawning in restored Cemetery Creek channel in June, 2009

3.2.2 Juvenile Rearing (smolt trap)

3.2.2.1 Introduction

Ponds and backwater habitats constructed in the Cemetery and West Cemetery Creek channels in 2006 were designed primarily to improve salmonid rearing habitat, especially for species like coho who require perennial off-channel habitats for rearing. Prior to construction, juvenile salmonids anticipated in the Cemetery Creek system were coho (*Oncorhynchus kisutch*), rainbow/steelhead trout (*Onchorynchus mykiss*) and cutthroat trout (*Onchorynchus clarkii*) due to their long residence time in freshwater (1-2 years). Chinook, chum and pink salmon were also possible, based on connectivity to Whatcom Creek. Seasonal seine netting was originally envisioned in the 2006 *Monitoring and Maintenance Plan.* However, this monitoring activity was discontinued in 2007 because the density of large wood made seining impractical.

3.2.2.2 Objective

The objective of monitoring the outmigration of juvenile salmonids from the Cemetery Creek restoration site is to document seasonal use of constructed habitats by juvenile salmonids. Smolt trap results, in tandem with spawner survey results, are used to assess the following criteria for success, as specified in the *Monitoring and Maintenance Plan* (COB 2006):

Success Criteria:

- Resident and anadromous fish utilize all features of the restoration site for migration, spawning and rearing.

3.2.2.3 Methods

Use of the created ponds and stream network as rearing habitat for juvenile salmonids was monitored using a smolt trap in post-construction years 1, 3, 6, 7 and 10 (2007, 2009, 2012, 2013 and 2016; see **Appendix A**. Smolt traps are passive, non-lethal sampling devices that capture migratory fishes as they move upstream or downstream in a river system. State and federal permits were acquired for all smolt trap operations (

Table 3-9). Because Cemetery Creek is a small stream, we were able to install a channel-spanning smolt trap. This channel-spanning design allowed us to identify, count and measure all juvenile salmonids outmigrating from the Cemetery Creek restoration area into the mainstem of Whatcom Creek during the periods of deployment. Smolt traps were installed during the spring in order to capture the salmonid outmigration window, typically mid-March through sometime in June. The Cemetery Creek smolt trap was installed between the North and West Ponds (**Figure 3-21**). Installation at the original target location, downstream of the restoration area, was precluded by high water levels in Whatcom Creek which produced a backwatered area over 5 feet-deep downstream of the North Pond. Therefore, smolt trap results account for fish utilizing the West and South Ponds only.

Table 3-9 Smolt trap permit numbers by operation year.

	Washington Department of Fish and Wildlife		National Marine Fisheries Service
Smolt Trap Operation Year	Hydraulic Project Approval Permit #	Scientific Collecion Permit #	ESA Section 10 Permit #
2007	00000G2504-2	07-100	10020
2009	116271-1	09-065	10020
2012	116271-2	11-372	10020
2013	12099-1	12-333	10020-3M
2016	2015-4-96+01	14-359	10020-4M

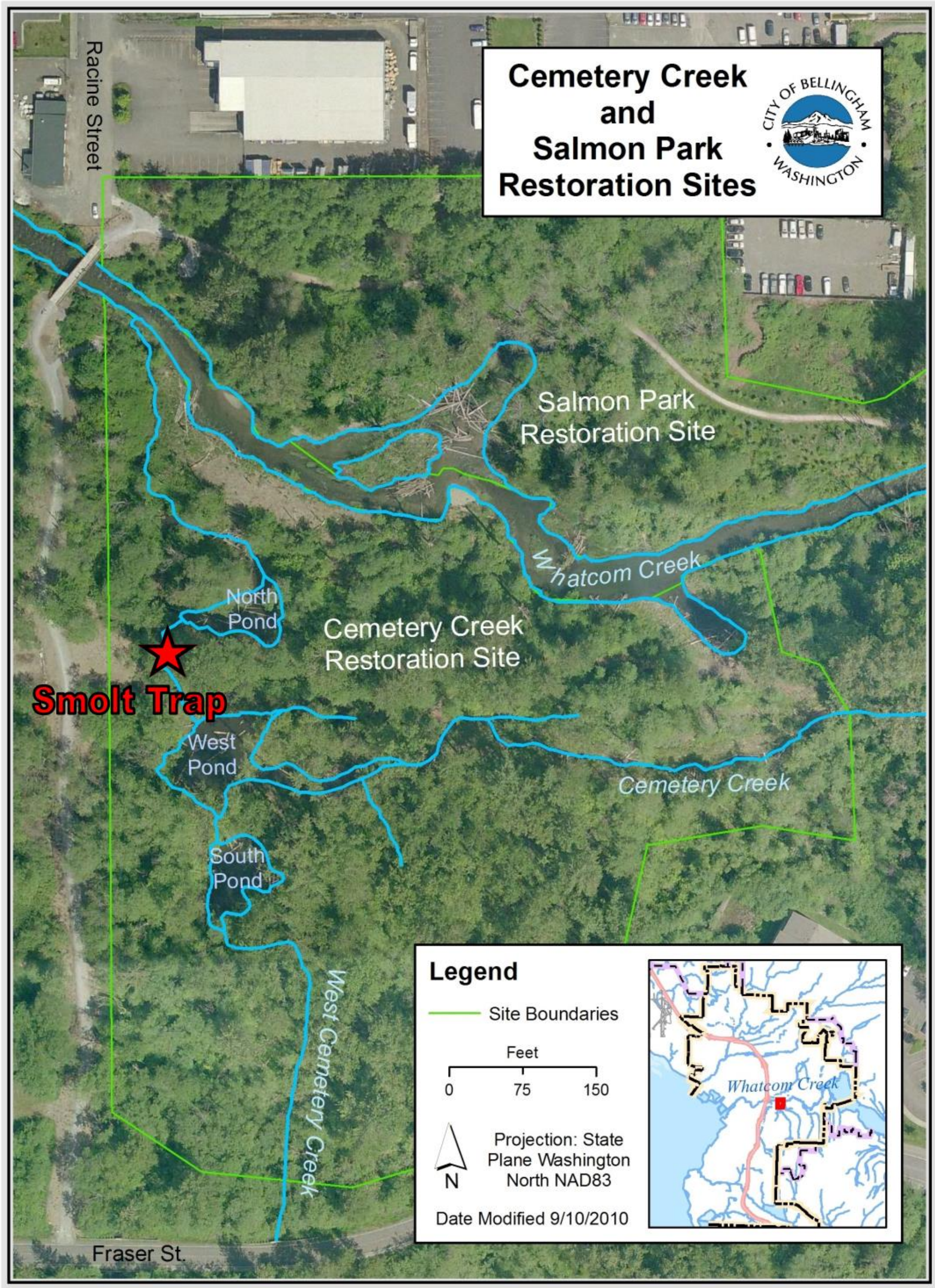
Our smolt trap was modeled after WDFW's design (Blankenship & Tivel 1980). The trap design included a V-shaped weir composed of large screen panels that funneled fish into a live box while allowing water and small debris to pass through the mesh (**Figure 3-22**). The 3 x 6-foot panels were covered with ½- x ½-inch vinyl coated mesh screens, and were positioned to span the entire stream channel, extending well above the ordinary high water mark (OHWM). To ensure no fish could pass under the weir, the bottom 16 inches of the weir is flashed with polyethylene plastic that extends far enough in front of the weir to be covered with gravel bags. All panels are lashed together with wooden and metal supports and anchored in the stream with 7-foot steel fence posts. The combination of flow and weir design guides fish into the live box. The live box is made of wood and stands 2 feet tall by 4 feet long by 2 feet wide). The box is installed to keep water levels in the box at a minimum of 8 inches. The side of the live box is covered with ½- x ½-inch mesh screens. Sandbags and box design create high-flow refuge for captured fish holding in the live box. An adult migration pipe was installed to allow spawning anadromous fish (eg. coastal cutthroat trout or steelhead) to navigate upstream into a temporary holding pool.

Smolt trap methods were modified from those found in "Relation of salmonid survival, growth, and outmigration to environmental conditions in a disturbed, urban stream, Squalicum Creek, Washington" (Downen 1999). Each smolt trap was installed in early spring (typically mid-March) and then removed according to flow levels, typically mid-June. The box, weirs, and adult holding pool were all checked at least twice daily at approximately 7:30 am and 5:00 pm. The trap was checked more frequently during periods of heavy rain or high flows. At each check, fish intercepted by the juvenile trap were identified to species (when possible) and measured[4] (fork length), then released downstream on their travel path. Any fish found in the adult holding pool would have been moved upstream, however none were intercepted. Any fish held temporarily outside of the live box was placed in a clean, aerated 5-gallon

[4] In the first two years of smolt trapping (2007 & 2009) fork lengths were not recorded and fish were simply grouped into size classes.

bucket filled with fresh creek water for no longer than 15 minutes, before being released back into the stream. Water temperature and water level was also recorded on each visit, to ensure that safe temperatures and adequate depths were maintained in the holding box. All accumulated debris was cleared from panel screens during each site visit.

Figure 3-21 Location of smolt trap between the North and West Ponds on Cemetery Creek.



3.2.2.4 Results

Trap operation was aimed at capturing the entire juvenile outmigration window, however both trap installation and removal were weather and flow dependent (Figure 3-22), and occasional over-topping of the weirs during high flow events means that all numbers reported here are a minimum census. The window of trap operation typically began in mid-March and ended in June. Fish counts by species for all monitored years are summarized in Table 3-10, below.

Figure 3-22 Smolt trap installation during moderate flows in 2012 (left) and lower flows in 2016 (right).

Table 3-10 Smolt trap counts by species for all monitored years.

Species	Common Name	2007 (Mar 28-Jun 7)	2009 (Mar 18-May 26)	2012 (Mar 13-Jun 11)	2013 (Mar 12-Jun 25)	2016 (Mar 11-Jun 14)
Onchorynchus kisutch	Coho	871	528	769	1614	1257
Onchorynchus clarki	Cutthroat Trout	294	178	32	177	62
Onchorynchus sp.	Trout species	-	87	15	11	35
Onchorynchus mykiss	Steelhead/Rainbow Trout	9	63	58	118	100
Oncorhynchus tshawytscha	Chinook	-	-	-	-	1
Onchorynchus sp.	Salmon species	771	27	8	1	3
Oncorhynchus gorbuscha	Pink	-	-	1	-	-
Cottus sp.	Sculpin	6	22	43	67	12
Lampetra sp.	Lamprey	9	12	1	2	273
Gasterosteus aculeatus	Stickleback	8	6	8	5	69
Richarsonius balteatus	Red-sided Shiner	1	1	-	-	-
Micropterus dolomieu	Smallmouth bass	1	-	-	1	-
Lepomis macrochirus	Blue Gill	-	-	-	-	1
Lepomis gibbosus	Pumpkinseed	-	-	-	1	-
Pimephales promelas	Fat Head Minnow	-	-	-	-	1
Perca sp.	Perch	-	-	-	1	-
Carassius auratus	Goldfish	8	-	-	-	-
Ameiurus natalis	Bullhead	-	-	-	-	1
Unknown	Unknown	-	8	9	2	-
	Total	1,978	932	944	2,000	1,815
	Total Salmonids	**1,945**	**883**	**883**	**1,921**	**1,458**

A maximum number of 2,000 fish were intercepted at the trap in 2013, with a minimum of 932 in 2009. During the first smolt trap season in 2007, many salmonids (40%) were removed from the trap and passed downstream without identification, primarily during flood events. This strategy emphasized safe transport of fish over identification. However, in all future years, unknown fish were at minimum broken out into broad categories of “salmon” or “trout” whenever possible, and overall identification certainty increased. Very few non-native fish species were encountered, but an occasional perch, bullhead, minnow, bass, shiner or sunfish did show up in the traps. In fact, 8 goldfish were found in the 2007 trap.

In all years, coho salmon (*Onchorynchus kisutch)* dominated the outmigration totals, followed by cutthroat trout (*Onchorynchus clarkii)* and steelhead (*Onchorynchus mykiss)* (**Table 3-10**, **Figure 3-24**). Only one juvenile Chinook (87mm fork length) was positively identified in 2016. Genetic analysis suggested that this individual was a fall Chinook with Samish Hatchery origin.

Figure 3-23 Photo of coho juvenile intercepted by smolt trap in April, 2016

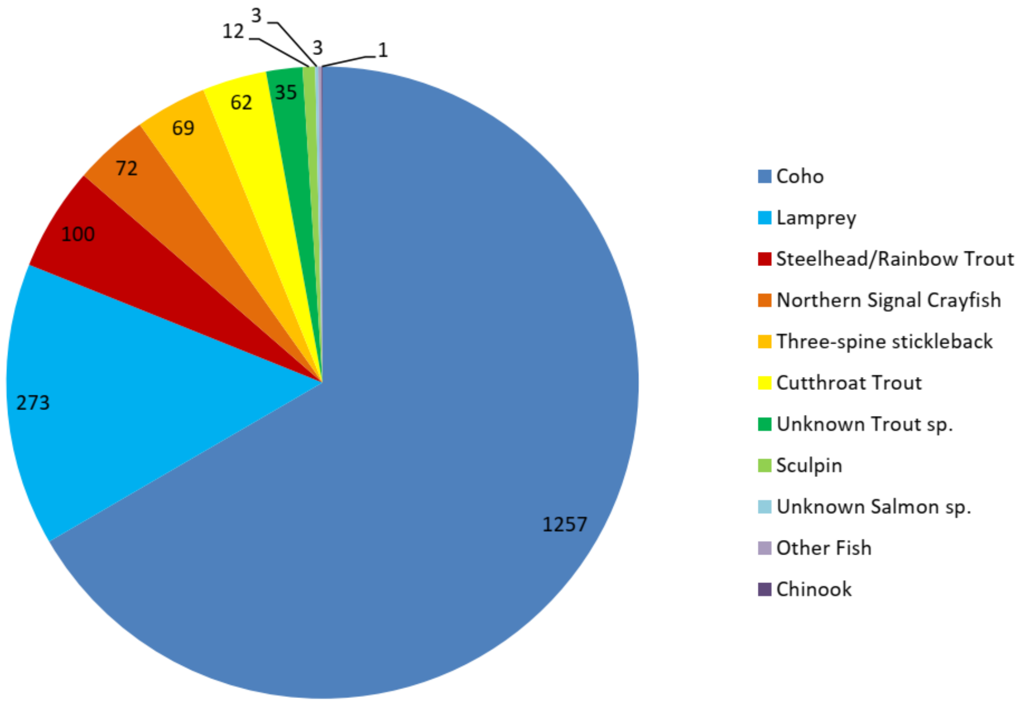


Figure 3-24 Smolt trap counts by species in 2016.

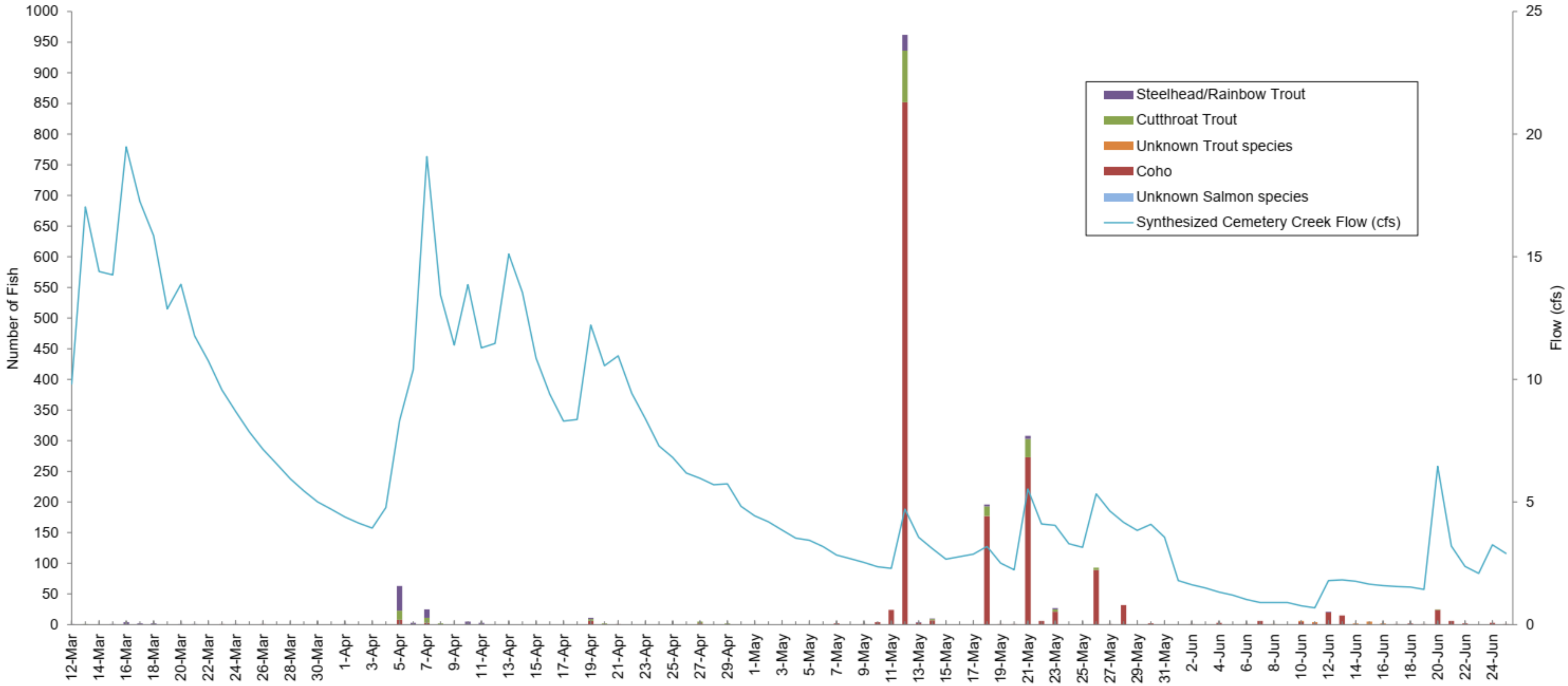
The number of lamprey counted in 2016 was exceptional, with a total of 273 lamprey counted compared with no more than 12 in all previous years (Figure 3-24). Steelhead numbers peaked in 2013 and 2016 with 118 and 100 total juveniles (Table 3-10). No spawning adult steelhead were encountered in Cemetery Creek during post-construction monitoring, however three anadromous adult coastal cutthroat trout were intercepted in 2013 (Figure 3-25).

Figure 3-25 Adult anadromous coastal cutthroat trout intercepted by smolt trap in April, 2013

In all years, outmigration at the Cemetery Creek smolt trap peaked with rain events in late April or May; **Figure 3-26** shows a typical outmigration pattern. Rain events earlier or later in the season would also bring some fish downstream, but the vast majority of fish moved through the trap during late April and May. Appendix E contains additional charts depicting smolt trap counts by day for each monitored year, paired with discharge measurements. Appendix F contains bar charts showing the size class distribution of fish intercepted by the trap during each surveyed year.

In 2013 and 2016, non-lethal genetic samples were collected from *O. mykiss* at the smolt trap in order to assign population(s) of origin. In 2013, 71% of the sampled *O. mykiss* assigned to Kendall/Chambers Creek Hatchery and 29% assigned to Nooksack or Samish natural origin populations. In 2016, 56% of the sampled *O. mykiss* assigned to Kendall/Chambers Creek Hatchery and 44% assigned to Nooksack or Samish natural origin populations. Genetic analysis reports are contained in Appendix G.

Figure 3-26 Smolt trap outmigration numbers by day paired with stream



3.2.3 Discussion

The objective of spawner surveys was to confirm that habitat within the restoration area is being used by salmonids for spawning, and the objective of smolt trap surveys was to document seasonal use of constructed habitats by juvenile salmonids. As such, the success criteria established in the *Monitoring and Maintenance Plan* (COB 2006) were fulfilled:

> **Success Criteria:**
> - Resident and anadromous fish utilize all features of the restoration site for migration, spawning and rearing. **Spawner survey and smolt trap results confirm that resident and anadromous fish used the restoration site for migration, spawning and rearing.**

Spawner surveys documented that anadromous fish utilized the restored stream channel for migration and spawning during six of the nine survey years between 2006 and 2016 (the 10-year monitoring period). However, spawner surveys did not include GPS locations or other references to specific habitat features, therefore it is not possible to correlate use with specific features. Five years of smolt trap operations conducted in post-construction years 1, 3, 6, 7 and 10 confirmed thousands of juvenile salmonids outmigrating from the South and West Ponds, clearly documenting use of constructed habitats by juvenile salmonids for both migration and rearing. Further, in addition to the anadromous salmonids that these surveys were aimed at, resident native western brook lamprey were documented spawning in the restoration site.

As the site evolves, the Cemetery Creek project area may be best suited to juvenile coho (*Oncorhynchus kisutch*) rearing and year-round habitat for resident western brook lamprey (*Lampetra richardsoni*). The Cemetery Creek system, with its many backwater areas and ponds with deep silty bottoms in combination with areas of fine spawning gravel provides ideal spawning and rearing habitat for western brook lamprey. Although Chinook (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) may occasionally access and use the restoration area (as observed in our monitoring), the Cemetery Creek channel is inherently too small and shallow to provide suitable spawning habitat for these species.

3.2.4 Recommendations

No further actions are recommended.

3.3 AQUATIC MACROINVERTEBRATES

3.3.1 Introduction

Benthic macroinvertebrates are a diverse assemblage of organisms that inhabit the substrate of aquatic systems and are visible to the unaided eye. Many of these species are in their larval or nymph stage of life, such as dragonflies and damselflies (**Figure 3-28** and **Figure 3-27**), and will eventually emerge from the water. Other benthic macroinvertebrates live their entire life cycle in the aquatic environment, such as aquatic worms, mites, and amphipods. Because of their short life spans, abundance, and diversity, macroinvertebrates are a good indicator of stream health and water quality. Parameters measured include community composition, functional feeding groups, taxa abundance, species richness and abundance.

Figure 3-27 Northern Bluet damselfly (*Enallagma annexum*) at the Cemetery Creek ponds.

Figure 3-28 Dragonflies at the Cemetery Creek ponds: Cardinal Meadowhawk (*Sympetrum illotum)* on left, and unknown dragonfly nymph exuvia on right.

3.3.2 Objective

The objective of aquatic macroinvertebrate sampling was to document colonization and survivorship by the macroinvertebrate community in reconstructed channels in the restoration site. Macroinvertebrate results are compared against the following criteria for success, as specified in the *Monitoring and Maintenance Plan* (COB 2006):

Success Criteria:

- Trends in community composition and structure, functional feeding groups, taxa abundance, species richness, and other indices should show improvement or remain stable over a 10-year post-construction period as compared to baseline population information.

3.3.3 Methods

Comprehensive methods and results are available in Appendix H: *Biological Assessment of Cemetery Creek: Bellingham, Washington Aquatic Invertebrate Assemblages 2007-2013* (Bollman 2014).

Macroinvertebrate samples were collected from three sites within the reconstructed Cemetery Creek channel (**Figure 3-31**) in September 2007, 2009, 2011, and 2013. Macroinvertebrate samples were originally planned for September in post-construction years 1, 2, 3, 5, 7, and 10, corresponding to years 2007, 2008, 2009, 2011, 2013, and 2016, respectively. However, samples were only collected and analyzed for 2007, 2009, 2011, and 2013 due to incompatible site conditions in 2008 and 2016.

Samples collected in 2008 were not processed due to backwatering of the Cemetery Creek restoration area in the weeks prior to sampling. Backwatering from Whatcom Creek occurred frequently in September 2008 and was presumed to be a product of construction at the Red Tail Reach project, however this backwatered condition persisted through time, especially at Site 1. Samples were not collected or analyzed in 2016 due to dry streambed conditions during the month prior to sampling at sites 2 & 3, and back-watered conditions at Site 1. The decision to forego sampling and/or analysis in 2008 and 2016 was based on the following considerations: (1) The Benthic Index of Biological Integrity (B-IBI) assessment tool is aimed at inference in perennial stream habitats (Kleindl 1995, Fore et al. 1996, Karr and Chu 1999); (2) Re-colonization after de-watering can take up to 6 months, which will skew macroinvertebrate assemblages (eg. lack of semivoltines, which have a brood or generation less often than once per year); (3) Backwatered sites end up with too much sediment, which will skew macroinvertebrate assemblages (eg. lack of shredders). **Figure 3-29** provides an example of Site 1 replicate sample locations during low flow in September 2011. Plotnikoff and Wiseman (2001) identify a macroinvertebrate sampling index period of July 1 through October 15 for Washington state rivers and streams for the following reasons:

- *Adequate time is available for the instream environment to stabilize following natural* *disturbances (e.g. spring floods).*

- *Many macroinvertebrates reach body sizes that can be readily identified.*
  Representation of benthic macroinvertebrate species reaches a maximum, particularly during periods of pre-emergence (typically mid-spring to late-summer).

With this in mind, staff attempted to avoid low-flow and backwatered site conditions in 2016 by shifting the sampling window earlier into July and then later into October, but incompatible site conditions persisted throughout the sampling index window and therefore no samples were collected in 2016.

Figure 3-29 Site 1 macroinvertebrate replicate locations during low flow in September 2011.

Macroinvertebrate sampling followed the methodology found in "Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams" (Plotnikoff and Wiseman, 2001), with some modifications. Samples were collected using a D-frame kick net with a 2.0 ft^2 (0.186 m2) delineation square and four replicate samples were taken from riffles within each of the three sites. Rocks within the frame were brushed for collection and substrates disturbed to release the macroinvertebrates.

Samples collected in 2007 and 2009 were processed and analyzed by R2 Resource Consultants, Inc. and samples collected in 2011 and 2013 were processed and analyzed by Rhithron Associates, Inc. Data from all years (2007-2013) were compiled and assessed according to the *Biological Assessment Of Cemetery Creek: Bellingham, Washington Aquatic Invertebrate Assemblages 2007-2013 (Bollman 2014)* by Rhithron Associates, Inc. and this comprehensive report is available in Appendix H, along with full taxa lists and metric summaries.

This report (Appendix H) uses the invertebrate biota to detect impairment to biological health, using two assessment tools: the B-IBI (Benthic Index of Biological Integrity) (Kleindl 1995, Fore et al. 1996, Karr and Chu 1999), calculated by the Puget Sound Stream Benthos (PSSB) website application, which is a battery of 10 biological metrics calibrated for streams of the Pacific Northwest, and a predictive model (RIVPACS – the River InVertebrate Prediction and Classification System) developed by the Washington Department of Ecology. RIVPACS compares the occurrence of taxa at a site with the taxa expected at a similar site with minimal human influence and yields a score that summarizes the comparison. These assessment tools provide a summary score of biological condition, and the B-IBI can be translated into biological health condition classes (i.e., excellent, good, fair, poor, and very poor) based on ranking criteria used by King County and other agencies and organizations in the Puget Sound region as per the Puget Sound Stream Benthos (PSSB) database (http://pugetsoundstreambenthos.org/). For this study, the "coarse"

Figure 3-30 Macroinvertebrate sample collection at Site 2 on Cemetery Creek in 2009.

level of taxonomic resolution was used. In addition, this report identifies probable stressors which may account for diminished stream health, basing these observations on demonstrated and expected associations between patterns of response of B-IBI metrics and other metric expressions, as well as the taxonomic and functional composition of the benthic assemblages. The analysis examines common stressors associated with urbanization: water quality degradation, changes to natural thermal regimes, loss and impairment of instream habitats due to sediment deposition and altered flow regimes, and disturbance to reach scale habitat features such as streambanks, channel morphology, and riparian zone integrity.

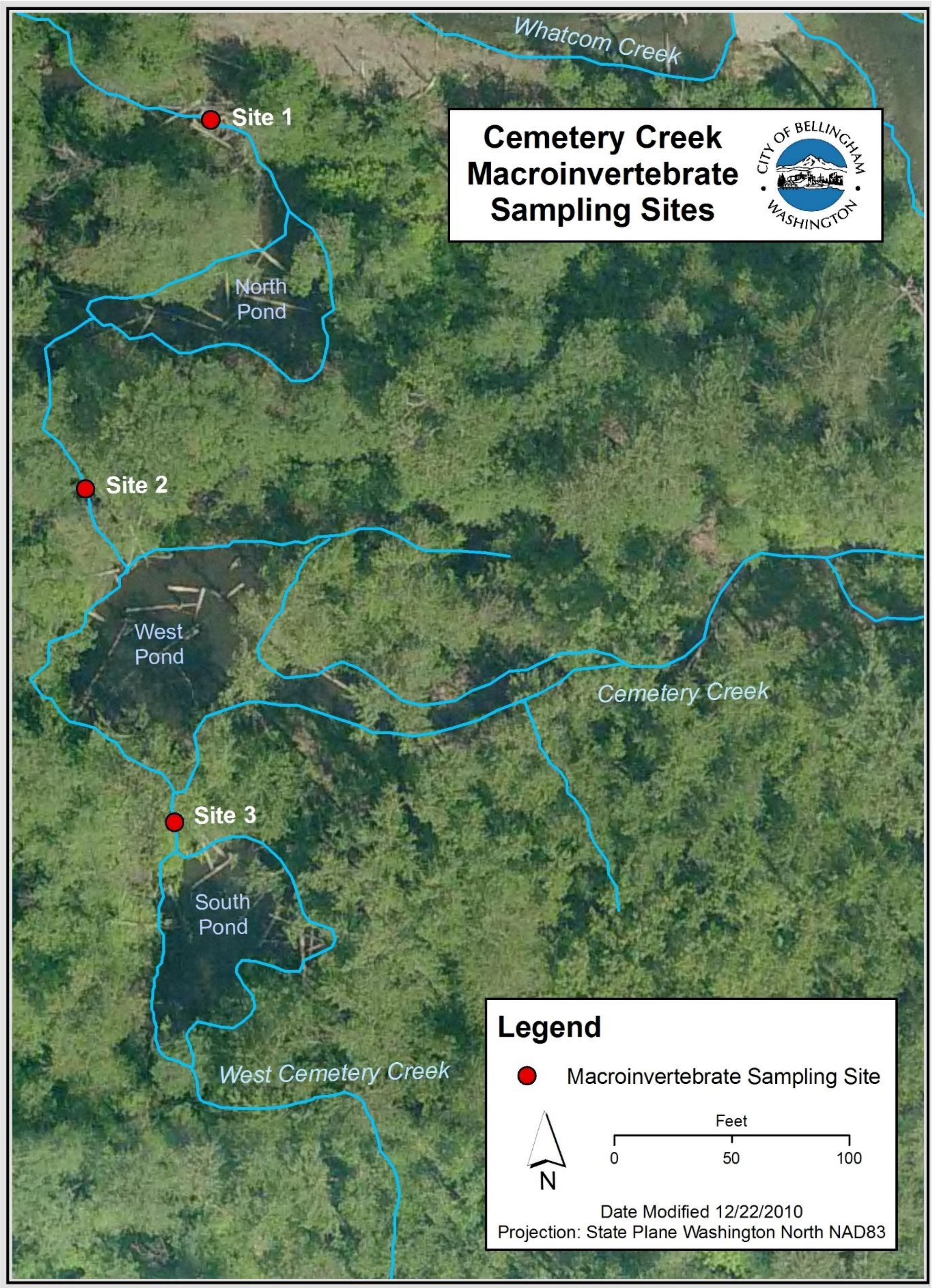


Figure 3-31 Map of macroinvertebrate sampling sites.

3.3.4 Results

The comprehensive study in Appendix H summarizes and interprets macroinvertebrate data collected on Cemetery Creek, fulfilling the stated objective to document colonization and survivorship by the macroinvertebrate community in reconstructed channels in the restoration site (COB 2006

Macroinvertebrate community composition and structure, functional feeding groups, taxa abundance, and species richness are all rolled into the B-IBI and RIVPACS assessment tools. The B-IBI consistently ranked all surveyed sites in all years (2007, 2009, 2011 and 2013) as being in “very poor” biological health (**Figure 3-32**). The RIVPACS model also consistently rated all sites in all years as “impaired” (**Figure 3-33**). This is identical to the “very poor” B-IBI scores reported from baseline surveys in 2001 and 2002 at Cemetery Creek Site 2 (Vandersypen 2006, PSSB 2010).

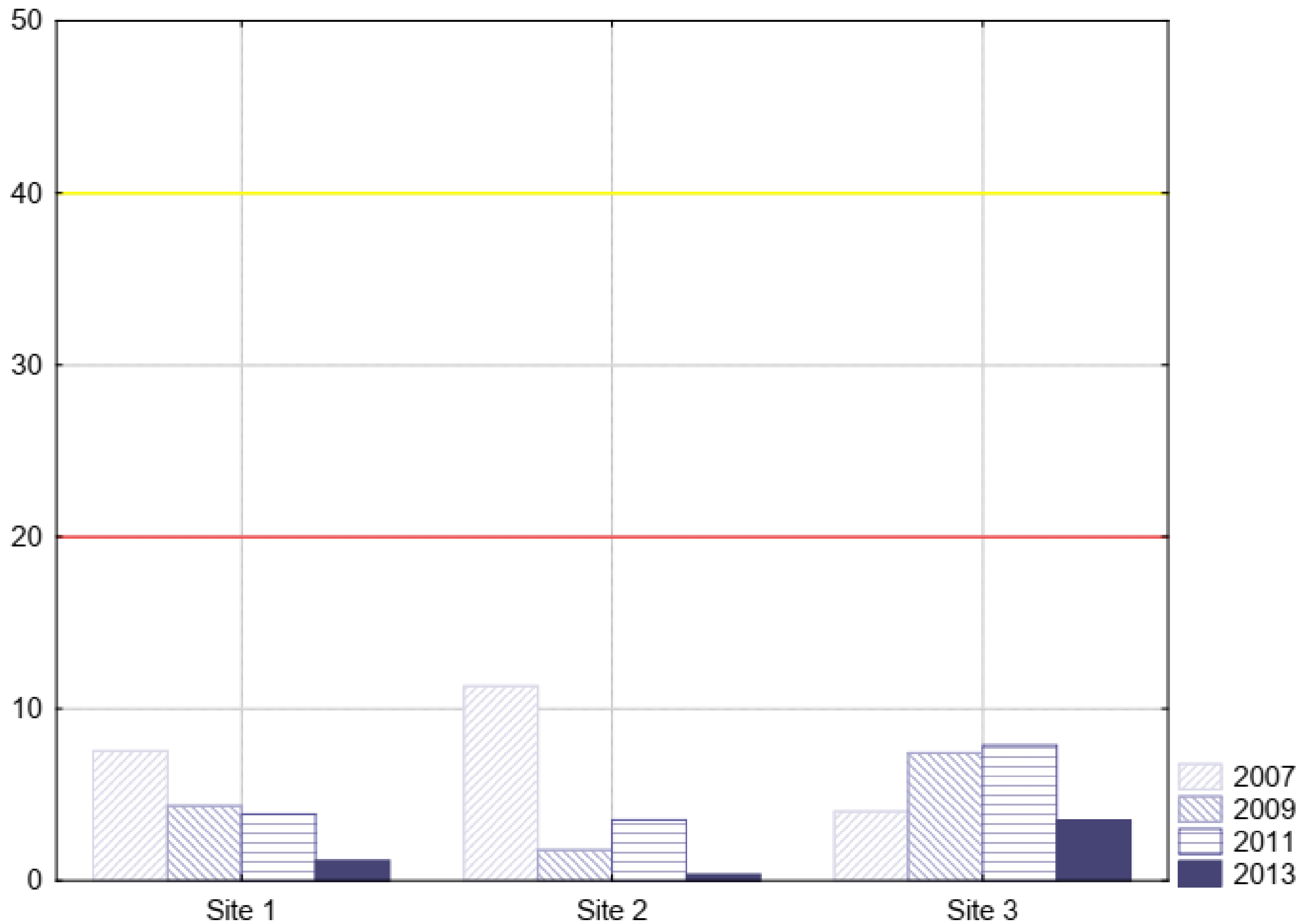


Figure 3-32 Mean B-IBI site scores for Cemetery Creek sites, 2007-2013. Site scores were calculated by averaging total B-IBI scores across replicates. The yellow line is the threshold (B-IBI = 40) for “fair” conditions; scores falling below the threshold indicate “poor” conditions. Scores falling below the red line (B-IBI = 20) indicate “very poor” conditions.

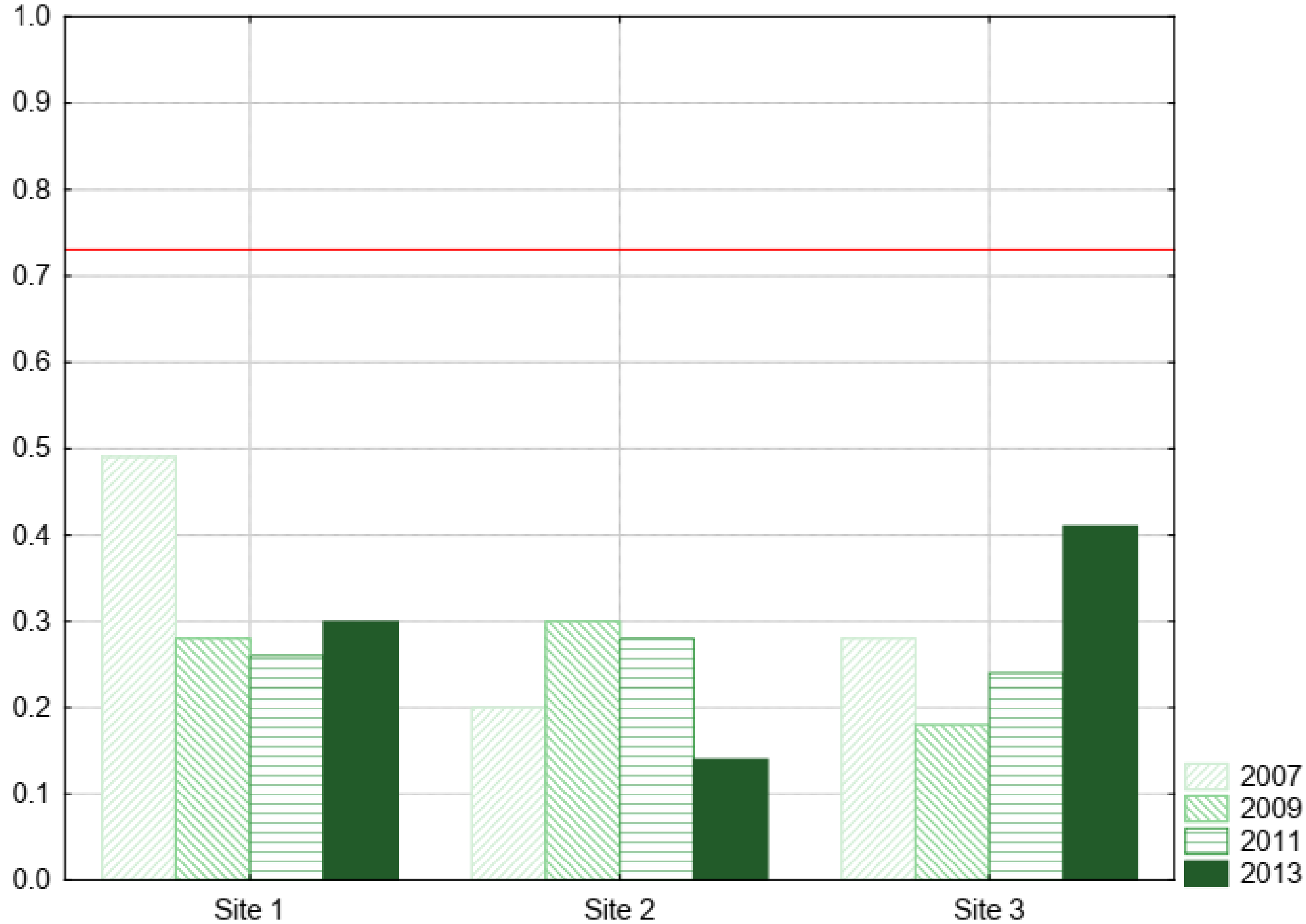


Figure 3-33 Mean RIVPACS scores for Cemetery Creek sites, 2007-2013. The red line indicates the threshold (RIVPACS = 0.73) for "unimpaired" conditions, set by the Washington Department of Ecology. Scores below the threshold indicate impaired conditions.

3.3.5 Discussion

The B-IBI and RIVPACS results described above show that these metrics remained "very poor" and "impaired" over the course of the monitoring period. An additional analysis employed in the comprehensive macroinvertebrate study (Appendix H) used characteristics of individual taxa collected at each site to predict stressors which may have influenced the composition of the invertebrate assemblages over the years. Based on this analysis, evidence for degraded water quality and sediment deposition could be detected at all sites. Thermal stress from warm water temperature, and instream and/or reach-scale habitat disruptions may have additionally limited the biotic potential of the sites. An analysis of community similarity and further examination of the invertebrates characterizing the sites suggested that hypoxic sediments may have been more influential in the earlier years of the study, with some improvement in these conditions by 2011 and 2013. Hypoxic sediments may be associated with nutrient enrichment and warm water temperatures.

These results, combined with bathymetric profiles of the constructed ponds (see **4.1.1 Ponds - Bathymetry**), led City staff to further investigate the cause and source of fine sediment deposition in the restoration area. The *West Cemetery Creek Sediment Management Alternatives and Feasibility Study* completed by Element Solutions in 2013 identified several primary contributing sources as well as a suite of potential management alternatives.

Success Criteria:

- Trends in community composition and structure, functional feeding groups, taxa abundance, species richness, and other indices should show improvement or remain stable over a 10-year post-construction period as compared to baseline population information. **Macroinvertebrate indices remained stable over the 10-year period and did not change compared with baseline data.**

3.3.6 Recommendations

The City is designing the West Cemetery Creek restoration project and Wildflower bridge replacement, addressing the three top priority alternatives identified in the *West Cemetery Creek Sediment Management Alternatives and Feasibility Study*. The projects are scheduled for construction in 2021 and will protect and restore natural processes in the Whatcom Creek corridor by arresting excessive sediment migration and increasing bank stability. No further actions are recommended.

3.4 RIPARIAN AND TERRESTRIAL WILDLIFE

3.4.1 Amphibian Surveys

3.4.1.1 Introduction

Amphibians are considered good indicators of general ecosystem health because of their close association with various aquatic habitats and sensitivity to different environmental stresses (USGS 2006). According to Eissinger (2003), ten species of amphibians (nine of them native) have been historically documented in the City of Bellingham (**Table 3-11**).

Table 3-11 Historically documented amphibians within the City of Bellingham. List and abundance determination from Eissinger (2003).

Common Name	Latin Name	Abundance
Northwestern salamander	*Ambystoma gracile*	Uncommon
Long-toed salamander	*Ambystoma macrodactylum*	Uncommon
Pacific giant salamander	*Dicamptodon tenebrosus*	Rare
Ensatina	*Ensatina eschscholtzii*	Uncommon
Western red-backed salamander	*Plethodon vehiculum*	Uncommon
Rough-skinned newt	*Taricha granulosa*	Uncommon
Western toad	*Bufo boreas*	Rare
Pacific chorus frog	*Pseudacris regilla*	Common
Red-legged frog	*Rana aurora*	Common
American bullfrog*	*Rana catesbeiana*	Undetermined

*Non-native invasive species

Figure 3-34 Neotenic pacific giant salamander (*Dicamptadon teneborsus*) observed in Cemetery Creek smolt trap on May 13, 2013.

3.4.1.2 Objective

The objective of amphibian surveys as specified in the *Monitoring and Maintenance Plan* (COB 2006) is to document successful recolonization of the restoration sites by amphibians. The following success criteria were established to determine whether this objective has been achieved:

Success Criteria:

- Presence and habitat utilization by native amphibian species at the restoration sites over the 10-year period following restoration construction.
- Absence of non-native species (i.e. bull frog) within the restoration site over the monitoring period

Collected data will be used to compile a list of amphibian species encountered at the restoration sites each year. The *Monitoring and Maintenance Plan* (COB 2006) also proposed to measure species composition, abundance, and characterization of habitats used however these metrics were not possible due to survey design.

3.4.1.3 Methods

Transect and perimeter monitoring follows "Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians" (Heyer et al. 1994) with some modifications. Terrestrial habitats were sampled along twenty transects, and starting in 2008 two seasonally inundated wetland sub-ponds (a habitat type missing from the original monitoring scope) were also added (**Figure 3-36**). Surveys began in March and were completed approximately every 21 days until June. Sampling periods were separated by approximately 21 days to allow for seasonal shifts in activity to be triggered.

Incidental sightings (outside of survey transects) were collected during amphibian surveys and while other work was being completed at the restoration sites. At the start of each survey, surveyors randomly selected the right or left bank (determined while facing downstream) of each transect for sampling (**Figure 3-36**). Sample areas were 30 feet wide and extended from the transect end to the water's edge. Surveys were conducted by turning over objects and sifting through leaf litter within each of the designated transects (**Figure 3-35**). The search was constrained to a maximum of 20 minutes per transect. When an amphibian was found, the species was identified (if possible) and the transect location was noted.

Figure 3-35 Surveyors lifting logs and debris wile completing amphibian surveys in 2007.

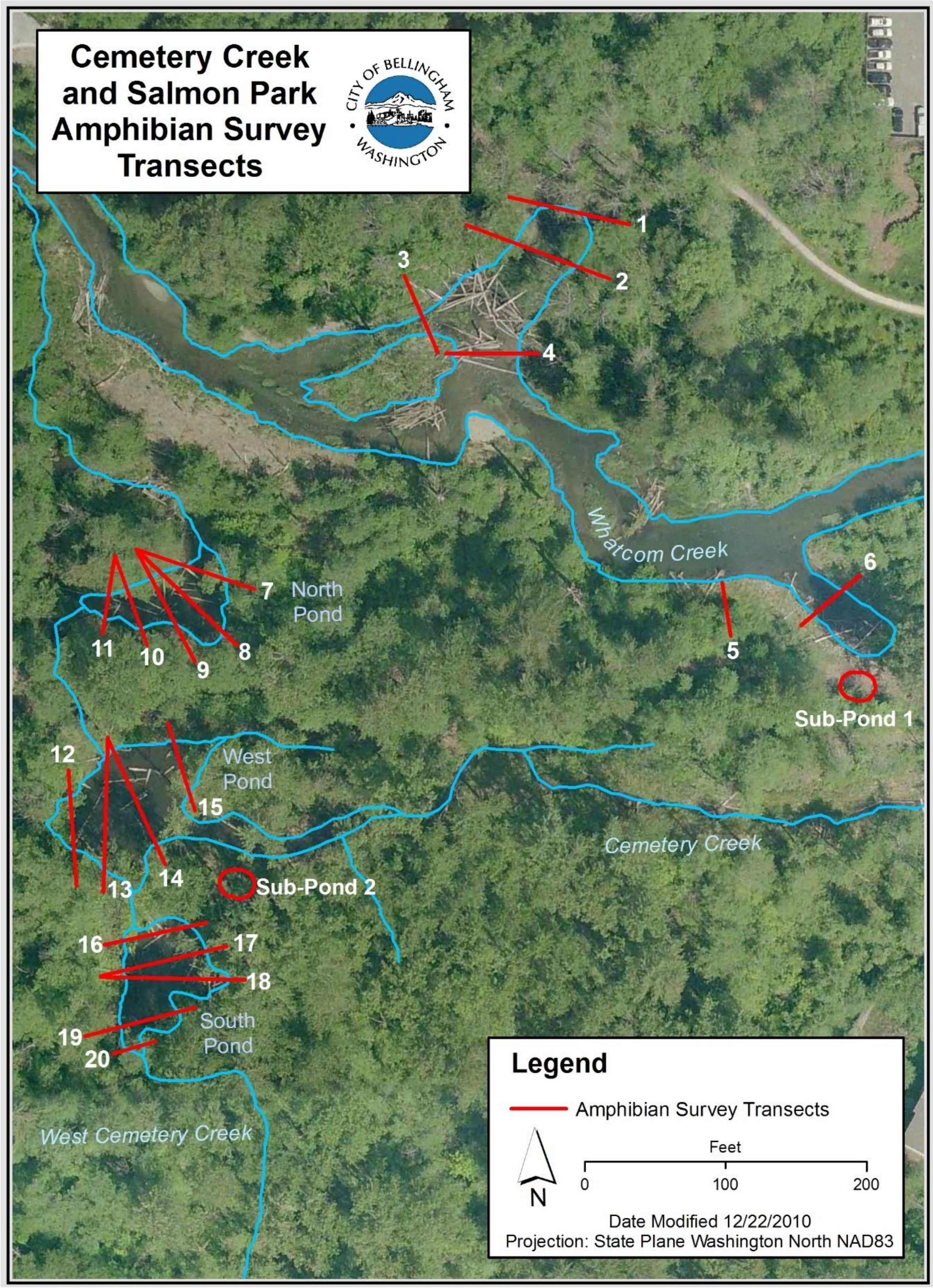


Figure 3-36 Map of amphibian survey transects. Surveyors randomly selected the right or left bank of each transect for sampling.

Perimeter searches were used to find and identify egg masses at the three constructed ponds, the Whatcom Creek swale, and Salmon Park swale. Surveys were completed by walking along the water line for each pond and swale within a 30-minute time constraint. When an egg mass was found, the species was identified (if possible) and the location described.

3.4.1.1 Results

The total number of transects and perimeters searched per year has been summarized in Table 3-12 below. With the exception of 2007 (before the sub-ponds were added to the surveys), an average of 160 transects and perimeters were searched each year. Table 3-12 also shows the number of amphibian detections (individuals or egg masses) detected during all surveys across all years[5]. Only 8% of transects surveyed yielded any amphibian detections.

Table 3-12 Summary of ampibian survey effort and detections.

Year	Number of detections	Number of transects and perimeters searched
2007	10	89
2008	4	161
2009	12	162
2011	8	154
2013	27	161
2016	6	162
Total	**67**	**889**

Table 3-13 Total positively identified amphibian detections (survey detections & incidental sightings).

Common Name	Species	2007	2008	2009	2011	2013	2016
Pacific chorus frog	*Pseudacris regilla*	2	1	1	3	3	1
Red-legged frog	*Rana aurora*	1	3	1	5	9	0
Long-toed salamander	*Ambystoma macrodactylum*	0	1	2	1	1	0
Pacific giant salamander	*Dicamptodon tenebrosus*	0	0	0	0	1	1
Northwest salamander	*Ambystoma gracile*	0	0	0	0	3	0
American bullfrog*	*Lithobates catesbeianus*	1	6	9	2	7	4
	Total	**4**	**11**	**13**	**11**	**24**	**6**

* Non-native invasive species

[5] Note that multiple egg masses or hatchlings of same species in one location on one day were always considered to be just a single "detection."

A summary of positively identified detections for both survey and incidental records during all survey years is presented in Table 3-13. Any amphibian detections without a positive species identification are excluded from these totals. Full results for 2007-2016 amphibian surveys are available in Appendix I.

Table 3-14 shows positively identified amphibian detections for surveys (time-constrained transects and perimeter searches only) by year, including the percentage of those detections that were non-native American bullfrog (*Lithobates catesbeianus*). The relative percentage of non-native bullfrog detections increased over time up to a peak of 75% by the final monitoring year. This may indicate an overall increase in abundance of this species since 2007 or may be related to sample size and sampling constraints.

Table 3-14 Percent non-native (eg. American bullfrog) amphibian survey detections.

Species	Species	2007	2008	2009	2011	2013	2016
Pacific chorus frog	*Pseudacris regilla*	2	1	1	2	3	1
Red-legged frog	*Rana aurora*	0	0	0	4	8	0
Long-toed salamander	*Ambystoma macrodactylum*	0	1	2	1	1	0
Pacific giant salamander	*Dicamptodon tenebrosus*	0	0	0	0	0	0
Northwestern salamander	*Ambystoma gracile*	0	0	0	0	3	0
American bullfrog*	*Lithobates catesbeianus*	1	1	5	0	7	3
Total	Total	3	3	8	7	22	4
Percent Non-native Survey Detections		**33%**	**33%**	**63%**	**0%**	**32%**	**75%**

* Non-native invasive species

3.4.1.2 Discussion

The objective of amphibian surveys as specified in the *Monitoring and Maintenance Plan* (COB 2006) was to document successful recolonization of the restoration sites by amphibians, and measured using the following success criteria:

Success Criteria:

- Presence and habitat utilization by native amphibian species at the restoration sites over the 10-year period following restoration construction. **Criterion met—native amphibians were detected at the restoration sites over the 10-year monitoring period.**
- Absence of non-native species (i.e. bull frog) within the restoration site over the monitoring period. **Criterion not met. Non-native bullfrog(s) detected in all monitoring years.**

The first criterion was to document "presence and habitat utilization by native amphibian species" which was achieved in all monitoring years, however abundance estimates and characterization of habitats was not possible due to survey design. The second criterion was "absence of non-native species" within the restoration sites, and this was not met. American bullfrogs are present in both the Cemetery Creek and Whatcom Creek systems. However, in all years at least some native amphibians were observed to coexist with the bullfrogs.

Absence of non-native American bullfrog within the project area is unrealistic due to the presence of this species in the surrounding landscape and the inclusion of habitat types that are suitable for this species. American bullfrog depends on a permanent water source. Because the Cemetery Creek restoration site contains year-round ponding to benefit juvenile salmonid rearing, American bullfrog cannot be excluded from the restoration sites without substantial habitat modifications and impacts to juvenile salmonid habitat.

3.4.1.3 Recommendations

No further actions are recommended.

3.4.2 Avian Surveys

3.4.2.1 Introduction

Avian monitoring offers many advantages over fish or macroinvertebrate assessments, as it is much more time and cost effective and yields a more direct measure of riparian habitat quality. While aquatic organisms are directly influenced by in-stream conditions, the terrestrial sources that cause these conditions can only be inferred (Bryce et al. 2002). On the other hand, birds are ideal indicators for measuring the success of restoration activities because they are relatively abundant, occupy a diversity of ecosystem niches, are moderately high on the food chain, are easy to study (with nationally standardized protocols) and they respond more directly to land-based changes that precede in-stream water quality impacts (Burnett et al. 2005). Eissinger (2003) estimated that the Whatcom Creek watershed may support up to 112 different bird species. Christmas Bird Count data from 2016, 2018 and 2019 tallied 43, 38 and 39 total species (respectively) over the course of one day in mid-December each year (Brown, *personal communication*).

3.4.2.2 Objective

The stated objective of avian surveys as specified in the *Monitoring and Maintenance Plan* (COB 2006) is to document avian use of the restoration areas during the breeding season by tracking *species composition*, *richness*, and *abundance* at the restoration sites over time. The following avian success criteria were established:

Success Criteria:

- Presence and persistent habitat utilization by **native avian species** at the restoration sites over the 10-year period following restoration construction.
- Absence or continued low levels of **non-native, invasive species** (eg. European starling, house sparrow, brown-headed cowbird, Canada goose).

3.4.2.3 Methods

Monitoring protocols follow standard USDA methods found in the "Handbook of field methods for monitoring landbirds" (Ralph 1993). Point counts are conducted at three locations within the restoration area (**Figure 3-37**). While the point count sites are not quite 820 feet (250 meters) away from one another as specified by the protocol, bird calls that are more than 500 feet away are not counted to reduce overlap. Ralph (1993) states that more than 99 percent of individual birds are detected within 410 feet (125 meters) of the observer, especially in forested habitats.

Point counts begin 30-45 minutes after sunrise and are completed within two hours. Surveyors approach the point count sites with as little disturbance as possible. Counts are conducted over three minutes. Birds are identified by sight and sound and are placed in distance categories: 0-150 feet (approximately 0-50 meters), 150-500 feet (approximately 50-150 meters) and flyovers. Individuals are tallied into distance categories and no individual is to be counted twice. If a bird flees when surveyors arrive at the point, the bird is included according to its take-off location. Birds flushed within 150 feet of a point's center while entering or leaving the point are counted as being at the point if no other individuals of that species are seen during the count period. Flocks or unknown individuals detected during counts can be followed at the end of the count to confirm flock composition, size and individual identity.

Surveys begin in March and are conducted every 20-30 days through June. Incidental sightings are also recorded when previously undocumented species are observed within the point count locations outside of the survey time frame. Birds are not surveyed during poor weather conditions; rain, wind, fog and cold weather can all interfere with visibility, audibility and activity of birds.

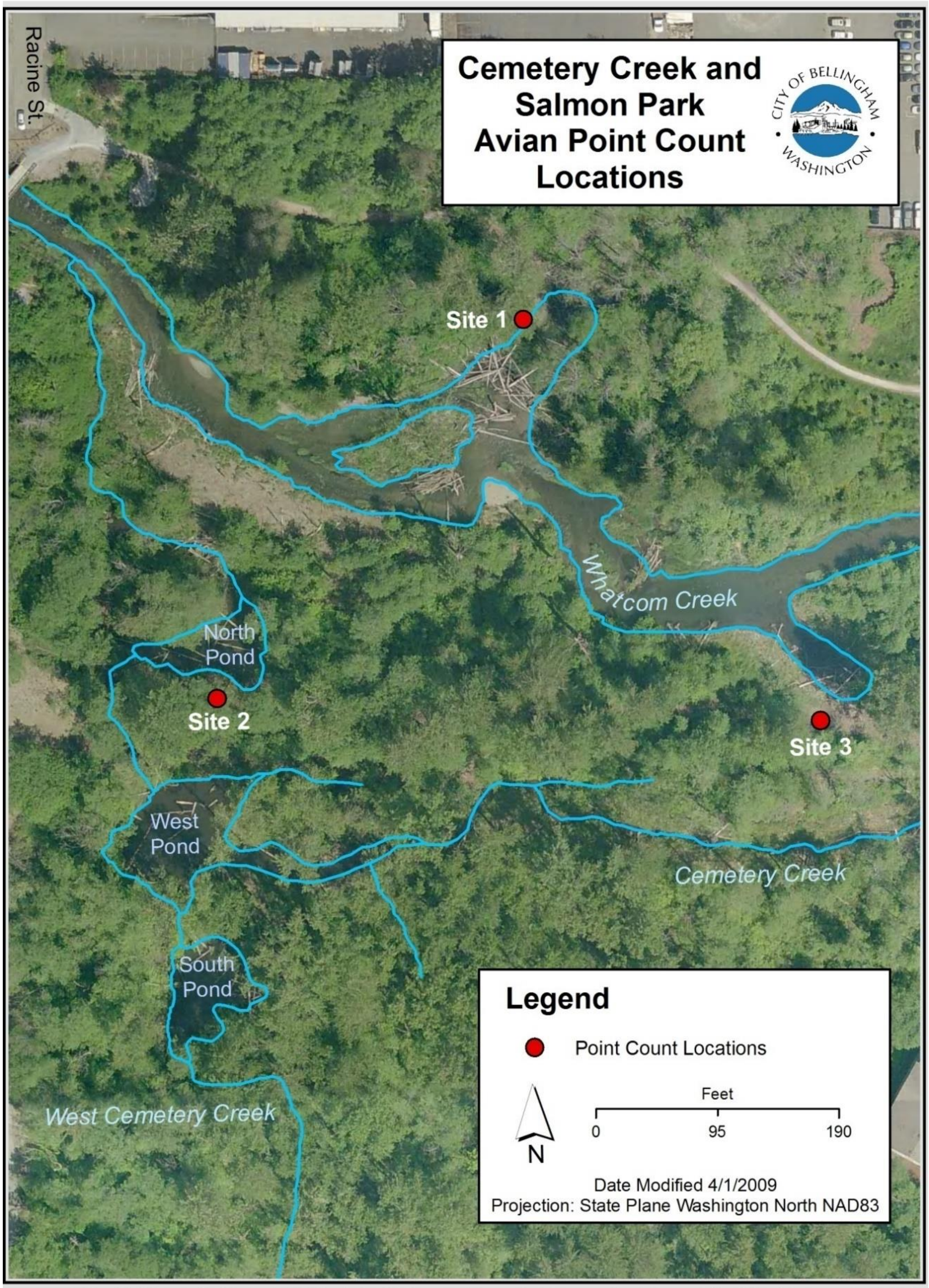


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Figure 3-37 Map of avian point count locations.

3.4.2.1 Results

A map of point count locations is presented in **Figure 3-37** and a summary of point count data is shown in Table 3-15.

All point count surveys occurred between March and June within 30 minutes of sunrise. While point count surveys provide a systematic and quantitative estimate of the species and number of birds present at a site during the breeding season, it should be noted that point counts may not provide reliable data on waterfowl and certain land birds that are particularly quiet or nocturnal (Ralph 1993).

Observations of previously unrecorded bird species within the point count locations but outside of the survey time frame were still recorded as "incidental sightings." The complete species list for the restoration site (all species detected during point counts and incidental sightings) is presented in **Table 3-16**.

Table 3-15 Summary of avian survey results.

		2007		2008		2009		2011		2013		2016	
		3/6/07-6/28/07		3/7/08-6/18/08		3/14/09-5/21/09		3/11/11-6/24/11		3/11/13-6/17/13		3/19/16-6/29/16	
Point Count Station	**Survey number**	Number of Individuals	Species Richness	Number of Individuals	Species Richness	Number of Individuals	Species Richness	Number of Individuals	Species Richness	Number of Individuals	Species Richness	Number of Individuals	Species Richness
1	**1**	20	9	14	8	11	7	10	5	28	11	19	10
1	**2**	15	7	13	6	25	11	23	8	25	13	18	9
1	**3**	11	5	16	9	15	9	17	11	16	11	19	8
1	**4**	21	11	15	11	13	8	16	11	16	6	16	11
1	**5**	27	14	10	6	14	9	17	10	15	8	22	10
1	**6**	22	11	15	8	23	15	31	13	10	8	17	11
1	**7**	-	-	-	-	-	-	-	-	-	-	29	12
1	**8**	-	-	-	-	-	-	-	-	-	-	24	11
1	**9**	-	-	-	-	-	-	-	-	-	-	23	12
2	**1**	17	9	18	8	26	11	24	14	16	8	16	7
2	**2**	19	9	23	15	22	11	8	14	34	11	20	8
2	**3**	12	5	20	9	16	9	22	13	23	8	24	14
2	**4**	30	16	17	10	17	9	11	8	21	7	12	10
2	**5**	18	8	13	7	14	11	25	10	14	9	18	14
2	**6**	19	13	15	8	19	11	9	7	10	5	25	15
2	**7**	-	-	-	-	-	-	-	-	-	-	31	18
2	**8**	-	-	-	-	-	-	-	-	-	-	25	11
2	**9**	-	-	-	-	-	-	-	-	-	-	27	14
3	**1**	14	8	12	7	27	12	20	9	17	9	21	11
3	**2**	18	10	13	7	29	12	12	7	20	9	23	13
3	**3**	14	8	13	8	13	11	17	8	13	11	16	8
3	**4**	31	17	18	10	18	10	13	7	14	9	15	10
3	**5**	20	13	15	12	19	13	13	10	12	7	22	11
3	**6**	19	13	17	10	16	9	12	9	9	7	26	15
3	**7**	-	-	-	-	-	-	-	-	-	-	27	15
3	**8**	-	-	-	-	-	-	-	-	-	-	23	14
3	**9**	-	-	-	-	-	-	-	-	-	-	21	11

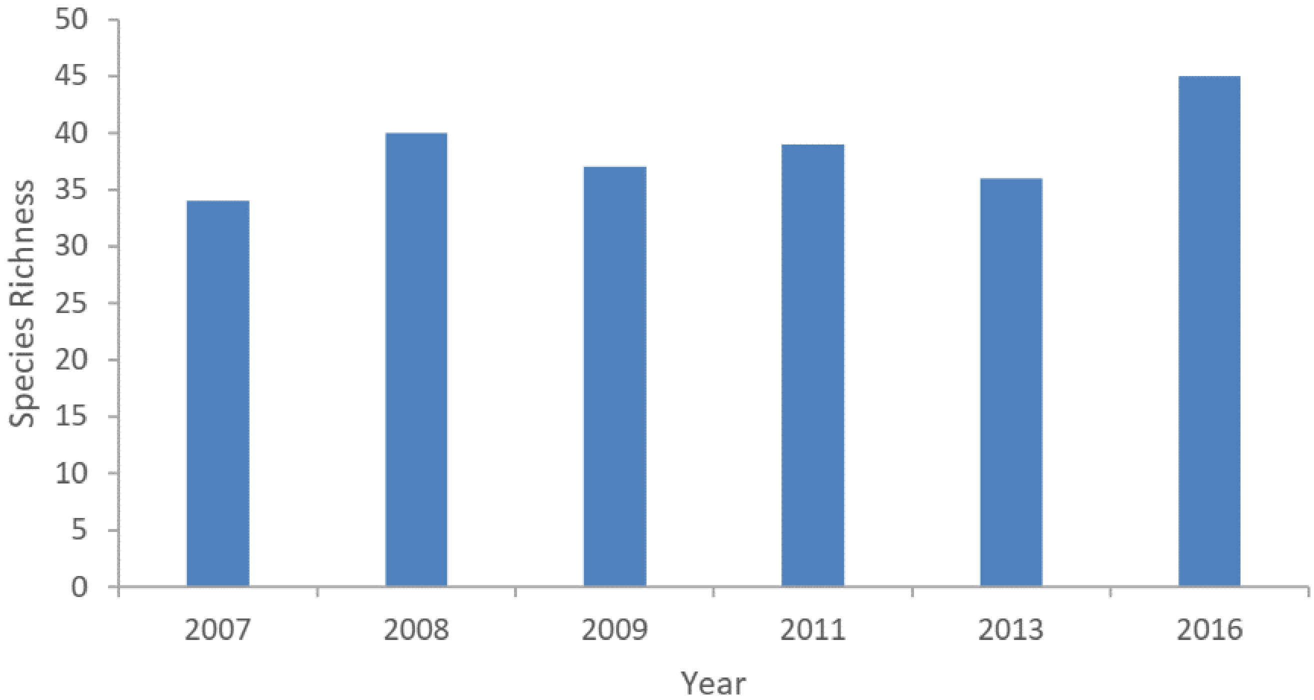

Figure 3-38 Avian species richness (total number of species counted) per year.

Table 3-16 Complete Species List from Avian Point Counts and Incidental Sightings: 2007-2016.

Common Name	Scientific Name	Common Name	Scientific Name
American Dipper	*Cinclus mexicanus*	Macgillivray's Warbler	*Oporornis tolmiei*
American Goldfinch	*Carduelis tristis*	Mallard	*Anas platyrhynchos*
American Robin	*Turdus migratorius*	Marsh Wren	*Cistothorus palustris*
Anna's Hummingbird	*Calypte anna*	Merlin	*Falco columbarius*
Bald Eagle	*Haliaeetus leucocephalus*	Northern Flicker	*Colaptes auratus*
Barn Swallow	*Hirundo rustica*	Northern Harrier	*Circus cyaneus*
Barred Owl	*Strix varia*	Orange-crowned Warbler	*Vermivora celata*
Belted Kingfisher	*Megaceryle alcyon*	Pacific-slope Flycatcher	*Empidonax difficilis*
Bewick's Wren	*Thryomanes bewickii*	Pacific Wren	*Troglodytes pacificus*
Black-capped Chickadee	*Poecile atricapillus*	Pileated Woodpecker*	*Dryocopus pileatus*
Black-headed Grosbeak	*Pheucticus melanocephalus*	Pine Siskin	*Carduelis pinus*
Brown Creeper	*Certhia americana*	Purple Finch	*Carpodacus purpureus*
Brown-Headed Cowbird†	*Molothrus ater*	Red-breasted Nuthatch	*Sitta canadensis*
Bufflehead*	*Bucephala albeola*	Red-breasted Sapsucker	*Sphyrapicus ruber*
Bullock's Oriole	*Icterus bullockii*	Red-eyed Vireo	*Vireo olivaceus*
Bushtit	*Psaltriparus minimus*	Red-tailed Hawk	*Buteo jamaicensis*
Canada Goose†	*Branta canadensis*	Red-winged Blackbird	*Agelaius phoeniceus*
Caspian Tern	*Sterna caspia*	Rock Pigeon	*Columba livia*
Cedar Waxwing	*Bombycilla cedrorum*	Ruby-crowned Kinglet	*Regulus calendula*
Chestnut-backed Chickadee	*Poecile rufescens*	Rufous Hummingbird	*Selasphorus rufus*
Common Merganser	*Mergus merganser*	Sharp-shinned Hawk	*Accipiter striatus*
Common Nighthawk	*Chordeiles minor*	Song Sparrow	*Melospiza melodia*
Common Yellowthroat	*Geothlypis trichas*	Spotted Towhee	*Pipilo maculatus*
Northwestern Crow	*Corvus caurinus*	Steller's Jay	*Cyanocitta stelleri*
Dark-eyed Junco	*Junco hyemalis*	Swainson's Thrush	*Catharus ustulatus*
Double-crested Cormorant*	*Phalacrocorax auritus*	Townsend's Warbler	*Setophaga townsendi*
Downy Woodpecker	*Picoides pubescens*	Turkey Vulture	*Cathartes aura*
Evening Grosbeak	*Coccothraustes vespertinus*	Varied Thrush	*Ixoreus naevius*
European Starling†	*Sturnus vulgaris*	Vaux's Swift*	*Chaetura vauxi*
Fox Sparrow	*Passerella iliaca*	Violet-green Swallow	*Tachycineta thalassina*
Golden-crowned Kinglet	*Regulus satrapa*	Warbling Vireo	*Vireo gilvus*
Golden-crowned Sparrow	*Zonotrichia atricapilla*	Western Tanager	*Piranga ludoviciana*
Great Blue Heron*	*Ardea herodias*	Western Wood-Pewee	*Contopus sordidulus*
Green heron	*Butorides virescens*	White-crowned Sparrow	*Zonotrichia leucophrys*
Gull species	*Laridae* family	Willow Flycatcher	*Empidonax traillii*
Hairy Woodpecker	*Picoides villosus*	Wilson's Snipe	*Gallinago delicata*
Hammond's Flycatcher	*Empidonax hammondii*	Wilson's Warbler	*Wilsonia pusilla*
Hooded Merganser*	*Lophodytes cucullatus*	Wood Duck*	*Aix sponsa*
House Finch	*Carpodacus mexicanus*	Yellow Warbler	*Dendroica petechia*
House Sparrow†	*Passer domesticus*	Yellow-rumped Warbler	*Dendroica coronata*
Killdeer	*Charadrius vociferus*		

* WDFW Priority Species

† Non-native, invasive species

Abundance: Avian abundance was estimated using the average of birds counted per survey (a measure of birds counted per unit of equivalent effort) and is summarized by point for each survey year in **Figure 3-39**. The average abundance per year varied from a low of 15.4 in 2008 to a high of 21.4 in 2016. In terms of native versus non-native bird abundance, **Figure 3-40** shows that non-native individuals constituted from 3-11% of the total birds counted per year. Over all years, only 5% of all counted birds were non-native species (129 non-native individuals out of 2,506 birds counted).

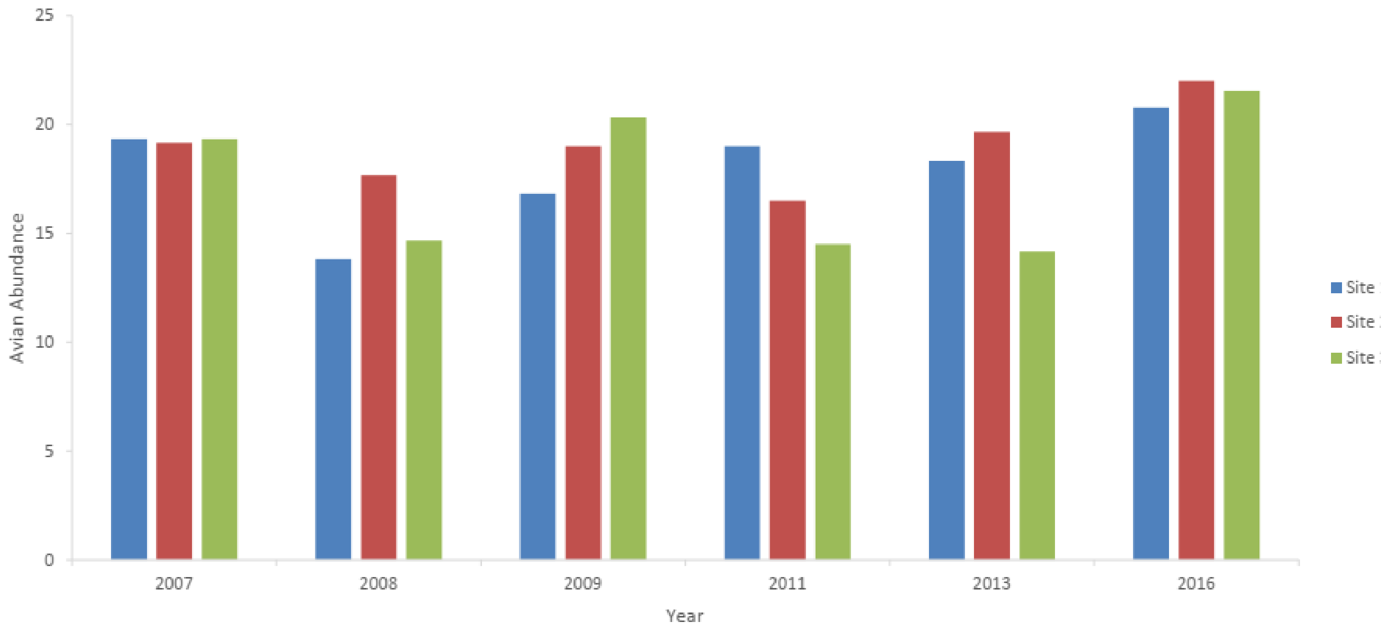

Figure 3-39 Avian abundance (average number of birds counted per survey) by site and survey year.

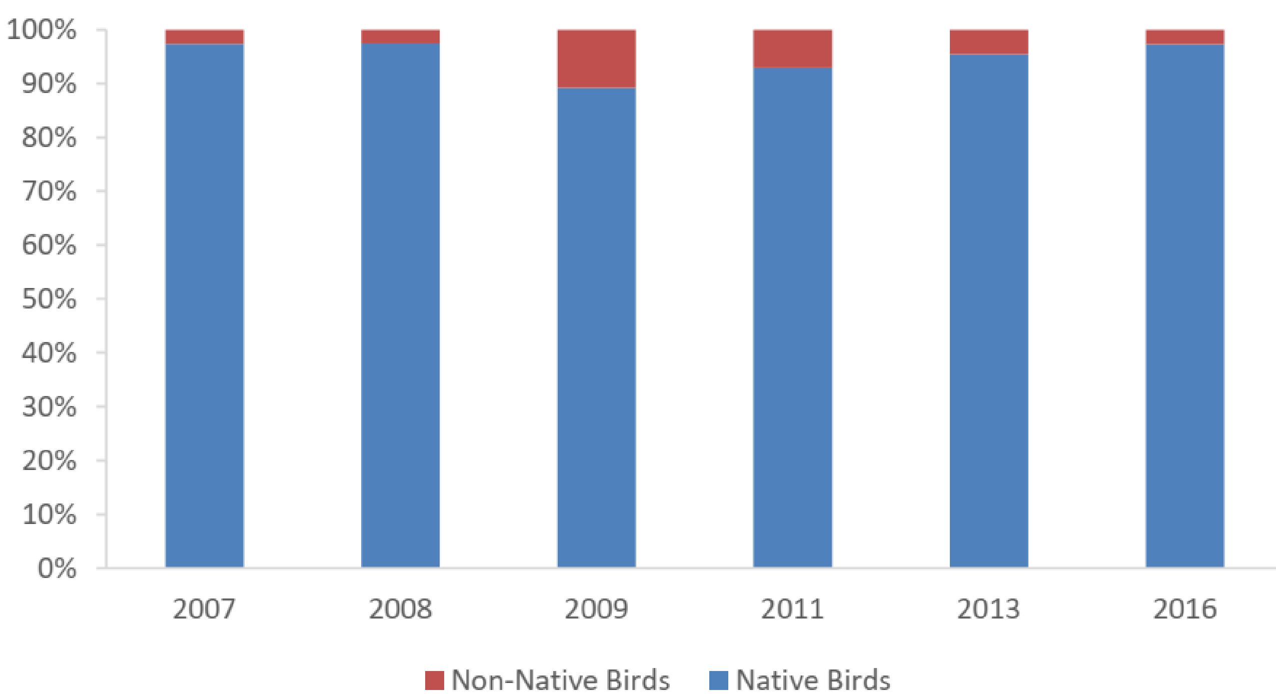

Figure 3-40 Non-native compared with native bird abundance (total number of birds counted) by year.

Species composition: Out of the 81 total bird species observed, 95% were native to western Washington. Most of the observed species were permanent residents[6] (52%), while 41% were summer residents (typically present during the summer breeding season only). Despite conducting surveys during the breeding season, 6% of the observed bird species are typically considered winter visitors only, and only one strictly migrant species was observed utilizing the area as spring stop-over habitat (Golden-crowned Sparrow, *Zonotrichia atricapilla*).

Out of the 81 total bird species observed, only four (5%) were non-native invasive species: brown-headed cowbird (*Molothrus ater*), Canada goose (*Branta canadensis*), European starling (*Sturnus vulgaris*), and house sparrow (*Passer domesticus*). These non-native species are marked with a dagger in **Table 3-16**.

Native bird species positively identified as nesting in the restoration area included: American robin (*Turdus migratorius*; Figure 3-41), black-capped chickadee (*Poecile atricapillus*), brown creeper (*Certhia Americana*), bushtit (*Psaltriparus minimus*), hooded merganser (*Lophodytes cucullatus*), and song sparrow (*Melospiza melodia;* Figure 3-42). shows a hooded merganser nesting in one of the nest boxes at the Cemetery Creek restoration site. European Starlings (*Sturnus vulgaris*) were the only non-native invasive species positively observed nesting in the project area.

Figure 3-41 American robin (*Turdus migratorius*) nests with occupants near West Pond on Cemetery Creek, June 2011 (left) and May 2009 (right).

[6] Note that 42 of the 81 observed species are permanent residents who remain at the site through the winter months. This total aligns with Christmas Bird Count data from 2016, 2018 and 2019 which tallied 43, 38 and 39 total species (respectively) observed in the Whatcom Creek corridor (from Interstate 5 up to Scudder Pond) over the course of one day in mid-December each year (Brown, *personal communication*).

Figure 3-42 Song sparrow (*Melospiza melodia*) egg in nest, June 2011.

3.4.2.2 Discussion

The stated objective of avian surveys as specified in the *Monitoring and Maintenance Plan* (COB 2006) was to document avian use of the restoration areas during the breeding season and across years, in order to determine *species richness*, *composition* and *abundance* as well assess the prescribed success criteria:

Success Criteria:

- Presence and persistent habitat utilization by **native avian species** at the restoration sites over the 10-year period following restoration construction. **Criterion met—native species were observed using the restoration sites over the 10-year monitoring period.**
- Absence or continued low levels of **non-native, invasive species** (eg. European starling, house sparrow, brown-headed cowbird, Canada goose). **Criterion met—only four non-native bird species were observed at the sites and in low numbers across all years (5% of the total birds observed during surveys).**

Native avian species: Use of the restoration sites as foraging, resting and nesting habitat by native permanent, summer and winter resident passerines is ongoing. As the projects mature, these sites should provide important stopover habitat for migratory species as well (Moore et al. 2005). In fact, surveys documented the presence of seven Washington Department of Fish and Wildlife Priority species: bufflehead (*Bucephala albeola*), double-crested cormorant (*Phalacrocorax auratus*), great blue heron (*Ardea herodias*), hooded merganser (*Lophodytes cucullatus*), pileated woodpecker (*Dryocopus* *pileatus*), and Vaux's swift (*Chaetura vauxi*) (WDFW 2019). These Priority species are marked with an asterisk in **Table 3-16**.

Future avian monitoring work aimed at determining restoration effectiveness or human-caused disturbance would be better leveraged if analysis included a biotic integrity index, similar to the Benthic Index of Biotic Integrity (BIBI) (Karr et al. 1986) which has been developed and calibrated for benthic macroinvertebrate communities in Puget Sound lowland streams. Karr and Chu (1999) suggest that multimetric indices offer greater precision in complex systems where causal processes are uncertain or cumulative.

Additionally, because riparian areas provide critical stopover habitat for up to 10 times the number of neotropical migrants as adjacent non-riparian sites (Stevens et al. 1977), riparian restoration projects have great potential to benefit migratory bird species. Future riparian restoration efforts could increase benefit for migratory birds by including a diversity of shrubs to provide cover, fruits and flowers and a diversity of tree species (both coniferous and deciduous) for nesting and foraging (Gardner, 1999).

Non-native avian species: Non-native house sparrows are common in developed and disturbed areas and are less discriminate cavity nesters, using a variety of man-made structures somewhat more often than holes in trees. However, where abundant, house sparrows will still outcompete native species for limited cavity spaces. Non-native European starling are an aggressive cavity-nesting species which outcompete and often eject other nesting birds from cavities. An unpublished study of cavity-nesting birds at the restoration sites (Dolan 2008) is available in Appendix J. Brown-headed cowbirds continue to be present at the sites, especially in the early spring. Although historically present in the short-grass prairies of Washington, cowbirds have steadily extended their range into areas of human impact, and are currently present in most areas of Washington, outside of forest interiors. Cowbirds are nest parasites with common hosts including cedar waxwings, American robins and Steller's jays, all of which can recognize cowbird eggs in the nest and will often eject them or rebuild their nest. Other common hosts cannot recognize cowbird eggs and often lose their broods to cowbird nestlings; these include the two most often parasitized species in the United States, yellow warblers and song sparrows (Seattle Audubon Society 2009), both of which are present at the restoration sites. Use of the restoration site by these non-native species, which prefer open habitats, is not likely to decrease due to the fragmented nature of the habitat surrounding the restoration sites.

3.4.2.3 Recommendations

No further actions are recommended.

Figure 3-43 Green heron (*Butorides virescens*) utilizing an installed snag on Whatcom Creek in July 2012.

3.4.3 Mammals

3.4.3.1 Introduction

Limited documentation exists on the distribution and composition of mammalian communities in the Whatcom Creek watershed. Small mammal communities are likely well represented; medium and large mammals are also potentially diverse and commonly include raccoon, opossum, beaver, muskrat, river otter and coyote (Eissinger 2003).

3.4.3.2 Objectives

The *Monitoring and Maintenance Plan* (COB 2006) calls for incidental documentation of mammals at the site in order to generate a list of species, focusing on any Washington State Priority species and/or Federally listed or candidate species, any evidence of denning or breeding, and any damage caused by mammals at the site. The following success criteria were defined relative to mammals:

Success Criteria:

- Presence and habitat utilization by **native mammal** species at the restoration sites over the 10-year period following restoration construction.
- Absence of major site damage from mammals throughout the monitoring period.

3.4.3.3 Methods

Observations of mammals at the restoration sites were all opportunistic and incidental, occurring year-round throughout the ten-year monitoring period. No formal mammal surveys were conducted. Observations that documented mammal use included direct sightings, tracks, scat, or browse patterns. Field notes on mammals included detailed descriptions of key sightings (e.g. Priority species, evidence of denning or breeding, damage, etc).

3.4.3.4 Results

Incidental mammal observations were documented at the restoration sites in order to determine “presence and habitat utilization by **native mammal** species at the restoration sites over the 10-year period following restoration construction” and “absence of **major site damage** from mammals throughout the monitoring period” as per the *Monitoring and Maintenance Plan* (COB 2006).

Fourteen distinct mammal genera were positively identified at the restoration sites and are listed in Table 3-17. Eastern cottontails and eastern gray squirrels were the only non-native mammals observed. Mammal documentation included track, sign and direct observation. A sampling of mammal observation photos are presented in **Figure 3-44**.

Table 3-17 List of mammals observed at the restoration sites.

Common name	Species	Notes
American shrewmole	*Neurotrichus gibbsii*	Found dead in grass adjacent to hill on west side of restoration area
Beaver	*Castor canadensis*	Adults seen; also tracks, browse & dam construction
Black-tailed deer	*Odocoileus virginianus*	Multiple sightings of adults and fawns
Common opossum	*Didelphis virginiana*	One sighting
Coyote	*Canis latrans*	Multiple scat and track observations
Eastern cottontail	*Sylvilagus floridanus*	Non-native species
Eastern gray squirrel	*Sciurus carolinensis*	Non-native species; both gray & black morphs; adults & young
American mink	*Neovison vison*	Multiple sightings of adults, also two kits
Mole species	*Scapanus sp.*	Found dead by South Pond; either Townsend's (*S. townsendii*) or Pacific (*S. orarius*)
Muskrat	*Ondatra zibethicus*	West Pond, smolt trap live box
Raccoon	*Procyon lotor*	Sleeping in cedar tree by North Pond, tracks
River otter	*Lontra canadensis*	Swimming in West Pond, tracks
Rodent species	*Arvicolinae* subfamily	Likely vole species-- babies found in nest
Townsend's chipmunk	*Tamias townsendii*	Multiple sightings
Vole species	*Microtus sp.*	Live sighting in grass at Cemetery Creek-- either Townsend's (*M. townsendii*) or Creeping (*M. oregoni*)

Figure 3-44 Cemetery Creek mammal observations. Clockwise from upper left: Black-tailed deer (*Odocoileus virginianus*), unknown Arvicolinae subfamily (young in nest), American mink (*Neovison vison*), American shrewmole (*Neurotrichus gibbsii*).

Native mammals: Mammal species observed were consistent with common urban mammalian wildlife as per Eissinger (2003). For example, river otter (*Lontra canadensis*) used the ponds intermittently while foraging for fish (Figure 3-45). However, Eissinger did list American mink as "rare" in the City of Bellingham whereas they were commonly observed during all monitoring years and seasons in the Cemetery Creek ponds engaged in breeding, rearing young, feeding and hunting (Figure 3-46).

Figure 3-45 River otter (*Lontra canadensis*) eating a resident trout at the West Pond in January 2012 (left), trout roe and otter tracks in snow following the meal (right).

Figure 3-46 American mink (*Neovison vison*) stalking a female mallard (*Anas platyrhynchos*) at the West Pond.

The only state-listed priority species identified at the site were the Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*), which are listed strictly as a species of "Recreational, Commercial, and/or Tribal Importance" (WDFW 2019).

Site damage by mammals: The two mammals with the most impact on success of restoration plantings at the sites were deer and beaver. Although deer browse and rubbing was observed on installed restoration plantings, it was never significant enough to raise concern or warrant targeted preventive measures.

On the other hand, beaver were active at the Cemetery Creek restoration site in all monitoring years (Figure 3-47). In 2006 and 2007 beaver activity damaged trees at the restoration site and fencing was installed to discourage this activity. In 2008 and 2009 beaver activity was reported as "minimal" but still present. In November of 2012 beaver activity increased starting with dam construction at the North Pond outlet. Within a week of this first evidence of increased beaver activity at the North Pond, a 4ft dam was constructed, elevating the pond surface well above the water surface gauge. Within two weeks, water surface elevation gauges in all three ponds were completely submerged with overland flow from the West Pond outlet to the North Pond inlet (lower right, Figure 3-47) as well as across the water line trail between the West Pond and North Pond. Given these conditions, and in anticipation of the planned 2013 smolt trap, a "beaver deceiver" structure was installed in the North Pond dam on March 11, 2013 to maintain a water surface elevation that would not endanger the smolt trap. During the final year of smolt trap operation in 2016, the trap was installed in March without any recent beaver activity in the area. However, in early May of 2016, beaver began to build a dam immediately upstream of the smolt trap. Over the course of that month field crews removed the dam material multiple times, only to have it rebuilt by the following day. Eventually the beavers moved on to a different location. Since completion of the 10-year monitoring period at Cemetery Creek in 2016, beaver activity has continued in and around the Cemetery Creek ponds without active management. As a result, ponding at the Cemetery Creek restoration site has increased in expanse and duration.

Figure 3-47 Beavers at Cemetery Creek: Beaver observed in March of 2009 at upper left, right hind and left front beaver tracks at upper right, beaver dam on West Pond in 2013 at lower left, overland flow (from the West Pond into the North Pond) caused by beaver dams in 2012 at lower right.

3.4.3.1 Discussion

Sightings recorded from 2007 to 2016 indicate the presence and habitat utilization by several native mammal species at the restoration sites, effectively meeting the first criterion. And although beaver activity at the restoration sites altered plantings, water levels, and stream flow from the designed condition, it would be misleading to claim these changes as “major site damage.” Historically in the Pacific northwest (pre-20th century), stream systems were often characterized by slow, cold, deep water and extensive floodplain wetlands that were a product of ubiquitous beaver activity across the landscape (Pollock et al.2015). Although beaver activity has created a system that deviates from the intended design, their activity has the potential to create more complex habitats, additional water storage, cooler water temperatures, and a more stable hydrograph during low-flow periods. Therefore, because beaver activity has assisted natural processes, the second criterion is also considered to be met.

Success Criteria:

- Presence and habitat utilization by **native mammal** species at the restoration sites over the 10-year period following restoration construction. **Criterion met—native mammals were observed using the restoration sites over the 10-year monitoring period.**
- Absence of **major site damage** from mammals throughout the monitoring period. **Criterion met—no major site damage from mammals.**

3.4.3.2 Recommendations

We recommend allowing beavers to remain active at the site with periodic monitoring to ensure beaver activity does not impact surrounding infrastructure or create life/safety risks.

4. PHYSICAL MONITORING

4.1 POND HYDROLOGY

4.1.1 Ponds - Bathymetry

4.1.1.1 Introduction

Three ponds were created in the Cemetery Creek channel to provide rearing habitat for juvenile salmonids: North Pond, West Pond and South Pond (**Figure 4-1**). Bathymetric cross sections collected over time in these ponds help reveal whether pond habitat is being maintained, aggrading, or scouring.

4.1.1.2 Objectives

The objective of pond hydrology surveys was to confirm that the three ponds maintained their functional intent and their **designed depth and volume characteristics** for the duration of the monitoring period.

Success Criteria:

- Created ponds maintain designed hydrologic and habitat forming functions such as seasonal wetted area, adequate cover, and structural stability.
- Pond LWD loading remains constant or increase over the 10-year monitoring period.

The original pond "Hydrology & Habitat" task as identified in the *Monitoring and Maintenance Plan* (COB 2006) included seasonal wetted area, adequate cover, structural stability and large woody debris (LWD) loading in addition to pond bathymetry. This original study plan also called for the development of schematic maps of each pond including LWD features. However, this monitoring component was determined to be redundant with data collected as part of stream habitat surveys and was therefore dropped at the outset of monitoring (Forester 2009). Therefore, maintenance of designed hydrologic functions is evaluated based on bathymetry surveys (e.g. depth and volume characteristics) while habitat forming functions such as seasonal wetted area, adequate cover, and structural stability were not assessed (Forester 2009). LWD loading in ponds is assessed as part of stream channel habitat and LWD surveys since constructed ponds are counted as pool habitat in the stream system (**see 4.2.2 Stream Channels – Habitat & Large Woody Debris).**

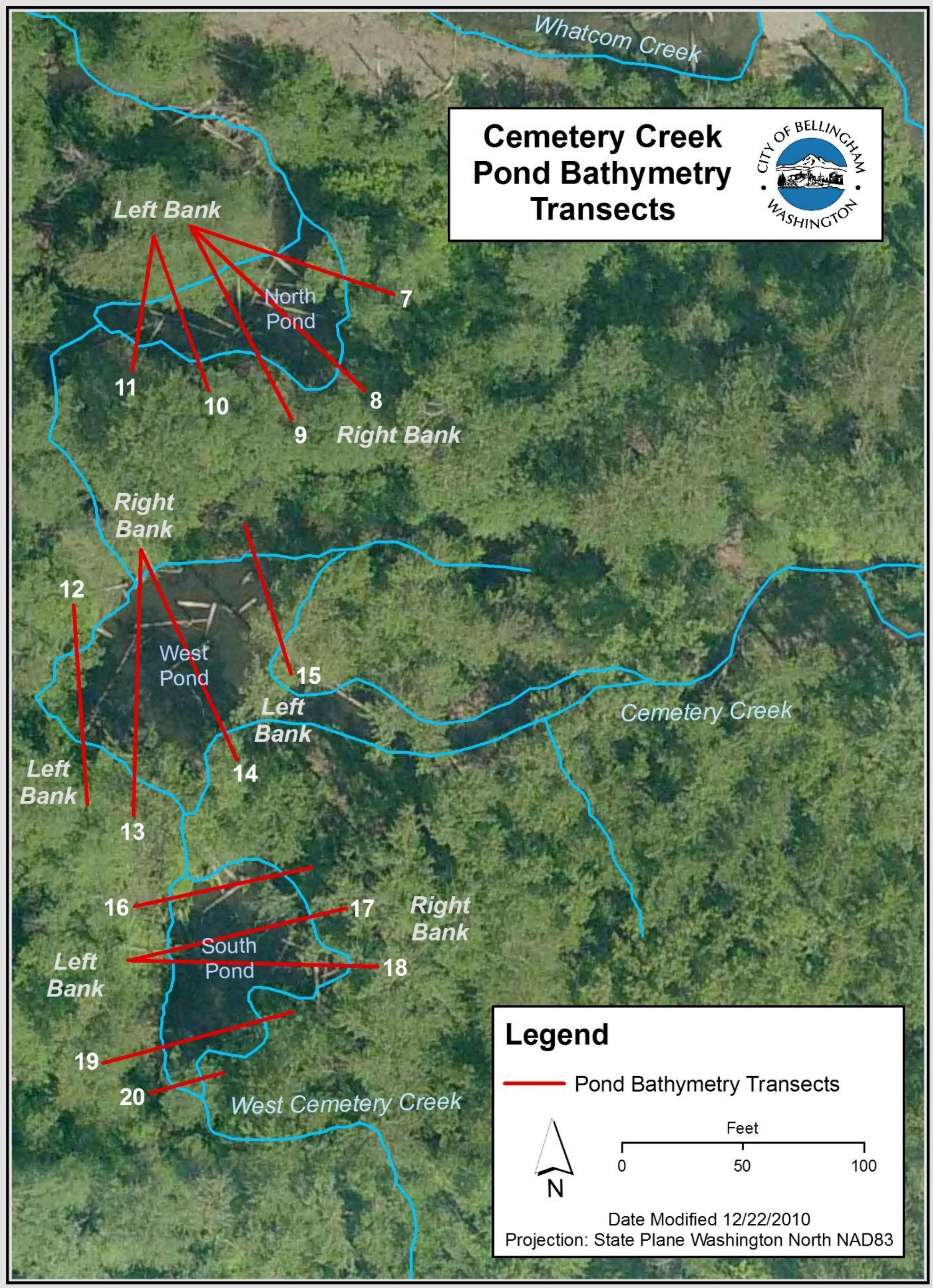

Figure 4-1 Map of pond bathymetry transects.

4.1.1.3 Methods

Fourteen bathymetric survey transects were established on the Cemetery Creek ponds: five in the North pond, four in the West Pond, and five in the South Pond (**Figure 4-1**). Pond bathymetry transects are numbered 7-20. Transects 1-6 were originally established as pond bathymetry transects but were subsequently reassigned as stream channel cross-sections 13-17 (**4.2.1Stream Channels – Cross-sections**) .

Water surface elevation: A staff gauge was installed in each of the three ponds to facilitate tracking of fluctuations in pond water surface elevation (WSE), and each staff gauge was linked to a local benchmark. As per the *Monitoring and Maintenance Plan* (COB 2006), water surface elevation was recorded during all pond bathymetry surveys, as well as during most other site visits (eg. water quality sampling, spawner surveys, etc).

Pond bathymetry: To conduct bathymetry surveys, the depth of each pond was measured across all established transects. The WSE was recorded at the start and end of each survey. Pond depth relative to the WSE was measured at 1 to 2 foot intervals across each transect. Bathymetry surveys were conducted in 2007, 2008, 2009, 2011, 2013 and 2016. In 2007 and 2008 these depths were measured using a stadia rod, however a variable layer of soft substrate present at the bottom of the ponds made results difficult to reproduce using this method. Therefore, to minimize error, a "weight and tape" method was developed. The "weight and tape" method employed a 4-ounce fishing weight attached to a Kevlar measuring tape which was lowered until it rested on the bottom of the pond. The "weight and tape" method standardized the pressure applied at the top of the substrate, providing a consistent level of penetration into the soft mud layer, and therefore more comparable depth measurements. In 2009, selected transects in each pond were resurveyed using the 2007-2008 method to compare results between the two methods. The new "weight and tape" method resulted in decreases in almost all depth measurements and was adopted from 2009 forward, except in cases where sediment was firm and the water was shallow (less than approximately 4 inches), when the stadia rod was still used to take depth measurements.

During analysis, survey data are corrected to a common reference elevation to facilitate interannual comparisons. Changes in pond depth along each transect indicates whether the pond habitat is maintained, aggrading, or scouring. Transect endpoints were located well back from the original pond margins, and the same transects were used for vegetation and amphibian surveys.

4.1.1.4 Results

Water surface elevation: The chart shown in Error! Reference source not found. documents all recorded W SE measurements. Please note that WSE readings reported as "4.0" indicate that the water level was over topping the gauge (eg. >3.34 ft), while readings reported as "0.0" indicate that the water level was below the bottom of the gauge. In both cases the actual water level relative to the gauge could not be measured. In the winter of 2012-2013, the North Pond gauge was submerged by water impounded behind a beaver dam. Similarly, in winter of 2015-2016, the South Pond gauge was submerged due to multiple dams on both the West and South Ponds, resulting in flooding across the project area. No success criteria were associated with this monitoring task.

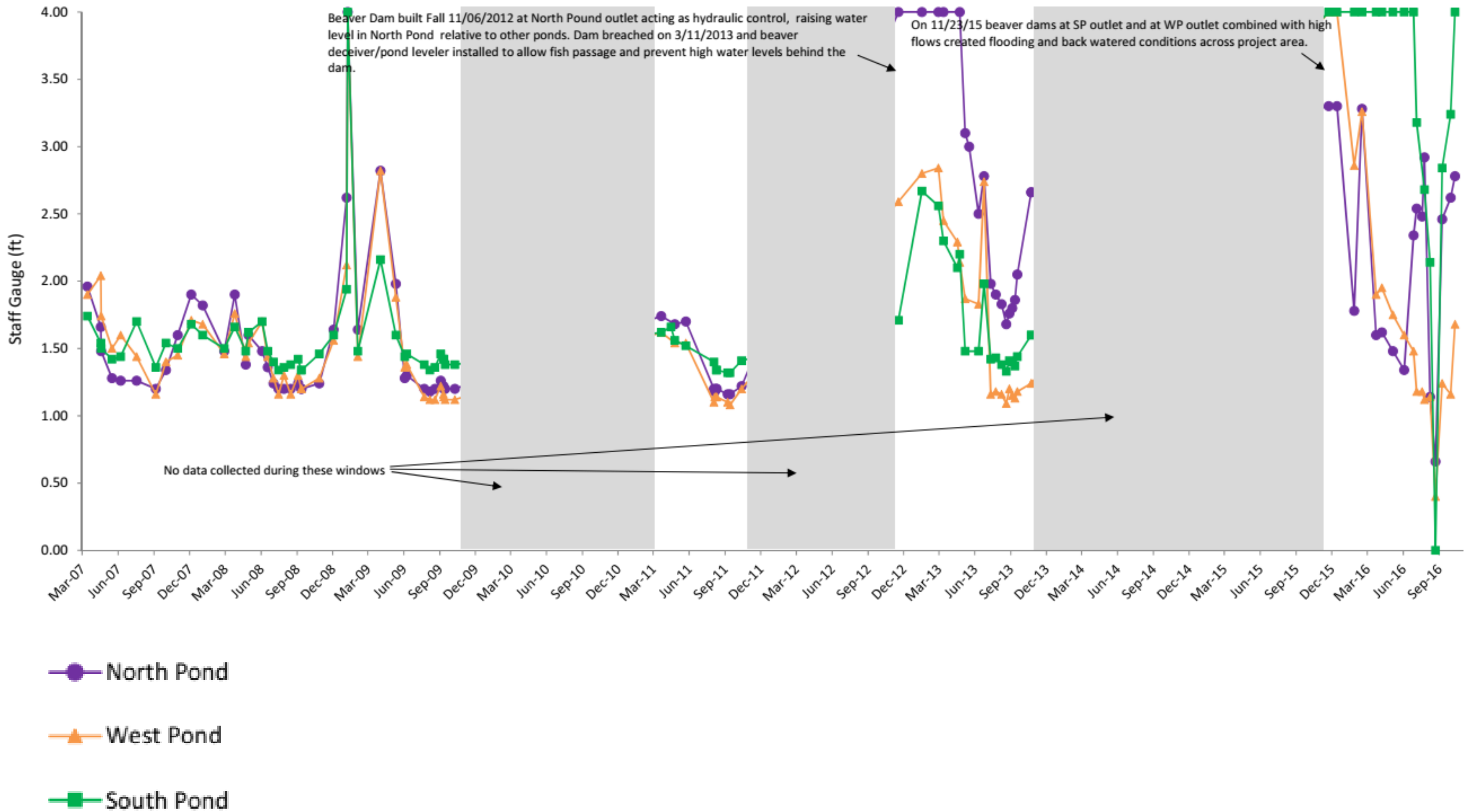

Figure 4-2 Pond water surface elevation (WSE).

Pond bathymetry: Bathymetry surveys were conducted in 2007, 2008, 2009, 2011, 2013 and 2016 and all bathymetric profiles (at fourteen total transects) are available in Appendix K. Results reported here are aimed at assessing whether the three ponds maintained their functional intent and their **designed depth and volume characteristics** for the duration of the monitoring period. Maximum depths for each pond from 2007-2016 are presented in **Table 4-2** and average depth of each transect for each year is presented in **Table 4-1**. **Figure 4-3** plots the mean depth for each transect by year and clearly illustrates the ubiquitous depth decrease at all transects over time. All of these data show that, on average, all

Table 4-2 Maximum pond depth by year.

	Maximum Depth (ft)					
	2007*	2008*	2009	2011	2013	2016
North Pond	4.83	5.58	4.32	3.79	3.31	3.15
West Pond	7.84	8.67	7.43	6.28	5.92	5.51
South Pond†	7.45	7.70	6.89	6.22	5.69	4.85

*2007 & 2008 methodology differs from 2009 forward. See text for details.

†PTR20 data excluded from volume calculation; transect crosses stream inflow and is not representative of pond conditions.

transects became progressively shallower over time.

Table 4-1 Average pond depth by transect and year.

		Average Depth (ft)						% Change
	Transect	2007*	2008*	2009	2011	2013	2016	2009-2016
North Pond	7	2.49	2.52	2.18	1.91	1.82	0.98	-55%
	8	2.50	2.65	2.49	2.19	1.93	1.85	-26%
	9	2.92	3.06	2.51	1.94	1.55	0.54	-78%
	10	2.06	2.30	1.90	1.57	1.28	0.34	-82%
	11	1.89	2.10	1.98	1.83	1.43	0.19	-91%
West Pond	12	3.77	3.85	3.31	3.00	2.80	2.73	-17%
	13	4.48	4.70	3.92	3.34	3.14	3.55	-9%
	14	4.82	4.96	4.07	3.71	3.40	3.12	-23%
	15	2.23	2.59	2.05	1.86	1.60	1.72	-16%
South Pond	16	1.85	2.10	1.60	1.36	1.04		-35%
	17	4.56	5.04	4.24	3.67	2.67	1.88	-56%
	18	3.81	3.96	3.18	2.62	2.02	1.61	-49%
	19	2.96	3.30	2.05	0.90	0.15	-0.45	-122%
	20†	0.25	0.24	0.28	0.26	0.03	-0.10	-136%

*2007 & 2008 data were collected using a slightly different method-- see text for details.
†PTR20 transect crosses stream inflow and is not representative of pond conditions.

Note: Positive percent change indicates increased depths (erosion/scour) and negative percent change indicates decreased depths (deposition/fill).

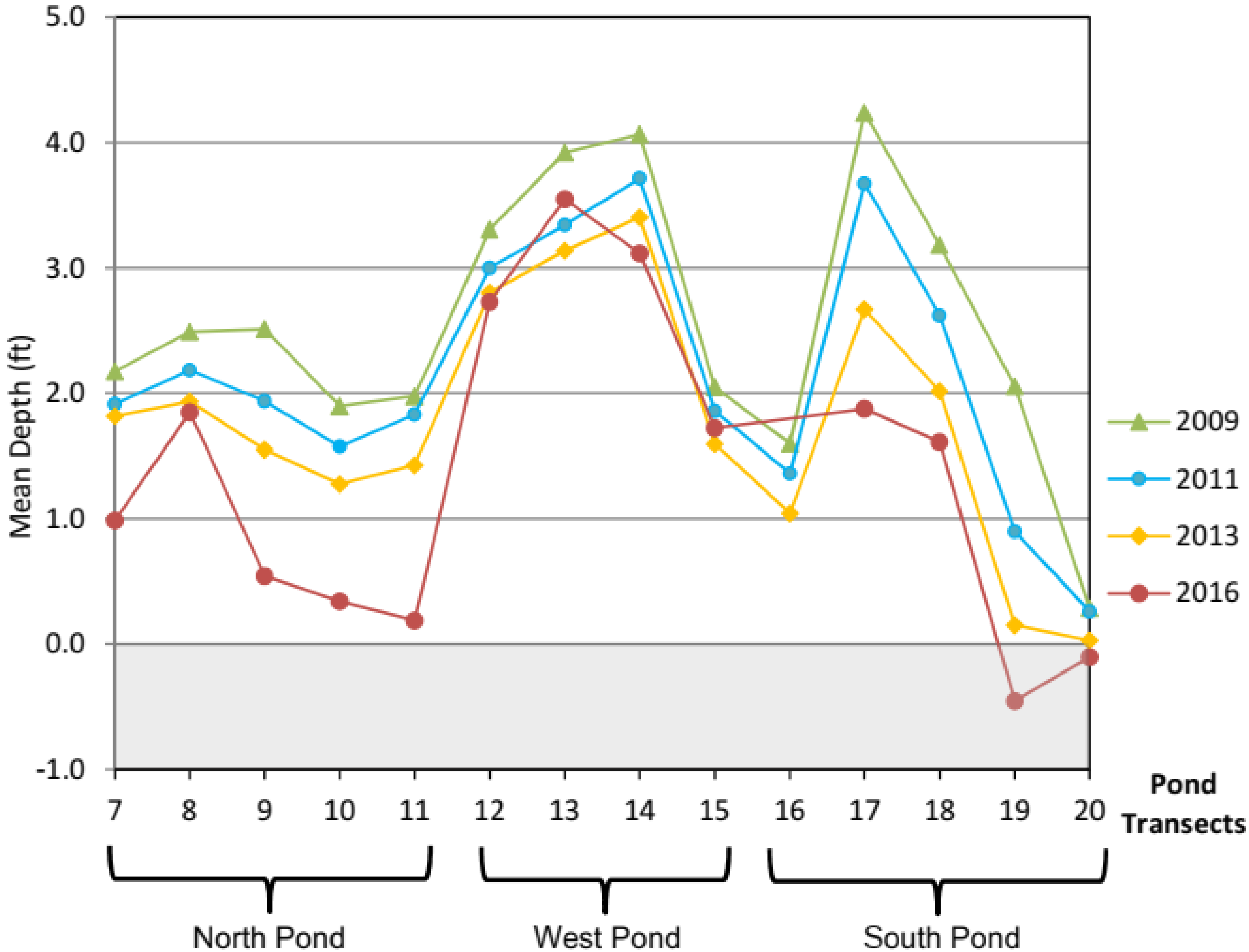

Figure 4-3 Mean transect depth by year.

Table 4-3 shows average volume (average width x average depth x length) of each pond by year, including change from 2009 to 2016. All ponds lost volumetric capacity over time, especially the North and South Ponds which lost more than half of their capacity from 2009 to 2016. **Figure 4-4** plots volumetric change for each of the ponds from 2009 to 2016 and shows that while all ponds lost capacity, the North and South Ponds dropped most significantly. In fact, the South Pond lost 10,000 ft^3 of capacity from 2009 to 2016.

Table 4-3 Pond volume by year, plus change from 2009-2016.

	Volume (ft^3)						% Change	
	2007*	2008*	2009	2011	2013	2016	2009-2016	Δ 2016-2009
North Pond	10,195	10,791	9,501	8,065	6,669	2,515	-74%	-6,986
West Pond	19,164	20,160	16,715	14,927	13,702	13,809	-17%	-2,905
South Pond†	19,682	21,136	16,186	12,656	8,626	6,109	-62%	-10,077

*2007 & 2008 data were collected using a slightly different method-- see Methods text for details.
†PTR20 data excluded from South Pond volume calculation; transect crosses stream inflow and is not representative of pond conditions.

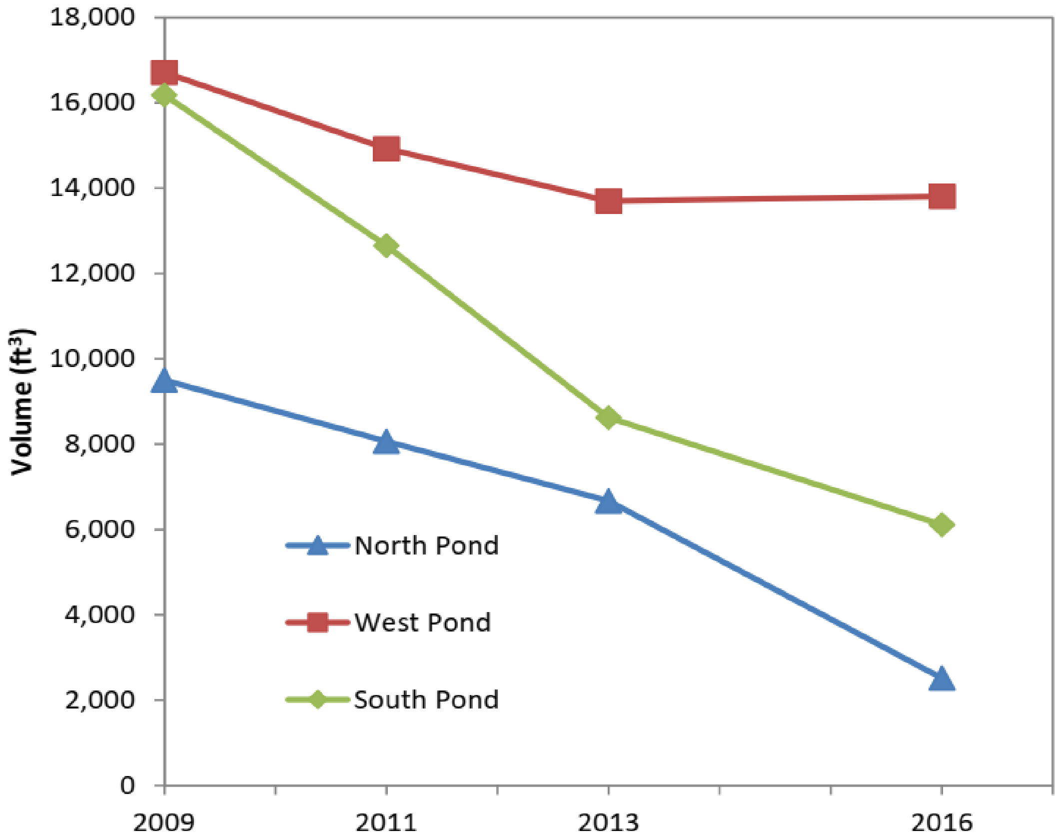

Figure 4-4 Pond volume change over time.

Finally, the two bathymetric profiles included below in **Figure 4-5** and **Figure 4-6** show the two transects with the most and least change over the monitoring period. Transect 13 in the West Pond exhibited the least amount of change over time, while Transect 19 in the South Pond aggraded to the point of becoming subaerial above the 2007 water surface elevation reference level.

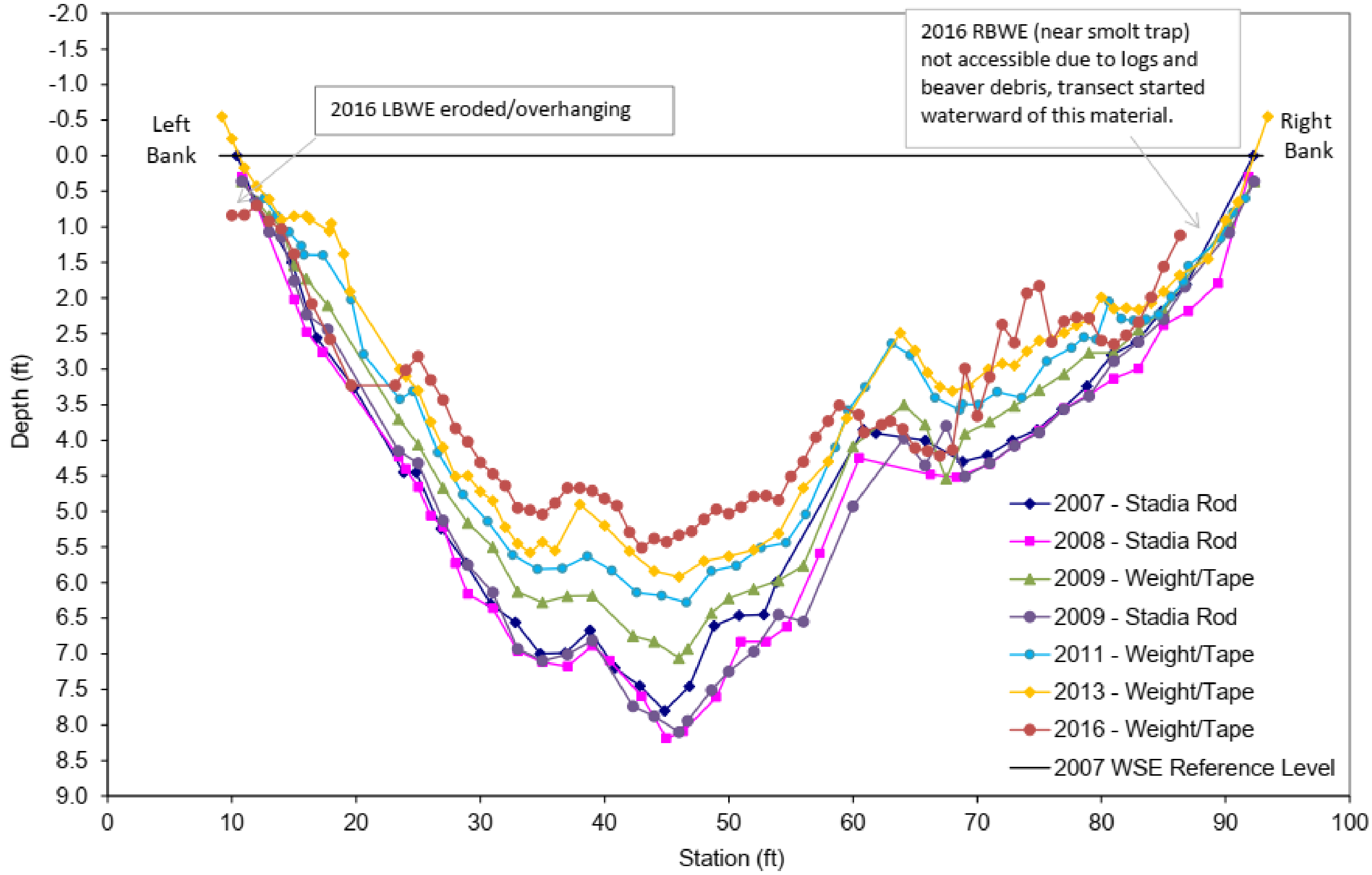

Figure 4-5 Bathymetry profile from West Pond Transect 13.

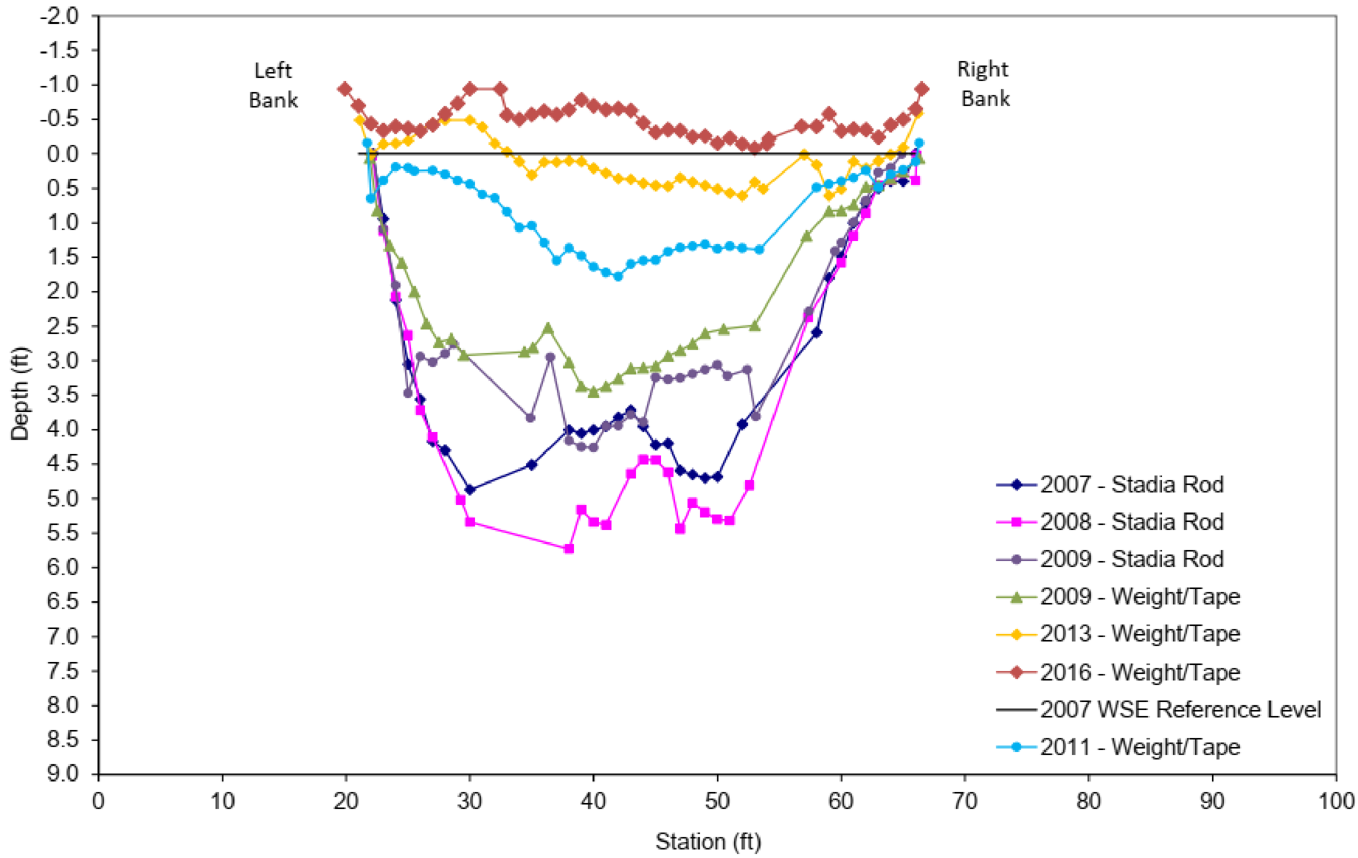

Figure 4-6 Bathymetry profile from South Pond Transect 19.

4.1.1.5 Discussion

Pond bathymetry was assessed in order to determine whether or not the constructed ponds maintained their designed hydrologic functions as indicated by depth and volume characteristics. Increases in depth are considered evidence of scour, while decreases in depth are considered evidence of sediment deposition. Results show that depth and volume characteristics decreased within all three ponds, but that the North and South Ponds experienced the most dramatic changes over the 10-year monitoring period. **Figure 4-4** illustrates how the West and South Ponds started with similar volumetric capacities in 2009 but by the final year of monitoring in 2016 the South Pond was 6,109 ft^3 and the West Pond was 13,809 ft^3—a difference of 7,700 cubic feet. Between 2009 and 2016, the South Pond lost the most net

Success Criteria:

- Created ponds maintain designed hydrologic and habitat forming functions such as seasonal wetted area, adequate cover, and structural stability. **Criterion not met-- all transects experienced a net loss of depth and volume. Seasonal wetted area, adequate cover and structural stability were not assessed.**
- Pond LWD loading remains constant or increase over the 10-year monitoring period. **Criterion met. Details in 4.2.2 Stream Channels – Habitat & Large Woody Debris.**

volume at 10,000 ft^3 of capacity lost. Therefore, created ponds did not maintain designed hydrologic functions and habitat forming functions such as seasonal wetted area, adequate cover, and structural stability were not assessed (Forester 2009). The second criterion, pertaining to LWD loading in the ponds, was met and is detailed in **4.2.2 Stream Channels – Habitat & Large Woody Debris.**

These results, combined with macroinvertebrate monitoring (see **3.3 AQUATIC MACROINVERTEBRATES)**, led City staff to further investigate the cause and source of fine sediment deposition in the restoration area. The *West Cemetery Creek Sediment Management Alternatives and Feasibility Study* completed by Element Solutions in 2013 identified several primary contributing sources as well as a suite of potential management alternatives.

4.1.1.6 Recommendations

The City is designing the West Cemetery Creek restoration project and Wildflower bridge replacement, addressing the three top priority alternatives identified in the *West Cemetery Creek Sediment Management Alternatives and Feasibility Study*. The projects are scheduled for construction in 2021 and will protect and restore natural processes in the Whatcom Creek corridor by arresting excessive sediment migration and increasing bank stability. No further actions are recommended.

4.2 STREAM HABITAT

4.2.1 Stream Channels – Cross-sections

4.2.1.1 Introduction

Restoration actions included constructing new portions of the Cemetery Creek and West Cemetery Creek channels to produce a meandering planform, reduce channel incision and increase habitat complexity. The newly created channels resulted in increased channel length, decreased channel slope and altered channel cross-sections in some places. A series of seventeen channel cross sections were surveyed to document the post-project channel configuration (**Figure 4-7**).

4.2.1.2 Objectives

The original objective of stream channel cross sections was to "document that reconstructed stream channels are functioning as designed and provide suitable habitat for salmonids." While cross sectional surveys can be used to track changes in channel depth and shape over time, providing some indication

Success Criteria:

- Restored stream channels habitat features will maintain designed hydrologic and habitat forming functions such as pools, LWD loading, suitable spawning areas, and stable banks.

of whether the functional intent of the design has been maintained, channel suitability for salmonids cannot be directly measured with this work. In the *Monitoring and Maintenance Plan* (COB 2006), just one success criterion was identified for all physical stream monitoring:

Stream cross sectional data was used to assess one part of this criterion: restored stream channels habitat features will **maintain designed hydrologic function** and **stable banks**. Originally, bank stability was to be assessed by measuring the length and height of actively eroding areas, however this work was abandoned in favor of cross-sectional profiles which can also provide information on bank stability (Forester 2009). Similarly, thalweg profiles were discontinued at the outset of the monitoring period in favor of these stream channel cross sections, which include thalweg elevations (Forester 2009. The remainder of the criterion including pools, LWD, and suitable spawning areas were assessed using other monitoring activities as described in sections **4.6.2 Stream Channels – Habitat & Large Woody Debris** and **4.6.3 Stream Channels – Spawning Gravel**.

4.2.1.3 Methods

Cross section end points are marked with wooden stakes or nails in trees and labeled with aluminum tags and located using GPS. As a result, all transects extend beyond the bankfull channel margins. Surveys are conducted during the winter or early spring when visibility is enhanced due to leaf fall.

In 2007, channel transects 1-10 were surveyed using an autolevel and stadia rod. Survey data were linked to local benchmarks. From 2008 forward an autolevel was not available, therefore transects 1-10 were surveyed using the sag tape method. Due to insufficient staff time, transects 11-17 were not surveyed during the 2007 or 2008 seasons (Forester 2009). Stream transect 16 was discontinued in 2011 after the bank eroded and water levels became too deep to access this location safely.

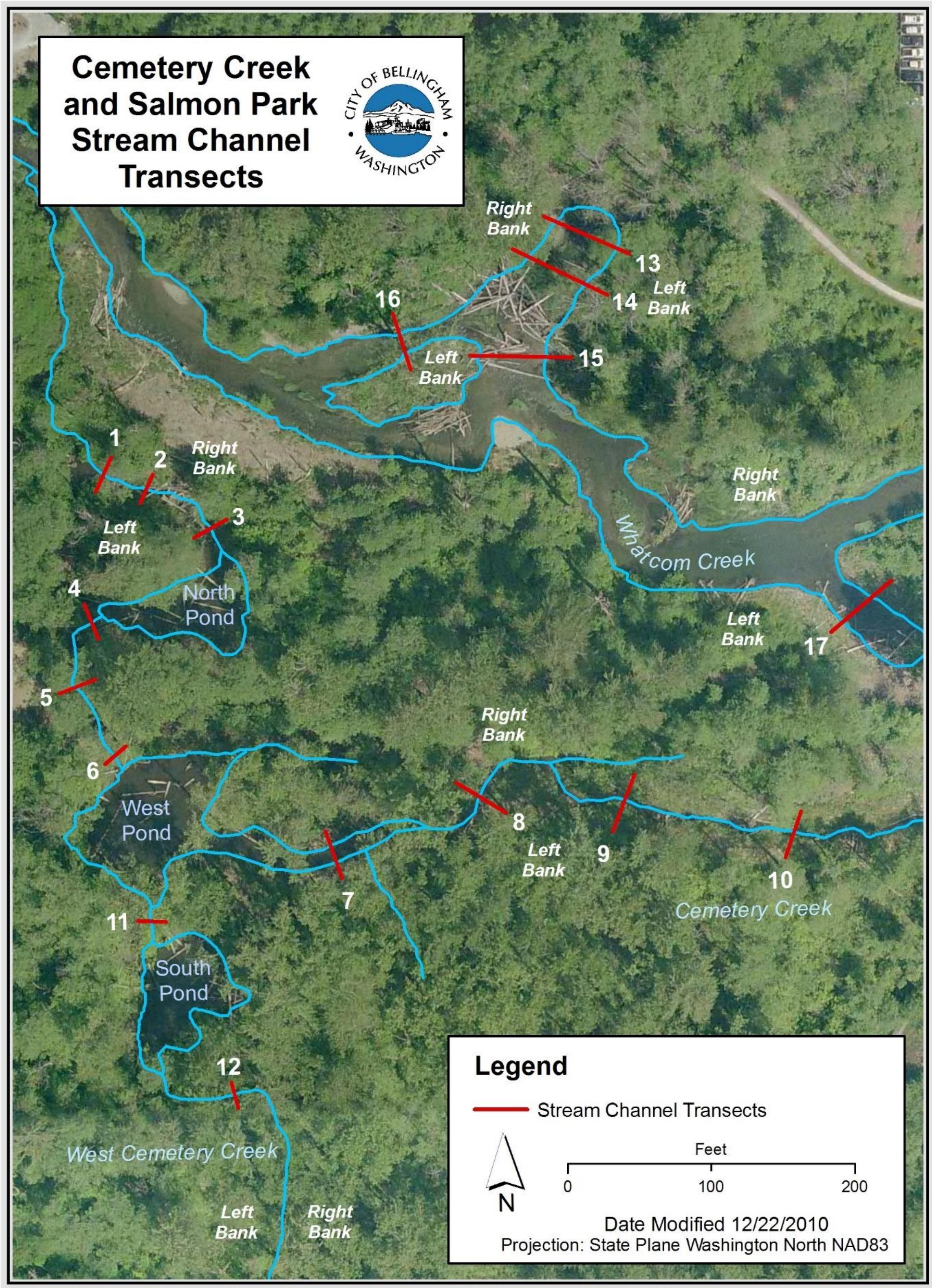

Figure 4-7 Map of stream channel cross-section transects.

4.2.1.4 Results

A total of ten channel cross sections (Transects 1-10) were surveyed on Cemetery and West Cemetery Creeks in 2007 and 2008, while all transects were surveyed in 2009, 2011, 2013 and 2016. All seventeen cross sectional profiles are provided in Appendix L.

Mean bed elevations were calculated for each survey transect for each survey year, as well as the change in mean bed elevation between the first survey year (either 2007 or 2009) and the last year (2016) (**Table 4-4**). Overall, changes in channel cross sections over the monitoring period have been relatively small. Most net changes in mean bed elevation have been positive, indicating aggradation. A few transects exhibited a net loss of bed elevation, indicating scour, and a few more exhibited little to no change, indicating that the channel form has been more or less maintained since construction.

Table 4-4 Mean bed elevations calculated from stream channel cross sections.

Transect	Mean Bed Elevation (ft) 2007	2008	2009	2011	2013	2016	Change in Mean Bed Elevation (ft)	
Cemetery Creek Transects								
1	95.75	95.81	95.95	96.05	95.85	95.96	0.21	2007 to 2016
2	95.39	95.47	95.47	95.55	95.92	95.51	0.12	2007 to 2016
3	94.99	95.07	95.05	94.95	95.71	95.09	0.10	2007 to 2016
4	93.64	93.81	93.70	93.89	94.07	93.77	0.13	2007 to 2016
5	95.31	95.23	95.08	95.25	95.24	95.13	-0.18	2007 to 2016
6	95.24	95.34	94.96	95.20	-- [1]	95.22	No Change [2]	2007 to 2016
7	94.83	94.94	95.03	95.34	95.32	95.34	0.51	2007 to 2016
8	96.64	96.67	96.67	96.43	96.61	96.48	-0.16	2007 to 2016
9	96.22	96.22	96.28	96.42	96.52	96.50	0.28	2007 to 2016
10	98.45	98.36	98.53	98.48	98.59	98.34	-0.11	2007 to 2016
11	--	--	93.91	94.00	93.94	94.12	0.21	2009 to 2016
12	--	--	93.69	93.38	93.38	93.65	No Change [2,4]	2009 to 2016
Whatcom Creek Transects								2009 to 2016
13	--	--	96.60	96.67	96.64	96.95	0.34	2009 to 2016
14	--	--	92.41	93.05	92.76	-- [1]	0.35	2009 to 2016
15	--	--	93.06	94.25	93.76	94.05	0.99	2009 to 2016
16	--	--	91.01 [3]					2009 to 2016
17	--	--	90.09	90.81	90.43	90.63	0.54	2009 to 2016

[1] No 2013 data at Transect 6 due to placement of smolt trap. No 2016 data at Transect 14.
[2] Any mean bed elevation difference <0.10 ft is classified here as "No Change."
[3] Stream transect 16 has been discontinued & will be omitted from all future surveys. Flooding took out substantial portion of right bank including the right bank rebar pin. Additionally, Whatcom Creek has become too deep at this location to complete this transect safely.
[4] Transect 12 has an overhanging, undercut bank which creates negative space not easily captured by these survey methods.

Aggradation/Fill: According to **Table 4-4** (above), the greatest net change in bed elevation was at transect 15 at the low end of the constructed Salmon Park swale (**Figure 4-8**). However, both **Table 4-4** and **Figure 4-8** reveal that the cross sectional profile at this location fluctuated from year to year: increasing from 2009 to 2011, decreasing from 2011 to 2013, and then increasing again from 2013 to 2016. A similar pattern can be observed at transects 14 and 13, the upstream end of that same Salmon Park swale, as well as transect 17 (the unnamed swale on the left bank of Whatcom Creek)(**Figure 4-7** and **Appendix L**). In other words, all the constructed swales on the Whatcom Creek mainstem share this pattern of fluctuating bed elevation. On the other hand, Transect 7 provides a clear example of a small but steady aggradation from year to year (**Figure 4-9**).

Scour: Although the greatest net loss in bed elevation from 2007 to 2016 occurred at transect 5, most of this change happened right after construction, between 2007 and 2008 (**Table 4-4** and **Figure 4-10**). An installed log near the right bank side of the transect was associated with significant bank erosion, however a large rooted tree just downstream on the right bank arrested any further erosion (**Figure 4-10**). On the other hand, transect 8 provides one clear example of a small but progressive pattern of scour (**Figure 4-8**).

Figure 4-12 provides a summary map showing which stream channels exhibited a net increase ("fill") or decrease ("scour") of mean bed elevation from the start of the monitoring period to the end. Two transects, numbers 6 and 12, exhibited no appreciable change (eg. <0.10 ft) over the course of the monitoring period (**Table 4-4**), and are therefore labelled as "maintained" in **Figure 4-12**. Only three cross sections (numbers 5, 8 and 10) exhibited any measurable scour (**Table 4-4** and **Figure 4-12**), which was concentrated on the stream banks (Appendix L) .

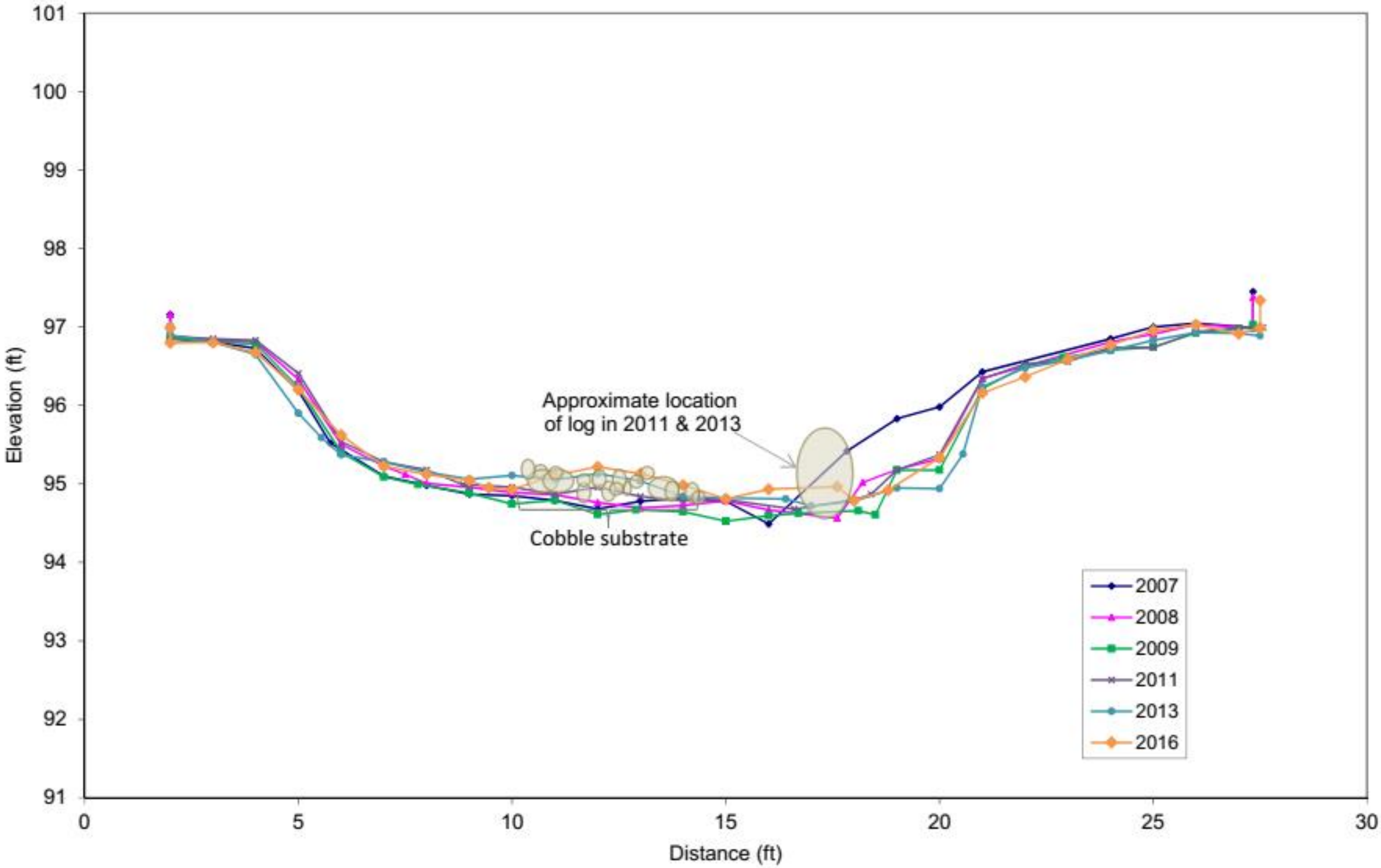

Figure 4-8 Transect 15 stream channel cross sectional profile.

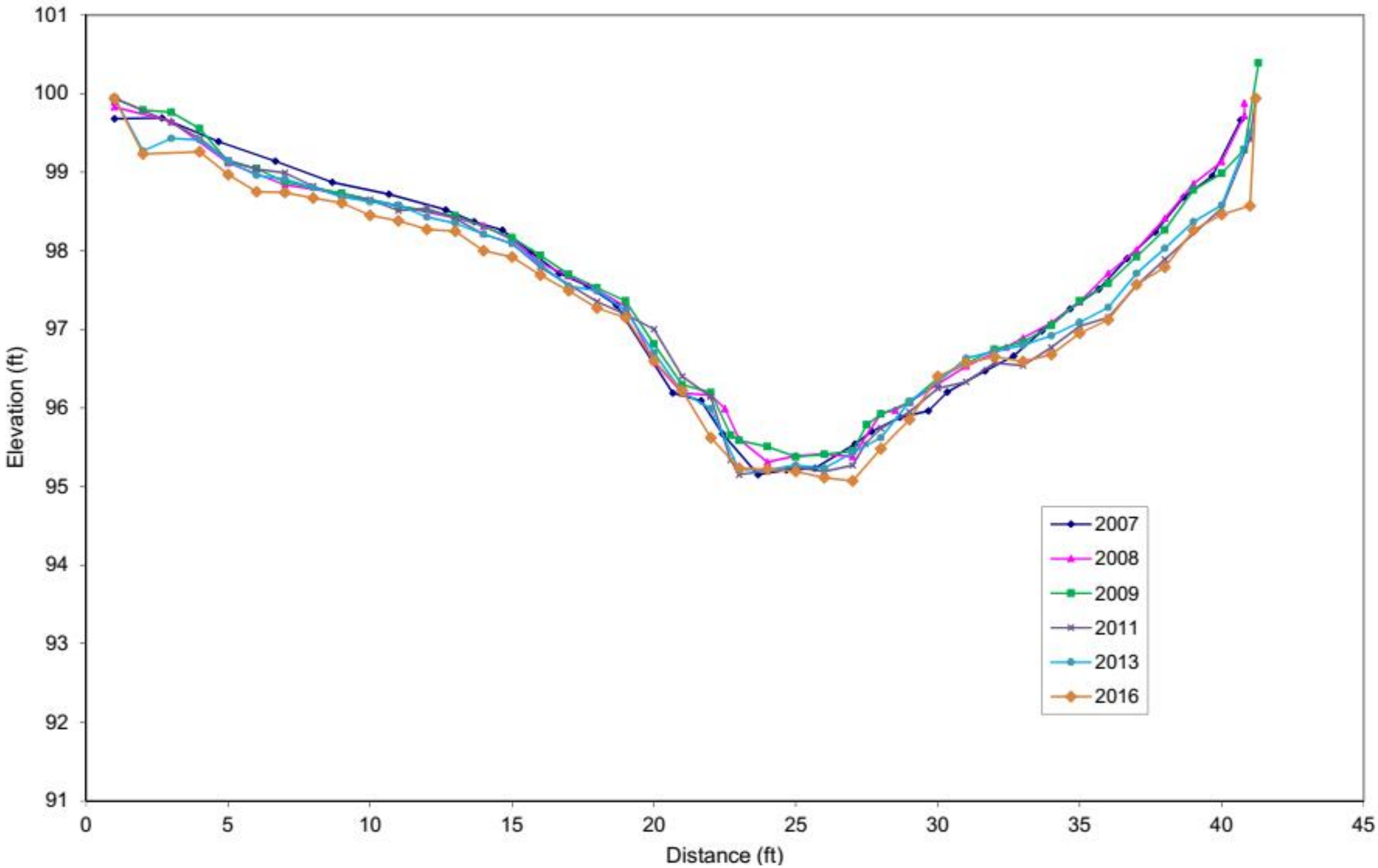

Figure 4-9 Transect 7 stream channel cross sectional profile.

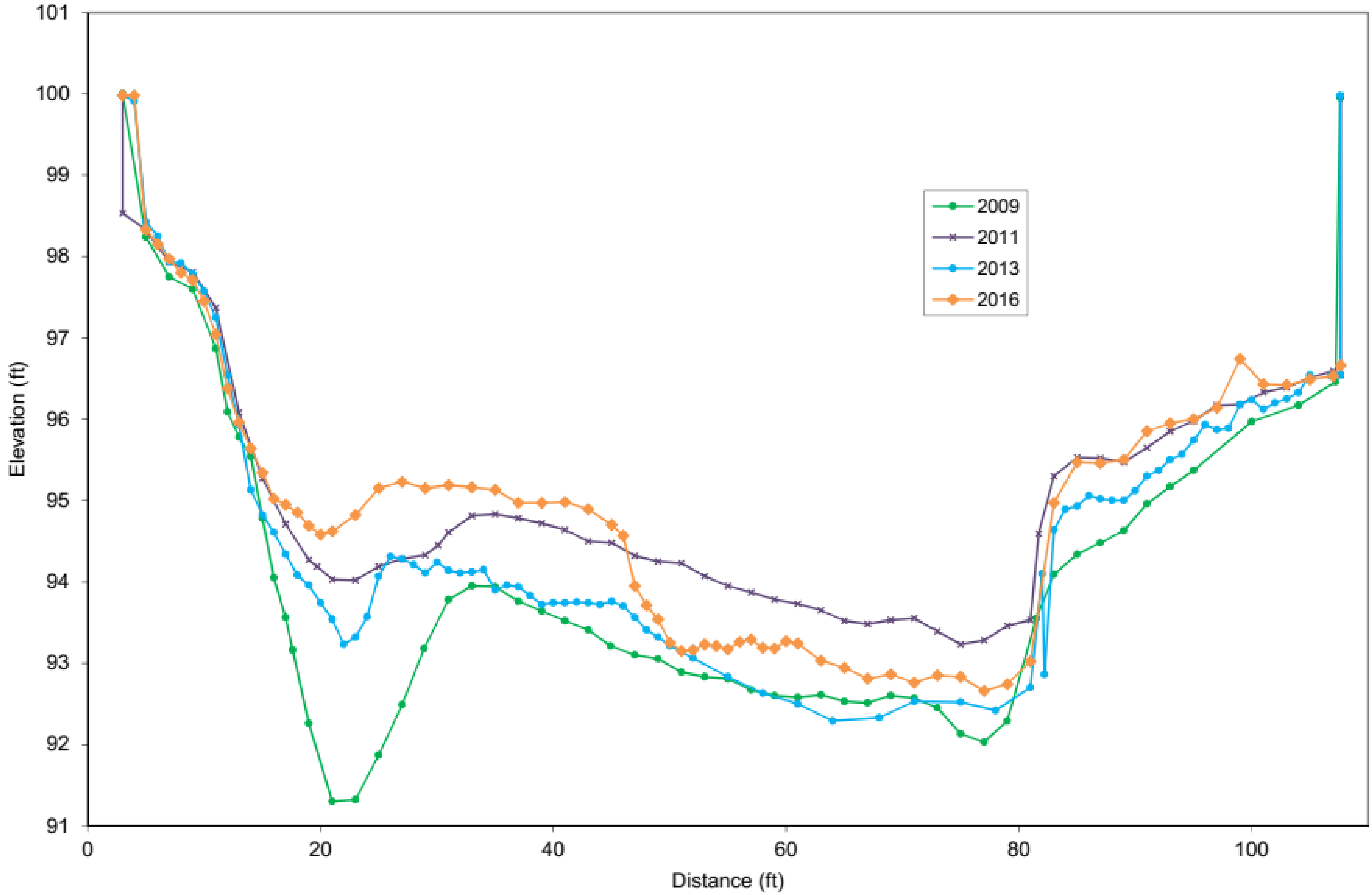

Figure 4-10 Transect 5 stream channel cross sectional profile.

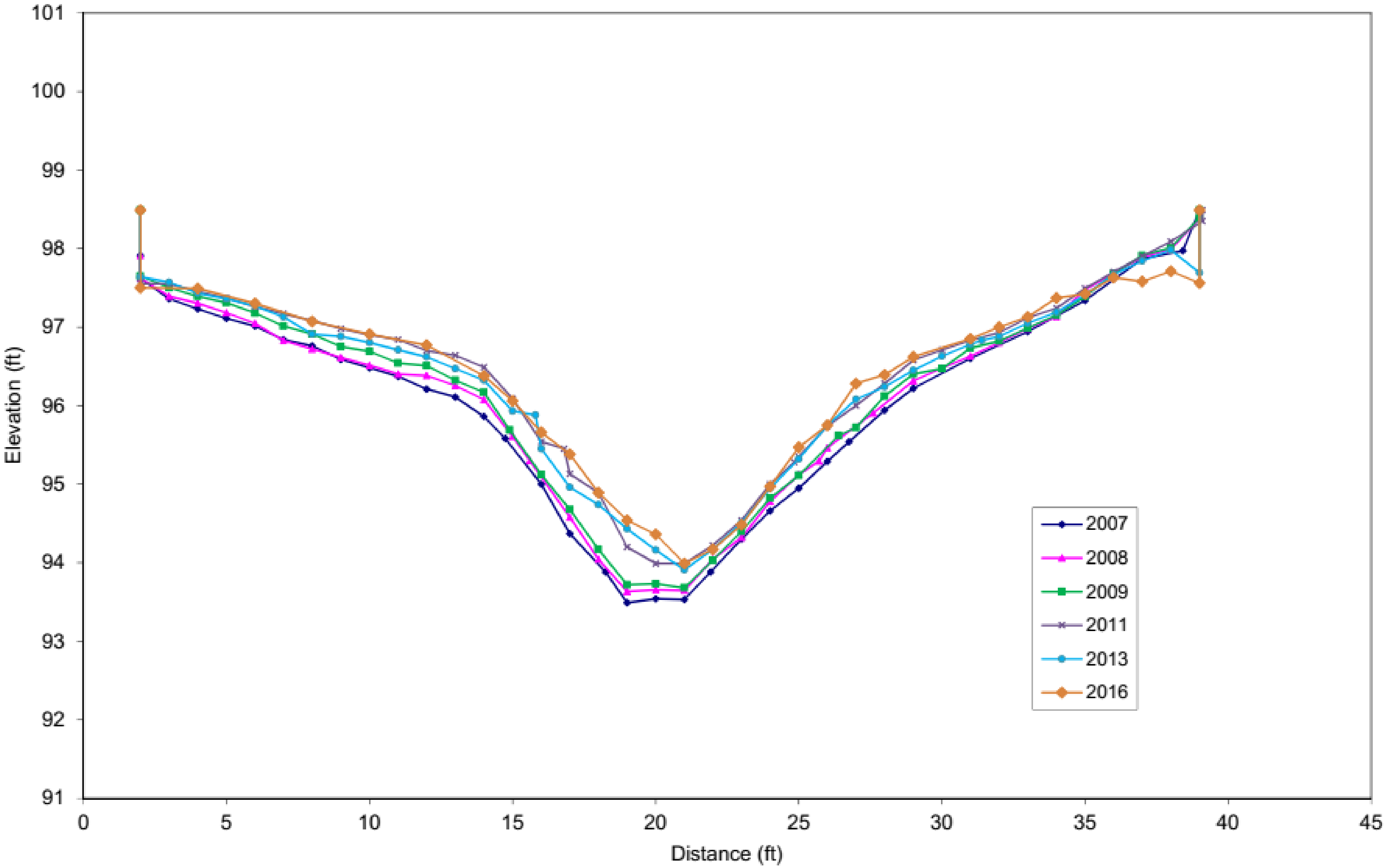

Figure 4-11 Transect 8 stream channel cross sectional profile.

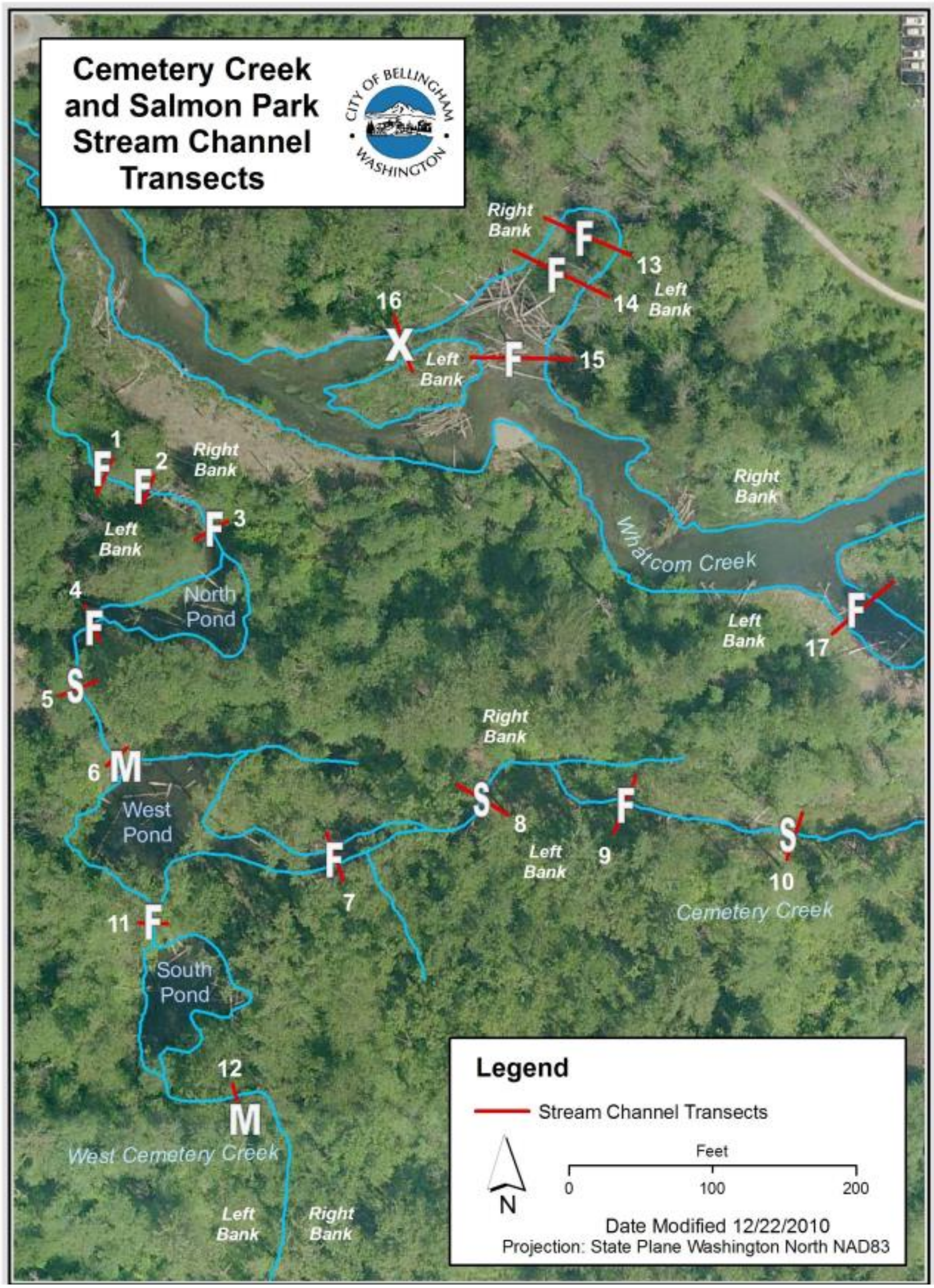

Figure 4-12 Map of stream channel fill and scour areas. F= fill, S= scour, M= maintained/ no change, X= not surveyed. Areas marked "fill" exhibited a net increase in mean bed elevation over the monitoring period while "scour" areas exhibited a net decrease. All fill and scour occurred passively after restoration project construction (not part of construction activities).

4.2.1.5 Discussion

The constructed stream channels exhibited relatively small changes, especially when juxtaposed with the substantial aggradation documented within the constructed ponds (Appendices K and L).

Overall, stream-channel transects appear to be maintaining their designed configuration and stream banks have remained stable, with only three transects showing only minimal signs of bank erosion. Therefore, this aspect of the physical stream monitoring success criterion has been achieved:

Success Criteria:

- Restored stream channels habitat features will **maintain designed hydrologic and habitat forming functions** such as pools, LWD loading, suitable spawning areas, and **stable banks**. **Restored stream channels have maintained their designed configuration, and stream banks have remained stable overall.**

4.2.2 Stream Channels – Habitat & Large Woody Debris

4.2.2.1 Introduction

Channel complexity in streams has been demonstrated to support salmonid production. Pool-riffle sequences provide important habitat diversity both in terms of flow and substrate in gravel bed streams. Pools provide deep water habitat during low-flow or ice cover while riffles provide spawning gravels, high macroinvertebrate diversity, and food production. Together, pool-riffle sequences exhibit an undulating bedform which fosters hyporheic exchange and therefore stream temperature buffering. Pools and large woody debris (LWD) are also important for numerous salmonid life stages. The frequency that pools occur within a stream channel is a fundamental component of channel morphology (Montgomery et al. 1995). Pool frequency is a primary channel attribute that is very sensitive to LWD loading in pool-riffle channel types, such as Cemetery Creek. Wood placed as part of the construction project generally consisted of large conifers with attached rootwads. LWD was placed in the channel to provide cover, increase complexity, stabilize banks and maintain pools. Pools formed in association with LWD are often deep low velocity habitat with cover, an important habitat type for salmonids of varying life stages. Deep pools are especially beneficial for rearing fish, as they provide enhanced protection from predators and improved temperature and flow regulation. Residual pool depths greater than 3-feet (“holding pools”) are also important for holding adult salmon prior to spawning. In the Cemetery Creek system the three pools that qualify as holding pools are the constructed North, West and South ponds.

4.2.2.2 Objectives

In the *Monitoring and Maintenance Plan* (COB 2006), the objective of habitat surveys was to "document that reconstructed stream channels are functioning as designed and provide suitable habitat for salmonids." To accomplish this, the following specific habitat quality indices were identified:

- **Habitat units**: pool/riffle ratio
- **Pool indices**: pool frequency, pool spacing & percent pools by length
- **LWD indices**: frequency (pieces/channel width) & key piece frequency (pieces/channel width)

As described above, just one success criterion was identified for all physical stream monitoring:

Success Criteria:

- Restored stream channels habitat features will maintain designed hydrologic and habitat forming functions such as pools, LWD loading, suitable spawning areas, and stable banks.

Habitat and LWD survey data was used to assess two parts of this criterion: restored stream channels habitat features will **maintain designed habitat forming functions such as pools** and **LWD loading**.

4.2.2.3 Methods

All stream habitat surveys were conducted along the full length of restored stream channel (Figure 4-7) following a modified version of the Timber Fish and Wildlife Methodology (TFW) for Habitat Unit Surveys (Pleus et al. 1999) and Level 2 LWD Surveys (Schuett-Hames et al. 1999). Staff gauges were monitored each survey day to ensure water surface elevations were comparable between survey dates. In 2007, due to lack of staff time, habitat and LWD surveys were not conducted. In future years, habitat and LWD surveys were conducted during summer low-flows (August and September). In 2008, 2011 and 2013 special supplemental habitat surveys were also conducted at high flows (January and February), for reasons described below.

Stream channel habitat: Habitat surveys were conducted by two surveyors working downstream to upstream (**Figure 4-7**). Lengths of units were measured using a fiberglass tape; wetted channel widths were measured with the tape or stadia rod. For pool units, maximum and outlet control depths were measured with the stadia rod. Residual pool depth, the difference between the maximum depth and the outlet control depth, were calculated from these measurements. Pool forming factors are also noted.

Habitat was broken down into two core types: fast water (*riffles*) and slow water (*pools*). Sub-unit types (*riffle, run, glide,* and *pool*) were also identified, but these data were complicated by annual and seasonal variability (described below) and are not reported here. Constructed ponds are included in the habitat survey and are counted as pools.

Based on TFW methods (Pleus, 1999 p. 3), the late summer/early fall low-flow period is best suited for habitat surveys under moderate to low-flow conditions because conditions are most stable (in non-glacial streams). Additionally, higher flows increase data variability due to decreased visibility & access resulting from turbidity, turbulence and water depth. However, this is tempered with a caveat related to extreme low-flow conditions that may be associated with drought (Pleus, 1999 p. 13). Surveying under these conditions may limit usefulness for trend analysis if those conditions are anomalous. All of this is complicated by uncertainty around what a "typical" hydrologic regime would be in a newly constructed stream system that did not previously exist in its newly created geomorphic state. To mitigate for this uncertainty, supplemental habitat surveys were completed under winter flow conditions in 2008, 2011 and 2013.

Large Woody Debris: Level 2 LWD surveys were conducted concurrent with habitat unit surveys (Figure 4-7). Parameters measured included piece diameter, length in zones 1-3 (within the bankfull channel), stability, and channel orientation. LWD jams were identified as structures with a minimum of ten pieces of LWD, with at least one piece entering zones 1 or 2 as per TFW protocol (Schuett-Hames et al. 1999). Jams were tallied by size class, with key pieces noted. The location of LWD in the stream channel is tallied by zones. For example, wood extending into the wetted channel (zone 1) contributes to aquatic habitat complexity.

The methods used in the identification of “key pieces” of LWD in jams was altered after 2008. The technique used in 2008 surveys was largely subjective; the protocol was changed in 2009 in order to standardize identification across survey years. The TFW “*LWD Key Piece Volume Criteria*” field sheet (Schuett-Hames et al. 1999a) was used to identify key pieces. The bankfull width of >0 m to <5 m was used to categorize LWD based on minimum diameter and length of each piece. This method was used in all subsequent surveys, however key piece data collected in 2008 are not comparable to data collected in subsequent years and are therefore omitted. Key pieces aid in trapping additional wood in the channel and enhance woody debris and channel stability. Similarly, stability and orientation of individual pieces was documented, as these variables may influence the long-term effectiveness of LWD in promoting habitat complexity.

In 2009 (Forester 2009), LWD indices for pool-forming function and sediment storage were discontinued. Despite guidelines provided in the TFW manual, designation of these characteristics was deemed too subjective. Furthermore, because channels and pools are constructed and most of the LWD is placed and/or cabled, the usefulness of these indices for documenting habitat function was considered minimal.

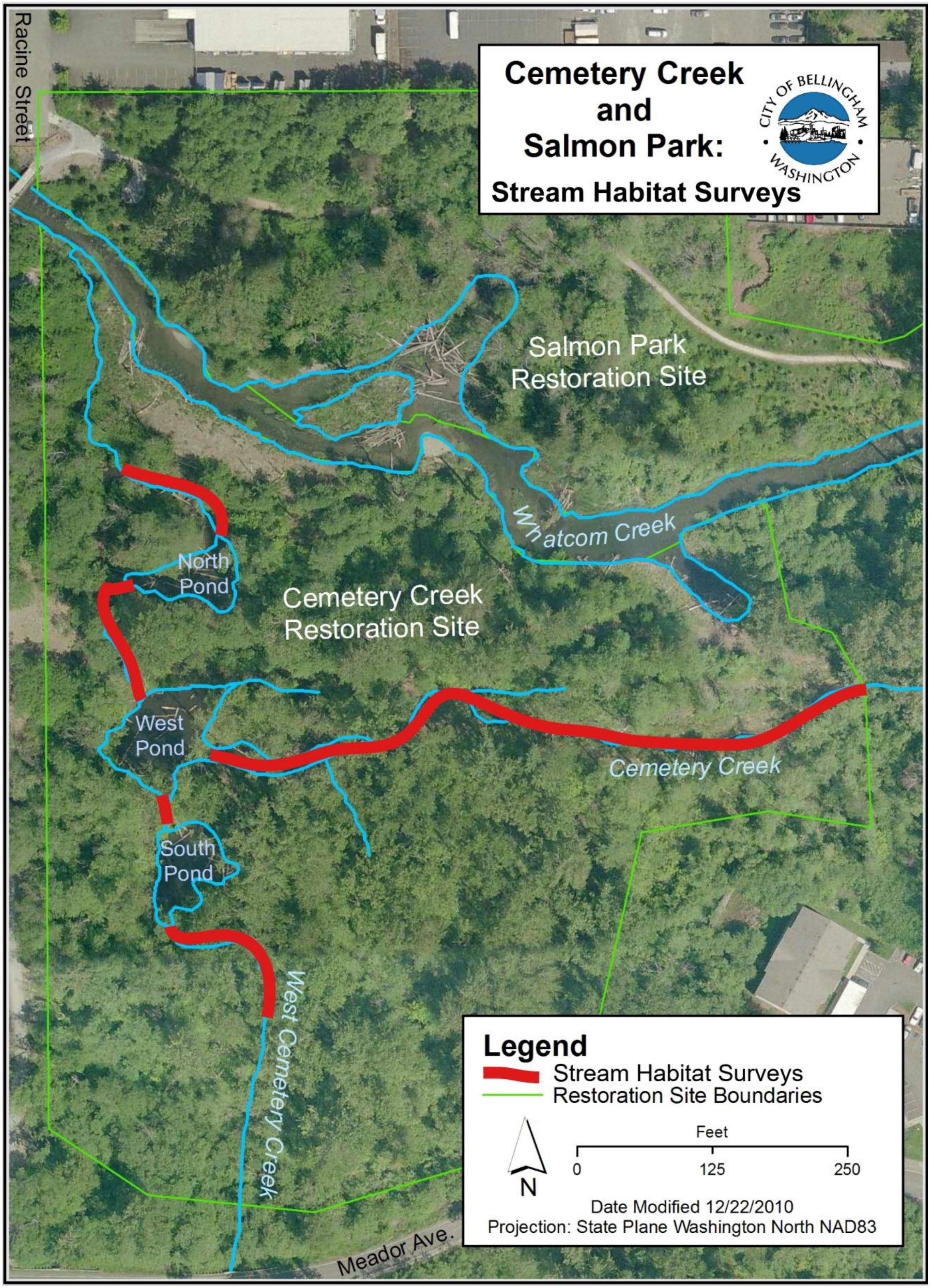
Cemetery Creek
and
Salmon Park:
Stream Habitat Surveys
CITY OF BELLINGHAM
WASHINGTON
Racine Street
Salmon Park
Restoration Site
Whatcom Creek
North
Pond
Cemetery Creek
Restoration Site
West
Pond
Cemetery Creek
South
Pond
West Cemetery Creek
Meador Ave.
Legend
Stream Habitat Surveys
Restoration Site Boundaries
N
Feet
0
125
250
Date Modified 12/22/2010
Projection: State Plane Washington North NAD83

Figure 4-13 Map of stream habitat survey reaches (stream channel habitat, Large Woody Debris and spawning gravel surveys).

4.2.2.4 Results

Habitat Units[7]: Core habitat units are either *riffles* or *pools*, as summarized in **Table 4-5**, below. Habitat unit lengths were derived from data collected in the summer months, while habitat unit types were determined in the office based on both summer and winter surveys (2008, 2011, 2013) combined with site knowledge. From 2008 to 2016 the pool/riffle ratio steadily declined, indicating an increase in riffle habitat over pools. This same trend is illustrated in **Figure 4-14**. Although the relative proportions of these two core habitat unit types hovered near 50/50 over the course of the entire monitoring period, there was a steady annual shift away from pool dominance.

Table 4-5 Core habitat unit proportions (percent of total length), pool/riffle ratios and total lengths.

Core Habitat Units	2008	2009	2011	2013	2016
Pool	54%	52%	47%	47%	40%
Riffle	46%	48%	53%	53%	60%
Pool/Riffle	1.18	1.09	0.90	0.89	0.67
Total Length (ft)	1481	1483	1444	1466	1394

[7] Although all attempts were made to determine habitat sub-units (eg. *riffle, run, glide, pool*) during both low and high flow conditions, these sub-units were ambiguous, obscured, or not comparable across years due to seasonally and annually variable conditions including intermittent sub-surface flows during drought years. No habitat sub-unit metrics were originally proposed in the *Monitoring and Maintenance Plan* (COB 2006). The relevant subdivision is at the level of *slower/deeper* areas versus *faster/shallower* areas (a.k.a. *pools* versus *riffles),* which are more consistent across years and discharge levels. Therefore, all sub-units defined as *riffle, glide,* or *run* habitats were grouped together and called *riffles*. This is supported by guidance of Pleus, 1999, p. 8: "...assume that everything is a riffle unless proven otherwise."

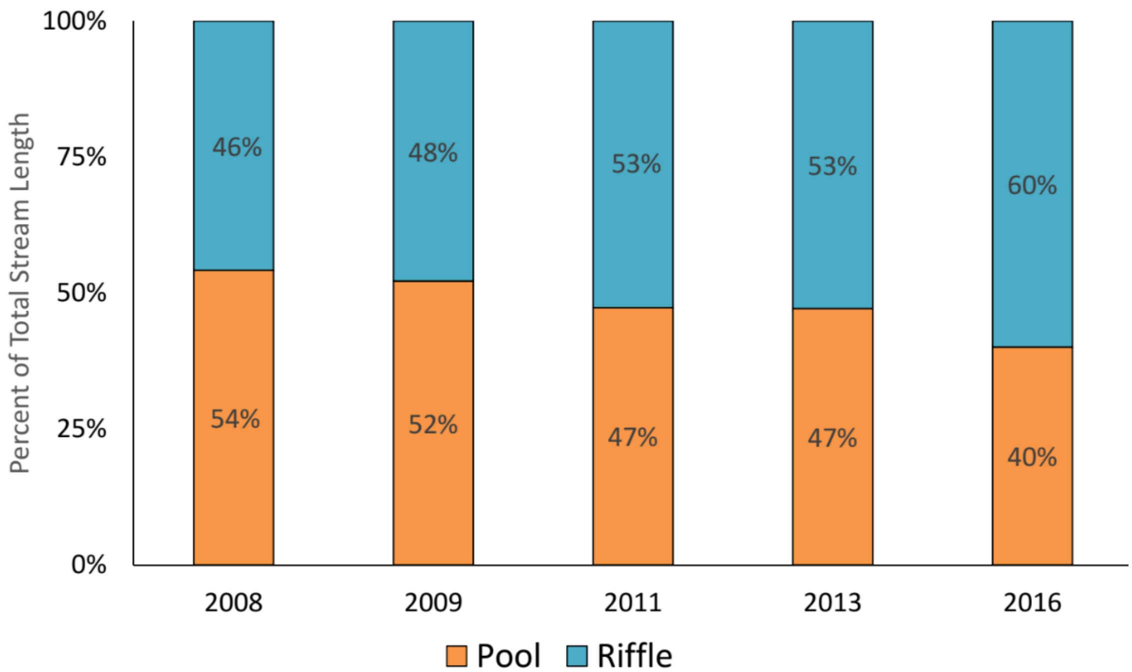

Figure 4-14 Pool and riffle proportions by year.

Table 4-6 Pool indices.

Pool Index	2008	2009	2011	2013	2016
Pool Tally (#)	24	24	21	18	17
Pool Percentage (by length)	54%	52%	47%	47%	40%
Pool Frequency (pools/mile)[1]	85.6	85.4	76.8	64.9	64.4
Pool Spacing (channel widths/pool)[2]	3.7	3.7	4.2	4.9	5.0
Holding Pools (residual depth > 3 ft)	3	3	3	3	3
Average Residual Pool Depth (ft)	2.3	2.2	2.5	2.1	2.2

[1]From NMFS (1996)

[2]From Montgomery (1995)

Pool indices: Pool indices (such as pool frequency, pool spacing & percent pools by length) provide simple quantitative indicators of habitat quantity and quality. Pool indices for the Cemetery Creek restoration site from 2008-2016 are presented in Table 4-6. Pool spacing was calculated by dividing the reach length by both the number of pools and the reach-average channel width, yielding a pool-to-pool spacing in units of channel width (i.e. channel widths per pool) (Montgomery, 1995). Pool frequency is expressed as pools per mile (NMFS, 1996). From 2008 to 2016, pool spacing increased from 3.7 to 5.0 and pool frequency decreased from 85.6 to 64.4 (Table 4-6); both metrics illustrate the same trend of diminishing pool habitat over time. The constructed North, West and South ponds retained their status as "holding pools" (with residual pool depths of >3 ft) in all years, maintaining the associated benefits to salmonids over the duration of the monitoring period.

LWD indices: Similar to pool indices, large woody debris (LWD) indices provide quantitative indicators of habitat quantity and quality. They also allow for comparison over time and adaptive management, as LWD shifts, washes out, and is added to the stream through natural recruitment. **Table 4-7** shows the total tally of LWD pieces (jams, rootwads, small, medium and large logs) in each of the constructed ponds during monitoring years. Between 2008 and 2016, the North Pond retained its LWD load, the West Pond increased its load, and the South Pond had only a very minor net loss (only 2 pieces out of 39) (**Table 4-7** and **Figure 4-15**). A summary of all LWD indices by year for the Cemetery and West Cemetery Creek project reaches is included here in **Table 4-8.** Frequency (pieces per channel width) for both total and key LWD pieces were essentially stable over the monitoring period, decreasing only slightly from 2.8 to 2.6 for total pieces and from 0.3 to 0.1 for key pieces (**Table 4-8** and **Figure 4-16**).

Table 4-7 Large woody debris in the constructed ponds of Cemetery Creek.

	North Pond					West Pond					South Pond				
	2008	2009	2011	2013	2016	2008	2009	2011	2013	2016	2008	2009	2011	2013	2016
Jams	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Rootwads	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Small Logs	0	1	4	1	2	0	3	3	4	1	1	4	9	8	1
Medium Logs	23	22	24	23	21	15	17	33	25	24	30	22	24	21	32
Large Logs	0	0	0	0	0	3	3	4	3	2	8	9	5	5	4
Total # Pieces	**23**	**23**	**28**	**24**	**23**	**18**	**23**	**40**	**32**	**27**	**39**	**35**	**39**	**34**	**37**

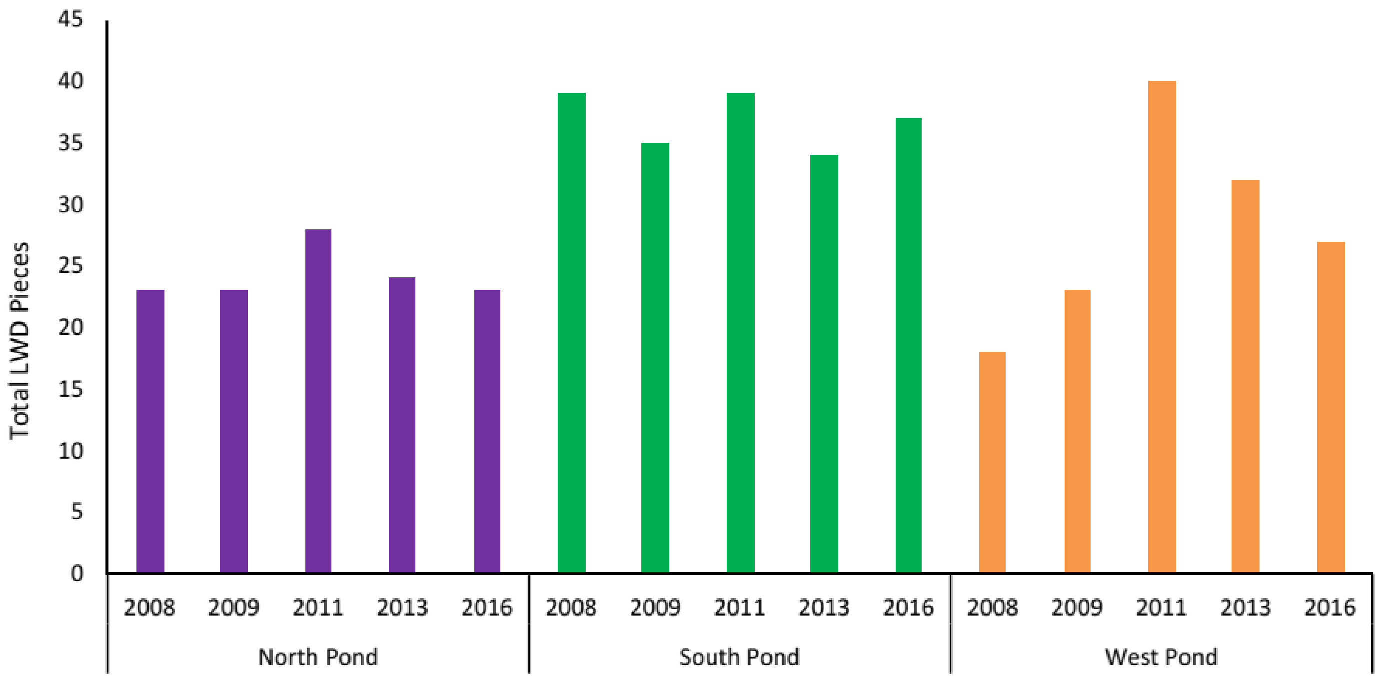

Figure 4-15 Large woody debris pieces by pond and year.

Table 4-8 Large woody debris indices.

Large Woody Debris Index	2008	2009	2011	2013	2016
Total number of LWD *(pieces and jams)*	249	274	260	239	222
Pieces per channel width (p/cw)	2.8	3.0	3.0	2.7	2.6
Large pieces* *(pieces and jams)*	32	28	20	20	17
Large pieces per channel width (p/cw)	0.4	0.3	0.2	0.2	0.2
Key pieces *(jams only)*	--[†]	28	24	23	8
Key pieces per channel width (p/cw)	--[†]	0.3	0.3	0.3	0.1
(all of the following indices are pieces only)					
Average diameter (inches)	13.8	12.5	13.1	12.2	12.9
Average piece length (Zones 1-3; feet)	13.2	12.9	15.2	18.4	20.6
Number of pieces in Zone 1	72	81	55	59	27
Number of pieces in Zone 2	19	27	18	29	26
Number of pieces in Zone 3	10	8	7	0	7
Percentage of pieces in Zone 1	71%	70%	69%	67%	44%
Percentage of pieces in Zone 2	19%	23%	23%	33%	43%
Percentage of pieces in Zone 3	10%	7%	9%	0%	11%
Orientation in the channel:					
Perpendicular	45	45	34	22	26
Parallel	34	30	30	12	18
Upstream	14	24	7	5	6
Downstream	7	17	7	3	5
Stable Pieces (#)	91	105	73	71	48
Unstable Pieces (#)	10	11	16	26	13

*Piece diameter ≥ 20 inches

[†] Key piece determinations abondoned in 2008, see Methods

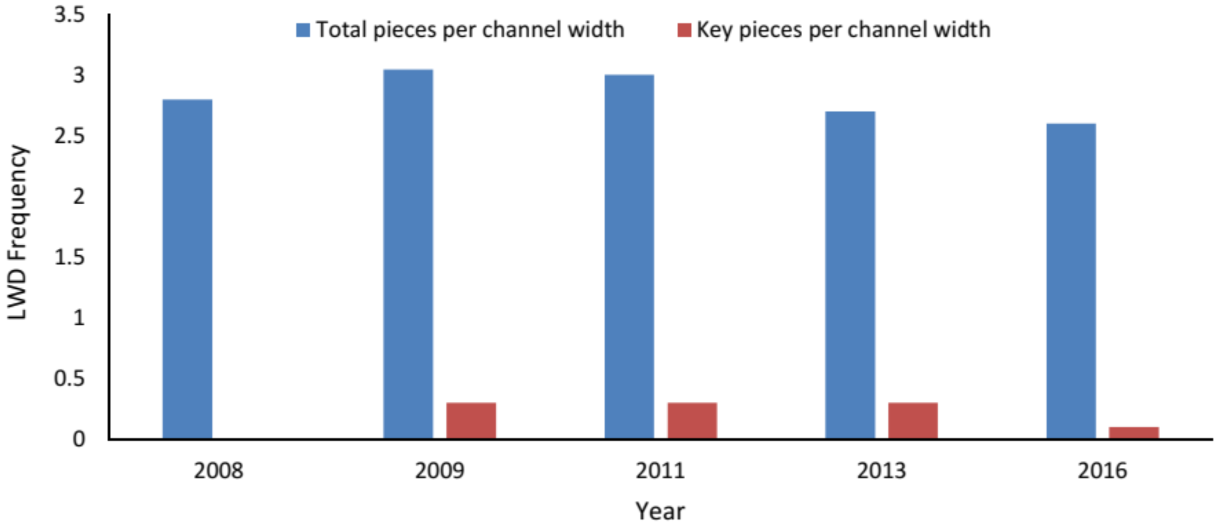

Figure 4-16 Large woody debris (LWD) frequency by year.

Table 4-9 summarizes pool and LWD indices and includes habitat quality ratings using diagnostics developed by the Washington Forest Practices Board (1997), National Marine Fisheries Service (1996), and Montgomery (1995). It's important to point out that these diagnostics were all developed based on conditions typically found in undisturbed forest streams and therefore may not represent realistic target conditions for an urban stream system. Nonetheless, these metrics do provide a means of evaluating the effectiveness of restoration activities over time. Pool percentage maintained a "fair" rating over the course of the project period, while pool spacing shifted from "fair" to "poor," and pool frequency moved from "good" to "fair." LWD frequency remained "good" over the 10-year monitoring period while key piece frequency remained "fair" until 2016 when it shifted to "poor." Overall, no habitat or LWD ratings improved over the monitoring period and a few degraded (**Table 4-9**). Two parameters went unchanged (pool percentage and LWD frequency).

Table 4-9 Habitat quality indices and ratings.

Parameter	Channel Morphology	Habitat Quality			Site Value					Site Rating				
		Good	Fair	Poor	2008	2009	2011	2013	2016	2008	2009	2011	2013	2016
Pool Percentage[1]	< 2% Gradient < 50 ft wide	>55%	40-55%	<40%	54%	52%	47%	47%	40%	Fair	Fair	Fair	Fair	Fair
Pool Spacing[2]	< 2% Gradient < 50 ft wide	<2 cw/pool	2-4 cw/pool	>4 cw/pool	3.7	3.7	4.2	4.9	5.0	Fair	Fair	Poor	Poor	Poor
Pool Frequency[3]	15-20 ft wide	>70 pools/mile	56-70 pools/mile	<56 pools/mile	85.6	85.4	76.8	64.9	64.4	Good	Good	Good	Fair	Fair
LWD frequency[1]	< 50 ft wide	>2	1-2	<1	2.8	3.0	3.0	2.7	2.6	Good	Good	Good	Good	Good
Key piece frequency[1]	Bankfull width < 33 ft	>0.30	0.15-0.30	<0.15	--	0.3	0.3	0.3	0.1	--	Fair	Fair	Fair	Poor

[1]From WFPB (1997)
[2]From Montgomery (1995)
[3]From NMFS (1996)

Although these diagnostics are imperfect (since they are not based on a comparable undisturbed stream channel), they do reveal trends. For example, a common free-formed pool spacing is 5-7 channel widths, but with LWD loading this spacing can be increased or "forced" up to 2-4 channel widths (Leopold et al. 1964). If Cemetery Creek is considered a wood-forced stream, then the pool spacings (which range from 3.7 to 5.0 channel widths/pool) might rank higher on our rating scale, however the downward trend in habitat quality would remain.

4.2.2.5 Discussion

As described previously, just one success criterion was identified for all physical stream monitoring activities in the *Monitoring and Maintenance Plan* (COB 2006). Habitat and LWD survey data were used to assess two parts of this criterion: restored stream channels habitat features will **maintain designed habitat forming functions such as pools** and **LWD loading**. Specific habitat and LWD indices were prescribed to evaluate success, all of which have been summarized in **Table 4-9**.

Using the assigned qualitative success criteria below, two of the pool indices (pool spacing and pool frequency) received a progressively lower quality rating over time, while the third (pool percentage) remained stable. Key piece frequency also declined from "fair" to "poor" but overall LWD frequency was rated as "good" over the course of the project. Therefore, it would appear that the success criterion below was met with respect to LWD loading and was partially met with respect to maintenance of pool habitat.

Success Criteria:

- Restored stream channels habitat features will **maintain designed hydrologic and habitat forming functions such as pools, LWD loading**, suitable spawning areas, and stable banks. **This criterion was partially met with respect to pool habitat. This criterion was met with respect to LWD loading.**

4.2.3 Stream Channels – Spawning Gravel

4.2.3.1 Introduction

As a small tributary, Cemetery Creek is expected to provide suitable spawning habitat for smaller bodied salmonids such as coho, sea-run cutthroat and resident trout. However, larger salmonids such as steelhead, Chinook and chum have also been observed in the stream. Small spawning gravel (≥8 to 64 mm) is most often used by small-bodied salmonids, such as resident trout and anadromous cutthroat trout. Both small and large spawning gravel (≥8 to 128 mm) are used by large bodied salmonids, such as pink, chum, coho, steelhead, and Chinook (Schuett-Hames et al. 1999b). As part of this restoration project, spawning gravels were installed in all of the constructed channels on Cemetery and West Cemetery Creeks.

4.2.3.2 Objectives

The objective of spawning gravel surveys is to assess the availability of potential suitable spawning habitat at the Cemetery Creek restoration site and to document any changes in spawning habitat availability over time. In the *Monitoring and Maintenance Plan* (COB 2006), the following spawning gravel parameters were proposed:

- Suitable spawning areas
- Substrate size distribution

As with all other physical stream channel monitoring identified in the *Monitoring and Maintenance Plan* (COB 2006), just one success criterion was identified:

Success Criteria:

- Restored stream channels habitat features will maintain designed hydrologic and habitat forming functions such as pools, LWD loading, suitable spawning areas, and stable banks.

Spawning gravel survey data will be used to assess one part of this criteria: restored stream channels habitat features will maintain… **suitable spawning areas.**

4.2.3.3 Methods

As with all other physical stream channel monitoring, spawning gravel surveys were conducted along the full length of restored stream channel (**Figure 4-7**). Spawning gravel surveys were conducted following a modified version of the TFW methodology for assessing salmonid spawning habitat availability (Schuett-Hames et al. 1999b). Surveys were conducted by two surveyors working downstream to upstream; all channels within the restoration site were surveyed. Spawning gravel is categorized into two main groups, small spawning gravel (≥8 to 64 mm; minimum area 1 ft^2) and large spawning gravel (≥64 to 128 mm; minimum area 10.8 ft^2). Gravel must meet a minimum patch size to qualify as suitable spawning habitat. A "small patch" must be at least 1 ft^2 and can only be comprised of small gravel. A "large patch" must measure at least 10.8 ft^2 (1 m^2) and can be composed of either small or large gravel.

When a qualifying patch was identified, the dominant gravel size class was determined. The presence of boulders, bedrock or other substrates, such as LWD, in spawning gravel patches was noted. Sub-patches were identified if there were qualifying patches of different gravel size within a larger patch.

To ease identification and measurement of spawning gravel patches as well as avoid disturbing fish during the spawning season, surveys were conducted during low flows before the start of spawning. Surveyors returned during winter base flows (flows representative of spawning conditions) to confirm depth and water velocity criteria. Water depth criteria are: (1) at least 2 inches of water over small gravel patches, and (2) at least 4 inches of water over large gravel patches. For the water velocity criterion to be met, water flow over the spawning gravel patch must be greater than “slack”.

4.2.3.4 Results

Spawning gravel surveys were not completed in 2007 or 2008 due to a lack of staff time, therefore data presented here are for 2009, 2011, 2013 and 2016. **Table 4-10** summarizes all spawning gravel results. At the end of the monitoring period in 2016, the restoration site was providing 1,448 ft^2 of spawning habitat for small-bodied salmonids and western brook lamprey (all patches with small sized gravels); this is a slight increase in habitat compared with 2009, the first year of monitoring (**Figure 4-17**). Large-bodied salmonids, which will use both small and large sized clasts, had access to 1,889 ft^2 of spawning habitat in the restoration site; this represents a decrease in salmonid spawning area compared with 2009 (**Figure 4-17**). The total available spawning area composed of large gravels decreased over time (**Figure 4-18**), as did the number of patches composed of large gravels (**Figure 4-19**). Similarly, the number of patches composed of small gravels decreased over time (**Figure 4-18**), however the available spawning area composed of small gravels increased slightly (**Figure 4-19**). In other words, those patches composed of small gravel became larger but less numerous over time, while patches composed of large gravels became smaller and less numerous (**Figure 4-18**, **Figure 4-19**).

Table 4-10 Spawning gravel patches and size distribution summary.

	2009		2011		2013		2016	
	Small Gravel (≥8 to 64 mm)	Large Gravel (≥64 to 128 mm)	Small Gravel (≥8 to 64 mm)	Large Gravel (≥64 to 128 mm)	Small Gravel (≥8 to 64 mm)	Large Gravel (≥64 to 128 mm)	Small Gravel (≥8 to 64 mm)	Large Gravel (≥64 to 128 mm)
Total # of Spawning Gravel Patches	25	18	16	20	12	13	19	8
Total Surface Area (ft^2)	1331	1455	935	1736	1150	910	1448	444
# Small Patches (at least 1 ft^2)	4	NA	2	NA	1	NA	1	NA
Surface Area of Small Patches (ft^2)	26	NA	12	NA	11	NA	2	NA
# Large Patches (at least 10.8 ft^2)	21	18	14	20	11	13	18	8
Surface Area of Large Patches (ft^2)	1305	1455	924	1736	1139	910	1445	444
Total Lamprey Spawning Area (ft^2)	1331		935		1150		1448	
Total Salmonid Spawning Area (ft^2)	2760		2660		2049		1889	

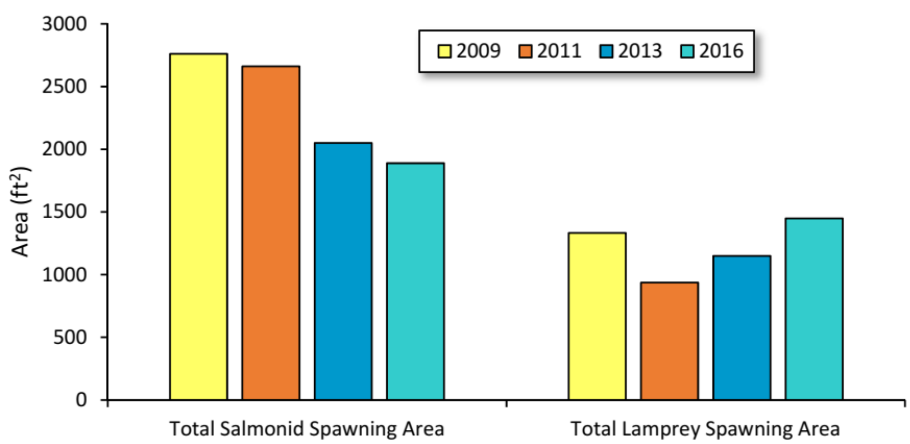

Figure 4-17 Salmonid and lamprey spawning gravel area by year.

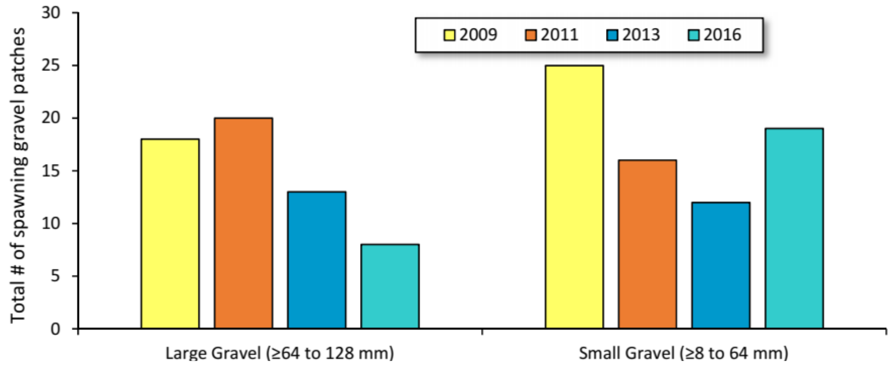

Figure 4-19 Number of large and small spawning gravel patches by year.

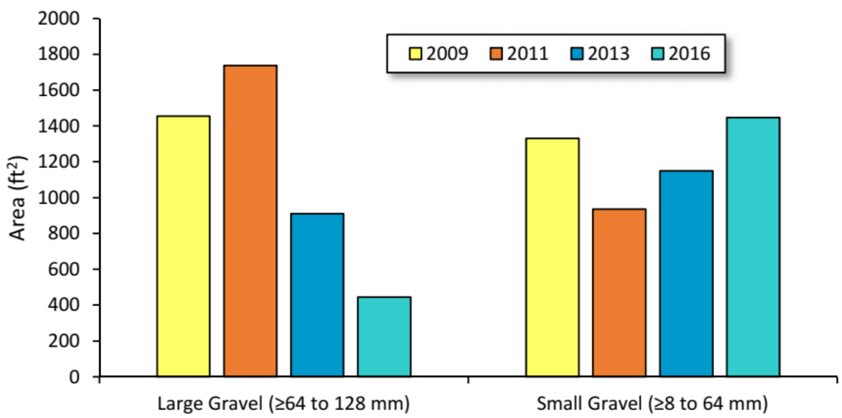

Figure 4-18 Spawning gravel area composed of large and small gravels by year.

4.2.3.5 Discussion

The number, type and size of spawning gravel patches were dynamic; however the overall trend was a decrease in available, suitable spawning habitat, especially for salmonids. Because the "designed" spawning habitat installed at construction was not maintained, and in fact decreased over time, this aspect of the physical stream success criteria was not met:

Success Criteria:

- Restored stream channels habitat features will maintain designed hydrologic and habitat forming functions such as pools, LWD loading, **suitable spawning areas**, and stable banks. **These criteria have not been met with regards to maintenance of designed suitable spawning gravel.**

Similar to discussions under Aquatic Macroinvertebrates and Pond Hydrology, loss of total available salmonid spawning area over the course of the monitoring period was likely caused by sediment deposition from upstream sources. These results led City staff to further investigate the cause and source of fine sediment deposition in the restoration area. The *West Cemetery Creek Sediment Management Alternatives and Feasibility Study* completed by Element Solutions in 2013 identified several primary contributing sources as well as a suite of potential management alternatives.

4.2.4 Recommendations

The City is designing the West Cemetery Creek restoration project and Wildflower bridge replacement, addressing the three top priority alternatives identified in the *West Cemetery Creek Sediment Management Alternatives and Feasibility Study*. The projects are scheduled for construction in 2021 and will protect and restore natural processes in the Whatcom Creek corridor by arresting excessive sediment migration and increasing bank stability. No further actions are recommended.

4.3 WATER QUALITY

The goal of water quality monitoring was to assess whether or not the streams and ponds provide suitable year-round habitat conditions for native salmonids, and to document if the Washington state water quality standards are met. There are four primary water quality parameters of concern for salmonids: dissolved oxygen, specific conductivity, pH and temperature. In addition, one parameter, fecal coliform, was measured to document conditions that may affect human health.

According to WAC 173-201A-600, the Cemetery Creek restoration area has a designated aquatic life use category of “Core Summer Salmonid Habitat” characterized by: “summer (June 15 - September 15) salmonid spawning or emergence, adult holding, and use as important summer rearing habitat by one or more salmonids.” Other aquatic life uses in this category include “spawning outside of the summer season, rearing, and migration by salmonids,” all of which have been observed at the Cemetery Creek restoration area. All applicable Washington state water quality standards are based on this designated use.

4.3.1 Dissolved oxygen, pH & Conductivity – Discrete

4.3.1.1 Introduction

Dissolved oxygen: Aquatic organisms require oxygen to survive. Oxygen in water is measured in its dissolved form, dissolved oxygen (DO). Dissolved oxygen varies directly in response to atmospheric pressure and water temperature. Higher atmospheric pressure results in higher oxygen solubility in water and higher DO. Higher temperatures result in lower oxygen solubility and lower DO. Photosynthesis by aquatic plants and the turbulence of running water both increase DO. Dissolved oxygen levels vary seasonally. Dissolved oxygen is also affected by inputs of pollution: feces from animals and failing septic systems, grass clippings, and urban and agricultural runoff all contain organic matter that is decomposed by microorganisms, which consume oxygen in the decomposition process and can thus reduce DO.

Washington state aquatic life DO criteria are based on discrete *point-in-time* measurements. The standard for Cemetery Creek is 9.5 mg/L, where DO concentrations are not to fall below this criterion at a probability frequency of more than once every ten years on average (WAC 173-201A-200). Cemetery Creek has been listed as a Category 5 water body for DO levels in the Washington state Water Quality Assessment since 2004 (Ecology 2019). Category 5 represents the state's 303(d) list of impaired waters. Washington state standards for DO represent optimal conditions for salmonid growth in streams. In the restoration site ponds, where DO levels are important for rearing juvenile salmonids, lethal and sublethal DO levels can be instructive guidelines for habitat suitability. Spence et al. (1996) recognized 3.3 mg/l as a lethal DO level for salmonids, with DO levels of 5.0 mg/l reducing salmonid growth.

pH: The pH of a stream can affect both the physiology and behavior of organisms living in the water. The chemical conditions in acidified (low pH) waters are intolerable to some aquatic creatures or have sublethal physiological effects; some animals may actively avoid such waters. There are also indirect effects. The solubility and availability of nutrients can be affected by pH. Heavy metals can be more soluble at lower pH, and therefore more bioavailable and consequently more toxic. A change in pH can indicate the presence of pollution. Organic matter introduced into streams during periods of low flow can cause low pH values. Lime used for industrial applications or applied to agricultural lands, lawns, and golf courses can be washed into streams during storm events, raising pH. Additionally, photosynthesis, respiration, and decomposition also affect pH levels. The pH of uncontaminated rainwater in equilibrium with atmospheric carbon dioxide is 5.6; normally the acids in rainwater are neutralized as the rainwater passes through soil (Allan 1995). In urbanized areas much of the precipitation falls onto impervious surfaces and flows directly into rivers and streams. Runoff from these surfaces may increase in acidity before entering streams (Mason 1989). Regardless of the extent of impervious surfaces in an urban area, the acid-neutralizing mechanisms in the soil may not be able to keep pace during heavy continuous rain. During such events rainwater runs over the surface instead of filtering through the soil and enters streams with its chemical composition little changed (Mason 1989). The effects of high pH on fish include damage to outer surfaces like gills, eyes, and skin; an inability to dispose of metabolic wastes, and possible death. Low pH inhibits olfaction in salmonids, and therefore diminishes their ability to avoid predators (William 2018). Extreme pH may also increase the toxicity of other substances.

Ecology aquatic life pH criteria are represented as the negative logarithm of the hydrogen ion concentration. Washington state aquatic life criteria for Cemetery Creek is within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units. (WAC 173-201A-200). pH measurements above or below these criteria do not meet the Washington state standard. Cemetery

Creek has been listed as a Category 2 water body in the Washington state Water Quality Assessment since 2004 (Ecology 2019). Category 2 represents water bodies where there is some evidence of a water quality problem, but not enough to show persistent impairment or require production of a water quality improvement project.

Conductivity: Specific conductivity (SpC) in stream water can be extremely variable. Natural variation is due mainly to the type of rocks weathered in the watershed, how much precipitation falls in the watershed, the chemical composition of the precipitation (which is largely dependent on distance from the ocean) and the relative contribution of ground water to total flow (Allan 1995). Warmer water temperatures also increase conductivity. Groundwater typically contains higher concentrations of ions than surface water because of longer contact with rocks containing minerals (Allan 1995). Stream flow consists of a combination of both surface water and groundwater, with their relative influence changing seasonally. During drier periods SpC may increase as stream flow becomes more dependent on groundwater inputs. Evaporation can also contribute to increased conductivity levels by concentrating ions in water. In urban settings, pollution from point and non-point sources can contribute to the amount of dissolved ions in water, increasing SpC. Conductivity is useful as a general water quality measurement. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements.

Significant changes in conductivity measurements can indicate contamination from point and non-point pollution sources. Washington state Department of Ecology has not specified standards for SpC, and therefore this metric cannot be used to assess the original monitoring success criteria. However, the U.S. Environmental Protection Agency (EPA) has designated a range that generally supports good mixed fisheries; this range is between 0.150 and 0.500 mS/cm (U.S. EPA 1997). Although the conductivity of rivers in the U.S. ranges from 0.050 to 1.500 mS/cm, conductivity outside the above range could indicate that water is not suitable for certain species of fish or macroinvertebrates (U.S. EPA 1997).

4.3.1.2 Objectives

In the *Monitoring and Maintenance Plan* (COB 2006), the objectives of water quality monitoring were to document that streams and ponds provide suitable year-round habitat conditions for native salmonids, ensure that Washington state water quality standards were met, and create temporal documentation of water quality data. The following water quality success criteria were established for all ponds and streams within the restoration area:

Success Criteria:

- Water temperature, **pH**, and **dissolved oxygen** in restoration sites will meet current Washington state water quality standards during the 10-year monitoring period.

Discrete (*point-in-time*) water quality measurements will be used to assess whether or not Washington state water quality standards were met during the 10-year monitoring period for the following parameters: **pH** and **dissolved oxygen.** Discrete temperature data, however, cannot be used to determine compliance with Washington state standards, which are based on the 7-day average of daily maximum temperatures (7-DADMax). Therefore, **Section 4.3.2** presents continuous temperature data for this purpose. Discrete conductivity data is also presented here, however it cannot be assessed relative to Washington state standards, because state standards do not exist for this parameter.

4.3.1.3 Methods

Sampling occurred monthly from February 2007 to June 2008, but it was noted that summer water temperatures and DO levels were not meeting state standards. Therefore, beginning in 2008, the protocol was modified to increase sampling to every two weeks during the summer season (June to September), returning to a monthly sampling frequency for the remainder of each year. This modified sampling schedule was continued through the duration of the monitoring period during all designated monitoring years (eg. years 1, 2, 3, 5, 7, and 10).

Three stations were designated per pond, for a total of nine pond water quality stations (**Figure 4-20**). Water quality parameters were measured at 0.5 foot vertical intervals from the surface to construct a depth profile at each pond station. Five stream sampling stations were also established (**Figure 4-20**). Stream data was collected in the thalweg at mid-depth in the water column. Station SWQ4 was moved upstream beginning on February 4, 2008 since its previous location closer to the West Pond was frequently backwatered. The new sampling site is indicated on the map in **Figure 4-20**.

Discrete measurements of water temperature, DO, pH, and SpC were monitored monthly in each of the ponds and tributaries of Cemetery Creek within the restoration area using a multiparameter meter; from 2007 to 2013 a Hydrolab Quanta meter was used, and in 2016 a YSI Pro meter was used. A multiparameter meter measures multiple conventional water quality parameters *in-situ* and simultaneously. Before recording each measurement, the meter was allowed to equilibrate for at least one minute, or until DO (which tends to exhibit the greatest fluctuations) had stabilized. The meter was calibrated before each survey session and audited before and after sampling to ensure data accuracy. Post-sampling audits that did not meet the QC standards were noted, and the data were flagged or omitted. Calibration protocols for both the Hydrolab Quanta and YSI Pro are provided here in **Appendix M.**

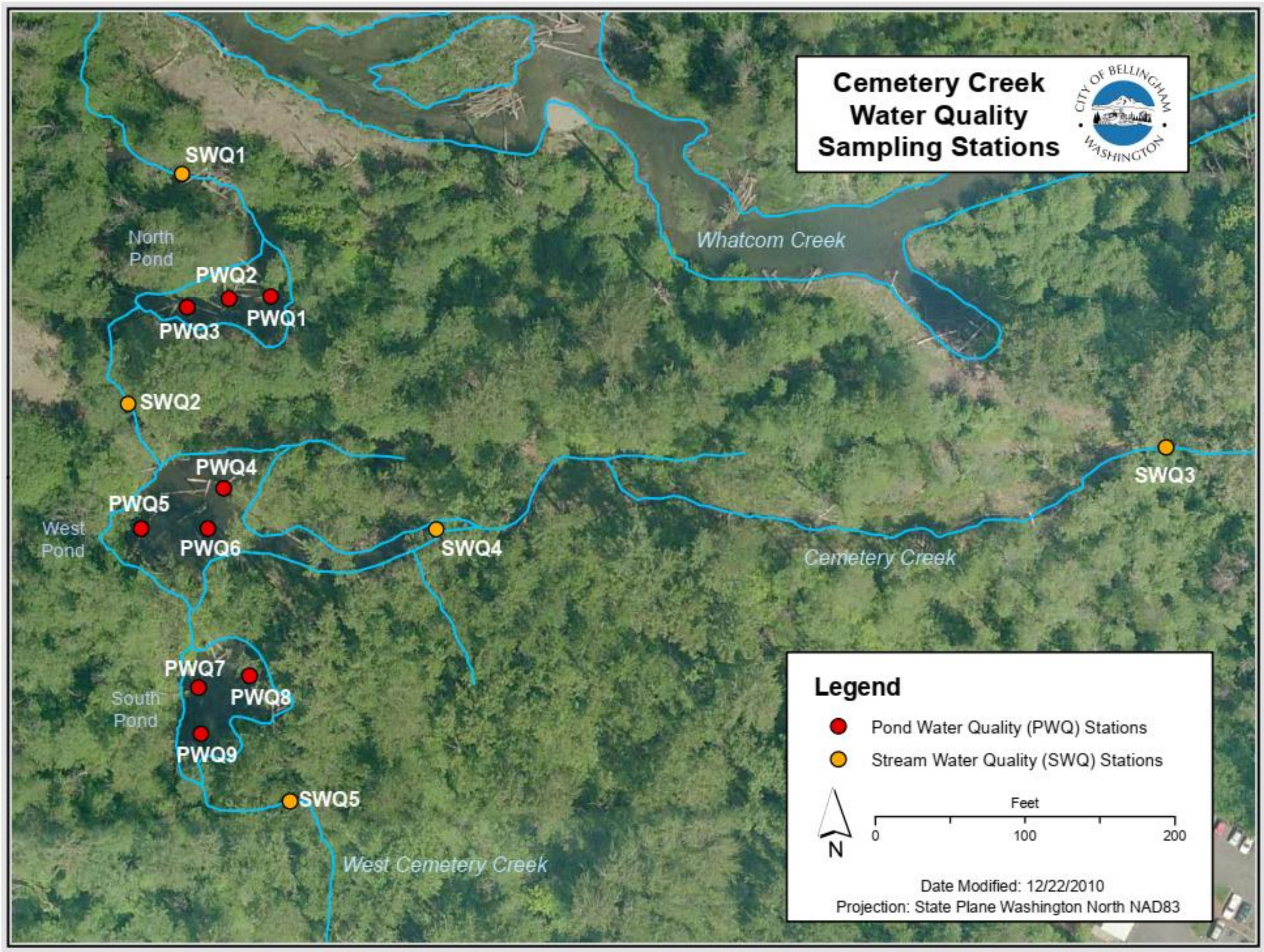

Figure 4-20 Map of Cemetery Creek water quality stations.

4.3.1.1 Results

Charts representing all discrete water quality measurements (all dates, parameters, depths, and stations) have been compiled here in **Appendix N**. All parameters (water temperature, pH, DO, and conductivity) have been plotted along with the relevant Washington state Water Quality standards, where applicable. Additionally, estimated discharge ("synthesized flow[8]") has been plotted on a secondary axis to provide seasonal context. Typically, the wettest months of the year occur between November 1 and April 31 and the driest months occur between May 1 and October 31. During wet

[8] **Synthesized flows**: There is no continuous monitoring of flow on Cemetery Creek, so flows have been synthesized from daily average values measured at the City of Bellingham's Padden and Chuckanut Creek gauge sites. Neither of these drainages are directly comparable to Cemetery Creek in terms of geomorphology and development: Padden contains a lake and Chuckanut is largely undeveloped. However, these creeks are comparable to Cemetery Creek in terms of climate, precipitation, size, and average level of development, and thus the average unit value of runoff for all these is considered to reasonably represent Cemetery Creek. Flow per unit drainage area is calculated for each gauged basin in order to provide an estimate of Cemetery Creek flows. These "synthesized flows" are included on water quality charts to provide context for observed seasonal patterns.

months, soil moisture content is generally high and surface water storage capacity decreases, resulting in increased water runoff. Consequently, during the wet season flows in Cemetery Creek tend to be flashy. During the dry season, flows respond more moderately to precipitation.

Dissolved oxygen: Dissolved oxygen levels in the streams and ponds varied consistently with season: high DO levels during the wet winter season and low DO levels during the dry summer season (**Figure 4-21** and **Figure 4-22**).

In the ponds, dissolved oxygen also decreased with depth, especially in the summer (**Appendix N**). Dissolved oxygen levels are determined by a myriad of factors such as temperature, turbulence, photosynthesis, decomposition, and respiration. The winter wet season brings lower ambient temperatures and higher flows with increased turbulence that aerates the water, especially near the surface. For these reasons, the lowest recorded DO levels occurred at depth in the ponds during the summer months where lack of atmospheric exchange combined with high temperatures, low photosynthesis, and decomposition of organic matter consistently lowered oxygen levels well below the state standards, with regular annual excursions into potentially lethal ranges (i.e. below 3.3mg/L) (**Appendix N, Figure 4-21**). The South Pond was consistently cooler in all years except 2016, which may have contributed to the decreased frequency of DO excursions into the lethal range when compared with the other two ponds. The South Pond also became markedly more shallow over time, and these shallower waters likely retained better atmospheric oxygen exchange as well as the benefit of photosynthetic oxygen during daylight hours.

Dissolved oxygen followed a similar seasonal pattern at the stream monitoring sites, and all stream stations exhibited similar DO levels, except SWQ5 which consistently exhibited higher DO and lower temperature readings (**Figure 4-23**). Stream station SWQ5 is located on West Cemetery Creek, just upstream of the South Pond (**Figure 4-20**). This location receives drainage from a large upstream wetland complex, which may contribute to the higher DO and lower temperatures relative to the other stream stations.

As shown in **Table 4-11**, during the summer months (June-September) DO measurements within the North, West and South ponds failed to meet state water quality standards 100%, 95% and 97% of the time, respectively. In fact, over the course of the entire 10-year monitoring period between 1,269 and 2,332 separate DO measurements were recorded per pond, and 14% to 22% of these records were below the lethal limit of 3.3 mg/L (Spence 1996) (**Table 4-11**). Similarly, most stream water quality measurements did not meet Washington state water quality standards for dissolved oxygen during the summer months, with exceedances occurring from 88% to 100% of the time (**Table 4-12**). Lethal conditions were less frequent at stream stations, where turbulence and flow maintained better oxygen saturation levels than the deep and stagnant parts of the ponds (**Figure 4-22** and **Table 4-12**). **Figure 4-22** shows that the lowest summer DO levels in the streams occurred in 2019, when the daily average of all stream data dipped below the lethal limit on two occasions.

pH: In general, pH decreased with depth, a common pattern in lakes and ponds where carbon dioxide tends to accumulate at depth (Appendix N). Photosynthesis, respiration, decomposition and other chemical reactions can cause pH stratification in freshwater ponds, along with temperature, rainwater, or pollutant inputs. In fact, a rain event in January 2009 caused pH to plummet sharply in the South and West ponds, particularly at station PWQ4 (**Figure 4-20**) which reached an extreme low of 6.5 near the surface (**Figure 4-25**). This drop in pH was likely caused by the abrupt introduction of rainwater (usually between 5.5 and 6.0), as well as the probable introduction of large amounts of organic matter during the flood event, which can also lower pH.

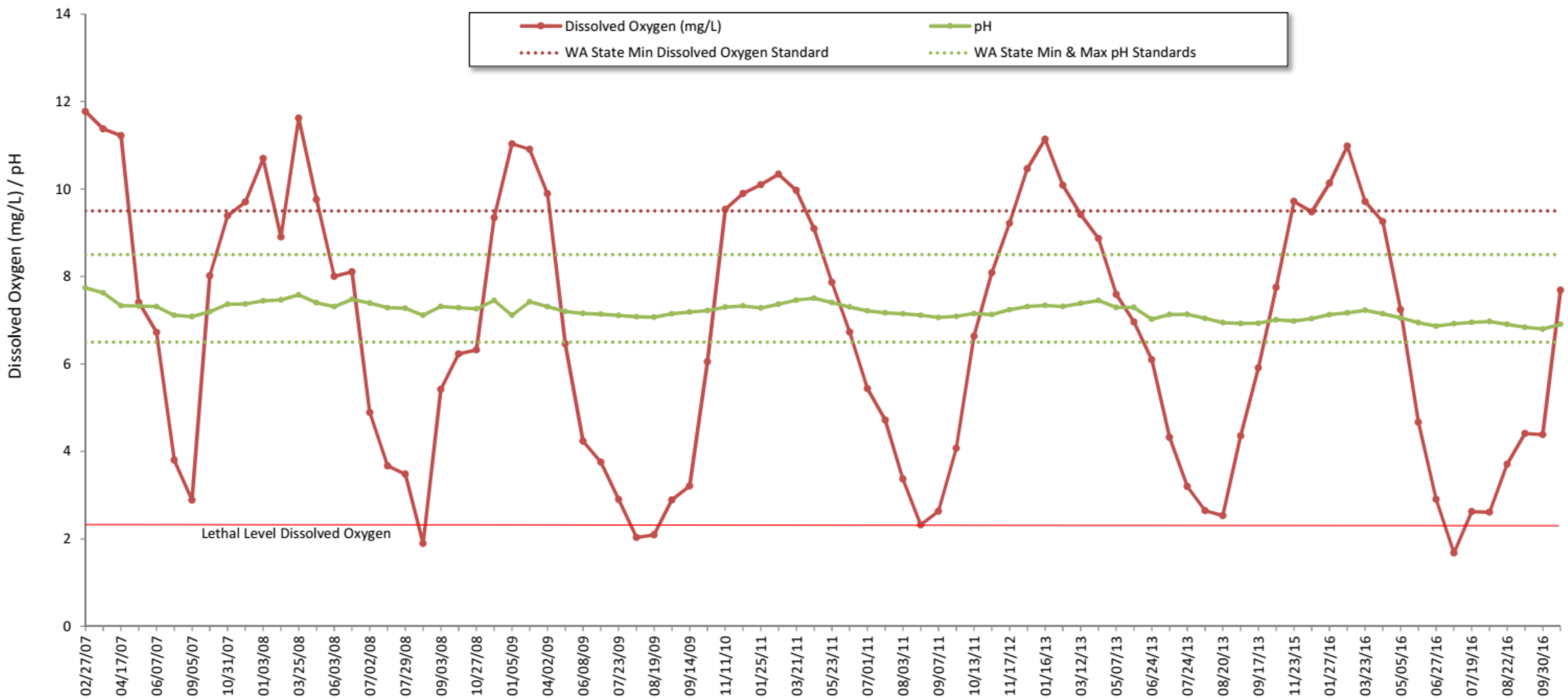

Figure 4-21 Daily average (across all pond stations) of discrete DO & pH pond water quality data

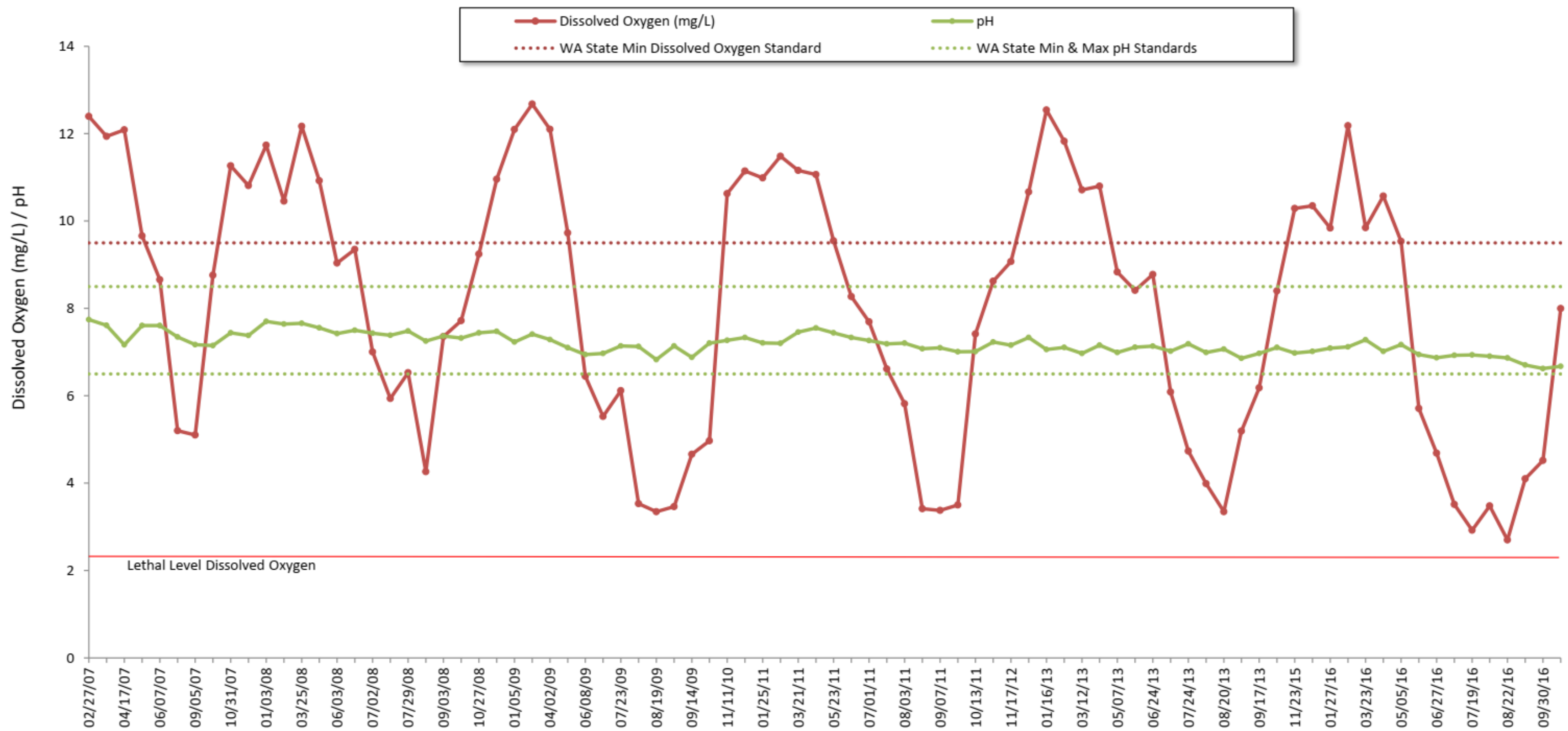

Figure 4-22 Daily average (across all stream stations) of discrete DO & pH stream water quality data.

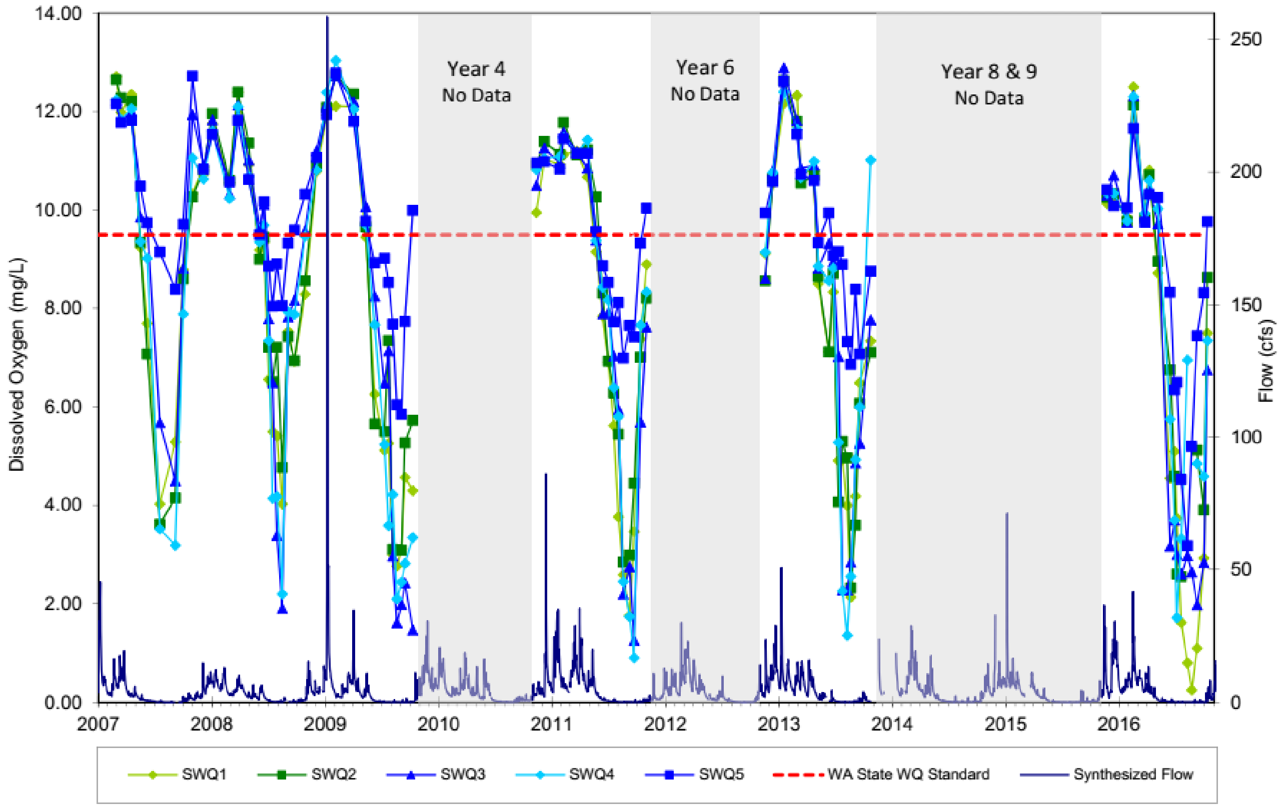

Figure 4-23 Discrete dissolved oxygen data from each stream station.

Table 4-11 Summary of pond water quality exceedances by pond.

	North Pond			West Pond			South Pond		
	SpC	DO	pH	SpC	DO	pH	SpC	DO	pH
Total Measurements	1483	1482	1482	2333	2332	2330	1268	1269	1269
Total Exceedances[8]	908	921	5	1494	1611	0	1158	898	0
% Total Exceedances	61%	62%	0%	64%	69%	0%	91%	71%	0%
Summer[9] Measurements	617	617	617	1086	1086	1086	564	564	564
Summer Exceedances	18	617	4	107	1033	0	27	549	0
% Summer Exceedances	3%	100%	1%	10%	95%	0%	5%	97%	0%
Lethal Measurements		329			490			178	
% Lethal Measurements		22%			21%			14%	

[9] An "Exceedance" is a measurement that does not meet the following water quality standards:

- ▪ SpC standard is between 0.150 and 0.500 mS/cm (U.S. EPA 1997).
- ▪ DO standard is >9.5 mg/L (WAC 173-201A-200), and <3.3 mg/L may be lethal (Spence 1996).
- ▪ pH standard is between 6.5 and 8.5 (WAC 173-201A-200).

Table 4-12 Summary of stream water quality exceedances by station.

	SWQ1			SWQ2			SWQ3			SWQ4			SWQ5		
	SpC	DO	pH	SpC	DO	pH	SpC	DO	pH	SpC	DO	pH	SpC	DO	pH
Total Measurements	84	84	83	82	82	82	84	84	84	83	83	83	84	84	84
Total Exceedances[8]	29	54	6	27	50	0	38	47	1	38	49	0	6	39	0
% Total Exceedances	35%	64%	7%	33%	61%	0%	45%	56%	1%	46%	59%	0%	7%	46%	0%
Summer[9] Measurements	41	41	40	39	39	39	41	41	41	40	40	40	41	41	41
Summer Exceedances	3	41	5	1	39	0	4	38	0	4	39	0	2	36	0
% Summer Exceedances	7%	100%	13%	3%	100%	0%	10%	93%	0%	10%	98%	0%	5%	88%	0%
Lethal Measurements		11			8			19			12			1	
% Lethal Measurements		13%			10%			23%			14%			1%	

The vast majority of pH measurements recorded in both the streams and ponds during the monitoring period fell within the Washington state aquatic life criteria for Cemetery Creek of pH 6.5 to 8.5 (**Table 4-11** & **Table 4-12**). Four out of the five total exceedances recorded for the ponds occurred on June 24, 2013 at PWQ1, with the single additional exceedance measured at the same site on November 1, 2011 (**Table 4-11** & **Appendix N**); this is out of a total of 5,081 pH measurements in the North, West and South Ponds combined (<0.1%). At the stream sites, there were seven recorded pH exceedances, six of which occurred at SWQ1 during the summer months (August & September), with one additional exceedance on October 11, 2016 at SWQ3 (**Table 4-12** & Appendix N); this is out of a grand total of 416 pH measurements at all of the stream stations combined (<2%).

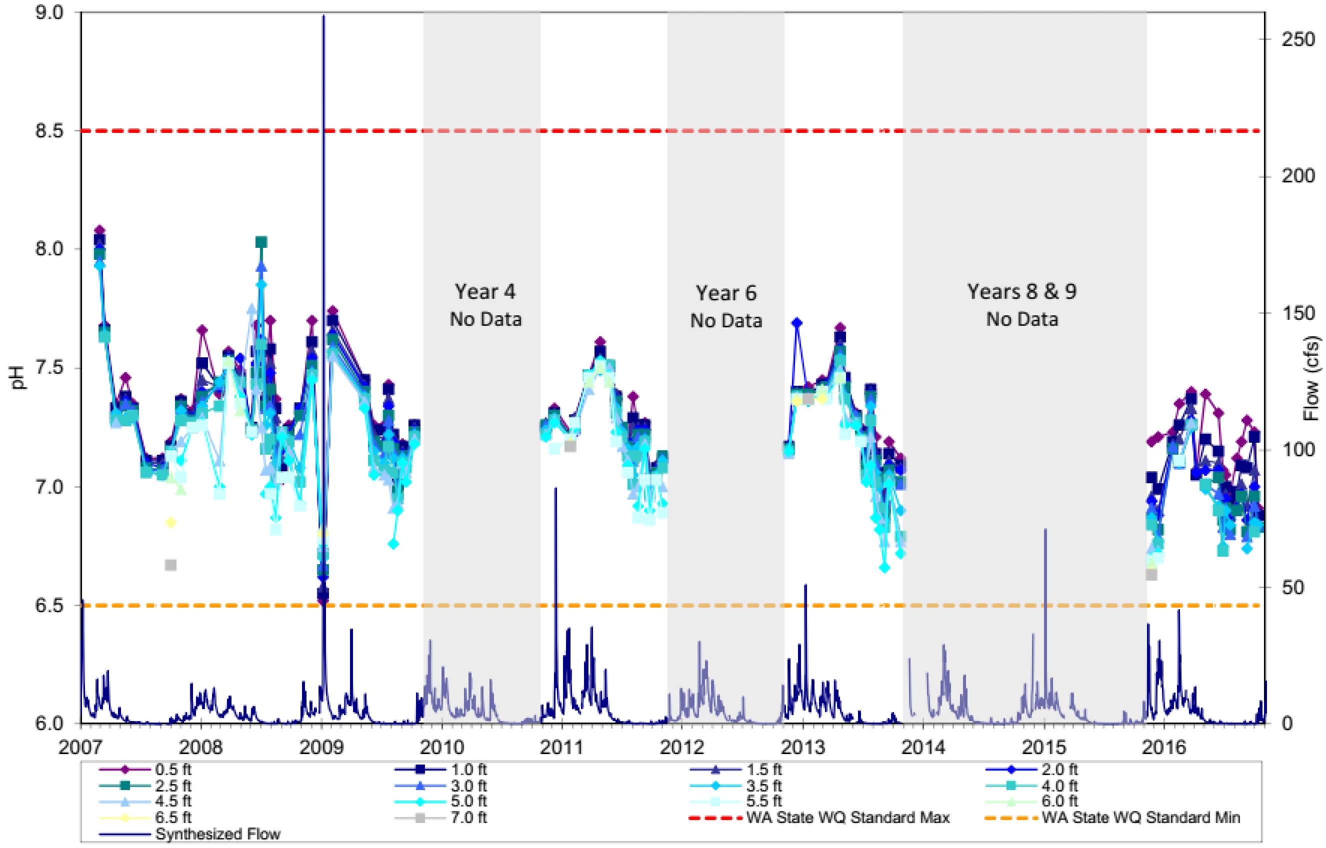

Figure 4-25 Discrete pH data at PWQ4 in the West Pond.

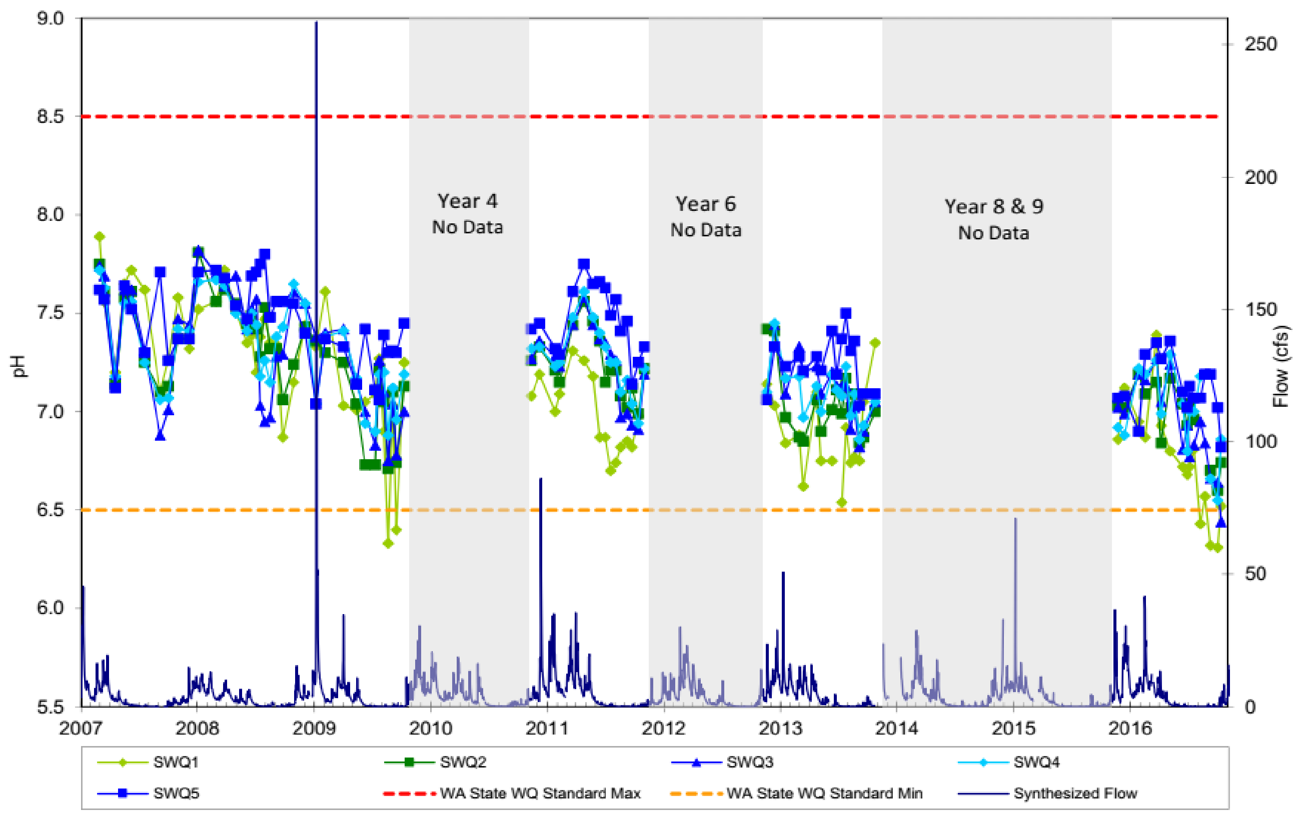

Figure 4-24 Discrete pH data from all stream stations.

Conductivity: Although conductivity is dependent upon many factors, each system tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison. The EPA has identified the range from 0.150 and 0.500 mS/cm as generally supportive of good mixed fisheries (U.S. EPA, 1997), and the Cemetery Creek streams and ponds typically ranged from 0.100 to 0.300 mS/cm. In fact, **Table 4-11** and **Table 4-12** show that only 3% to 10% of all SpC readings at stream and pond stations were outside of the EPA "fish friendly" range. However, excursions outside of this range did occur. In the West Pond, SpC spiked in early years (2007-2009) up to a high of 1.20 mS/cm, while SpC in the South Pond was more tightly constrained, generally ranging from 0.100 to 0.300 mS/cm (**Appendix N**). Conductivity at the stream stations typically ranged between 0.10 and 0.30 mS/cm except for regular spikes up to 0.430 mS/cm around the month of August at the upstream end of the Cemetery Creek mainstem (SWQ3), as well as one anomalously high spike at the downstream end of the project (SWQ1) that persisted for the month of August in 2016 (**Figure 4-20**, **Figure 4-26**). Conductivity in all of the ponds showed a pattern of spiking during the summer and then again with the onset of the wet season, particularly at greater depths (**Appendix N**); this may be attributable to decreased flow and increased evaporation rates in the summer, density stratification, and a "first flush" effect at the start of the wet season.

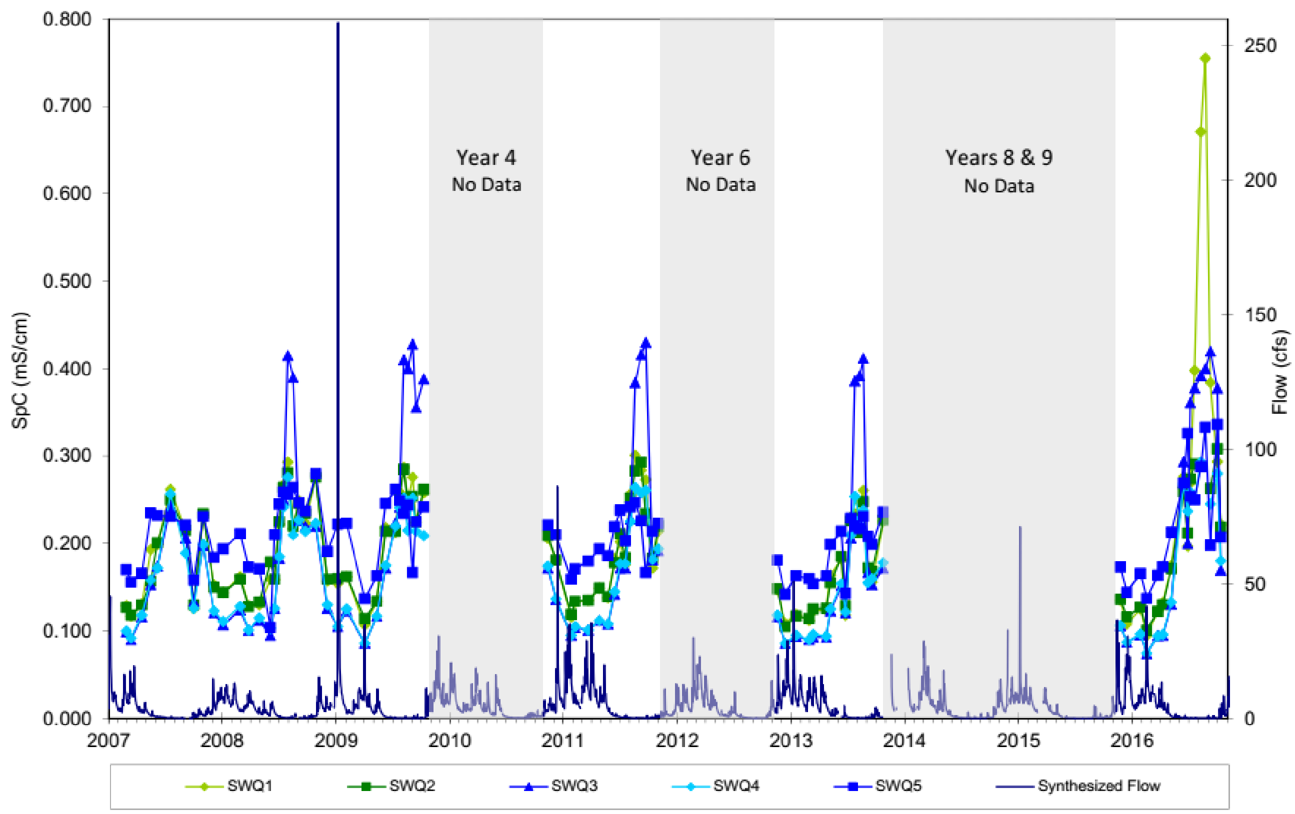

Figure 4-26 Specific conductivity at stream stations.

4.3.2 Temperature – Continuous

4.3.2.1 Introduction

Temperature: Water temperature is an important measure of water quality because all aquatic organisms are dependent upon certain temperature ranges for optimal health. Oxygen solubility is directly correlated with temperature, and temperature impacts the physiology and behavior of aquatic organisms. Salmonids are especially sensitive to high temperatures.

Unlike DO, pH and conductivity, the Washington state aquatic life temperature criterion for "Core Summer Salmonid Habitat" is based on the 7-day average of the daily maximum temperatures (7-DADMax) and therefore cannot be assessed using the discrete measurements presented in **Appendix N**. This criterion is based on daily *maximum* temperatures because aquatic ecosystem health is most compromised by high water temperature excursions. Daily maximum temperatures are derived from continuous monitoring data collected with a sampling interval of 30 minutes or less. The highest allowable 7-DADMax for Cemetery Creek is 16°C (60.8°F), and temperatures are not to exceed this standard more than once every ten years on average (WAC 173-201A-200). Additionally, Cemetery Creek has a more stringent temperature criterion that is applied seasonally to further protect salmonid spawning and egg incubation. This "Supplemental Spawning" criteria is 13°C (7-DADMax) from February 15 to June 15 in the Cemetery Creek Restoration area and Whatcom Creek at Salmon Park (**Figure 4-27**).

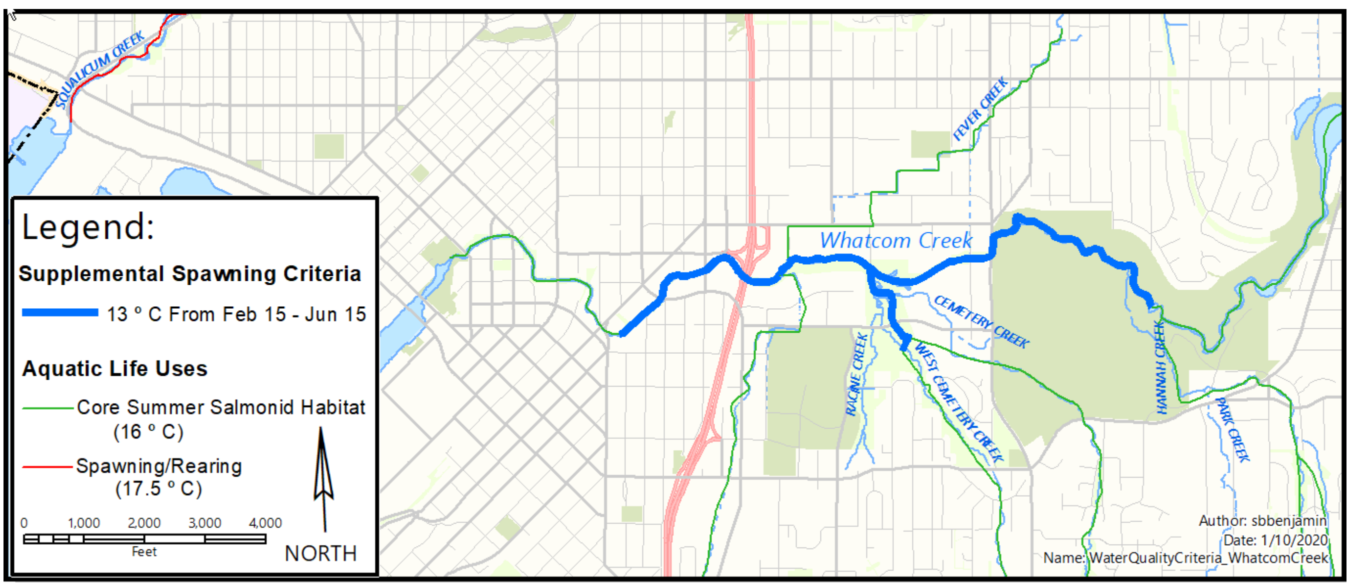

Figure 4-27 State aquatic life use and supplemental spawning temperature criteria for Whatcom Creek.

Cemetery Creek was listed as a Category 5 water body for temperature exceedances in the Washington state Water Quality Assessment (Ecology 2019) from 2004 until 2011, when an EPA-approved "Total Maximum Daily Load" (TMDL) was published for Whatcom, Squalicum and Padden Creeks in Bellingham: *Whatcom, Squalicum, and Padden Creeks, Temperature Total Maximum Daily Load; Water Quality Improvement Report* (Hood 2011). Today, Cemetery Creek is listed as a Category 4a waterbody. Category 4a represents the state's 303(d) list of impaired waters that already have an EPA-approved TMDL plan in place and implemented, in this case the above temperature TMDL.

4.3.2.1 Objectives

The stated objective of all water quality monitoring within the Cemetery Creek streams and ponds was to "document that ponds provide suitable year-round habitat conditions for native salmonids" (COB 2006), and the following success criteria were established:

Success Criteria:

- Water **temperature**, pH and dissolved oxygen in restoration sites will meet current Washington state water quality standards during the 10-year monitoring period.

However, as previously mentioned in **Section 4.2.1.2**, Washington state water quality standards for pH and dissolved oxygen are expressed as discrete *point-in-time* criteria; whereas state **temperature** criteria are expressed as a 7-day running average of daily maximum temperatures (7-DADMax). 7-DADMax values are derived from continuous monitoring datasets. Therefore, this section is devoted to assessing the continuous 7-DADMax temperature patterns as compared with state standards.

4.3.2.1 Methods

Beginning in 2008, continuous temperature loggers were installed at the outlets of each of the three ponds from June to September during all monitoring years (2008, 2009, 2011, 2013, 2016) (**Figure 4-28**). The summer months were targeted since Washington state temperature standards are based on maximum temperatures, which occur during the summer season. Continuous temperature loggers were not installed in stream reaches because low summer flows would have left loggers subaerial. Loggers were programmed to collect temperature every 30 minutes. Each water logger was paired with a nearby ambient air temperature logger. Air temperature loggers were secured in shaded areas as close as possible to the location of water temperature loggers. Water temperature loggers were secured in the ponds by attaching the logger to the inside of a piece of 3-inch diameter PVC pipe secured to a piece of rebar pounded into the sediment. The rebar anchored the logger in place, while the PVC shaded the logger from direct sunlight. The PVC pipe was oriented parallel to the direction of flow.

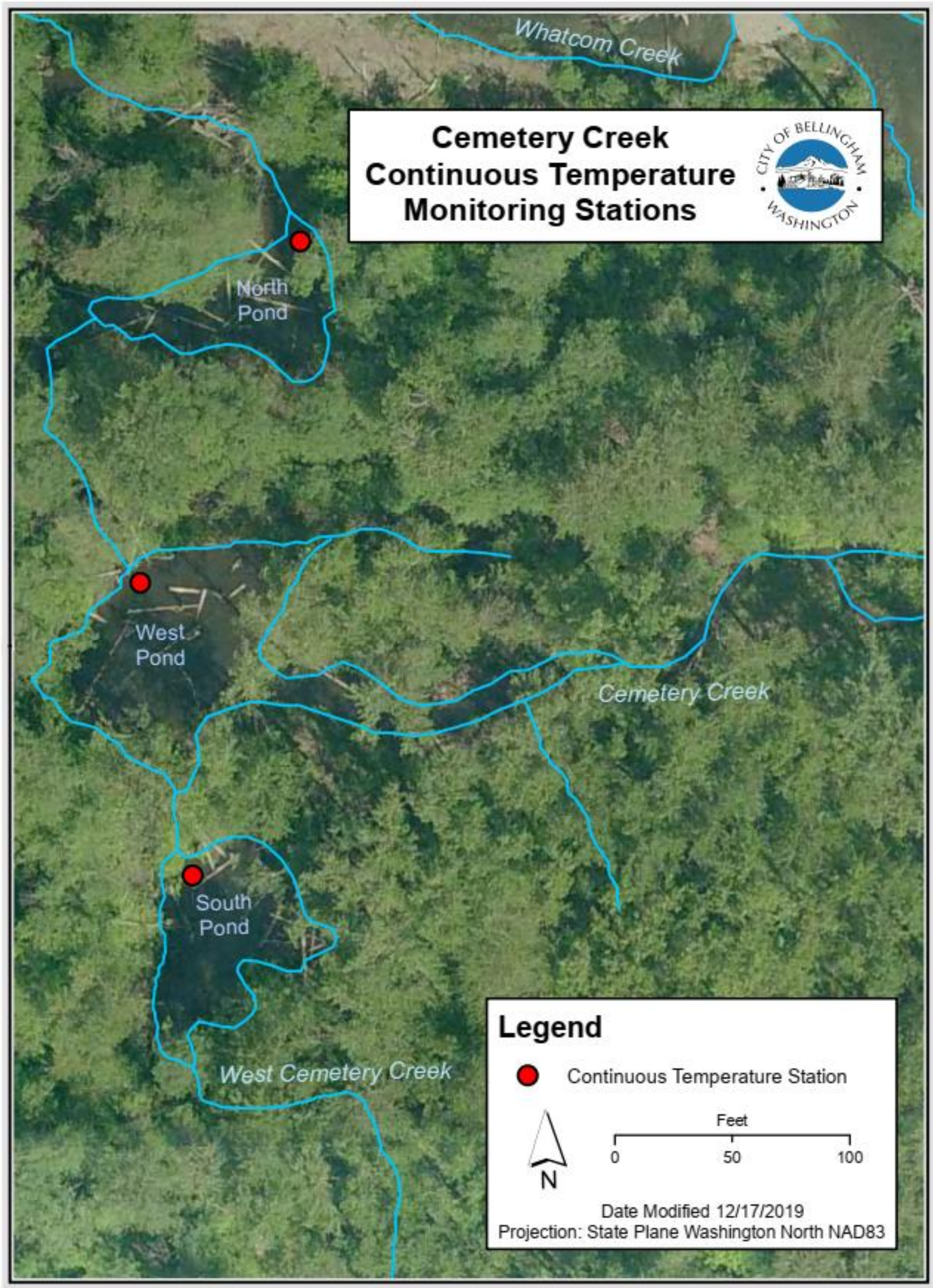

Figure 4-28 Map of continuous temperature stations in the Cemetery Creek ponds.

Loggers were checked and downloaded approximately every two weeks. During these data retrieval visits, both air and water temperature loggers were compared against a calibrated field thermometer as a periodic quality assurance and quality control measure. These checks verified that the loggers were performing according to specifications and provided a log of verified temperatures to be used for troubleshooting purposes during post-season calibration checks. Detailed procedures are available in Appendix O: *Protocol for Continuous Temperature Monitoring Data Retrieval and Maintenance*. Temperature logger field sheets are also available in Appendix O. All continuous temperature loggers and handheld field thermometers were also calibrated prior to deployment and re-checked at the end of each season according to the *Protocol for Continuous Temperature Monitoring Calibration and Quality Control Procedures* available in Appendix O.

4.3.2.1 Results

Continuous temperature data is required in order to calculate 7-DADMax temperatures to determine compliance with Washington state water quality standards. While water temperatures vary diurnally and seasonally, with ambient air temperatures driving these oscillations, the 7-day running average (7-DADMax) smooths these fluctuations. Table 4-13 summarizes all 7-DADMax temperatures for the three ponds during all monitoring years. No continuous temperature loggers were installed at the stream stations. Average water depth at the three continuous temperature pond stations was 2.3 feet, with an average tidbit logger depth of 1.4 feet (**Table 4-13**). Temperature exceedances occurred during all years at all pond stations, however the South Pond experienced fewer days with 7-DADMax temperature exceedances, as well as fewer days when minimum temperatures exceeded state standards

Table 4-13 Continuous temperature indices for Cemetery Creek ponds.

	North Pond					West Pond					South Pond				
	2008	2009	2011	2013	2016	2008	2009	2011	2013	2016	2008	2009	2011	2013	2016
Average water depth (ft)	2.66	2.27	2.25	2.77	2.93	2.32	2.17	2.33	2.51	1.84	2.39	2.06	2.17	1.93	1.84
Average tidbit depth (ft)	1.55	1.33	1.39	1.94	2.1	1.35	1.32	1.44	1.67	1.94	1.36	1.13	1.08	0.71	1.22
Maximum 7-DADMax (°C) water temperature	18.67	21.97	17.8	20.54	25.02	18.94	22.96	18.77	20.39	25.02	17.34	20.16	16.95	18.15	22.21
Average diurnal water temperature fluctuation (°C)	1.51	1.22	1.03	1.64	1.32	1.56	1.55	1.09	1.66	2.58	1.08	1.10	0.79	1.42	1.86
% of summer days exceeding WA State WQ Standards	48%	88%	60%	74%	78%	48%	87%	67%	73%	87%	22%	43%	25%	71%	59%
# of days where minimum daily water temperature exceeds 16°C	37	55	24	79	75	37	49	39	77	71	8	25	10	38	53

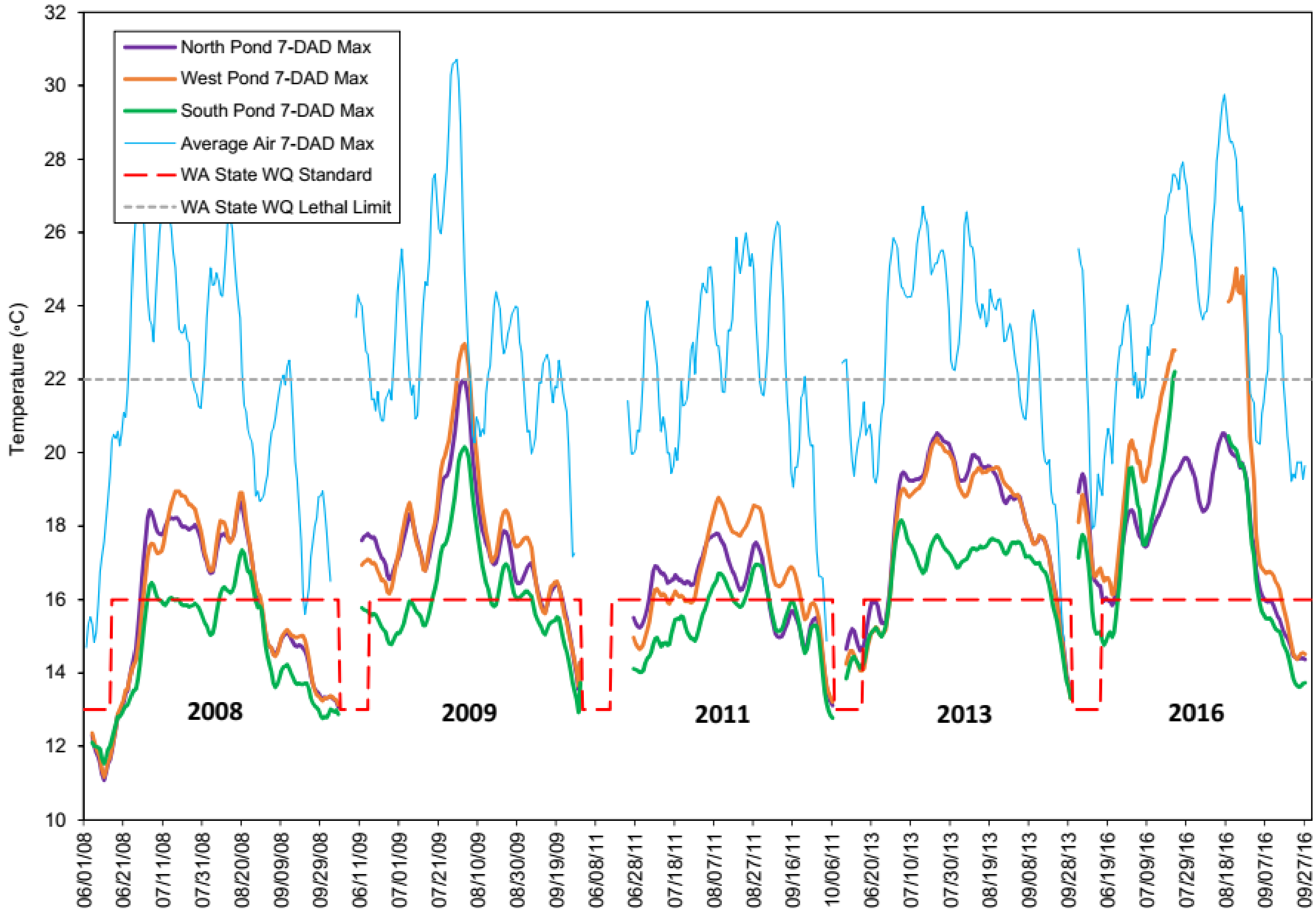

Figure 4-29 Continuous temperature (7-DADMax) in the Cemetery Creek ponds.

In fact, water temperatures entering the South Pond from West Cemetery Creek (SWQ5) were consistently cooler than those in the mainstem of Cemetery Creek (SWQ3 and SWQ4) (**Figure 4-28**; **Appendix N**). This likely contributed to the consistently lower temperatures (and slightly higher DO levels) in the South Pond and may reflect greater ground water influence from the large forested wetland located upstream of the South Pond (**Figure 4-30**). SWQ5 exhibited the least amount of variability in temperature throughout the year (**Appendix N**), likely due to the mediating effects of ground water. Likewise, the South Pond is clearly influenced by the temperature regime of this inflow, maintaining the coolest temperatures overall of the three ponds throughout the summer months (**Figure 4-30** and **Appendix N**). On the other hand, continuous temperatures in the West and North ponds were very similar, tracking each other well in all years except 2016, when the North Pond began to stay cooler while the South and West ponds warmed significantly (**Figure 4-29**).

Figure 4-30 Percentage of summer days exceeding water quality standards for water temperature.

Average diurnal temperature fluctuations were 1.34°C in the North Pond, 1.69°C in the West Pond, and 1.25°C in the South Pond (**Table 4-13**). In all years except 2016, the North and West Ponds both experienced 20-50% more summer days when even *minimum* temperatures exceeded the 16°C threshold compared with the South Pond (**Table 4-13**); in other words, on these days water temperatures exceeded state standards all day and all night for an entire 24 hour period. The Washington state salmonid lethal temperature limit (above 22°C) was exceeded within the ponds in only two years, 2009 and 2016 (**Figure 4-29**).

As previously mentioned, discrete temperature measurements cannot be used to determine compliance with state standards. By sampling at 30 min intervals, continuous temperature loggers are better able to capture temperature extremes which are key to revealing true temperature impacts on aquatic ecosystems.

4.3.3 Fecal Coliform

4.3.3.1 Introduction

Fecal coliform concentrations are used as an indicator of pathogenic bacterial levels in surface waters because they are easily quantified. Sources of fecal contamination to surface waters include domestic and wild animal feces, human feces, on-site septic system leaks, and stormwater runoff. Although they are generally not harmful themselves, fecal coliform bacteria indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems. In addition to the possible human health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand (U.S. EPA 1997). Fecal coliform bacteria are generally not a health or habitat concern for salmonids or other fish.

During the monitoring period (2006-2016), the Washington state bacterial indicator was fecal coliform[10] expressed as colony forming units or (cfu), and the freshwater criteria was based on the anticipated level of recreational use and was measured as a geometric mean[11] value of all samples. Cemetery Creek was designated for "Primary Contact Recreation" which included direct contact with water to the point of complete submergence (e.g. swimming) and thus the standard for fecal coliform was a geometric mean value of 100 cfu/100 mL, with not more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 cfu/100 mL (WAC 173-201A-200, Ecology 2006). Cemetery Creek is listed as a Category 5 water body for fecal coliform in the Washington state 2008 Water Quality Assessment (Ecology 2019). Category 5 represents the state's 303(d) list of impaired waters. In 2004 a *Whatcom Creek Fecal Coliform Total Maximum Daily Load Study* was conducted by the City of Bellingham in partnership with Ecology (Shannahan et al. 2004), and a Whatcom Creek bacteria TMDL is currently being developed by the Washington state Department of Ecology which will include Cemetery Creek.

4.3.3.1 Objectives

The objective of monitoring fecal bacteria levels was to document conditions that may affect human health. Although the *Monitoring and Maintenance Plan* (COB 2006) does not specify any success criteria for bacteria, the plan does state that "fecal coliform will be compared to current Washington State standards."

4.3.3.2 Methods

Fecal coliform grab samples were obtained monthly from the eight sampling stations in the Cemetery Creek restoration area (**Figure 4-31**) during all designated monitoring years (eg. years 1, 2, 3, 5, 7, and 10 corresponding to 2007, 2008, 2009, 2011, 2013 and 2016; **Figure 3-5**). Fecal coliform samples were collected at all stream water quality stations, plus one sample from each of the constructed ponds. Pond samples were collected from an approximate depth of 1 foot below the surface, and only one sample was taken from each pond station since fecal coliform levels are not expected to vary by depth. Two field replicate samples were taken on each per sampling event. Samples were immediately stored in a cooler on ice and delivered to EDGE analytical laboratory for analysis within four hours of sample collection.

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[10] Fecal coliform expires as the Washington state bacterial indicator on December 31, 2020 and will be replaced by *E. coli.*

[11] A minimum of three samples is required to calculate a geometric mean for comparison to the geometric mean criteria. Sample collection dates shall be well distributed throughout the averaging period so as not to mask noncompliance periods.

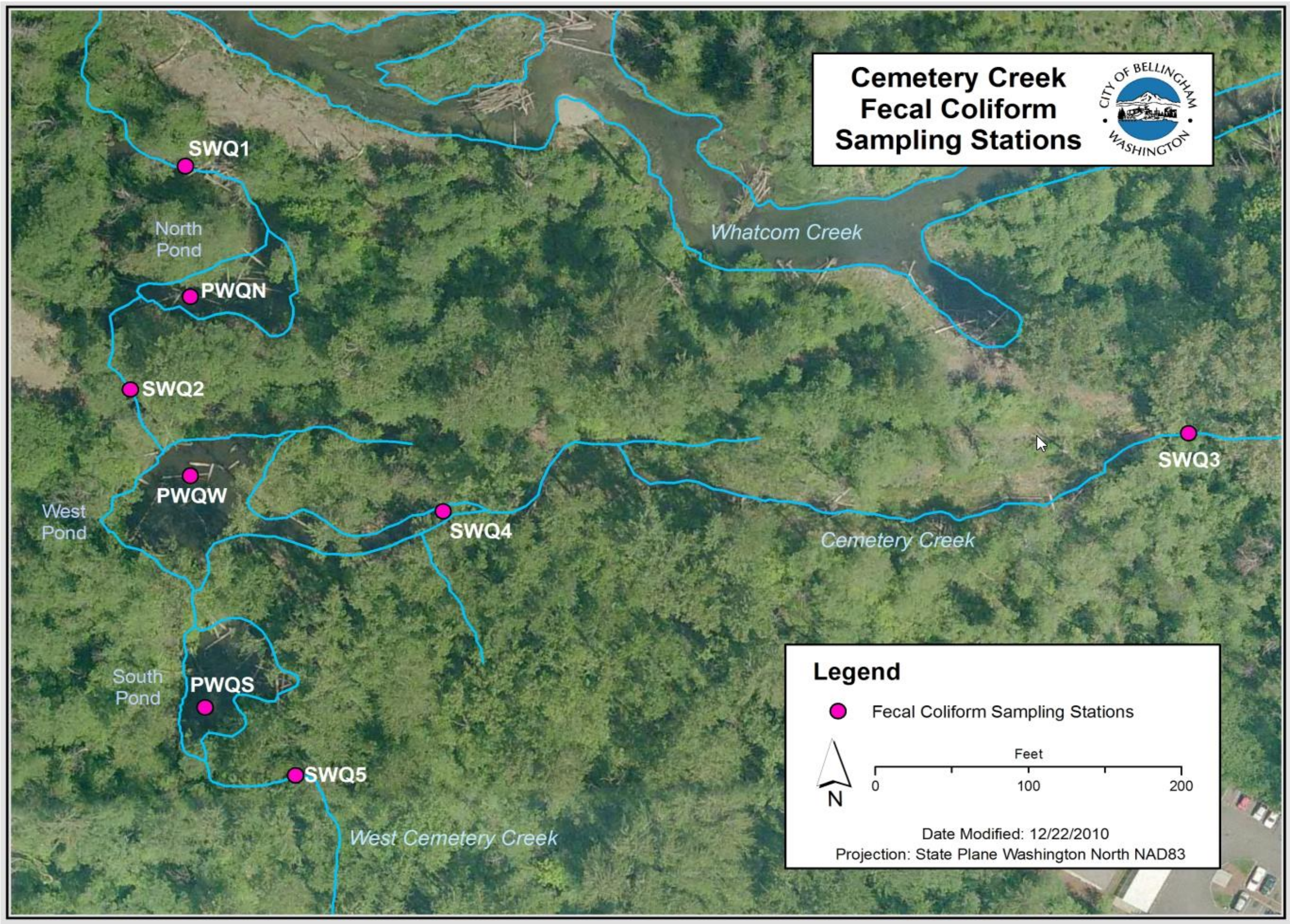

Figure 4-31 Map of fecal coliform sampling stations.

4.3.3.3 Results

Fecal coliform samples were collected from eight sites in the restoration area (**Figure 4-31**). Fecal coliform concentrations were generally lowest during the wet season and highest during the dry season, most likely due to concentration resulting from reduced flows (**Figure 4-32**). The highest fecal coliform spikes occurred during the first few years after construction, gradually decreasing in peak concentration over the years (**Figure 4-32**). Although four sample sites downstream from the West Pond achieved geomeans of less than 100 cfu/mL over the 10 year averaging period, all sample sites exceeded state water quality standards based on the requirement that no more than 10% of all samples may exceed 200 cfu/mL (**Table 4-14**).

For more information on fecal coliform levels in the Whatcom Creek watershed, please refer to the *Whatcom Creek Fecal Coliform Total Maximum Daily Load Study* (Shannahan et al. 2004).

Table 4-14 Fecal coliform indices across all monitoring years.

Fecal Coliform Metric	SWQ1	PWQN	SWQ2	PWQW	SWQ3	SWQ4	PWQS	SWQ5
Geomean (cfu/100mL)	96	90	92	90	100	104	128	130
# Samples >200 cfu/100 mL	17	15	18	15	18	17	22	23
% Samples >200 cfu/100 mL	25%	22%	26%	22%	26%	25%	32%	34%

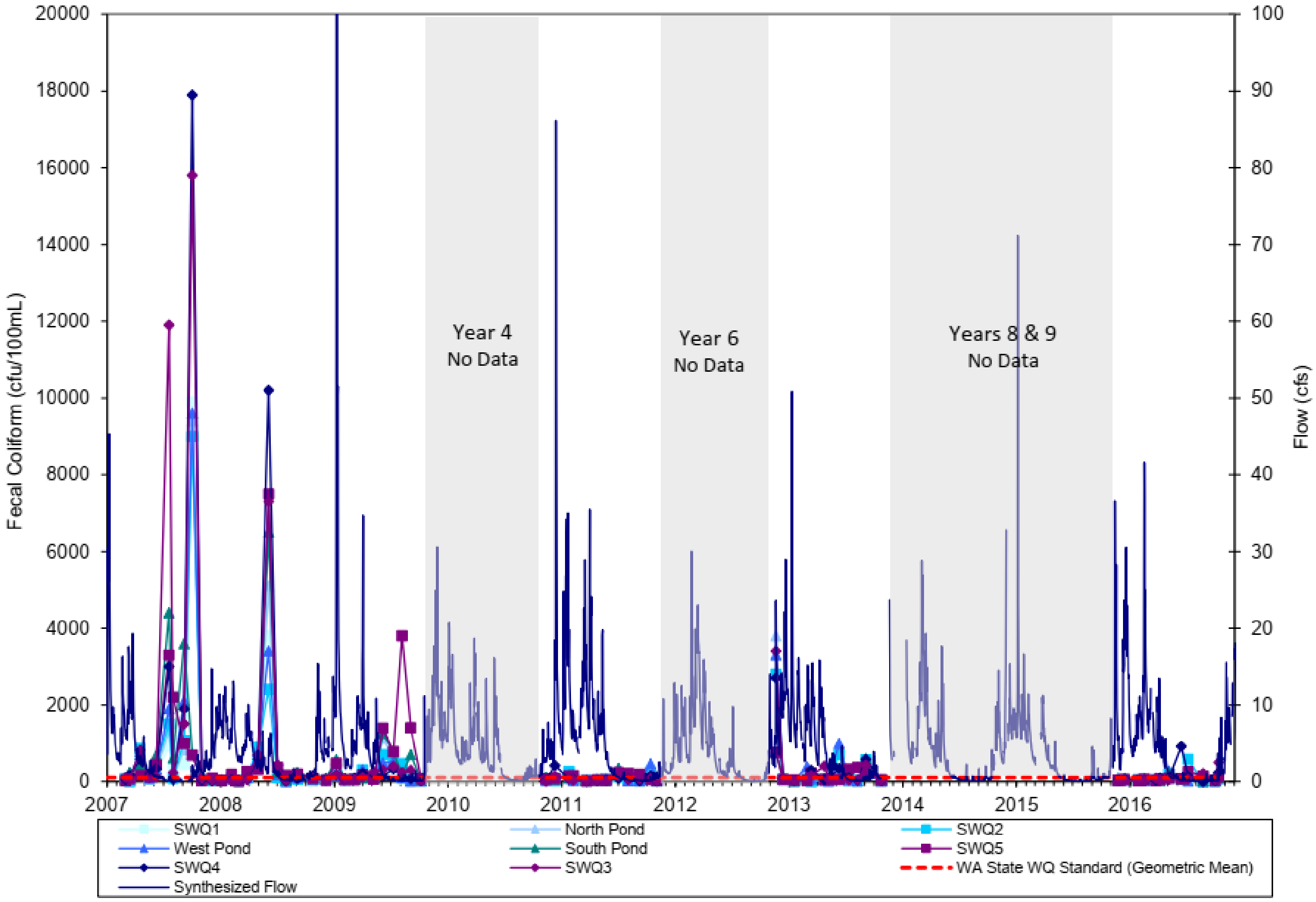

Figure 4-32 Raw fecal coliform data from all stations.

4.3.4 Discussion

Dissolved oxygen: As shown in **Table 4-11**, during the summer months (June-September) DO measurements within the North, West and South ponds failed to meet state water quality standards 100%, 95% and 97% of the time, respectively. Similarly, most stream water quality measurements did not meet Washington state water quality standards for dissolved oxygen during the summer months, with exceedances occurring from 88% to 100% of the time (**Table 4-12**).

Temperature: Although the Washington state lethal temperature limit was exceeded within the ponds in only two years (2009 and 2016)(Figure 4-29), applicable temperature standards were exceeded during all years at all pond stations (**Table 4-13**). (Note: Temperature criteria could not be assessed for stream stations where only discrete temperature data were collected.)

pH: The vast majority of pH measurements recorded in both the streams and ponds during the monitoring period fell within the Washington state aquatic life criteria for Cemetery Creek of pH 6.5 to 8.5 (**Table 4-11** & **Table 4-12**).

Success Criteria:

- Water temperature, pH, and dissolved oxygen in restoration sites will meet current Washington state water quality standards during the 10-year monitoring period. **These criteria have not been met for dissolved oxygen or temperature. However, the criterion for pH was met.**

Meeting Washington state water quality standards within the project area is unrealistic due to the impaired contributing basin and limited influence of the relatively small project area. Nevertheless, the project area can have localized improvements and contribute to downstream water quality. Because dissolved oxygen is driven in large part by temperature, these two parameters are correlated. Within the scope of this restoration effort, the primary factor that can be controlled to influence water temperature is canopy cover (to shade stream and pond habitats from solar radiation). Canopy cover is expected to increase over time as the forest matures. Additionally, allowing beaver activity to accelerate a natural succession toward more complex habitats should increase water storage in the landscape and help buffer stream temperatures during the vulnerable summer low-flow periods.

4.3.5 Recommendations

To assist with improved temperature and dissolved oxygen conditions, we recommend allowing beavers to remain active at the site with periodic monitoring to ensure beaver activity does not impact surrounding infrastructure or create life/safety risks. We also recommend continued forest protection.

4.4 PHOTODOCUMENTATION

4.4.1 Introduction & Objective

According to the *Monitoring and Maintenance Plan* (COB 2006), the objective of photo monitoring was to provide a visual record of habitat recovery within the restoration sites. No success criteria were identified.

4.4.2 Methods

Permanent photo points were established at 16 locations throughout the restoration area (**Figure 4-33**). Photo point locations are selected to represent the range of habitat features within the project area. Each photo point contained an easily recognizable feature that was anticipated to remain in place throughout the 10-year monitoring period. Most photo points have multiple angles, identified with letters (a, b, and c). Photo point locations have been documented using metal tags on wooden stakes, trees or large woody debris. GPS coordinates have also been collected at each site to facilitate future relocation. Photopoints 16a and 16b were added in February 2007 to track bank erosion mitigation efforts. Photos are taken at each designated point using a digital camera. Photos are taken during July-September (i.e. summer leaf-on period) and December-January (leaf-off).

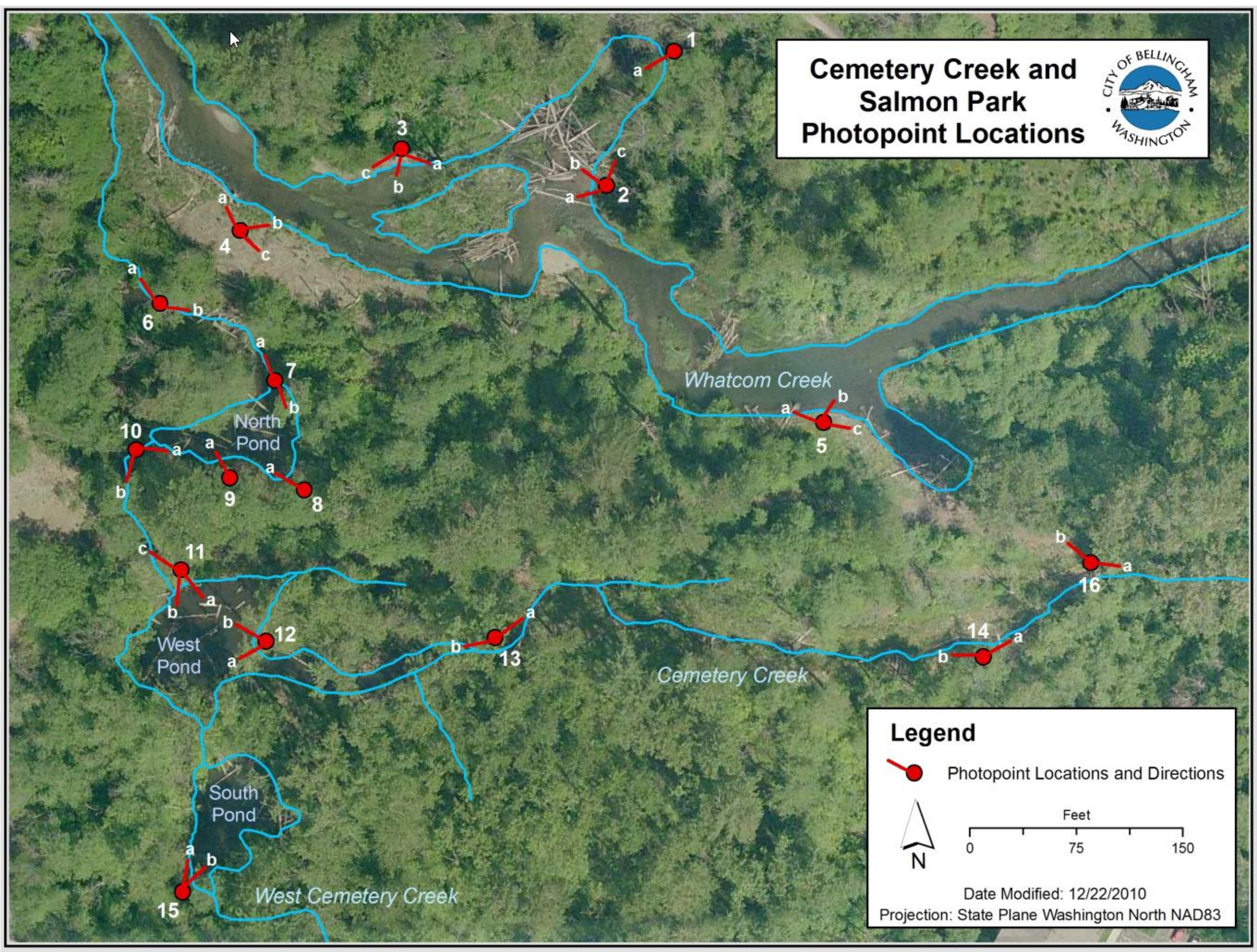

Figure 4-33 Map of repeat photo point locations.

4.4.3 Results

All repeat photos from the 10-year monitoring period can be viewed in **Appendix P**. Similar to vegetation monitoring, photos revealed gradual growth of restoration plantings in the first few years with a burst of vegetative cover starting in 2009. Photo documentation successfully captured a "a visual record of habitat recovery within the restoration sites."

5. LITERATURE

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APPENDIX A:

MONITORING AND MAINTENANCE MODIFICATION

Modifications to the MONITORING AND MAINTENANCE PLAN associated with the Whatcom Creek Restoration Plan Developed for the June 10, 1999 Olympic Pipe Line Gasoline Spill

Original Restoration Monitoring schedule:

The Monitoring and Maintenance Plan (City of Bellingham, 2006) specifies that monitoring of the restoration sites shall occur in post-construction years 1, 2, 3, 5, 7, and 10, corresponding to years 2007, 2008, 2009, 2011, 2013, and 2016, respectively. Monitoring of juvenile salmonids using a smolt trap was the only monitoring component following a different schedule, occurring in post-construction years 1, 3, 6, and 10, corresponding to years 2007, 2009, 2012 and 2016, respectively.

Modified schedule for monitoring spawning adults and outmigrating juvenile salmonids:

The proposed monitoring schedule will: (1) add spawner surveys in post-construction years 6, 8, and 9 and (2) add a smolt trap event in post-construction year 7.

Rationale:

Spawner surveys have shown both adult coho and Chinook salmon utilizing the Cemetery Creek restoration site. Chinook in Whatcom Creek are known to be "ocean type," spawning in fall and outmigrating the same spring, while coho are known to spawn in fall and rear in-stream for 1 to 2 years before outmigrating. Therefore, a smolt trap installed in the spring of post-construction year 6 would presumably intercept outmigrating Chinook resulting from spawning activity observed in spawner surveys from that same monitoring year (i.e. post-construction year 6). However, any outmigrating coho intercepted in year 6 would be associated with spawning adults surveyed during either of the two *previous* years (i.e. post-construction years 4 and/or 5). Therefore, to better correlate patterns of spawning adults with outmigrating juvenile salmonids, annual spawner surveys are required.

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Post-Construction Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Original Schedule	Juvenile Salmonids (Smolt Trap)		1		3			6				10
	Adult Salmonid (Spawner Surveys*)		1	2	3		5		7			10
Modified Schedule	Juvenile Salmonids (Smolt Trap)		1		3			6	7			10
	Adult Salmonid (Spawner Surveys*)		1	2	3		5	6	7	8	9	10
All other monitoring			1	2	3		5		7			10

* The monitoring of adult salmonids with spawner surveys begins in the fall and ends in the spring, spanning two calendar years. Therefore "2007" spawner survey data includes data collected during the fall of 2006 and spring of 2007.

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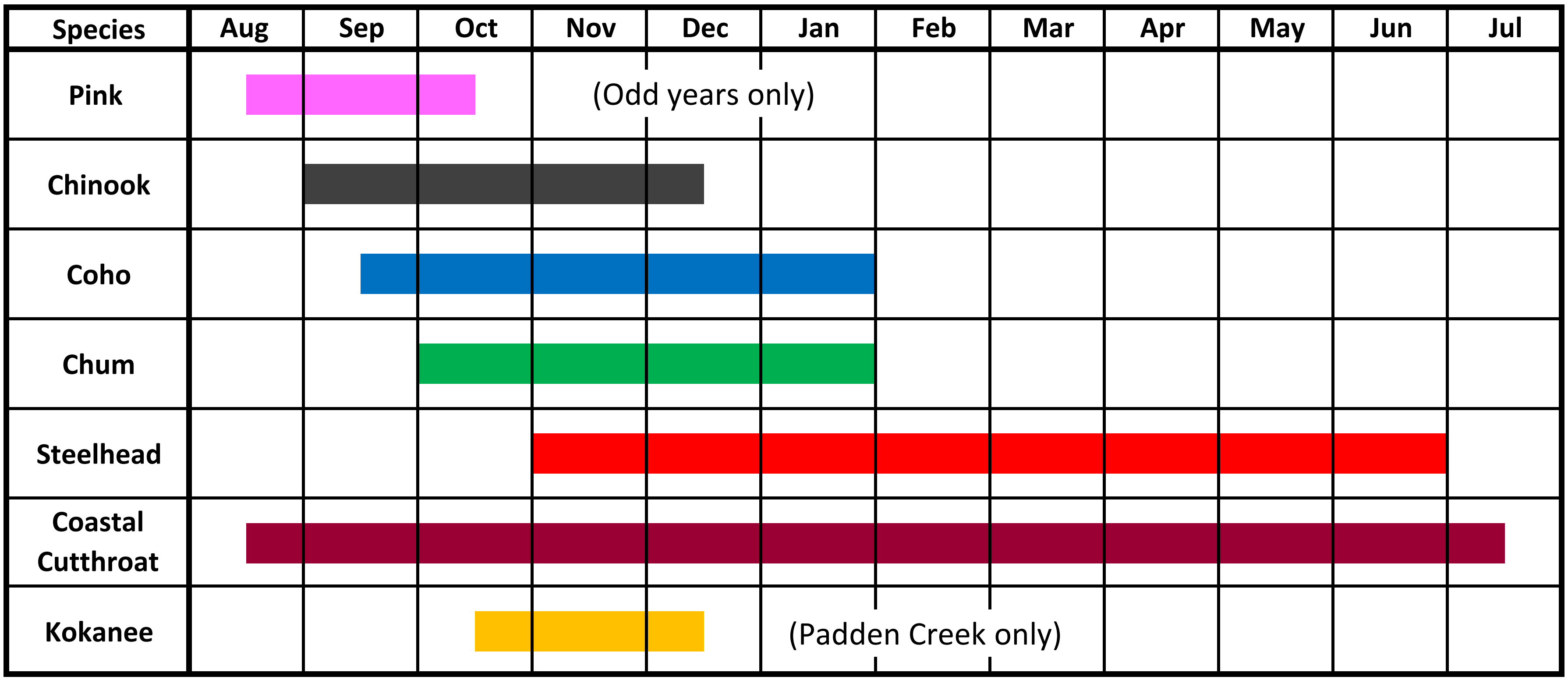
APPENDIX B:

OBSERVED RUN TIMING OF SALMONIDS IN BELLINGHAM STREAMS

Observed Run Timing of Salmonids in Bellingham Streams*



*Based on BTC returns to Whatcom Creek and WDFW/COB/NSEA Spawner Surveys available as of 8/29/17. Kokanee timing estimate based on spawner surveys & pers. comm. with Larry Sisson at WDFW Lake Whatcom Trout Hatchery.

APPENDIX C:

2007-2016 SPAWNER TABLES COMBINED

2007-2008 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
10/04/07	-	0	0	0	100%	
10/18/07	-	0	0	0	95%	
10/25/07	-	0	0	0	100%	
11/01/07	Chinook	0	**1**	0	100%	Male Chinook, not spawned; found in upper part of East Fork
11/13/07	Coho	**1**	0	0	95%	Digging in East Fork; redd not fully formed
11/21/07	Coho	0	0	**1**	95%	Upmost pool in East Fork; more developed
11/28/07	Unknown	0	**1**	0	95%	Female, spawned; coho or Chinook
12/04/07	-	0	0	0	10%	
12/06/07	Unknown	0	**1**	0	60%	Scavenged carcass
12/10/07	-	0	0	0	90%	
12/18/07	-	0	0	0	95%	
12/26/07	Unknown	0	**1**	**1**	80%	Redd located midway up East Fork
01/09/08	-	0	0	0	95%	
01/28/08	Coho	0	**1**	0	95%	Scavenged; still identifiable
02/07/08	-	0	0	0	75%	
02/20/08	-	0	0	0	90%	
02/26/08	-	0	0	0	80%	
03/10/08	-	0	0	0	10%	
	TOTAL	**1**	**5**	**2**		

2008-2009 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
09/08/08	-	0	0	0	95%	
09/24/08	-	0	0	0	90%	
10/09/08	-	0	0	0	90%	
10/16/08	-	0	0	0	95%	
10/24/08	-	0	0	0	95%	
11/03/08	-	0	0	0	95%	
11/12/08	-	0	0	0	5%	
11/17/08	Unknown	0	0	**2**	95%	No fish seen, but likely coho redds.
11/26/08	-	0	0	0	100%	Test redd seen in Cem. Cr.
12/04/08	-	0	0	0	95%	
12/15/08	-	0	0	0	75%	
01/02/09	-	0	0	0	60%	
01/08/09	-	0	0	0	0%	Area flooded; gages submerged.
01/16/09	-	0	0	0	75%	Flood event shifted gravel and LWD.
01/26/09	-	0	0	0	75%	
02/05/09	-	0	0	0	95%	
02/18/09	-	0	0	0	95%	
02/23/09		0	0	0	95%	
03/06/09		0	0	0	90%	
03/26/09	-	0	0	0	80%	
	TOTAL	**0**	**0**	**2**		

2010-2011 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/9/2010	-	0	0	0	90%	
9/16/2010	-	0	0	0	90%	
9/24/2010	-	0	0	0	85%	
9/30/2010	-	0	0	0	85%	
10/7/2010	-	0	0	0	85%	
10/14/2010	Chinook	**4**	0	0	90%	One live, male Chinook w/ Whatcom Hatchery tag.
10/21/2010	Chinook	**2**	**1**	0	90%	One live Chinook is same individual as last week (above). Suspect other 2 (live and dead) are also same as last week- found in same holding pool. Dead Chinook was male, milt present.
10/29/2010	Chinook	**1**	**2**	0	90%	One live Chinook is same tagged male as previous 2 weeks. One dead female Chinook not yet spawned. One dead and scavenged Chinook on log in North Pond.
11/6/2010	Unknown	**1**	0	**1**	90%	Approx. 2.5' x 3.5' redd in riffle below first small pool w/ root wad. One unknown spawner at WP inlet.
11/6/2010	Chinook	**1**	0	0	90%	One live, male Chinook w/ Whatcom Hatchery tag.
11/12/2010	Unknown	0	**1**	0	90%	One unknown dead fish on log in South Pond, scavenged.
11/18/2010	Unknown	**1**	0	0	70%	
11/26/2010	-	0	0	0	70%	Backwater between Whatcom Crk and North Pond frozen. Ponds partially frozen.
12/3/2010	Coho	0	**1**	0	90%	Tagged, dead female coho below North Pond outlet. Spawned (no eggs).
12/9/2010	-	0	0	0	50%	
12/15/2010	-	0	0	0	30%	
12/22/2010	-	0	0	0	70%	
12/30/2010	-	0	0	0	80%	
1/6/2011	-	0	0	0	30%	
1/13/2011	-	0	0	0	20%	
1/22/2011	-	0	0	0	70%	
1/30/2011	-	0	0	0	80%	
2/6/2011	-	0	0	0	80%	
2/14/2011	-	0	0	0	80%	
2/21/2011	-	0	0	0	95%	
3/5/2011	-	0	0	0	95%	
3/13/2011	-	0	0	0	70%	
3/20/2011	-	0	0	0	80%	
3/27/2011	-	0	0	0	98%	
	TOTAL	**10**	**5**	**1**		

2011-2012 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/7/2011	-	0	0	0	70%	Approx. 40% of gravels dry/subaerial in mainstem Cemetery Creek.
9/14/2011	-	0	0	0	70%	Mainstem still dry w/ isolated pools.
9/22/2011	-	0	0	0	55%	Approx. 20-30% of mainstem still dry and disconnected from the West Pond.
9/29/2011	-	0	0	0	90%	Mainstem re-connected. No dry sections remain. Flows increasing but still low.
10/7/2011	-	0	0	0	90%	
10/13/2011	-	0	0	0	85%	
10/20/2011	-	0	0	0	90%	
10/25/2011	-	0	0	0	90%	
11/2/2011	-	0	0	0	95%	
11/9/2011	Coho	0	**1**	0	95%	Male coho w/ small amt. of milt -- prob spawned. ~24" length.
11/15/2011	Coho	0	**1**	0	95%	High WSE. Female coho w/ eggs found at deeper pool w/rootwad at US end of mainstem.
11/23/2011	-	0	0	0	45%	Very dark water-- "first flush." Only ~5% of creek bottom visible.
11/25/2011	Coho	**2**	0	**2**	95%	At least two (prob. three) coho. First redd at WP outlet, second redd ~50' DS from end of restoration site on mainstem. Both likely coho.
11/30/2011	Unknown	0	0	**1**	93%	Third redd-- btwn. two white bridges on mainstem. Approx. 6 days old.
12/7/2011	-	0	0	0	98%	
12/14/2011	O. Mykiss	**1**	0	0	97%	All 3 ponds partially frozen. Rainbow/steelhead trout ~9".
12/23/2011	-	0	0	0	98%	All 3 ponds partially frozen.
12/28/2011	-	0	0	0	25%	
1/5/2012	-	0	0	0	20%	
1/11/2012	-	0	0	0	80%	
1/18/2012	Unk. Trout	**2**	0	0	10%	All 3 ponds 99% frozen, large stretches of creek also frozen. Two unk. Trout, (prob. Cutthroat) pulled out of West Pond alive and then eaten by a river otter (observed).
1/26/2012	-	0	0	0	80%	
2/1/2012	-	0	0	0	55%	High WSE.
2/8/2012	-	0	0	0	65%	
2/14/2012	-	0	0	0	60%	
2/22/2012	-	0	0	0	10%	High WSE. Turbid water, large volume.
2/28/2012	-	0	0	0	85%	High WSE. North Pond gauge submerged. Better clarity than last week.
3/7/2012	-	0	0	0	20%	High WSE. North Pond gauge submerged.
3/16/2012	-	0	0	0	30%	First spawner survey after installation of smolt trap on 3/13/12.
3/21/2012	-	0	0	0	95%	Lower WSE, dropped by ~1 ft. Last survey.
	TOTAL	**5**	**2**	**3**		

2012-2013 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/4/2012	-	0	0	0	95%	
9/13/2012	-	0	0	0	90%	
9/20/2012	-	0	0	0	75%	
9/28/2012	-	0	0	0	60%	
10/2/2012	-	0	0	0	Not recorded	
10/11/2012	-	0	0	0	75%	
10/16/2012	Unknown	**1**	0	0	Not recorded	Probably male: thin bodied, no tag, adipose clipped. Small for Chinook, might be a jack.
10/23/2012	-	0	0	0	100%	
10/31/2012	-	0	0	0	30%	
11/6/2012	Coho	**1**	0	**1**	85%	Likely female, tagged, nearly dead & guarding redd. 22 inches in length. Redd located 75ft DS from end of site.
11/13/2012	-	0	0	0	90%	
11/20/2012	-	0	0	0	31%	
11/27/2012	Unknown	0	0	**1**	80%	Possible new redd @ same location as 11/6, but much bigger.
12/6/2012	-	0	0	0	20%	Very high WSE.
12/12/2012	Unknown	0	**1**	0	Not recorded	Female found with eggs nearby.
12/20/2012	-	0	0	0	Not recorded	WSE too high - not surveyable.
12/27/2012	Unknown	0	0	**1**	65%	Possible redd upstream of WP (DS of previously found redd).
1/4/2013	-	0	0	0	20%	
1/7/2013	-	0	0	0	10%	High WSE - water flowing btwn ponds.
1/17/2013	-	0	0	0	85%	Ponds frozen around edges.
1/23/2013	-	0	0	0	75%	
1/30/2013	-	0	0	0	85%	
2/5/2013	-	0	0	0	80%	
2/13/2013	-	0	0	0	85%	
2/21/2013	-	0	0	0	60%	
2/27/2013	-	0	0	0	90%	
3/7/2013	-	0	0	0	95%	
3/13/2013	-	0	0	0	80%	
3/21/2013	-	0	0	0	95%	
3/27/2013	-	0	0	0	Not recorded	
	TOTAL	**2**	**1**	**3**		

2013-2014 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/4/2013	-	0	0	0	95%	Low flows and high muddy beaver dams; probably not fish passable.
9/10/2013	-	0	0	0	95%	Mainstem is contiguous w/ water (i.e. not dry anymore), but little to no flow (slack water).
9/18/2013	-	0	0	0	95%	
9/26/2013	-	0	0	0	95%	
10/2/2013	-	0	0	0	Not recorded	
10/9/2013	-	0	0	0	Not recorded	
10/16/2013	-	0	0	0	95%	
10/24/2013	-	0	0	0	100%	
10/31/2013	-	0	0	0	65%	
11/6/2013	Unknown	0	0	**1**	95%	First redd located 50ft downstream from last white bridge (near Grizzly end of restoration site); fist-sized, clean cobbles; following rain events over weekend. Unknown species. No spawning adults.
11/14/2013	-	0	0	0	95%	
11/20/2013	Coho	0	**1**	0	65%	Female (adipose fin, no BTC tag) w/ 200-500 eggs found near rootwad pool just US from backwatered swale on mainstem.
11/28/2013	-	0	0	0	90%	
12/5/2013	-	0	0	0	100%	Majority of ponds covered in layer of ice. Edges of creek frozen.
12/11/2013	-	0	0	0	65%	Ponds nearly all frozen - ice layer 2.5-3" thick at edge.
12/19/2013	Uknown	0	0	**1**	95%	Possible redd found & flagged upstream of last large pool in mainstem of creek.
12/25/2013	-	0	0	0	75%	
12/31/2013	-	0	0	0	85%	
1/9/2014	-	0	0	0	65%	
1/16/2014	-	0	0	0	90%	
1/28/2014	-	0	0	0	90%	
2/5/2014	-	0	0	0	60%	Ponds frozen.
2/12/2014	-	0	0	0	73%	
2/18/2014	-	0	0	0	35%	Heavy creek flow. SP high water; could notch dam.
2/27/2014	-	0	0	0	80%	SP very flooded due to melting snow and beaver dam.
3/5/2014	-	0	0	0	25%	Very flooded, low visibility - could see less than 6" below water surface.
3/13/2014	-	0	0	0	75%	
3/20/2014	-	0	0	0	50%	Dam between NP and SP backed up: SP is re-routing its outflow along walking trail on left bank.
3/27/2014	-	0	0	0	70%	
	TOTAL	**0**	**1**	**2**		

2014-2015 Cemetery Creek Spawner Survey Data

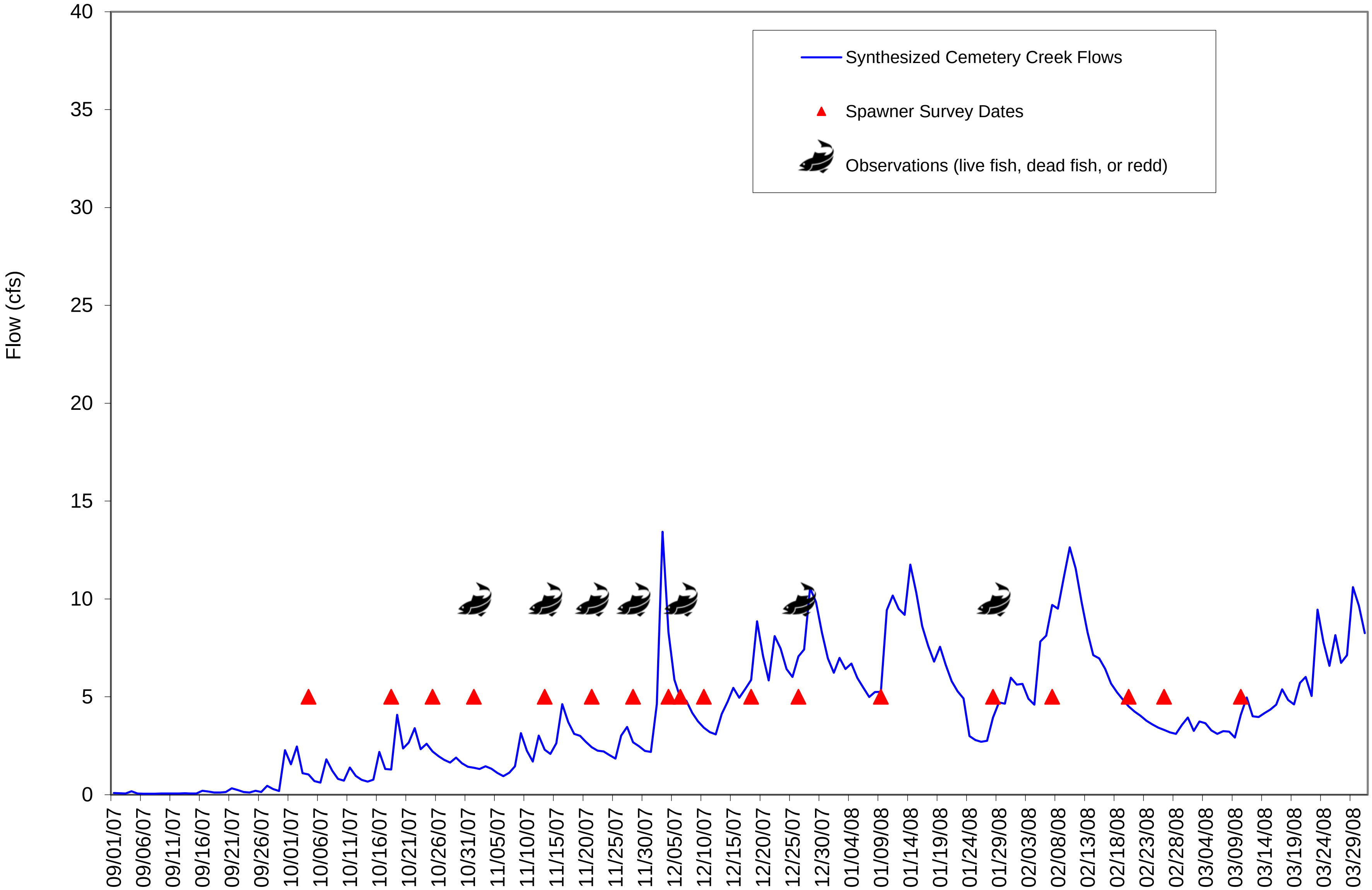
Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/5/2014	-	0	0	0	95%	
9/17/2014	-	0	0	0	100%	
9/24/2014	-	0	0	0	15-20%	Beaver dam, appears fish-passable.
9/29/2014	-	0	0	0	95%	
10/7/2014	-	0	0	0	95%	
10/13/2014	-	0	0	0	Blank	
10/21/2014	Chinook	1	0	0	40%	
10/28/2014	-	0	0	0	40%	
11/5/2014	Coho	0	1	1	60%	
11/10/2014	-	0	0	**0**	65%	
11/19/2014	-	0	0	0	70%	Debris dam developing in the stream by the Stream Gauge.
11/25/2014	-	0	**0**	2	35%	Two redds on Cemetery Creek (mainstem).
12/4/2014	Coho	0	1	1	55%	One redd 20 ft downstream of the beaver dam at the North end of North Pond.
12/8/2014	Uknown	0	1	0	75%	
12/16/2014	-	0	0	1	60%	
12/22/2014	-	0	0	**0**	85%	
12/29/2014	-	0	0	0	80%	
1/7/2015	-	0	0	0	60%	
1/12/2015	-	0	0	0	80%	
1/21/2015	-	0	0	0	80%	
1/26/2015	-	0	0	0	75%	
2/2/2015	-	0	0	0	75%	
2/11/2015	-	0	0	0	60%	
2/19/2015	-	0	0	0	80%	
3/2/2015	-	0	0	0	95%	
3/12/2015	-	0	0	0	90%	
3/23/2015	-	0	0	0	50%	
	TOTAL	**1**	**3**	**5**		

2015-2016 Cemetery Creek Spawner Survey Data

Survey Date	Species	# Live	# Dead	# Redds	Visibility	Notes
9/15/2015	NA	0	0	0	95%	
9/25/2015	NA	0	0	0	95%	
10/6/2015	NA	0	0	0	90%	
10/14/2015	NA	0	0	0	99%	
10/21/2015	NA	0	0	0	90%	
10/29/2015	NA	0	0	0	40%	
11/12/2015	NA	0	0	0	65%	
11/18/2015	NA	0	0	0	10%	
11/23/2015	NA	0	0	0	40%	
12/1/2015	NA	0	0	0	60%	
12/9/2015	NA	0	0	0	30%	
12/14/2015	NA	0	0	0	45%	
12/28/2015	NA	0	0	0	45%	
1/7/2016	NA	0	0	0	90%	
1/12/2016	NA	0	0	0	70%	
1/20/2016	NA	0	0	0	90%	
1/26/2016	NA	0	0	0	65%	
2/3/2016	NA	0	0	0	80%	
2/10/2016	NA	0	0	0	60%	
2/18/2016	NA	0	0	0	50%	
2/25/2016	NA	0	0	0	70%	
3/2/2016	NA	0	0	0	80%	
3/24/2016	NA	0	0	0	30%	
3/30/2016	NA	0	0	0	95%	
	TOTAL	**0**	**0**	**0**		

APPENDIX D:

2007-2016 SPAWNER CHARTS COMBINED



Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
Flow (cfs)
40
35
30
25
20
15
10
5
0
09/01/07
09/06/07
09/11/07
09/16/07
09/21/07
09/26/07
10/01/07
10/06/07
10/11/07
10/16/07
10/21/07
10/26/07
10/31/07
11/05/07
11/10/07
11/15/07
11/20/07
11/25/07
11/30/07
12/05/07
12/10/07
12/15/07
12/20/07
12/25/07
12/30/07
01/04/08
01/09/08
01/14/08
01/19/08
01/24/08
01/29/08
02/03/08
02/08/08
02/13/08
02/18/08
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02/28/08
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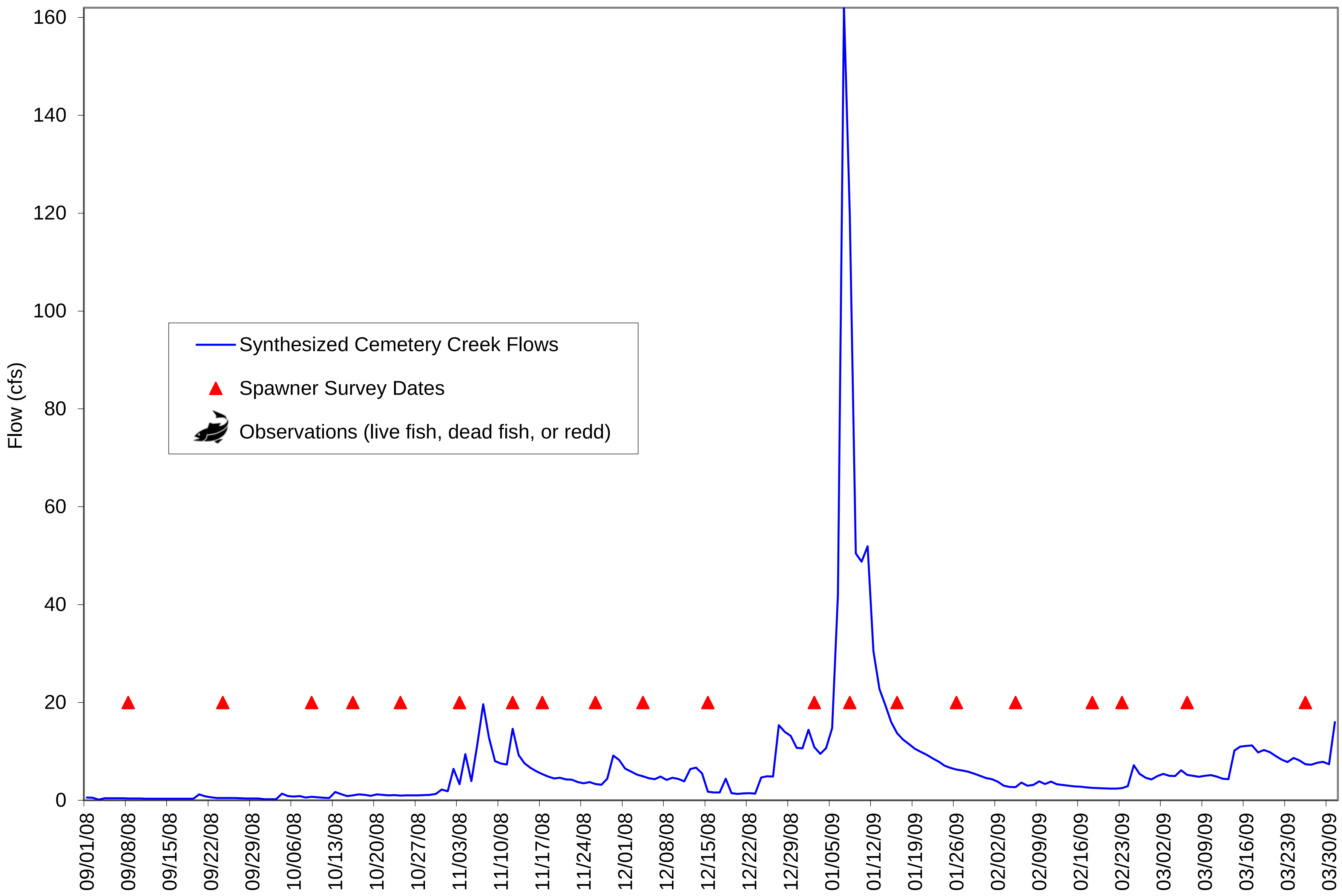
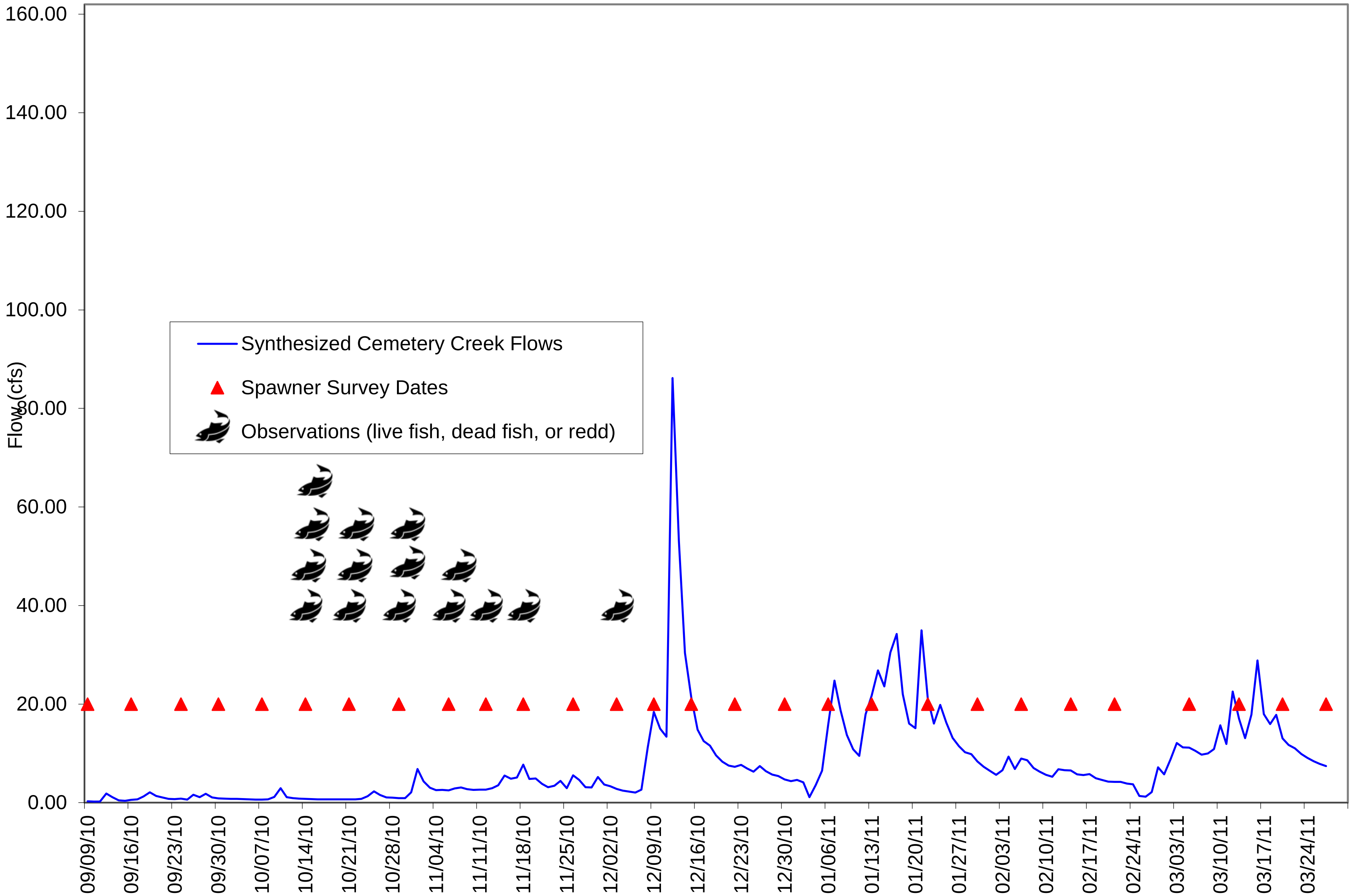
03/09/08
03/14/08
03/19/08
03/24/08
03/29/08


Flow (cfs)
160
140
120
100
80
60
40
20
0
Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
09/01/08
09/08/08
09/15/08
09/22/08
09/29/08
10/06/08
10/13/08
10/20/08
10/27/08
11/03/08
11/10/08
11/17/08
11/24/08
12/01/08
12/08/08
12/15/08
12/22/08
12/29/08
01/05/09
01/12/09
01/19/09
01/26/09
02/02/09
02/09/09
02/16/09
02/23/09
03/02/09
03/09/09
03/16/09
03/23/09
03/30/09



160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Flow (cfs)
Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
09/09/10
09/16/10
09/23/10
09/30/10
10/07/10
10/14/10
10/21/10
10/28/10
11/04/10
11/11/10
11/18/10
11/25/10
12/02/10
12/09/10
12/16/10
12/23/10
12/30/10
01/06/11
01/13/11
01/20/11
01/27/11
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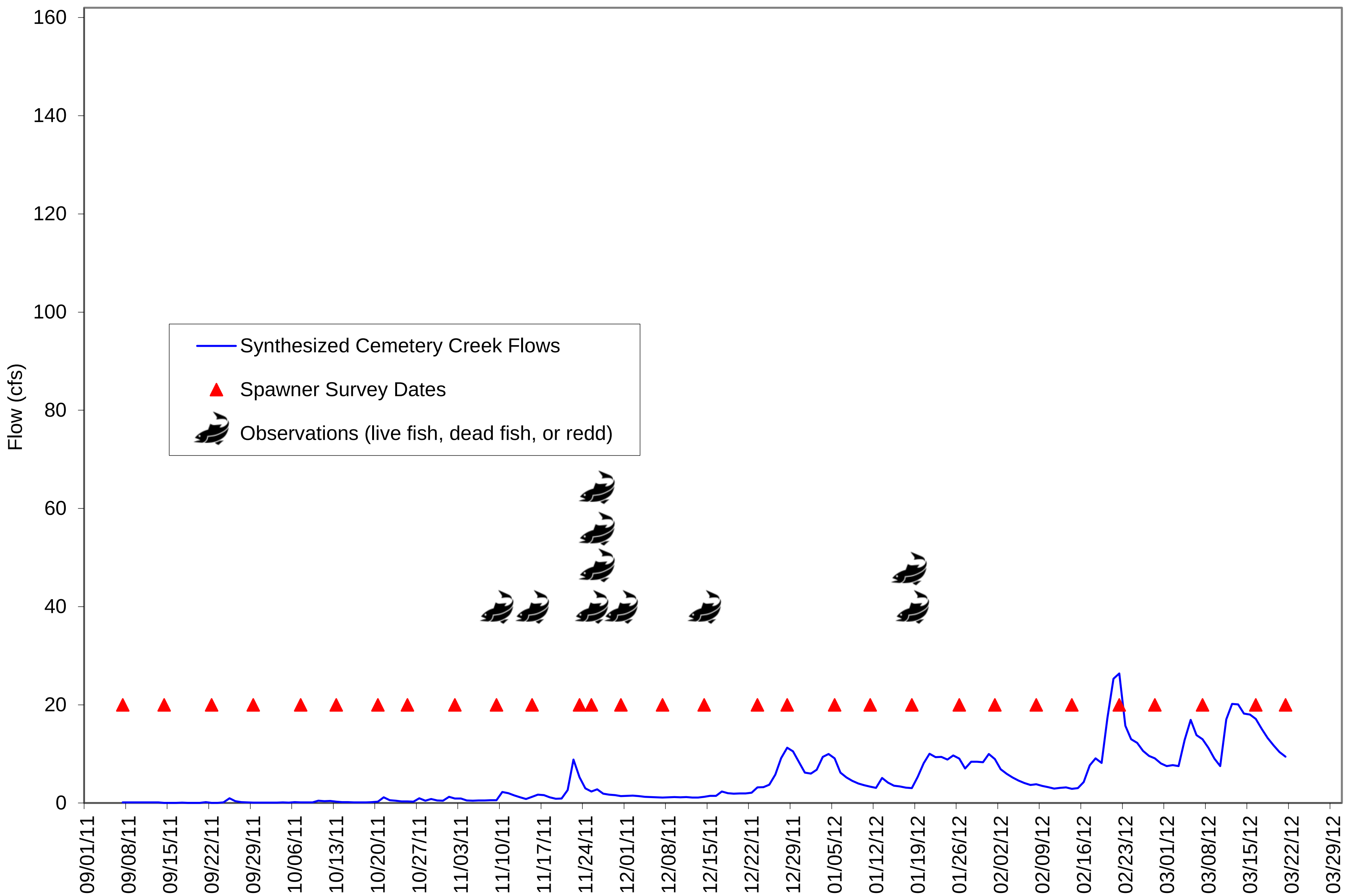
03/10/11
03/17/11
03/24/11



Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
Flow (cfs)
160
140
120
100
80
60
40
20
0
09/01/11
09/08/11
09/15/11
09/22/11
09/29/11
10/06/11
10/13/11
10/20/11
10/27/11
11/03/11
11/10/11
11/17/11
11/24/11
12/01/11
12/08/11
12/15/11
12/22/11
12/29/11
01/05/12
01/12/12
01/19/12
01/26/12
02/02/12
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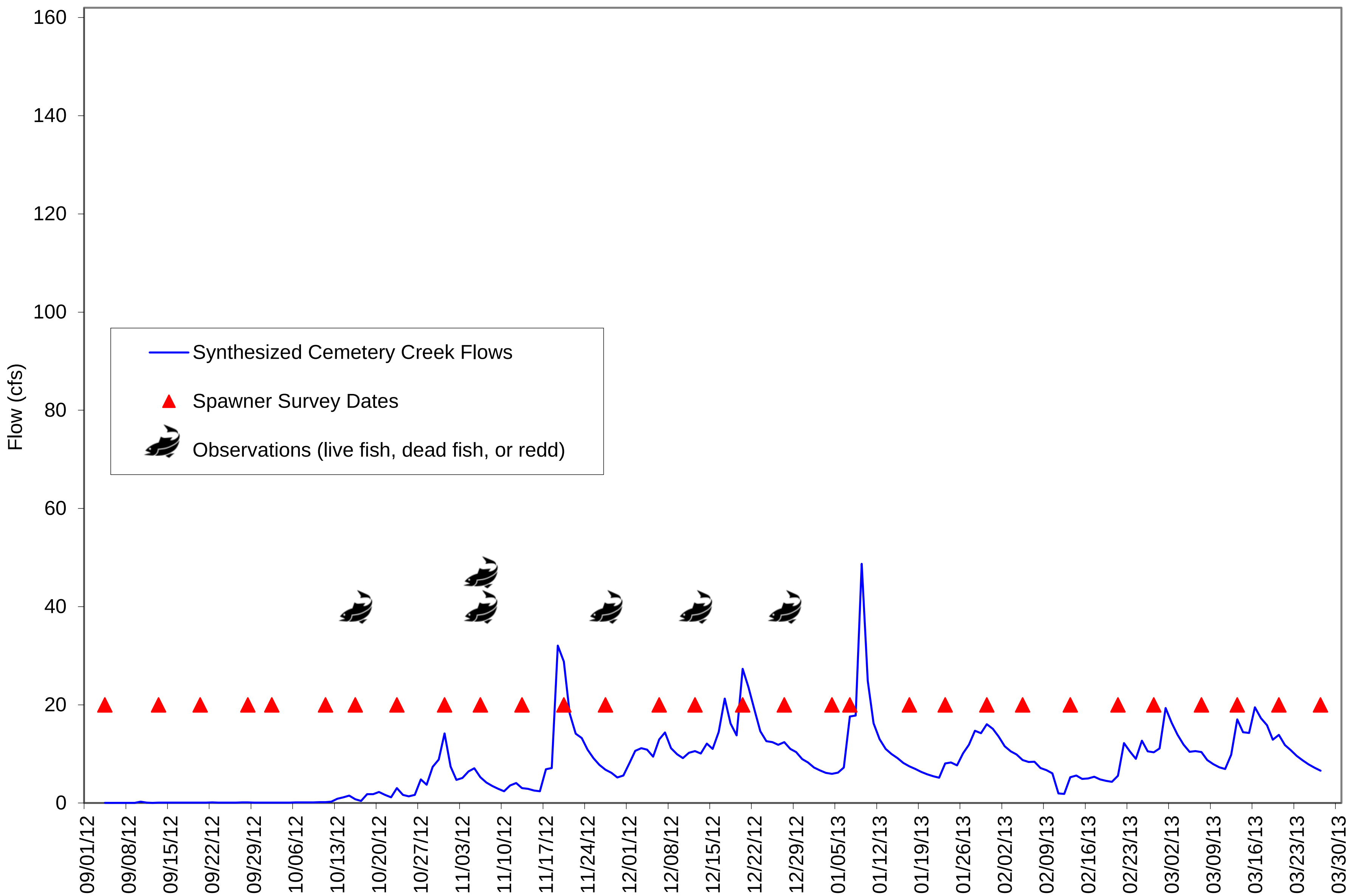
02/16/12
02/23/12
03/01/12
03/08/12
03/15/12
03/22/12
03/29/12


Flow (cfs)
160
140
120
100
80
60
40
20
0
Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
09/01/12
09/08/12
09/15/12
09/22/12
09/29/12
10/06/12
10/13/12
10/20/12
10/27/12
11/03/12
11/10/12
11/17/12
11/24/12
12/01/12
12/08/12
12/15/12
12/22/12
12/29/12
01/05/13
01/12/13
01/19/13
01/26/13
02/02/13
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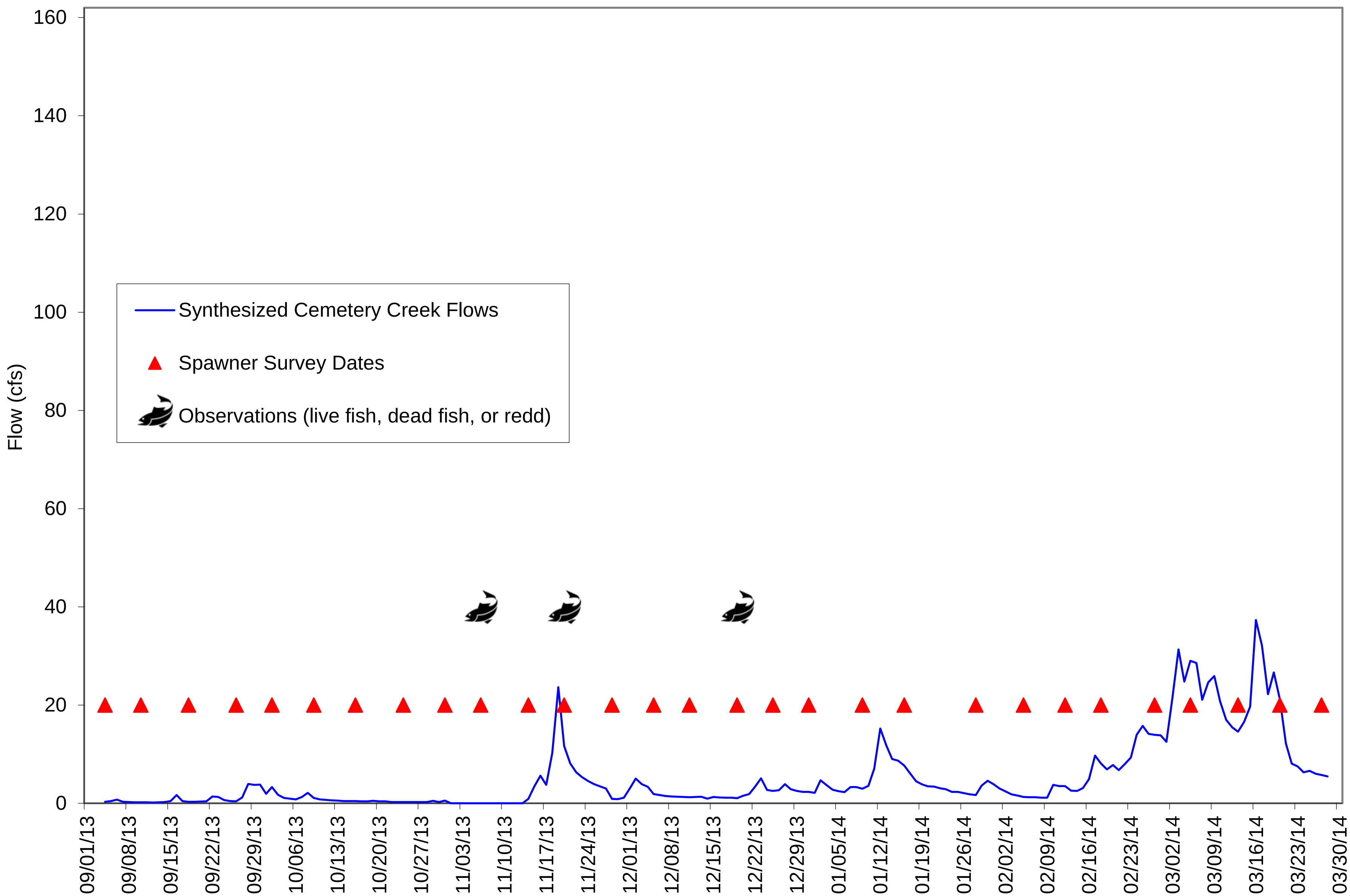
03/02/13
03/09/13
03/16/13
03/23/13
03/30/13



Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
Flow (cfs)
0
20
40
60
80
100
120
140
160
09/01/13
09/08/13
09/15/13
09/22/13
09/29/13
10/06/13
10/13/13
10/20/13
10/27/13
11/03/13
11/10/13
11/17/13
11/24/13
12/01/13
12/08/13
12/15/13
12/22/13
12/29/13
01/05/14
01/12/14
01/19/14
01/26/14
02/02/14
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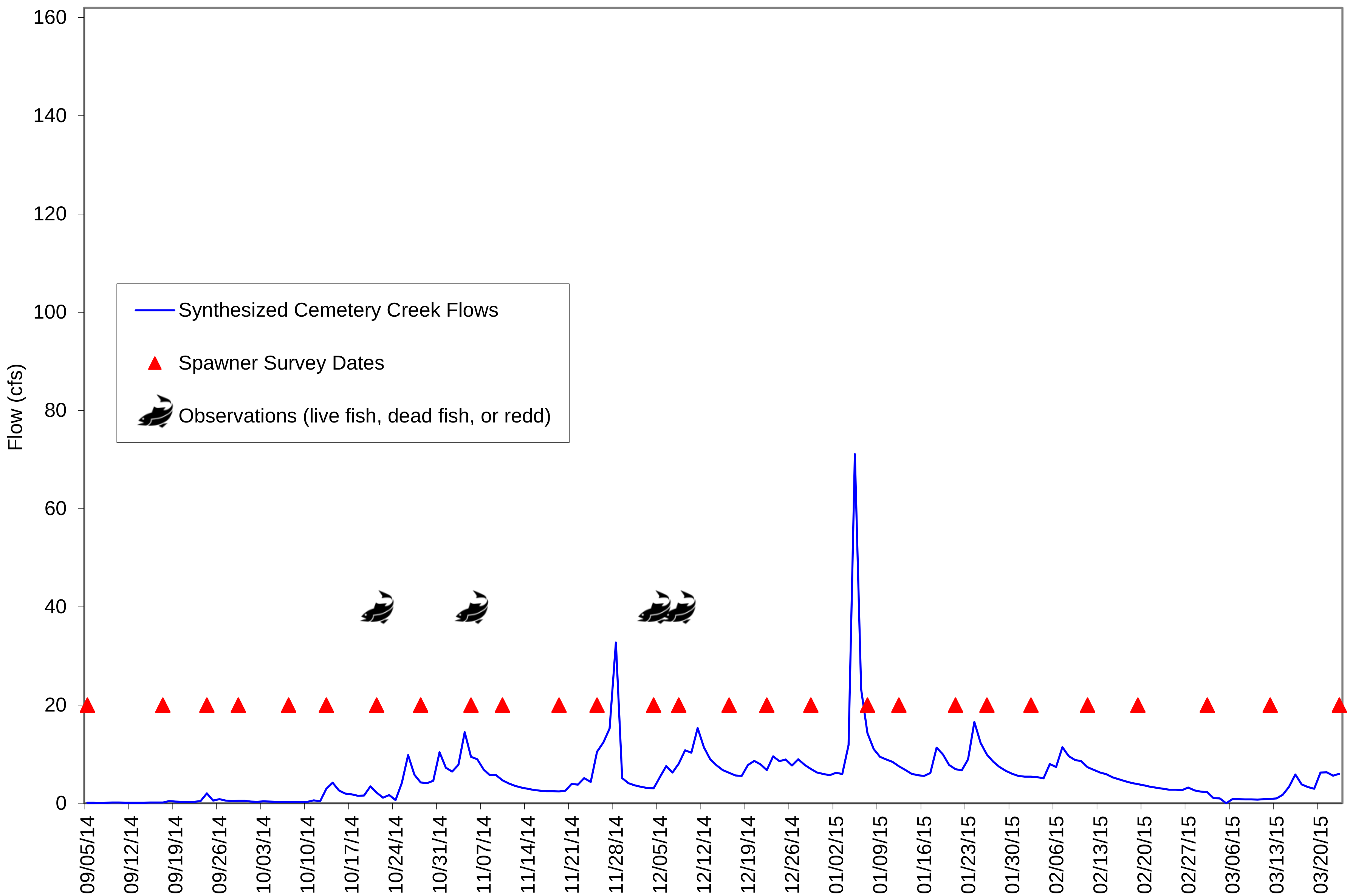
02/16/14
02/23/14
03/02/14
03/09/14
03/16/14
03/23/14
03/30/14



Synthesized Cemetery Creek Flows
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
Flow (cfs)
160
140
120
100
80
60
40
20
0
09/05/14
09/12/14
09/19/14
09/26/14
10/03/14
10/10/14
10/17/14
10/24/14
10/31/14
11/07/14
11/14/14
11/21/14
11/28/14
12/05/14
12/12/14
12/19/14
12/26/14
01/02/15
01/09/15
01/16/15
01/23/15
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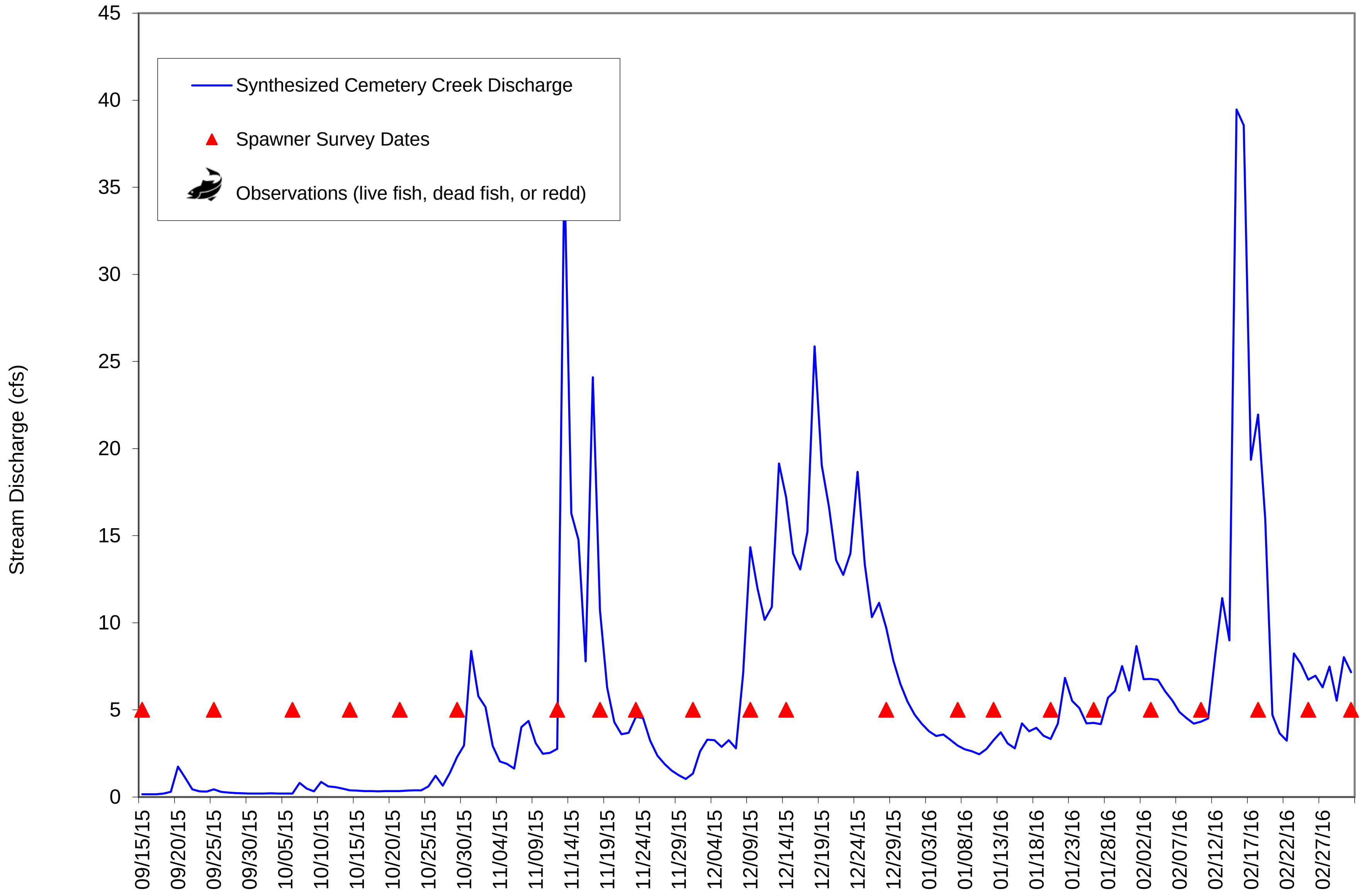
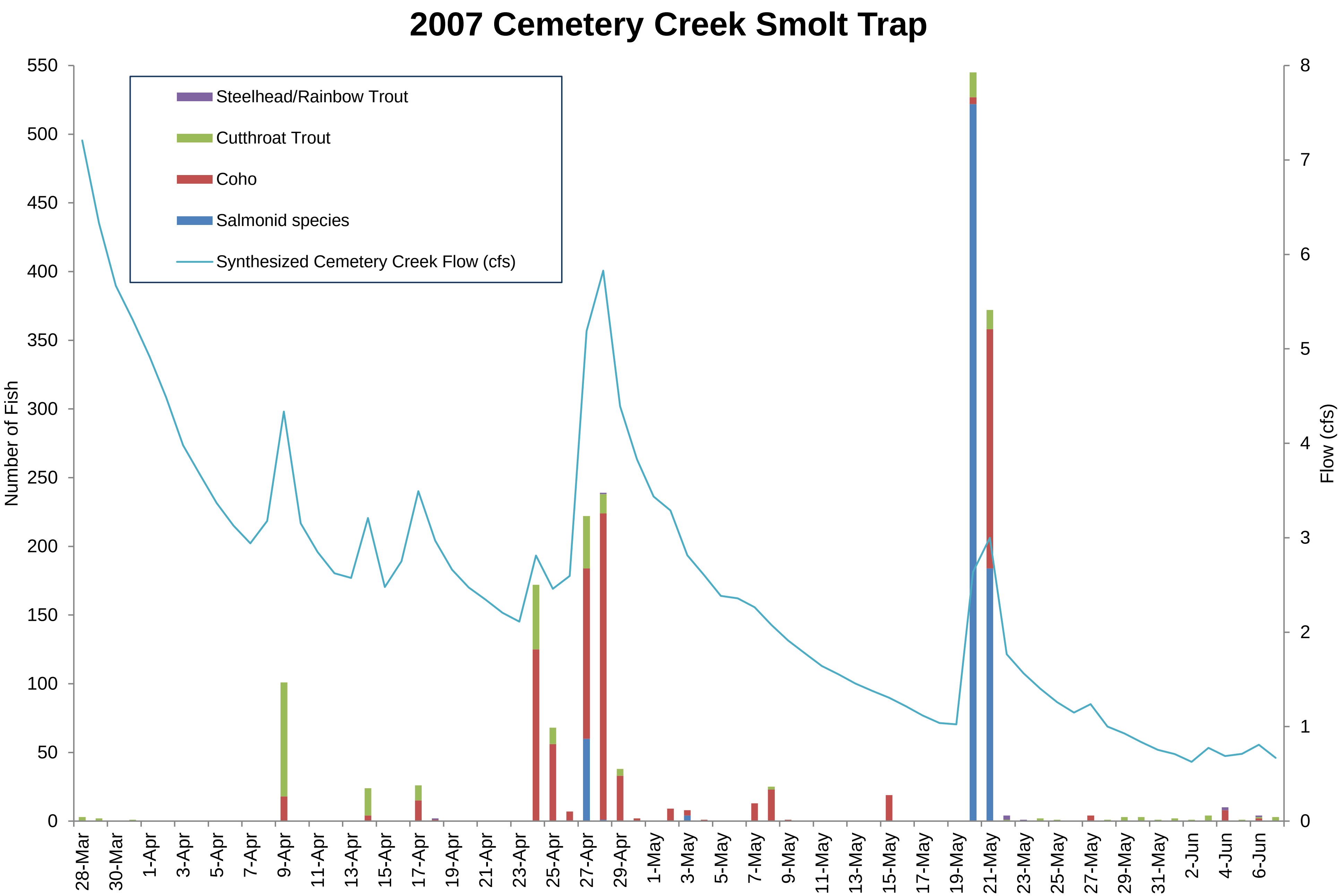
02/27/15
03/06/15
03/13/15
03/20/15

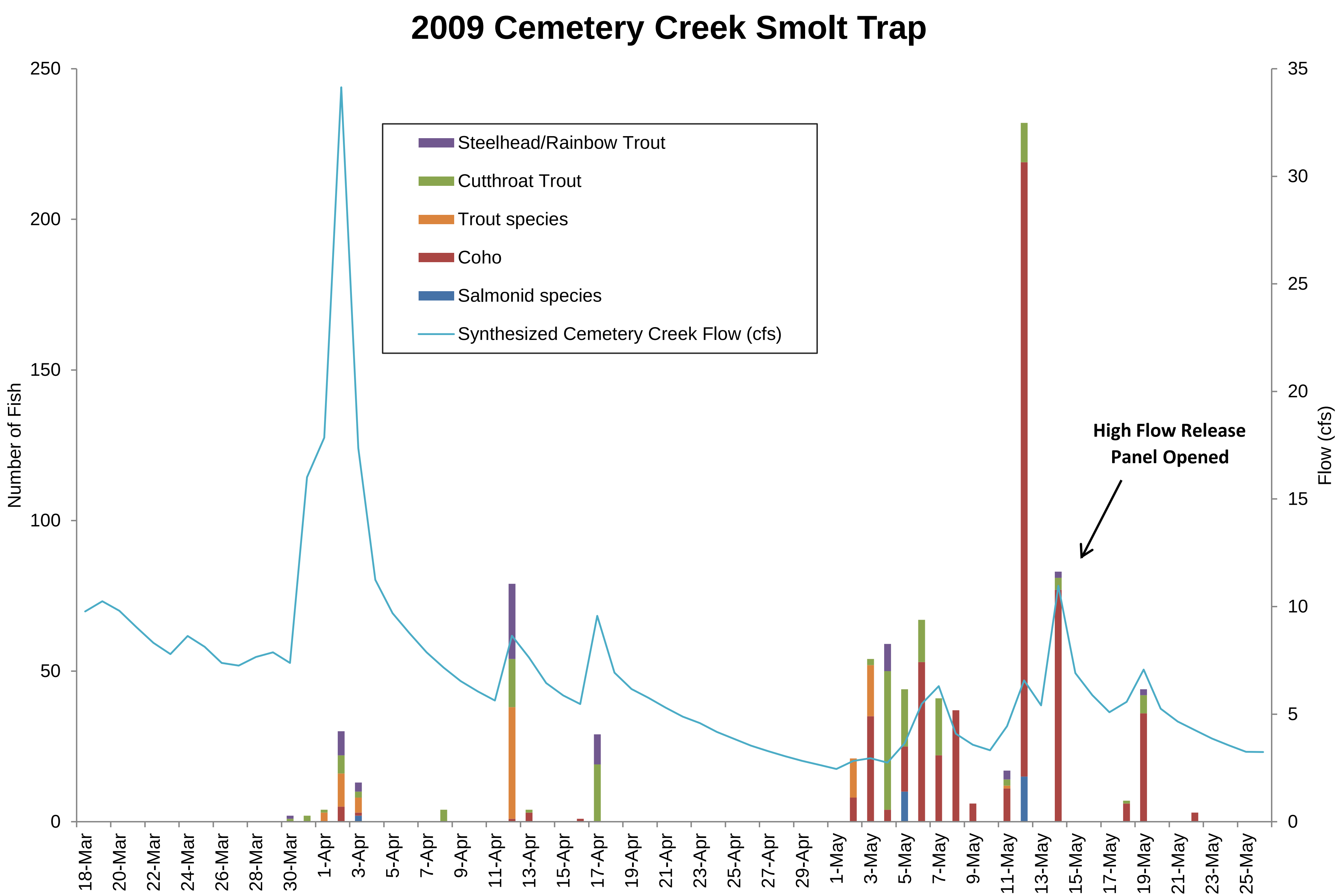


Stream Discharge (cfs)
45
40
35
30
25
20
15
10
5
0
Synthesized Cemetery Creek Discharge
Spawner Survey Dates
Observations (live fish, dead fish, or redd)
09/15/15
09/20/15
09/25/15
09/30/15
10/05/15
10/10/15
10/15/15
10/20/15
10/25/15
10/30/15
11/04/15
11/09/15
11/14/15
11/19/15
11/24/15
11/29/15
12/04/15
12/09/15
12/14/15
12/19/15
12/24/15
12/29/15
01/03/16
01/08/16
01/13/16
01/18/16
01/23/16
01/28/16
02/02/16
02/07/16
02/12/16
02/17/16
02/22/16
02/27/16

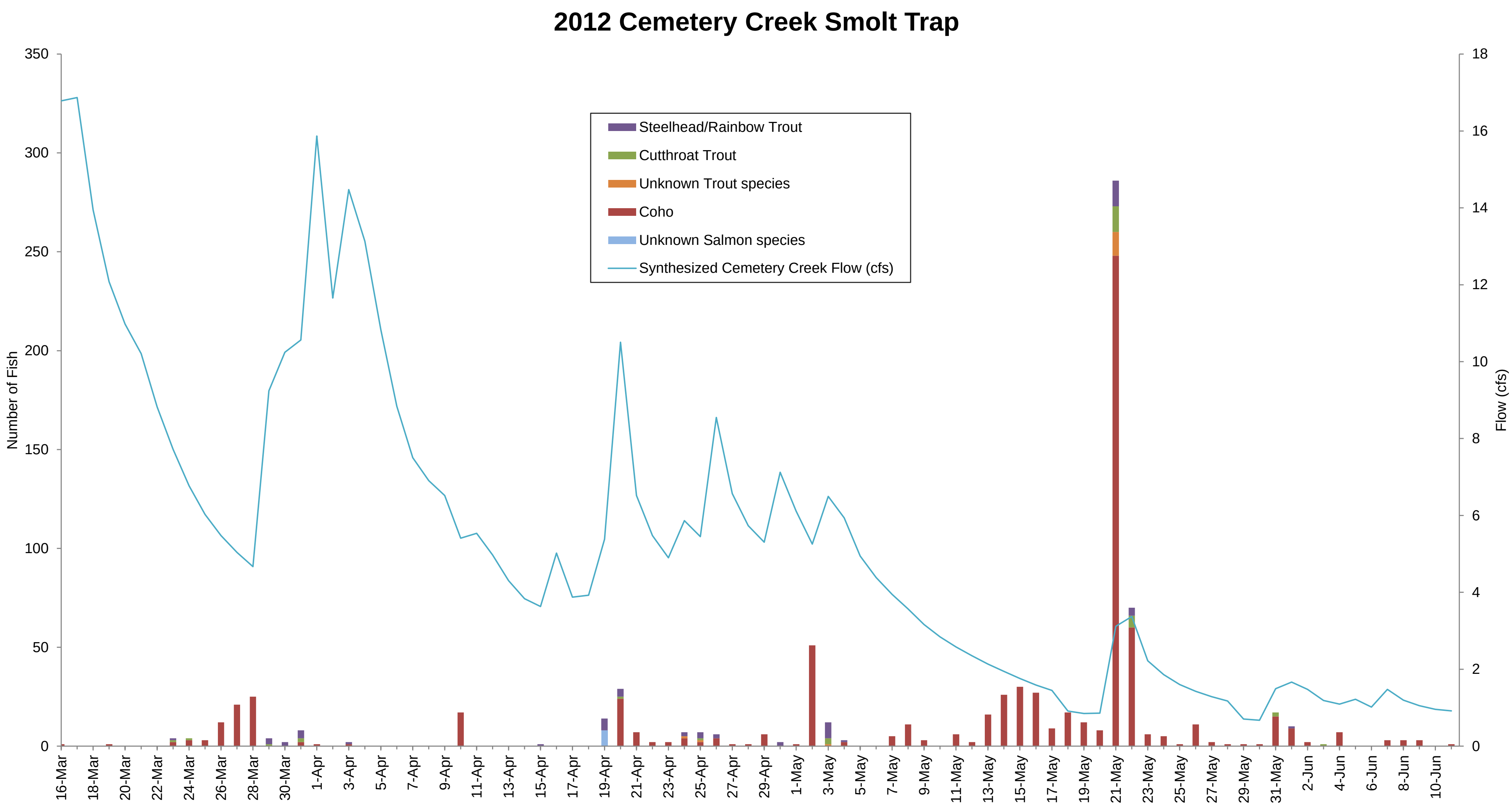
APPENDIX E:

SMOLT TRAP CHARTS BY DAY WITH FLOW

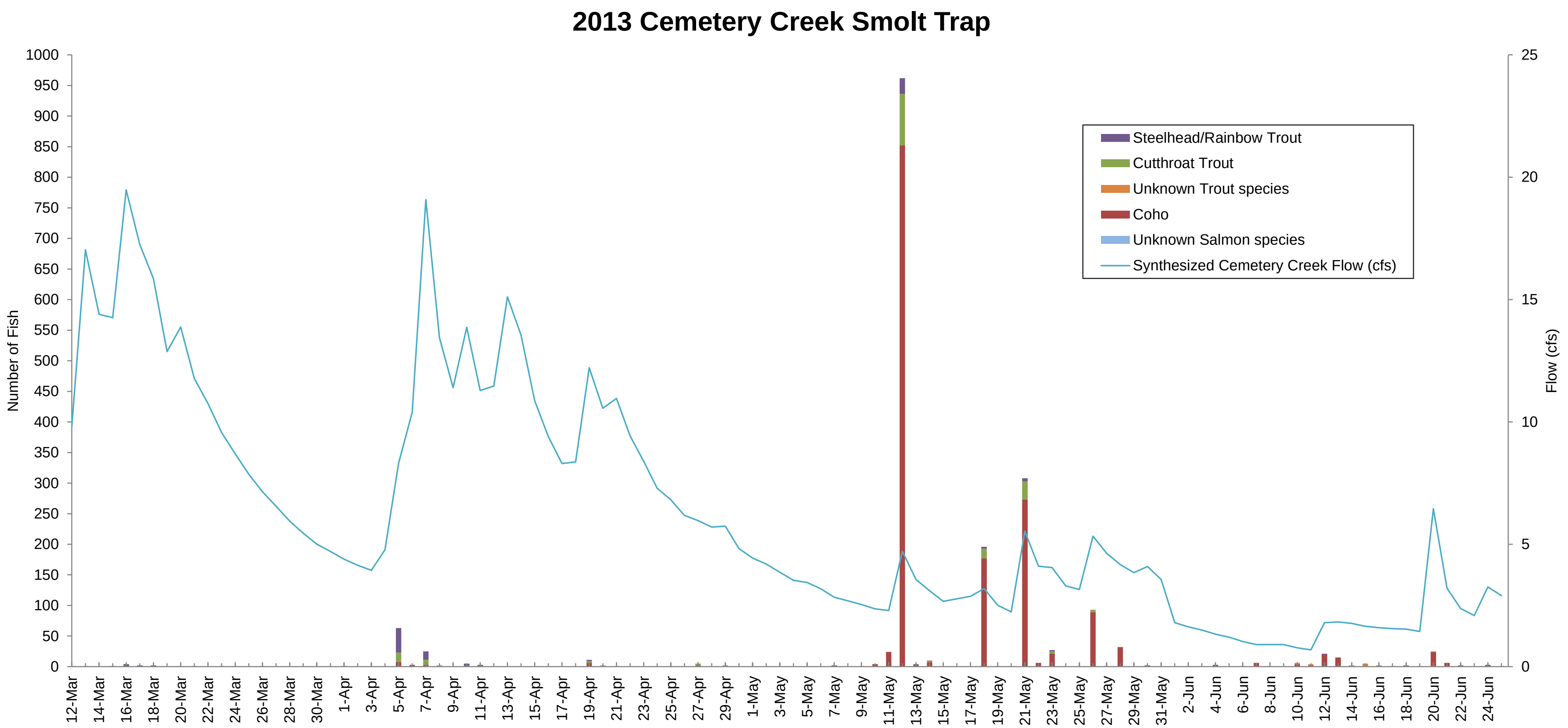

2007 Cemetery Creek Smolt Trap
Steelhead/Rainbow Trout
Cutthroat Trout
Coho
Salmonid species
Synthesized Cemetery Creek Flow (cfs)
Number of Fish
Flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
550
0
1
2
3
4
5
6
7
8
28-Mar
30-Mar
1-Apr
3-Apr
5-Apr
7-Apr
9-Apr
11-Apr
13-Apr
15-Apr
17-Apr
19-Apr
21-Apr
23-Apr
25-Apr
27-Apr
29-Apr
1-May
3-May
5-May
7-May
9-May
11-May
13-May
15-May
17-May
19-May
21-May
23-May
25-May
27-May
29-May
31-May
2-Jun
4-Jun
6-Jun



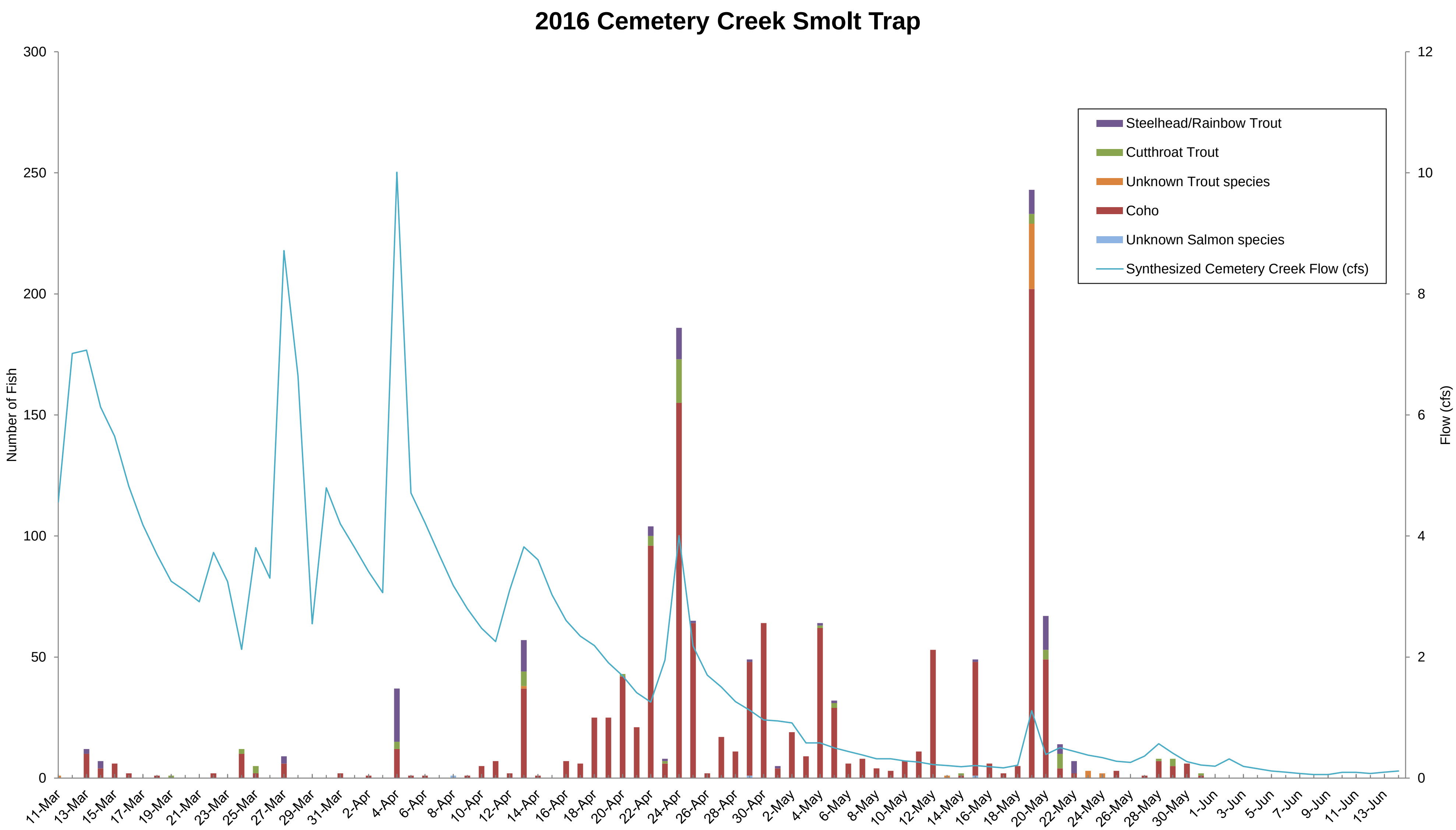
2009 Cemetery Creek Smolt Trap
Number of Fish
Flow (cfs)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
Steelhead/Rainbow Trout
Cutthroat Trout
Trout species
Coho
Salmonid species
Synthesized Cemetery Creek Flow (cfs)
High Flow Release
Panel Opened
18-Mar
20-Mar
22-Mar
24-Mar
26-Mar
28-Mar
30-Mar
1-Apr
3-Apr
5-Apr
7-Apr
9-Apr
11-Apr
13-Apr
15-Apr
17-Apr
19-Apr
21-Apr
23-Apr
25-Apr
27-Apr
29-Apr
1-May
3-May
5-May
7-May
9-May
11-May
13-May
15-May
17-May
19-May
21-May
23-May
25-May



2012 Cemetery Creek Smolt Trap
Number of Fish
Flow (cfs)
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout species
Coho
Unknown Salmon species
Synthesized Cemetery Creek Flow (cfs)



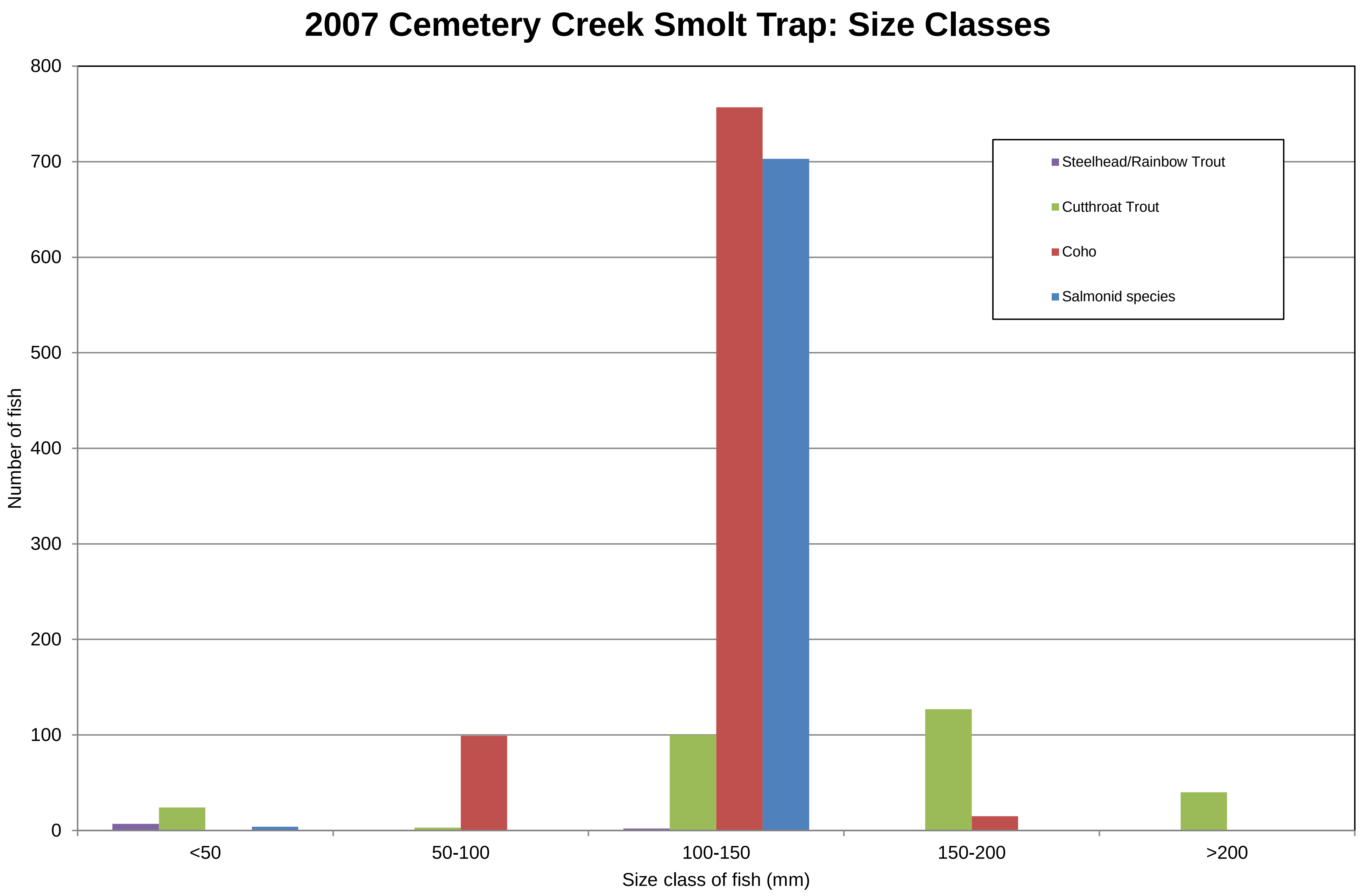
2013 Cemetery Creek Smolt Trap
Number of Fish
Flow (cfs)
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout species
Coho
Unknown Salmon species
Synthesized Cemetery Creek Flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
0
5
10
15
20
25
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
26-Mar
28-Mar
30-Mar
1-Apr
3-Apr
5-Apr
7-Apr
9-Apr
11-Apr
13-Apr
15-Apr
17-Apr
19-Apr
21-Apr
23-Apr
25-Apr
27-Apr
29-Apr
1-May
3-May
5-May
7-May
9-May
11-May
13-May
15-May
17-May
19-May
21-May
23-May
25-May
27-May
29-May
31-May
2-Jun
4-Jun
6-Jun
8-Jun
10-Jun
12-Jun
14-Jun
16-Jun
18-Jun
20-Jun
22-Jun
24-Jun

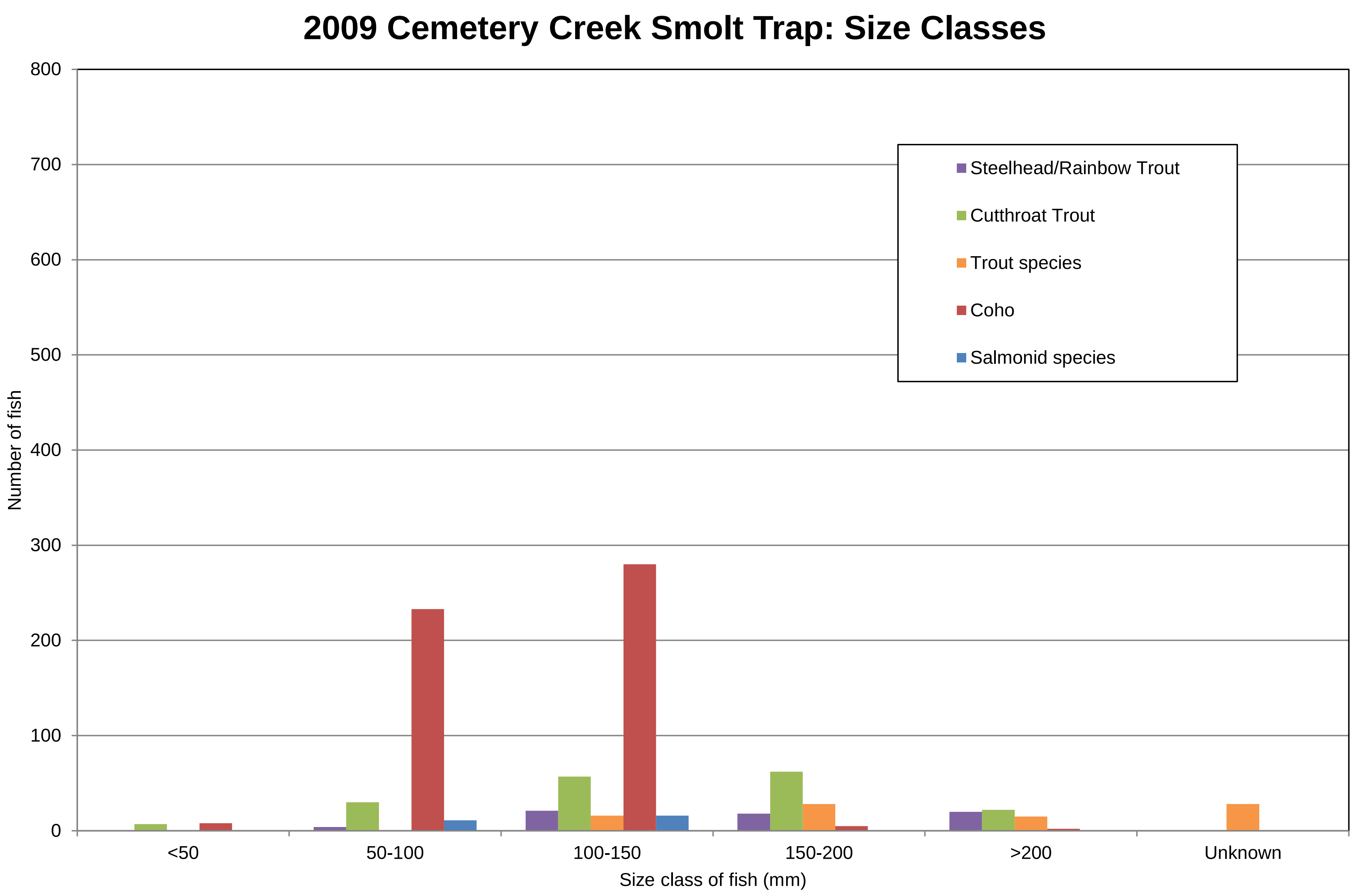


2016 Cemetery Creek Smolt Trap
Number of Fish
Flow (cfs)
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout species
Coho
Unknown Salmon species
Synthesized Cemetery Creek Flow (cfs)
0
50
100
150
200
250
300
0
2
4
6
8
10
12
11-Mar
13-Mar
15-Mar
17-Mar
19-Mar
21-Mar
23-Mar
25-Mar
27-Mar
29-Mar
31-Mar
2-Apr
4-Apr
6-Apr
8-Apr
10-Apr
12-Apr
14-Apr
16-Apr
18-Apr
20-Apr
22-Apr
24-Apr
26-Apr
28-Apr
30-Apr
2-May
4-May
6-May
8-May
10-May
12-May
14-May
16-May
18-May
20-May
22-May
24-May
26-May
28-May
30-May
1-Jun
3-Jun
5-Jun
7-Jun
9-Jun
11-Jun
13-Jun

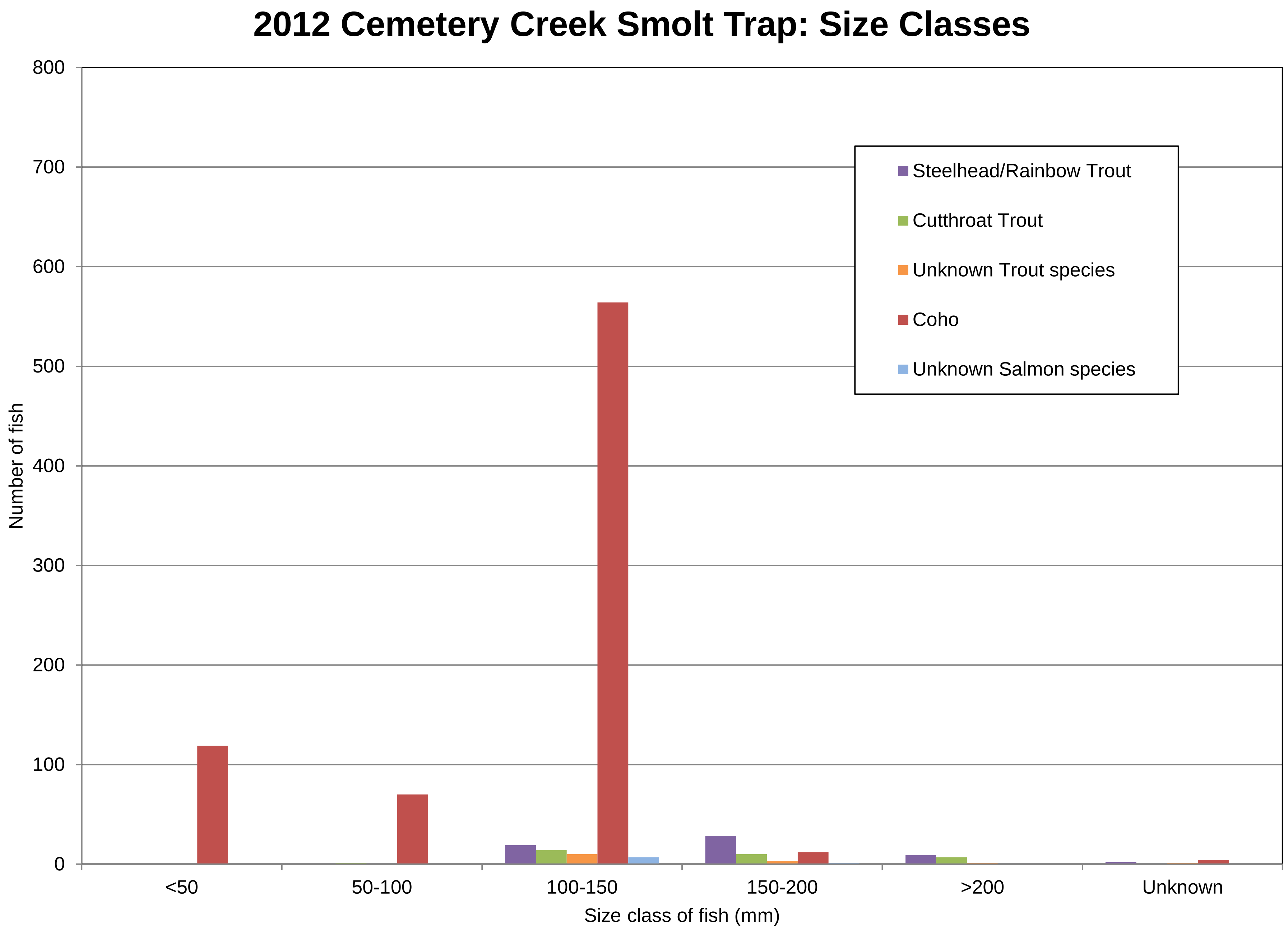
APPENDIX F:

SMOLT TRAP CHARTS SIZE CLASS

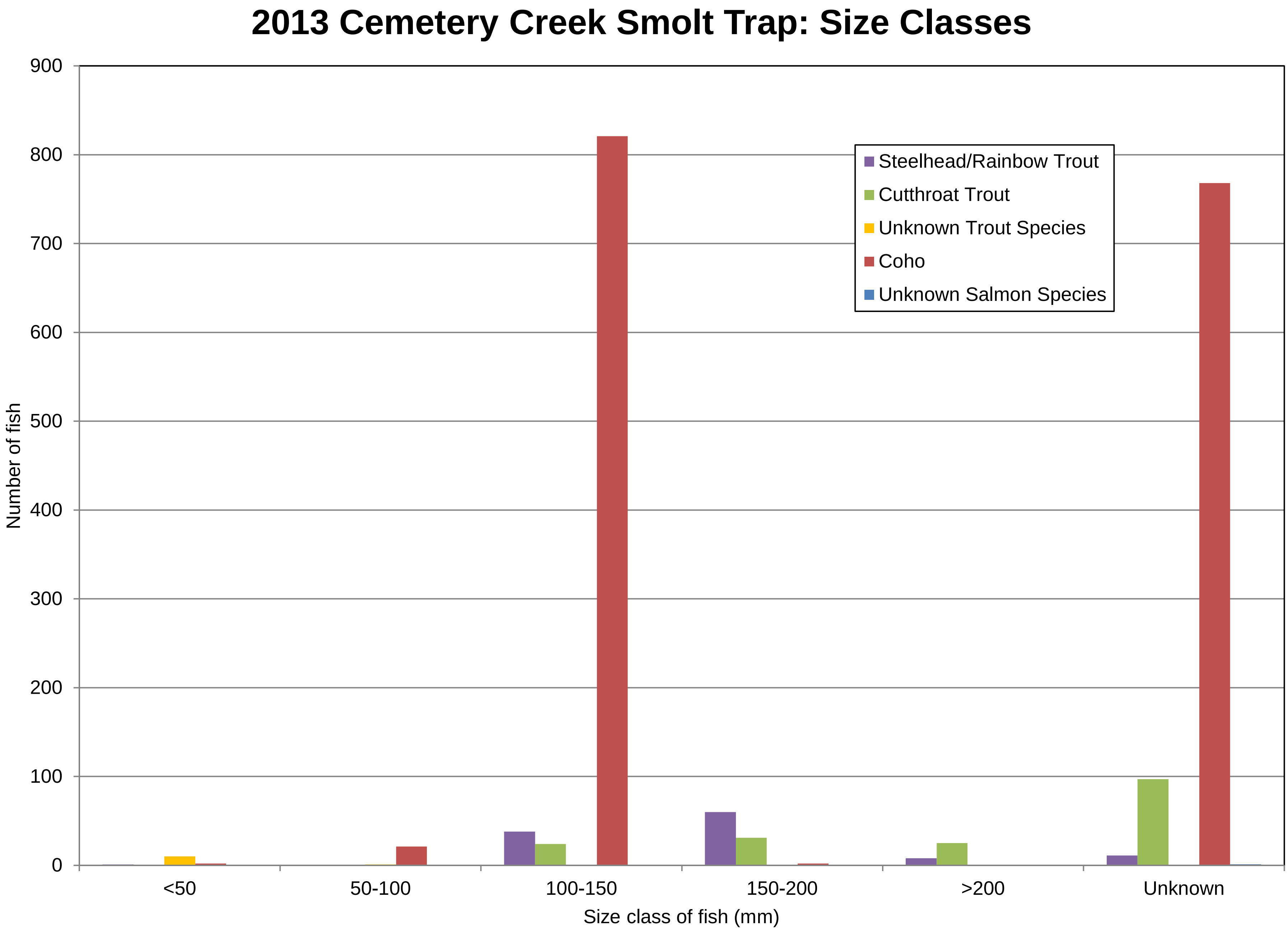

2007 Cemetery Creek Smolt Trap: Size Classes
Number of fish
0
100
200
300
400
500
600
700
800
Steelhead/Rainbow Trout
Cutthroat Trout
Coho
Salmonid species
<50
50-100
100-150
150-200
>200
Size class of fish (mm)

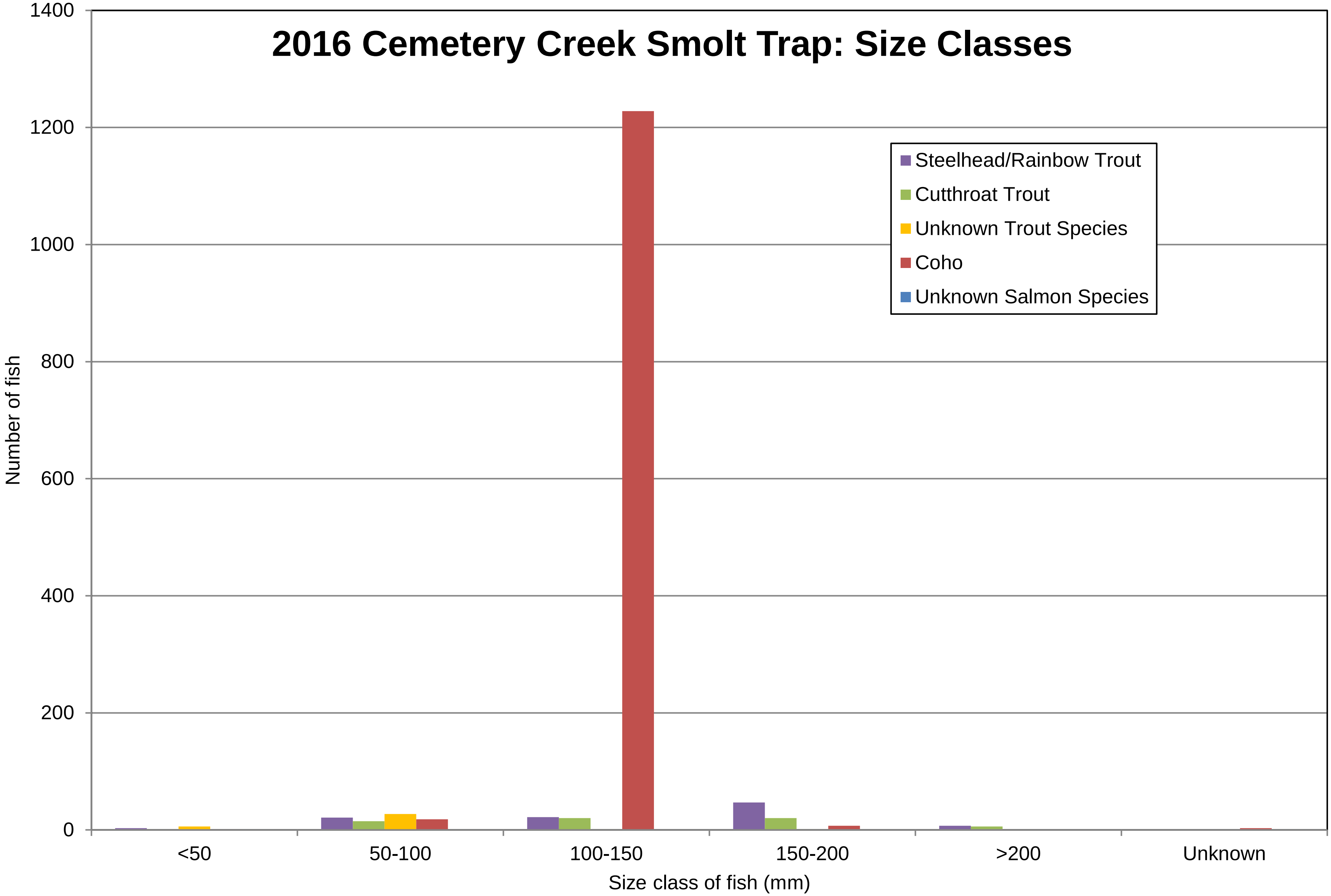


2009 Cemetery Creek Smolt Trap: Size Classes
800
700
600
500
400
300
200
100
0
Number of fish
Steelhead/Rainbow Trout
Cutthroat Trout
Trout species
Coho
Salmonid species
<50
50-100
100-150
150-200
>200
Unknown
Size class of fish (mm)



2012 Cemetery Creek Smolt Trap: Size Classes
800
700
600
500
400
300
200
100
0
Number of fish
<50
50-100
100-150
150-200
>200
Unknown
Size class of fish (mm)
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout species
Coho
Unknown Salmon species


2013 Cemetery Creek Smolt Trap: Size Classes
Number of fish
900
800
700
600
500
400
300
200
100
0
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout Species
Coho
Unknown Salmon Species
<50
50-100
100-150
150-200
>200
Unknown
Size class of fish (mm)


2016 Cemetery Creek Smolt Trap: Size Classes
Number of fish
1400
1200
1000
800
600
400
200
0
Steelhead/Rainbow Trout
Cutthroat Trout
Unknown Trout Species
Coho
Unknown Salmon Species
<50
50-100
100-150
150-200
>200
Unknown
Size class of fish (mm)

APPENDIX G:

2013 AND 2016 STEELHEAD GENETIC REPORTS

Cemetery Creek Steelhead

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December 2013

Abstract

A genetic analysis using 192 single nucleotide polymorphism (SNP) assays were used to conduct a population-of-origin analysis on a total of 24 *Onchorynchus mykiss* samples collected from Cemetery Creek (tributary to Whatcom Creek). Steelhead data from the Nooksack River, Samish River, and Kendall Creek Hatchery were used as a baseline to determine the population of origin for the Cemetery Creek samples. Of the 24 individuals, 17 assigned to populations at probabilities greater than 80%: five assigned to either the Nooksack or Samish natural-origin collections and 12 assigned to Kendall Creek Hatchery. Three of the 24 samples had cutthroat alleles and were excluded, one did not successfully amplify and three other individuals could not be assigned to a population at probabilities 80% or greater, and were not identified.

Introduction

The City of Bellingham is involved in a habitat restoration project that includes monitoring steelhead in Cemetery Creek (tributary of Whatcom Creek). In 2006, Cemetery Creek went through a habitat enhancement project that involved the development of ponds and reconfiguration of the Creek. Since then funding has been provided for monitoring and maintenance of Cemetery Creek.

The long-term monitoring plan includes smolt trapping efforts to document use of the site by juvenile salmonids. Results to date from smolt trap recoveries indicate that there have been 248 *Onchorynchus mykiss* recovered in Cemetery Creek. The objective of this project is to use a genetic analysis to provide population of origin assignments for 24 *O. mykiss* samples that have been captured. These assignments will estimate if the juvenile *O.mykiss* in Cemetery Creek are of hatchery or natural-origin.

Methods

A total of 24 steelhead were sampled from Cemetery Creek and sent by a staff biologist at the City of Bellingham to the Washington Department of Fish and Wildlife Molecular Genetics Laboratory in Olympia, WA.

Genomic DNA was extracted from all samples by digesting a small piece of fin tissue using silica membrane based kits obtained from Qiagen (Valencia, CA, USA) following the manufacturers recommendations. One hundred and ninety two single nucleotide polymorphism (SNP) assays were screened for this study including three loci used to identify cutthroat trout (*O. clarki*) alleles (Table 1). PCR reactions were conducted with a thermal profile as follows: an initial denaturation step of 2 min at 94^{o}C, 40 cycles of denaturation at 94^{o}C for 15 s, 30 s at the appropriate temperature for each multiplex, and 1 min at 72^{o}C, plus a final extension at 72^{o}C for 10 min and final holding step at 10 ^{o}C. Genotypes were visualized using Fluidigm software.

The program ONCOR (Kalinowski et al. 2008) was used to assign each individual to one of the baseline collections (Nooksack and Samish Rivers, and Kendall Creek Hatchery). ONCOR uses conditional maximum likelihood to estimate mixture proportions (Millar 1987) and genotype probabilities are calculated using a partial Bayesian procedure method of Rannala and Mountain (1997). This Rannala and Mountain (1997) method uses the expectation-maximization (EM) algorithm to calculate the population-source probabilities (posterior probabilities) for each sample.

Results / Discussion

Three individuals were identified as having cutthroat alleles at one or more of the three species ID SNP loci, and were removed from the analysis (two samples were identified as a hybrid while one sample was likely a cutthroat). One sample did not amplify at any of the SNP loci likely from lower quality or quantity of DNA for that sample; therefore, it was not identified to a population. Six SNP loci did not amplify and were therefore excluded in the analysis. The remaining 183 SNP assays were used for the population of origin analysis.

Assignments to population of origin for the remaining 20 individuals are shown in Table 2. Some individuals had probability of assignment to two collections; therefore the probability of assignment for each population is shown. The Kendall Creek Hatchery accounted for 70.5% of the assignments and 29.5% of the assignments were to the Nooksack River (6%) or Samish River (23.5%). Three of the 20 Cemetery Creek samples amplified, but were not considered because the probability of assignment was below 80% (Table 2). The genotype of these three samples was similar between populations and therefore the probability of assignment to a single population was lower and they could not be assigned to a single population with confidence.

Acknowledgements

Funding for this study was provided by City of Bellingham, and by WA State General Funds. I acknowledge Sarah Bell for contributions to the lab processing of the samples used in this study.

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Kalinowki, S.T., K.R. Manlove, and M.L. Taper. 2008. ONCOR. A computer program for genetic stock identification. http://www.montana.edu/kalinowski/Software/ONCOR.htm

Millar, R.B. 1987. Maximum likelihood estimation of mixed stock fishery composition. Canadian Journal of Fisheries and Aquatic Sciences 44: 583–590.

Rannala, B. and J.L. Mountain. 1997. Detecting immigration by using multilocus genotypes. Proceedings of the National Academy of Sciences USA 94, 9197-9201.

Table 1. SNP assays used for analysis of steelhead (panels E & F) in Cemetery Creek. Three assays are for identification of cutthroat alleles (AspI001, 014, and 018) and six assays were not used because of missing data in the baseline collections (highlighted grey).

#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname
1	AOmy005	41	AOmy100	81	AOmy195	121	AOmy240	161	AOmy288
2	**AOmy010**	42	AOmy105	82	AOmy197	122	AOmy241	162	**AOmy289**
3	AOmy014	43	AOmy107	83	AOmy198	123	AOmy242	163	AOmy290
4	AOmy015	44	AOmy108	84	AOmy199	124	AOmy243	164	AOmy291
5	AOmy016	45	AOmy110	85	AOmy200	125	AOmy244	165	AOmy292
6	AOmy021	46	AOmy111	86	AOmy201	126	AOmy246	166	AOmy293
7	AOmy023	47	AOmy113	87	AOmy202	127	AOmy247	167	AOmy294
8	AOmy026	48	AOmy114	88	AOmy203	128	AOmy248	168	AOmy295
9	AOmy027	49	AOmy117	89	AOmy204	129	AOmy249	169	AOmy296
10	AOmy028	50	AOmy118	90	AOmy205	130	AOmy250	170	AOmy297
11	**AOmy029**	51	AOmy120	91	AOmy206	131	AOmy252	171	AOmy298
12	AOmy042	52	AOmy123	92	AOmy207	132	AOmy253	172	AOmy299
13	AOmy047	53	AOmy125	93	AOmy208	133	AOmy254	173	AOmy300
14	AOmy048	54	AOmy129	94	AOmy209	134	AOmy255	174	AOmy301
15	AOmy049	55	AOmy132	95	AOmy210	135	AOmy256	175	AOmy302
16	AOmy051	56	AOmy134	96	AOmy211	136	AOmy257	176	AOmy303
17	AOmy056	57	AOmy137	97	AOmy212	137	AOmy258	177	AOmy305
18	AOmy058	58	AOmy144	98	AOmy213	138	AOmy260	178	AOmy306
19	AOmy059	59	AOmy147	99	AOmy214	139	AOmy261	179	AOmy311
20	**AOmy061**	60	AOmy149	100	AOmy215	140	AOmy262	180	AOmy320
21	AOmy062	61	AOmy152	101	AOmy216	141	AOmy263	181	AOmy322
22	AOmy065	62	AOmy173	102	AOmy218	142	AOmy265	182	AOmy324
23	AOmy067	63	AOmy174	103	AOmy220	143	AOmy266	183	AOmy326
24	AOmy068	64	AOmy176	104	AOmy221	144	AOmy267	184	AOmy327
25	AOmy072	65	AOmy177	105	AOmy222	145	AOmy268	185	AOmy328
26	AOmy073	66	AOmy179	106	AOmy223	146	AOmy269	186	AOmy329
27	**AOmy074**	67	AOmy180	107	AOmy225	147	AOmy270	187	AOmy331
28	AOmy078	68	AOmy181	108	AOmy226	148	**AOmy271**	188	AOmy335
29	AOmy079	69	AOmy182	109	AOmy227	149	AOmy272	189	AOmy341
30	AOmy081	70	AOmy183	110	AOmy228	150	AOmy273	190	**ASpI001**
31	AOmy082	71	AOmy184	111	AOmy229	151	AOmy274	191	**ASpI014**
32	AOmy084	72	AOmy185	112	AOmy230	152	AOmy275	192	**ASpI018**
33	AOmy087	73	AOmy186	113	AOmy231	153	AOmy276		
34	AOmy088	74	AOmy187	114	AOmy232	154	AOmy277		
35	AOmy089	75	AOmy189	115	AOmy233	155	AOmy279		
36	AOmy091	76	AOmy190	116	AOmy234	156	AOmy280		
37	AOmy092	77	AOmy191	117	AOmy235	157	AOmy283		
38	AOmy094	78	AOmy192	118	AOmy237	158	AOmy284		
39	AOmy095	79	AOmy193	119	AOmy238	159	AOmy285		
40	AOmy096	80	AOmy194	120	AOmy239	160	AOmy286		

Table 2. Results of the population of origin assignments for 24 steelhead in Cemetery Creek to individual populations. Three individuals in grey highlight are below 80% probability to a population. One individual did not amplify and three were identified as having cutthroat alleles.

Individual	Best Estimate	Probability	2nd Best Estimate	Probability
13EI0001	Kendall Creek hatchery	0.9404	Samish R.	0.0596
13EI0002	Kendall Creek hatchery	0.9982		
13EI0003	Samish R.	0.9607	Kendall Creek hatchery	0.0393
13EI0004	did not amplify			
13EI0005	Nooksack R.	0.9913		
13EI0006	Samish R.	0.9901		
13EI0007	Kendall Creek hatchery	0.9942		
13EI0008	Kendall Creek hatchery	0.602	Samish R.	0.3892
13EI0009	Kendall Creek hatchery	0.9995		
13EI0010	Kendall Creek hatchery	0.5548	Samish R.	0.4446
13EI0011	Kendall Creek hatchery	0.9883	Samish R.	0.0116
13EI0012	Kendall Creek hatchery	0.9982		
13EI0013	cutthroat			
13EI0014	Kendall Creek hatchery	0.9873	Samish R.	0.0126
13EI0015	Kendall Creek hatchery	0.9834	Samish R.	0.0129
13EI0016	Kendall Creek hatchery	0.9999		
13EI0017	cutthroat			
13EI0018	Samish R.	0.5929	Kendall Creek hatchery	0.4014
13EI0019	cutthroat			
13EI0020	Kendall Creek hatchery	0.9916		
13EI0021	Kendall Creek hatchery	0.9475	Samish R.	0.0521
13EI0022	Samish R.	0.9995		
13EI0023	Samish R.	0.9308	Kendall Creek hatchery	0.0638
13EI0024	Kendall Creek hatchery	0.8841	Samish R.	0.1152

Summary of assignments	
Kendall Creek hatchery	12 / 17 = 70.5%
Samish R.	4 / 17 = 23.5%
Nooksack R.	1 / 17 = 6.0%
Probability < 80%	3
cutthroat alleles	3
did not amplify	1
	24

Cemetery Creek Steelhead

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Abstract

A genetic analysis using 192 single nucleotide polymorphism (SNP) assays were used to conduct a population-of-origin analysis on a total of 48 *Onchorynchus mykiss* samples collected from Cemetery Creek (tributary to Whatcom Creek). Steelhead data from the Nooksack River, Samish River, and Kendall Creek Hatchery were used as a baseline to determine the population of origin for the Cemetery Creek samples. Of the 48 individuals, 34 assigned to populations at probabilities greater than 80%: 15 assigned to either the Nooksack or Samish natural-origin collections and 19 assigned to Kendall Creek Hatchery. Eight of the 48 samples had cutthroat alleles and were therefore excluded. Six other individuals could not be assigned to a population at probabilities 80% or greater, and were not identified.

Introduction

The City of Bellingham is involved in a habitat restoration project that includes monitoring steelhead in Cemetery Creek (tributary of Whatcom Creek). In 2006, Cemetery Creek went through a habitat enhancement project that involved the development of ponds and reconfiguration of the Creek. Since then funding has been provided for monitoring and maintenance of Cemetery Creek.

The long-term monitoring plan includes smolt trapping efforts to document use of the site by juvenile salmonids. The objective of this project is to use a genetic analysis to provide population of origin assignments for 48 *Onchorynchus mykiss* samples that have been captured. These assignments will estimate if the juvenile *O.mykiss* in Cemetery Creek are of hatchery or natural-origin.

Methods

A total of 48 *Onchorynchus* individuals were sampled from Cemetery Creek and sent by a staff biologist at the City of Bellingham to the Washington Department of Fish and Wildlife Molecular Genetics Laboratory in Olympia, WA.

Genomic DNA was extracted from all samples by digesting a small piece of fin tissue using silica membrane based kits obtained from Qiagen (Valencia, CA, USA) following the manufacturers recommendations. One hundred and ninety two single nucleotide polymorphism (SNP) assays were screened for this study including three loci used to identify cutthroat trout (*O. clarki*) alleles (Table 1). PCR reactions were conducted with a thermal profile as follows: an initial denaturation step of 2 min at 94^{o}C, 40 cycles of denaturation at 94^{o}C for 15 s, 30 s at the appropriate temperature for each multiplex, and 1 min at 72^{o}C, plus a final extension at 72^{o}C for 10 min and final holding step at 10 ^{o}C. Genotypes were visualized using Fluidigm software.

The program ONCOR (Kalinowski et al. 2008) was used to assign each individual to one of the baseline collections (Nooksack and Samish Rivers, and Kendall Creek Hatchery). ONCOR uses conditional maximum likelihood to estimate mixture proportions (Millar 1987) and genotype probabilities are calculated using a partial Bayesian procedure method of Rannala and Mountain (1997). This Rannala and Mountain (1997) method uses the expectation-maximization (EM) algorithm to calculate the population-source probabilities (posterior probabilities) for each sample.

Results / Discussion

Six SNP loci did not amplify and were therefore excluded in the analysis. The remaining 183 SNP assays were used for the population of origin analysis. Eight individuals were identified as having cutthroat alleles at one or more of the three species ID SNP loci, and were removed from the analysis.

Assignments to population of origin for the remaining 40 individuals are shown in Table 2. Some individuals had probability of assignment to two collections; therefore the probability of assignment for each population is shown. Six of the 40 Cemetery Creek samples amplified, but were not considered because the probability of assignment was below 80% (Table 2). The genotype of these samples was similar between populations and therefore the probability of assignment to a single population was lower and they could not be assigned to a single population with confidence. The Kendall Creek Hatchery accounted for 55.9% of the assignments and 44.1% of the assignments were to a collection of natural origin steelhead (Nooksack River - 8.8% or Samish River - 35.3%).

Acknowledgements

Funding for this study was provided by City of Bellingham, and by WA State General Funds. I acknowledge Cherril Bowman for contributions to the lab processing of the samples used in this study.

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Kalinowki, S.T., K.R. Manlove, and M.L. Taper. 2008. ONCOR. A computer program for genetic stock identification. http://www.montana.edu/kalinowski/Software/ONCOR.htm

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Table 1. SNP assays used for analysis of steelhead (panels E & F) in Cemetery Creek. Three assays are for identification of cutthroat alleles (AspI001, 014, and 018) and six assays were not used because of missing data in the baseline collections (highlighted grey).

#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname	#	WDFW Assay nickname
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2	**AOmy010**	42	AOmy105	82	AOmy197	122	AOmy241	162	**AOmy289**
3	AOmy014	43	AOmy107	83	AOmy198	123	AOmy242	163	AOmy290
4	AOmy015	44	AOmy108	84	AOmy199	124	AOmy243	164	AOmy291
5	AOmy016	45	AOmy110	85	AOmy200	125	AOmy244	165	AOmy292
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7	AOmy023	47	AOmy113	87	AOmy202	127	AOmy247	167	AOmy294
8	AOmy026	48	AOmy114	88	AOmy203	128	AOmy248	168	AOmy295
9	AOmy027	49	AOmy117	89	AOmy204	129	AOmy249	169	AOmy296
10	AOmy028	50	AOmy118	90	AOmy205	130	AOmy250	170	AOmy297
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14	AOmy048	54	AOmy129	94	AOmy209	134	AOmy255	174	AOmy301
15	AOmy049	55	AOmy132	95	AOmy210	135	AOmy256	175	AOmy302
16	AOmy051	56	AOmy134	96	AOmy211	136	AOmy257	176	AOmy303
17	AOmy056	57	AOmy137	97	AOmy212	137	AOmy258	177	AOmy305
18	AOmy058	58	AOmy144	98	AOmy213	138	AOmy260	178	AOmy306
19	AOmy059	59	AOmy147	99	AOmy214	139	AOmy261	179	AOmy311
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21	AOmy062	61	AOmy152	101	AOmy216	141	AOmy263	181	AOmy322
22	AOmy065	62	AOmy173	102	AOmy218	142	AOmy265	182	AOmy324
23	AOmy067	63	AOmy174	103	AOmy220	143	AOmy266	183	AOmy326
24	AOmy068	64	AOmy176	104	AOmy221	144	AOmy267	184	AOmy327
25	AOmy072	65	AOmy177	105	AOmy222	145	AOmy268	185	AOmy328
26	AOmy073	66	AOmy179	106	AOmy223	146	AOmy269	186	AOmy329
27	**AOmy074**	67	AOmy180	107	AOmy225	147	AOmy270	187	AOmy331
28	AOmy078	68	AOmy181	108	AOmy226	148	**AOmy271**	188	AOmy335
29	AOmy079	69	AOmy182	109	AOmy227	149	AOmy272	189	AOmy341
30	AOmy081	70	AOmy183	110	AOmy228	150	AOmy273	190	**ASpI001**
31	AOmy082	71	AOmy184	111	AOmy229	151	AOmy274	191	**ASpI014**
32	AOmy084	72	AOmy185	112	AOmy230	152	AOmy275	192	**ASpI018**
33	AOmy087	73	AOmy186	113	AOmy231	153	AOmy276		
34	AOmy088	74	AOmy187	114	AOmy232	154	AOmy277		
35	AOmy089	75	AOmy189	115	AOmy233	155	AOmy279		
36	AOmy091	76	AOmy190	116	AOmy234	156	AOmy280		
37	AOmy092	77	AOmy191	117	AOmy235	157	AOmy283		
38	AOmy094	78	AOmy192	118	AOmy237	158	AOmy284		
39	AOmy095	79	AOmy193	119	AOmy238	159	AOmy285		
40	AOmy096	80	AOmy194	120	AOmy239	160	AOmy286		

Table 2. Results of the population of origin assignments for 48 samples collected in Cemetery Creek to individual populations. Six individuals in grey highlight are below 80% probability to a population. Eight were identified as having cutthroat alleles.

Individual	Best Estimate	Probability	2nd Best Estimate	Probability
16GW0001	Kendall Creek hatchery	1.0000		
16GW0002	Kendall Creek hatchery	1.0000		
16GW0003	cutthroat	N/A		
16GW0004	Samish R.	0.9890	Kendall Creek hatchery	0.0094
16GW0005	Samish R.	0.9743	Nooksack River	0.0203
16GW0006	Samish R.	0.6516	Nooksack River	0.3424
16GW0007	Kendall Creek hatchery	1.0000		
16GW0008	Kendall Creek hatchery	0.9197	Samish R.	0.0538
16GW0009	Kendall Creek hatchery	0.9175	Samish R.	0.0823
16GW0010	Nooksack River	0.9201	Samish R.	0.0796
16GW0011	Kendall Creek hatchery	1.0000		
16GW0012	Samish R.	0.8778	Nooksack River	0.0556
16GW0013	Kendall Creek hatchery	1.0000		
16GW0014	Samish R.	0.9559	Nooksack River	0.0220
16GW0015	Samish R.	0.5561	Nooksack River	0.4419
16GW0016	Samish R.	0.9237	Nooksack River	0.0736
16GW0017	Kendall Creek hatchery	0.8055	Samish R.	0.1942
16GW0018	Kendall Creek hatchery	0.8557	Samish R.	0.0744
16GW0019	Samish R.	0.8078	Nooksack River	0.1460
16GW0020	Samish R.	0.9403	Kendall Creek hatchery	0.0375
16GW0021	Samish R.	0.9827	Nooksack River	0.0081
16GW0022	Kendall Creek hatchery	0.9500	Samish R.	0.0500
16GW0023	Samish R.	0.9634	Nooksack River	0.0273
16GW0024	Kendall Creek hatchery	0.9493	Samish R.	0.0507
16GW0025	Nooksack River	1.0000		
16GW0026	Samish R.	0.5222	Kendall Creek hatchery	0.4777
16GW0027	Samish R.	0.7194	Kendall Creek hatchery	0.2749
16GW0028	Kendall Creek hatchery	0.5815	Nooksack River	0.2151
16GW0029	Kendall Creek hatchery	0.9965		
16GW0030	Kendall Creek hatchery	0.9999		
16GW0031	Kendall Creek hatchery	0.9993		
16GW0033	Kendall Creek hatchery	1.0000		
16GW0034	Samish R.	0.9516	Kendall Creek hatchery	0.0376
16GW0035	Samish R.	0.6966	Kendall Creek hatchery	0.2981
16GW0036	Samish R.	0.9053	Kendall Creek hatchery	0.0905
16GW0037	cutthroat	N/A		
16GW0038	Kendall Creek hatchery	1.0000		
16GW0039	Kendall Creek hatchery	0.9989		
16GW0040	Nooksack River	0.8835	Samish R.	0.1055

Table 2 continued.

Individual	Best Estimate	Probability	2nd Best Estimate	Probability
16GW0041	Samish R.	0.9881	Nooksack River	0.0118
16GW0042	Kendall Creek hatchery	0.9994		
16GW0043	Kendall Creek hatchery	1.0000		
16GW0044	cutthroat	N/A		
16GW0045	cutthroat	N/A		
16GW0046	cutthroat	N/A		
16GW0047	cutthroat	N/A		
16GW0048	cutthroat	N/A		
16GW0049	cutthroat	N/A		
	Summary of assignments			
	Kendall Creek Hatchery	19 / 34 = 55.9%		
	Samish R.	12 / 34 = 35.3%		
	Nooksack R.	3 / 34 = 8.8%		
	Probability < 80%	6		
	cutthroat alleles	8		
	# Samples Analyzed	48		

APPENDIX H:

AQUATIC INVERTEBRATE ASSEMBLAGES REPORT

BIOLOGICAL ASSESSMENT OF CEMETERY CREEK: BELLINGHAM, WASHINGTON AQUATIC INVERTEBRATE ASSEMBLAGES

2007 - 2013

Report to the City of Bellingham
Public Works, Natural Resources Division
Sara Brooke Benjamin, Project Manager

Prepared by

Wease Bollman
Rhithron Associates, Inc.
Missoula, Montana
June 2014

EXECUTIVE SUMMARY

This report summarizes and interprets data collected from Cemetery Creek as part of a Long-term Restoration Plan, which was a response to a gasoline fire catastrophe in the watershed in 1999. The goals of the Plan include determining impacts of the disaster and identifying measures to improve and enhance salmonid habitat. The benthic macroinvertebrate data summarized in this report were collected as part of the biological monitoring component of the Restoration Plan. Samples of benthic macroinvertebrates are useful in determining whether impairments to water quality or aquatic habitat integrity are present, and they also may, in certain circumstances, provide clues to the identification of stressors that may be causing impairment. Samples were collected in 2007, 2009, 2011, and 2013. Four replicate samples were collected at each of 3 sites on Cemetery Creek in each year. Samples collected in 2007 and 2009 were processed and analyzed by R2 Resource Consultants, Inc. and samples collected in 2011 and 2013 were processed and analyzed by Rhithron Associates, Inc. The effects of differences in sample processing and analysis between the two laboratories were minimized by data adjustments prior to subsequent data analysis.

Data resulting from the analysis of samples was used to derive scores to compare and rank the biological health of streams using two analytical tools, the Benthic Index of Biotic Integrity (B-IBI) and the River InVertebrate Prediction and Classification System (RIVPACS). The B-IBI consistently ranked all sites in all years as being in "very poor" biological health. The RIVPACS model also consistently rated all sites in all years as "impaired".

An additional analysis employed in this study used characteristics of individual taxa collected at each site to predict stressors which may have influenced the composition of the invertebrate assemblages over the years. Evidence for degraded water quality and sediment deposition could be detected at all sites. Thermal stress from warmer-than-expected water temperature, and instream and/or reach-scale habitat disruptions may have additionally limited the biotic potential of the sites.

An analysis of community similarity and further examination of the invertebrates characterizing the sites suggested that hypoxic sediments may have been more influential in the earlier years of the study, with some improvement in these conditions by 2011 and 2013. Hypoxic sediments may be associated with nutrient enrichment and warm water temperatures.

BACKGROUND

On June 10, 1999 an underground pipeline ruptured in Bellingham, Washington, releasing approximately 277,200 gallons of unleaded gasoline into Hannah and Whatcom Creeks. The gasoline was subsequently ignited, resulting in a fire which burned approximately 25 acres of riparian vegetation along the Whatcom Creek corridor. During this event, the fishery and aquatic resources of Whatcom Creek were severely impacted. A Long-term Restoration Plan was designed to determine the impacts of the spill on natural resources and identify measures that would be implemented to restore those injured resources. The goals for rehabilitation and enhancement center on addressing injuries by creating and improving salmonid habitat associated with Whatcom

Creek. To this end, the Cemetery Creek and Salmon Park restoration projects were completed in 2006. Monitoring of these sites was started in 2007 and will continue through 2016. Monitoring of the Cemetery Creek and Salmon Park restoration sites focuses on eight areas, subdivided into three groups:

1) Biological Monitoring
   - Vegetation
   - Fish community
   - Aquatic macroinvertebrates
   - Riparian and terrestrial wildlife community

2) Physical Monitoring
   - Hydrology
   - Instream habitat
   - Water quality

3) Photodocumentation

The Monitoring and Maintenance Plan (COB 2006) specifies that monitoring of the restoration sites shall occur in post-construction years 1, 2, 3, 5, 7, and 10, corresponding to years 2007, 2008, 2009, 2011, 2013, and 2016, respectively. This report details macroinvertebrate monitoring results from post-construction years 1, 3, 5 and 7. Macroinvertebrate data collected in post-construction year 2 (2008) were not analyzed due to persistent backwatering through the lower sample sites in the weeks prior to sampling.

INTRODUCTION

Benthic macroinvertebrates are a diverse assemblage of organisms that inhabit the substrate of aquatic systems for at least part of their life cycle and are visible to the unaided eye (Klemm et al. 1990; Rosenberg and Resh 1993). Freshwater macroinvertebrates include nematodes, annelids, crustaceans, flatworms, mollusks, and insects, and are usually defined in size as being retained by mesh sizes between 0.2 to 0.5 mm. Insects are the most species-rich, and often most abundant, group of benthic macroinvertebrates residing in freshwater habitats (Hershey and Lamberti 2001; Ward 1992).

Macroinvertebrate communities are usually more diverse than fish communities; in addition, they are abundant, easy to collect, somewhat sedentary, and have relatively short life spans of several months to a few years (Barbour et al. 1999). These characteristics allow macroinvertebrate communities to reflect local conditions and the recent past, making them good indicators of stream health and water quality, and useful in evaluating the success of stream restorations.

The objective of aquatic macroinvertebrate sampling on Cemetery Creek is to document colonization and survivorship by the macroinvertebrate community in reconstructed channels in the restoration site. To accomplish this objective, baseline samples were collected from Cemetery Creek in 2007, one year after completion of the restoration project. Sample collections have been repeated in successive years. Figure 1 maps the Whatcom Creek watershed, showing the location of the Cemetery Creek restoration project.

This report details the results of the 2007, 2009, 2011 and 2013 collections, and uses the invertebrate biota to detect impairment to biological health, using two assessment tools: the B-IBI (Benthic Index of Biological Integrity) (Kleindl 1995, Fore et al. 1996, Karr and Chu 1999), calculated by the Puget Sound Stream Benthos (PSSB) website application, which is a battery of 10 biological metrics calibrated for streams of the Pacific Northwest, and a predictive model (RIVPACS – the River InVertebrate Prediction and Classification System) developed by the Washington Department of Ecology (WADOE). RIVPACS compares the occurrence of taxa at a site with the taxa expected at a similar site with minimal human influence, and yields a score that summarizes the comparison. These assessment tools provide a summary score of biological condition, and the B-IBI can be translated into biological health condition classes (i.e., excellent, good, fair, poor, and very poor) based on ranking criteria used by King County and other agencies and organizations in the Puget Sound region (http://pugetsoundstreambenthos.org/). For this study, the “coarse” level of taxonomic resolution was used. In addition, this report identifies probable stressors which may account for diminished stream health, basing these observations on demonstrated and expected associations between patterns of response of B-IBI metrics and other metric expressions, as well as the taxonomic and functional composition of the benthic assemblages. The analysis examines common stressors associated with urbanization: water quality degradation, changes to natural thermal regimes, loss and impairment of instream habitats due to sediment deposition and altered flow regimes, and disturbance to reach scale habitat features such as streambanks, channel morphology, and riparian zone integrity.

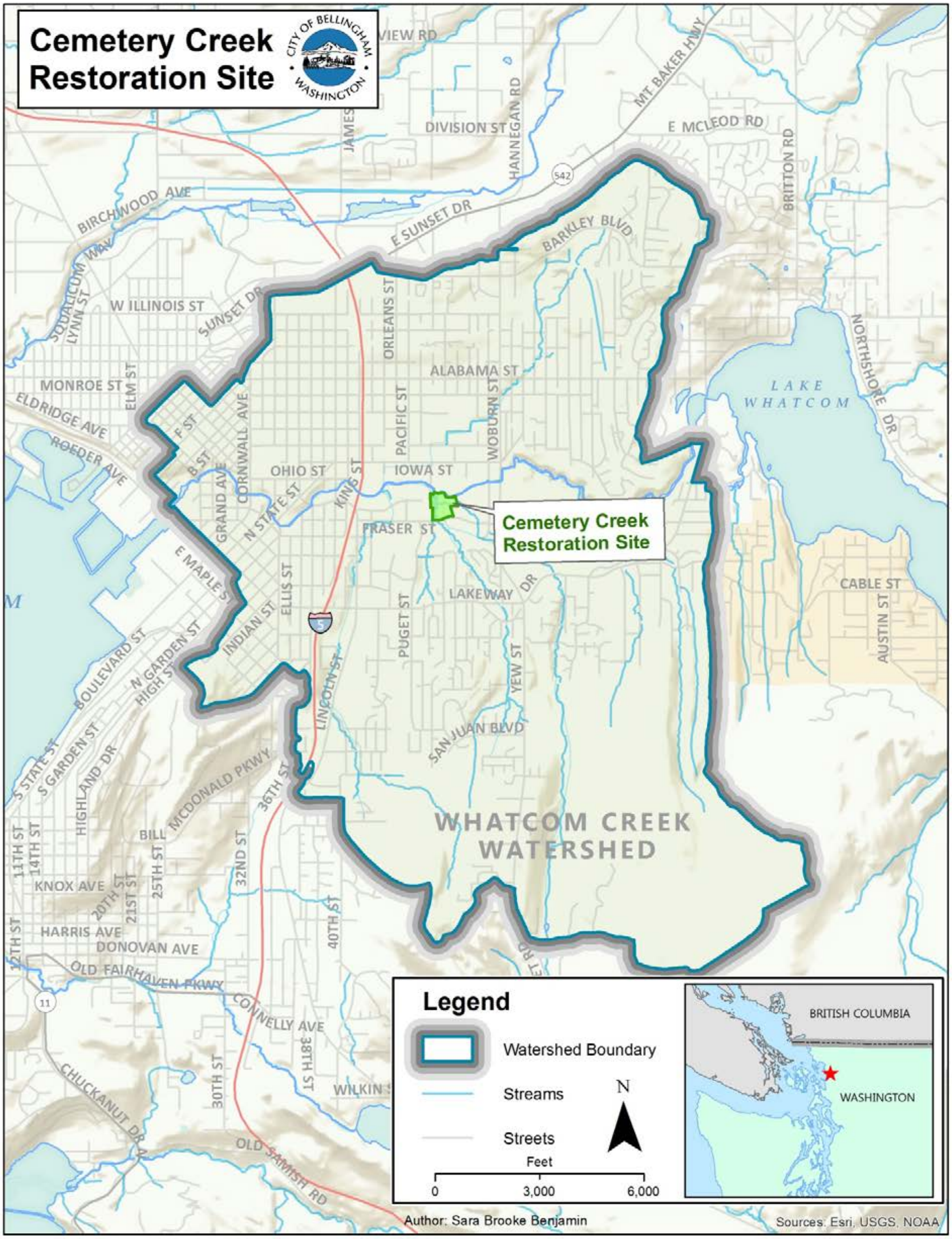

Figure 1. Location map, showing Whatcom Creek watershed boundaries and the location of the Cemetery Creek restoration site.

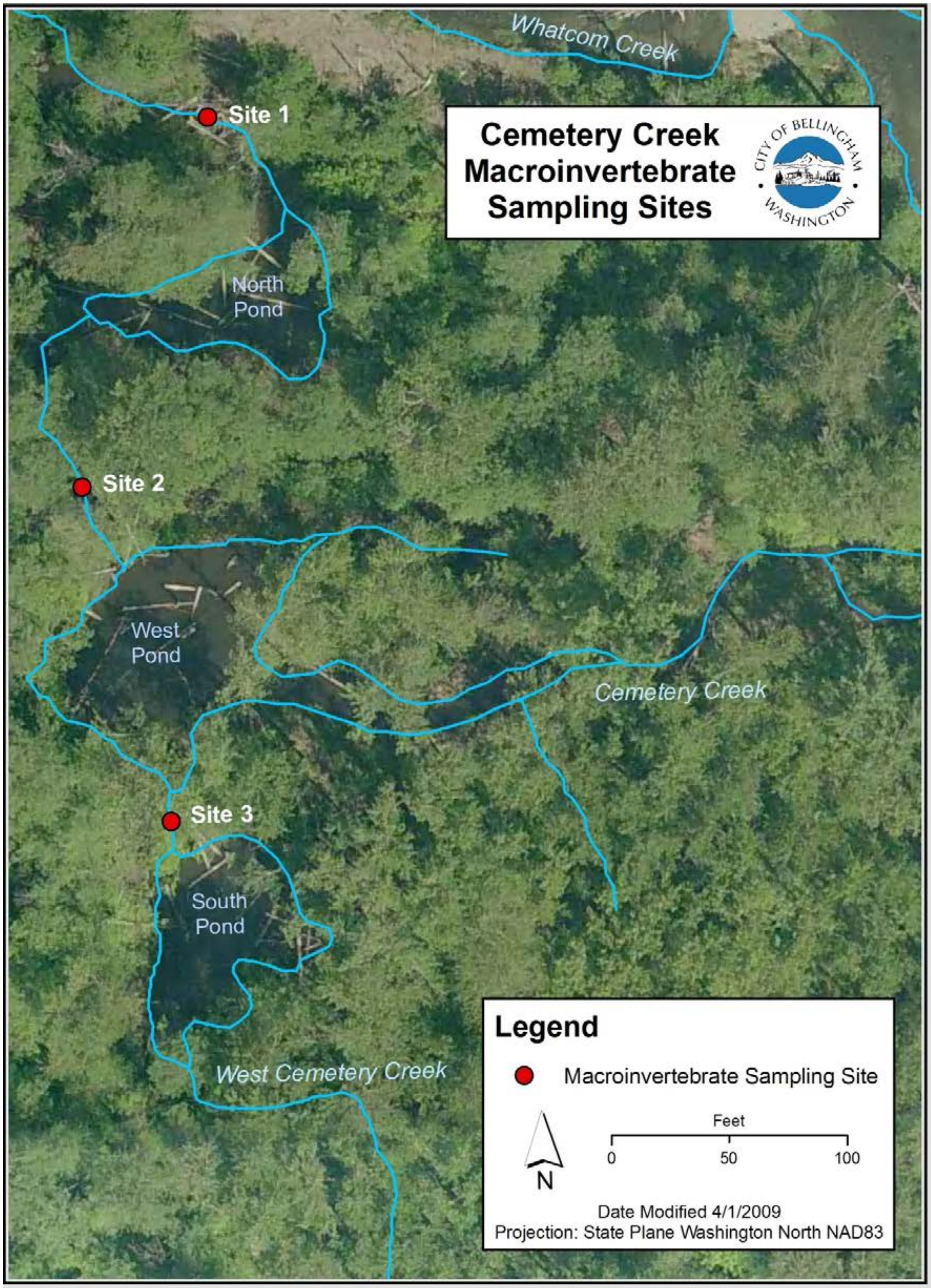

Figure 2. Sampled sites on Cemetery Creek 2007 – 2013.

METHODS

Sampling

Macroinvertebrate samples were collected from three sites within the reconstructed Cemetery Creek channel (Figure 2) on 25 September 2007, 15 September 2009, 21 September 2011, and 24 September 2013.

Macroinvertebrate sampling followed the methodology found in “Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams” (Plotnikoff and Wiseman, 2001), with some modifications. In each year, four replicate samples were taken from riffles within each of the three sites. Samples were collected using a D-frame kick net with a 2.0 ft2 (0.186 m2) delineation square. Rocks within the frame were brushed for collection and substrates disturbed to release the macroinvertebrates.

Samples were contained separately in half and one-liter polycarbonate containers and preserved in 85% ethanol. Each sample included a waterproof label with watershed and stream name, site number and riffle number, and the date and collector. Sample collection was conducted by trained City of Bellingham (COB) and Washington Conservation Corps (WCC) staff.

Qualitative observations were recorded at each site: water clarity, water odors, sediment odors and surface films. Water quality parameters (temperature, pH, conductivity, and dissolved oxygen) were recorded at each site using a Hydrolab, which reads each parameter simultaneously. The Hydrolab was calibrated before the survey session, and audited before and after sampling to ensure data accuracy. Before measurement at each point, the Hydrolab was allowed to equilibrate by waiting for at least two minutes, or until dissolved oxygen had stabilized.

Associated habitat data were collected at each sampled riffle. Substrate measurements were collected using a metal grid with 50 equidistant points. The substrate at each point was classified by size class and recorded. Canopy cover was recorded using a canopy densiometer, counting closed intersections. Six measurements were taken at each riffle: four at the center of the stream (facing upstream, downstream, right bank and left bank), and one on each stream bank, standing with the collector’s back to the stream. Stream reach profile measurements were taken at each riffle and included: wetted width, bankfull width, maximum depth, and gradient.

Sample processing

Samples collected in 2007 and 2009 were processed and identified by R2 Resource Consultants, Inc. (R2). Processing and identification methods used by R2 were described in Appendices A and B of the "Whatcom Creek Restoration Project Report: 2009" (Forester, 2010).

Samples collected in 2011 and 2013 were processed and identified by Rhithron Associates, Inc. (Rhithron).

At Rhithron, standard sorting protocols were applied to achieve representative subsamples of aquatic organisms. Caton sub-sampling devices (Caton 1991), divided into 30 grids, each approximately 6 cm by 6 cm were used. Each individual sample was thoroughly mixed in its jar(s), poured out and evenly spread into the Caton tray, and individual grids were randomly selected. The contents of each grid were examined under stereoscopic microscopes using 10x-30x magnification. All aquatic invertebrates from each selected grid were sorted from the substrate, and placed in ethanol for subsequent identification. This process was continued until subsamples of at least 300 organisms were obtained from each sample. The final selected grid was completely sorted of all organisms. All unsorted sample fractions were retained and stored at the Rhithron laboratory.

Organisms were individually examined by certified taxonomists, using 10x – 80x stereoscopic dissecting scopes (Leica S8E) and identified to target taxonomic levels consistent with B-IBI for Puget Sound Lowlands streams protocols, using appropriate published taxonomic references and keys. Midges (Diptera: Chironomidae) were identified to genus/species group/species and Oligochaetes were identified to subclass. Identification, counts, life stages, and information about the condition of specimens were recorded on electronic bench sheets. To obtain accuracy in richness measures, organisms that could not be identified to the target level specified were designated as “not unique” if other specimens from the same group could be taken to target levels. Organisms designated as “unique” were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 95% ethanol in labeled vials, and archived at the Rhithron laboratory.

Midges were carefully morphotyped using 10x – 80x stereoscopic dissecting microscopes (Leica S8E) and representative specimens were slide mounted and examined at 200x – 1000x magnification using an Olympus BX 51 compound microscope with Hoffman contrast. Slide mounted organisms were archived at the Rhithron laboratory.

Quality assurance (QA)/ quality control (QC) procedures

Quality control procedures for 2007 and 2009 samples involved checking sorting efficiency for 2 samples in each year. R2 reported (Forester 2010) that sorting efficiency exceeded the target goal of 90% for all four QC samples.

For 2011 and 2013 samples, Rhithron’s sorting technicians also checked sorting efficiency. These checks were conducted on all of the samples by independent observers who microscopically re-examined 25% of the sorted substrate from 100% of samples. All organisms that were missed were counted and this number was added to the total number obtained in the original sort. Sorting efficiency was evaluated by applying the following calculation:

$$SE = \frac{n_1}{n_{1+2}} \times 100$$

where: SE is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens expected in the second sort. Target efficiency for these samples was 90%. Failure to achieve 90% sorting efficiency for any QC sample triggers the selection of an additional QC sample from the pool of samples sorted by the technician whose sample failed the QC test.

Rhithron's quality assurance procedures for taxonomic determinations of invertebrates for 2011 and 2013 samples involved checking accuracy, precision and enumeration. Four samples were randomly selected and all organisms re-identified and counted by an independent taxonomist. Taxa lists and enumerations were compared by calculating the Percent Taxonomic Difference (PTD), the Percent Difference in Enumeration (PDE), and a Bray-Curtis similarity statistic (Bray and Curtis 1957) for each selected sample. Routinely, discrepancies between the original identifications and the QC identifications are discussed among the taxonomists, and necessary rectifications to the data are made. Discrepancies that cannot be rectified by discussions are routinely sent out to taxonomic specialists for identification. However, taxonomic certainty for identifications in this project was high, and no external verifications were necessary.

Comparing and contrasting processing and QA/QC methods

R2 used Caton sub-sampling devices (Caton 1991) for sample sorting, and reported that they acquired a fixed-count subsample of 300 (±20%) organisms. Data files, however, include subsample numbers in excess of 360 (300 + 20%) for several samples. This suggests that subsampling efforts, in most cases, was similar to Rhithron's approach, in which randomly selected Caton grids were fully sorted. In one instance, R2 reported sorting a partial grid. Large-rare organism sorts were conducted by both laboratories. R2 added organisms found in this sort to subsample data by multiplying counts for each large-rare taxon by the proportion of the sample that was subsampled. However, when analyzing this historic data, Rhithron discounted these large-rare organisms, and used a count of 1 in each case, rendering the data consistent with PSSB calculations for B-IBI and consistent with Rhithron's methodology.

R2 did not fully identify midges (Diptera: Chironomidae), while Rhithron identified midges to genus level where possible. Rhithron standardized taxonomy to sub-family level for all data prior to PSSB calculation of the B-IBI.

R2 scientists applied QA/QC to sample processing by evaluating sorting efficiency for a total of 4 samples for 2007-2009 samples, and reported sorting efficiency of 90% or better for each sample. The procedure involved a complete resort of processed detritus. Rhithron evaluated sorting efficiency for all samples in 2011 and 2013, by resorting 25% of processed detritus from 100% of samples. Sorting efficiency was calculated in a consistent manner by both laboratories.

While R2 did not report QA/QC for taxonomy and enumeration, Rhithron performed checks for taxonomic similarity, Percent Taxonomic Disagreement, and Percent Difference in Enumeration. Rhithron's QA/QC parameters are reported in Table 1.

Data analysis

B-IBI metrics and scores were calculated for data from all years by the Puget Sound Stream Benthos (PSSB) database application (www.pugetsoundstreambenthos.org), using the "coarse" level of taxonomic resolution. This taxonomic resolution is defined and described on the PSSB website as "This (STE) is the closest to historical, pre-2012 King County sampling efforts. Oligochaetes at "Oligochaeta", Acari at "Acari", snails at family, Dytiscidae to family for adults and larvae, Simuliidae larvae and pupae at family, Chironomids at family, Trichoptera larvae to genus/species/species group and pupae to Trichoptera."

RIVPACS scores were obtained by entering data into a web-based application maintained by the Utah State University's Western Center for Monitoring and Assessment of Freshwater Ecosystems. Related applications on this website produce a taxa list from each sample by a random re-sampling routine that standardizes sample sizes and taxonomic resolution. Output from the RIVPACS applications provide a RIVPACS score for each replicate. Additional biological metrics used in the narrative ecological interpretations of the benthic assemblages were calculated by Rhithron's RAILIS database application (RAILIS v. 1.2 – Rhithron Associates, Inc.).

Metric and taxonomic signals for sediment deposition, thermal stress, water quality (including the presence of possible metals contamination), and habitat indicators were investigated and described in narrative interpretations. These interpretations of the taxonomic and functional composition of invertebrate assemblages are based on demonstrated associations between assemblage components and habitat and water quality variables gleaned from the published literature, the writer's own research and professional judgment, and those of other expert sources (e.g. Wisseman 1998). These interpretations are not intended to replace canonical procedures for stressor identification, such as US EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS), since such procedures require substantial surveys of habitat, and historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology, and other resources that were not readily available for this study.

Instead, attributes of invertebrate taxa that are well-substantiated in diverse literature, published and unpublished research, and that are generally accepted by regional aquatic ecologists, are combined into descriptions of probable water quality and instream and reach-scale habitat conditions. The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and other attributes that are interpreted as evidence of habitat integrity. To arrive at impairment hypotheses, attributes are considered individually, so information is maximized by not relying on a single cumulative score, which may mask stress on the biota. Replicate samples were compiled for the narrative analyses.

Water quality variables are estimated by examining mayfly taxa richness and the Hilsenhoff Biotic Index (HBI) value. Other indications of water quality include the richness and abundance of hemoglobin-bearing taxa and the richness of sensitive taxa. Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g. Bollman 1998, Fore et al. 1996, Wisseman 1998). The Biotic Index (BI) is an adaptation of the Hilsenhoff Biotic Index (HBI: Hilsenhoff 1987). The HBI has a long history of use and validation (Cairns and Pratt 1993). The Biotic Index used in this study uses the relative abundance of taxa and tolerance values associated with them to calculate a score representative of the tolerance of a benthic invertebrate assemblage. Higher BI scores indicate more tolerant assemblages. In one study, the BI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae (Bollman 1998). Crops of filamentous algae are also suspected when macroinvertebrates associated or dependent on it (e.g. LeSage and Harrison 1980, Anderson 1976) are abundant. Nutrient enrichment in streams often results in large crops of filamentous algae (Watson 1988). Hemoglobin-bearing taxa are very tolerant of environments with low oxygen concentrations, since the hemoglobin in their circulating fluids enables them to carry more oxygen than organisms without it. Low oxygen concentrations are often a result of nutrient enrichment in situations where enrichment has encouraged excessive plant growth; nocturnal respiration by these plants creates hypoxic conditions. Sensitive taxa exhibit intolerance to a wide range of stressors (e.g. Wisseman 1998, Hellawell 1986, Barbour et al. 1999), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and other causes of degraded ecosystem health. These taxa are expected to be present in predictable numbers in functioning streams.

Thermal characteristics of the sampled site are predicted by the richness and abundance of cold stenotherm taxa (Clark 1997) which require low water temperatures, and by calculation of the predicted temperature preference of the macroinvertebrate assemblage (Brandt 2001). Hemoglobin-bearing taxa are also indicators of warm water temperatures (Walshe 1947). Dissolved oxygen is associated with water temperature (colder water can hold more dissolved oxygen) and can also vary with the degree of nutrient enrichment. Increased temperatures and high nutrient concentrations can, alone or in concert, create conditions favorable to hypoxic sediments, habitats preferred by hemoglobin-bearers.

Metals sensitivity for some groups, especially the heptageniid mayflies, is well-known (e.g. Clements 1999, Clements 2004, Fore 2003). In the present approach, the absence of these groups in environs where they are typically expected to occur is considered a signal of possible metals contamination, especially when these signals are combined with a measure of overall assemblage tolerance of metals. The Metals Tolerance Index (MTI) (McGuire 1998) ranks taxa according to their sensitivity to metals. Weighting taxa by their abundance in a sample, assemblage tolerance is estimated by averaging the tolerance of all sampled individuals. Higher values for the MTI indicate assemblages with greater tolerance to metals contamination.

The condition of instream and streamside habitats is also estimated by characteristics of the macroinvertebrate assemblages. Stress from sediment deposition is evaluated by caddisfly richness and by clinger richness (Kleindl 1995, Bollman 1998, Karr and Chu 1999). The Fine Sediment Biotic Index (FSBI) (Relyea et al. 2000) is also used. Similar to the BI, tolerance values are assigned to taxa based on the substrate particle sizes with which the taxa are most frequently associated. Scores are determined by weighting these tolerance values by the relative abundance of taxa in a sample. Higher values of the FSBI indicate assemblages with greater fine sediment sensitivity. However, it appears that FSBI values may decrease at sites characterized by the presence of other deposited material, such as large organic material, including leaves and woody debris.

The functional characteristics of macroinvertebrate assemblages are based on the morphology and behaviors associated with feeding, and are interpreted in terms of the River Continuum Concept (Vannote et al. 1980) in the narratives. Alterations from predicted patterns may be interpreted as evidence of water quality or habitat disruption. For example, shredders and the microbes they depend on are sensitive to modifications of the riparian zone vegetation (Plafkin et al. 1989), and the abundance of invertebrate predators is likely to be related to the diversity of invertebrate prey species, and thus the complexity of instream habitats.

RESULTS

Quality Control Procedures

Results of quality control procedures for subsampling and taxonomy for 2011 and 2013 samples are given in Table 1. Quality control procedures and results for sample processing of 2007 and 2009 samples were reported in Appendices A and B of Forester (2010). For Rhithron-processed samples,m sorting efficiency averaged 99.27%. PDE, PTD, and similarity statistics for samples processed for taxonomy QC met Rhithron’s internal data quality criteria (Rhithron Associates 2013), and were all well within industry standards for taxonomy data quality (Stribling et al. 2003).

Data analysis

Taxa lists and counts, and values and scores for standard bioassessment metrics for composited replicate samples are given in the Appendix. Metric results given in the Appendix were calculated by Rhithron’s database application, and values may differ from PSSB database results, since these applications do not always agree on the assignment of taxa attributes. Table 2 summarizes B-IBI and RIVPACS scores for sample replicates. B-IBI scores, using the “coarse” level of taxonomic resolution, varied from 0.0 to 19.4 for Cemetery Creek samples collected for this study. These scores indicated “very poor” conditions for all samples. B-IBI site scores (mean scores over replicates from each site in each year) are graphed in Figure 3.

RIVPACS scores varied from 0.08 to 0.57. These scores indicated impaired biological conditions for all samples.

Table 1. Results of Rhithron's internal quality control procedures for subsampling and taxonomy. Cemetery Creek 2011 and 2013. Quality control results for 2007 and 2009 samples reported by R2 (Forester 2010) indicated that sorting efficiency was measured at >90% for 2 samples in 2007 and 2 samples in 2009.

year	Site	replicate	Sorting efficiency (%)	Bray-Curtis similarity	Percent Taxonomic Disagreement (PTD)	Percent Difference in Enumeration (PDE)
2011	Site 1	1	98.4			
		2	98.79			
		3	98.7			
		4	100			
	Site 2	1	100			
		2	100	96.48%	3.46%	0.51%
		3	99.43	97.82%	2.32%	0.07%
		4	100			
	Site 3	1	100			
		2	100			
		3	98.89			
		4	100			
2013	Site 1	1	100			
		2	99.44			
		3	100			
		4	100	99.35%	0.86%	0.22%
	Site 2	1	100			
		2	99.12			
		3	100	99.60%	0.53%	0.13%
		4	97.8			
	Site 3	1	100			
		2	98.75			
		3	97.72			
		4	95.52			

Table 2. B-IBI ("coarse" taxonomic resolution) and RIVPACS scores for replicates. B-IBI scores ≤20.0 indicate "very poor" conditions. RIVPACS scores ≤ 0.73 indicate impaired conditions. Cemetery Creek 2007 – 2013.

Site	replicate	B-IBI				RIVPACS			
		2007	2009	2011	2013	2007	2009	2011	2013
Site 1	1	6.8	3.7	3.5	0.7	0.16	0.57	0.16	0.32
	2	11.6	3.2	1.2	2.7	0.49	0.41	0.24	0.41
	3	2.2	4.7	9.0	0.0	0.32	0.49	0.49	0.32
	4	9.6	5.8	1.8	1.3	0.16	0.49	0.16	0.16
Site 2	1	8.4	1.4	0.5	0.3	0.49	0.08	0.24	0.24
	2	17.0	1.4	3.2	0.0	0.24	0.24	0.32	0.16
	3	6.8	3.0	6.0	1.2	0.16	0.32	0.32	0.08
	4	13.1	1.4	4.5	0.0	0.32	0.16	0.24	0.08
Site 3	1	0.8	7.4	3.6	0.2	0.16	0.32	0.16	0.32
	2	4.2	6.2	1.8	7.1	0.24	0.16	0.24	0.57
	3	6.1	7.3	19.4	5.2	0.16	0.41	0.32	0.32
	4	5.0	8.8	6.8	1.6	0.16	0.24	0.24	0.41

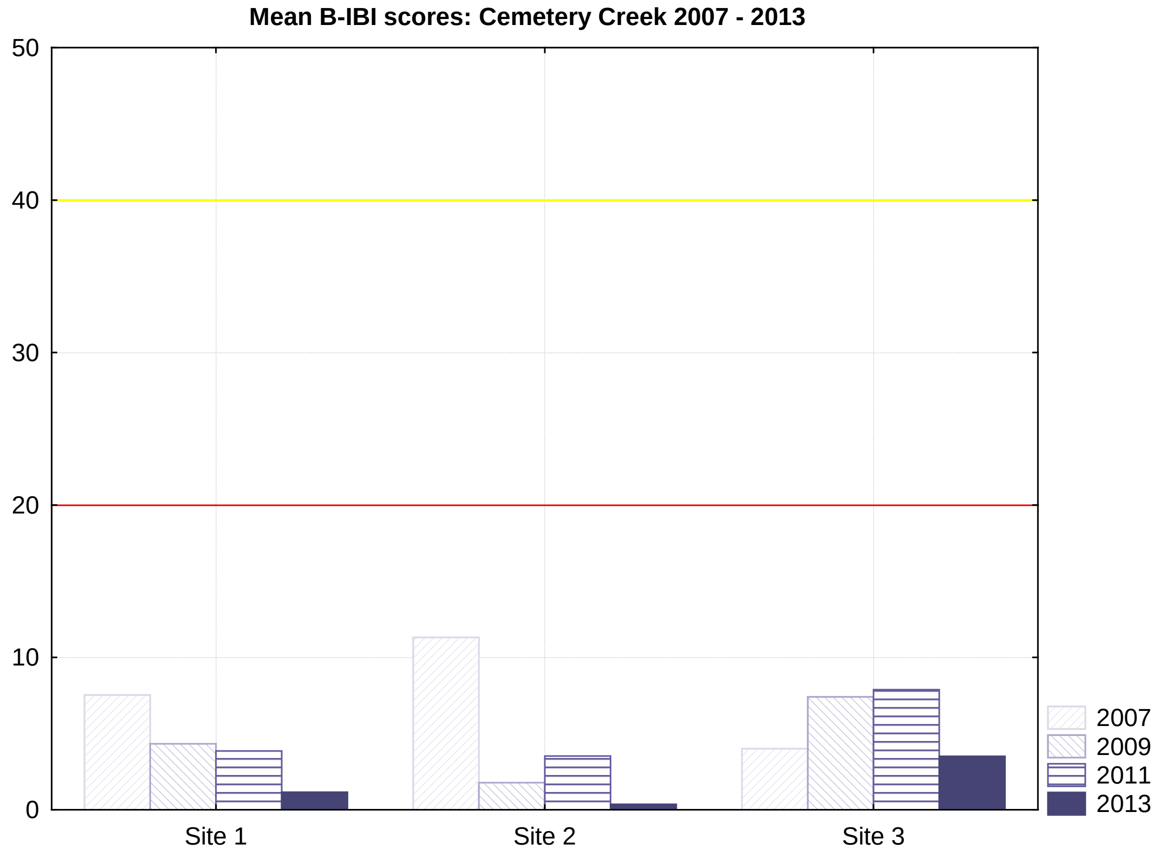

Figure 3. Mean B-IBI site scores for Cemetery Creek sites, 2007-2013. Site scores were calculated by averaging total B-IBI scores across replicates. The yellow line is the threshold (B-IBI = 40) for “fair” conditions; scores falling below the threshold indicate “poor” conditions. Scores falling below the red line (B-IBI = 20) indicate “very poor” conditions.

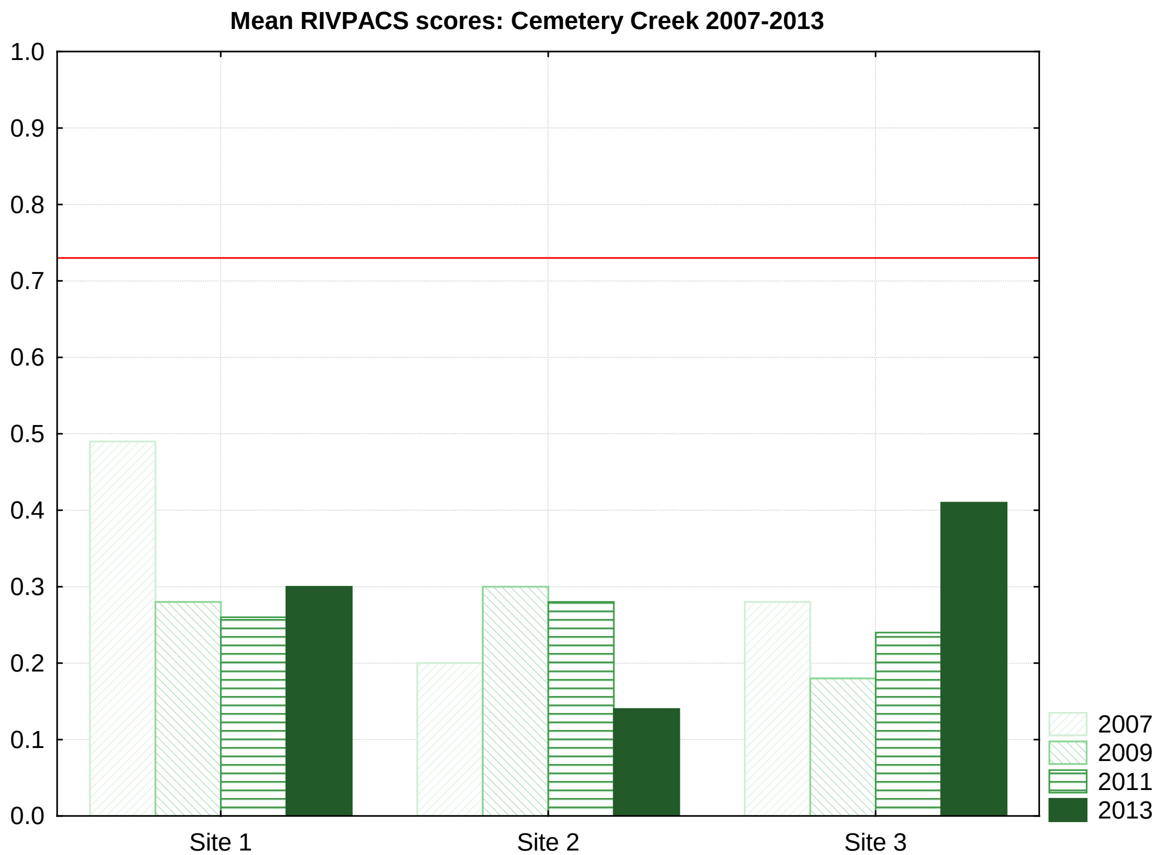

Figure 4. Mean RIVPACS scores for Cemetery Creek sites, 2007-2013. The red line indicates the threshold (RIVPACS = 0.73) for "unimpaired" conditions, set by the Washington Department of Ecology. Scores below the threshold indicate impaired conditions.

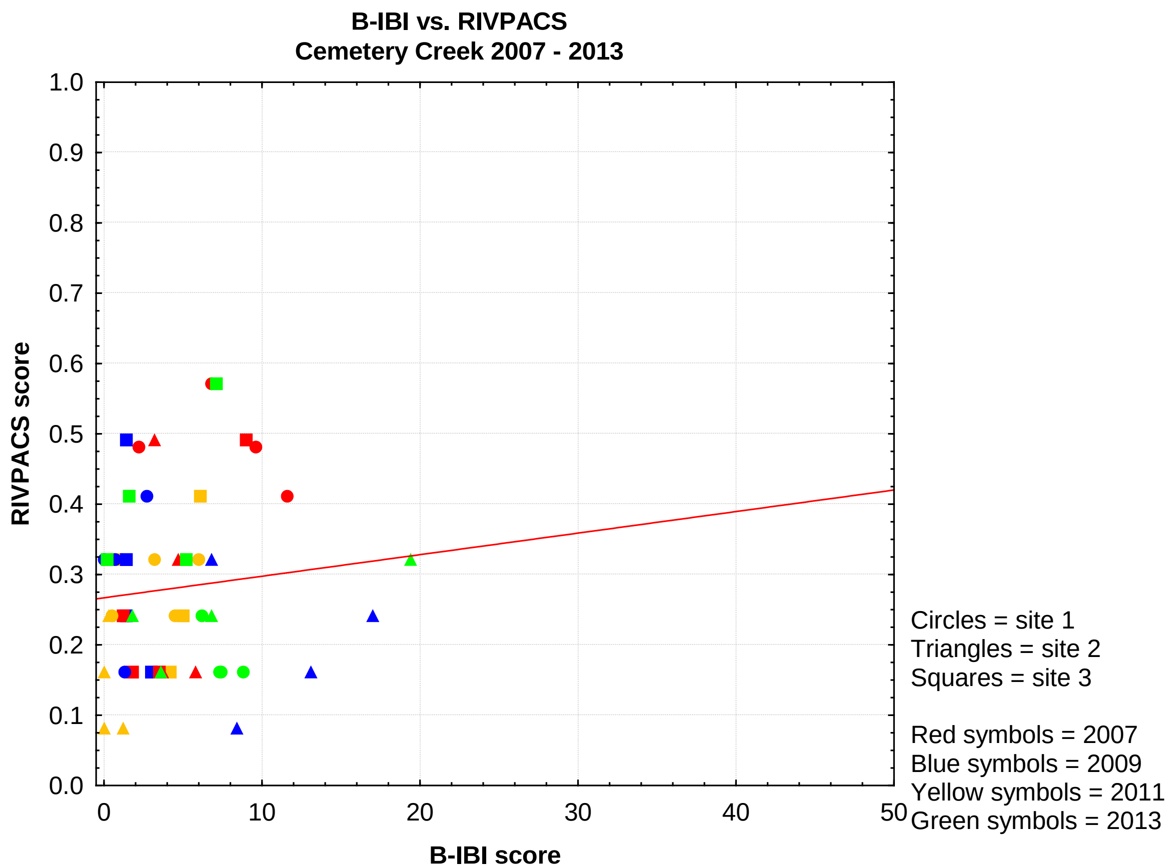

Figure 5. Correlation between B-IBI scores and RIVPACS scores for replicate samples collected in Cemetery Creek 2007 – 2013. The relationship is not significant: r= 0.102, p = 0.491. Key: circles = Site 1, triangles = Site 2, squares = Site 3; red symbols = 2007, blue symbols = 2009, yellow symbols = 2011, green symbols = 2013.

Ecological interpretation of macroinvertebrate assemblages

Narrative interpretations of the taxonomic composition of the aquatic invertebrate assemblages and their autecological attributes are based on composited replicate samples.

Site 1
<u>Bioassessment scores: 2007 - 2013</u>

B-IBI scores for Cemetery Creek Site 1, calculated based on "coarse" level taxonomic resolution, indicated "very poor" biological conditions in each year of sampling. B-IBI scores declined from year to year over the study period, reaching their lowest values in 2013. RIVPACS scores indicated impaired conditions in each year of sampling: scores declined between 2007 and 2009, and were nearly the same in 2011 as in 2009; scores improved somewhat for 2013 samples.

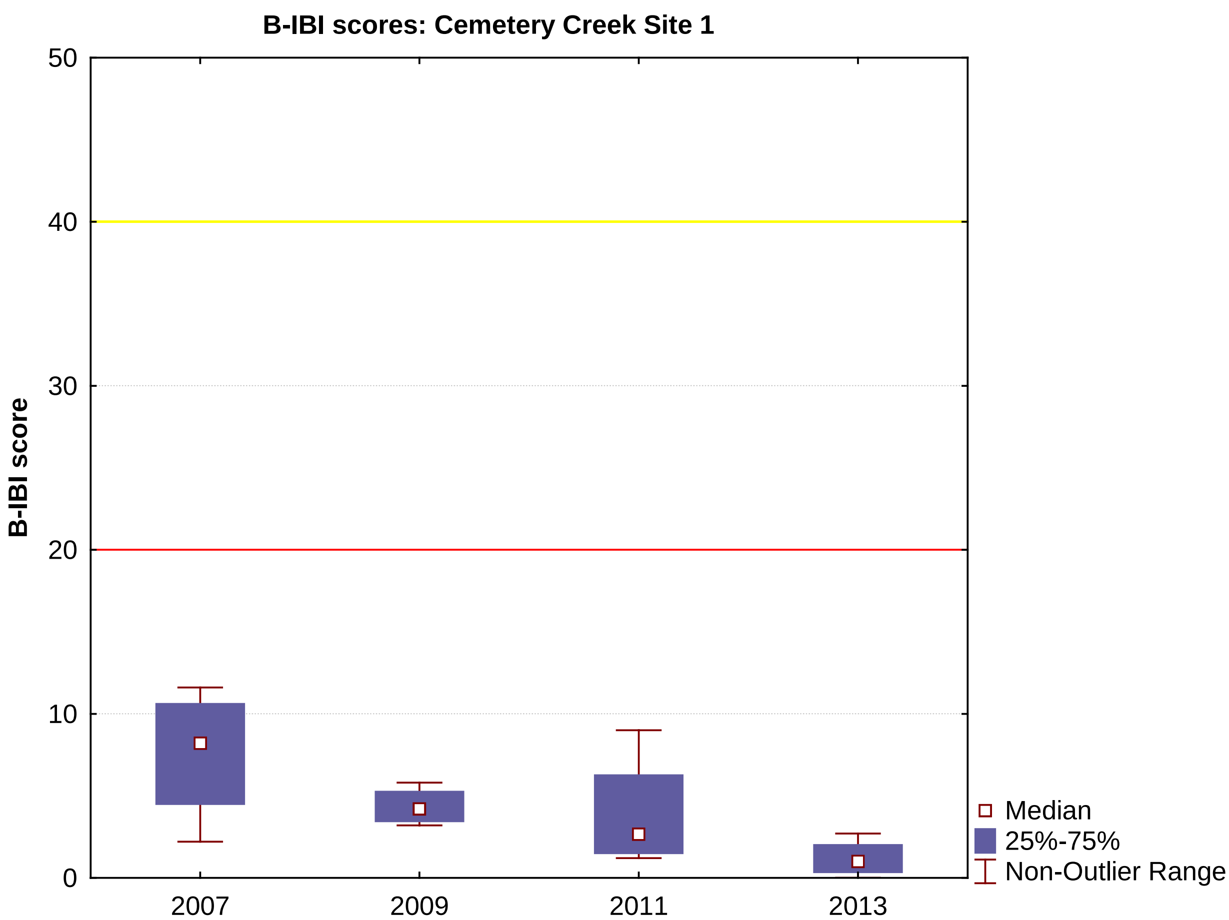

Figure 6. Median B-IBI scores and ranges for replicated samples collected at Cemetery Creek Site 1: 2007-2013. B-IBI scores are based on "coarse" taxonomic resolution over all years. The yellow line is the threshold (B-IBI = 40) for "fair" conditions; scores falling below the threshold indicate "poor" conditions. Scores falling below the red line (B-IBI = 20) indicate "very poor" conditions. Among-year differences in B-IBI scores were statistically significant: Kruskal Wallis H = 7.88, p = 0.049.

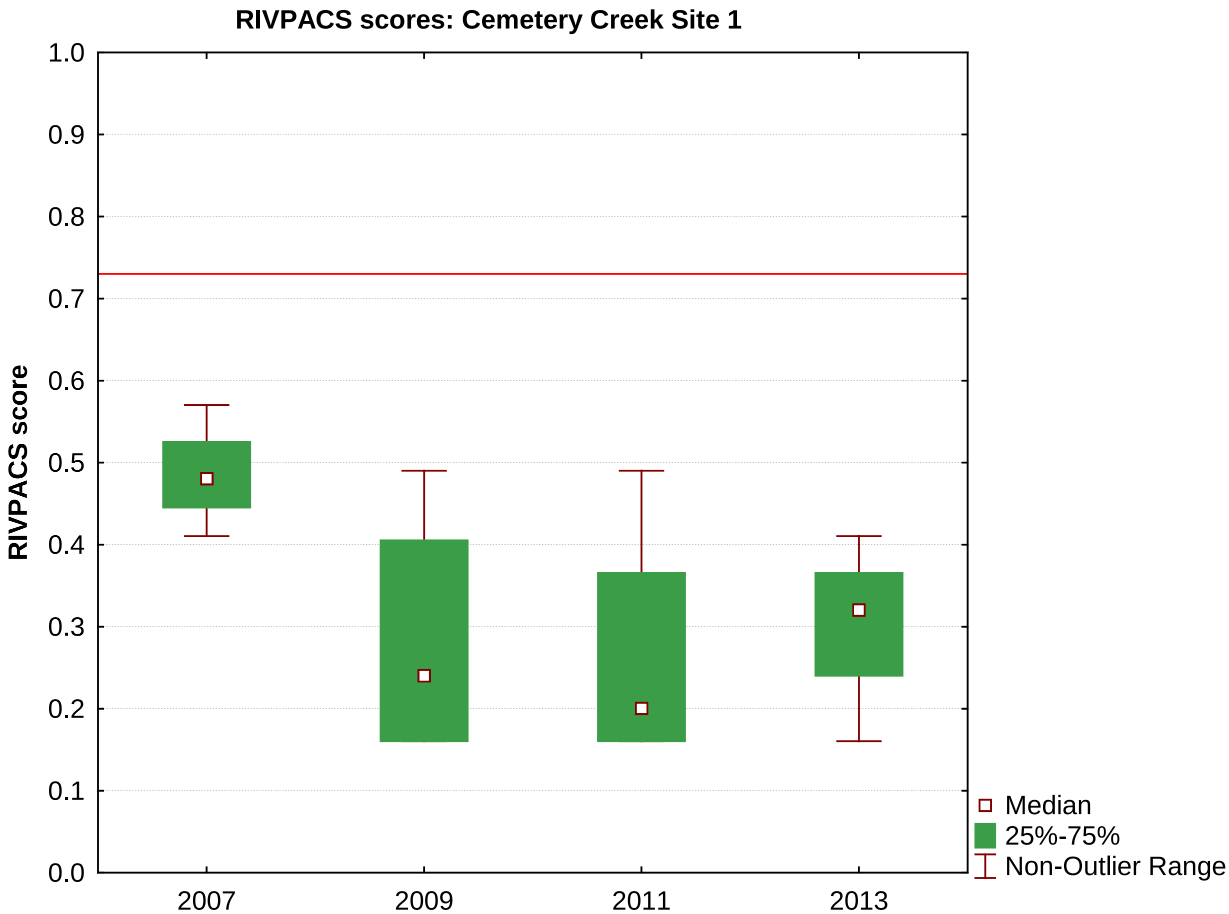

Figure 7. Median RIVPACS scores and ranges for replicated samples collected at Cemetery Creek Site 1: 2007-2013. The red line indicates the threshold (RIVPACS = 0.73) for “unimpaired” conditions, set by the Washington Department of Ecology. Scores below the threshold indicate impaired conditions. Among-year differences in RIVPACS scores were not statistically significant: Kruskal Wallis H = 4.74, p = 0.192.

Indicators of ecological condition: 2007 - 2013

a. Water quality

Metric indicators of water quality suggest poor conditions at Site 1 in each year of the study. Mayfly taxa richness varied between 2 and 3 taxa, and the group always included the ubiquitous species *Baetis tricaudatus*. A single specimen of the sensitive heptageniid mayfly *Cinygma* sp. was collected in 2009. Mayflies were never abundant in any sample in any year. The biotic index values (range: 7.04 – 7.44) were much higher than expected for a Puget Sound Lowlands stream, indicating tolerant invertebrate assemblages. Midges (Diptera: Chironomidae), non-insects, and oligochaetes overwhelmed the taxonomic composition of the fauna. Dominant taxa at the site in each year were the isopod *Caecidotea* sp. and the amphipod *Crangonyx* sp. Ten hemoglobin-bearing taxa, accounting for 7.6% of sampled animals, were present in 2011, suggesting intermittent periods or areas of hypoxic substrates. These conditions may be associated with nutrient enrichment. No evidence for metals contamination could be discerned.

b. Thermal condition

Thermal preferences for assemblages in each year ranged from 14.5 to 16.1°C. Although a cold stenotherm taxon, *Cinygma* sp., appeared in 2009, it was represented by a single specimen, and seems to have been an anomaly in assemblages characterized by warm-water-preferring taxa. These included leeches (undetermined genera in Glossiphoniidae in 2011 and 2013) snails (*Physa* sp. in 2007, 2009, and 2011; *Menetus* sp. in 2009 and 2011) and certain midges (*Dicrotendipes* sp., *Procladius* sp., *Protanypus* sp., *Tribelos* sp. and others, identified in 2011 and 2013).

c. Sediment deposition

Neither “clingers” (ranging from 4 to 10 taxa over the study period) nor caddisflies (range: 1 to 4 taxa) were common in any year, strongly suggesting that sediment deposition limited colonization of stony substrate habitats in this reach. (As noted below, deposition of leafy and woody material of riparian origin could also be a factor in the dearth of these taxa.) The FSBI values (range: 2.57 to 3.88) indicated a sediment-tolerant assemblage.

d. Habitat diversity and integrity

Taxa richness was calculated using sub-family designations for chironomids to account for resolution differences between 2007-2009 and 2011-2013. The parameter ranged from 21 to 32, lower than expected for a Puget Sound Lowlands stream. This suggests monotonous or disrupted instream habitats. The presence of cladocerans and copepods in 2011 suggests that flowing as well as lentic conditions were included in sampling efforts. The abundance of the amphipod *Crangonyx* sp. in each year suggests that ample deposits of leafy and woody material from riparian vegetation may have been present. Such material may have covered stony substrates and may explain the scarcity of “clingers”. Stonefly taxa richness (range: 1 – 3) was lower than expected. Low diversity in this group may be related to disturbed riparian function, altered channel morphology, or unstable streambanks, but also may be a result of impaired water quality. The presence of hydrozoas in 2011 and 2013 suggest that the site may have been downstream of a lake outlet or beaver dam. Composited replicates contained from 1 to 3 long-lived taxa, but in each case, these were represented by only a single specimen, and the group included some taxa (an undetermined genus in Dytiscidae, *Brychius* sp., *Hydraena* sp.) that are pioneers, characterized by more mobility than most benthic taxa. These findings suggest that periodic catastrophes may limit the site’s ability to support a more stable invertebrate fauna. Such events might include periodic thermal stress, scouring sediment pulses, or inputs of toxic pollutants, none of which can be ruled out. Gatherers overwhelmed the functional composition of these samples, a pattern which is sometimes interpreted as evidence of water-quality impairment. No other feeding groups were adequately represented.

Site 2

Bioassessment scores: 2007-2013

B-IBI scores for Cemetery Creek Site 2, calculated based on "coarse" level taxonomic resolution, indicated "very poor" biological conditions in each year of sampling. B-IBI scores declined between 2007 and 2009, improved very slightly in 2011, and declined to their lowest values in 2013. RIVPACS scores indicated impaired conditions in each year of sampling. Scores improved somewhat between 2007 and 2009, and were nearly the same in 2011 as in 2009. Scores declined to their lowest values for 2013 samples.

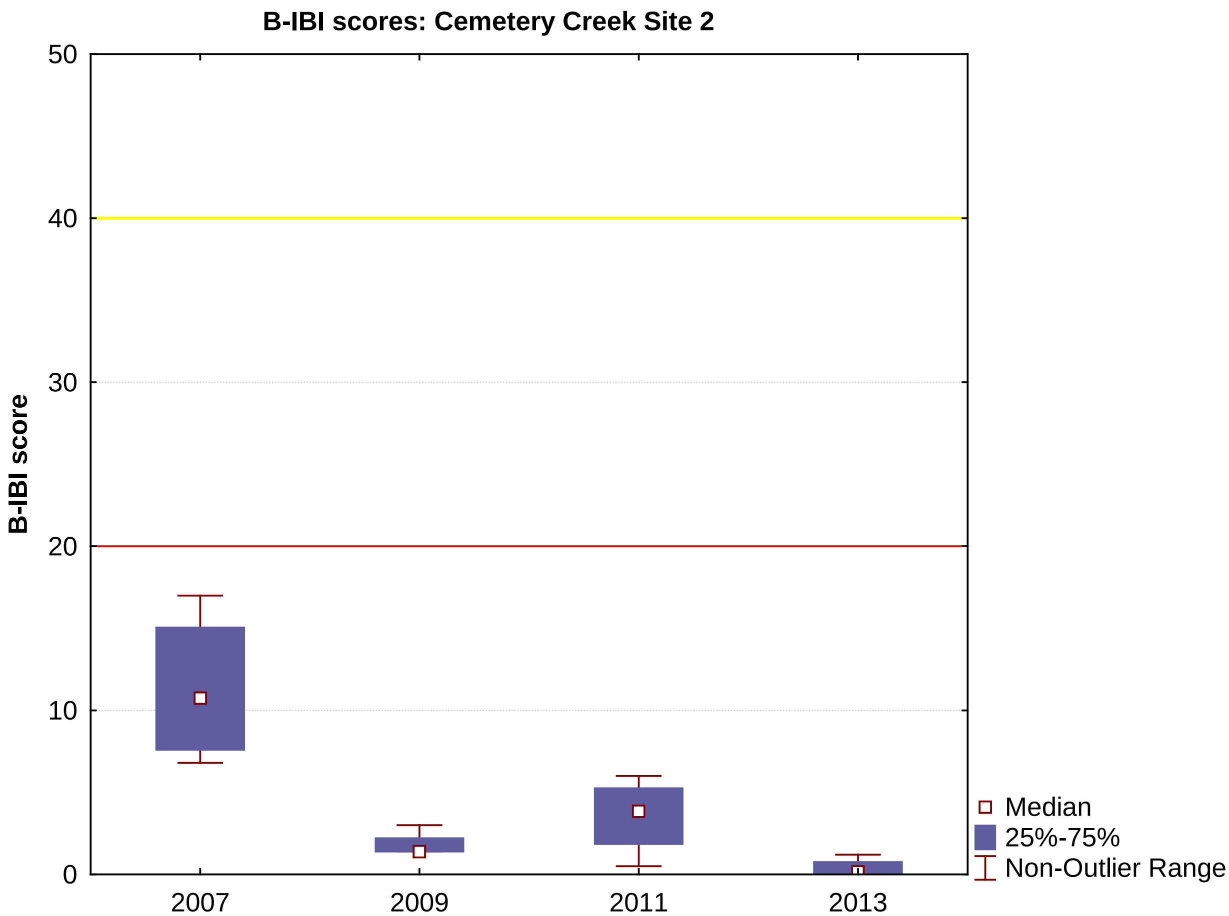

Figure 8. Median B-IBI scores and ranges for replicated samples collected at Cemetery Creek Site 2: 2007-2013. B-IBI scores are based on "coarse" taxonomic resolution over all years. The yellow line is the threshold (B-IBI = 40) for "fair" conditions; scores falling below the threshold indicate "poor" conditions. Scores falling below the red line (B-IBI = 20) indicate "very poor" conditions. Among-year differences in B-IBI scores were statistically significant: Kruskal Wallis H = 12.56, p = 0.006.

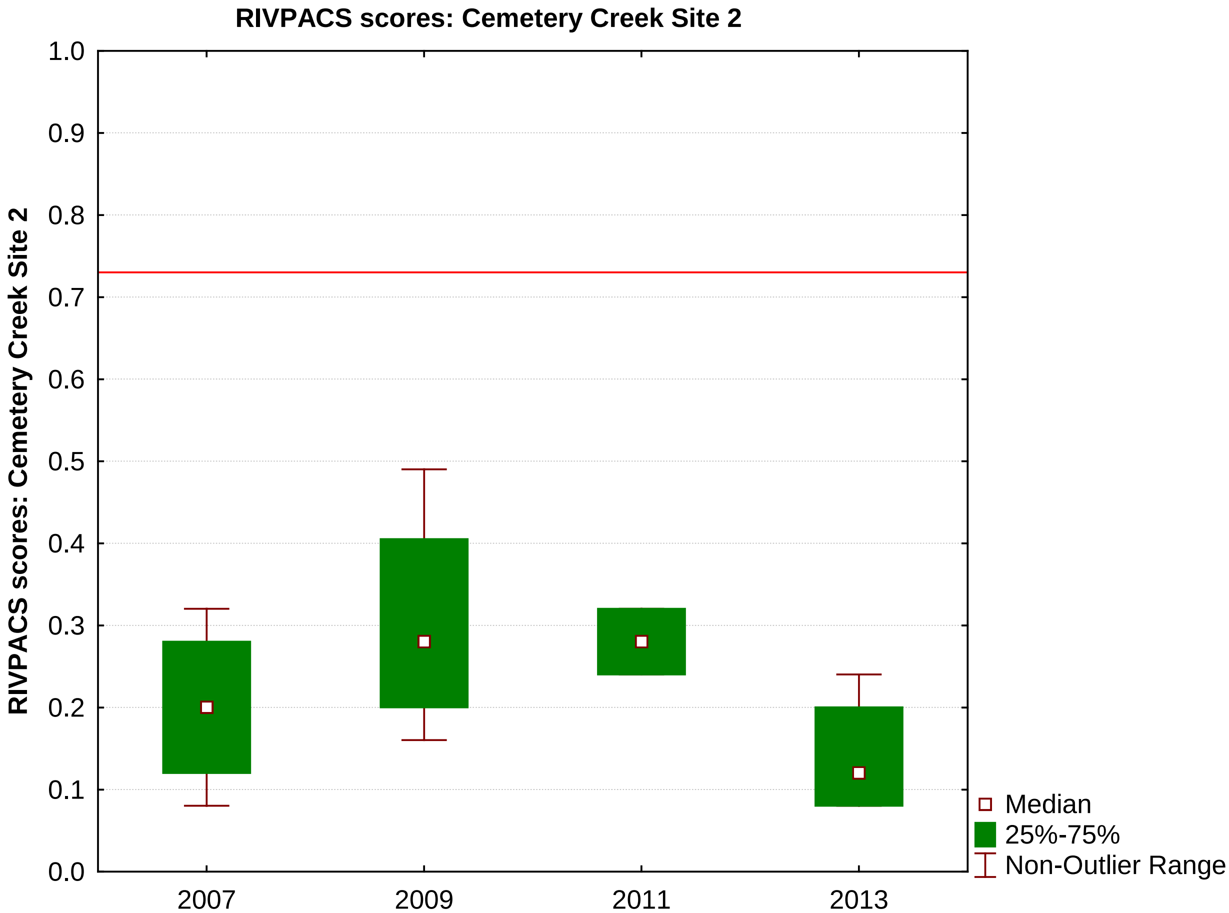

Figure 9. Median RIVPACS scores and ranges for replicated samples collected at Cemetery Creek Site 2: 2007-2013. The red line indicates the threshold (RIVPACS = 0.73) for "unimpaired" conditions, set by the Washington Department of Ecology. Scores below the threshold indicate impaired conditions. Among-year differences in RIVPACS scores were not statistically significant: Kruskal Wallis H = 5.70, p = 0.127.

Indicators of ecological condition: 2007-2013

a. Water quality

Mayflies were neither diverse nor abundant in any year of the study. Richness in this group ranged from 1 to 3 taxa, and no taxon was represented by more than 2 specimens in any given year. A single specimen of the sensitive heptageniid mayfly *Cinygma* sp. was collected in each of the years 2009 and 2011. Values for the biotic index ranged from 6.69 to 7.42: these values are much higher than expected, and indicate tolerant assemblages. Similar to Site 1, dominant taxa included midges, non-insects (especially *Caecidotea* sp. and *Crangonyx* sp.), and oligochaetes. Hemoglobin-bearing taxa were not as abundant here as at Site 1: hypoxic substrates do not appear to have influenced the composition of the assemblage. Impaired water quality is suggested by the taxonomic composition of the assemblage: organic and/or nutrient enrichment may be present. Turbellarian flatworms, including *Polycelis coronata*, which was identified in 2011, were abundant in 3 of the 4 years of sampling, suggesting that groundwater inputs may have augmented surface flow in this reach. *Polycelis coronata* is frequently observed near groundwater seepage areas.

b. Thermal condition

The composition of the benthic fauna suggested cool-to-warm water temperatures: the calculated preferences for the assemblages ranged from 14.2 to 17.4°C. The cold stenotherm taxon *Cinygma* sp. was collected in 2009 and 2011: in each year, a single specimen was counted in samples. There were distinctly fewer warm-water indicators among the taxa at Site 2, compared to Site 1.

c. Sediment deposition

Similar to the findings at Site 1, "clingers" and caddisflies were poorly represented at Site 2. The number of "clinger" taxa ranged from 1 to 7, with very low abundances in the group evident in each year of the study. Caddisflies were absent from samples in 2009 and 2013, and represented by 3 taxa in 2007 (one of which was *Hydroptila* sp., typically associated with filamentous algae, and not influenced by the composition of benthic substrates) and 2 taxa in 2011. These findings suggest that stony substrate habitats may have been obliterated by sediment deposition or by coarse organic material such as leaves and woody debris. The FSBI values ranged widely from 4.50 in 2007, indicating a sediment-sensitive assemblage, to 2.45 in 2011, indicating a sediment-tolerant assemblage. These results may have been unreliable, due to a lack of taxa with associated sediment sensitivity ratings.

d. Habitat diversity and integrity

Taxa richness was calculated using sub-family designations for chironomids to account for resolution differences between 2007-2009 and 2011-2013. Samples exhibited low diversity compared to expectations for a Puget Sound Lowlands stream: overall richness ranged from 16 to 31 unique taxa. This suggests that instream habitats may have been monotonous or disrupted. The presence of hydrozoas in 2011 and 2013 suggest that the site may have been downstream of a lake outlet or beaver dam, and the presence of cladocerans and copepods in 2011 suggests that flowing as well as lentic conditions were included in sampling efforts. Stoneflies were represented by 3 taxa in 2011, including *Zapada cinctipes*, which accounted for 2.1% of the fauna in that year, and which suggests that leafy and woody debris was a common substrate component. However, overall richness of stoneflies was low in all years: low diversity in this group may be related to impaired riparian function, altered channel morphology, or unstable streambanks, but may also be an indication of impaired water quality. Less motile semivoltine taxa were almost completely absent from these samples. Thus, catastrophic dewatering, scour, thermal stress, or toxic pollutants cannot be ruled out at Site 2. Similar to Site 1, the fauna at this site was overwhelmed by gatherer taxa, which may be a further indication of water quality impairment. Predators, especially dance flies (e.g. *Chelifera* sp., *Hemerodromia* sp.) in 2007 and 2011, and turbellarian flatworms in 2013, were also significant contributors to the functional composition of assemblages in 3 of the 4 years. However, other expected feeding groups, such as shredders and scrapers, were notably scarce at this site.

Site 3

Bioassessment scores: 2007-2013

B-IBI scores for Cemetery Creek Site 3, calculated based on "coarse" level taxonomic resolution, indicated "very poor" biological conditions in each year of sampling. B-IBI scores improved somewhat between 2007 and 2009, but declined in each subsequent year of sampling. In 2013, values were at their lowest level. RIVPACS scores indicated impaired conditions in each year of sampling. Scores declined between 2007 and 2009, and improved somewhat in subsequent years.

Indicators of ecological condition: 2007-2013

a. Water quality

Low mayfly abundance and diversity characterized this site in each year of the study. Taxa richness in this group ranged from 1 to 3 taxa, with abundances never exceeding 14 individuals in any year: in 2007, a single specimen was counted. The sensitive heptageniid mayfly *Cinygma* sp. was present in each year: 6 specimens of *Cinygma* were collected in both 2009 and 2011. The biotic index values calculated for the assemblages at this site ranged from 5.21 to 7.05, and indicated tolerant assemblages in each year. Impaired water quality is strongly suggested by these findings. However, biotic index values were generally lower at this site than at Sites 1 and 2, suggesting that the site supported a marginally more sensitive fauna compared to the downstream sites. The fauna here differed from the other two sites in that midges (Diptera: Chironomidae) dominated the assemblages in each of the years 2007, 2009, and 2011 at Site 3. In 2013, the amphipod *Crangonyx* sp. was the dominant taxon.

b. Thermal condition

Cool-to-warm thermal conditions were suggested by the composition of the aquatic fauna at Site 3. The thermal preferences calculated for the assemblages ranged from 13.5 to 15.9°C: these are the coolest thermal preferences among the sites in this study. A cold stenotherm taxon (*Cinygma* sp.) was present here in each year.

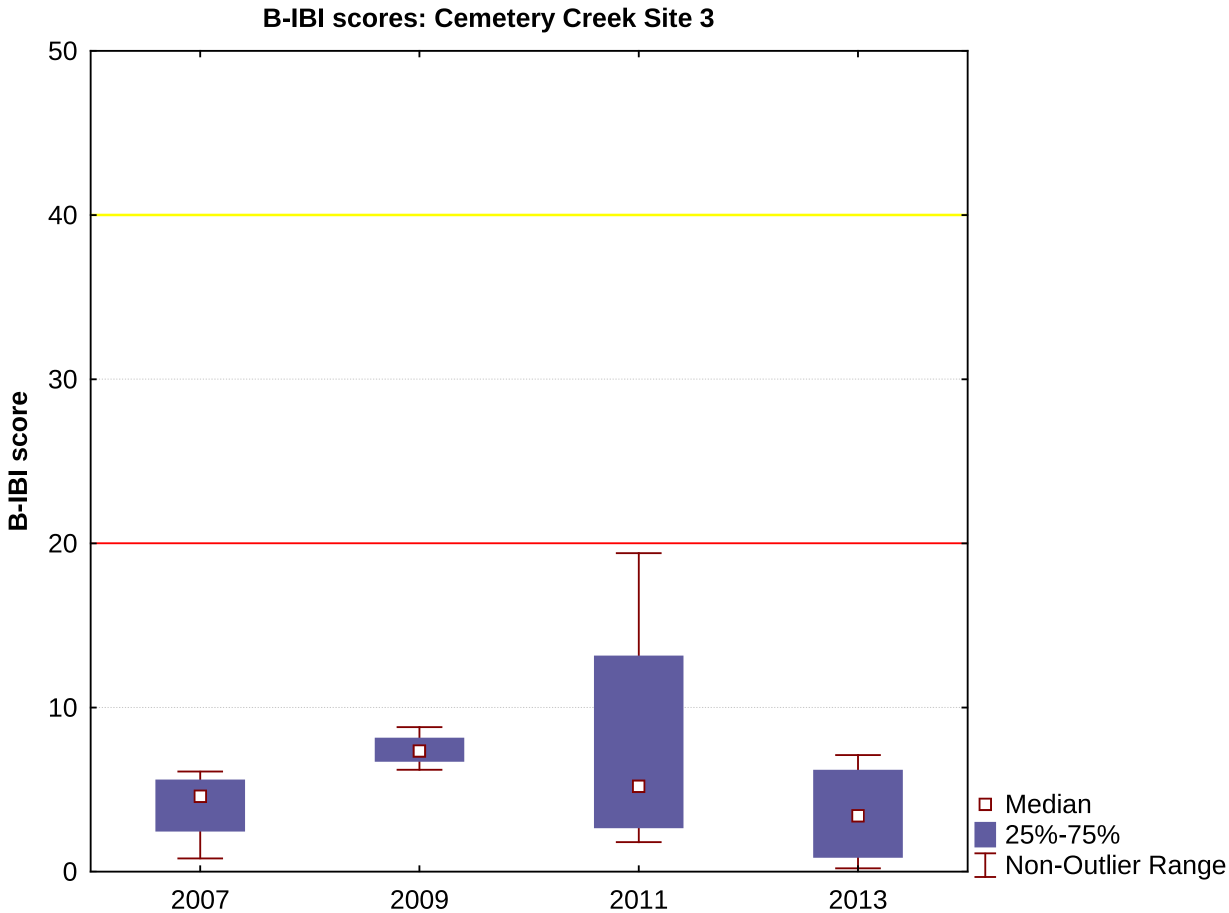

Figure 10. Median B-IBI scores and ranges for replicated samples collected at Cemetery Creek Site 3: 2007-2013. B-IBI scores are based on “coarse” taxonomic resolution over all years. The yellow line is the threshold (B-IBI = 40) for “fair” conditions; scores falling below the threshold indicate “poor” conditions. Scores falling below the red line (B-IBI = 20) indicate “very poor” conditions. Among-year differences in B-IBI scores were not statistically significant: Kruskal Wallis H = 5.82, p = 0.121.

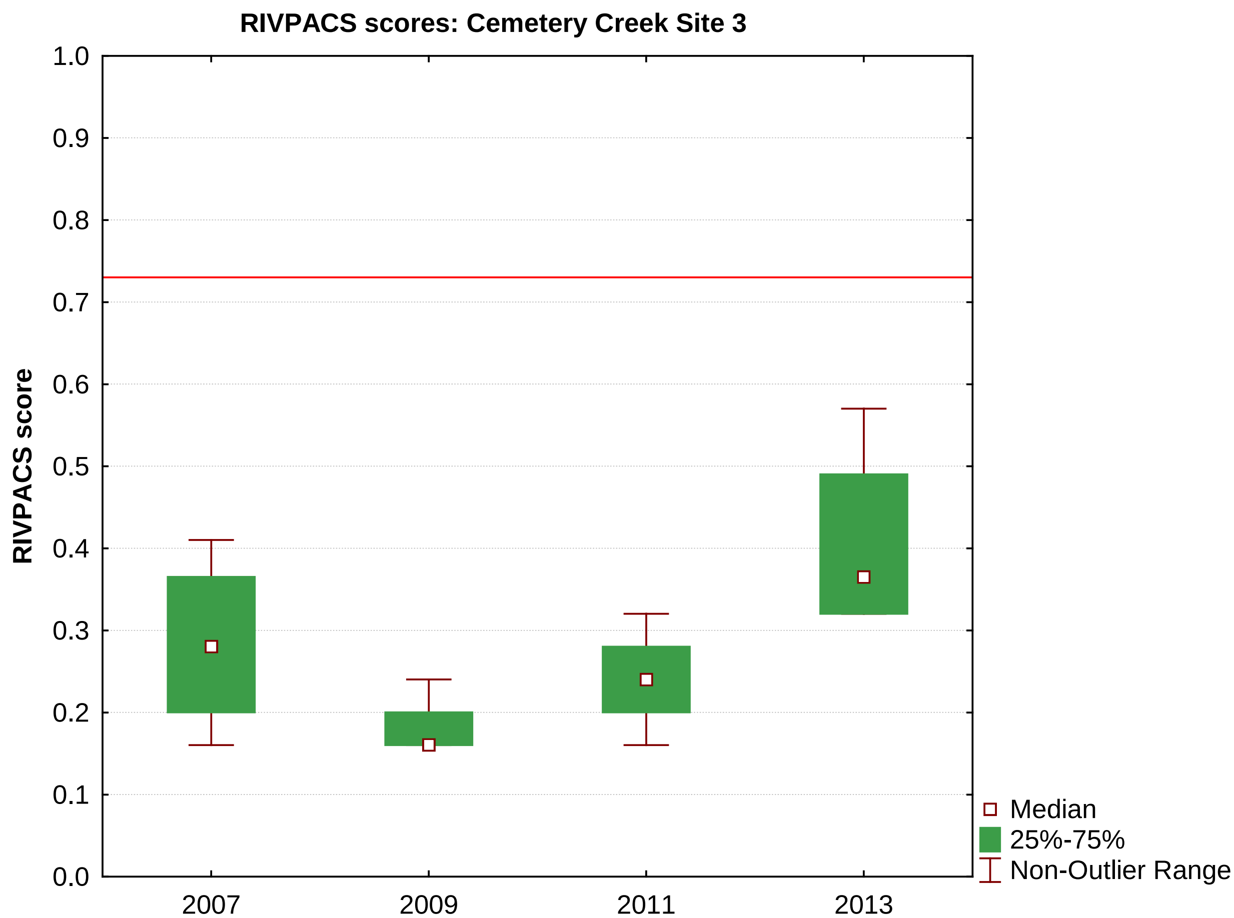

Figure 11. Median RIVPACS scores and ranges for replicated samples collected at Cemetery Creek Site 3: 2007-2013. The red line indicates the threshold (RIVPACS = 0.73) for "unimpaired" conditions, set by the Washington Department of Ecology. Scores below the threshold indicate impaired conditions. Among-year differences in RIVPACS scores were statistically significant: Kruskal Wallis H = 8.37, p = 0.039.

c. Sediment deposition

"Clingers" (range: 2 to 7) and caddisflies (range: 1 to 3) were not as diverse or as abundant as expected. Substantial sediment deposition cannot be ruled out at the site, although obliteration of the stony substrates by large amounts of leafy and woody debris of riparian origin may also cause findings similar to these. The FSBI values ranged from 2.47 to 3.15, indicating a sediment-tolerant fauna.

d. Habitat diversity and integrity

Taxa richness was calculated using sub-family designations for chironomids to account for resolution differences between 2007-2009 and 2011-2013. Similar to the other sites in this study, Site 3 supported a less-diverse invertebrate assemblage than expected for a Puget Sound Lowlands stream.

Monotonous or disrupted instream habitats may account for these findings. The presence of hydrozoas in 2011 and 2013 suggest that the site may have been downstream of a lake outlet or beaver dam, and the presence of cladocerans and copepods in 2011 suggests that flowing as well as lentic conditions were included in sampling efforts. Disturbance to reach-scale features such as riparian zone integrity, channel morphology, or streambank stability may be present: this is suggested by low stonefly diversity. Stonefly taxa richness ranged from 1 taxon to 3 taxa, and most taxa were not abundant. The exception to this was *Zapada cinctipes*, which accounted for 3.2% of sampled animals in the 2011 sample: the common occurrence of this shredder may indicate ample deposition of leaves and woody debris at the site. Semivoltine taxa were uncommon, suggesting the possibility that catastrophic sediment scour, dewatering, toxic pollutants, or thermal stress may have prevented the completion of long life cycles at this site. Gatherers dominated the functional mix in all years, but other functional groups were more prominent here than at other sites.

DISCUSSION

Analysis of data for this project was complicated by inconsistent taxonomic resolution applied to samples over the years of the study: in 2007 and 2009, midges (Diptera: Chironomidae) were identified to subfamily levels, a relatively coarse taxonomic resolution. In 2011 and 2013, midges were identified to genus and species groups. To standardize the data for B-IBI calculations, the PSSB application setting for “coarse” taxonomic resolution was used for all data. The revised B-IBI 0-100 scoring system was used to obtain ratings and scores. Scoring systems are described at the PSSB website: (http://pugetsoundstreambenthos.org/BIBI-Scoring-Types.aspx). The RIVPACS application also standardized the taxonomic data by translating entries into Operational Taxonomic Units (OTUs).

While the variation in taxonomic resolution for midges did not influence B-IBI or RIVPACS scores, the loss of information about midges from 2007 and 2009 samples did influence the ecological interpretations. Chironomid genera are represented in many functional feeding groups, they have many varying autecological characteristics (e.g. some are clingers, some burrowers, etc.; some are hemoglobin bearers, some indicate the presence of filamentous algae), and there is a wide range of pollution tolerance among the members of this diverse family. Ecological interpretations for 2007 and 2009 samples were limited in scope because the large numbers of midges in many of these samples could not be classified according to their autecological attributes.

Besides the variations in taxonomic resolution between the two analytical laboratories, there may have been other, less detectable differences in sample handling that could have affected bioassessment score outcomes, and that did affect the information available for narrative interpretations. For example, it is not known whether the 2007 and 2009 samples contained organisms such as cladocerans (Crustacea: Branchiopoda: Cladocera), copepods (Crustacea: Malacostraca: Copepoda) or hydrozoids (Cnidaria: Hydrozoa) which may have been excluded from samples sorted for identification. Records of these animals do not occur in 2007 and 2009 samples. Such organisms were included in 2011 and 2013 samples, since their habitat requirements and preferences signal certain characteristics about flow conditions and upstream geomorphic features.

The composition and characteristics of benthic invertebrate assemblages suggested water quality perturbations at all 3 Cemetery Creek sites. Mayfly taxa richness was limited, and tolerant assemblages characterized the fauna. There is some evidence suggesting that nutrient enrichment may be the source of water quality impairment in Cemetery Creek. Sediment deposition may also have limited the biological potential at these sites, but it is also possible that stony substrate habitats were simply covered by leafy and woody debris. Semivoltine taxa were scarce at all sites, suggesting periodic disturbances or continuous conditions that limited the completion of long life cycles. Table 3 summarizes the stressors suggested by the analysis of the taxonomic and functional characteristics of the biotic assemblages.

Table 3. Summary of some possible stressors, as suggested by the taxonomic and functional composition of invertebrate assemblages. Symbols: "+" = evidence for stressor discernible in the data; "?" = evidence for stressor may be present; "-"= evidence for stressor not discernible in the data. Cemetery Creek, 2007 – 2013.

Site	water quality degradation	metals	sediment deposition	thermal stress	habitat disruption
Site 1 (downstream)	+	-	+	?	?
Site 2 (middle)	+	-	+	?	?
Site 3 (upstream)	+	-	+	?	?

To further explore the data, an ordination (NMDS, non-metric multidimensional scaling: McCune and Grace 2002) of the taxonomic composition of samples was produced. Ordination is an exploratory statistical technique that is useful in describing strong patterns in species composition. Ordination of Cemetery Creek benthic assemblages demonstrated 2 general groups of samples (Figure 12). These groups are separated along Axis 2. One group ("Group 1") includes all sites in 2013, as well as sites 1 and 2 in 2009 and 2011.The second group ("Group 2") includes all three sites in 2007, as well as site 3 in 2009 and 2011. The wide scatter of Group 2 sites across Axis 1 is due to the presence of diamesine midges (Chironomidae: Diamesinae) at site 3 in 2011: this subfamily is unique to a single replicate from the 2011 sampling event there.

The taxonomic composition of samples suggests that hypoxic sediments may have differentiated the 2 ordinated groups. Hypoxic sediments may be associated with any or all of the following conditions: warm water temperatures, nutrient enrichment, excessive algal growth, lentic conditions, and other phenomena. Group 2 samples were generally characterized by greater numbers of chironomid subfamilies with the potential to be hemoglobin-bearers: these subfamilies include the Chironominae and the Tanypodinae. Similar to the ecological narratives, interpretation of the ordination outcome is inhibited by the loss of information due to coarse taxonomic resolution. This is especially problematic for the midges: Tanytarsini and Chironomini were both identified to the sub-family Chironominae. While Tanytarsini have varying ecological requirements, Chironomini are typically hemoglobin-bearers that preferentially inhabit low oxygen substrate habitats.

Group 2 samples also tended to have larger counts of lymnaeid and physid snails, which are typically associated with warmer water and nutrient enrichment. Group 1 samples tended to be characterized by numerous *Caecidotea* sp. The presence of large numbers of *Caecidotea* suggests a lot of leafy debris. Turbellarian flatworms were also more likely to be present in the Group 1 samples, but the coarse level of taxonomic resolution applied to this group in most of the samples in this study prevents any meaningful observations. Stoneflies, especially *Sweltsa*, were more likely to be in the Group 1 samples.

These findings suggest that conditions promoting hypoxic sediments may have diminished somewhat between 2007 and 2013, particularly at sites 1 and 2.

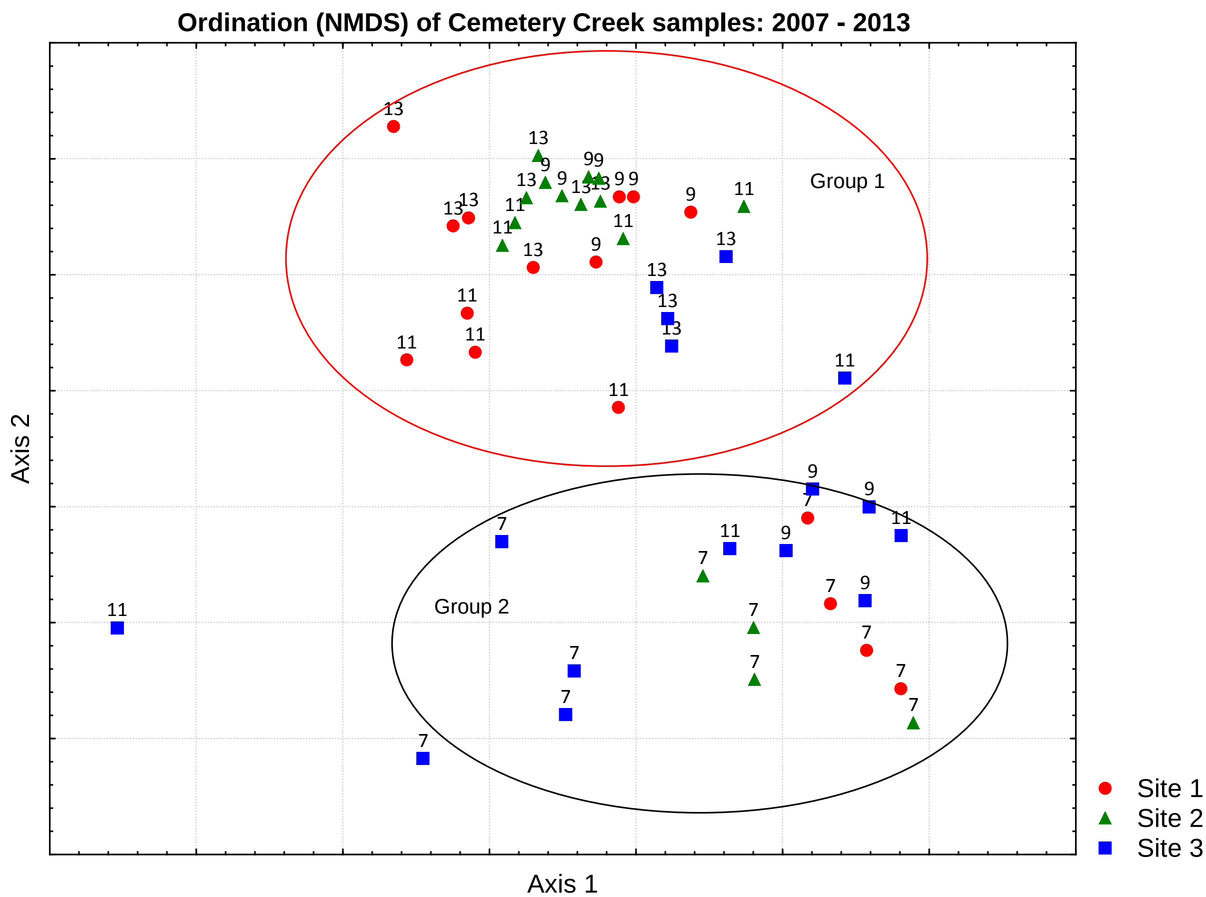

Figure 12. Ordination (NMDS) of aquatic macroinvertebrate samples collected at 3 sites on Cemetery Creek 2007 – 2013. Numbers represent the year of sampling, symbols indicate sites.

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APPENDIX

Taxa lists and metric summaries for composite samples

Cemetery Creek, City of Bellingham, Washington

2007 – 2013

LIST OF ABBREVIATIONS

BI	**Biotic index**
PRA	**Percent relative abundance**
R	**Richness**
A	**Abundance**
E	**Ephemeroptera**
P	**Plecoptera**
T	**Trichoptera**

Aquatic Invertebrate Functional Groups

PR	**Predator**
PA	**Parasite**
CG	**Collector-Gatherer**
CF	**Collector-Filterer**
MH	**Macrophyte Herbivore**
PH	**Piercing Herbivore**
XY	**Xylophage**
SC	**Scraper**
SH	**Shredder**
OM	**Omnivore**
UN	**Unknown**

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C001

RAI No.: CBELhist-C001 | Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
Date Coll.: 9/26/2007 | No. Jars: | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	7	0.54%	Yes	Unknown		5	PR
Gastropoda	1	0.08%	No	Immature	Damaged	7	SC
Asellidae							
Caecidotea sp.	54	4.15%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	203	15.59%	Yes	Unknown		6	CG
Physidae							
Physa sp.	16	1.23%	Yes	Unknown		8	SC
Oligochaeta							
Oligochaeta	4	0.31%	Yes	Unknown		10	CG
Odonata							
Coenagrionidae							
Coenagrionidae	1	0.08%	Yes	Larva	Early Instar	7	PR
Ephemeroptera							
Baetidae							
Baetis tricaudatus	1	0.08%	Yes	Larva		4	CG
Leptophlebiidae							
Paraleptophlebia sp.	3	0.23%	Yes	Larva		1	CG
Plecoptera							
Nemouridae							
Malenka sp.	1	0.08%	Yes	Larva		1	SH
Zapada cinctipes	3	0.23%	Yes	Larva		3	SH
Trichoptera							
Trichoptera	1	0.08%	No	Larva	Early Instar	11	UN
Hydropsychidae							
Cheumatopsyche sp.	1	0.08%	Yes	Larva		5	CF
Hydropsyche sp.	1	0.08%	Yes	Larva		5	CF
Lepidostomatidae							
Lepidostoma sp.	1	0.08%	Yes	Larva		1	SH
Polycentropodidae							
Polycentropus sp.	1	0.08%	Yes	Larva		6	PR
Coleoptera							
Dytiscidae							
Dytiscidae	1	0.08%	Yes	Adult		5	PR
Elmidae							
Elmidae	1	0.08%	Yes	Larva	Early Instar	4	CG

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C001

RAI No.: CBELhist-C001
Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
Date Coll.: 9/26/2007
No. Jars:
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Empididae							
Chelifera sp.	4	0.31%	Yes	Larva		5	PR
Clinocera sp.	2	0.15%	Yes	Larva		5	PR
Hemerodromia sp.	9	0.69%	Yes	Larva		6	PR
Simuliidae							
Simulium sp.	1	0.08%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	1	0.08%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	26	2.00%	No	Pupa		10	CG
Chironominae	776	59.60%	Yes	Larva		8	CG
Orthocladiinae	122	9.37%	Yes	Larva		6	CG
Tanypodinae	60	4.61%	Yes	Larva		7	PR
Sample Count	1302						

Taxa Listing

RAI No.: CBELhist-C002 **Sta. Name:** Cemetery
Client ID: CemeteryCrkSite2
Date Coll.: 9/25/2007 **No. Jars:** **STORET ID:**

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	9	0.77%	Yes	Unknown		5	PR
Gastropoda	2	0.17%	No	Immature	Damaged	7	SC
Ancylidae							
Ancylidae	1	0.09%	Yes	Unknown		6	SC
Asellidae							
Caecidotea sp.	23	1.97%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	133	11.41%	Yes	Unknown		6	CG
Lymnaeidae							
Lymnaeidae	1	0.09%	Yes	Immature		6	SC
Physidae							
Physa sp.	18	1.54%	Yes	Unknown		8	SC
Planorbidae							
Planorbidae	2	0.17%	Yes	Immature		6	SC
Sphaeriidae							
Pisidium sp.	1	0.09%	Yes	Unknown		5	CF
Oligochaeta							
Oligochaeta	74	6.35%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	2	0.17%	Yes	Larva		4	CG
Heptageniidae							
Nixe sp.	1	0.09%	Yes	Larva		4	SC
Plecoptera							
Nemouridae							
Nemouridae	1	0.09%	No	Larva	Early Instar	2	SH
Zapada cinctipes	1	0.09%	Yes	Larva		3	SH
Trichoptera							
Hydropsychidae							
Cheumatopsyche sp.	1	0.09%	Yes	Larva		5	CF
Hydroptilidae							
Hydroptila sp.	1	0.09%	Yes	Larva		6	PH
Hydroptilidae	1	0.09%	No	Larva	Early Instar	4	PH
Lepidostomatidae							
Lepidostoma sp.	1	0.09%	Yes	Larva		1	SH
Coleoptera							
Haliplidae							
Brychius sp.	1	0.09%	Yes	Larva		5	SC
Haliplidae	1	0.09%	No	Larva	Early Instar	7	SH

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C002

RAI No.: CBELhist-C002
Sta. Name: Cemetery
Client ID: CemeteryCrkSite2
Date Coll.: 9/25/2007
No. Jars:
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Dixidae							
Dixa sp.	1	0.09%	Yes	Larva		1	CG
Empididae							
Chelifera sp.	10	0.86%	Yes	Larva		5	PR
Clinocera sp.	5	0.43%	Yes	Larva		5	PR
Empididae	2	0.17%	No	Larva	Early Instar	6	PR
Hemerodromia sp.	90	7.72%	Yes	Larva		6	PR
Muscidae							
Limnophora sp.	1	0.09%	Yes	Larva		11	PR
Simuliidae							
Simulium sp.	5	0.43%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	1	0.09%	Yes	Larva		3	PR
Tipula sp.	1	0.09%	Yes	Larva		4	SH
Tipulidae	2	0.17%	No	Larva	Early Instar	3	SH
Chironomidae							
Chironomidae							
Chironomidae	19	1.63%	No	Pupa		10	CG
Chironominae	534	45.80%	Yes	Larva		8	CG
Orthocladiinae	33	2.83%	Yes	Larva		6	CG
Tanypodinae	187	16.04%	Yes	Larva		7	PR
Sample Count	1166						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C003

RAI No.: CBELhist-C003   Sta. Name: Cemetery
Client ID: CemeteryCrkSite3
Date Coll.: 9/25/2007   No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	25	5.18%	Yes	Unknown		5	PR
Gastropoda	8	1.66%	No	Immature	Damaged	7	SC
Crangonyctidae							
Crangonyx sp.	126	26.09%	Yes	Unknown		6	CG
Lymnaeidae							
Lymnaeidae	2	0.41%	Yes	Immature		6	SC
Physidae							
Physa sp.	31	6.42%	Yes	Unknown		8	SC
Planorbidae							
Planorbidae	6	1.24%	Yes	Immature		6	SC
Sphaeriidae							
Sphaeriidae	3	0.62%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	15	3.11%	Yes	Unknown		10	CG
Ephemeroptera							
Heptageniidae							
Cinygma sp.	1	0.21%	Yes	Larva		0	SC
Plecoptera							
Nemouridae							
Zapada cinctipes	1	0.21%	Yes	Larva		3	SH
Trichoptera							
Leptoceridae							
Leptoceridae	6	1.24%	Yes	Larva	Early Instar	4	CG
Diptera							
Ceratopogonidae							
Ceratopogoninae	3	0.62%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	4	0.83%	Yes	Larva		1	CG
Empididae							
Chelifera sp.	1	0.21%	Yes	Larva		5	PR
Empididae	2	0.41%	No	Larva	Early Instar	6	PR
Hemerodromia sp.	5	1.04%	Yes	Larva		6	PR
Psychodidae							
Pericoma sp.	1	0.21%	Yes	Larva		4	CG
Chironomidae							
Chironomidae							
Chironomidae	4	0.83%	No	Pupa		10	CG
Chironomidae	3	0.62%	No	Larva	Early Instar	10	CG
Chironominae	168	34.78%	Yes	Larva		8	CG
Orthocladiinae	47	9.73%	Yes	Larva		6	CG
Tanypodinae	21	4.35%	Yes	Larva		7	PR
Sample Count	483						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C004

RAI No.: CBELhist-C004 Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
Date Coll.: 9/15/2009 No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	41	2.71%	Yes	Unknown		5	PR
Gastropoda	4	0.26%	No	Immature	Damaged	7	SC
Ancylidae							
Ancylidae	51	3.37%	Yes	Unknown		6	SC
Asellidae							
Caecidotea sp.	662	43.73%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	556	36.72%	Yes	Unknown		6	CG
Physidae							
Physa sp.	14	0.92%	Yes	Unknown		8	SC
Planariidae							
Planariidae	2	0.13%	Yes	Unknown		1	OM
Planorbidae							
Planorbidae	14	0.92%	Yes	Immature		6	SC
Oligochaeta							
Oligochaeta	68	4.49%	Yes	Unknown		10	CG
Odonata							
Aeshnidae							
Aeshnidae	1	0.07%	Yes	Larva		5	PR
Ephemeroptera							
Baetidae							
Baetis tricaudatus	4	0.26%	Yes	Larva		4	CG
Heptageniidae							
Cinygma sp.	1	0.07%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	1	0.07%	Yes	Larva		1	CG
Plecoptera							
Chloroperlidae							
Sweltsa sp.	1	0.07%	Yes	Larva		0	PR
Nemouridae							
Malenka sp.	4	0.26%	Yes	Larva		1	SH
Zapada cinctipes	5	0.33%	Yes	Larva		3	SH
Trichoptera							
Polycentropodidae							
Polycentropus sp.	1	0.07%	Yes	Larva		6	PR
Coleoptera							
Elmidae							
Lara sp.	1	0.07%	Yes	Larva		1	SH
Haliplidae							
Brychius sp.	1	0.07%	Yes	Larva		5	SC

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C004

RAI No.: CBELhist-C004 Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
Date Coll.: 9/15/2009 No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Ceratopogonidae							
Ceratopogoninae	2	0.13%	Yes	Larva		6	PR
Empididae							
Chelifera sp.	10	0.66%	Yes	Larva		5	PR
Simuliidae							
Simulium sp.	8	0.53%	Yes	Larva		6	CF
Tabanidae							
Chrysops sp.	1	0.07%	Yes	Larva		6	PR
Tipulidae							
Dicranota sp.	3	0.20%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	1	0.07%	No	Pupa		10	CG
Chironominae	39	2.58%	Yes	Larva		8	CG
Orthocladiinae	10	0.66%	Yes	Larva		6	CG
Tanypodinae	8	0.53%	Yes	Larva		7	PR
Sample Count	1514						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C005

RAI No.: CBELhist-C005 Sta. Name: Cemetery
Client ID: CemeteryCrkSite2
Date Coll.: 9/15/2009 No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	2	0.16%	Yes	Unknown		5	PR
Nematoda	1	0.08%	Yes	Unknown		5	UN
Ancylidae							
Ancylidae	5	0.41%	Yes	Unknown		6	SC
Asellidae							
Caecidotea sp.	726	59.51%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	362	29.67%	Yes	Unknown		6	CG
Planariidae							
Planariidae	82	6.72%	Yes	Unknown		1	OM
Sphaeriidae							
Sphaeriidae	1	0.08%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	24	1.97%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	1	0.08%	Yes	Larva		4	CG
Heptageniidae							
Cinygma sp.	1	0.08%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	1	0.08%	Yes	Larva		1	CG
Plecoptera							
Nemouridae							
Malenka sp.	1	0.08%	Yes	Larva		1	SH
Zapada cinctipes	3	0.25%	Yes	Larva		3	SH
Coleoptera							
Elmidae							
Lara sp.	1	0.08%	Yes	Larva		1	SH
Diptera							
Ceratopogonidae							
Ceratopogoninae	1	0.08%	Yes	Larva		6	PR
Chironomidae							
Chironomidae							
Chironominae	2	0.16%	Yes	Larva		8	CG
Orthocladiinae	2	0.16%	Yes	Larva		6	CG
Tanypodinae	4	0.33%	Yes	Larva		7	PR
Sample Count	1220						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C006

RAI No.: CBELhist-C006 | Sta. Name: Cemetery
Client ID: CemeteryCrkSite3
Date Coll.: 9/15/2009 | No. Jars: | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	9	0.68%	Yes	Unknown		5	PR
Hirudinea	1	0.08%	Yes	Unknown		8	PR
Nematoda	1	0.08%	Yes	Unknown		5	UN
Ancylidae							
Ancylidae	1	0.08%	Yes	Unknown		6	SC
Asellidae							
Caecidotea sp.	15	1.14%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	402	30.48%	Yes	Unknown		6	CG
Physidae							
Physa sp.	51	3.87%	Yes	Unknown		8	SC
Planariidae							
Planariidae	5	0.38%	Yes	Unknown		1	OM
Planorbidae							
Planorbidae	10	0.76%	Yes	Immature		6	SC
Sphaeriidae							
Sphaeriidae	30	2.27%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	5	0.38%	Yes	Unknown		10	CG
Odonata							
Coenagrionidae							
Coenagrionidae	1	0.08%	Yes	Larva	Early Instar	7	PR
Ephemeroptera							
Heptageniidae							
Cinygma sp.	6	0.45%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	2	0.15%	Yes	Larva		1	CG
Plecoptera							
Nemouridae							
Malenka sp.	1	0.08%	Yes	Larva		1	SH
Zapada cinctipes	5	0.38%	Yes	Larva		3	SH
Megaloptera							
Sialidae							
Sialis sp.	1	0.08%	Yes	Larva		4	PR
Trichoptera							
Lepidostomatidae							
Lepidostoma sp.	1	0.08%	Yes	Larva		1	SH
Phryganeidae							
Yphria californica	1	0.08%	Yes	Larva		11	PR
Polycentropodidae							
Polycentropus sp.	1	0.08%	Yes	Larva		6	PR
Lepidoptera							
Lepidoptera	1	0.08%	Yes	Larva	Damaged	7	SH

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C006

RAI No.: CBELhist-C006 | Sta. Name: Cemetery
Client ID: CemeteryCrkSite3
Date Coll.: 9/15/2009 | No. Jars: | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Coleoptera							
Elmidae							
Lara sp.	1	0.08%	Yes	Larva		1	SH
Diptera							
Ceratopogonidae							
Ceratopogoninae	5	0.38%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	1	0.08%	Yes	Larva		1	CG
Dixella sp.	1	0.08%	Yes	Larva		4	CG
Empididae							
Chelifera sp.	15	1.14%	Yes	Larva		5	PR
Hemerodromia sp.	5	0.38%	Yes	Larva		6	PR
Simuliidae							
Simulium sp.	2	0.15%	Yes	Larva		6	CF
Tabanidae							
Chrysops sp.	1	0.08%	Yes	Larva		6	PR
Tipulidae							
Dicranota sp.	3	0.23%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Chironomidae	33	2.50%	No	Pupa		10	CG
Chironominae	519	39.35%	Yes	Larva		8	CG
Orthocladiinae	48	3.64%	Yes	Larva		6	CG
Tanypodinae	135	10.24%	Yes	Larva		7	PR
Sample Count	1319						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C007

RAI No.: CBELhist-C007
Client ID: Cemetery Creek S1
Date Coll.: 9/21/2011
No. Jars:
Sta. Name: Cemetery Creek Site 1 between N. Pond & Whatcom
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	24	1.96%	Yes	Unknown		5	PR
Amphipoda	67	5.48%	No	Unknown	Damaged	4	CG
Cladocera	1	0.08%	Yes	Unknown		8	CF
Copepoda	5	0.41%	Yes	Unknown		8	CG
Hydrozoa	3	0.25%	Yes	Unknown		5	PR
Nemata	5	0.41%	Yes	Unknown		5	UN
Ostracoda	2	0.16%	Yes	Unknown		8	CG
Turbellaria	3	0.25%	Yes	Unknown		4	PR
Ancylidae							
Ferrissia sp.	11	0.90%	Yes	Unknown		6	SC
Asellidae							
Caecidotea sp.	405	33.14%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	181	14.81%	Yes	Unknown		6	CG
Glossiphoniidae							
Glossiphoniidae	1	0.08%	Yes	Unknown		9	PR
Physidae							
Physidae	1	0.08%	Yes	Unknown		8	SC
Planariidae							
Polycelis coronata	2	0.16%	Yes	Unknown		1	OM
Planorbidae							
Menetus sp.	2	0.16%	Yes	Unknown		6	SC
Planorbidae	2	0.16%	No	Immature		6	SC
Sphaeriidae							
Sphaeriidae	4	0.33%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	233	19.07%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	11	0.90%	Yes	Larva		4	CG
Heptageniidae							
Rhithrogena sp.	1	0.08%	Yes	Larva		0	SC
Plecoptera							
Nemouridae							
Zapada cinctipes	1	0.08%	Yes	Larva		3	SH
Megaloptera							
Sialidae							
Sialis sp.	1	0.08%	Yes	Larva		4	PR
Trichoptera							
Lepidostomatidae							
Lepidostoma sp.	1	0.08%	Yes	Larva		1	SH
Limnephilidae							
Limnephilidae	1	0.08%	Yes	Larva	Early Instar	3	SH

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C007

RAI No.: CBELhist-C007
Sta. Name: Cemetery Creek Site 1 between N. Pond & Whatcom
Client ID: Cemetery Creek S1
Date Coll.: 9/21/2011 **No. Jars:** **STORET ID:**

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Coleoptera							
Elmidae							
Elmidae	1	0.08%	Yes	Larva	Early Instar	4	CG
Hydraenidae							
Hydraena sp.	1	0.08%	Yes	Adult		5	PR
Diptera							
Dixidae							
Dixella sp.	3	0.25%	Yes	Larva		4	CG
Empididae							
Clinocera sp.	3	0.25%	Yes	Larva		5	PR
Empididae	1	0.08%	No	Larva	Early Instar	6	PR
Ephydridae							
Ephydridae	7	0.57%	Yes	Larva		6	CG
Simuliidae							
Simulium sp.	14	1.15%	Yes	Larva		6	CF
Tipulidae							
Antocha monticola	1	0.08%	Yes	Larva		3	CG
Chironomidae							
Chironomidae							
Alotanypus sp.	1	0.08%	Yes	Larva		6	PR
Brillia sp.	2	0.16%	Yes	Larva		4	SH
Chironomus sp.	39	3.19%	Yes	Larva		10	CG
Conchapelopia sp.	1	0.08%	Yes	Pupa		6	PR
Corynoneura sp.	1	0.08%	Yes	Larva		7	CG
Dicrotendipes sp.	11	0.90%	Yes	Larva		8	CG
Eukiefferiella Gracei Gr.	1	0.08%	Yes	Larva		8	CG
Micropsectra sp.	62	5.07%	Yes	Larva		4	CG
Micropsectra sp.	4	0.33%	No	Pupa		4	CG
Orthocladius sp.	1	0.08%	Yes	Pupa		6	CG
Parametriocnemus sp.	8	0.65%	Yes	Larva		5	CG
Paraphaenocladius sp.	1	0.08%	Yes	Larva		4	CG
Paratanytarsus sp.	10	0.82%	Yes	Larva		6	CG
Paratendipes sp.	8	0.65%	Yes	Larva		10	CG
Phaenopsectra sp.	6	0.49%	Yes	Larva		7	SC
Polypedilum sp.	6	0.49%	Yes	Larva		6	SH
Procladius sp.	10	0.82%	Yes	Larva		9	PR
Prodiamesa sp.	6	0.49%	Yes	Larva		3	CG
Protanypus sp.	1	0.08%	Yes	Larva		6	CG
Rheotanytarsus sp.	1	0.08%	Yes	Larva		6	CF
Tanytarsus sp.	4	0.33%	No	Pupa		6	CF
Tanytarsus sp.	14	1.15%	Yes	Larva		6	CF
Thienemanniella sp.	2	0.16%	Yes	Larva		6	CG
Thienemannimyia Gr.	15	1.23%	No	Larva		5	PR
Tribelos sp.	7	0.57%	Yes	Larva		10	CG
Tvetenia Bavarica Gr.	1	0.08%	Yes	Larva		5	CG
Sample Count	1222						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C008

RAI No.: CBELhist-C008
Client ID: Cemetery Creek S2
Date Coll.: 9/20/2011
No. Jars:
Sta. Name: Cemetery Creek Site 2 between N. Pond & W. Pond
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	26	1.90%	Yes	Unknown		5	PR
Amphipoda	50	3.66%	No	Unknown	Damaged	4	CG
Cladocera	2	0.15%	Yes	Unknown		8	CF
Copepoda	4	0.29%	Yes	Unknown		8	CG
Hydrozoa	5	0.37%	Yes	Unknown		5	PR
Nemata	12	0.88%	Yes	Unknown		5	UN
Ostracoda	1	0.07%	Yes	Unknown		8	CG
Turbellaria	77	5.64%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	503	36.85%	Yes	Unknown		8	CG
Astacidae							
Pacifastacus leniusculus	1	0.07%	Yes	Unknown		6	SH
Crangonyctidae							
Crangonyx sp.	424	31.06%	Yes	Unknown		6	CG
Planariidae							
Polycelis coronata	2	0.15%	Yes	Unknown		1	OM
Sphaeriidae							
Sphaeriidae	8	0.59%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	121	8.86%	Yes	Unknown		10	CG
Ephemeroptera							
Heptageniidae							
Cinygma sp.	1	0.07%	Yes	Larva		0	SC
Plecoptera							
Chloroperlidae							
Sweltsa sp.	1	0.07%	Yes	Larva		0	PR
Nemouridae							
Malenka sp.	2	0.15%	Yes	Larva		1	SH
Zapada cinctipes	28	2.05%	Yes	Larva		3	SH
Trichoptera							
Limnephilidae							
Limnephilidae	1	0.07%	Yes	Larva	Early Instar	3	SH
Rhyacophilidae							
Rhyacophila narvae	1	0.07%	Yes	Larva		0	PR
Coleoptera							
Dytiscidae							
Dytiscidae	1	0.07%	Yes	Larva		5	PR
Hydraenidae							
Hydraena sp.	1	0.07%	Yes	Adult		5	PR

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C008

RAI No.: CBELhist-C008
Client ID: Cemetery Creek S2
Date Coll.: 9/20/2011
No. Jars:
Sta. Name: Cemetery Creek Site 2 between N. Pond & W. Pond
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Ceratopogonidae							
Ceratopogoninae	3	0.22%	Yes	Larva		6	PR
Forcipomyiinae	1	0.07%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	18	1.32%	Yes	Larva		1	CG
Dixella sp.	3	0.22%	Yes	Larva		4	CG
Dixidae	1	0.07%	No	Pupa		4	CG
Empididae							
Empididae	1	0.07%	No	Larva	Early Instar	6	PR
Hemerodromia sp.	3	0.22%	Yes	Larva		6	PR
Neoplasta sp.	11	0.81%	Yes	Larva		5	PR
Psychodidae							
Pericoma sp.	3	0.22%	Yes	Larva		4	CG
Chironomidae							
Chironomidae							
Diplocladius cultriger	2	0.15%	Yes	Larva		8	CG
Heterotrissocladius sp.	1	0.07%	Yes	Larva		0	CG
Micropsectra sp.	8	0.59%	Yes	Larva		4	CG
Orthocladius sp.	2	0.15%	Yes	Larva		6	CG
Parametriocnemus sp.	18	1.32%	Yes	Larva		5	CG
Polypedilum sp.	1	0.07%	Yes	Larva		6	SH
Tanytarsus sp.	7	0.51%	Yes	Larva		6	CF
Thienemannimyia Gr.	10	0.73%	Yes	Larva		5	PR
Sample Count	1365						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C009

RAI No.: CBELhist-C009
Sta. Name: Cemetery Creek Site 3 between W. Pond & S. Pond
Client ID: Cemetery Creek S3
Date Coll.: 9/20/2011
No. Jars:
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	18	1.57%	Yes	Unknown		5	PR
Amphipoda	65	5.65%	No	Unknown	Damaged	4	CG
Cladocera	8	0.70%	Yes	Unknown		8	CF
Copepoda	3	0.26%	Yes	Unknown		8	CG
Hydrozoa	53	4.61%	Yes	Unknown		5	PR
Nemata	1	0.09%	Yes	Unknown		5	UN
Turbellaria	35	3.04%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	24	2.09%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	336	29.22%	Yes	Unknown		6	CG
Sphaeriidae							
Sphaeriidae	11	0.96%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	21	1.83%	Yes	Unknown		10	CG
Ephemeroptera							
Heptageniidae							
Cinygma sp.	6	0.52%	Yes	Larva		0	SC
Leptophlebiidae							
Leptophlebiidae	6	0.52%	Yes	Larva	Damaged	2	CG
Plecoptera							
Nemouridae							
Malenka sp.	4	0.35%	Yes	Larva		1	SH
Zapada cinctipes	37	3.22%	Yes	Larva		3	SH
Megaloptera							
Sialidae							
Sialis sp.	1	0.09%	Yes	Larva		4	PR
Trichoptera							
Limnephilidae							
Limnephilidae	2	0.17%	Yes	Larva	Early Instar	3	SH
Coleoptera							
Elmidae							
Lara sp.	1	0.09%	Yes	Larva		1	SH
Haliplidae							
Brychius sp.	1	0.09%	Yes	Adult		5	SC
Hydraenidae							
Hydraena sp.	1	0.09%	Yes	Adult		5	PR

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C009

RAI No.: CBELhist-C009
Client ID: Cemetery Creek S3
Date Coll.: 9/20/2011
No. Jars:
Sta. Name: Cemetery Creek Site 3 between W. Pond & S. Pond
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Ceratopogonidae							
Ceratopogoninae	1	0.09%	Yes	Larva		6	PR
Dixidae							
Dixa sp.	4	0.35%	Yes	Larva		1	CG
Empididae							
Clinocera sp.	7	0.61%	Yes	Larva		5	PR
Empididae	1	0.09%	No	Pupa		6	PR
Neoplasta sp.	12	1.04%	Yes	Larva		5	PR
Psychodidae							
Pericoma sp.	1	0.09%	Yes	Larva		4	CG
Tipulidae							
Dicranota sp.	2	0.17%	Yes	Larva		3	PR
Tipulidae	1	0.09%	Yes	Larva	Early Instar	3	SH
Chironomidae							
Chironomidae							
Alotanypus sp.	1	0.09%	Yes	Larva		6	PR
Brillia sp.	1	0.09%	Yes	Larva		4	SH
Corynoneura sp.	1	0.09%	Yes	Larva		7	CG
Dicrotendipes sp.	1	0.09%	Yes	Larva		8	CG
Diplocladius cultriger	6	0.52%	Yes	Larva		8	CG
Heterotrissocladius sp.	1	0.09%	Yes	Larva		0	CG
Limnophyes sp.	1	0.09%	Yes	Larva		8	CG
Micropsectra sp.	1	0.09%	No	Pupa		4	CG
Micropsectra sp.	227	19.74%	Yes	Larva		4	CG
Parametriocnemus sp.	21	1.83%	Yes	Larva		5	CG
Paratendipes sp.	2	0.17%	Yes	Larva		10	CG
Polypedilum sp.	5	0.43%	Yes	Larva		6	SH
Prodiamesa sp.	7	0.61%	Yes	Larva		3	CG
Tanypodinae	2	0.17%	No	Larva	Early Instar	7	PR
Tanytarsini	4	0.35%	No	Pupa	Damaged	6	CF
Tanytarsini	2	0.17%	No	Larva	Damaged	6	CF
Tanytarsus sp.	110	9.57%	Yes	Larva		6	CF
Tanytarsus sp.	9	0.78%	No	Pupa		6	CF
Thienemannimyia Gr.	84	7.30%	Yes	Larva		5	PR
Tribelos sp.	1	0.09%	Yes	Larva		10	CG
Sample Count	1150						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C010

RAI No.: CBELhist-C010 | Sta. Name: Cemetary Creek Site 1
Client ID: Cemetary Creek S1
Date Coll.: 9/24/2013 | No. Jars: | STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	16	1.50%	Yes	Unknown		5	PR
Amphipoda	12	1.12%	No	Unknown	Damaged	4	CG
Hydrozoa	7	0.66%	Yes	Unknown		5	PR
Nemata	5	0.47%	Yes	Unknown		5	UN
Turbellaria	36	3.37%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	624	58.48%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	151	14.15%	Yes	Unknown		6	CG
Glossiphoniidae							
Glossiphoniidae	2	0.19%	Yes	Unknown		9	PR
Sphaeriidae							
Sphaeriidae	16	1.50%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	122	11.43%	Yes	Unknown		10	CG
Odonata							
Coenagrionidae							
Coenagrionidae	1	0.09%	Yes	Larva	Damaged	7	PR
Ephemeroptera							
Baetidae							
Baetis tricaudatus	5	0.47%	Yes	Larva		4	CG
Leptophlebiidae							
Paraleptophlebia sp.	7	0.66%	Yes	Larva		1	CG
Plecoptera							
Nemouridae							
Zapada cinctipes	2	0.19%	Yes	Larva		3	SH
Trichoptera							
Lepidostomatidae							
Lepidostoma sp.	1	0.09%	Yes	Larva		1	SH
Coleoptera							
Hydraenidae							
Hydraena sp.	1	0.09%	Yes	Adult		5	PR
Diptera							
Ceratopogonidae							
Ceratopogoninae	1	0.09%	Yes	Larva		6	PR
Empididae							
Neoplasta sp.	2	0.19%	Yes	Larva		5	PR
Tipulidae							
Dicranota sp.	6	0.56%	Yes	Larva		3	PR

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C010

RAI No.: CBELhist-C010   Sta. Name: Cemetary Creek Site 1
Client ID: Cemetary Creek S1
Date Coll.: 9/24/2013   No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Chironomidae							
Chironomidae							
Cricotopus (Cricotopus) sp.	1	0.09%	Yes	Larva		7	SH
Dicrotendipes sp.	4	0.37%	Yes	Larva		8	CG
Diplocladius cultriger	2	0.19%	Yes	Larva		8	CG
Eukiefferiella Claripennis Gr.	1	0.09%	Yes	Larva		8	CG
Micropsectra sp.	25	2.34%	Yes	Larva		4	CG
Micropsectra sp.	1	0.09%	No	Pupa		4	CG
Parametriocnemus sp.	1	0.09%	No	Pupa		5	CG
Parametriocnemus sp.	2	0.19%	Yes	Larva		5	CG
Polypedilum sp.	2	0.19%	Yes	Larva		6	SH
Procladius sp.	1	0.09%	Yes	Larva		9	PR
Rheotanytarsus sp.	3	0.28%	Yes	Larva		6	CF
Rheotanytarsus sp.	1	0.09%	No	Pupa		6	CF
Tanytarsini	3	0.28%	No	Larva	Damaged	6	CF
Thienemanniella sp.	1	0.09%	Yes	Larva		6	CG
Thienemannimyia Gr.	2	0.19%	Yes	Larva		5	PR
Sample Count	1067						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C011

RAI No.: CBELhist-C011
Sta. Name: Cemetary Creek Site 2
Client ID: Cemetary Creek S2
Date Coll.: 9/24/2013
No. Jars:
STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	4	0.28%	Yes	Unknown		5	PR
Copepoda	1	0.07%	Yes	Unknown		8	CG
Hydrozoa	10	0.70%	Yes	Unknown		5	PR
Nemata	1	0.07%	Yes	Unknown		5	UN
Turbellaria	125	8.79%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	813	57.17%	Yes	Unknown		8	CG
Crangonyctidae							
Crangonyx sp.	349	24.54%	Yes	Unknown		6	CG
Hyalellidae							
Hyalella sp.	1	0.07%	Yes	Unknown		8	CG
Planorbidae							
Menetus sp.	1	0.07%	Yes	Unknown		6	SC
Sphaeriidae							
Sphaeriidae	14	0.98%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	68	4.78%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	2	0.14%	Yes	Larva		4	CG
Diptera							
Empididae							
Hemerodromia sp.	1	0.07%	Yes	Larva		6	PR
Chironomidae							
Chironomidae							
Cricotopus (Cricotopus) sp.	1	0.07%	Yes	Larva		7	SH
Dicrotendipes sp.	6	0.42%	Yes	Larva		8	CG
Diplocladius cultriger	2	0.14%	Yes	Larva		8	CG
Micropsectra sp.	10	0.70%	Yes	Larva		4	CG
Parametriocnemus sp.	1	0.07%	Yes	Larva		5	CG
Paratanytarsus sp.	2	0.14%	Yes	Larva		6	CG
Tanytarsus sp.	1	0.07%	Yes	Larva		6	CF
Thienemannimyia Gr.	9	0.63%	Yes	Larva		5	PR
Sample Count	1422						

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C012

RAI No.:	CBELhist-C012	**Sta. Name:**	Cemetary Creek Site 3
Client ID:	Cemetary Creek S3		
Date Coll.:	9/24/2013	**No. Jars:**	**STORET ID:**

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Other Non-Insect							
Acari	41	3.27%	Yes	Unknown		5	PR
Hydrozoa	1	0.08%	Yes	Unknown		5	PR
Nemata	1	0.08%	Yes	Unknown		5	UN
Turbellaria	94	7.50%	Yes	Unknown		4	PR
Asellidae							
Caecidotea sp.	349	27.83%	Yes	Unknown		8	CG
Astacidae							
Pacifastacus leniusculus	1	0.08%	Yes	Unknown		6	SH
Crangonyctidae							
Crangonyx sp.	464	37.00%	Yes	Unknown		6	CG
Erpobdellidae							
Erpobdellidae	1	0.08%	Yes	Unknown		8	PR
Lymnaeidae							
Lymnaeidae	3	0.24%	Yes	Immature		6	SC
Sphaeriidae							
Sphaeriidae	29	2.31%	Yes	Unknown		8	CF
Oligochaeta							
Oligochaeta	23	1.83%	Yes	Unknown		10	CG
Ephemeroptera							
Baetidae							
Baetis tricaudatus	10	0.80%	Yes	Larva		4	CG
Heptageniidae							
Cinygma sp.	3	0.24%	Yes	Larva		0	SC
Leptophlebiidae							
Paraleptophlebia sp.	1	0.08%	Yes	Larva		1	CG
Plecoptera							
Chloroperlidae							
Sweltsa sp.	1	0.08%	Yes	Larva		0	PR
Nemouridae							
Malenka sp.	2	0.16%	Yes	Larva		1	SH
Zapada cinctipes	3	0.24%	Yes	Larva		3	SH
Trichoptera							
Trichoptera	1	0.08%	Yes	Pupa	Damaged	11	UN
Coleoptera							
Elmidae							
Lara sp.	4	0.32%	Yes	Larva		1	SH
Hydraenidae							
Hydraena sp.	1	0.08%	Yes	Adult		5	PR

Taxa Listing

Project ID: CBELhist-C
RAI No.: CBELhist-C012

RAI No.: CBELhist-C012 Sta. Name: Cemetary Creek Site 3
Client ID: Cemetary Creek S3
Date Coll.: 9/24/2013 No. Jars: STORET ID:

Taxonomic Name	Count	PRA	Unique	Stage	Qualifier	BI	Function
Diptera							
Ceratopogonidae							
Ceratopogoninae	6	0.48%	Yes	Larva		6	PR
Empididae							
Empididae	1	0.08%	No	Larva	Damaged	6	PR
Neoplasta sp.	1	0.08%	Yes	Larva		5	PR
Psychodidae							
Pericoma sp.	1	0.08%	Yes	Larva		4	CG
Simuliidae							
Simulium sp.	5	0.40%	No	Pupa		6	CF
Simulium sp.	6	0.48%	Yes	Larva		6	CF
Tipulidae							
Dicranota sp.	1	0.08%	Yes	Larva		3	PR
Chironomidae							
Chironomidae							
Dicrotendipes sp.	3	0.24%	Yes	Larva		8	CG
Diplocladius cultriger	3	0.24%	Yes	Larva		8	CG
Micropsectra sp.	98	7.81%	Yes	Larva		4	CG
Orthocladius sp.	1	0.08%	Yes	Larva		6	CG
Parametriocnemus sp.	51	4.07%	Yes	Larva		5	CG
Paraphaenocladius sp.	2	0.16%	Yes	Larva		4	CG
Paratanytarsus sp.	3	0.24%	Yes	Larva		6	CG
Prodiamesa sp.	1	0.08%	Yes	Larva		3	CG
Tanytarsini	1	0.08%	No	Larva	Damaged	6	CF
Tanytarsini	2	0.16%	No	Pupa	Damaged	6	CF
Tanytarsus sp.	1	0.08%	No	Pupa		6	CF
Tanytarsus sp.	21	1.67%	Yes	Larva		6	CF
Thienemannimyia Gr.	12	0.96%	Yes	Larva		5	PR
Tvetenia Bavarica Gr.	1	0.08%	Yes	Larva		5	CG
Sample Count	1254						

Metrics Report

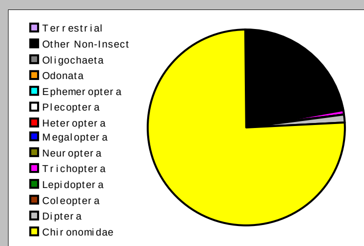
Project ID: CBELhist-C
RAI No.: CBELhist-C001
Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
STORET ID
Coll. Date: 9/26/2007
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1302
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	4	281	21.58%
Oligochaeta	1	4	0.31%
Odonata	1	1	0.08%
Ephemeroptera	2	4	0.31%
Plecoptera	2	4	0.31%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	4	5	0.38%
Lepidoptera			
Coleoptera	2	2	0.15%
Diptera	5	17	1.31%
Chironomidae	3	984	75.58%

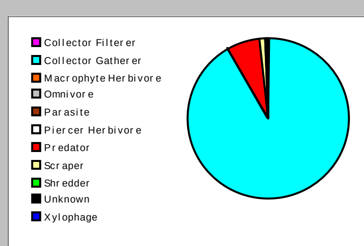


Dominant Taxa

Category	A	PRA
Chironominae	776	59.60%
Crangonyx	203	15.59%
Orthocladiinae	122	9.37%
Tanypodinae	60	4.61%
Caecidotea	54	4.15%
Chironomidae	26	2.00%
Physa	16	1.23%
Hemerodromia	9	0.69%
Acari	7	0.54%
Oligochaeta	4	0.31%
Chelifera	4	0.31%
Zapada cinctipes	3	0.23%
Paraleptophlebia	3	0.23%
Clinocera	2	0.15%
Gastropoda	1	0.08%

Functional Composition

Category	R	A	PRA
Predator	9	86	6.61%
Parasite			
Collector Gatherer	8	1190	91.40%
Collector Filterer	3	3	0.23%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	1	17	1.31%
Shredder	3	5	0.38%
Omnivore			
Unknown	0	1	0.08%

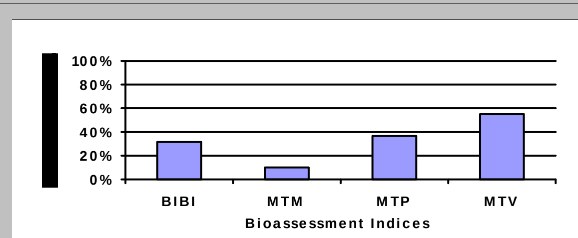


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	24
E Richness	2
P Richness	2
T Richness	4
EPT Richness	8
EPT Percent	1.00%
All Non-Insect Abundance	285
All Non-Insect Richness	5
All Non-Insect Percent	21.89%
Oligochaeta+Hirudinea Percent	0.31%
Baetidae/Ephemeroptera	0.250
Hydropsychidae/Trichoptera	0.400
Dominance	
Dominant Taxon Percent	59.60%
Dominant Taxa (2) Percent	75.19%
Dominant Taxa (3) Percent	84.56%
Dominant Taxa (10) Percent	98.08%
Diversity	
Shannon H (loge)	1.352
Shannon H (log2)	1.951
Margalef D	3.217
Simpson D	0.409
Evenness	0.084
Function	
Predator Richness	9
Predator Percent	6.61%
Filterer Richness	3
Filterer Percent	0.23%
Collector Percent	91.63%
Scraper+Shredder Percent	1.69%
Scraper/Filterer	5.667
Scraper/Scraper+Filterer	0.850
Habit	
Burrower Richness	0
Burrower Percent	0.00%
Swimmer Richness	3
Swimmer Percent	0.38%
Clinger Richness	8
Clinger Percent	0.84%
Characteristics	
Cold Stenotherm Richness	0
Cold Stenotherm Percent	0.00%
Hemoglobin Bearer Richness	
Hemoglobin Bearer Percent	
Air Breather Richness	2
Air Breather Percent	0.15%
Voltinism	
Univoltine Richness	17
Semivoltine Richness	2
Multivoltine Percent	76.19%
Tolerance	
Sediment Tolerant Richness	2
Sediment Tolerant Percent	0.38%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.478
Pollution Sensitive Richness	0
Pollution Tolerant Percent	5.61%
Hilsenhoff Biotic Index	7.397
Intolerant Percent	0.38%
Supertolerant Percent	67.28%
CTQa	80.714

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	16	32.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	11	36.67%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	10	55.56%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	2	9.52%	Severe



Tuesday, June 24, 2014

Metrics Report

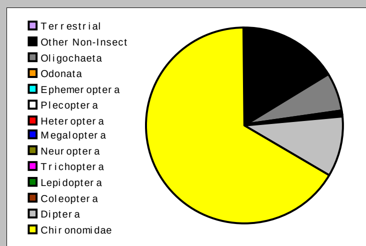
Project ID: CBELhist-C
RAI No.: CBELhist-C002
Sta. Name: Cemetery
Client ID: CemeteryCrkSite2
STORET ID
Coll. Date: 9/25/2007
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1166
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	8	190	16.30%
Oligochaeta	1	74	6.35%
Odonata			
Ephemeroptera	2	3	0.26%
Plecoptera	1	2	0.17%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	3	4	0.34%
Lepidoptera			
Coleoptera	1	2	0.17%
Diptera	8	118	10.12%
Chironomidae	3	773	66.30%

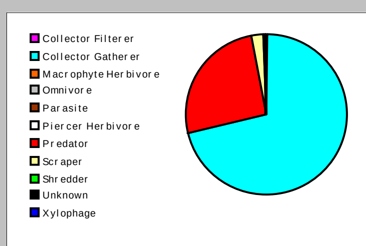


Dominant Taxa

Category	A	PRA
Chironominae	534	45.80%
Tanypodinae	187	16.04%
Crangonyx	133	11.41%
Hemerodromia	90	7.72%
Oligochaeta	74	6.35%
Orthocladiinae	33	2.83%
Caecidotea	23	1.97%
Chironomidae	19	1.63%
Physa	18	1.54%
Chelifera	10	0.86%
Acari	9	0.77%
Simulium	5	0.43%
Clinocera	5	0.43%
Tipulidae	2	0.17%
Planorbidae	2	0.17%

Functional Composition

Category	R	A	PRA
Predator	7	305	26.16%
Parasite			
Collector Gatherer	7	819	70.24%
Collector Filterer	3	7	0.60%
Macrophyte Herbivore			
Piercer Herbivore	1	2	0.17%
Xylophage			
Scraper	6	26	2.23%
Shredder	3	7	0.60%
Omnivore			
Unknown			

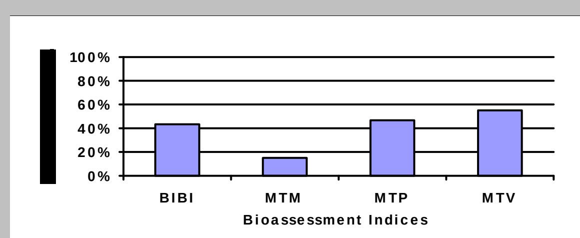


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	27
E Richness	2
P Richness	1
T Richness	3
EPT Richness	6
EPT Percent	0.77%
All Non-Insect Abundance	264
All Non-Insect Richness	9
All Non-Insect Percent	22.64%
Oligochaeta+Hirudinea Percent	6.35%
Baetidae/Ephemeroptera	0.667
Hydropsychidae/Trichoptera	0.250
Dominance	
Dominant Taxon Percent	45.80%
Dominant Taxa (2) Percent	61.84%
Dominant Taxa (3) Percent	73.24%
Dominant Taxa (10) Percent	96.14%
Diversity	
Shannon H (loge)	1.758
Shannon H (log2)	2.537
Margalef D	3.695
Simpson D	0.272
Evenness	0.085
Function	
Predator Richness	7
Predator Percent	26.16%
Filterer Richness	3
Filterer Percent	0.60%
Collector Percent	70.84%
Scraper+Shredder Percent	2.83%
Scraper/Filterer	3.714
Scraper/Scraper+Filterer	0.788
Habit	
Burrower Richness	1
Burrower Percent	0.26%
Swimmer Richness	2
Swimmer Percent	0.26%
Clinger Richness	7
Clinger Percent	1.46%
Characteristics	
Cold Stenotherm Richness	0
Cold Stenotherm Percent	0.00%
Hemoglobin Bearer Richness	1
Hemoglobin Bearer Percent	0.17%
Air Breather Richness	2
Air Breather Percent	0.34%
Voltinism	
Univoltine Richness	19
Semivoltine Richness	1
Multivoltine Percent	67.41%
Tolerance	
Sediment Tolerant Richness	5
Sediment Tolerant Percent	6.95%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.228
Pollution Sensitive Richness	0
Pollution Tolerant Percent	4.20%
Hilsenhoff Biotic Index	7.415
Intolerant Percent	0.26%
Supertolerant Percent	57.29%
CTQa	84.650

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	22	44.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	14	46.67%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	10	55.56%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	3	14.29%	Severe



Metrics Report

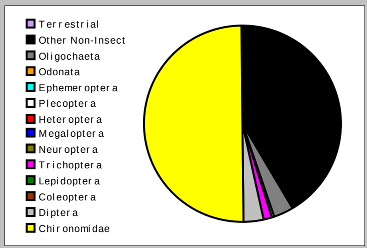
Project ID: CBELhist-C
RAI No.: CBELhist-C003
Sta. Name: Cemetery
Client ID: CemeteryCrkSite3
STORET ID
Coll. Date: 9/25/2007
Latitude: **Longitude:**

Abundance Measures

Sample Count: 483
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	6	201	41.61%
Oligochaeta	1	15	3.11%
Odonata			
Ephemeroptera	1	1	0.21%
Plecoptera	1	1	0.21%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	1	6	1.24%
Lepidoptera			
Coleoptera			
Diptera	5	16	3.31%
Chironomidae	3	243	50.31%

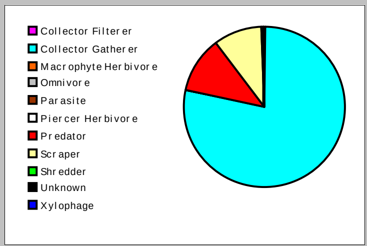


Dominant Taxa

Category	A	PRA
Chironominae	168	34.78%
Crangonyx	126	26.09%
Orthocladiinae	47	9.73%
Physa	31	6.42%
Acari	25	5.18%
Tanypodinae	21	4.35%
Oligochaeta	15	3.11%
Gastropoda	8	1.66%
Chironomidae	7	1.45%
Planorbidae	6	1.24%
Leptoceridae	6	1.24%
Hemerodromia	5	1.04%
Dixa	4	0.83%
Sphaeriidae	3	0.62%
Ceratopogoninae	3	0.62%

Functional Composition

Category	R	A	PRA
Predator	5	57	11.80%
Parasite			
Collector Gatherer	7	374	77.43%
Collector Filterer	1	3	0.62%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	4	48	9.94%
Shredder	1	1	0.21%
Omnivore			
Unknown			

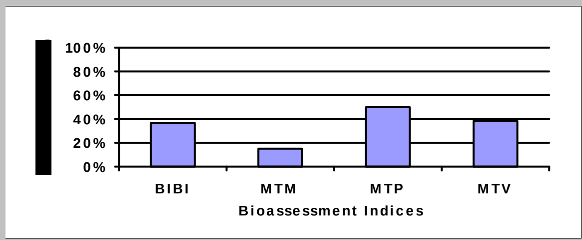


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	18
E Richness	1
P Richness	1
T Richness	1
EPT Richness	3
EPT Percent	1.66%
All Non-Insect Abundance	216
All Non-Insect Richness	7
All Non-Insect Percent	44.72%
Oligochaeta+Hirudinea Percent	3.11%
Baetidae/Ephemeroptera	0.000
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	34.78%
Dominant Taxa (2) Percent	60.87%
Dominant Taxa (3) Percent	70.60%
Dominant Taxa (10) Percent	94.00%
Diversity	
Shannon H (loge)	1.883
Shannon H (log2)	2.717
Margalef D	2.767
Simpson D	0.223
Evenness	0.099
Function	
Predator Richness	5
Predator Percent	11.80%
Filterer Richness	1
Filterer Percent	0.62%
Collector Percent	78.05%
Scraper+Shredder Percent	10.14%
Scraper/Filterer	16.000
Scraper/Scraper+Filterer	0.941
Habit	
Burrower Richness	1
Burrower Percent	0.21%
Swimmer Richness	1
Swimmer Percent	0.83%
Clinger Richness	2
Clinger Percent	0.41%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.21%
Hemoglobin Bearer Richness	1
Hemoglobin Bearer Percent	1.24%
Air Breather Richness	1
Air Breather Percent	0.21%
Voltinism	
Univoltine Richness	14
Semivoltine Richness	0
Multivoltine Percent	55.49%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	4.76%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.347
Pollution Sensitive Richness	1
Pollution Tolerant Percent	8.07%
Hilsenhoff Biotic Index	6.936
Intolerant Percent	1.04%
Supertolerant Percent	46.38%
CTQa	93.385

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	18	36.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	15	50.00%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	7	38.89%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	3	14.29%	Severe



Tuesday, June 24, 2014

Metrics Report

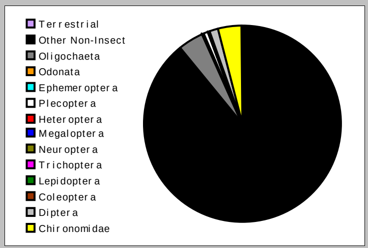
Project ID: CBELhist-C
RAI No.: CBELhist-C004
Sta. Name: Cemetery
Client ID: CemeteryCrkSite1
STORET ID
Coll. Date: 9/15/2009
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1514
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	7	1344	88.77%
Oligochaeta	1	68	4.49%
Odonata	1	1	0.07%
Ephemeroptera	3	6	0.40%
Plecoptera	3	10	0.66%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	1	1	0.07%
Lepidoptera			
Coleoptera	2	2	0.13%
Diptera	5	24	1.59%
Chironomidae	3	58	3.83%

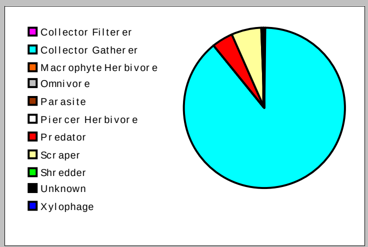


Dominant Taxa

Category	A	PRA
Caecidotea	662	43.73%
Crangonyx	556	36.72%
Oligochaeta	68	4.49%
Ancylidae	51	3.37%
Acari	41	2.71%
Chironominae	39	2.58%
Planorbidae	14	0.92%
Physa	14	0.92%
Orthocladiinae	10	0.66%
Chelifera	10	0.66%
Tanypodinae	8	0.53%
Simulium	8	0.53%
Zapada cinctipes	5	0.33%
Malenka	4	0.26%
Gastropoda	4	0.26%

Functional Composition

Category	R	A	PRA
Predator	9	68	4.49%
Parasite			
Collector Gatherer	7	1341	88.57%
Collector Filterer	1	8	0.53%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	5	85	5.61%
Shredder	3	10	0.66%
Omnivore	1	2	0.13%
Unknown			

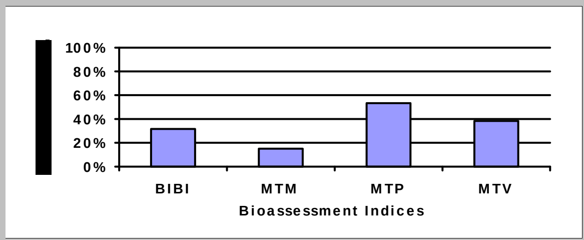


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	26
E Richness	3
P Richness	3
T Richness	1
EPT Richness	7
EPT Percent	1.12%
All Non-Insect Abundance	1412
All Non-Insect Richness	8
All Non-Insect Percent	93.26%
Oligochaeta+Hirudinea Percent	4.49%
Baetidae/Ephemeroptera	0.667
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	43.73%
Dominant Taxa (2) Percent	80.45%
Dominant Taxa (3) Percent	84.94%
Dominant Taxa (10) Percent	96.76%
Diversity	
Shannon H (loge)	1.504
Shannon H (log2)	2.170
Margalef D	3.416
Simpson D	0.333
Evenness	0.096
Function	
Predator Richness	9
Predator Percent	4.49%
Filterer Richness	1
Filterer Percent	0.53%
Collector Percent	89.10%
Scraper+Shredder Percent	6.27%
Scraper/Filterer	10.625
Scraper/Scraper+Filterer	0.914
Habit	
Burrower Richness	1
Burrower Percent	0.07%
Swimmer Richness	2
Swimmer Percent	0.33%
Clinger Richness	8
Clinger Percent	1.45%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.07%
Hemoglobin Bearer Richness	1
Hemoglobin Bearer Percent	0.92%
Air Breather Richness	2
Air Breather Percent	0.26%
Voltinism	
Univoltine Richness	17
Semivoltine Richness	3
Multivoltine Percent	6.80%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	5.61%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.885
Pollution Sensitive Richness	1
Pollution Tolerant Percent	49.08%
Hilsenhoff Biotic Index	7.044
Intolerant Percent	0.66%
Supertolerant Percent	51.78%
CTQa	75.167

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	16	32.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	16	53.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	7	38.89%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	3	14.29%	Severe



Tuesday, June 24, 2014

Metrics Report

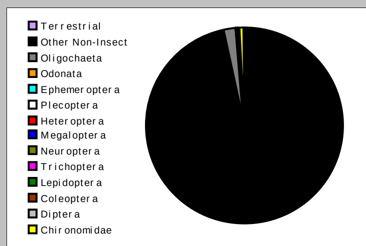
Project ID: CBELhist-C
RAI No.: CBELhist-C005
Sta. Name: Cemetery
Client ID: CemeteryCrkSite2
STORET ID
Coll. Date: 9/15/2009
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1220
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	7	1179	96.64%
Oligochaeta	1	24	1.97%
Odonata			
Ephemeroptera	3	3	0.25%
Plecoptera	2	4	0.33%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera			
Lepidoptera			
Coleoptera	1	1	0.08%
Diptera	1	1	0.08%
Chironomidae	3	8	0.66%

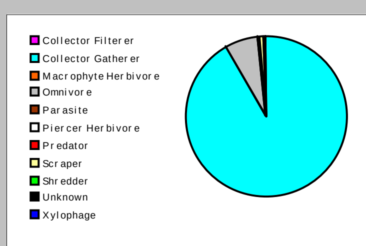


Dominant Taxa

Category	A	PRA
Caecidotea	726	59.51%
Crangonyx	362	29.67%
Planariidae	82	6.72%
Oligochaeta	24	1.97%
Ancylidae	5	0.41%
Tanypodinae	4	0.33%
Zapada cinctipes	3	0.25%
Orthocladiinae	2	0.16%
Chironominae	2	0.16%
Acari	2	0.16%
Malenka	1	0.08%
Lara	1	0.08%
Cinygma	1	0.08%
Ceratopogoninae	1	0.08%
Baetis tricaudatus	1	0.08%

Functional Composition

Category	R	A	PRA
Predator	3	7	0.57%
Parasite			
Collector Gatherer	7	1118	91.64%
Collector Filterer	1	1	0.08%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	2	6	0.49%
Shredder	3	5	0.41%
Omnivore	1	82	6.72%
Unknown	1	1	0.08%

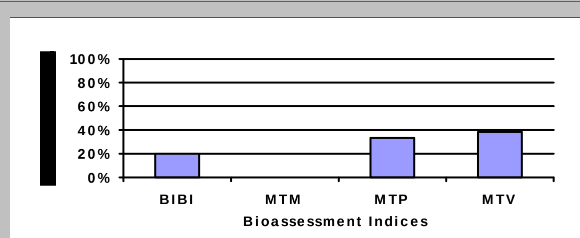


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	18
E Richness	3
P Richness	2
T Richness	0
EPT Richness	5
EPT Percent	0.57%
All Non-Insect Abundance	1203
All Non-Insect Richness	8
All Non-Insect Percent	98.61%
Oligochaeta+Hirudinea Percent	1.97%
Baetidae/Ephemeroptera	0.333
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	59.51%
Dominant Taxa (2) Percent	89.18%
Dominant Taxa (3) Percent	95.90%
Dominant Taxa (10) Percent	99.34%
Diversity	
Shannon H (loge)	1.062
Shannon H (log2)	1.533
Margalef D	2.392
Simpson D	0.447
Evenness	0.105
Function	
Predator Richness	3
Predator Percent	0.57%
Filterer Richness	1
Filterer Percent	0.08%
Collector Percent	91.72%
Scraper+Shredder Percent	0.90%
Scraper/Filterer	6.000
Scraper/Scraper+Filterer	0.857
Habit	
Burrower Richness	0
Burrower Percent	0.00%
Swimmer Richness	2
Swimmer Percent	0.16%
Clinger Richness	4
Clinger Percent	0.49%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.08%
Hemoglobin Bearer Richness	
Hemoglobin Bearer Percent	
Air Breather Richness	0
Air Breather Percent	0.00%
Voltinism	
Univoltine Richness	10
Semivoltine Richness	1
Multivoltine Percent	0.98%
Tolerance	
Sediment Tolerant Richness	1
Sediment Tolerant Percent	1.97%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.972
Pollution Sensitive Richness	1
Pollution Tolerant Percent	59.92%
Hilsenhoff Biotic Index	6.912
Intolerant Percent	7.05%
Supertolerant Percent	61.72%
CTQa	84.333

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	10	20.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	10	33.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	7	38.89%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	0	0.00%	Severe



Tuesday, June 24, 2014

Metrics Report

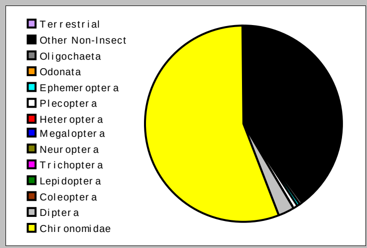
Project ID: CBELhist-C
RAI No.: CBELhist-C006
Sta. Name: Cemetery
Client ID: CemeteryCrkSite3
STORET ID
Coll. Date: 9/15/2009
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1319
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	10	525	39.80%
Oligochaeta	1	5	0.38%
Odonata	1	1	0.08%
Ephemeroptera	2	8	0.61%
Plecoptera	2	6	0.45%
Heteroptera			
Megaloptera	1	1	0.08%
Neuroptera			
Trichoptera	3	3	0.23%
Lepidoptera	1	1	0.08%
Coleoptera	1	1	0.08%
Diptera	8	33	2.50%
Chironomidae	3	735	55.72%

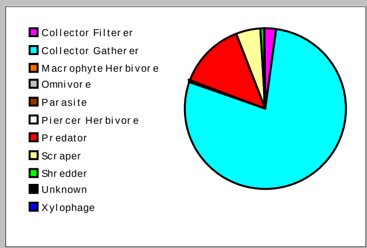


Dominant Taxa

Category	A	PRA
Chironominae	519	39.35%
Crangonyx	402	30.48%
Tanypodinae	135	10.24%
Physa	51	3.87%
Orthocladiinae	48	3.64%
Chironomidae	33	2.50%
Sphaeriidae	30	2.27%
Chelifera	15	1.14%
Caecidotea	15	1.14%
Planorbidae	10	0.76%
Acari	9	0.68%
Cinygma	6	0.45%
Zapada cinctipes	5	0.38%
Planariidae	5	0.38%
Hemerodromia	5	0.38%

Functional Composition

Category	R	A	PRA
Predator	12	178	13.50%
Parasite			
Collector Gatherer	8	1026	77.79%
Collector Filterer	2	32	2.43%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	4	68	5.16%
Shredder	5	9	0.68%
Omnivore	1	5	0.38%
Unknown	1	1	0.08%

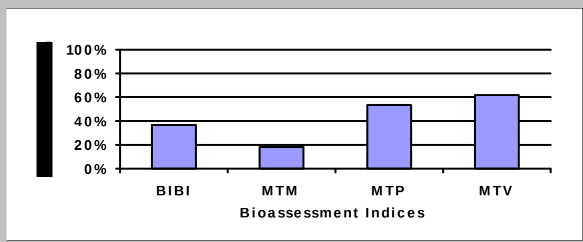


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	33
E Richness	2
P Richness	2
T Richness	3
EPT Richness	7
EPT Percent	1.29%
All Non-Insect Abundance	530
All Non-Insect Richness	11
All Non-Insect Percent	40.18%
Oligochaeta+Hirudinea Percent	0.45%
Baetidae/Ephemeroptera	0.000
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	39.35%
Dominant Taxa (2) Percent	69.83%
Dominant Taxa (3) Percent	80.06%
Dominant Taxa (10) Percent	95.38%
Diversity	
Shannon H (loge)	1.726
Shannon H (log2)	2.490
Margalef D	4.470
Simpson D	0.275
Evenness	0.086
Function	
Predator Richness	12
Predator Percent	13.50%
Filterer Richness	2
Filterer Percent	2.43%
Collector Percent	80.21%
Scraper+Shredder Percent	5.84%
Scraper/Filterer	2.125
Scraper/Scraper+Filterer	0.680
Habit	
Burrower Richness	2
Burrower Percent	0.15%
Swimmer Richness	3
Swimmer Percent	0.30%
Clinger Richness	7
Clinger Percent	1.29%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.45%
Hemoglobin Bearer Richness	1
Hemoglobin Bearer Percent	0.76%
Air Breather Richness	2
Air Breather Percent	0.30%
Voltinism	
Univoltine Richness	25
Semivoltine Richness	1
Multivoltine Percent	56.48%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	1.36%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	3.602
Pollution Sensitive Richness	1
Pollution Tolerant Percent	6.07%
Hilsenhoff Biotic Index	7.045
Intolerant Percent	1.29%
Supertolerant Percent	49.58%
CTQa	87.043

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	18	36.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	16	53.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	11	61.11%	Slight
MTM	Montana DEQ Mountains (Bukantis 1998)	4	19.05%	Severe



Tuesday, June 24, 2014

Metrics Report

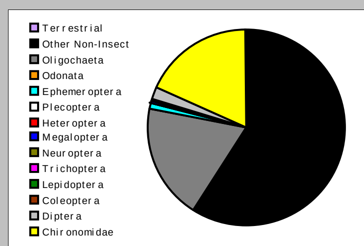
Project ID: CBELhist-C
RAI No.: CBELhist-C007
Sta. Name: Cemetery Creek Site 1 between N. Pond & Whatcom
Client ID: Cemetery Creek S1
STORET ID
Coll. Date: 9/21/2011
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1222
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	15	719	58.84%
Oligochaeta	1	233	19.07%
Odonata			
Ephemeroptera	2	12	0.98%
Plecoptera	1	1	0.08%
Heteroptera			
Megaloptera	1	1	0.08%
Neuroptera			
Trichoptera	2	2	0.16%
Lepidoptera			
Coleoptera	2	2	0.16%
Diptera	5	29	2.37%
Chironomidae	23	223	18.25%

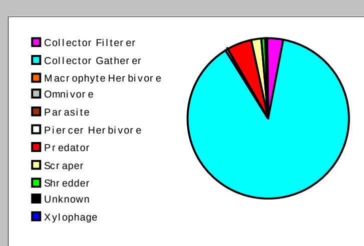


Dominant Taxa

Category	A	PRA
Caecidotea	405	33.14%
Oligochaeta	233	19.07%
Crangonyx	181	14.81%
Amphipoda	67	5.48%
Micropsectra	66	5.40%
Chironomus	39	3.19%
Acari	24	1.96%
Tanytarsus	18	1.47%
Thienemannimyia Gr.	15	1.23%
Simulium	14	1.15%
Ferrissia	11	0.90%
Dicrotendipes	11	0.90%
Baetis tricaudatus	11	0.90%
Procladius	10	0.82%
Paratanytarsus	10	0.82%

Functional Composition

Category	R	A	PRA
Predator	10	64	5.24%
Parasite			
Collector Gatherer	25	1079	88.30%
Collector Filterer	5	38	3.11%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	5	23	1.88%
Shredder	5	11	0.90%
Omnivore	1	2	0.16%
Unknown	1	5	0.41%

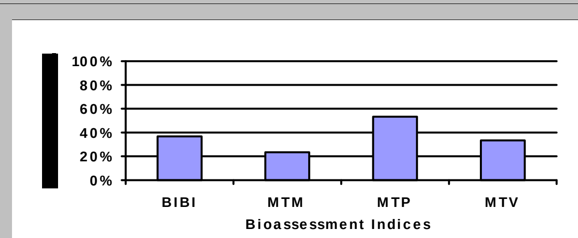


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	52
E Richness	2
P Richness	1
T Richness	2
EPT Richness	5
EPT Percent	1.23%
All Non-Insect Abundance	952
All Non-Insect Richness	16
All Non-Insect Percent	77.91%
Oligochaeta+Hirudinea Percent	19.15%
Baetidae/Ephemeroptera	0.917
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	33.14%
Dominant Taxa (2) Percent	52.21%
Dominant Taxa (3) Percent	67.02%
Dominant Taxa (10) Percent	86.91%
Diversity	
Shannon H (loge)	2.201
Shannon H (log2)	3.175
Margalef D	7.256
Simpson D	0.202
Evenness	0.067
Function	
Predator Richness	10
Predator Percent	5.24%
Filterer Richness	5
Filterer Percent	3.11%
Collector Percent	91.41%
Scraper+Shredder Percent	2.78%
Scraper/Filterer	0.605
Scraper/Scraper+Filterer	0.377
Habit	
Burrower Richness	8
Burrower Percent	6.22%
Swimmer Richness	2
Swimmer Percent	1.15%
Clinger Richness	10
Clinger Percent	3.27%
Characteristics	
Cold Stenotherm Richness	0
Cold Stenotherm Percent	0.00%
Hemoglobin Bearer Richness	10
Hemoglobin Bearer Percent	7.61%
Air Breather Richness	1
Air Breather Percent	0.08%
Voltinism	
Univoltine Richness	19
Semivoltine Richness	2
Multivoltine Percent	22.59%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	20.21%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.283
Pollution Sensitive Richness	0
Pollution Tolerant Percent	39.93%
Hilsenhoff Biotic Index	7.334
Intolerant Percent	0.33%
Supertolerant Percent	59.57%
CTQa	98.146

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	18	36.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	16	53.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	6	33.33%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	5	23.81%	Moderate



Tuesday, June 24, 2014

Metrics Report

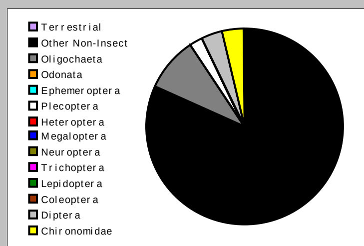
Project ID: CBELhist-C
RAI No.: CBELhist-C008
Sta. Name: Cemetery Creek Site 2 between N. Pond & W. Pond
Client ID: Cemetery Creek S2
STORET ID
Coll. Date: 9/20/2011
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1365
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	12	1115	81.68%
Oligochaeta	1	121	8.86%
Odonata			
Ephemeroptera	1	1	0.07%
Plecoptera	3	31	2.27%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	2	2	0.15%
Lepidoptera			
Coleoptera	2	2	0.15%
Diptera	7	44	3.22%
Chironomidae	8	49	3.59%

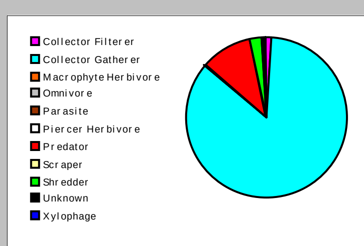


Dominant Taxa

Category	A	PRA
Caecidotea	503	36.85%
Crangonyx	424	31.06%
Oligochaeta	121	8.86%
Turbellaria	77	5.64%
Amphipoda	50	3.66%
Zapada cinctipes	28	2.05%
Acari	26	1.90%
Parametriocnemus	18	1.32%
Dixa	18	1.32%
Nemata	12	0.88%
Neoplasta	11	0.81%
Thienemannimyia Gr.	10	0.73%
Sphaeriidae	8	0.59%
Micropsectra	8	0.59%
Tanytarsus	7	0.51%

Functional Composition

Category	R	A	PRA
Predator	12	141	10.33%
Parasite			
Collector Gatherer	13	1159	84.91%
Collector Filterer	3	17	1.25%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	1	1	0.07%
Shredder	5	33	2.42%
Omnivore	1	2	0.15%
Unknown	1	12	0.88%

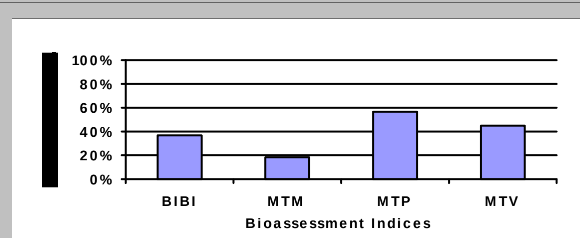


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	36
E Richness	1
P Richness	3
T Richness	2
EPT Richness	6
EPT Percent	2.49%
All Non-Insect Abundance	1236
All Non-Insect Richness	13
All Non-Insect Percent	90.55%
Oligochaeta+Hirudinea Percent	8.86%
Baetidae/Ephemeroptera	0.000
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	36.85%
Dominant Taxa (2) Percent	67.91%
Dominant Taxa (3) Percent	76.78%
Dominant Taxa (10) Percent	93.55%
Diversity	
Shannon H (loge)	1.810
Shannon H (log2)	2.612
Margalef D	4.875
Simpson D	0.264
Evenness	0.082
Function	
Predator Richness	12
Predator Percent	10.33%
Filterer Richness	3
Filterer Percent	1.25%
Collector Percent	86.15%
Scraper+Shredder Percent	2.49%
Scraper/Filterer	0.059
Scraper/Scraper+Filterer	0.056
Habit	
Burrower Richness	2
Burrower Percent	1.03%
Swimmer Richness	3
Swimmer Percent	1.68%
Clinger Richness	6
Clinger Percent	2.49%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.07%
Hemoglobin Bearer Richness	1
Hemoglobin Bearer Percent	0.07%
Air Breather Richness	2
Air Breather Percent	0.29%
Voltinism	
Univoltine Richness	18
Semivoltine Richness	3
Multivoltine Percent	12.67%
Tolerance	
Sediment Tolerant Richness	1
Sediment Tolerant Percent	8.86%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.654
Pollution Sensitive Richness	2
Pollution Tolerant Percent	36.92%
Hilsenhoff Biotic Index	6.685
Intolerant Percent	1.90%
Supertolerant Percent	46.96%
CTQa	91.143

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	18	36.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	17	56.67%	Slight
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	8	44.44%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	4	19.05%	Severe



Tuesday, June 24, 2014

Metrics Report

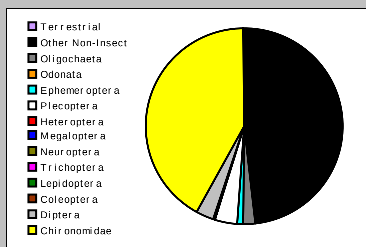
Project ID: CBELhist-C
RAI No.: CBELhist-C009
Sta. Name: Cemetery Creek Site 3 between W. Pond & S. Pond
Client ID: Cemetery Creek S3
STORET ID
Coll. Date: 9/20/2011
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1150
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	9	554	48.17%
Oligochaeta	1	21	1.83%
Odonata			
Ephemeroptera	2	12	1.04%
Plecoptera	2	41	3.57%
Heteroptera			
Megaloptera	1	1	0.09%
Neuroptera			
Trichoptera	1	2	0.17%
Lepidoptera			
Coleoptera	3	3	0.26%
Diptera	7	29	2.52%
Chironomidae	15	487	42.35%

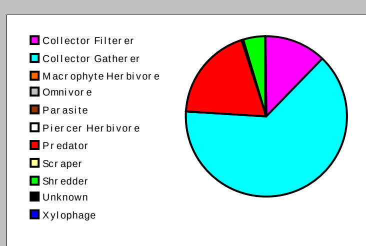


Dominant Taxa

Category	A	PRA
Crangonyx	336	29.22%
Micropsectra	228	19.83%
Tanytarsus	119	10.35%
Thienemannimyia Gr.	84	7.30%
Amphipoda	65	5.65%
Hydrozoa	53	4.61%
Zapada cinctipes	37	3.22%
Turbellaria	35	3.04%
Caecidotea	24	2.09%
Parametriocnemus	21	1.83%
Oligochaeta	21	1.83%
Acari	18	1.57%
Neoplasta	12	1.04%
Sphaeriidae	11	0.96%
Cladocera	8	0.70%

Functional Composition

Category	R	A	PRA
Predator	11	218	18.96%
Parasite			
Collector Gatherer	17	729	63.39%
Collector Filterer	3	144	12.52%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	2	7	0.61%
Shredder	7	51	4.43%
Omnivore			
Unknown	1	1	0.09%

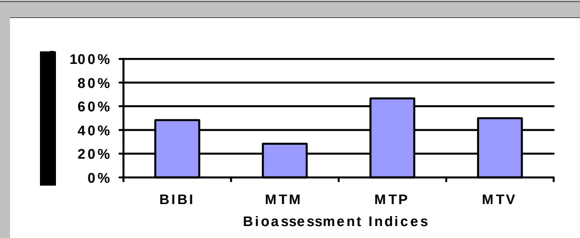


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	41
E Richness	2
P Richness	2
T Richness	1
EPT Richness	5
EPT Percent	4.78%
All Non-Insect Abundance	575
All Non-Insect Richness	10
All Non-Insect Percent	50.00%
Oligochaeta+Hirudinea Percent	1.83%
Baetidae/Ephemeroptera	0.000
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	29.22%
Dominant Taxa (2) Percent	49.04%
Dominant Taxa (3) Percent	59.39%
Dominant Taxa (10) Percent	87.13%
Diversity	
Shannon H (loge)	2.320
Shannon H (log2)	3.347
Margalef D	5.738
Simpson D	0.168
Evenness	0.067
Function	
Predator Richness	11
Predator Percent	18.96%
Filterer Richness	3
Filterer Percent	12.52%
Collector Percent	75.91%
Scraper+Shredder Percent	5.04%
Scraper/Filterer	0.049
Scraper/Scraper+Filterer	0.046
Habit	
Burrower Richness	9
Burrower Percent	1.83%
Swimmer Richness	1
Swimmer Percent	0.35%
Clinger Richness	7
Clinger Percent	4.96%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.52%
Hemoglobin Bearer Richness	5
Hemoglobin Bearer Percent	0.87%
Air Breather Richness	3
Air Breather Percent	0.35%
Voltinism	
Univoltine Richness	18
Semivoltine Richness	3
Multivoltine Percent	48.00%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	2.09%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	2.520
Pollution Sensitive Richness	2
Pollution Tolerant Percent	2.61%
Hilsenhoff Biotic Index	5.208
Intolerant Percent	1.91%
Supertolerant Percent	6.78%
CTQa	93.118

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	24	48.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	20	66.67%	Slight
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	9	50.00%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	6	28.57%	Moderate



Metrics Report

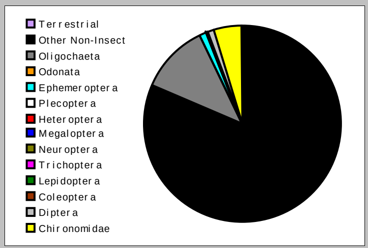
Project ID: CBELhist-C
RAI No.: CBELhist-C010
Sta. Name: Cemetary Creek Site 1
Client ID: Cemetary Creek S1
STORET ID
Coll. Date: 9/24/2013
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1067
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	8	869	81.44%
Oligochaeta	1	122	11.43%
Odonata	1	1	0.09%
Ephemeroptera	2	12	1.12%
Plecoptera	1	2	0.19%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	1	1	0.09%
Lepidoptera			
Coleoptera	1	1	0.09%
Diptera	3	9	0.84%
Chironomidae	11	50	4.69%

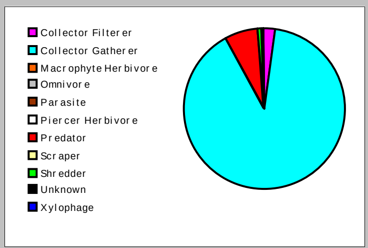


Dominant Taxa

Category	A	PRA
Caecidotea	624	58.48%
Crangonyx	151	14.15%
Oligochaeta	122	11.43%
Turbellaria	36	3.37%
Micropsectra	26	2.44%
Sphaeriidae	16	1.50%
Acari	16	1.50%
Amphipoda	12	1.12%
Paraleptophlebia	7	0.66%
Hydrozoa	7	0.66%
Dicranota	6	0.56%
Nemata	5	0.47%
Baetis tricaudatus	5	0.47%
Rheotanytarsus	4	0.37%
Dicrotendipes	4	0.37%

Functional Composition

Category	R	A	PRA
Predator	11	75	7.03%
Parasite			
Collector Gatherer	11	958	89.78%
Collector Filterer	2	23	2.16%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper			
Shredder	4	6	0.56%
Omnivore			
Unknown	1	5	0.47%

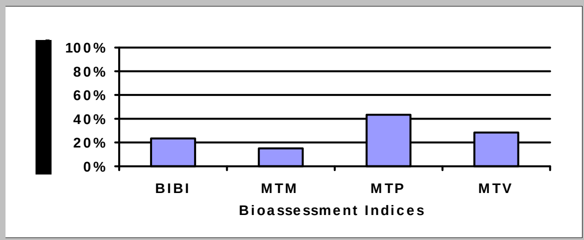


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	29
E Richness	2
P Richness	1
T Richness	1
EPT Richness	4
EPT Percent	1.41%
All Non-Insect Abundance	991
All Non-Insect Richness	9
All Non-Insect Percent	92.88%
Oligochaeta+Hirudinea Percent	11.62%
Baetidae/Ephemeroptera	0.417
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	58.48%
Dominant Taxa (2) Percent	72.63%
Dominant Taxa (3) Percent	84.07%
Dominant Taxa (10) Percent	95.31%
Diversity	
Shannon H (loge)	1.493
Shannon H (log2)	2.153
Margalef D	4.026
Simpson D	0.390
Evenness	0.078
Function	
Predator Richness	11
Predator Percent	7.03%
Filterer Richness	2
Filterer Percent	2.16%
Collector Percent	91.94%
Scraper+Shredder Percent	0.56%
Scraper/Filterer	0.000
Scraper/Scraper+Filterer	0.000
Habit	
Burrower Richness	2
Burrower Percent	0.56%
Swimmer Richness	2
Swimmer Percent	1.12%
Clinger Richness	4
Clinger Percent	0.75%
Characteristics	
Cold Stenotherm Richness	0
Cold Stenotherm Percent	0.00%
Hemoglobin Bearer Richness	3
Hemoglobin Bearer Percent	0.66%
Air Breather Richness	1
Air Breather Percent	0.56%
Voltinism	
Univoltine Richness	13
Semivoltine Richness	1
Multivoltine Percent	10.50%
Tolerance	
Sediment Tolerant Richness	2
Sediment Tolerant Percent	12.00%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.652
Pollution Sensitive Richness	0
Pollution Tolerant Percent	59.04%
Hilsenhoff Biotic Index	7.439
Intolerant Percent	0.75%
Supertolerant Percent	72.35%
CTQa	91.375

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	12	24.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	13	43.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	5	27.78%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	3	14.29%	Severe



Tuesday, June 24, 2014

Metrics Report

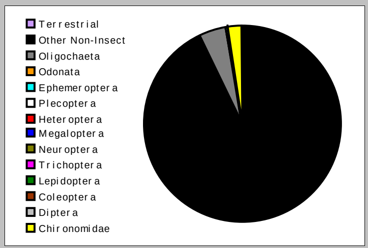
Project ID: CBELhist-C
RAI No.: CBELhist-C011
Sta. Name: Cemetary Creek Site 2
Client ID: Cemetary Creek S2
STORET ID
Coll. Date: 9/24/2013
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1422
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	10	1319	92.76%
Oligochaeta	1	68	4.78%
Odonata			
Ephemeroptera	1	2	0.14%
Plecoptera			
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera			
Lepidoptera			
Coleoptera			
Diptera	1	1	0.07%
Chironomidae	8	32	2.25%

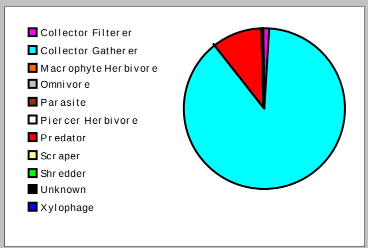


Dominant Taxa

Category	A	PRA
Caecidotea	813	57.17%
Crangonyx	349	24.54%
Turbellaria	125	8.79%
Oligochaeta	68	4.78%
Sphaeriidae	14	0.98%
Micropsectra	10	0.70%
Hydrozoa	10	0.70%
Thienemannimyia Gr.	9	0.63%
Dicrotendipes	6	0.42%
Acari	4	0.28%
Paratanytarsus	2	0.14%
Diplocladius cultriger	2	0.14%
Baetis tricaudatus	2	0.14%
Parametriocnemus	1	0.07%
Nemata	1	0.07%

Functional Composition

Category	R	A	PRA
Predator	5	149	10.48%
Parasite			
Collector Gatherer	11	1255	88.26%
Collector Filterer	2	15	1.05%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	1	1	0.07%
Shredder	1	1	0.07%
Omnivore			
Unknown	1	1	0.07%

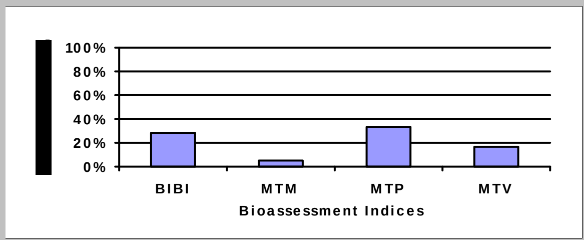


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	21
E Richness	1
P Richness	0
T Richness	0
EPT Richness	1
EPT Percent	0.14%
All Non-Insect Abundance	1387
All Non-Insect Richness	11
All Non-Insect Percent	97.54%
Oligochaeta+Hirudinea Percent	4.78%
Baetidae/Ephemeroptera	1.000
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	57.17%
Dominant Taxa (2) Percent	81.72%
Dominant Taxa (3) Percent	90.51%
Dominant Taxa (10) Percent	99.02%
Diversity	
Shannon H (loge)	1.279
Shannon H (log2)	1.845
Margalef D	2.755
Simpson D	0.397
Evenness	0.097
Function	
Predator Richness	5
Predator Percent	10.48%
Filterer Richness	2
Filterer Percent	1.05%
Collector Percent	89.31%
Scraper+Shredder Percent	0.14%
Scraper/Filterer	0.067
Scraper/Scraper+Filterer	0.063
Habit	
Burrower Richness	1
Burrower Percent	0.42%
Swimmer Richness	1
Swimmer Percent	0.14%
Clinger Richness	1
Clinger Percent	0.07%
Characteristics	
Cold Stenotherm Richness	0
Cold Stenotherm Percent	0.00%
Hemoglobin Bearer Richness	2
Hemoglobin Bearer Percent	0.49%
Air Breather Richness	0
Air Breather Percent	0.00%
Voltinism	
Univoltine Richness	8
Semivoltine Richness	0
Multivoltine Percent	11.60%
Tolerance	
Sediment Tolerant Richness	1
Sediment Tolerant Percent	4.78%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.773
Pollution Sensitive Richness	0
Pollution Tolerant Percent	57.59%
Hilsenhoff Biotic Index	7.159
Intolerant Percent	0.00%
Supertolerant Percent	63.64%
CTQa	104.938

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	14	28.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	10	33.33%	Moderate
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	3	16.67%	Severe
MTM	Montana DEQ Mountains (Bukantis 1998)	1	4.76%	Severe



Tuesday, June 24, 2014

Metrics Report

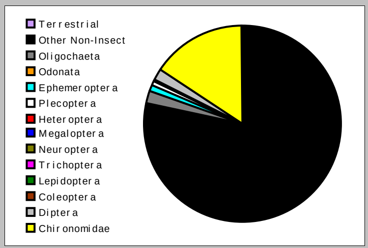
Project ID: CBELhist-C
RAI No.: CBELhist-C012
Sta. Name: Cemetary Creek Site 3
Client ID: Cemetary Creek S3
STORET ID
Coll. Date: 9/24/2013
Latitude: **Longitude:**

Abundance Measures

Sample Count: 1254
Sample Abundance: of sample used
Coll. Procedure:
Sample Notes:

Taxonomic Composition

Category	R	A	PRA
Terrestrial			
Other Non-Insect	10	984	78.47%
Oligochaeta	1	23	1.83%
Odonata			
Ephemeroptera	3	14	1.12%
Plecoptera	3	6	0.48%
Heteroptera			
Megaloptera			
Neuroptera			
Trichoptera	1	1	0.08%
Lepidoptera			
Coleoptera	2	5	0.40%
Diptera	5	21	1.67%
Chironomidae	11	200	15.95%

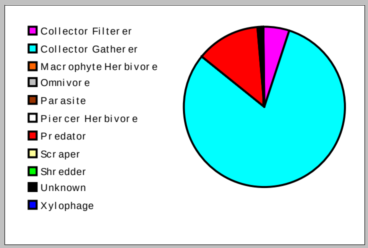


Dominant Taxa

Category	A	PRA
Crangonyx	464	37.00%
Caecidotea	349	27.83%
Micropsectra	98	7.81%
Turbellaria	94	7.50%
Parametriocnemus	51	4.07%
Acari	41	3.27%
Sphaeriidae	29	2.31%
Oligochaeta	23	1.83%
Tanytarsus	22	1.75%
Thienemannimyia Gr.	12	0.96%
Simulium	11	0.88%
Baetis tricaudatus	10	0.80%
Ceratopogoninae	6	0.48%
Lara	4	0.32%
Dicrotendipes	3	0.24%

Functional Composition

Category	R	A	PRA
Predator	10	160	12.76%
Parasite			
Collector Gatherer	15	1011	80.62%
Collector Filterer	3	65	5.18%
Macrophyte Herbivore			
Piercer Herbivore			
Xylophage			
Scraper	2	6	0.48%
Shredder	4	10	0.80%
Omnivore			
Unknown	2	2	0.16%

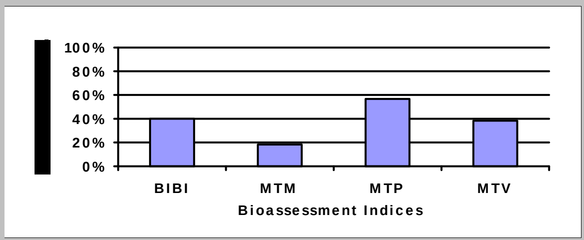


Metric Values and Scores

Metric	Value
Composition	
Taxa Richness	36
E Richness	3
P Richness	3
T Richness	1
EPT Richness	7
EPT Percent	1.67%
All Non-Insect Abundance	1007
All Non-Insect Richness	11
All Non-Insect Percent	80.30%
Oligochaeta+Hirudinea Percent	1.91%
Baetidae/Ephemeroptera	0.714
Hydropsychidae/Trichoptera	0.000
Dominance	
Dominant Taxon Percent	37.00%
Dominant Taxa (2) Percent	64.83%
Dominant Taxa (3) Percent	72.65%
Dominant Taxa (10) Percent	94.34%
Diversity	
Shannon H (loge)	1.935
Shannon H (log2)	2.792
Margalef D	4.912
Simpson D	0.233
Evenness	0.079
Function	
Predator Richness	10
Predator Percent	12.76%
Filterer Richness	3
Filterer Percent	5.18%
Collector Percent	85.81%
Scraper+Shredder Percent	1.28%
Scraper/Filterer	0.092
Scraper/Scraper+Filterer	0.085
Habit	
Burrower Richness	3
Burrower Percent	0.40%
Swimmer Richness	2
Swimmer Percent	0.88%
Clinger Richness	7
Clinger Percent	1.99%
Characteristics	
Cold Stenotherm Richness	1
Cold Stenotherm Percent	0.24%
Hemoglobin Bearer Richness	2
Hemoglobin Bearer Percent	0.40%
Air Breather Richness	2
Air Breather Percent	0.16%
Voltinism	
Univoltine Richness	17
Semivoltine Richness	3
Multivoltine Percent	27.59%
Tolerance	
Sediment Tolerant Richness	3
Sediment Tolerant Percent	2.15%
Sediment Sensitive Richness	0
Sediment Sensitive Percent	0.00%
Metals Tolerance Index	4.049
Pollution Sensitive Richness	1
Pollution Tolerant Percent	28.31%
Hilsenhoff Biotic Index	6.215
Intolerant Percent	0.88%
Supertolerant Percent	32.54%
CTQa	90.167

Bioassessment Indices

BioIndex	Description	Score	Pct	Rating
BIBI	B-IBI (Karr et al.)	20	40.00%	
MTP	Montana DEQ Plains (Bukantis 1998)	17	56.67%	Slight
MTV	Montana Revised Valleys/Foothills (Bollman 1998)	7	38.89%	Moderate
MTM	Montana DEQ Mountains (Bukantis 1998)	4	19.05%	Severe



Tuesday, June 24, 2014

APPENDIX I:

AMPHIBIAN TABLES

Species	Species	2007	2008	2009	2011	2013	2016
Pacific chorus frog	*Pseudacris regilla*	2	1	1	2	3	1
Red-legged frog	*Rana aurora*	0	0	0	4	8	0
Long-toed salamander	*Ambystoma macrodactylum*	0	1	2	1	1	0
Pacific giant salamander	*Dicamptodon tenebrosus*	0	0	0	0	0	0
Northwestern salamander	*Ambystoma gracile*	0	0	0	0	3	0
American bullfrog*	*Lithobates catesbeianus*	1	1	5	0	7	3
Total	Total	3	3	8	7	22	4
Percent Non-native Survey Detections		**33%**	**33%**	**63%**	**0%**	**32%**	**75%**

* Non-native invasive species

APPENDIX J:

SURVEY OF THE CAVITY NESTING BIRDS OF WHATCOM CREEK

Common Name	Scientific Name	Common Name	Scientific Name
American Dipper	*Cinclus mexicanus*	Macgillivray's Warbler	*Oporornis tolmiei*
American Goldfinch	*Carduelis tristis*	Mallard	*Anas platyrhynchos*
American Robin	*Turdus migratorius*	Marsh Wren	*Cistothorus palustris*
Anna's Hummingbird	*Calypte anna*	Merlin	*Falco columbarius*
Bald Eagle	*Haliaeetus leucocephalus*	Northern Flicker	*Colaptes auratus*
Barn Swallow	*Hirundo rustica*	Northern Harrier	*Circus cyaneus*
Barred Owl	*Strix varia*	Orange-crowned Warbler	*Vermivora celata*
Belted Kingfisher	*Megaceryle alcyon*	Pacific-slope Flycatcher	*Empidonax difficilis*
Bewick's Wren	*Thryomanes bewickii*	Pacific Wren	*Troglodytes pacificus*
Black-capped Chickadee	*Poecile atricapillus*	Pileated Woodpecker*	*Dryocopus pileatus*
Black-headed Grosbeak	*Pheucticus melanocephalus*	Pine Siskin	*Carduelis pinus*
Brown Creeper	*Certhia americana*	Purple Finch	*Carpodacus purpureus*
Brown-Headed Cowbird†	*Molothrus ater*	Red-breasted Nuthatch	*Sitta canadensis*
Bufflehead*	*Bucephala albeola*	Red-breasted Sapsucker	*Sphyrapicus ruber*
Bullock's Oriole	*Icterus bullockii*	Red-eyed Vireo	*Vireo olivaceus*
Bushtit	*Psaltriparus minimus*	Red-tailed Hawk	*Buteo jamaicensis*
Canada Goose†	*Branta canadensis*	Red-winged Blackbird	*Agelaius phoeniceus*
Caspian Tern	*Sterna caspia*	Rock Pigeon	*Columba livia*
Cedar Waxwing	*Bombycilla cedrorum*	Ruby-crowned Kinglet	*Regulus calendula*
Chestnut-backed Chickadee	*Poecile rufescens*	Rufous Hummingbird	*Selasphorus rufus*
Common Merganser	*Mergus merganser*	Sharp-shinned Hawk	*Accipiter striatus*
Common Nighthawk	*Chordeiles minor*	Song Sparrow	*Melospiza melodia*
Common Yellowthroat	*Geothlypis trichas*	Spotted Towhee	*Pipilo maculatus*
Northwestern Crow	*Corvus caurinus*	Steller's Jay	*Cyanocitta stelleri*
Dark-eyed Junco	*Junco hyemalis*	Swainson's Thrush	*Catharus ustulatus*
Double-crested Cormorant*	*Phalacrocorax auritus*	Townsend's Warbler	*Setophaga townsendi*
Downy Woodpecker	*Picoides pubescens*	Turkey Vulture	*Cathartes aura*
Evening Grosbeak	*Coccothraustes vespertinus*	Varied Thrush	*Ixoreus naevius*
European Starling†	*Sturnus vulgaris*	Vaux's Swift*	*Chaetura vauxi*
Fox Sparrow	*Passerella iliaca*	Violet-green Swallow	*Tachycineta thalassina*
Golden-crowned Kinglet	*Regulus satrapa*	Warbling Vireo	*Vireo gilvus*
Golden-crowned Sparrow	*Zonotrichia atricapilla*	Western Tanager	*Piranga ludoviciana*
Great Blue Heron*	*Ardea herodias*	Western Wood-Pewee	*Contopus sordidulus*
Green heron	*Butorides virescens*	White-crowned Sparrow	*Zonotrichia leucophrys*
Gull species	*Laridae* family	Willow Flycatcher	*Empidonax traillii*
Hairy Woodpecker	*Picoides villosus*	Wilson's Snipe	*Gallinago delicata*
Hammond's Flycatcher	*Empidonax hammondii*	Wilson's Warbler	*Wilsonia pusilla*
Hooded Merganser*	*Lophodytes cucullatus*	Wood Duck*	*Aix sponsa*
House Finch	*Carpodacus mexicanus*	Yellow Warbler	*Dendroica petechia*
House Sparrow†	*Passer domesticus*	Yellow-rumped Warbler	*Dendroica coronata*
Killdeer	*Charadrius vociferus*		

* WDFW Priority Species

† Non-native, invasive species

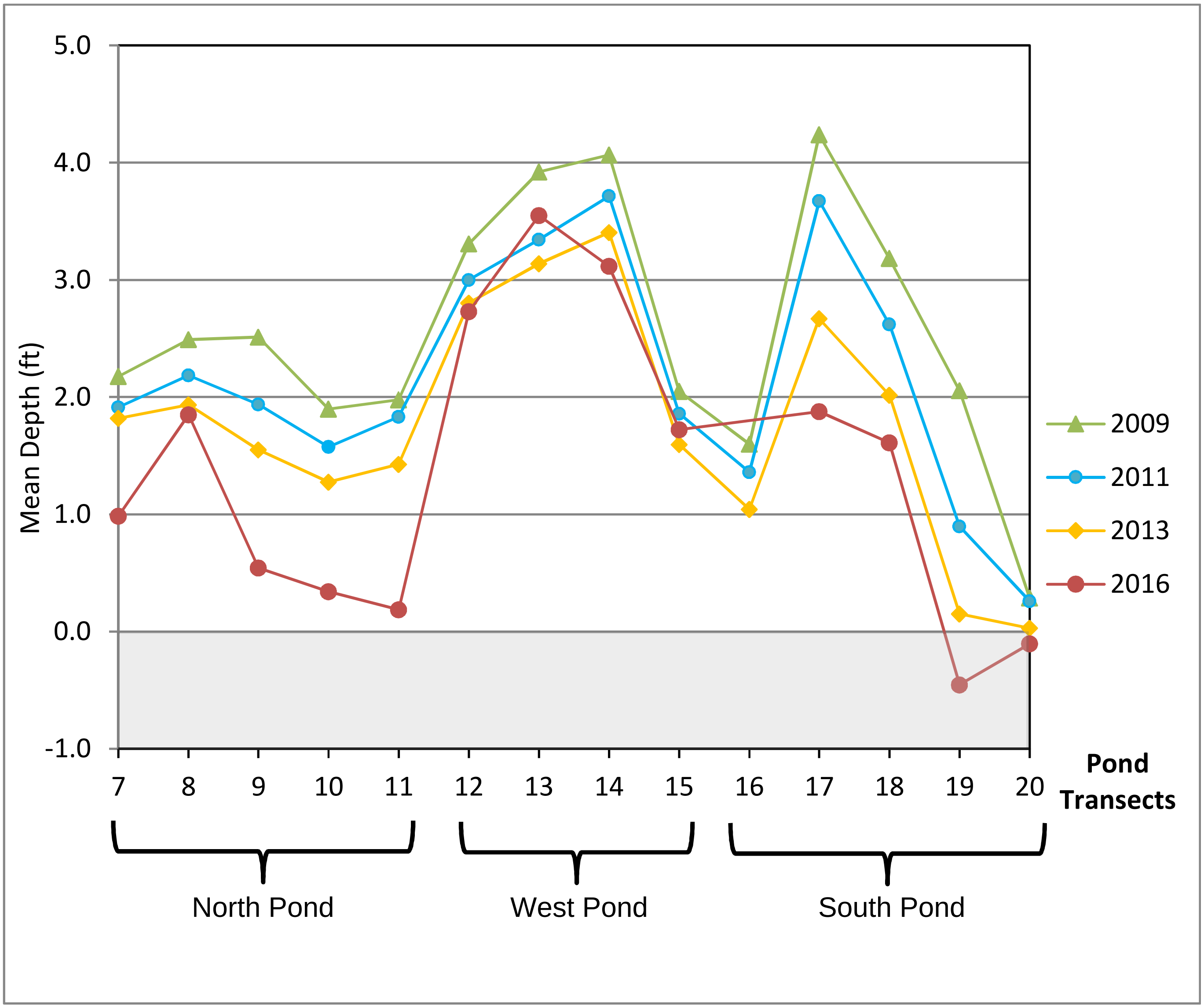
APPENDIX K:

BATHYMETRY 2007-2016

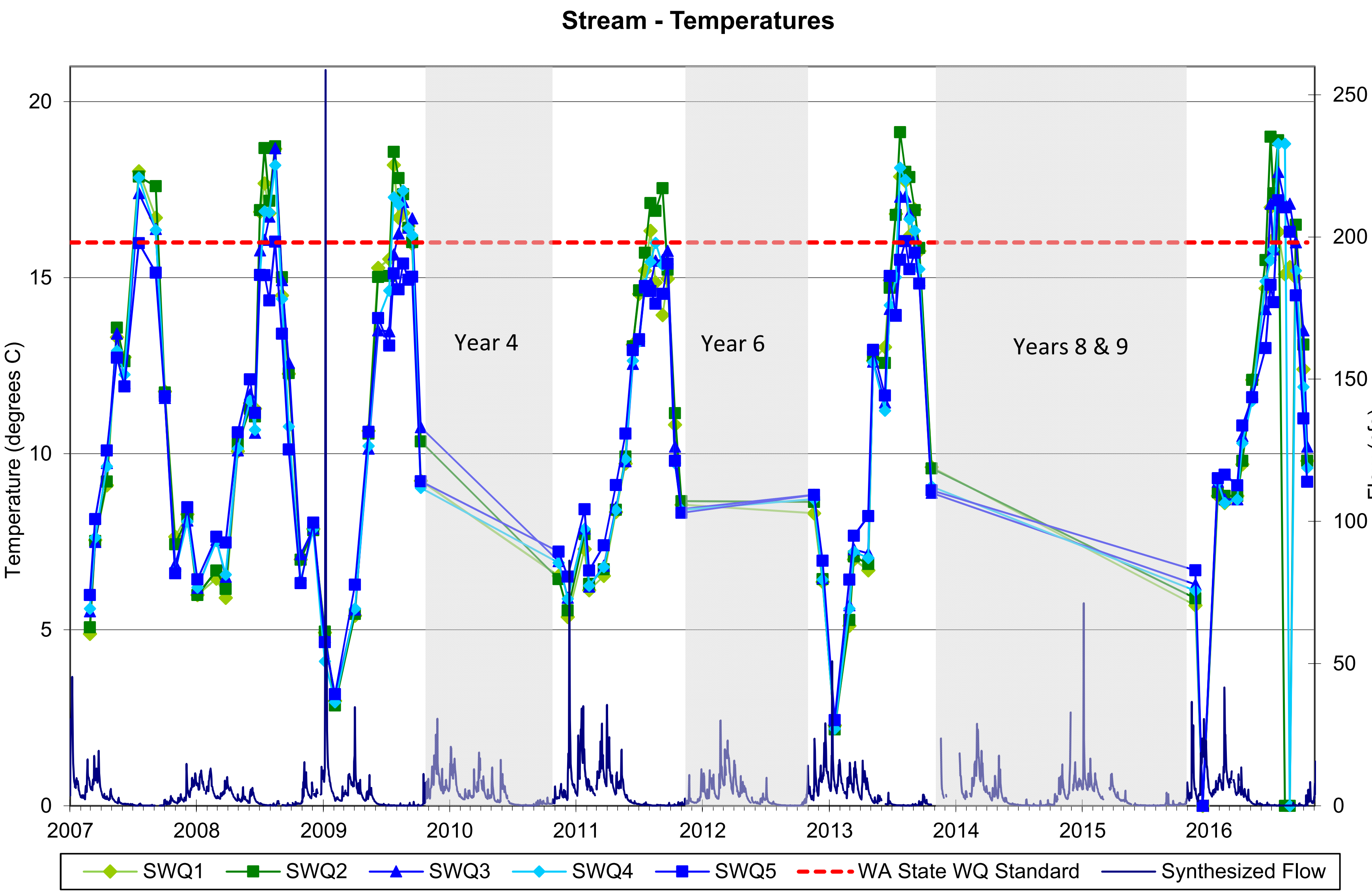
	Maximum Depth (ft)					
	2007*	2008*	2009	2011	2013	2016
North Pond	4.83	5.58	4.32	3.79	3.31	3.15
West Pond	7.84	8.67	7.43	6.28	5.92	5.51
South Pond†	7.45	7.70	6.89	6.22	5.69	4.85

*2007 & 2008 methodology differs from 2009 forward. See text for details.

†PTR20 data excluded from volume calculation; transect crosses stream inflow and is not representative of pond conditions.



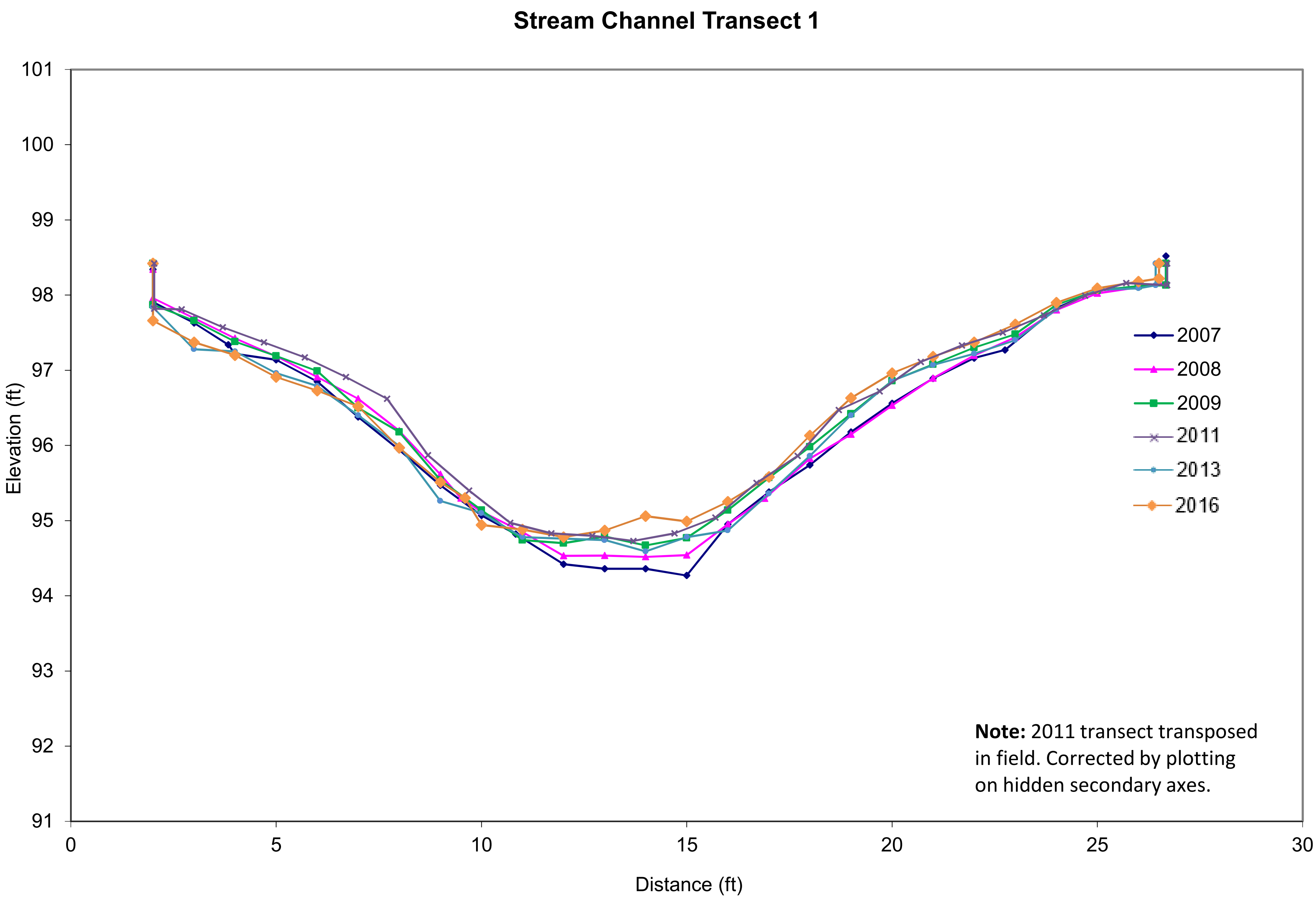
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
Mean Depth (ft)
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Pond Transects
2009
2011
2013
2016
North Pond
West Pond
South Pond

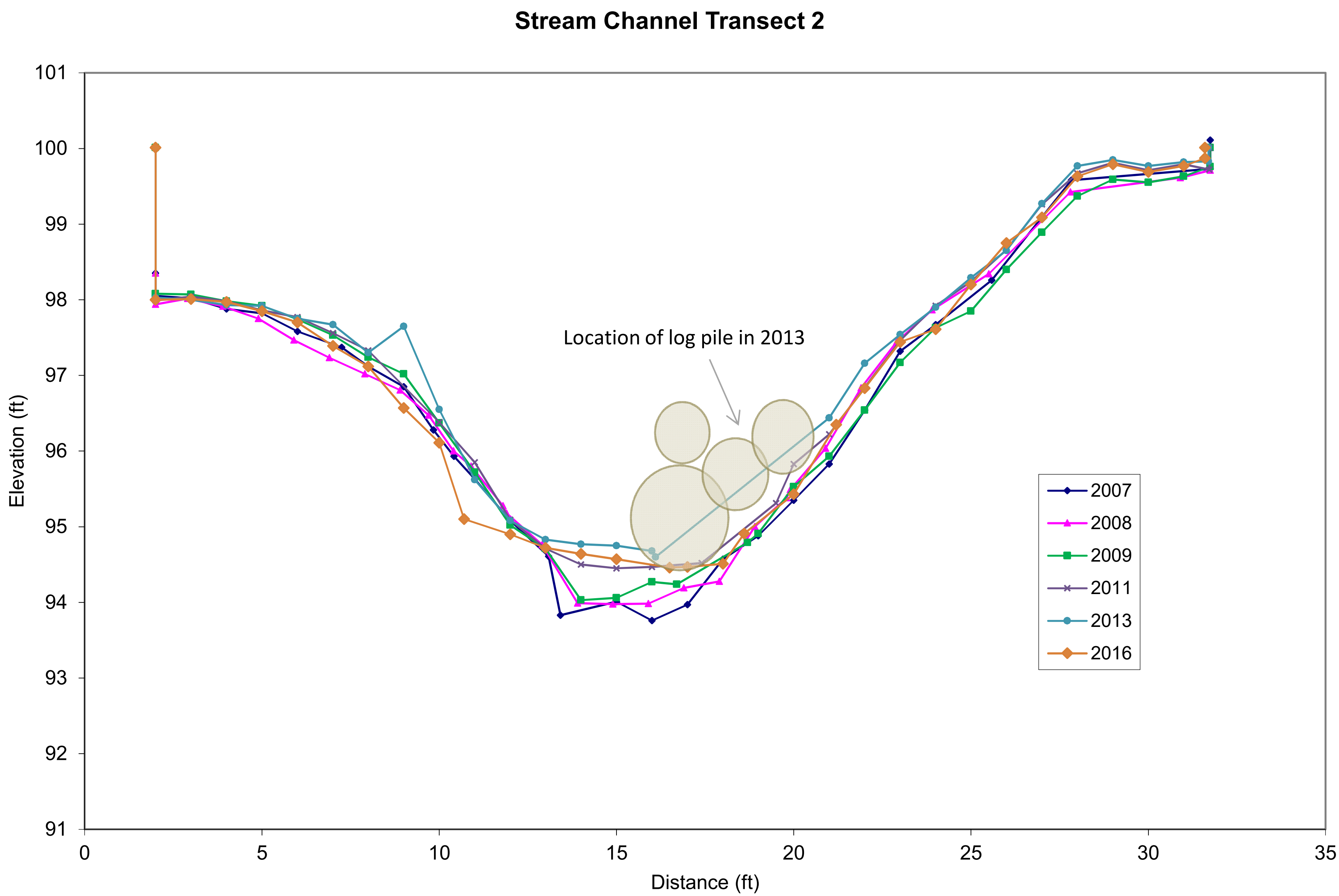


Note: Temp range for SWQ 5 is more constrained than other SWQ sites-- signature of thermally buffered groundwater?

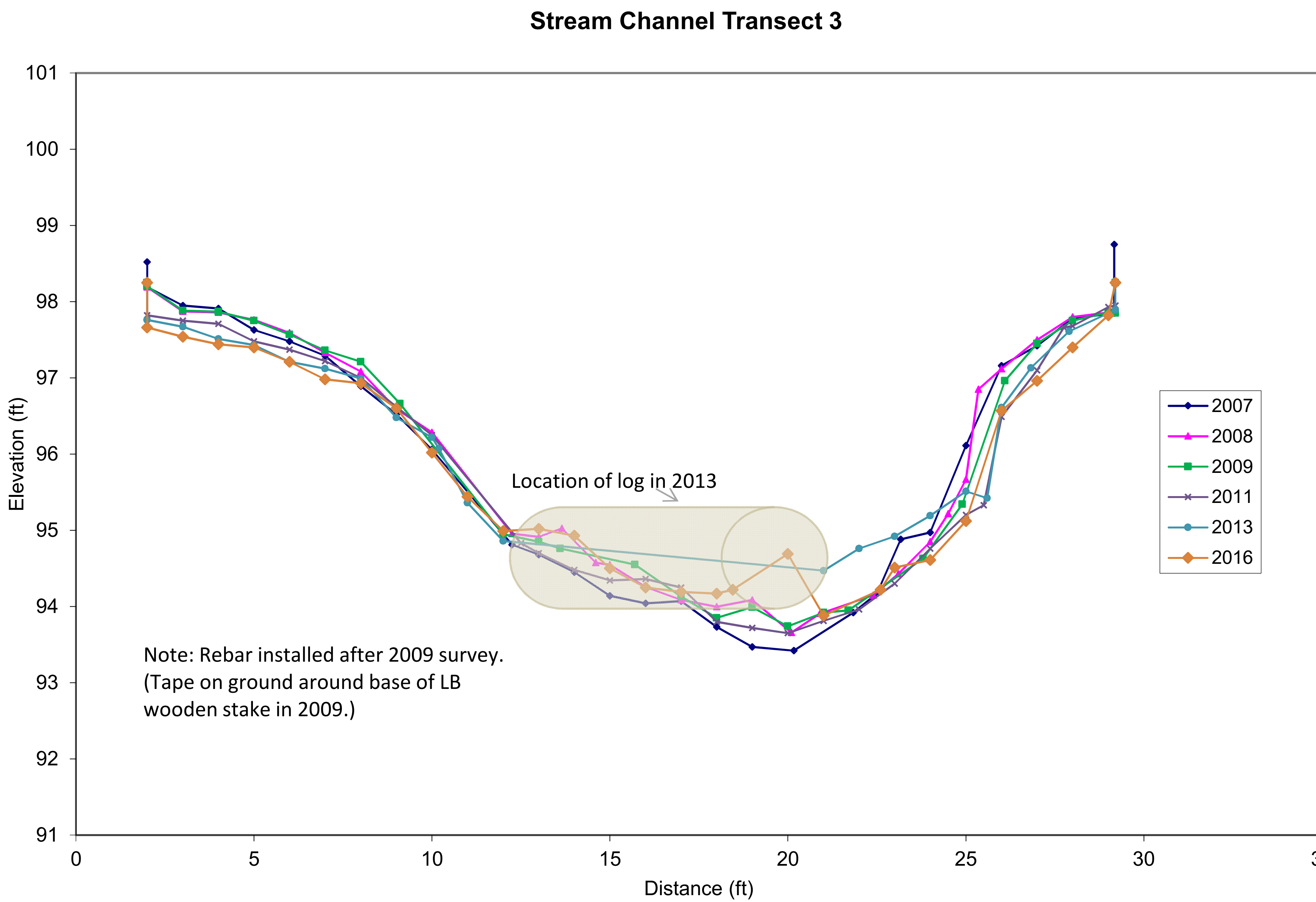
APPENDIX L:

2007-2016 STREAM TRANSECTS

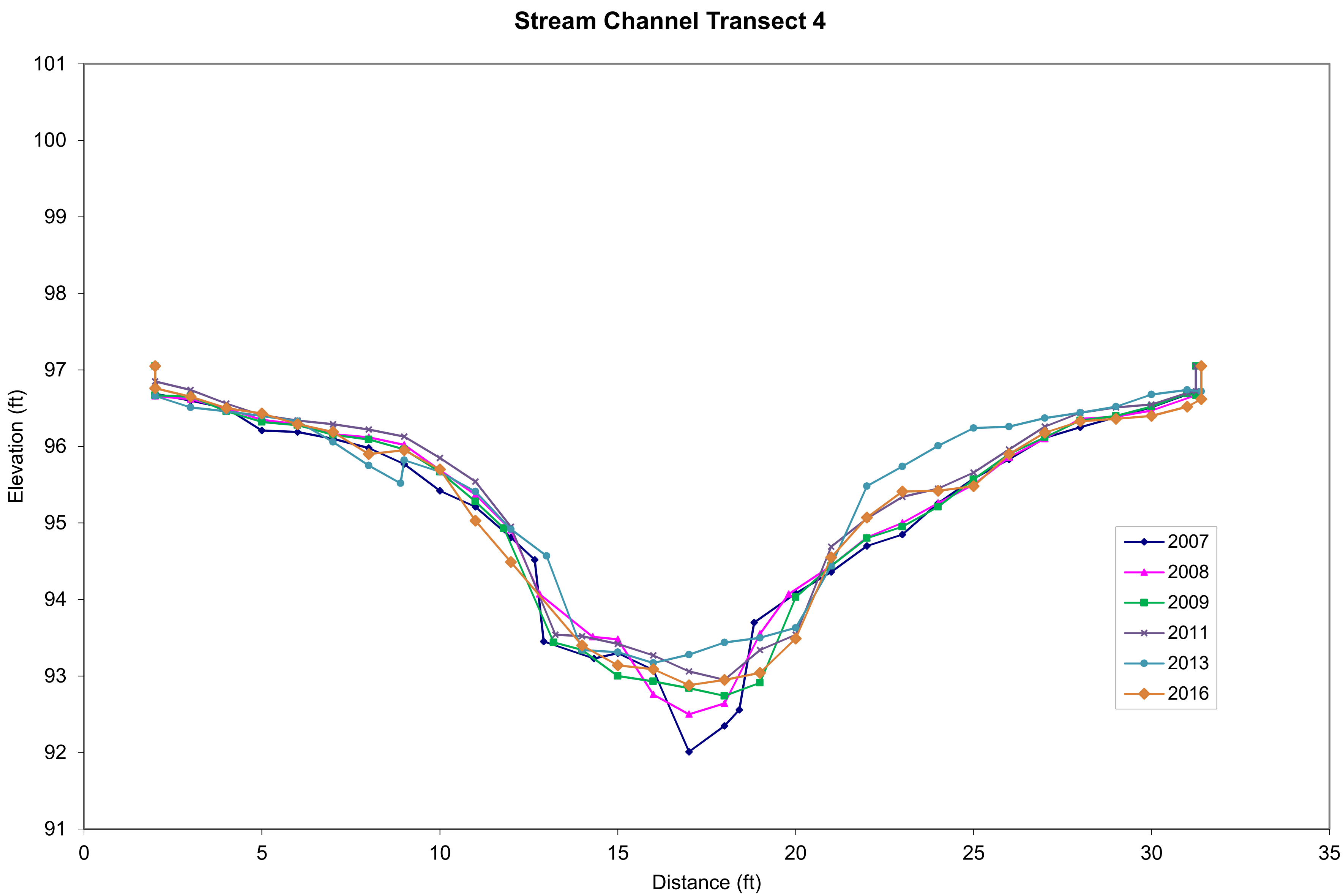

Stream Channel Transect 1
101
100
99
98
97
96
95
94
93
92
91
Elevation (ft)
0
5
10
15
20
25
30
Distance (ft)
2007
2008
2009
2011
2013
2016
Note: 2011 transect transposed in field. Corrected by plotting on hidden secondary axes.



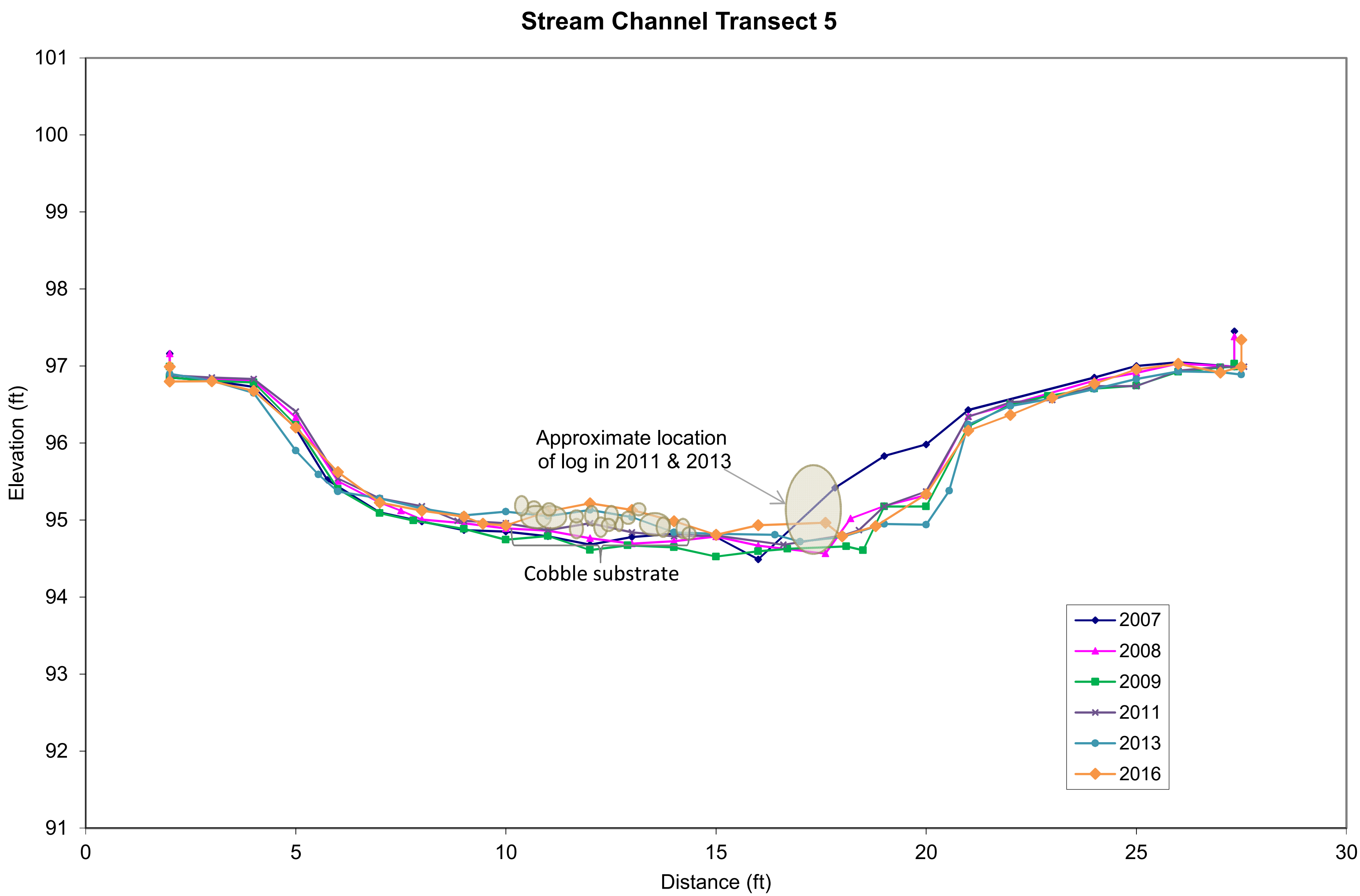
Stream Channel Transect 2
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
Distance (ft)
Location of log pile in 2013
2007
2008
2009
2011
2013
2016



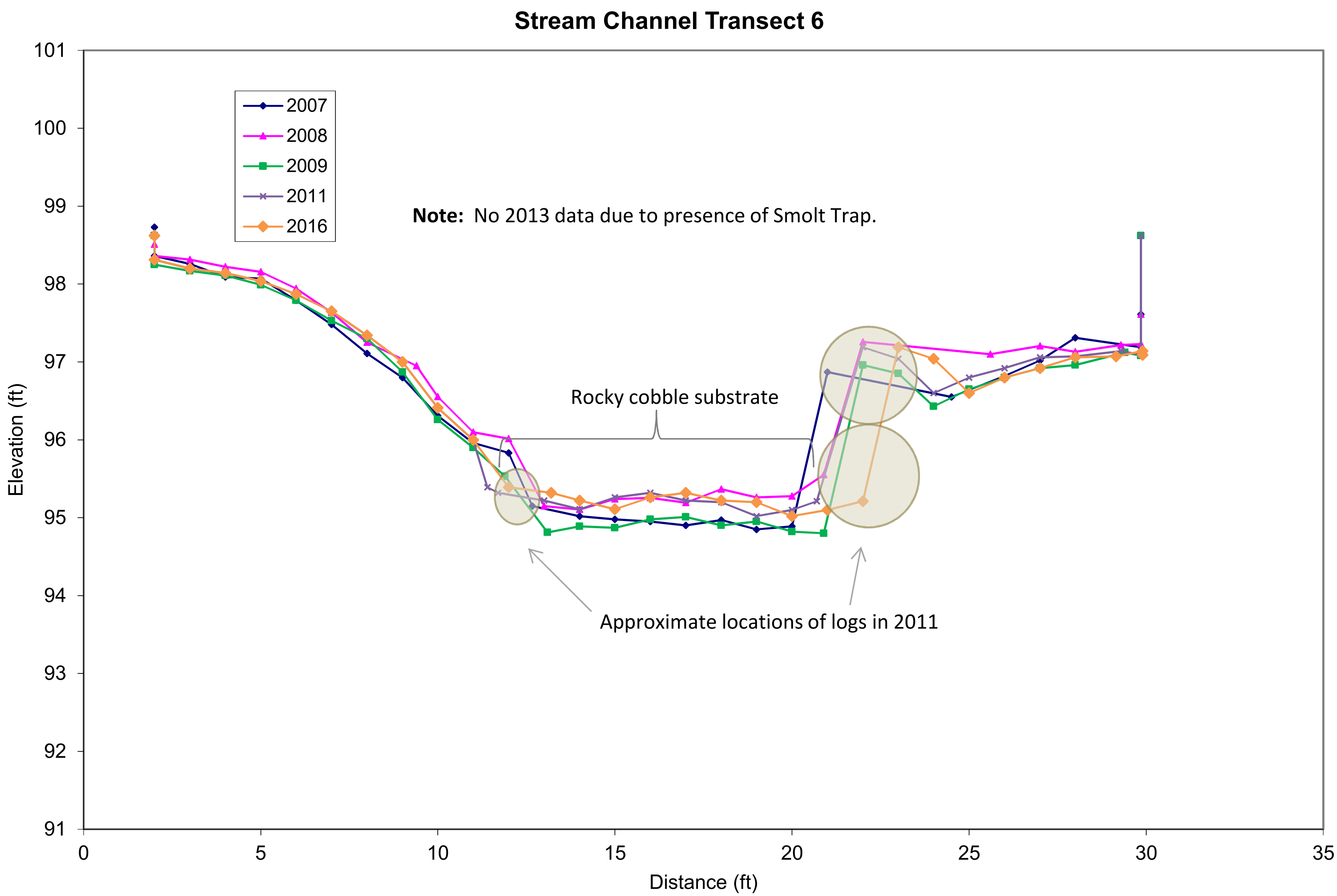
Stream Channel Transect 3
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
2007
2008
2009
2011
2013
2016
Location of log in 2013
Note: Rebar installed after 2009 survey.
(Tape on ground around base of LB
wooden stake in 2009.)



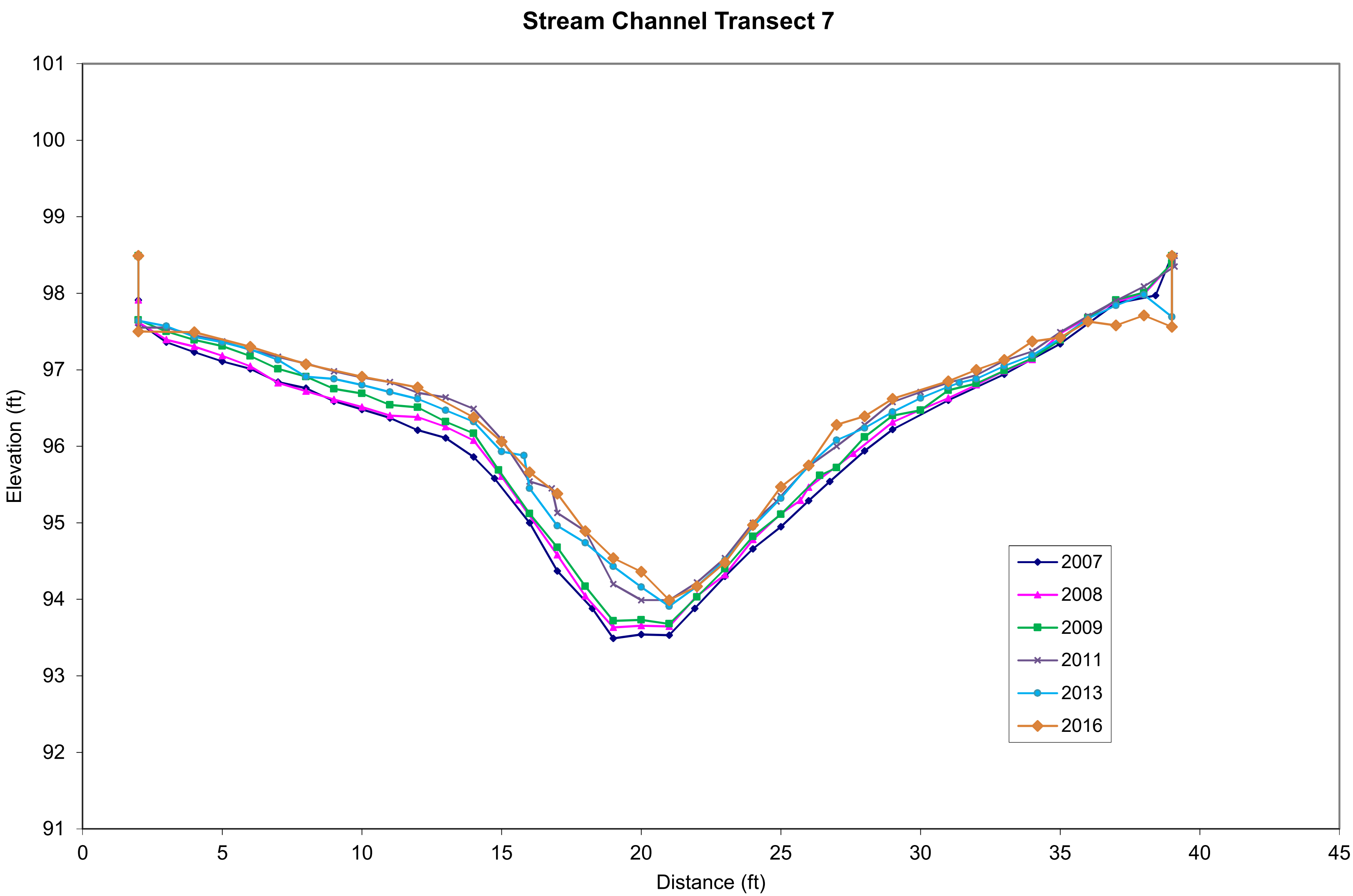
Stream Channel Transect 4
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
Distance (ft)
2007
2008
2009
2011
2013
2016

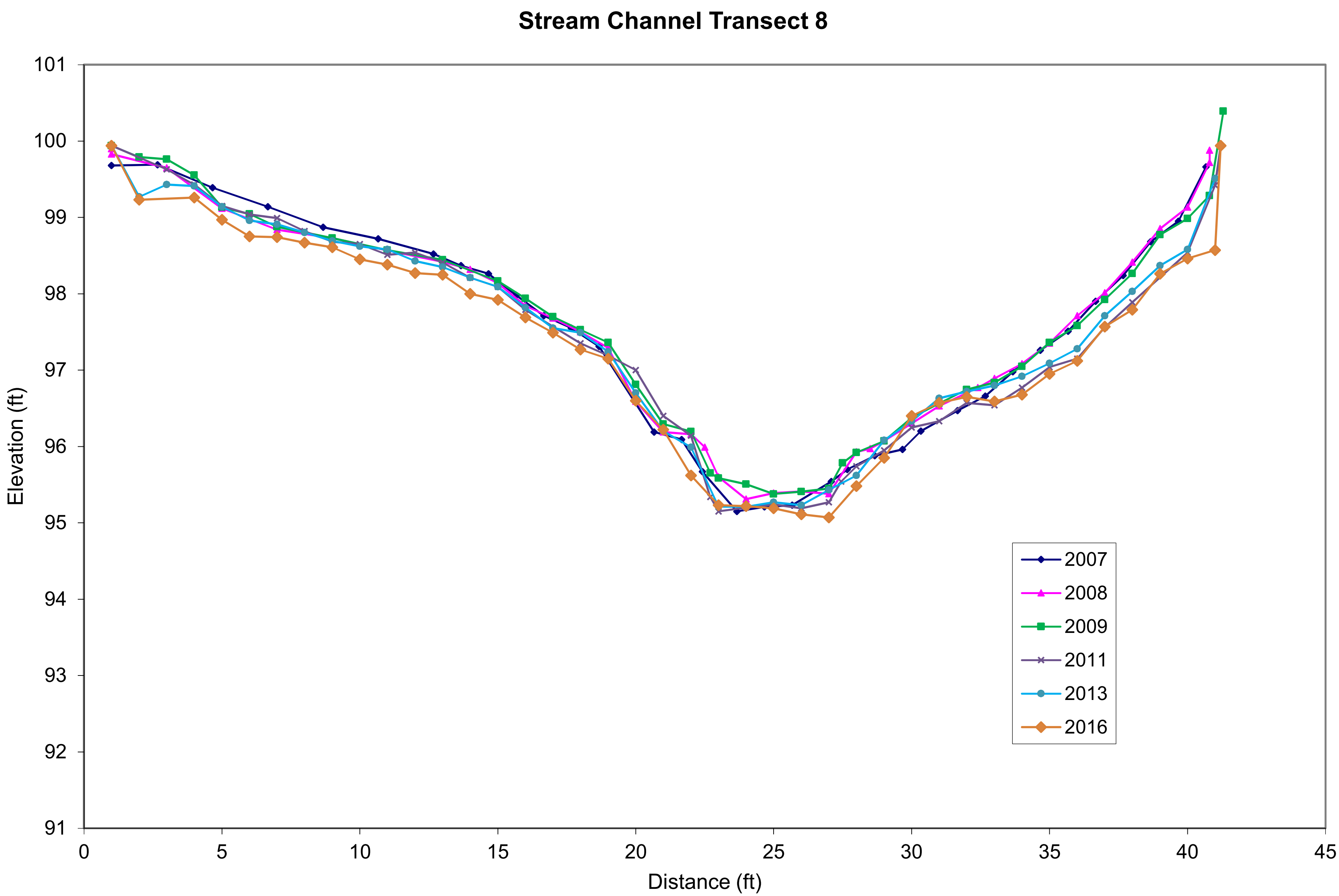


Stream Channel Transect 5
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
Approximate location of log in 2011 & 2013
Cobble substrate
2007
2008
2009
2011
2013
2016

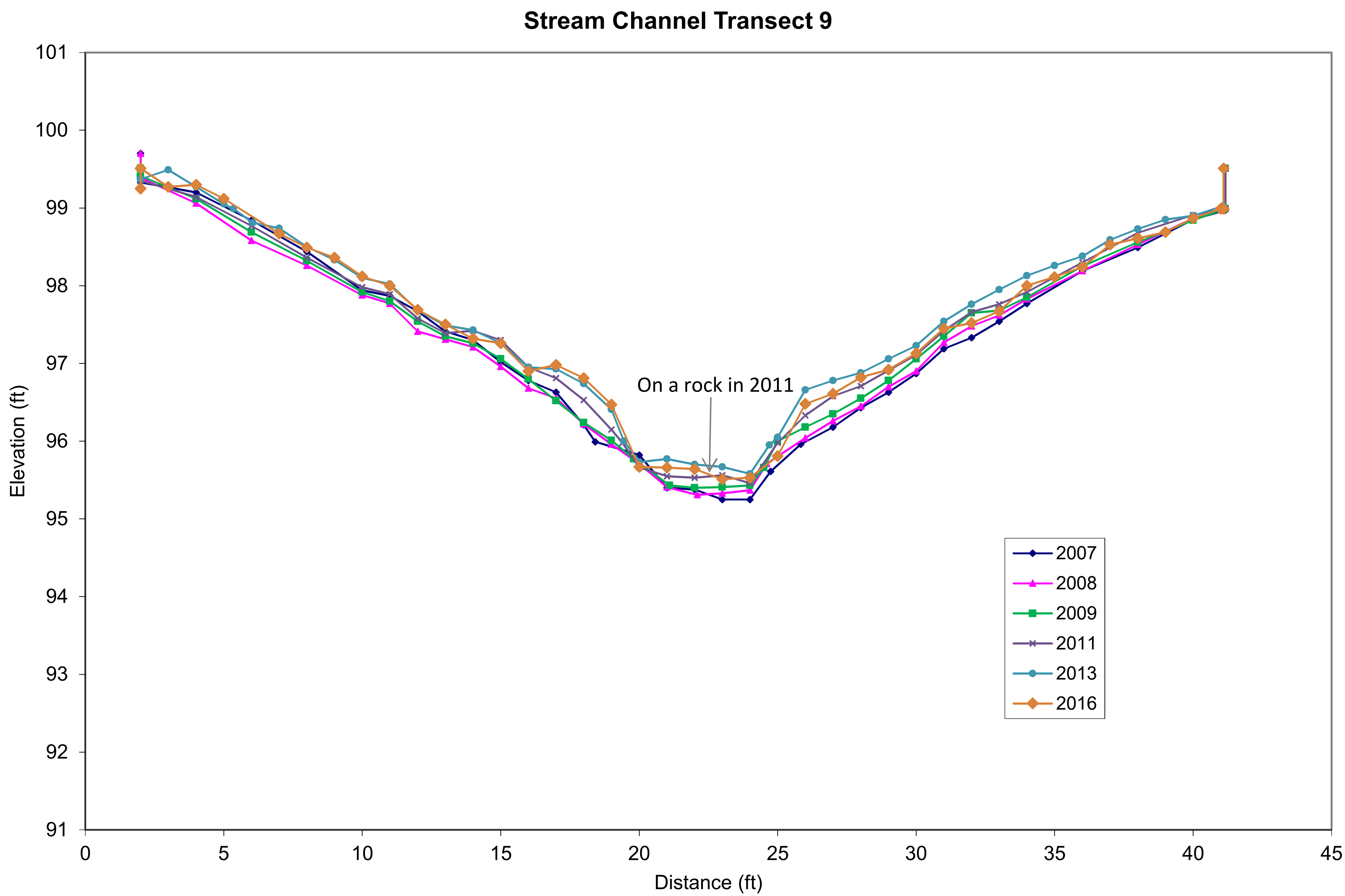


Stream Channel Transect 6
2007
2008
2009
2011
2016
Note: No 2013 data due to presence of Smolt Trap.
Rocky cobble substrate
Approximate locations of logs in 2011
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35

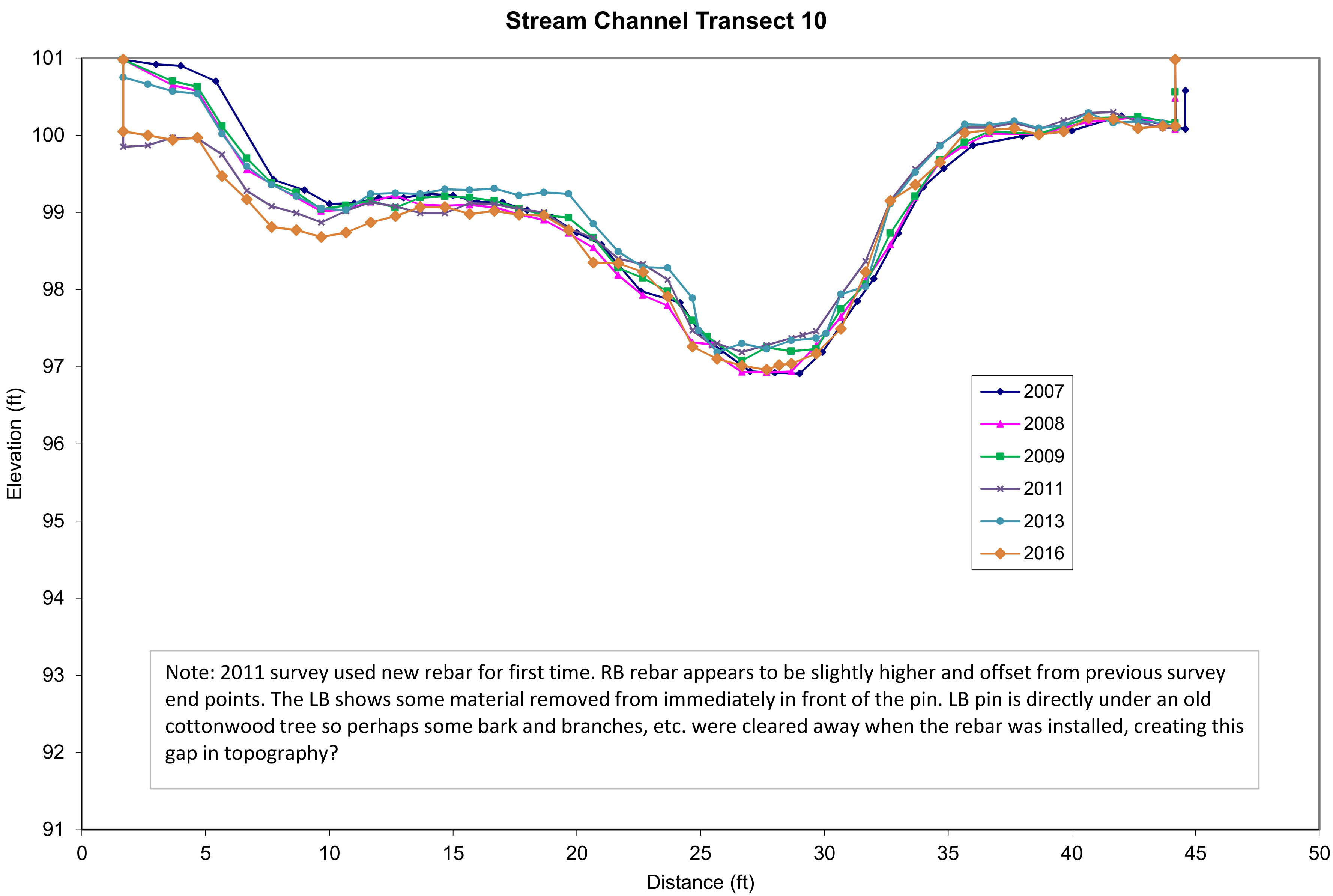

Stream Channel Transect 7
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
40
45
Distance (ft)
2007
2008
2009
2011
2013
2016



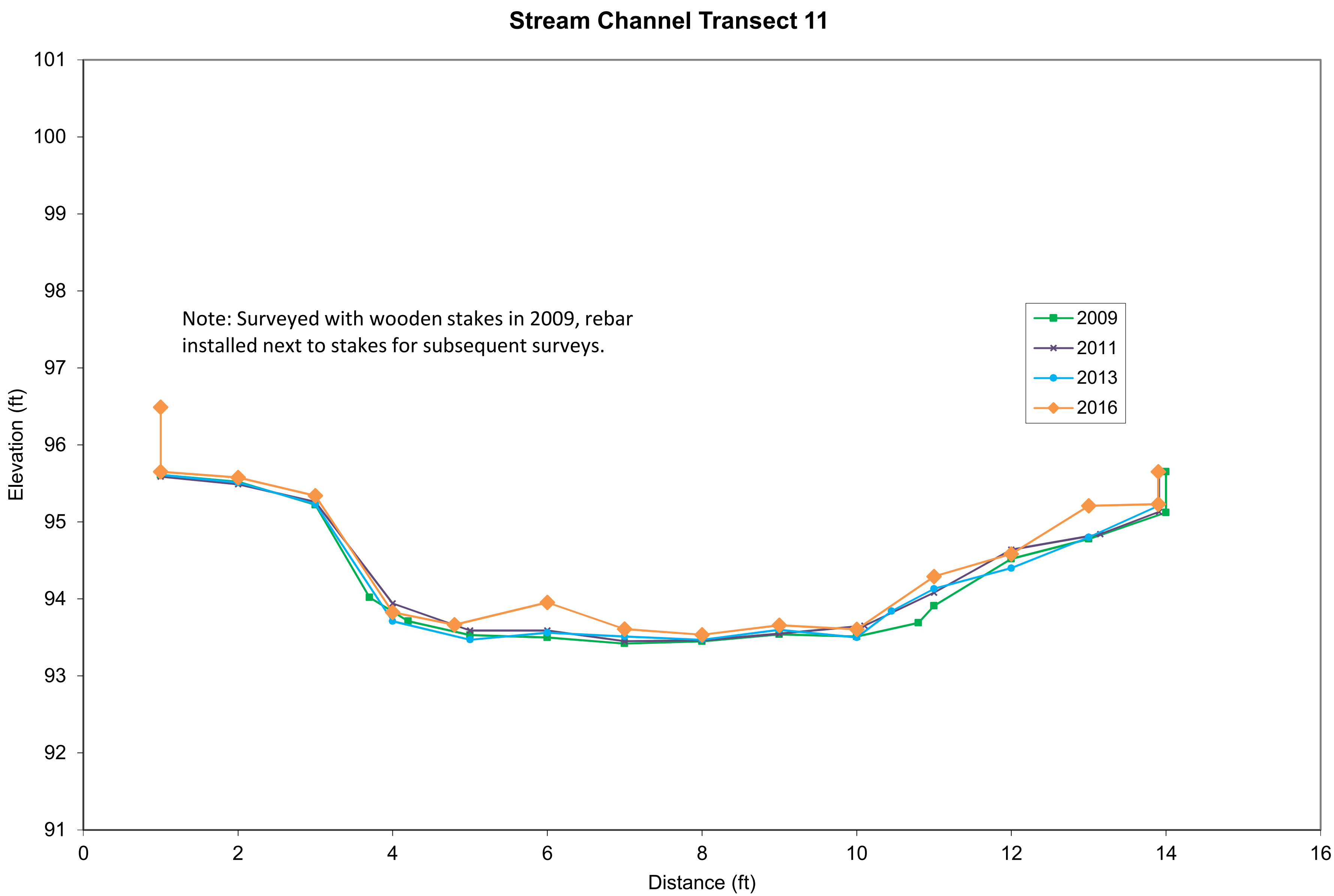
Stream Channel Transect 8
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
40
45
2007
2008
2009
2011
2013
2016

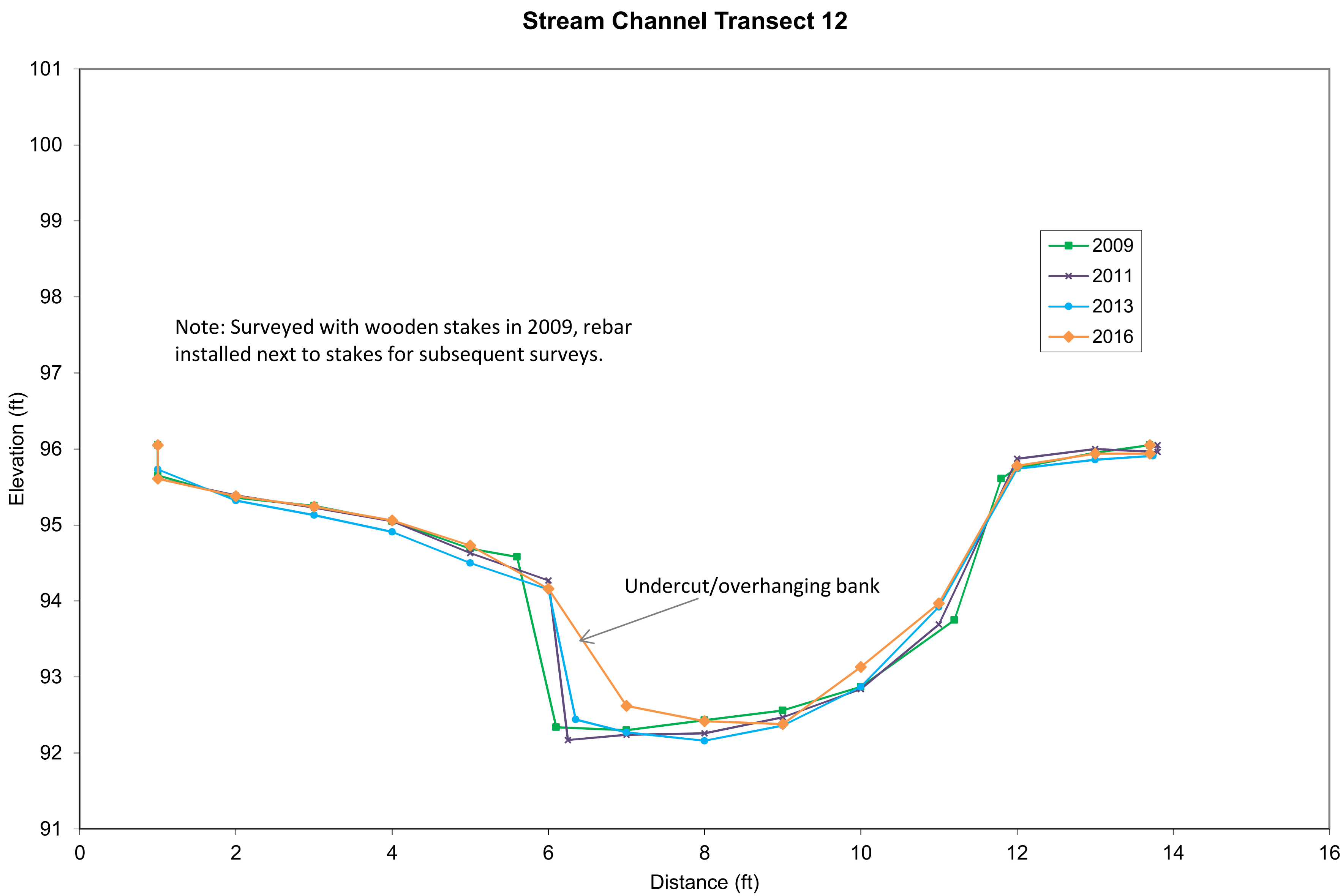


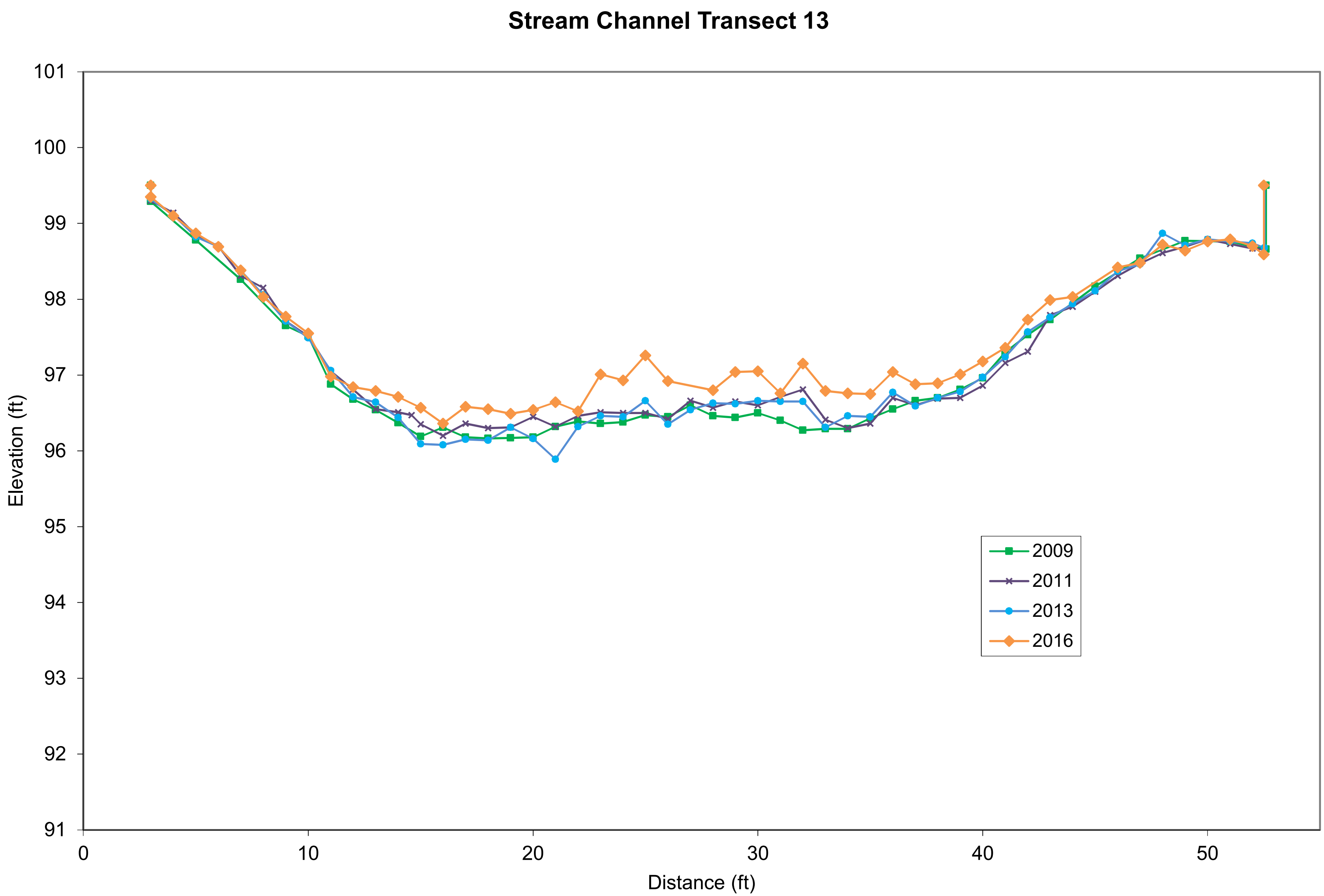
Stream Channel Transect 9
101
100
99
98
97
96
95
94
93
92
91
Elevation (ft)
0
5
10
15
20
25
30
35
40
45
Distance (ft)
On a rock in 2011
2007
2008
2009
2011
2013
2016

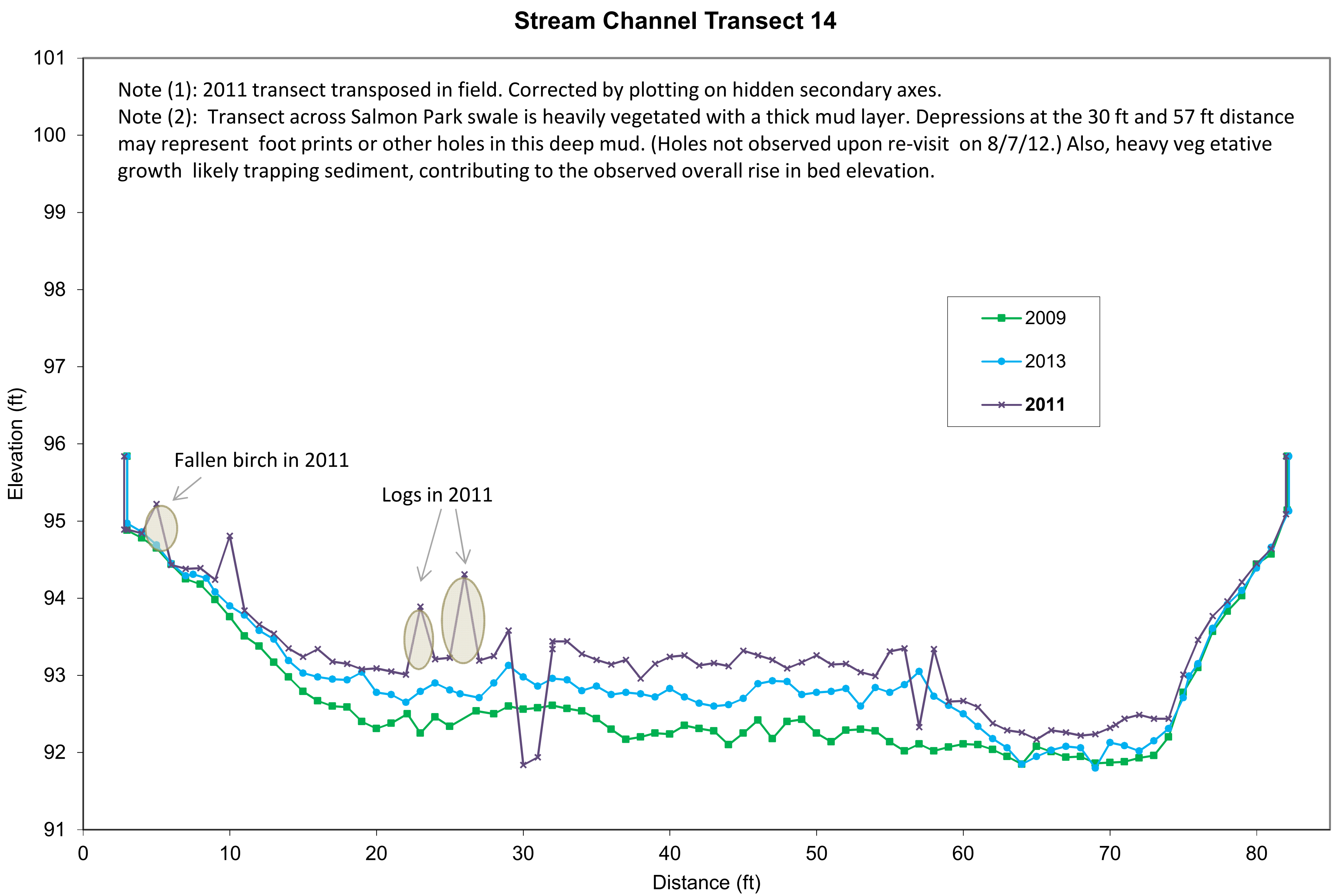

Stream Channel Transect 10
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
40
45
50
2007
2008
2009
2011
2013
2016
Note: 2011 survey used new rebar for first time. RB rebar appears to be slightly higher and offset from previous survey end points. The LB shows some material removed from immediately in front of the pin. LB pin is directly under an old cottonwood tree so perhaps some bark and branches, etc. were cleared away when the rebar was installed, creating this gap in topography?

Stream Channel Transect 11

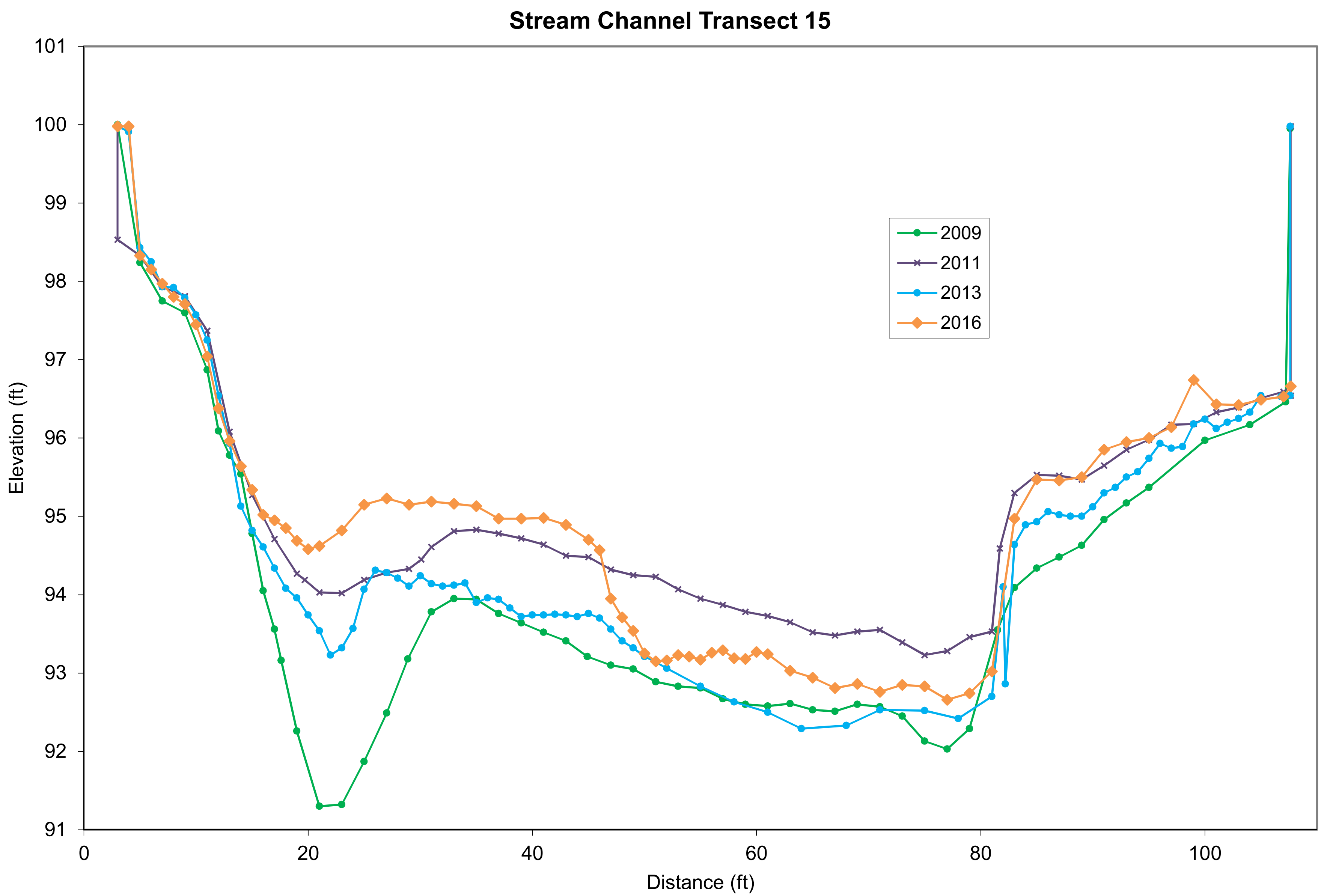


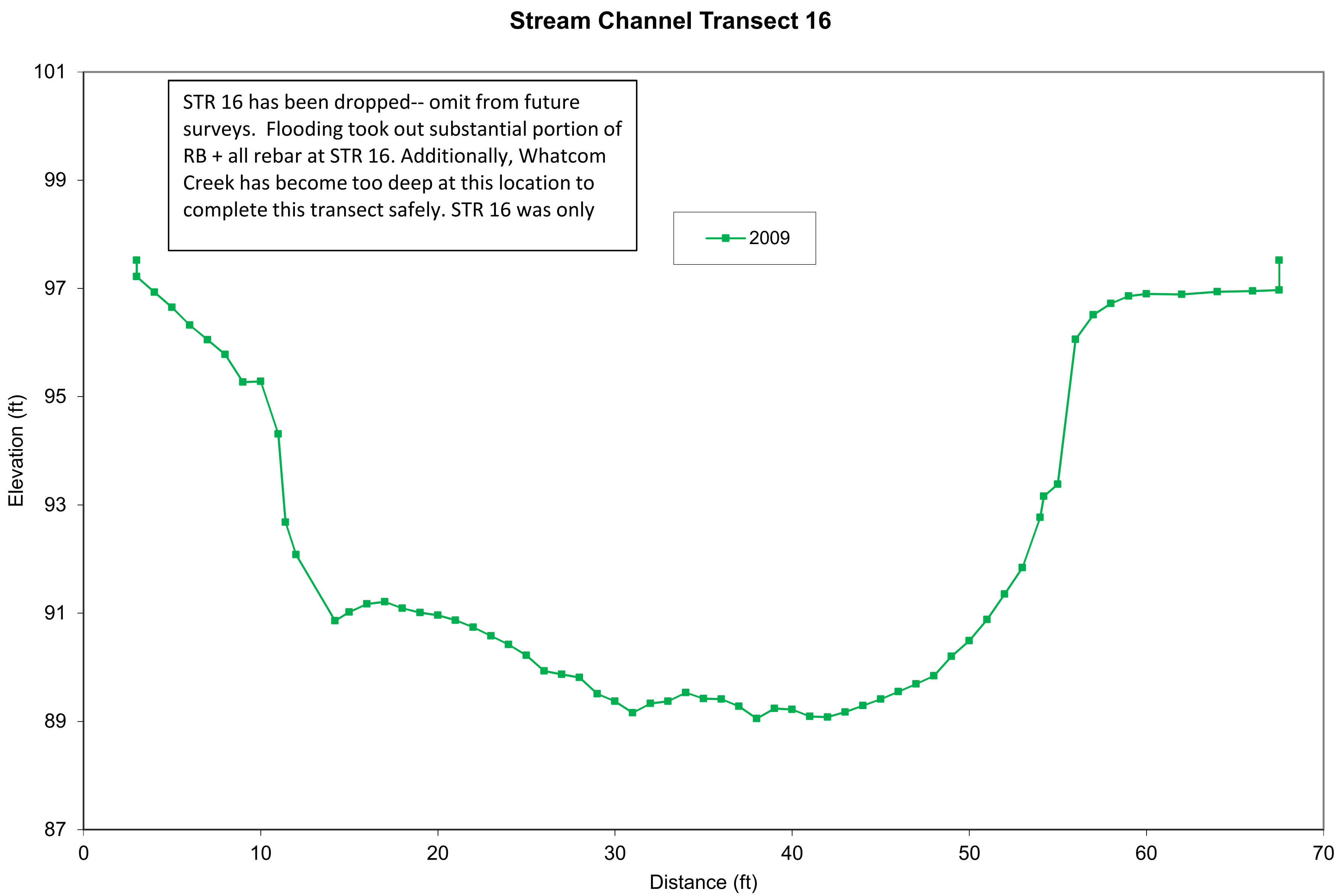

Stream Channel Transect 12
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
Distance (ft)
0
2
4
6
8
10
12
14
16
2009
2011
2013
2016
Note: Surveyed with wooden stakes in 2009, rebar installed next to stakes for subsequent surveys.
Undercut/overhanging bank


Stream Channel Transect 13
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
Distance (ft)
0
10
20
30
40
50
2009
2011
2013
2016

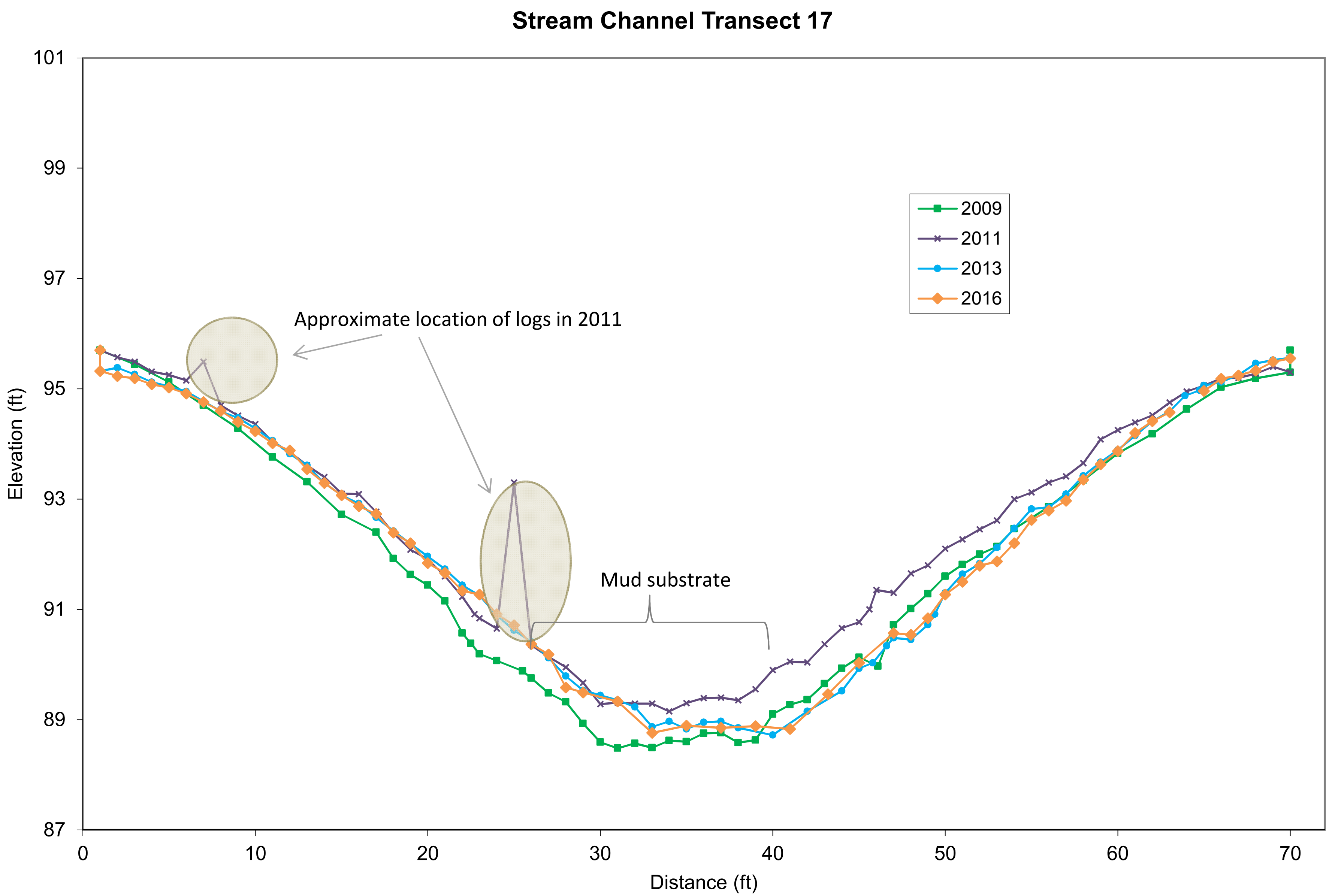


Stream Channel Transect 14
Note (1): 2011 transect transposed in field. Corrected by plotting on hidden secondary axes.
Note (2): Transect across Salmon Park swale is heavily vegetated with a thick mud layer. Depressions at the 30 ft and 57 ft distance may represent foot prints or other holes in this deep mud. (Holes not observed upon re-visit on 8/7/12.) Also, heavy veg etative growth likely trapping sediment, contributing to the observed overall rise in bed elevation.
Fallen birch in 2011
Logs in 2011
2009
2013
2011
Elevation (ft)
Distance (ft)
101
100
99
98
97
96
95
94
93
92
91
0
10
20
30
40
50
60
70
80


Stream Channel Transect 15
Elevation (ft)
101
100
99
98
97
96
95
94
93
92
91
0
20
40
60
80
100
Distance (ft)
2009
2011
2013
2016



Stream Channel Transect 16
STR 16 has been dropped-- omit from future surveys. Flooding took out substantial portion of RB + all rebar at STR 16. Additionally, Whatcom Creek has become too deep at this location to complete this transect safely. STR 16 was only
2009
Elevation (ft)
Distance (ft)
101
99
97
95
93
91
89
87
0
10
20
30
40
50
60
70



Stream Channel Transect 17
Elevation (ft)
Distance (ft)
2009
2011
2013
2016
Approximate location of logs in 2011
Mud substrate
101
99
97
95
93
91
89
87
0
10
20
30
40
50
60
70

APPENDIX M:

QUANTA HYDROLAB CALIBRATION METHODOLOGY

YSI Pro+ Multi-parameter Field Meter Quick Reference

Preparation

1. Replace the DO probe membrane the day before use to allow the new membrane to condition.

Calibration

Important: Make sure to calibrate in the order specified below.

Temperature

1. Submerge the probes and the reference thermometer in a 2000 ml beaker filled with DI water, allow a few minutes for acclimatization.
2. Record temperature values on calibration benchsheet.
3. If the temperature sensor is not reading within 0.3ºC of the traceable thermometer proceed to trouble shooting section in the SOP.

Conductivity

1. Use 'SPC-us/cm' for units.
2. Highlight 'Calibration value' and enter the specific conductance value of the standard.
3. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate. See troubleshooting in SOP for typical causes of this error message.
4. After accepting a good calibration, navigate to the GLP file and check the conductivity cell constant for the calibration. The cell constant should be 5.0 +/- 0.5.

pH

1. The Pro Plus has auto buffer recognition. If it doesn't work, highlight 'Calibration Value' and enter the pH value of the buffer solution.
2. Record the pH millivolts for each calibration point in order to calculate the mV span.
3. Wait for the pH to stabilize and then press 'Enter' to accept each calibration point.
4. After accepting your last calibration point, press 'Cal' to complete the calibration.
5. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate. See Troubleshooting in SOP.
6. After accepting a good calibration, navigate to the GLP file and check the pH Slope and Slope % of ideal. A good slope should be between 55 and 60 mVs while the ideal is 59 mV. If the slope drops below 53, the sensor should be reconditioned and recalibrated. 10. Calculate the mV span between pH 4 and 7 and/or 7 and 10. The mV values should be ≈ 165 to 180 mV. If the mV span drops below 160, clean the sensor and try to recalibrate.

Dissolved Oxygen

1. Place a small amount of water in the calibration/storage cup and place it over the sensors. Loosely place the calibration cup onto the sensor bulkhead.
2. Press 'Cal', highlight DO% and press 'Enter'.

3. Wait approximately 10 minutes for the storage container to become completely saturated and the sensor to stabilize. Use this time to check the accuracy of the built in barometer.
4. Check the barometer against the benchtop weather station. If the Pro+ is reading within 5 mmHg of the benchtop value, do not adjust. If adjustment is required, highlight 'Barometer' and input the corrected value.
5. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select ‘No’ and investigate. See troubleshooting in SOP.
6. Navigate to the GLP file and record the DO sensor’s value (sensor current in uA). Acceptable sensor current is between 4.31 uA, and 8.00 uA)

Field Operation

1. Turn the field meter on at least 5 minutes before taking measurements to allow the polarographic DO sensor to warm up.
2. Remove the calibration cup and replace it with the probe guard.
3. Submerge the probes in the sample to be analyzed and shake gently to release any air bubbles. If measuring in fast moving waters make sure to place the sensors perpendicular to the flow and not facing the flow.
4. Allow the temperature probe to acclimatize. If sampling slow-moving or stagnant waters, slowly move the probe in the sample to overcome the oxygen demand of the DO sensor (stir rate of 6 in/sec. recommended).
5. Record the measured values when all parameters have stabilized (indicated by when the letters AS next to the measurement stops blinking).
6. Remove and replace the sensors in the same location and perform steps 3-5 again if field duplicate values are required.
7. When sampling is completed, remove the probe guard and re-attach the calibration cup with a small amount of water in it.

Post Trip Calibration Check

Upon return to the laboratory, the Pro+ field meter must be checked for calibration drift. Ensure that the probes are clean and functioning, then test the probe responses in known standards (different from calibration standards).

For temperature, follow the same procedure as in the calibration section and record the values on the calibration benchsheet.

For conductivity and pH, test the probe response with traceable standards. Record values on calibration benchsheet.

For DO, place the probe in a 100% saturated air environment as is done for calibration. While waiting for the environment inside the calibration cup to saturate, enable the Pro+ to display DO% by pressing the probe button, choosing “display”, choosing “DO” and then finally “DO%”. When the probe has stabilized, record value on the calibration benchsheet.

YSI Pro+ Multi-parameter Field Meter Quick Reference

Preparation

1. Replace the DO probe membrane the day before use to allow the new membrane to condition.

Calibration

Important: Make sure to calibrate in the order specified below.

Temperature

1. Submerge the probes and the reference thermometer in a 2000 ml beaker filled with DI water, allow a few minutes for acclimatization.
2. Record temperature values on calibration benchsheet.
3. If the temperature sensor is not reading within 0.3ºC of the traceable thermometer proceed to trouble shooting section in the SOP.

Conductivity

1. Use 'SPC-us/cm' for units.
2. Highlight 'Calibration value' and enter the specific conductance value of the standard.
3. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select ‘No’ and investigate. See troubleshooting in SOP for typical causes of this error message.
4. After accepting a good calibration, navigate to the GLP file and check the conductivity cell constant for the calibration. The cell constant should be 5.0 +/- 0.5.

pH

1. The Pro Plus has auto buffer recognition. If it doesn't work, highlight 'Calibration Value' and enter the pH value of the buffer solution.
2. Record the pH millivolts for each calibration point in order to calculate the mV span.
3. Wait for the pH to stabilize and then press 'Enter' to accept each calibration point.
4. After accepting your last calibration point, press 'Cal' to complete the calibration.
5. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select ‘No’ and investigate. See Troubleshooting in SOP.
6. After accepting a good calibration, navigate to the GLP file and check the pH Slope and Slope % of ideal. A good slope should be between 55 and 60 mVs while the ideal is 59 mV. If the slope drops below 53, the sensor should be reconditioned and recalibrated. 10. Calculate the mV span between pH 4 and 7 and/or 7 and 10. The mV values should be ≈ 165 to 180 mV. If the mV span drops below 160, clean the sensor and try to recalibrate.

Dissolved Oxygen

1. Place a small amount of water in the calibration/storage cup and place it over the sensors. Loosely place the calibration cup onto the sensor bulkhead.
2. Press 'Cal', highlight DO% and press 'Enter'.

3. Wait approximately 10 minutes for the storage container to become completely saturated and the sensor to stabilize. Use this time to check the accuracy of the built in barometer.
4. Check the barometer against the benchtop weather station. If the Pro+ is reading within 5 mmHg of the benchtop value, do not adjust. If adjustment is required, highlight 'Barometer' and input the corrected value.
5. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select ‘No’ and investigate. See troubleshooting in SOP.
6. Navigate to the GLP file and record the DO sensor’s value (sensor current in uA). Acceptable sensor current is between 4.31 uA, and 8.00 uA)

Field Operation

1. Turn the field meter on at least 5 minutes before taking measurements to allow the polarographic DO sensor to warm up.
2. Remove the calibration cup and replace it with the probe guard.
3. Submerge the probes in the sample to be analyzed and shake gently to release any air bubbles. If measuring in fast moving waters make sure to place the sensors perpendicular to the flow and not facing the flow.
4. Allow the temperature probe to acclimatize. If sampling slow-moving or stagnant waters, slowly move the probe in the sample to overcome the oxygen demand of the DO sensor (stir rate of 6 in/sec. recommended).
5. Record the measured values when all parameters have stabilized (indicated by when the letters AS next to the measurement stops blinking).
6. Remove and replace the sensors in the same location and perform steps 3-5 again if field duplicate values are required.
7. When sampling is completed, remove the probe guard and re-attach the calibration cup with a small amount of water in it.

Post Trip Calibration Check

Upon return to the laboratory, the Pro+ field meter must be checked for calibration drift. Ensure that the probes are clean and functioning, then test the probe responses in known standards (different from calibration standards).

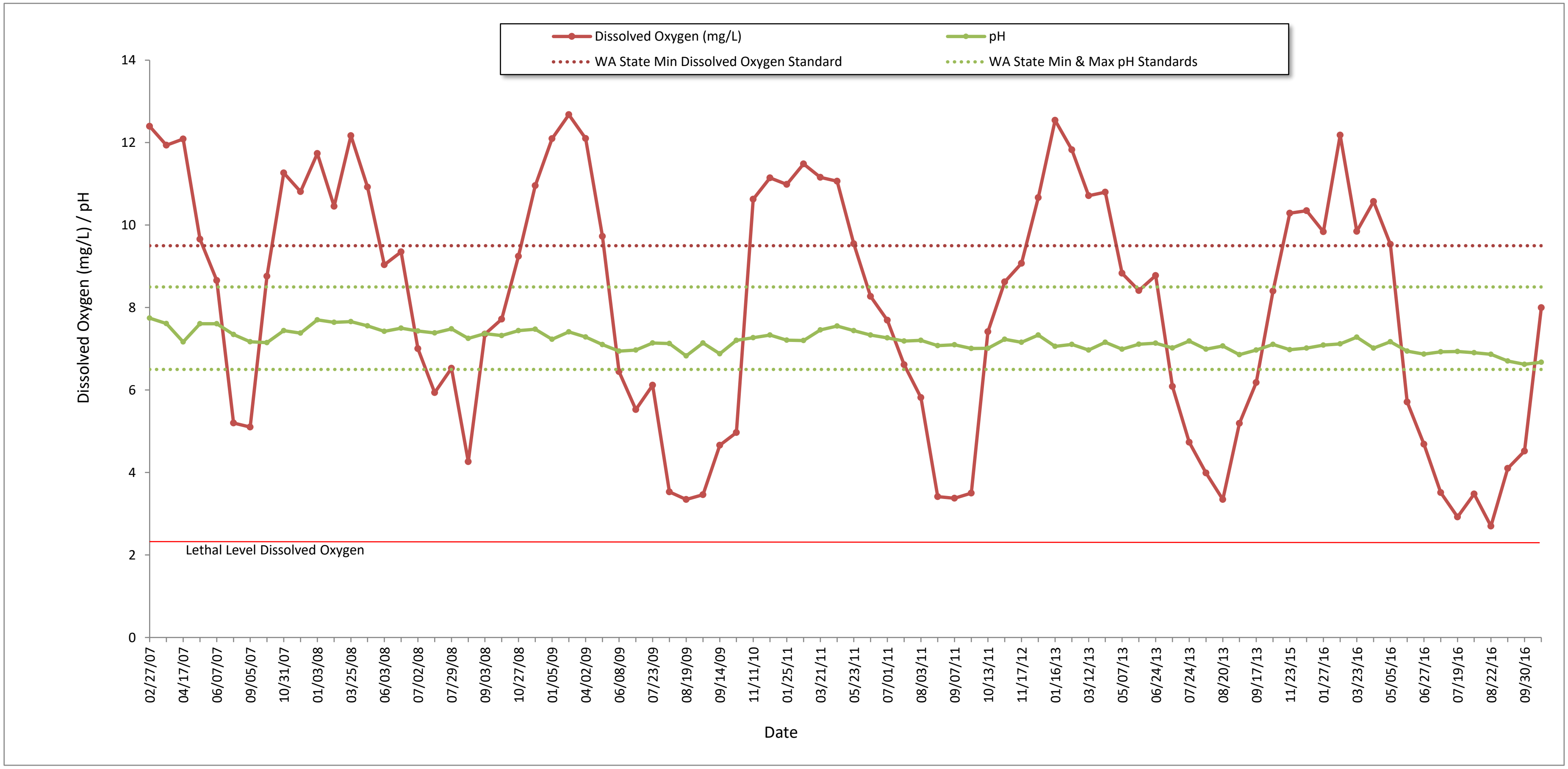
For temperature, follow the same procedure as in the calibration section and record the values on the calibration benchsheet.

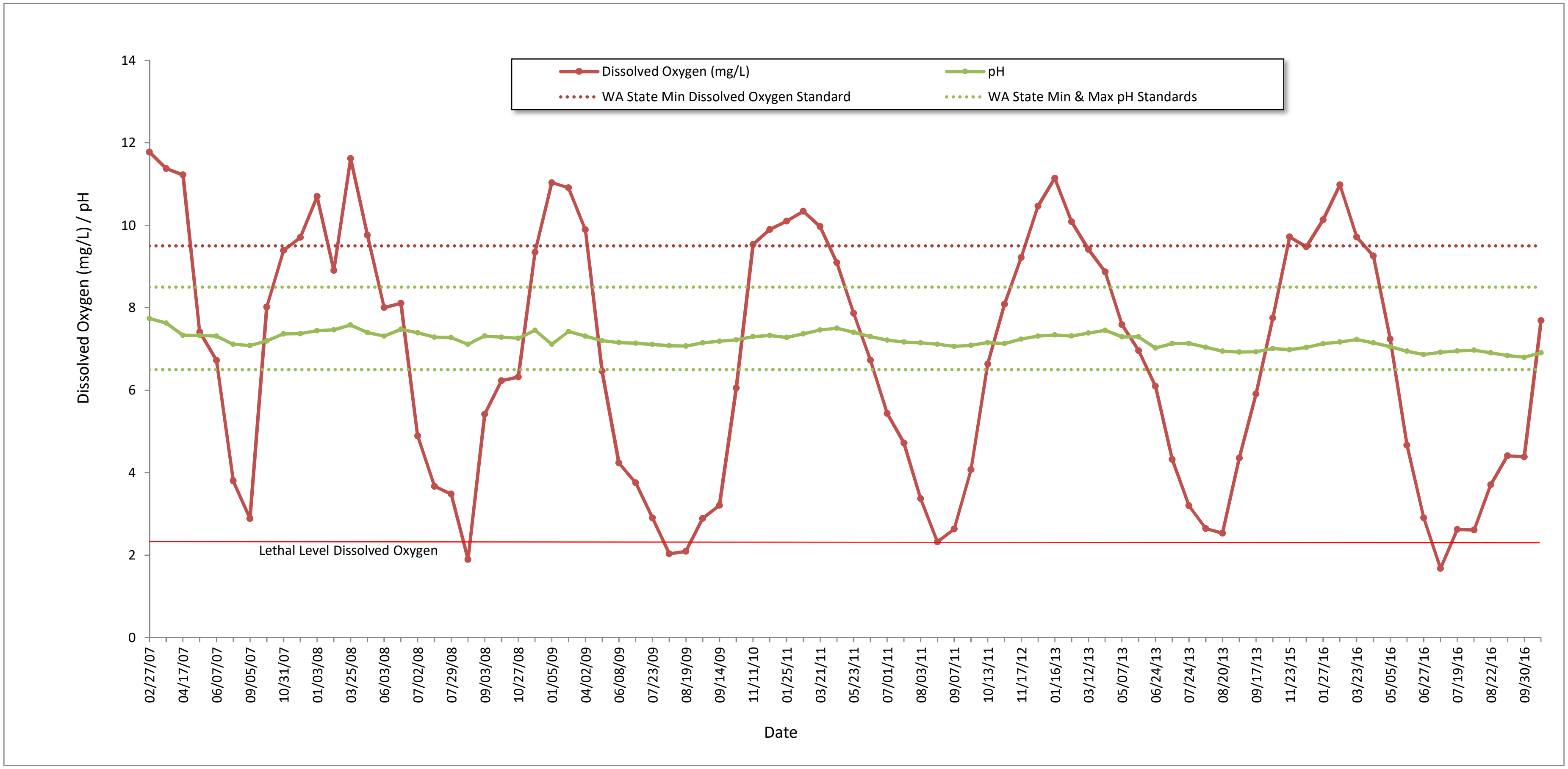
For conductivity and pH, test the probe response with traceable standards. Record values on calibration benchsheet.

For DO, place the probe in a 100% saturated air environment as is done for calibration. While waiting for the environment inside the calibration cup to saturate, enable the Pro+ to display DO% by pressing the probe button, choosing “display”, choosing “DO” and then finally “DO%”. When the probe has stabilized, record value on the calibration benchsheet.

APPENDIX N:

CEMETERY CREEK WATER QUALITY


Dissolved Oxygen (mg/L)
pH
WA State Min Dissolved Oxygen Standard
WA State Min & Max pH Standards
Dissolved Oxygen (mg/L) / pH
14
12
10
8
6
4
2
0
Lethal Level Dissolved Oxygen
02/27/07
04/17/07
06/07/07
09/05/07
10/31/07
01/03/08
03/25/08
06/03/08
07/02/08
07/29/08
09/03/08
10/27/08
01/05/09
04/02/09
06/08/09
07/23/09
08/19/09
09/14/09
11/11/10
01/25/11
03/21/11
05/23/11
07/01/11
08/03/11
09/07/11
10/13/11
11/17/12
01/16/13
03/12/13
05/07/13
06/24/13
07/24/13
08/20/13
09/17/13
11/23/15
01/27/16
03/23/16
05/05/16
06/27/16
07/19/16
08/22/16
09/30/16
Date



Dissolved Oxygen (mg/L)
pH
WA State Min Dissolved Oxygen Standard
WA State Min & Max pH Standards
Dissolved Oxygen (mg/L) / pH
Lethal Level Dissolved Oxygen
Date
0
2
4
6
8
10
12
14
02/27/07
04/17/07
06/07/07
09/05/07
10/31/07
01/03/08
03/25/08
06/03/08
07/02/08
07/29/08
09/03/08
10/27/08
01/05/09
04/02/09
06/08/09
07/23/09
08/19/09
09/14/09
11/11/10
01/25/11
03/21/11
05/23/11
07/01/11
08/03/11
09/07/11
10/13/11
11/17/12
01/16/13
03/12/13
05/07/13
06/24/13
07/24/13
08/20/13
09/17/13
11/23/15
01/27/16
03/23/16
05/05/16
06/27/16
07/19/16
08/22/16
09/30/16

APPENDIX O:

PROTOCOLS

Protocol for Continuous Temperature Monitoring
Calibration and Quality Control Procedures

Calibration of temperature loggers and handheld spirit filled field thermometers

1. Thermometers are checked against a reference National Institute of Standards and Technology (NIST) thermometer. Check the thermometer calibration report for correction factors and to make sure that it has been calibrated within the past year.
2. Inspect the condition of field thermometers and temperature loggers. Field thermometers should have minimum graduations in increments of 0.1°C. In addition, the fluid column should not be separated in the field thermometers.
3. Prepare an ice bath or room temperature bath as follows:

   Ice Bath: Make an ice bath using an ice chest, stir bar, chipped or shaved ice, and cold water. Put as much ice in the ice chest as possible and fill the spaces with cold water. Add just enough water to get the ice to float off the bottom of the ice chest so that the stir bar can spin freely.

   Room Temperature Bath: Make a room temperature bath by filling an ice chest with water. It is a good idea to let the room temperature bath acclimate for 24 hours in a draft free area if possible.

3. Program temperature loggers to record data every minute.
4. Place the certified thermometer and the temperature loggers or field thermometers to be calibrated in the bath. Try to place the bulbs of thermometers and temperature loggers as close together as possible.
5. Allow the water or ice bath and apparatus to acclimate for 15 minutes with the ice chest on a stir plate on low.
6. After the temperature on the certified thermometer is stable begin recording the water temperature on the calibration bench sheet. Note the time and certified thermometer temperature; also note field thermometer temperatures if applicable.
7. Record at least 10 temperatures per round. Remove the apparatus from the water or ice bath and calculate difference between the certified thermometer and the temperature logger or field thermometer readings. The average difference should not vary more than 0.2°C.
8. Perform at least two rounds of calibrations per bath for each instrument.
9. If the average difference of all accepted readings between the certified thermometer value and the temperature logger is greater than 0.2°C or is greater than 0.5°C for the field thermometer the instrument may either be (a) discarded (if supplies allow) or (b) a correction factor may be applied. The correction factor is the average difference of all readings.
10. Mark the calibrated thermometer with the correction factor and the date and keep a summary sheet of calibration information for temperature loggers. If a thermometer differs by more than 1°C from the reference thermometer, it should be discarded.

NOTE: Printable calibration datasheets for loggers and field thermometers and a formatted Excel calibration spreadsheet are available in the project folder on the COB network drive. Post Point Lab staff also have copies of these datasheets and the formatted calibration spreadsheet.

Temperature logger bias QC check

1. After the temperature logger is downloaded click the "Toggle View Details" button to see all temperatures recorded. Scroll down to the last temperature recorded.
2. Compare the thermometer reading with the latest temperature logger reading. For water loggers the temperatures should be within 0.3°C. For air loggers the temperatures should be within 2.0°C.
3. If not check the temperature again with the thermometer allowing the thermometer to acclimate for at least 10 minutes.
4. If the two readings still are not within the QC range change the temperature logger out with a spare calibrated temperature logger, noting the serial number and reason for change out on the field sheet.
5. NOTE: Air temperatures are highly variable; if the thermometer reading is taken too long after the logger reading (e.g. 30 minutes), the temperatures may be outside the QC range. Try to plan temperature readings for air loggers as close in time to the last logger temperature as possible. Be sure not to approach the logger too closely on the hour as this could bias the reading.

Verification that location in thermal reach is representative

1. Use this method to verify the representative nature of the temperature logger location at any time during the study **if you suspect it is not representative**.
2. Check the water temperature using the field thermometer at two to three other locations in the thermal reach. Make sure the thermometer is allowed to acclimate 10 – 15 minutes.
3. Select at least one location upstream of the logger, one downstream, and if possible in a similar sized channel nearby. Pick locations that also appear to be representative of the thermal reach.
4. Record a description of where you sampled and the temperature on the field sheet. If a temperature varies by more than 1°C double check the reading and also look for reasons why temperature might be different and note on the field sheet.
5. If you decide to move the location of the logger, document the reasons for the decision (e.g. temperature data collected in the procedure above) and take a GPS reading of the new location. Be sure to update all maps and spreadsheets with the new logger location.

Temperature Logger Field Sheets

Tidbit Temperature Loggers - Field Sheet			
Date:	Personnel:		
Weather:	Project/Stream:		
Equipment: Fully CHARGED laptop, Tidbit shuttle w/ cable, field therms x2,			
phone, field sheets, pencil(s), rag/hand towel, stadia rod, chest waders.			
Air Therm #:	Water Therm #:		
Tidbit Info			**p. 1 of ______**
Site:		**No.**	
Water depth=	Tidbit depth=		
Therm in @			
Tidbit out @			
Download @			
Last Temp @		=	
Delayed Start @			
Green light? ☐	Redeployed @		
Therm Temp @		=	
QC?			
Site:		**No.**	
Water depth=	Tidbit depth=		
Therm in @			
Tidbit out @			
Download @			
Last Temp @		=	
Delayed Start @			
Green light? ☐	Redeployed @		
Therm Temp @		=	
QC?			

Date:			**p. _____ of _____**
Site:		**No.**	
Water depth=	Tidbit depth=		
Therm in @			
Tidbit out @			
Download @			
Last Temp @		=	
Delayed Start @			
Green light? ☐	Redeployed @		
Therm Temp @		=	
QC?			
Site:		**No.**	
Water depth=	Tidbit depth=		
Therm in @			
Tidbit out @			
Download @			
Last Temp @		=	
Delayed Start @			
Green light? ☐	Redeployed @		
Therm Temp @		=	
QC?			
Notes:			

Protocol for Continuous Temperature Monitoring
Data Retrieval and Maintenance

Data Retrieval

The data retrieval duties are divided between two people.
Downloader: Records notes and data, times the acclimation period, downloads the data from the logger, and maintains contact with the Wader.
Wader: Obtains *in situ* temperature, retrieves the logger for downloading, and re-deploys the logger.

Use a pen and designated Temperature Logger Field Sheets (Appendix C) to record:

- Date
- Field Personnel names
- Weather conditions
- Project/Stream name
- Field Thermometer ID #(s)
- Page numbers
- Site ID
- Templogger (Tidbit) No.
- Water depth
- Logger depth
- Time Field Thermometer deployed (Therm in)
- Time Logger retrieved (Tidbit Out)
- Download time
- Last Logger temperature/time (Last Temp)
- Delayed Start time
- Check Logger: green light flashing?
- Launch/re-deployment time
- Field Thermometer temperature/time
- QC check (±0.30°C in water; ± 2.0°C in air)
- Block orientation & other observations

Each of the items mentioned above are explained in the procedures below. Loggers are set to record temperatures on the half hour. Avoid disturbing loggers in the five minutes before and after the hour and half hour. Whenever possible, visit sites prior to 1pm to avoid disturbance during peak temperature hours.

1. During the monitoring season continuous temperature data is retrieved approximately every other week. Equipment needed for data collection includes:
   - Backpack
   - Laptop
   - Onset base station, cable connection
   - Handheld thermometer(s)
   - Field Sheets and pen
   - Rag
   - Stadia rod
   - Stopwatch
   - Waders
   - Spare calibrated temperature loggers
2. Upon arrival at the site, the Downloader records the project **date, field personnel names, weather conditions** and **project/stream name**.
3. At the first site, and while the Wader is getting ready, the Downloader turns on the computer, connects the base station to the computer, opens the temperature logger software, and records the Site ID.
4. The Downloader is in charge of timing the acclimation period for the handheld thermometer(s). Thermometers in water take approximately 10 minutes to acclimate and must be submerged above the level of the red spirit. Thermometers in air take approximately 10 minutes to acclimate (20 if

the thermometer was first used to collect water temperature; if you have only one thermometer, collect air temperature first to minimize acclimation time).

5. Either the Downloader or the Wader should secure a field thermometer to a bush or tree in a shaded location. If the site has an air temperature logger, secure the field thermometer near the logger. Record the **thermometer serial ID number** on the field sheet**.** If there is only one thermometer, wait until the acclimation period is up and then record the temperature to the 100th by estimating the last digit to the nearest 0.05. Note that the air thermometer will respond to your body temperature very quickly so try to get as accurate a reading as possible as quickly as possible without touching the thermometer. If there are two thermometers you can leave the field air thermometer to acclimate while the water steps are completed. The air thermometer can then be recorded after the water logger is redeployed.
6. The Wader carries the stadia rod and thermometer to the location of the water logger in the stream.

   Caution: Never enter the creek if the level is too high or flow too fast to keep your footing. Use your best judgment at each site and do not enter the creek if it does not seem safe.

7. Place the thermometer in the water near the probe. Attach it to a branch or the stadia rod if possible; otherwise hold the thermometer in place.
8. Measure the depth of the water and temperature logger using the stadia rod. Read the stadia rod to the 100th by estimating the last digit to the nearest 0.05.
9. Tell the Downloader in a loud clear voice what the depths are. The Downloader should repeat the number in a loud clear voice and then record the **depth of the water** and **depth of temperature logger** on the field sheet after the Wader confirms it is correct.
10. The Wader should inspect the logger and PVC housing, noting the **position of the PVC opening with relation to the channel thalweg** (i.e. is water flowing through or obstructed). Communicate this information to the Downloader in a loud clear voice. The Downloader should ask any questions necessary to ensure that the correct information is heard and recorded on the field sheet .
11. When the acclimation period is up and the temperature logger has made a final recording the Downloader tells the Wader to read the thermometer.
12. The Wader reads the thermometer to the 100th by estimating the last digit to the nearest 0.05 and communicates to the Downloader in the same manner as for the temperature logger depth. The Downloader records the **water temperature and time**.
13. The Wader should remove the logger from the PVC housing using the brass clip. At that time, the Wader should inspect the cable and zip ties to insure that the logger is securely anchored to the rebar. Bring the logger to the Downloader and have the Downloader note **any needed maintenance**.
14. The Downloader should wipe the temperature logger clean and dry, note the **logger ID number**, and place it in the base station making sure the probe thermister is lined up in the hole so that the data can download. Once the probe is in place for downloading select the “Readout Logger” option. Record the **download time** on the field sheet.

    NOTE: Newer temperature loggers may allow you to check a “download but continue logging” option which can minimize user error and clock problems with the laptop. Modify steps 16-20 accordingly, and make note of any high temperatures(if any) that are recorded when the tidbit is out of the water during download. Remove these higher readings from the dataset manually.

15. Allow the temperature logger to download and then perform a temperature logger bias **QC check** against the thermometer reading (see Appendix B). Record the **last temperature/time from the logger.**
16. Once the data is downloaded initialize the temperature logger for a new study by selecting the logger "Launch" option.
17. Change the Study ID by highlighting the date portion of the study ID and changing it to the day's date. Use the format MMDDYY with no spaces or separators. Leave the rest of the ID the same. The ID should look like: SiteID_serial #_MMDDYY.
18. Check the Delayed start box then change the start time to a time that allows for at least 10 minutes of acclimation and is on a half hour interval (e.g. 08:00 or 08:30). Check that the start date and other options are correct. Record the **Delayed Start time** onthe field sheet.
19. Once the new study is started check to make sure the green LED on the temperature logger is blinking every 4-5 seconds.
20. The Wader then re-deploys the temperature logger. Record the **Launch/re-deployment time**. Orient the block so that water is flowing through the hole.
21. While the Wader is deploying the temperature logger the Downloader records any remaining information (eg. **temperature/time from field thermometer**, etc.).
22. Perform steps 14 through 20 to download and record data for the air temperature logger (if present at the site) and then re-deploy. Perform a QC bias check (see Appendix B).
23. Take one last look around the study site to make sure that everything is secured. Pack up the equipment and go to the next site.

Maintenance

1. Check the following items at each visit and note any changes in the project . Return to the site if maintenance is required.
2. Equipment that may be needed to perform routine maintenance includes equipment for data retrieval (above) as well as:
    - Brush clippers
    - Gloves
    - Cable
    - Cable cutters
    - Crimps and pliers
    - Brass clips
    - Zip ties
    - Spare concrete block
3. Check the cable securing the logger for wear. Replace the cable if it appears rusty and thin or brittle.
4. Check zip ties and clip for wear. If the clip becomes difficult to open, replace it to facilitate retrieval of the logger.
5. Make sure the temperature logger is working properly. After the logger is initialized the green LED will blink weakly approximately every 4-5 seconds. If it is not blinking at the right interval investigate the problem. Deploy a spare (starting at step 15 in data retrieval) if you cannot resolve the problem.
6. Clip back branches if site becomes hard to access. Keep in mind that if you are clearing a trail directly to the site it is advisable to keep the trailhead somewhat camouflaged so that curious individuals are not lead directly to the monitoring site where they may tamper with the equipment.

05/02/19

City of Bellingham Natural Resources Division

TIDBIT DATA PROCESSING PROCEDURE

I. Data Reduction and Compilation:

1) Copy and paste all .csv files from **last data download date** into a folder entitled: "Data to be compiled."
2) Open one .csv file in Excel. Delete/remove column "A" (record numbers); delete/remove rows "1" and "2" (headers); crop data according to survey dates to be uniform for each logger beginning at midnight and and ending at 11:30p. (eg. Start= 5/1/14 at 0:00, End= 9/30/14 at 23:30).
3) Search all rows with "logged" tags. Remove associated rows where temperature data is absent or when time stamp is out of regular sequence (eg. 14:38 instead of 14:00 or 14:30). Also, make a note where battery is logged as “bad” or “good.”
4) "Save as" **CSV (comma delimited) (*.csv)** file and close. Ignore any error messages.
5) Re-open .csv file with Notepad and "Save as" a text file by manually replacing ".csv" with ".txt"
6) Open Excel and browse to the ".txt" file that you just created. Open the file by choosing "tab," "comma," and "space" delimited. Then select "Finish."
7) Check the time stamps to ensure a continuous, uninterrupted times series (eg. 0:00, 0:30, 1:00, 1:30, etc).
8) Save the file in its current format as a **Text (Tab delimited) (*.txt)** file, then "Save As" an **Excel Workbook (*.xlsx)** file.
9) Repeat steps 2-8 for all remaining raw Tidbit data files.
10) Copy and paste raw data from each .xlsx file into separate worksheet tabs within a new template workbook (eg. "20xx Squalicum Crk Tidbit Data_RAW_Field Verified.xlsx").

II. Field Verification:

This step involves annotating data based on field QC notes while retaining all raw data. The resulting workbook should be entitled "20xx Squalicum Crk Tidbit Data_RAW_Field Verified.xlsx"

1) Scroll through each tidbit worksheet and add field QC thermometer temperatures, QC comments, and QC results (absolute difference between field thermometer and tidbit at approximately the same date/time).
2) The template spreadsheet should automatically flag values that exceed the QC thresholds with red/pink highlighted cells. QC thresholds are: $|\Delta| < 0.30$°C for water tidbits, and $|\Delta| < 2.0$°C for air tidbits.
3) Clean/ remove and annotate any data points logged during tidbit handling, based on field notes.
4) Next, find "Dailies" template worksheet. For each tidbit worksheet populated during the "Data Compilation" step, the daily max, min and average should have been automatically calculated.
5) Copy these columns and paste them as VALUES into a new worksheet that will serve as a temporary workspace.
6) Within this temporary workspace, select all 3 columns and follow this procedure for removing blank cells:

a. Select the range of data including the blank cells
b. Press F5 and then the 'Special...' button
c. Click the 'Blanks' radio button and press OK
d. Right click and choose Delete | Shift cells up to delete the blanks

7) After blanks are removed, copy and paste these daily max, min and average values into the appropriate columns in the "Dailies" worksheet. Repeat for all tidbit worksheets.
8) Once completed, delete the temporary workspace worksheet.
9) Next, copy and paste appropriate adjacent columns into each of the summary worksheets on the far right side (eg. the "Sunset Pond Inlet Data" worksheet contains dailies for upstream, downstream and air temperature loggers at the inlet to Sunset Pond).
10) Check formulas and completeness for each summary worksheet.

III. Data Validation:

This step involves editing and cleaning data according to field QC notes and based on anomalies identified in the graphic representations (charts). The resulting workbook should be entitled "20xx Squalicum Crk Tidbit Data_FINAL_Validated.xlsx"

1) "Field Verified" data is visualized graphically and scrutinized for anomalous records which might indicate that a water temperature logger was subaerial. In order to positively identify subaerial events, supporting information is consulted. Supporting information may include: paired (duplicate) logger information, air temperature data from a nearby air temperature logger, maximum and minimum temperatures, water and tidbit depth information, field notes, loggers placed in nearby parts of the stream, etc. Complete data validation by populating and assessing all plots included in the template spreadsheet.

2) Flag and/or remove any suspect data from the dataset, including explanatory comments.

APPENDIX P:

PHOTOPOINT SERIES COMPILATION


3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00


3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10


CADDIS