LOWER DUNGENESS RIVER
SECTION 544
ECOSYSTEM RESTORATION

APPENDIX B

ECOSYSTEM OUTPUTS

DRAFT Detailed Project Report and Environmental Assessment

US Army Corps of Engineers®
Seattle District

Appendix B – Ecosystem Outputs

For the purposes of assessing the relative cost-effectiveness of the three alternatives, the net average annual benefits that would accrue over the 50 year period of analysis were estimated for each of the three alternatives. Benefits scores were calculated by multiplying quantity (acres) by quality (indexed from 0.0 – 1.0).

To estimate quality scores for the existing conditions, and to forecast quality scores for alternative plans, University of Washington biologists under contract with the study team used the Puget Sound Lowlands Benthic Index of Biological Integrity (B-IBI) to assess stream health. Their work is detailed in the attached report. IBI is a methodology that has been endorsed for use in planning studies by the Corps' Ecosystem Restoration Center of Expertise. In order to estimate the biotic changes in the proposed project areas that would be less than permanently inundated (floodplain habitats, to which B-IBI is not applicable) terrestrial arthropods were sampled, and the results compared to a reference site.

The project delivery team used the quality scores developed by the contract biologists to develop net habitat scores for the alternatives. The scores used in the cost effectiveness and incremental cost analyses differ from those in the contract biologists' report for four reasons:

- Acreages of the final alternatives varied from those assumed by the biologists, whose work was completed prior.
- A weighting factor was applied to account for the importance of channel acreage as fish habitat, a key component of the project planning objectives.
- The change in benefits over time, while addressed by the biologists' report, was not factored into the scores they developed; the PDT factored that in.
- A third action alternative was developed after the biologists completed their report.

ANALYSIS OF RESTORATION ALTERNATIVES FOR PROPOSED LEVEE REMOVAL ON DUNGENESS RIVER (RM 0.9-1.5)

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Introduction

The Dungeness River begins in the Buckhorn Wilderness in the Northern Olympic Peninsula and flows about 30 miles to the Strait of Juan de Fuca. It supports runs of pink, chum, Coho, and Chinook salmon as well as steelhead trout. The Dungeness Chinook and summer run chum salmon are both listed as "threatened" under the Endangered Species Act and runs of all species with the exception of hatchery coho are in decline (Dungeness River Audubon Center). The last 3.3 miles of river channel are confined by levees on both banks that limit the development of side channels and cut off access to the historic floodplain. On the right bank the U.S. Army Corps of Engineers levee, constructed in 1963, runs from river mile 2.6 to the mouth of the river. There are no significant side channels in this lowermost reach of the river (Daraio et al. 2003).

In this section of the river several habitat restoration options have been proposed that include varying degrees of dike removal and/or setback, and a modeling study evaluated the impacts of a 100 year flood on each alternative (Lai et al. 2007). This study concluded that the current levee system would be overtopped by a 100 year flood near river mile 1.6 and 1.2 and that any of the proposed levee setback options would lower the floodwater level in the channel from the existing level by 3 to 6 feet. The model also suggested that setting back the levee would restore higher elevation floodplain surfaces, allowing inundation and deposition of fine sediment during flood events.

One of the primary goals of dike removal and setback restoration projects in the Pacific Northwest is to restore access to floodplain and off-channel habitat for salmon and trout species. Floodplains and side channels provide important spawning, rearing and foraging habitat to juvenile salmon and trout during periods of seasonal inundation (Brown and Hartman 1988; Bryant et al. 2005; Henning 2006, 2007). Such inundations are accompanied by high flows in the main channel and juvenile salmon and trout find refuge in lower velocity water provided by floodplains and off-channel habitat. Juvenile salmon and trout also benefit from increased growth rates and foraging opportunities in emergent marshes and inundated terrestrial vegetation (Sommer et al. 2001, 2005; Limm and Marchetti 2009; Eberle and Stanford 2010).

There are currently two proposed alternatives for removal of the USACE dike between river miles 0.9 and 1.5 on the Dungeness River. A third alternative is to leave dike and the site as it is. Both dike removal alternatives create side channel habitat and restore some portion of the historic floodplain to periodic inundation. The site has been used for agriculture in the past and is currently a seasonally wet field bisected by a single paved road (Towne Road). Section 544 of WRDA 2000 authorized the Secretary of the Army to conduct studies and implement critical restoration projects in the area of Puget Sound, Washington and adjacent waters, including watersheds that drain directly into Puget Sound, Admiralty Inlet, Hood Canal, Rosario Strait, and the Strait of Juan de Fuca to Cape Flattery. The projects must produce, consistent with Federal programs, projects, and activities, immediate and substantial ecosystem restoration, preservation and protection benefits. The proposed project on the Dungeness River would be accomplished under this authorization.

Description of Restoration Alternatives

Alternative 1) No Action. No restoration would take place under this alternative.

Alternative 2) Towne Road (see map in Figure 1). Removal of a section of the levee on the right bank between river mile 0.9 and 1.5. This plan calls for excavation of several side channels with three connections made to the river. This alternative would reconnect the lower Dungeness River to approximately 70 acres of its historic floodplain, about a mile upstream from the river's outlet at Dungeness Bay on the Strait of Juan de Fuca. The alternative would remove a section of the existing Corps levee on the right bank between river mile 0.9 and 1.5, and replace it with a setback levee. The setback levee in this alternative would be aligned with the north-south portion of Towne Road.

The Towne Road alternative includes reconnecting a historic side channel to the present-day main stem, excavation of back channels, and excavation of emergent planting areas. Excavated material would be used to create forested berms, encouraging initial side channel formation on the west side of the site instead of the east side, providing shading vegetation along the margins of the wetted areas, and enhancing habitat diversity.

This alternative would also utilize large wood in three ways: 1) buried wood on the west portion of the site would encourage initial side channel formation, 2) engineered log jams would help ensure that some flow remains in the present main stem, provide initial stability for the new channels, and create roughness and pool habitat, and 3) anchored wood clusters would create additional roughness and pool habitat. Areas of each of the habitat types in the Towne Road alternative are shown in Table 1**.**

Alternative 3) Meadowbrook (see map in Figure 2). The Meadowbrook Creek Alternative includes the Towne Road alternative but adds additional restored habitat by locating the setback levee closer to Meadowbrook Creek (farther from the main channel). The result is that this alternative reconnects the river to approximately 120 acres of its historic floodplain. The Meadowbrook Creek alternative includes the same area of side channel as the Towne Road alternative, and considerably more back channel, vegetated terrace, emergent marsh and other plantings. Areas of each habitat type in the Meadowbrook Creek alternative are shown in Table 1.

The purpose of this report is to estimate the timing and extent of real benefits that each project would provide within a 50-year project life. In order to make these estimations we conducted biological sampling in the aquatic and terrestrial habitats at the site, in order to establish the current status of the proposed restoration areas. These data allowed us to calculate metrics including diversity, population structure, and abundance, and to estimate the trajectories of change that these metrics might experience over time. Finally, we used the current conditions and restoration endpoint goals to establish scores for each habitat type that would be created, and then calculated the relative benefits of each alternative.

Table 1. Summary of acreage of various habitat types created in each of two alternative restoration plans.

Towne Road	
Side channel	10
Back channel	2
Vegetated Terraces	11.9
Emergent marsh	6
Other plantings	5.5
Additional habitat	34.6
total acres	**70**
Meadowbrook	
Side channel	10
Back channel	3
Vegetated Terraces	18
Emergent marsh	13
Other plantings	10
Additional habitat	66
total acres	**120**

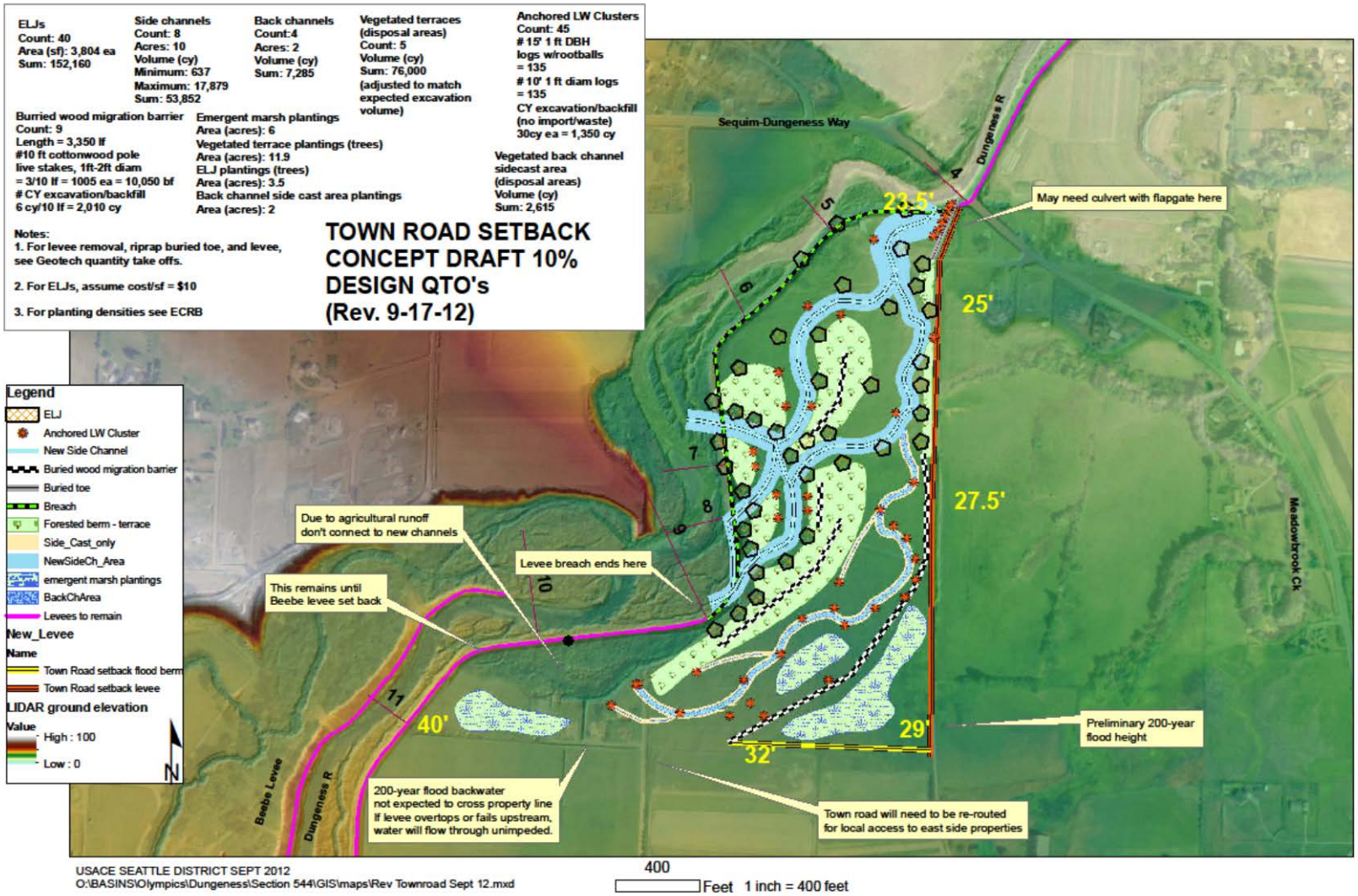

Figure 1. Restoration Alternative 1 – Towne Road

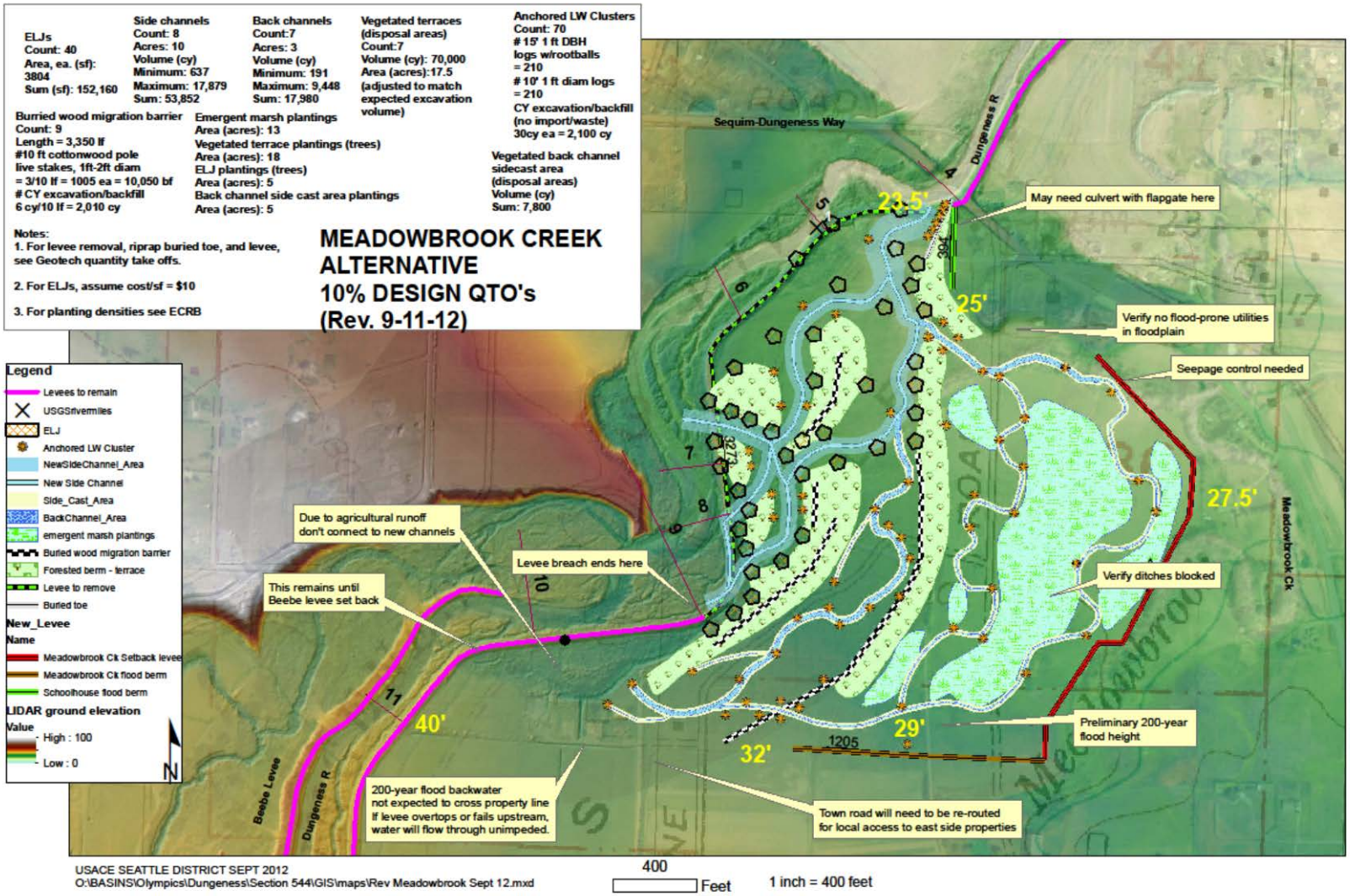

Figure 2. Restoration Alternative 2 – Meadowbrook.

Measures for estimating project benefits

In order to estimate how the project alternatives might develop realized benefits within the 50 year project life we conducted biological sampling to evaluate the current status of the site, and gathered information that would allow us to estimate how the resulting metrics may change over time given the expected circumstances of restoration. We used the stream benthic macroinvertebrate community and terrestrial arthropod communities to develop the metrics. Two main reasons led us to use these invertebrate communities: first, benthic macroinvertebrates are an important component of juvenile salmon and trout diets. Increasing macroinvertebrate diversity and abundance can increase foraging opportunities for juvenile salmon. Second, sampling macroinvertebrate assemblages in streams is an effective way of assessing the water quality and underlying health of the larger ecosystem (Rosenberg and Resh 1993, Kerans and Karr 1994, EPA 2002, Marchetti et al. 2008). Both restoration alternatives would create wetland, stream, and seasonally inundated floodplain habitats. In these types of habitats, invertebrates with both aquatic and terrestrial life stages influence nutrient cycling, primary productivity, litter decomposition, translocation of materials and plant community regulation as well as serving as prey items for numerous vertebrate predators (Wallace and Webster 1996, Reese and Batzer 2003, Balcombe et al. 2005).

The most common method of assessing stream health via benthic macroinvertebrates is to use a Benthic Index of Biological Integrity (B-IBI). Several such indices have been developed using metrics appropriate to different regions including the Pacific Northwest (Kerans and Karr 1994, Stribling et al. 1998, Karr and Chu 1999, Hayslip 2007). The macroinvertebrate community can act as a long term and continuous monitor because it is comprised of a large number of species with a wide range of tolerances and responses to environmental stressors (Rosenberg and Resh 1993). The metrics that make up the B-IBI measure taxa richness, population structure, pollution tolerance, behavior and other factors that can provide a summary of the biological conditions within the stream. Analysis of this data creates a single index score that can be used to compare stream conditions through time at the same location or among streams in different locations. The B-IBI score provides an overall view of the stream health and is sensitive to a broad range of disturbances. The importance of terrestrial and aquatic invertebrates in multiple aspects of stream, wetland, and riparian ecosystems as well as the ease of comparing B-IBI values across systems and through time made this an appropriate approach for establishing a restoration endpoint for this project.

In order to estimate the biotic changes in the proposed project areas that would become seasonally inundated (floodplain habitats) we chose to sample terrestrial arthropods. Many insects that are stream dwellers as juveniles use terrestrial habitats as adults. These include important salmon prey taxa such as chironomids, mayflies, and stoneflies. Some, like chironomids can be very important in juvenile salmon diets in all life stages (Allan et al. 2003, Hetrick et al. 1998, Mundie 1971). Other arthropods that are exclusively terrestrial such as aphids, ants, and spiders can also be important prey for juvenile salmon. To sample these terrestrial arthropods we used fallout traps that capture those individuals that could land on the surface of the water and thus become available to fish. Fallout traps have been used extensively to assess restoration projects in the greater Puget Sound region and the Columbia River (Armbrust et al. 2008, Cordell et al. 2008, Ramirez 2008, USGS and Nisqually Tribe 2012). Fallout traps provide a measure of

numbers of terrestrial arthropods potentially available as prey to fish and other terrestrial predators.

In this study we used both terrestrial fallout traps and B-IBI sampling to assess the current state of the Dungeness River main stem, the current riparian zone, and current field/wetland areas that would be included in the restoration alternatives. In this report we predict restoration trajectories as well as 50-year endpoint conditions, using restoration ecology literature and our own research experience.

Methods

Index of Biological Integrity

On August 16, 2012 we conducted benthic macroinvertebrate sampling in the reach from the Schoolhouse Bridge at river mile 0.7 to river mile 1.5 (Figure 3) based on standard protocols established for the Puget Sound Region (Karr and Chu 1999) and used extensively by agencies in Clallam County (www.pugetsoundstreambenthos.org) and the region (King County 2009). Within this reach we selected three riffles and at each riffle used a Surber sampler (1ft^2 with 500µm mesh) (Figure 4) to collect three replicate samples that were combined to yield one sample per riffle. Samples were fixed in 70% isopropanal in the field and transported to the laboratory where all invertebrates were identified to taxonomic levels indicated by B-IBI protocols, generally genus and species, and enumerated.

This data was used to calculate an Index of Biological Integrity (B-IBI) score for this reach of the lower Dungeness River. We used the standard species/family level 10 metric B-IBI developed for the Puget Sound region (Hayslip 2007). The metrics used fall into major categories and are described as follows.

Taxa Richness

1. Total taxa richness – the total number of distinct taxa identified in the sample. Number is expected to decrease with increased disturbance.
2. Mayfly taxa richness – total number of mayfly (Ephemeroptera) taxa identified in the sample. Number is expected to decrease with increased disturbance.
3. Stonefly taxa richness – total number of stonefly (Plecoptera) taxa identified in the sample. Number is expected to decrease with increased disturbance.
4. Caddisfly taxa richness – total number of caddisfly (Trichoptera) taxa identified in the sample. Number is expected to decrease with increased disturbance.

Population Attributes

5. Dominance – percent of individuals counted that are members of the three most abundant taxa. Number is expected to increase with increased disturbance.
6. Long lived –number of taxa that have fewer than one generation per year. Number is expected to decrease with increased disturbance.

Organic Pollution

7. Percent Tolerant – the percent of individuals that belong to taxa that are tolerant of organic pollution. Tolerance values have been published for most stream macroinvertebrates in the PNW (Barbour et al. 1999 and www.pugetstreambenthos.org)
8. Intolerant – the number of taxa that are intolerant to organic pollution.

Behavior

9. Predator – percent of individuals counted that are predators. Number is expected to decrease with increased disturbance.
10. Clingers - number of taxa that are adapted to attaching to surfaces in riffles. Lists of clinger species are published and widely available (Merritt and Cummins, www.pugetsoundbenthos.org)

Metric values were calculated for each sample and then the average of the three samples was given a score of 1, 3, or 5 based on standards developed for Puget Sound lowland streams (Hayslip 2007) and the sum of these scores comprised the B-IBI score.

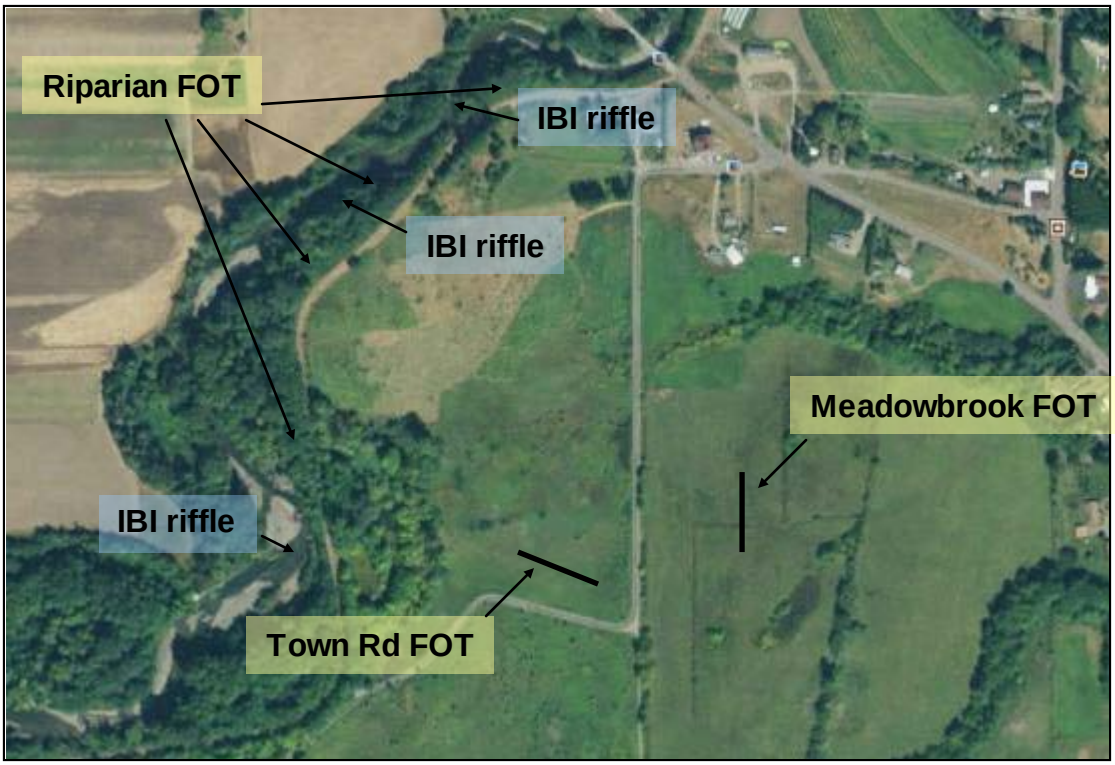

Figure 3. Map of project area showing placement of arthropod fallout traps (FOT). Riparian traps were spaced out along the length of the proposed dike removal (RM 0.9-1.5). Towne Road and Meadowbrook traps were placed along transects approximately 75 meters long.

Figure 4. Example of a riffle sampled on the lower Dungeness River, and B-IBI sampling equipment.

Terrestrial Arthropods

Pre-restoration baseline data for the terrestrial arthropod communities that are important salmonid prey were collected with arthropod fallout traps consisting of plastic tubs. Several centimeters of soapy water in each tub traps arthropods landing on the surface. Ten traps were deployed in each of three locations (existing riparian, back channel area of Towne Road alternative and emergent marsh area of Meadowbrook alternative) (Figures 5, 6, and 7).The traps were left out for 24 hours on two dates (6/28/2012 and 8/17/2012). Trap contents were retrieved, sieved and washed into labeled sample containers. Each sample was preserved with 70% isopropanol. Invertebrates were identified to order level, with the exception of important prey taxa for juvenile salmonids (e.g., Chironomidae, Aphididae), which were identified to family level, and enumerated.

Figure 5. Arthropod fallout trap deployed in riparian zone of the lower Dungeness River. The river channel is to the left.

Figure 6. Arthropod fallout trap deployed in potential back channel habitat within Towne Road restoration alternative.

Figure 7. Arthropod fallout trap deployed in potential emergent marsh habitat within Meadowbrook restoration alternative.

Results - Description of current condition

Index of Biological Integrity

We collected a total of 984 individuals belonging to 5 insect orders and 18 insect families (see Appendix A for taxa list). In addition, oligochaete worms, mites, nematodes, flatworms, and leeches were present in the samples. The values for each metric are given in Table 2. The total number of taxa (38) and number of mayfly taxa (12) both rated as excellent. The macroinvertebrate assemblage was not dominated by only the top three taxa. Instead, there was a diversity of abundant taxa present. We found only two taxa that take more than one year to complete their life cycle (long-lived), both species of riffle beetle (Elmidae). The small number of long-lived taxa may suggest lack of suitable permanent habitat. Taxa tolerant of pollution made up nearly 30% of the macroinvertebrate assemblage though their presence does not necessarily indicate a polluted state. The presence of 4 intolerant species of flies, mayflies and stoneflies indicates that the water is relatively free of pollution. In the Pacific Northwest a greater abundance of taxa modified to a lifestyle clinging to surfaces in fast flowing water are an indication of good stream health. We found 23 of these “clinger” taxa which resulted in a score of excellent for this metric. The percent of taxa that were predators (13.5%) was neither excellent nor poor and suggests a medium level of disturbance in the system. A larger proportion of predators in an assemblage would suggest long-term stability as predators tend to be sensitive to larger and slower shifts in a system (Culler 2008).

The overall B-IBI score in the proposed project reach is 38, which ranks as “good” in the B-IBI scoring system. For reference, Appendix B describes the biological conditions that are associated with ranges of B-IBI scores. The “good” score denotes a stream that has somewhat fewer overall taxa, especially mayflies, stoneflies, and caddisflies, and fewer long-lived taxa and predators than does a stream that is undisturbed. The score of 38 found here is higher than that previously calculated for the Dungeness River (average 25.3) and also higher than most of the streams in the Dungeness and other nearby drainage basins (Table 3).

Table 2. Summary of Index of Biological Integrity metric values and index score.

	2012	
Metric	**value**	**score**
Total Taxa richness	38	5
Mayfly taxa richness	12	5
Stonefly taxa richness	4	3
Caddisfly taxa richness	7	3
% Dominant (top 3)	50	5
"long-lived" taxa richness	2	1
Intolerant taxa richness	4	5
% Tolerant individuals	29.7	3
"clinger" taxa richness	23	5
% Predators	13.5	3
IBI score		**38**
Biological Condition		**good**

Table 3. A comparison of B-IBI scores for Dungeness and other nearby streams from studies by Washington State Department of Ecology and Streamkeepers of Clallam County. Data obtained from Puget Sound Stream Benthos website.

Stream name	**Watershed Basin**	**Year(s) sampled**	**IBI score**
Dungeness River	Dungeness	2004, 2005, 2006, 2007	25.3 (averaged)
Bell Creek	Dungeness	2002, 2003, 2005	13.4 (averaged)
Canyon Creek	Dungeness	2009	30
Cassalery Creek	Dungeness	2002	14.5
Grey Wolf River	Dungeness	2004, 2007	29.7 (averaged)
Jimmycomelately Creek	Port Townsend	2002, 2004, 2006, 2007, 2009	26 (averaged)
Johnson Creek	Port Townsend	2007	31.3
Siebert Creek	Port Angeles	2003, 2005, 2007	34.8 (averaged)
Surveyor Creek	Port Angeles	2009	42
Tumwater Creek	Port Angeles	2007, 2009	35.1 (averaged)

Terrestrial Arthropods

We collected arthropod taxa belonging to 17 orders, and taxa richness at the order level was the same at all three sites. The most abundant taxa in the current riparian zone were springtails (Collembola), and all other arthropod taxa had relatively low densities (Figure 8). Collembola are sometimes abundant in juvenile salmon diets from streams, especially during periods of high flow when they are washed out of the riparian zone (Minakawa and Kraft 1999). Another common salmon prey taxa, Psocoptera, appeared more abundant in the riparian zone than in the other two areas though this was not tested for statistical significance.

In the Towne Road alternative the area that would become a backchannel with flowing water currently produces abundant plant hoppers (suborder Auchenorrhyncha) and mites (Acari). Neither taxon is commonly abundant in juvenile salmon diets. Plant hoppers are also the most abundant terrestrial insect in the additional area included in the Meadowbrook alternative. The most common terrestrial arthropods found in juvenile salmon diets; chironomid flies, aphids, and booklice (Psocoptera) were present in both areas but in relatively low densities. Both the Towne Road and Meadowbrook areas currently produce many families of flies (Diptera) other than Chironomidae. A variety of

dipteran families are all consistently encountered in juvenile coho diets (Cordell et al. 2012). All three areas produce many other insect and non-insect taxa at low densities.

For total invertebrate densities, we calculated a 2-way ANOVA on Habitat and Date with interactions and found that habitat was significant (p=0.0007), date was not (p=0.31), but interaction with date was (p=0.008). Separate 1-way ANOVAs for each month found that there was no significant difference between habitats in June (p=0.06) but in August the riparian zone along the river had significantly higher densities than did the proposed Meadowbrook and Towne Road restoration areas (p=0.003).

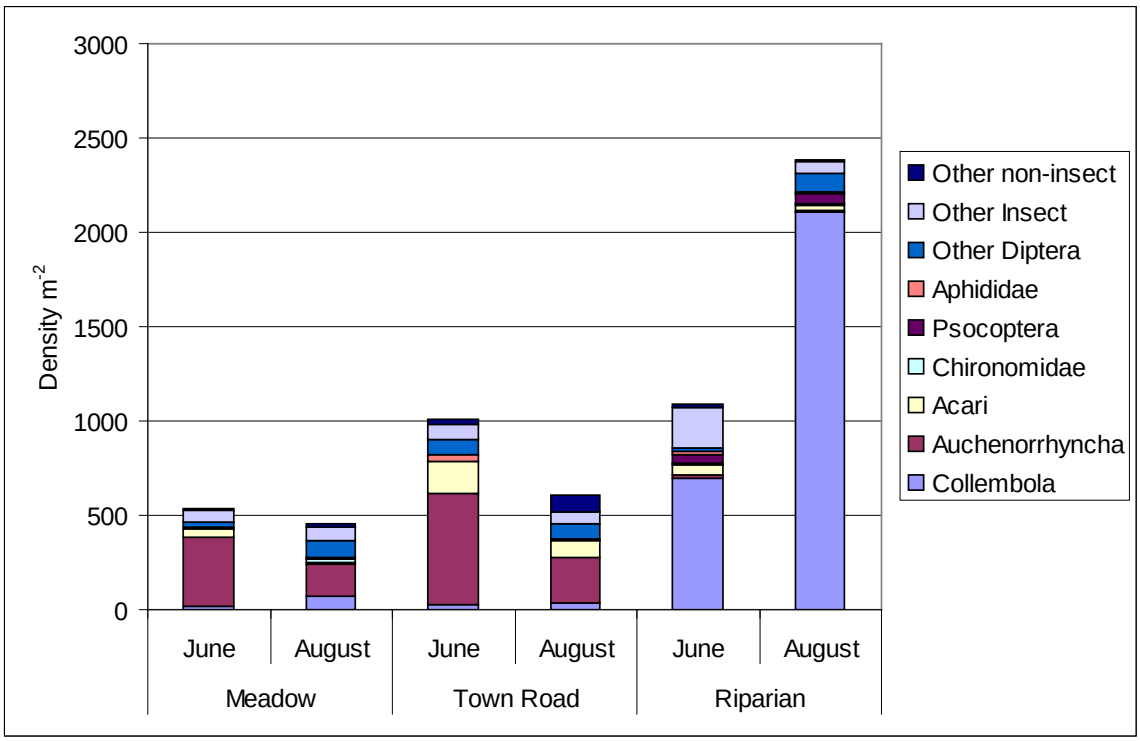

Figure 8. Total densities of invertebrates caught in fallout traps at all three alternatives.

Restoration Response Trajectories

Index of Biological Integrity

At the restoration site, the best scenario for achieving a smooth trajectory to good B-IBI scores and approaching an undisturbed reference state would be creation of a low stress environment with permanent stable hydraulic connections that encourage colonization by aquatic biota (Ballantine and Schneider 2009, Zedler and Callaway 1999). If this colonization pathway is created it is likely that the B-IBI score for the Towne Rd alternative will increase to near main stem values in 5 to 10 years (Figure 9). Invertebrate assemblages in restored habitats have been demonstrated to reach similar composition and densities to those found in reference wetlands within 3-10 years (Marchetti et al. 2008, Balcombe et al. 2005, Mitsch et al. 1998, Simenstad and Thom 1996) with no additional significant changes from 10 to 20 years (Marchetti et al. 2008). At a similar floodplain restoration and reconnection site on Hansen Creek, a tributary of the lower Skagit River in Washington State, flow that avulsed from the creek channel

into the restored floodplain carved new braided channels. B-IBI sampling in these new channels just one year after construction resulted in values very similar to those found in the main channel of the creek in the year prior to restoration (Cordell et al. 2012). The key to high and stable B-IBI scores at the Dungeness River project site will be the stability of flowing water there.

The B-IBI score from the main stem of the Dungeness River on the project site was good but was depressed by the low numbers of long-lived taxa. This metric would likely be even lower in side or back channel habitats where water levels and temperatures would be more variable. According to the project designs, 50% of the side channel, back channel and emergent marsh habitats will be inundated for the entire year. The remaining 50% may be inundated during the high flow period, November through June.

It is not appropriate to use the B-IBI in areas that are not wetted, and if water is present in some of the back channels only seasonally the community of invertebrates in that area will differ greatly from those in areas of year-round flowing water. Thus, the additional back channel area that is included in the Meadowbrook alternative would be difficult to characterize with B-IBI. Sampling there after restoration would likely find a slow increase in B-IBI scores that would be interrupted by variable seasonal changes in hydrology at the site. With a more variable and less direct surface water connection it would take longer for the aquatic taxa used in the B-IBI to become established, compared to areas with constant flow.

The B-IBI score in side channels with permanent flowing water may reach the score found at the main channel in 5 to 10 years. There is little reason to expect B-IBI scores in the restored floodplain to be higher than the "good" conditions found in the main channel or for the B-IBI value of the main channel to change significantly. However, if a large portion of the river diverts into the side channel system, such that the river becomes significantly shallower or slower, the score in the main stem could decrease.

Terrestrial Invertebrates

Colonization by terrestrial invertebrates may occur via wind drift, flight, or emergence from a desiccation resistant life stages present in the soil. Successful colonization by terrestrial invertebrates is strongly influenced by vegetation communities that develop in restored habitat (Berg 2006) and these communities may develop in unpredictable ways (Matthews et al. 2009). However, in some cases insect community restoration trajectories have been documented. Long-term monitoring of restoration sites on the Duwamish River in Seattle, Washington suggests a fast response to restoration by terrestrial insects. Nine restoration sites (General Services Administration, Terminal 105, Turning Basin Phases I and II, Hamm Creek, Herring's House, North Wind's Weir, Kenco Marine, and Site One) have been monitored for one to thirteen years after construction of restoration sites, and development of the insect community at each site was compared with that at local reference sites. While there were some changes in assemblage compositions over time, overall the restoration sites supported densities and taxa richness values comparable to or exceeding those at the reference sites in the first year after construction and in subsequent monitoring (Cordell et al. 2001, Cordell et al. 2008, Cordell et al. 2012).

Similar patterns have been found in other types of restored habitat. For example, species richness and diversity of ground dwelling insects were higher at three recently restored sites (2, 3 and 4 years post construction) compared to those in neighboring

reference and pre-restoration sites in a degraded forested region of India (Ramalingam and Priyadarsanan 2009). At a restored *Spartina alterniflora* salt marsh arthropod taxa richness and abundance were not different than at a reference site five years after removal of the invasive grass *Phragmites australis* (Gratton and Denno 2005). Three studies in the Sacramento Valley focused on the restoration response of either particular insect species or higher taxonomic groups (Golet et al. 2008). In one of these studies species richness of bees at an 8 year old riparian restoration site was not significantly different than at paired reference sites though there were significant differences in assemblage composition. In the second study, the abundance of a threatened twig boring beetle (*Desmocerus californicus dimorphus*) increased with the age of the restoration, and in the third study the number of beetle morphospecies increased as restoration sites matured (1-10 years) and approached the taxa richness of remnant undisturbed riparian habitat (>25 years).

At the Dungeness River restoration sites there will initially be very little riparian vegetation after site construction. After 10 years, however, we would expect willows, alders and other native vegetation to have established along new waterways and provide shade, refuge, and foraging opportunities for terrestrial invertebrates. This will be beneficial to arthropod communities because a diversity of herbaceous and woody plants provides the best habitat for establishing herbivorous invertebrates and their predators in restored riparian zones (Williams 2000). Mature riparian vegetation will also benefit the aquatic community via increased habitat complexity and organic input through twig and leaf fall. Thus, we estimate that 10 years is an appropriate amount of time to allow terrestrial arthropod assemblages in the restored areas to reach density and diversity levels similar to undisturbed wetland floodplain habitat (Figure 10). We expect the proportion of Diptera (flies) to mimic the rest of the arthropod population, increasing rapidly in the first five years and reaching proportions similar to reference sites in roughly 10 to 20 years (Figure 11). The Meadowbrook alternative would likely experience a faster initial increase and remain high due to the creation of the emergent marsh habitat and large abundances of chironomid flies that favor such habitat. In the following section we use the percent of chironomids and other Diptera to calculate project benefits.

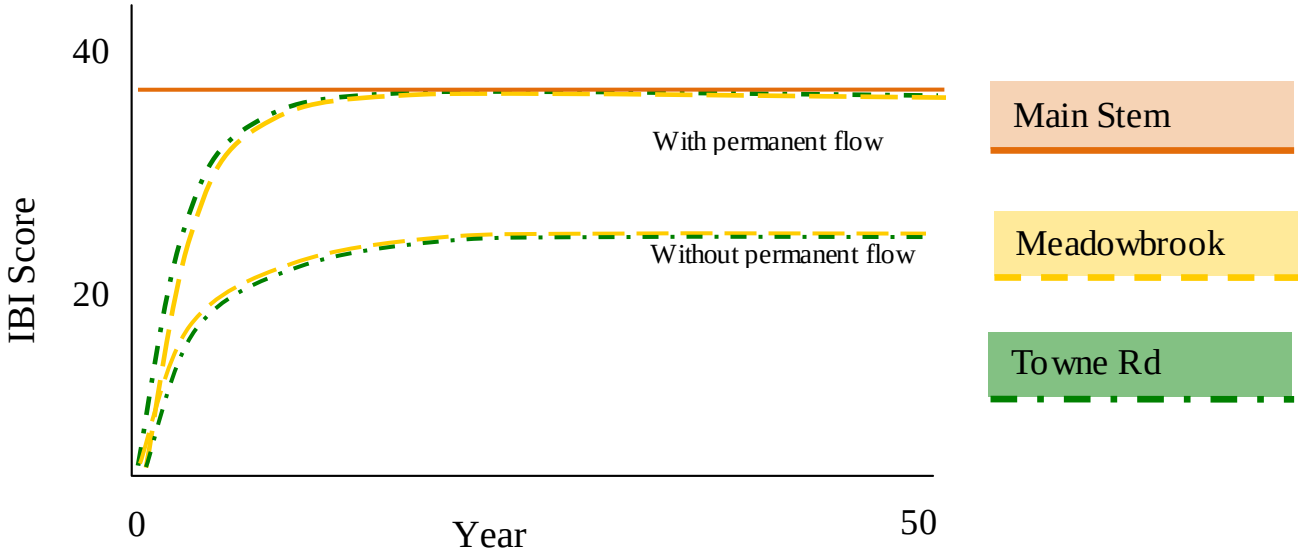

Figure 9. Predicted restoration response trajectories for aquatic macroinvertebrates, represented by the IBI score for the side channel habitat in each restoration alternative. The current score for Dungeness mainstem is 38, shown for reference. The "no restoration" scenario would not include any flow in the project footprint, so no IBI score is represented.

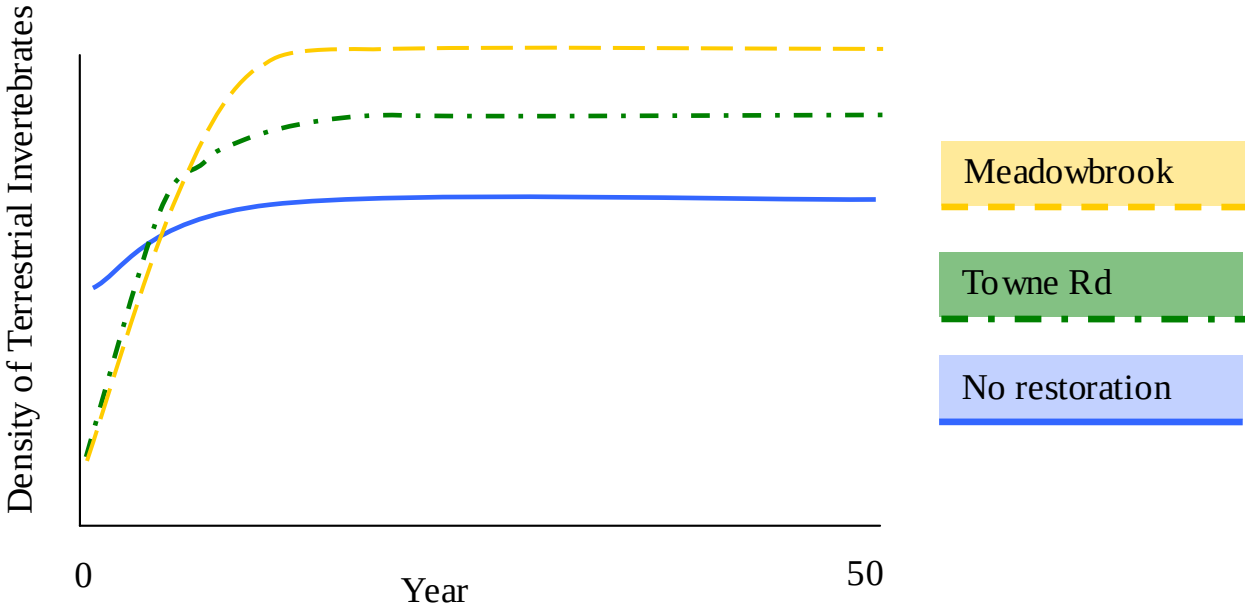

Figure 10. Predicted trajectories of response for density of terrestrial insects in all three restoration alternatives.

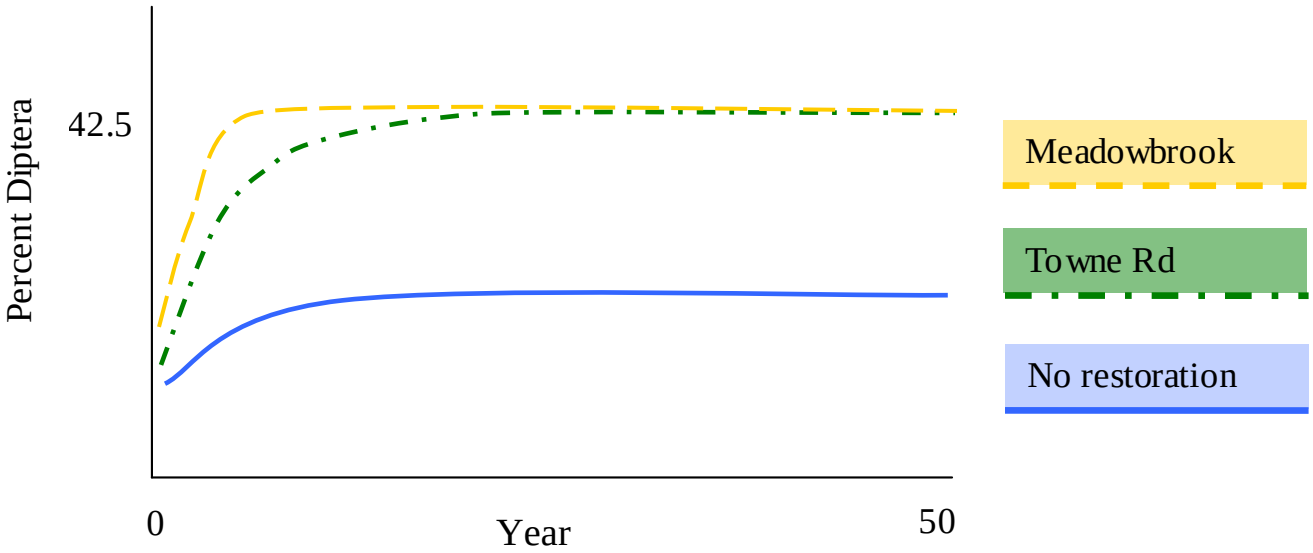

Figure 11. Predicted trajectories of response for percent Diptera in the arthropod assemblage for all three restoration alternatives.

Project Benefits Analysis

The main goal of this analysis is to summarize the current conditions and in conjunction with predicted restoration trajectories, to estimate the conditions under each of the three alternatives at the end of the 50-year project life. As shown in Table 1, each alternative would create different acreages of several habitat types. In order to compare the benefits gained from each alternative we systematically evaluated each habitat type and gave it a score that was scaled by the number of acres created. For the aquatic habitats we used the B-IBI score. In the Puget Sound region, B-IBI scores range between 0 and 50 and for this analysis we scaled these values between 0 and 1. For the terrestrial habitats we used the percent of invertebrates represented by the order Diptera (flies) and compared our scores with those from two natural reference riparian areas we have recently studied. The reference areas were Goldsborough Creek near Shelton, Washington and Hansen Creek near Sedro Woolley, Washington (unpublished data, Cordell et al. 2012). The percent Diptera at these two reference sites were similar and we used average (42.5%) as the restoration goal. Our fallout trap data was then calculated as a percent of the reference level and used as the score for the vegetation habitat types in each alternative. Other metrics could have been use but we chose Diptera because they are consistently found in the diets of juvenile salmon (Cordell et al. 2012).

In Table 4 each habitat type listed in Table 1 was scored and that score was multiplied by the number of acres represented by that habitat type in each alternative. Habitat scores per acre were summed to calculate the total score for the alternative and the net habitat gain over the no restoration alternative was calculated.

Restoration Alternatives Analysis – expectations after 50 years

1. No restoration

Apart from the possibility of natural avulsion of the river out of the current riverbed, there is no reason to expect major changes in the stream condition and B-IBI score if no action is taken. The historic floodplain area will remain disconnected wetland. Trees already planted will mature and in these areas the terrestrial arthropod assemblage may trend towards that produced in the current riparian zone in places where a mature tree canopy provides abundant shade. However, most of this production will not directly become part of the river ecosystem. Currently, Diptera represent only 10.2% of the terrestrial invertebrates captured in the area of the Towne Road project. This represents 24% of the reference level and so the terrestrial habitat in that area, if no restoration were to occur would receive a score of 0.24 (Table 4). Diptera represent a slightly larger percentage of the invertebrate assemblage in the Meadowbrook project area and are currently at 29% of the reference level. If no restoration were to occur the score for the terrestrial habitat in the Meadowbrook area would be 0.29.

Our predicted endpoint in terms of B-IBI score in the case of no action is 35-40 for the main stem, and no B-IBI score for the disconnected wetland area. See Table 4 for summary of habitat type scores for each alternative.

2. Towne Road Alternative

If good hydraulic connections to the main stem are maintained and permanent flow is established in the side channels, B-IBI scores in the range of the current main stem score are expected. Our predicted restoration endpoint in terms of B-IBI score for the Towne Road alternative is 35-40. After 50 years, we also expect density and composition of the terrestrial invertebrate assemblage to resemble that which would be found at an undisturbed site.

It has been demonstrated in coastal systems in the Pacific Northwest and Southern British Columbia that as channel flow increases in the fall, juvenile Coho salmon move from the main channel into off-channel habitats such as side channels and pools (Cederholm and Scarlett, 1982; Peterson 1982a,b; Brown and Hartman 1988; McMahon and Hartman 1989; Swales and Levings 1989; Sandercock 1991; Nickelson et al. 1992). Side channel habitat proposed in the Towne Road alternative will provide this type of habitat.

In addition to the side channel habitat, engineered log jams and anchored large wood clusters proposed in the Towne Road alternative have the potential for creating pool habitat. Nickelson et al. (1992) found that the addition of bundles of wood to mainstem pools increase the density of juvenile coho in the pools in winter. In Kloiya Creek, British Columbia, ninety nine percent of coho fry were found downstream of root wads in areas of low velocity water regardless of how flow in the channel was manipulated (Shirvell 1990). McMahon and Hartman (1989) found that coho densities increased with increasing cover complexity and that the most important features for supporting winter populations of coho were low velocity water, shade, and three dimensional complexity.

Instream wood is also an important habitat feature for macroinvertebrates that use it for shelter, food, and oviposition (Nilsen and Larimore 1973, Angermeier and Karr 1984,

Wallace et al. 1995). The biomass, abundance and diversity of stream invertebrates tends to increase sharply after the experimental addition of wood to a stream (Wallace et al. 1995, Nilsen and Larimore 1973). Johnson et al. (2003) found that habitat heterogeneity was the most important factor affecting increases in diversity of stream invertebrates.

Juvenile salmonids will benefit from increased foraging opportunities concurrent with an increase in terrestrial and aquatic macroinvertebrates. Both aquatic and terrestrial macroinvertebrates are important prey resources for juvenile salmon. Aquatic macroinvertebrates are a larger contributor to stomach contents than terrestrial arthropods in areas with closed canopies. Conversely, terrestrial arthropod taxa account for a greater proportion of the contents of juvenile salmon stomachs in areas with open canopy (Wipfli 1997, Hetrick 1998). Thus, production of terrestrial arthropods may be important in the period before the riparian canopy matures.

Planting the forested berms separating the side channels as well as the small emergent marshes in the southeast and southwest corners of the floodplain will increase terrestrial habitat heterogeneity. As the diversity and density of planted and naturally recruiting riparian vegetation increases, the restored habitat will provide for the establishment of herbivorous invertebrates and their predators (Williams 2000). Chironomid flies are among the most important salmon prey taxa and also some of the earliest colonizers of new aquatic habitats (Nilsen and Larimore 1973, Mackay 1992). A review by Mackay (1992) cites studies of recolonization by invertebrates following small and large disturbances including stream rerouting in which early colonizing insects (including chironomids) established stable populations within one year or less. We expect established populations of chironomids and other early colonizers in the constructed side channels within one year post construction. Within 20 years we expect the percent Diptera to reach the reference level of 42.5 percent and, thus, the habitat score for terrestrial habitats after 50 years is 1, or 100 percent of the goal. Table 4 summarizes habitat type scores for each alternative.

3. Meadowbrook Alternative

This restoration plan includes all the elements of the Towne Road alternative with additional adjacent back channel and connected emergent marsh habitat. We expect the side channel habitat in this alternative to establish as in the Towne Road alternative and the B-IBI score to reach 35-40. An end point B-IBI score for the additional floodplain restored in this plan is difficult to estimate and will depend on the amount of permanent flowing water present. As discussed previously, standing water would not be appropriate for B-IBI analysis, and low flow, shallow water would result in low B-IBI scores in this area because decreased flow negatively impacts several B-IBI metrics (taxa richness of mayflies, stoneflies and caddisflies, and percent dominance) (Davis et al. 2003). In Meridian Valley Creek a small stream in Kent, Washington stream flow was significantly slowed due to damming activity by beavers and the average B-IBI score was 22 (Armbrust et al. 2008) while further upstream where there was also a lack of riparian canopy the score was 12 (Reiser et al. 2006). A large-scale study of eleven watersheds in the Santa Clara Valley, California found that streams receiving the lowest B-IBI scores were those characterized as low gradient or intermittent (EOA, Inc 2007). The project

design for the Dungeness indicates that 50 percent of the back channel would be inundated for the entire year and between 50 and 100 percent would be inundated from November through June. We do not include a separate B-IBI score in Table 4 for the backchannel habitat because significant portions of the area are likely to be dry for most of the year. Our predicted restoration endpoint in terms of B-IBI score for the Meadowbrook alternative is 35 - 40 in areas with permanent flowing water.

A much larger area of emergent marsh would be connected to the river in the Meadowbrook alternative than in the Towne Road alternative. This habitat would likely be quickly colonized by chironomid flies (Nilsen and Larimore 1973, Mackay 1992) and other invertebrates with both aquatic and terrestrial life stages. The larger marsh and forested berm habitat would provide heterogeneous habitat structure that would likely support a greater density of terrestrial invertebrates than either the Towne Road or no restoration alternatives. Arthropods produced in the marsh would also be available as prey in the adjacent floodplain and main channel via aquatic drift or flight. The habitat score for terrestrial habitats is the same as in the Towne road alternative although we expect the goal of 42.5 percent Diptera to be reached in only 10 years. After 50 years when the percent Diptera has reached reference levels then 100 percent of the goal will be reached yielding a habitat score of 1. Intermittent drying and low flow will affect which organisms can exist in the back channels, favoring arthropods having desiccation-resistant life stages or other adaptations to ephemeral aquatic habitats.

The anchored large wood clusters planned in the Meadowbrook alternative could create pool habitat, providing refuge and feeding opportunities to juvenile fish as previously described. Table 4 summarizes habitat type scores for each alternative.

Summary

For this analysis of restoration benefits we collected invertebrate samples from both the aquatic and terrestrial habitats in the area proposed for levee removal and restoration. We used the aquatic invertebrate data to calculate a Benthic Index of Biological Integrity that yielded a score of 38 for the Dungeness River. This score describes a river in “good” biological condition for the Puget Sound region and is better than the scores received by other streams in the surrounding area (Puget Sound Stream Benthos). For the terrestrial habitats we used traps that are frequently used in riparian habitat to capture invertebrates that would land on the surface of water and be made available as prey items for fish. We calculated densities of invertebrate taxa and percent composition of the assemblage. Using information from the available literature on determining restoration success and tracking trajectories of recovery we estimated the trajectories and 50-year restoration endpoints for the three proposed restoration alternatives.

If no action is taken in the channelized lowermost 3.3 miles of river, the current levee system is predicted to fail in a 100 year flood near river mile 1.6 and 1.2. The course of no action would not result in any benefits to the runs of pink, chum, Coho, and Chinook salmon or steelhead trout currently supported by the river. There is no reason to expect any major changes in the stream condition and the current B-IBI score of 38 if no action is taken. There may be a change in the terrestrial arthropod assemblage to reflect the maturation of the overstory canopy where young trees have already been planted.

Both the Towne Road and Meadowbrook restoration alternatives would create in-stream habitat and restore access to floodplain and off-channel habitat that are beneficial to salmon and trout species. Both alternatives will provide diverse vegetation that supports establishment of a wide variety of aquatic and terrestrial arthropods. The Towne Road alternative creates mostly side channel and some back channel habitat with accompanying riparian tree plantings. Engineered log jams and anchored large wood clusters proposed in this alternative have the potential for creating pool habitat in the side channels. Increased availability and diversity of such habitats should increase the density and number of species of aquatic and terrestrial arthropods present. We expect a B-IBI score in the side channel habitat to reach that of the main stem (38) within 10 years. Using the metric of % Diptera to characterize the terrestrial invertebrate community we expect the Towne road and Meadowbrook alternatives to reach reference levels (42.5%) in 20 and 10 years respectively. Meadowbrook is expected to have a faster response due to the high densities of chironomid flies that can be expected to quickly colonize the emergent marsh habitat. The terrestrial arthropod assemblage will be most abundant and diverse in the Meadowbrook alternative because it represents the greatest variety and area of habitat that is connected to the river. Invertebrates produced in the emergent marsh habitat could be dispersed through the site via aquatic or wind driven drift and these taxa would include important salmon prey items such as chironomids, mayflies, and stoneflies.

After summing the result of habitat scores and acres for each alternative the final result is that the Towne Road alternative would yield a habitat gain of 50.8 over no restoration and the Meadowbrook alternative would yield a gain of 82.8 over no restoration.

Table 4. Summary of benefits analysis after 50 years with scores for B-IBI and Terrestrial Invertebrates.

	Acres	BIBI score	Terrestrial inverts score	Habitat Units
Towne Road Project				
Mainstem		.76	-	
Side channel	10	.76	-	7.6
Back channel	2	-	1	2
Vegetated Terraces	11.9	-	1	11.9
Emergent marsh	6	-	1	6
Other plantings	5.5	-	1	5.5
Additional habitat	34.6	-	1	34.6
total acres	**70**			**67.6**
Towne Road – no action				
Mainstem		.76		
total acres	**70**		.24	**16.8**
Net habitat gain from Towne Road project				**50.8**
Meadowbrook Project				
Mainstem		.76		
Side channel	10	.76		7.6
Back channel	3	-	1	3
Vegetated Terraces	18	-	1	18
Emergent marsh	13	-	1	13
Other plantings	10	-	1	10
Additional habitat	66	-	1	66
total acres	**120**			**117.6**
Meadowbrook – no action				
Mainstem		.76		
total acres	**120**		.29	**34.8**
Net habitat gain from Meadowbrook project				**82.8**

Note: Due to the intermittent wetted condition of the back channels, the terrestrial invert score for emergent marsh areas was also applied to the back channel acreage.

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Appendices

Appendix A. Species list for B-IBI. Taxa are listed in decreasing order of abundance within each grouping.

Order	Taxa
Coleoptera	Narpus, Heterlimnius, Elmidae
Diptera	Chironomidae, Dicranota, Antocha, Tipulidae, Hesperoconopa, Clinocera, Hexatoma, Simulium, Empididae
Ephemeroptera	Baetis tricaudatus, Cinygma, Serratella tibialis, Epeorus deceptivus, Rhithrogena, Cinygmula, Epeorus longimanus, Ameletus, Drunella flavilinea/coloradensis, Attenella delantala, Acentrella turbida, Baetidae, Drunella doddsii
Plecoptera	Sweltsa, Skwala, Kogotus, Chloroperlidae, Zapada cinctipes
Trichoptera	Hydroptilidae, Glossosoma, Rhyacophila Angelita Group, Hydropsychidae, Micrasema, Limnephilidae, Rhyacophila Brunnea/Vemna Group, Hydropsyche
non insect	Oligochaeta, Acari, Nematoda, Piscicola salmositica, Polycelis coronata, Turbellaria

Appendix B. Descriptions of biological condition associated with B-IBI scores for Puget Sound region. From Morley 2000.

Biological Condition	B-IBI Range	General Description
Excellent	46-50	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddisflies, long-lived, clinger, and intolerant taxa. Relative abundance of predators high.
Good	38-44	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddisflies; proportion of tolerant taxa increases.
Fair	28-36	Total taxa richness reduced - particularly intolerant, long-lived, stonefly, and clinger taxa. Relative abundance of predators declines; proportion of tolerant taxa continues to increase.
Poor	18-26	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high.
Very Poor	16-Oct	Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddisfly, clinger, long-lived and intolerant taxa largely absent. Relative abundance of predators very low.

Appendix C. List of all orders captured in fallout traps. Families represented are in alphabetical order.

Order	Suborder	Families present
Acari		
Araneae		
Hemiptera	Auchenorrhyncha	Cercopidae, Cicadellidae, Delphacidae
	Heteroptera	Lygaeidae, Miridae, Nabidae
	Sternorrhyncha	Aphididae, Coccoidea, Psyllidae
Coleoptera		Carabidae, Corylophidae, Hydrophilidae, Silphidae, Staphylinidae
Collembola		Entomobryiidae, Isotomidae, Sminthuridae
Dermaptera		
Diptera		Athericidae, Calliphoridae, Cecidomyiidae, Ceratopogonidae, Chironomidae, Chloropidae, Dolichopodidae, Empididae, Oestridae, Phoridae, Psychodidae, Sphaeroceridae, Stratiomyidae, Tabanidae, Tipulidae
Ephemeroptera		Baetidae
Gastropoda slug		
Hymenoptera		Chalcidoidea, Formicidae, Ichneumonidae
Lepidoptera		
Odonata		Coenagrionidae
Opiliones		
Psocoptera		
Thysanoptera		
Trichoptera		
Isopoda		Oniscoidea