City of Bainbridge Island,
SMA Grant Agreement
No. G1000036

City of Bainbridge Island
Addendum to the Summary of Science Report

Task 2.B

January 2011

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This report was funded in part through a grant from the Washington Department of Ecology.

ADDENDUM TO SUMMARY OF SCIENCE REPORT

Bainbridge Island

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January 26, 2011

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Glossary

Accretionary shoreform – Low-lying areas along the shoreline that consist of accumulated drift. Accretionary shoreforms are common on Bainbridge Island.

Anthropogenic – Caused either directly or indirectly by human activity.

Beach face – The steep part of the beach that is generally composed of gravel, although it can contain sand or even boulders. It is the most sedimentologically active portion of the nearshore.

Beach transect – A profile of elevations perpendicular to the shoreline.

Downdrift – In the direction of dominant alongshore sediment transport.

Fetch – The distance over which the wind blows to generate a given wave field.

Low-tide terrace – A broad, flat portion of the nearshore that extends from a few feet above to a few feet below MLLW. The low-tide terrace is finer grained that the beach face above it. In Coastal Drainage Areas 2 and 3, the low-tide terraces are composed primarily of mud.

Mean higher-high water (MHHW) – The average elevation of the two high tides in each day over a tidal epoch (19 years).

Mean lower-low water (MLLW) – The average elevation of the two low tides in each day over a tidal epoch (19 years).

Nearshore – In the context of Bainbridge Island, the nearshore is the area of marine and estuarine shoreline. It generally extends from the top of shoreline bank or bluff to the depth offshore where light penetrating the water falls below a level supporting plant growth, and upstream in estuaries to the head of tidal influence. It includes bluffs, beaches, mudflats, kelp and eelgrass beds, salt marshes, gravel spits, and estuaries.

Puget Lowland – The low area between the Olympic and Cascade Mountain ranges.

Puget Sound – All marine water contained south and east of Admiralty Inlet and Deception Pass.

Salish Sea – Broadly defined as the confined body water inland from Cape Flattery, including Puget Sound, the Strait of Juan de Fuca and the Strait of Georgia.

Seattle Fault Zone – The Seattle Fault Zone is broadly defined by a series of east-west trending faults (including the Toe Jam Hill Fault and Macs Point Fault) that cross the southern end of Bainbridge Island.

Swell – Long period waves originating from distant open-ocean wind storms.

Swash – The area on the shoreline that interacts with the water surface. Swash is typified by a series of bores that propagate up and down the beach.

Updrift – In the direction opposite of dominant alongshore sediment transport.

Vashon Stade – The time period between 20,000 and 13,000 years before present of glacial inundation of the Puget Lowland at the end of the last ice age.

1.0 Introduction

1.1 Purpose and Scope

This addendum augments the City of Bainbridge Island's existing *Summary of Best Available Science* prepared by Battelle dated October 2003 in support of the City of Bainbridge Island's (the City) Shoreline Master Program (SMP). The purpose of this addendum is to provide updated information on shoreline and nearshore ecology, physical processes, habitats, and biological resources of Bainbridge Island to assist with the City's SMP update. Based on the information presented in the Battelle (2003) report, and the purpose of this addendum, other key documents were specifically included in the review for this update. These documents include:

- Bainbridge Island Nearshore Habitat Characterization & Assessment, Management Strategy Prioritization, and Monitoring Recommendations (Williams et al. 2004)
- Marine and Estuarine Shoreline Modification Issues (Williams and Thom 2001)
- Living with the shore of Puget Sound and the Georgia Strait (Terich 1987)

The addendum offers a discussion and guidance on no net loss which is the standard the City is expected to meet to be in compliance with the Shoreline Management Act, and recommends general guidance for developing and monitoring a no net loss program.[1] In addition, the addendum provides information from recent scientific studies and current thinking on four specific topics relevant to the City's land use planning and shoreline development policies and practices, three relating to types of shoreline modifications. These topics were specifically covered at the request of the City and are:

- The ecological and functional impacts of shoreline stabilization structures and no net loss
- The ecological role of riparian vegetation in the marine shoreline environments and no net loss
- The effects of development on habitat in the shoreline zone, particularly residential development

[1] No net loss is not explicitly defined in the Shoreline Management Act however, Washington State Department of Ecology defines it as follows: Over time, the existing condition of shoreline ecological functions should remain the same as when the SMP is implemented. It is a standard designed to avoid new adverse impacts to shoreline ecological functions resulting from new development. (See *http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/Chapter4.pdf*)

- Recommendations for marine shoreline protective buffers considering geomorphic conditions and shoreline vegetation

The addendum was prepared using the most current, accurate and complete scientific and technical information, peer-reviewed research, best available science summaries, technical literature, and other scientific information related to shoreline and nearshore resources and functions. For the purpose of this document, scientific and technical information was defined according to the criteria provided by the Washington State administrative code (WAC) 173-26-201(2)(a). Information sources used in this review of science are listed in Section 6.0 *Literature Cited* of this document.

Recent science addressing the effects of the three types of nearshore modifications listed above (three first bullets) was analyzed. The approach to this analysis was primarily process-based, involving an examination of existing conditions as well as an assessment of human modifications. Physical processes lead to the formation of recognizable and classifiable geomorphic features that are then colonized by biota. Therefore scientific literature involving all aspects of shoreline processes and ecology relevant to the Puget Sound, in particular the main basin and Dyes Inlet and related passages, were examined. These shoreline processes were placed within the context of a limited set of human modifications that were identified by the City. Finally, the effects of human modifications were assessed by comparing such modifications to similar land-use practices and their related impacts to the marine nearshore environment found in the Salish Sea of Western Washington, or comparable environments elsewhere.

This review begins with a summary of science related to the physical conditions, habitats and biological resources of Bainbridge Island. It is followed by a discussion of no net loss related to effective shoreline management and general guidance for implementing a no net loss program in the City. Recent science addressing the effects of the three types of nearshore modifications listed above is discussed and suggestions for mitigation that can assist the City in achieving no net loss for associated impacts are provided. The report then summarizes recent science related to buffers recommended for protecting marine shoreline and nearshore ecological functions. Figure 1 provides a map indicating nearshore geography, streams, and locations referred to in this report.

Figure 1. Nearshore geography of City of Bainbridge Island.

2.0 Nearshore Areas of Bainbridge Island

The focus of this analysis is to present information not included Battelle (2003) either because the topic was not covered in the original analysis or because new work has been published since 2003. The conceptual ecological model used in Battelle (2003) (based upon Williams and Thom 2001) is fully consistent with recent scientific literature. However, some impacts that were previously only hypothesized in Battelle (2003), have now been formally documented in the peer-reviewed literature.

The nearshore analysis is broken into two parts. The first part focuses on the general physical environment of Bainbridge Island, with particular emphasis on the effects of climate change, which was not discussed in Battelle (2003). The second part addresses specific environments on the island, which are delineated by a new method that characterizes shorelines based on geomorphological conditions. This section also includes environments not addressed by Battelle (2003), such as rocky coasts. Both of these sections provide the physical template used for the analysis of the ecological impacts of human activities.

2.1 Physical Environment

2.1.1 Climate

The climate of Bainbridge Island is maritime and typified by cool dry summers and wet winters. The background climatology of the island is well characterized by Battelle (2003). However, there has been a large volume of recent scientific literature addressing climate change and its impact on the Pacific Northwest within the last few years. Climate change has been shown to increase stream temperatures (particularly in the summertime: Mantua et al. 2010), compromise habitat restoration actions (Battin et al. 2010), change the hydrology of stream basins (Elsner et al. 2010), and increase sea level (Canning 2005; Mote et al. 2008). Altered seasonal rainfall and effects on streamflow patterns and increased stream temperatures (Mantua et al. 2010) are likely to have significant effects on Bainbridge Island. Other effects, such as reduction in snowmelt, are expected to be negligible as alterations to basin hydrology attributed to snowmelt cited by recent climate change studies are dependent on seasonal changes to the transition from spring snowmelt to fall runoff typical of Cascadian rivers (Elsner et al. 2010). Since snowmelt is a negligible contributor to stream flow on Bainbridge, snow-based hydrologic effects are expected to be inconsequential on the island.

It has been shown that total precipitation will increase by the 2040s in the Puget Lowland, but this precipitation will fall increasingly in the winter, resulting in reduced summer precipitation and therefore lowering summer streamflow (Elsner et al. 2010). Because most of the work done on climatic effects on streamflow hydrology has been focused on the larger rivers that still tap snowmelt in a significant way (Elsner et al. 2010, Mantua et al. 2010, Battin et al. 2010), the influence of changing precipitation resulting from climatic change on the small streams on Bainbridge Island is uncertain.

Sea level rise is produced by the combined effects of global sea level rise and local factors, such as vertical land deformation (e.g., tectonic movements) as well as seasonal seawater surface elevation changes due to atmospheric circulation effects (Mote et al. 2008). In the case of Bainbridge Island, there is slight tectonic subsidence (Verdonck 2006), which somewhat increases the overall effect of global sea level rise (Canning 2005; Mote et al. 2008). This explains the relatively modest sea level rise observed at nearby Seattle in the twentieth century (2.06 mm/year: NOAA 2010), which would be indistinguishable from sea level rise observed on the island. It is important also to couch these changes in terms of interannual sea level variability associated with El Niño. Mojfeld (1992) has shown that during El Niño years the average water level can be up to one foot higher than in ordinary winters. This explains why (in light of sea level rise) the highest ever water level in Seattle was recorded in the early 1980s (NOAA 2010). It is unclear whether, and how, this particular effect will change in the future.

2.1.2 Waves and Currents

The overall oceanographic context of Bainbridge Island is well summarized by Battelle (2003). However, two recent observational studies have better documented conditions within Puget Sound and on the island (Finlayson 2006; Curtiss et al. 2009). As hypothesized in Battelle (2003), waves are the dominant mode of sediment transport alongshore for most of the County's shorelines (Finlayson 2006; Curtiss et al. 2009). It is likely that in areas where tidal currents are in excess of one knot or where vessel wakes are large (e.g., Rich and Agate Passage), tides and vessel wakes may play a secondary role (Curtiss et al. 2009). However, for most of the island, waves are generated exclusively by local winds, just as they generally are within the confines of Puget Sound (Finlayson 2006). As documented by these studies, the short-period, locally generated waves typical along the shores of Bainbridge Island are steep and can generate significant local shear stress (a physical process that strongly influences sediment transport), but these waves do not penetrate far down into the water column. This is important because any man-induced alteration of the wave's characteristics by the placement of structures along the shoreline could potentially affect the way sediment is transported although generally only along the portion of the shoreline where the influence of the waves is felt, due to reflected and refracted wave energy. For a full discussion of the physical impacts of shoreline armoring, see Section 5.1.1.

2.1.3 Geology

Geology was not addressed in detail by Battelle (2003), partly because much of the work characterizing the geology of Bainbridge Island has been published since 2003 (i.e., Nelson et al. 2003a; Hagerud 2005; Kelsey et al. 2008; MacLennan 2010). In particular, the Seattle Fault Zone, which crosses the southern end of the island, has recently been the subject of intense study. The geophysical origin of the fault system is related to north-south shortening of the Cascade forearc (Wells et al. 1998). Uplift along the Seattle Fault Zone has displaced Eocene rocks 8 to 10 kilometers higher than similar rocks underlying the Seattle Basin and Bainbridge Island to the north (Blakely et al. 2002). Nelson et al. (2003a) identified the Toe Jam Hill Fault as a north-dipping backthrust of the Seattle Fault Zone. The recurrence of slip on the Toe Jam

Hill fault has also been investigated by trenching the surface expression of that fault, which is apparent in LIDAR (Nelson et al. 2003a). The potential for blind thrusts (i.e., faults that do not have a surface expression) to be related to the Seattle Fault Zone has been investigated by Kelsey et al. (2008). This work found that blind thrusts are likely associated with the fault zone and interact with the surface faulting over geologic time scales. The locations of potential blind faults cannot be predicted until they break the surface, thereby imposing a seismic hazard uncertainty within the Seattle Fault Zone, south of Winslow.

In addition to these focused studies on the Seattle Fault Zone, the overall geology of the island was recently mapped and described by Hagerud (2005). As is typical of high-resolution geologic maps (i.e., 1:24,000 maps), a narrative description of the recent geologic history is provided, including the most recent glacial advance and its relationship to underlying sedimentary deposits and bedrock. MacLennan et al. (2010) mapped the feeder bluffs throughout the island, and Hagerud (2005) and MacLennan et al. (2010) describe the site specific details of shoreline geomorphology throughout the island, which is useful for understanding the geologic context of human modifications and their impact on the nearshore environment.

2.2 Nearshore Classification System

Battelle (2003) did not use any formal geomorphic classification scheme, but rather organized their literature around common island shoreforms (e.g., spits, marshes, etc.). Williams et al. (2004) used a geomorphic classification system based upon Terich (1987) to characterize all Bainbridge Island shorelines. A classification system was recently assembled by Ecology to reflect the most recent advancements in nearshore geomorphology (Shipman 2008). The Shipman (2008) classification scheme is hierarchical, with geomorphic systems comprised of different landforms, which each have a set of components. Shipman (2008) points out that this is the most effective means to identify the impacts to species from physical modifications. The new classification scheme is nearly identical and broadly consistent with Terich (1987); in fact, this earlier work was used as a template for the more recent, broader effort. However, because Battelle (2003) used somewhat different terminology than Shipman (2008), it is important to link the shoreline types developed in the Williams et al. (2004) characterization with the geomorphic systems in the new classification scheme. Table 1 summarizes how these two classification schemes interrelate.

Shipman (2008) divides Puget Sound shorelines into four broad geomorphic systems: 1) rocky coasts, 2) beaches, 3) embayments, and 4) large river deltas. Bainbridge Island has a relatively limited amount of rocky coast, but there are some shorelines that exhibit these characteristics along the southern edge of the island within the Seattle Fault Zone. Rocky coasts were not discussed in Battelle (2003), so a complete characterization is covered in this addendum.

Beaches and embayments are common on Bainbridge Island shorelines. Although these environments were addressed by Battelle (2003), updates of the latest science are provided for these areas because of their relative importance and the quantity of research that has been

conducted since 2003. Finally there are no large river deltas on Bainbridge Island, but there are a number of small creek deltas. Smaller creek deltas were addressed by Battelle (2003), but because of the relative lack of more recent research about them, they are not treated in depth in this addendum.

Table 1. Comparison of the nearshore geomorphic classifications schemes used by Shipman (2008) and Terich (1987).

Primary Document	Williams et al. (2004)	This Study
Geomorphic classification scheme	Terich (1987)	Shipman (2008)
Geomorphic systems (shoreline types)	Rocky	Rocky coast
	Marshes/lagoon	Embayment
	Spit/barrier/backshore	Beach
	Low bank (and beach)	
	High bluff (and beach)	

2.3 Nearshore Geomorphic Systems

The following nearshore geomorphic systems are those described by Shipman (2008) (see Figure 2). Only those nearshore geomorphic systems with substantial occurrence on the island are included along with discussions of scientific advances made since 2003.

2.3.1 Rocky Coasts

Rocky coasts are relatively rare on Bainbridge Island, but they represent an important environment at the southern end of the island within the Seattle Fault Zone. Shipman (2008) identified three landforms that typically occur along rocky coasts in Puget Sound: 1) plunging, 2) platform, and 3) pocket beaches. Plunging shorelines are virtually non-existent on Bainbridge Island, with the possible exception of a few small promontories at the east end of the Seattle Fault Zone. Most of the rocky coasts on Bainbridge Island are a hybrid of the platform and pocket beaches described by Shipman (2008). In particular, there is a bedrock platform along the southern shoreline of the island that was formed by the uplift associated with the most recent earthquake on the Seattle Fault Zone (Nelson et al. 2003a). This platform was the Holocene bench formed from wave erosion prior to the earthquake. As a consequence, the shoreline in this area is classified as a platform rocky shoreline. However, there is a modest amount of coarse substrate remaining on the upper beach (above the mean tide level) that forms a coarse sediment beach face throughout this area. These coarse sediment beach faces are continuous along the southern shoreline; therefore, they are not strictly pocket beaches since they are not contained within a “pocket” of bedrock.

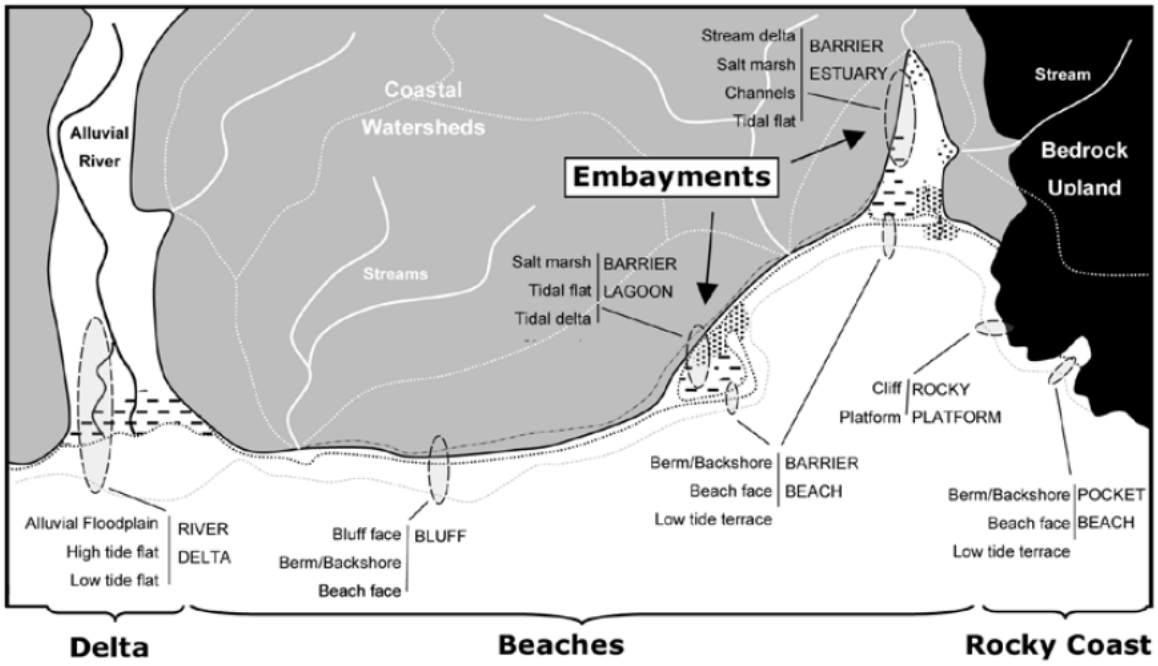

Figure 2. Coastal landforms typical of Puget Sound as identified in Shipman (2008).

Because of this, some of these areas were interpreted by Williams et al. (2004) to be barrier beaches. However, they likely behave similar to smaller, localized pocket beaches in that they are sediment starved and limited in vertical extent. Sediment transport is dominated by waves, but locally enhanced by strong tidal flows and boat and ferry traffic in the area (Curtiss et al 2009).

Habitat on rocky coasts is distinctly different than the more common sediment-rich shorelines in Puget Sound. Not only do rocky coasts lack the substrate required for a variety of habitat types (e.g., sand lance and surf smelt spawning), but the resident invertebrate and plant communities are also different. Key indicator species (species that can indicate physical, chemical, and biological habitat conditions) for rocky intertidal environments include rockweed (*Fucus gardneri*) (Jenkins et al. 2002) and bull kelp (*Nereocystis luetkeana*) (Battelle 2003). For example, kelp species require, and are indicative of, rocky (or otherwise coarse) substrates with low sedimentation levels. Physical habitat can be influenced by kelp presence as it creates structure for numerous organisms, providing nursery, foraging, and refuge opportunities. Kelp forests also contribute to the food web as a source of direct consumption and through the addition of carbon in the form of detritus (Mumford 2007). For a full discussion of kelp and its role in enhancing nearshore productivity, see Section 3.1.3. Invertebrates including limpets and barnacles are also common on rocky coasts; however, these smaller creatures do not generally create physical habitat structure to the same extent as macroalgae communities.

Rockweed communities have been shown to be prone to human disturbance in the Salish Sea (Jenkins et al. 2002). Even barnacles have been shown to be impacted negatively by pedestrian traffic (Brosnan and Crumrine 1994). Unlike mixed sediment beaches, mud flats and salt

marshes, which can be difficult to traverse, rocky coasts can often be easy to travel across, encouraging disturbance and potentially heightening the impacts of trampling. Kelp was identified as key indicator species by Battelle (2003) and more recent research is discussed further in Section 3.1.3 *Kelp Forests*.

2.3.2 Beaches

Beaches are by far the most common nearshore environment on the island. Shipman (2008) identifies two landforms associated with beaches: bluffs and barriers. Because these landforms have been studied independently, they are addressed individually in the subsections below.

Bluffs

Battelle (2003) describes the importance of bluffs, particularly the presence of landsliding, as a key aspect of the shoreline ecosystem through the delivery of large woody debris (LWD) and sediment to the nearshore. Landsliding is used to describe any type of downslope sediment transport due to slope instability. On Bainbridge Island, there are significant feeder bluffs (i.e., actively eroding and landsliding bluffs); however, bluffs in equilibrium with the shoreline and depositional shorelines (i.e., barrier beaches) are more common (Williams et al. 2004). A complete high-resolution catalog of landsliding was not available at the time of Battelle (2003), however, since that time, a geologic map of the City has been developed by Hagerud (2005). This map documents all of the landslide deposits on the island at a higher resolution than existed before. This map provides not only a record of existing geologic hazards, but also a record of past nearshore disturbance which can have legacy effects on nearshore ecology. MacLennan et al. (2010) have further documented bluff shorelines, particularly as they contribute sediment to the nearshore (i.e., feeder bluffs), using a methodology that has been applied to numerous areas throughout Puget Sound.

Barriers

Barriers (or barrier beaches), as defined by Shipman (2008), represent the most common landform along the Bainbridge Island shoreline. Because of their commonality throughout the region, they have been the subject of considerable research within the last few years, including some work that has occurred on the island. The two most relevant research studies on Puget Sound barrier beach dynamics are Finlayson (2006) and Curtiss et al. (2009). These efforts, which are both peer-reviewed and complementary in terms of approach, refine the more generic description provided in Battelle (2003). Both of these efforts had some portion of the research work performed on Bainbridge Island shorelines.

Finlayson (2006) examined a number of factors that influence the geomorphology of Puget Sound beaches and their nearshore ecology. His work highlights the complexity and mobility of sediment transport on Bainbridge Island shorelines. Finlayson (2006) is an amalgam of three different, complementary studies, along with a review of the literature describing Puget Sound beaches to date. The literature documents the relative uniqueness of the Puget Sound beaches.

The literature review found several factors that make Puget Sound shorelines an unusual physical setting:

- *Low energy* –Swell is precluded from the interior of Puget Sound, including all of Bainbridge Island. As a result, swash dominates transport. The waves that do interact with the shoreline are highly dependent on shoreline aspect and fetch because of the convoluted shoreline.

- *Large tide range* – The tide range in Puget Sound is large relative to most of the world's coasts. The tide-height distribution is also skewed, meaning that the median tide elevation is significantly higher than the average elevation. This, in combination with small wave heights leads to a concentration of wave energy on the highest portion of the beach. This gives rise to a well-defined, coarser upper beach (beach face, or in the terminology of Finlayson [2006], foreshore) and a broad, fine-grained lower beach (low-tide terrace).

- *Steep antecedent topography* – The post-glacial surface throughout the island is steep at the elevation of the modern shoreline. This leads to a convoluted coast with most of the shorelines being dominantly erosional. The erosional shorelines are backed by steep bluffs of glacially derived sediment. Depositional (or accretionary) shorelines are often comprised of sediments from adjacent shorelines.

- *Diversity in sediment supply* – Most Puget Sound shorelines have a diversity of sediment types available both from adjacent bluffs and from small local seasonal creeks. This leads to barrier beaches with a large size diversity of sediment, otherwise called mixed sediment beaches. This has ramifications for the mobility of sediment and groundwater interactions. The diversity of sediment is somewhat reflected in the cross-shore distribution of sediment into two distinct zones: a coarser steeper beach face and broad, finer low-tide terrace.

The first study within Finlayson (2006) was an investigation of beach shape (beach face slope, low tide terrace slope) and structure (sediment size) as it relates to forcing variables (proximity to a riverine sediment source, fetch and predicted wave variables). Finlayson (2006) analyzed the correlation of the geomorphic features on 23 beaches throughout Puget Sound, including at Fay Bainbridge State Park and Fort Ward State Park on Bainbridge Island, using a cluster analysis called AGNES. He found that there was limited statistical correlation between the various parameters, arguing that antecedent geology played a more crucial role in setting than modern environmental parameters. Further evidence of this was found subsequent to the publication of the thesis, which correlated the break in beach face and low-tide terrace slopes to the presence of and distance from local fluvial sediment supply (David Finlayson, personal communication).

In his second study, Finlayson (2006) documented beach change for more than two years through repeated surveys of Cama Beach on Camano Island, Washington (See Figure 3).

Figure 3. Photograph of Cama Beach where a bulkhead was constructed on an accreting beach. Note upland vegetation (red alder) growing in front of the bulkhead.

Change was observed between many of the observation events, particularly on the uppermost portion of the beach; however, the net change over the entire time period was small. Change below the beach-face-low-tide-terrace transition was always negligible. Sediment transport direction was highly seasonal, with sediment moved northward during the winter and southward during the summer. This differs from the classic description of Puget Sound drift cells and unidirectional transport. Transport was also highly variable in time, with only the strongest wind storms producing significant erosion and deposition, which typically occur in the wintertime. Erosion in the largest event was significant at the toe of a seawall in a particular area (approximately two vertical feet), though recovery was nearly complete after about a year. Since the study, the wall failed in this area and was replaced.

In the final analysis of Finlayson (2006), waves were modeled with a recent two-dimensional wave model using a time series of observed winds and compared to the presence of eelgrass along a three-mile long reach near Lofall, Washington, to determine the influence of wave energy on eelgrass. Despite significant variability in the eelgrass population along the reach, modeled wave disturbance was not correlated to eelgrass presence. Along with the earlier literature review, this led to the hypothesis that wave-induced shear stress is concentrated high on the beach (in the beach face, near MHHW) and eelgrass is controlled by other factors, such as water quality. It also supports the hypothesis that the low-tide terrace and the beach face are

sedimentologically distinct. The beach face, dominated by swash from local wind-waves, transports coarse bluff-derived sediment, while the low-tide terrace, dominated by a combination of waves and currents, transports sand and mud (though much less actively) derived from bluffs and local streams. Dominant net transport in the beach face and low-tide terrace need not be in the same direction owing to the different forces acting on them.

Curtiss et al. (2009) tracked sediment using radio-frequency identification (RFID) tags to track gravel on Point White on Bainbridge Island for nearly a year. They point out that from a sedimentological point of view; the beaches at Point White are similar to Cama Beach. However, Point White lacks the northern exposure found at Cama Beach, and even the fetches to the south are much smaller. As a result they found significant transport only in the winter – and only to the northeast. During the summer, transport was less and more random, implicating the increased importance of tides and vessel wakes during this time period. At Cama Beach, tides were not significant, but it is likely that tides influence a portion of Bainbridge Island shorelines, particularly throughout Rich Passage in the south and Agate Passage in the north. Although the beaches were all backed with bulkheads, Curtiss et al. (2009) made no attempt to assess the influence on the physical processes imposed by the bulkheads.

These works highlight the complexity and mobility of sediment transport on Bainbridge Island shorelines. The traditional notion of drift cells as outlined by Battelle (2003) is helpful in certain contexts, but transport is commonly bi-directional, even in areas protected from certain kinds of waves (Curtiss et al. 2009). Finlayson (2006) also highlights the physical processes altered by those features, which can have ecological consequences. Alterations to physical processes from these features are discussed in Section 5.1.1.

2.3.3 Embayments

The convoluted nature of Puget Sound shorelines and the limited sediment supply mean that there are many embayments along Bainbridge Island. These features were originally classified in Williams et al. (2004) as marshes and lagoons. Shipman (2008) identified four different landforms associated with embayments: open coastal inlets, barrier estuaries, barrier lagoons, and closed lagoons and marshes.

Embayments are key features in the Pacific Northwest landscape that produce physical and habitat complexity for a variety of organisms. In particular, pocket estuaries, a particular type of embayment, have been recently identified as important habitat type for juvenile salmonid survival and recovery. Strictly speaking, Shipman (2008) would classify a pocket estuary as a barrier estuary. However, there has been documentation of other landforms typical of embayments in Puget Sound performing the same habitat function as a barrier estuary (e.g., Ala Spit, an open coastal inlet: Beamer 2007, Herrera 2008a). The geomorphic context of Bainbridge Island means that all embayments delineated in Williams et al. (2004) as “marsh/lagoons” have the habitat attributes of pocket estuaries.

Generally speaking, pocket estuaries are typically tidally influenced, protected areas with fringing unvegetated flats, saltmarsh and tidal channels although they do not necessarily need to have extensive marshes associated with them. For instance, Hidden Cove likely meets most of the criteria set forth for pocket estuaries producing physical conditions similar to other pocket estuaries, though marshes in this area are relatively rare and the marshes, where they do occur, are not protected by barrier beaches. A considerable body of work has been developed since Battelle (2003) that has demonstrated the importance of these features to native salmon populations by documenting utilization and prey items, particularly during the juvenile life stage (Beamer 2003, 2005, Puget Sound Action Team 2005). Most of this work has been done in northern Puget Sound by the Skagit River System Cooperative, but it is expected that is generally applicable other similar environments in Puget Sound at large (Puget Sound Action Team 2005).

Juvenile Chinook salmon, along with other juvenile salmonids, are known to utilize pocket estuaries (Beamer et al. 2003, 2005, Puget Sound Action Team 2005). All Chinook utilizing pocket estuaries must find them via migration because typically the freshwater source is too small to support resident salmon. Although Bainbridge Island does not contain Chinook bearing streams, several other salmon bearing streams are present (Dorn and Best 2005) and eight species of salmon are known to use the nearshore habitat of Bainbridge Island (Battelle 2003).

Another species typical of Bainbridge Island embayments is pickleweed (*Salicornia virginica*). Pickleweed is a common plant of protected intertidal areas in Puget Sound, and is often used to delineate the ordinary high water mark in intertidal areas. Abrasion from sand and gravel often precludes it from most beach settings, but in areas where protection from waves is significant, pickleweed is common and therefore considered an indicator of pocket estuary habitat that is important to and likely used by sensitive species such as juvenile salmon.

The most significant and common impact to embayments has been shoreline modifications (see Section 5.1.1). Bainbridge Island's shoreline is already heavily modified (approximately 51 percent) (MacLennan et al. 2010), primarily by bulkheads (49 percent, R. Ericson, City of Bainbridge Island, personal communication with A. Azous, Herrera Environmental Consultants, December, 1, 2010) but also by significant fill and seawalls in former industrial areas (MacLennan et al. 2010). Armoring adjacent to marsh areas has been shown in similar settings to negatively affect the persistence and quality of habitat features by changing natural patterns of erosion and deposition (Bilkovic and Roggero 2008). Therefore proximity to an embayment, as well as to other sensitive habitats such as salmon streams or aquatic vegetation, is an important factor in determining the environmental impact of a particular bulkhead installation. Impacts can be most significant when armoring is placed near the MHHW elevation or below on the beach, and in moderate or high energy environments (MacLennan et al. 2010). Therefore, these conditions should also be considered in evaluating the potential or likely impacts of bulkhead placement.

3.0 Nearshore Biological Resources

3.1 Selected Vegetation Communities

3.1.1 Marine Riparian Zones

Considerable work has been undertaken since 2003 to understand the role of marine vegetation in the nearshore ecology of the Salish Sea (Brennan and Culverwell 2004, Romanuk and Levings 2006, Herrera 2007a, 2007b, Romanuk and Levings 2010, Sobocinski et al. 2010). Most of this work is described in detail in Section 5.2 *Marine Riparian Vegetation Modifications*.

3.1.2 Eelgrass Meadows

Eelgrass meadows are one of the most important aquatic vegetation habitats that occur along beaches in Puget Sound. The native eelgrass, *Zostera marina*, covers an estimated 9 percent of Puget Sound below mean lower low water (MLLW) making it an important plant community in the region (Nelson and Waaland 1997). Eelgrass is important cover for juvenile fish and invertebrates (Phillips 1984). Eelgrass also provides a necessary structural surface for a community of epibenthic organisms, making eelgrass communities one of the most productive ecotones in the Pacific Northwest (Ferraro and Cole 2007). Marine littoral vegetation is important for the colonization of organisms that are key prey resources for other species. Eelgrass provides both physical structure and trophic support for the biological community, and is nursery habitat for many sensitive species including salmon (Murphy et al. 2000, Mumford 2007, Bostrom et al. 2006). Native eelgrass has declined in Hood Canal and locations throughout the Puget Sound Region (Puget Sound Action Team 2007), but more information on eelgrass decline in Puget Sound is needed since historic and current data is limited (Essington et. al. 2010).

Bainbridge Island Occurrence

Eelgrass occupies an estimated 18.7 miles of Bainbridge Island shoreline (Washington State Department of Natural Resources 2001 as reported in Battelle 2003). Eelgrass is dominant along the northwestern, northern and eastern shorelines, and notably absent along the western shoreline from south of Battle Point north to Point White (Battelle 2003). No updated data for eelgrass occurrence along Bainbridge Island were available and the Coastal Atlas (Ecology 2010a) showed the same eelgrass beds as the map presented in Battelle (2003), except an eelgrass bed was shown to occur within the Point Monroe lagoon that was not identified in the Battelle report.

Habitat

Eelgrass beds commonly form near MLLW, but range from about two meters above MLLW to nine meters below MLLW. The depth to which eelgrass grows is determined mainly by water clarity (Mumford 2007). Factors including extremely low or high nutrient levels, substrate

composition, presence of algal species such as sea lettuce (*Ulva* spp.), and pollutants in the water can affect eelgrass distribution and abundance (Mumford 2007).

Threats

No specific data for Bainbridge Island were available regarding the potential change in eelgrass bed density or extent. Eelgrass loss, in general, is widely attributed to shading and disturbance caused by construction and activities associated with shoreline development such as overwater structures (docks and moorages), and direct substrate disturbance from dredging and filling (Mumford 2007, Fresh et al 2006, SSPS 2007); and these likely pose a current and future risk related to development activities on the island's shoreline.

Although bulkheading is frequently assumed to affect eelgrass bed occurrence, Finlayson (2006) demonstrated in northern Hood Canal that bulkheads did not have a statistically significant impact on eelgrass populations. His project area had numerous small streams that contributed to the sediment supply that may have reduced the impact of bulkheading on the substrate of the low-tide terrace, where eelgrass occurs. Along Bainbridge Island shorelines the potential effects of bulkheading on eelgrass may depend on several factors including whether localized sediment sources (e.g. stream vs. feeder bluffs) are present and how the bulkhead impacts wave energy, substrates or other environmental conditions. Although direct links between eelgrass loss and bulkheading have not been demonstrated conclusively, the linkage is likely in certain settings.

Human activities on shore, such as agriculture (which can increase pollutants in stormwater runoff), as well as vessel activity that results in boat propeller scour and impacts on water quality, are also potential contributing factors that are common throughout Puget Sound (Mumford 2007, SSPS 2007). Water quality degradation has also been implicated in eelgrass declines. In situations where there are excessive nutrients, algal species such as sea lettuce will overgrow eelgrass (Mumford 2007). Excessive nutrients also can cause overgrowth by epiphytes associated with eelgrass on the blades, blocking light, nutrients and gas exchange (Mumford 2007).

3.1.3 Kelp Forests

Kelp is associated with rocky coasts because they attach to rocky substrate and create habitat structure along these shorelines. Kelps are commonly divided into two categories – floating and non-floating varieties. Floating kelps including bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*) are found adjacent to approximately 11 percent of Washington's shoreline (Mumford 2007). The smaller, non-floating kelps such as soft brown kelp (e.g., *Laminaria* spp.) or chocolate brown kelp (e.g., *Hedophyllum* spp, *Lessoniopsy* spp.) are not easily monitored or mapped because they are often not readily visible in aerial photographs (EnviroVision et al. 2007). However, non-floating kelps are more widely distributed and more abundant than the floating varieties, and are found along approximately 31 percent of the state's shoreline. In Kitsap County non-floating kelp is found along 21 percent of the shoreline areas, while floating kelp is only found along less than 1 percent of the shoreline (Mumford 2007).

Kelp forests provide refuge habitat for a number of fish species (Mumford 2007). They provide important habitat for some rockfish species (74 FR 18521). Juvenile and subadult salmon are also known to use habitat created by kelp forests, and depend on many species that are associated with kelp forests for food. Kelp forests provide important food web interactions for sea urchins, herring, crabs, mollusks, marine-associated birds, and a variety of marine mammals including sea otters and whales (Steneck et al. 2002, Carter et al 2007, Mumford 2007, NOAA 2010b). Kelp forests also contribute to the food web as a source of direct consumption and through the addition of carbon in the form of detritus (Mumford 2007). As stated earlier, the habitat structure that is formed by kelp provides physical and biological conditions to support nursery, foraging, and refuge opportunities for sensitive species such as forage fish and salmon.

Bainbridge Island Occurrence

The Battelle (2003) study provided maps from the 2001 WDNR Shorezone Inventory that showed bull kelp beds have been observed at Wing Point on the eastern shore of Bainbridge Island and Point White along the southwestern shore. The Coastal Atlas (Ecology 2010a), which also uses the 1994 to 2000 WDNR Shorezone Inventory data, shows a combination of four types of kelp (bull, giant [floating kelp]; and soft and chocolate brown [non-floating kelp) as patchy areas along Bainbridge Island. The combined floating and non-floating kelp beds that were mapped for the Coastal Zone Atlas in addition to the bull kelp mapped by WDNR in 2001 include Agate Point, the point west of Port Madison Bay, Skiff Point, between Murden Cove and Yeomalt Point, Rockaway Beach, Restoration Point, immediately west of South Beach, two segments along Rich Passage, one small patch at Crystal Springs Beach, and the mouth of Fletcher Bay.

Habitat

Floating kelps are generally found along rocky shorelines in water with high salinity (>25 practical salinity units [psu]), low temperature (<15 Celsius), high ambient light, high wave energy, hard substrate, and minimal sedimentation (Mumford 2007). Most occur in the shallow subtidal zone from MLLW to about 65 feet (20 meters) below MLLW, and prefer high-energy environments where tidal currents renew available nutrients and prevent sediments from covering young plants (Mumford 2007). Floating kelps are not rooted plants, although they have a root-like mass or holdfast that anchors the thallus to the rocky substrate. However, unlike true roots, the holdfasts are not responsible for absorbing and delivering nutrients to the plant.

Non-floating kelp are also found along rocky shorelines but tend to be located in protected low to moderate energy areas that have solid substrate for growth, such as bedrock or rocks as small as pebbles, as well as a variety of artificial substrates such as boat bottoms, floats, docks and mooring buoys and chains (WDNR 2001, Dayton 1985). The non-floating kelp species are found in the lower intertidal and subtidal zones and do not have floats but are raised off the bottom by rigid stipes (examples include *Pterygophora*, *Laminaria complanata*). Other species have short stipes and create a canopy near the bottom, creating cover for a complex understory community of shade-loving, desiccation-intolerant kelp species (examples include *Agarum* spp., *Costaria costata*, *Saccharina subsessile*) (Dayton 1985). The importance of these smaller kelps is often

underestimated in comparison to the floating species, however their total contribution to the food web through direct consumption, detritus, and dissolved organic carbon is probably larger than the floating species (Duggins 1987, Duggins et al. 1989). This may particularly be the case considering the relatively high abundance of non-floating species compared to floating species (21 percent versus 1 percent) described above.

Habitat requirements for both floating and non-floating species differ slightly between life stages. Sporophytes (large plants) generally occur between MLLW (or higher in tidepools) and 20 meters below MLLW (Mumford 2007). Habitat used during the gametophyte life stage (small filamentous plants comprised of perhaps just a few cells) is less understood (Mumford 2007). Both stages should be considered when assessing potential or likely threats, and impacts of development.

Threats

Anecdotal reports of kelp bed loss from concerned citizens on Bainbridge Island were described in Mumford (2007), although specific locations are not noted. Kelp abundance is predominantly threatened by adverse changes in water quality, possible impacts on substrate composition (such as from sedimentation and from direct disturbance of substrates), and boat traffic for floating kelp. Kelp requires adequate light, cold temperatures, and nutrient levels that are suitably high but not excessively high for successful colonization and growth (Mumford 2007). Therefore, shoreline development that affects water clarity or available light, sedimentation (which can bury kelp), or nutrient levels can adversely impact kelp. Altered wave energy has also been shown to affect survival of kelp (Duggins et. al 2003).

Vegetation removal from land development may reduce infiltration and pollutant removal capacity in the watershed, and could result in greater run-off and increased turbidity from the addition of particulates. Increased turbidity would decrease growth due to reduced light in the water column. Increased nutrients in run-off may subsequently result in increased plankton growth (Steneck et al 2002) which could also reduce light availability. Abundance and distribution of kelp could also be reduced due to increased siltation that alters the substrate character (Mumford 2007). Other historical and potential future threats include loss of detritus feeders (e.g., sea cucumbers) that help maintain water quality, and increase of herbivores that eat kelp (Mumford 2007). Of these potential threats the impacts most closely tied to land use and development activities would be those associated with degraded water quality from increased pollutants or sediment delivery (see Section 5.0 *Effects of Nearshore Modifications*).

3.2 Selected Benthic Macroinvertebrates

As reported in Battelle (2003), shellfish listed for management by WDFW in Puget Sound include native littleneck, Manila littleneck, butter clam, cockle, Eastern softshell clam, Macoma, geoduck, horse clam, oyster, Dungeness crab, red rock crab, mussels, goose barnacles, sand shrimp, moon snails, and nudibranchs. Battelle (2003) summarized the ecology, management,

current status, and Bainbridge Island distributions of the more commonly harvested hardshell clam species (littleneck, Manila, and butter clams), geoduck, and Dungeness crab.

The following macroinvertebrates are listed as priority species on the Priority Habitat and Species (PHS) list (WDFW 2010a) for Kitsap County: Pinto (Northern) abalone, Geoduck, native littleneck, Manila littleneck, butter clam, Olympia oyster, Pacific oyster, Dungeness crab, and Pandalid shrimp. Of these species, the Pinto abalone is a candidate for listing on the State threatened and endangered species list and has been listed as a federal species of concern since 2004 (WDFW 2010a). However, according to WDFW (Bob Sizemore, WDFW, personal communication, December 3, 2010), pinto abalone would not be found in the waters near Bainbridge Island and therefore they are not addressed in this report. Also, Olympia oyster is a candidate for listing on the State threatened and endangered species list.

Since Battelle (2003) did not cover the candidate species Olympia oyster, a summary of their local occurrence, ecology, and threats to this species is provided in this section. Pandalid shrimp, on the WDFW list of priority habitat and species are also covered in this report because they were not addressed by Battelle (2003).

3.2.1 Olympia Oyster

Bainbridge Island Occurrence

Olympia oysters (*Ostrea conchaphila*) were once found in tidal channels, estuarine flats, bays and sounds from Southeast Alaska to Baja California. In Washington, they were especially abundant in the coastal estuaries and in southern Puget Sound and were a subsistence fishery for native Americans (Steele 1957).

Oyster beds are mapped where suitable rocky outcrops exist on Bainbridge Island and were reported by WDFW (2010g) and Battelle (2003) to occur in Fletcher Bay, Manzanita Bay, and along the shoreline of Rich Passage. Olympia oyster prefer lagoons, channels, or impounded tidal areas that are flushed by freshwater and therefore would likely also be found in Point Monroe lagoon area and Murden Cove (Bob Sizemore, WDFW, personal communication, December 3, 2010). They may also prefer brackish water with salinities between 23 and 24 parts per thousand (Peter-Contesse, undated).

Habitat

Olympia oyster is primarily a subtidal species (Hertlein 1959), although they are sometimes found and can be cultured in the intertidal zone. The organization Puget Sound Restoration Fund has been actively promoting restoration of the species through culturing at sites including Bainbridge Island (Peter-Contesse, undated). Natural oyster reefs are 0 to 10 meters below MLLW, bordered above by mudflats and sometimes below by eelgrass beds. They prefer firm substrates comprised of mixed sand, mud, shell material, and rock (Peter-Contesse, undated), but are sometimes found in the intertidal zone attached to undersides of cobbles (Couch and Hassler

1989; reviewed by Baker 1995). Oysters are filter feeders, consuming plankton and particulate organic matter.

Threats

Oyster drills are the most serious predators that attack oysters directly (Galtsoff 1930, WDFW 2010b). The Japanese oyster drill (*Ceratostoma inornatum*) was imported from Japan with the first planting of Japanese oyster seed in Samish Bay. The Japanese drill cuts a hole in the juvenile oysters and eats the meat of the oyster (WDFW 2010b). Scaups, scoters, and oystercatchers are also predators (Galtsoff 1930, WDFW 2010b). Human activities such as shoreline development that may increase the risk of invasive species introduction and colonization may, therefore, threaten oysters due to increased predation. Oysters can be adversely impacted by degraded water quality, and their habitats are adversely affected by silt and pollutants from highway construction and upland development or other activities that result in sedimentation (Armstrong et al. 1993, WDFW 2010b). Commercial harvesting of the Olympia oyster has occurred since the 1850's and has caused a decline in the species. The Olympia oyster populations are also limited by temperature, low productivity, and loss of suitable rocky areas for attachment (Couch and Hassler 1989). Shoreline development and other development that results in impacts to water quality in nearshore embayments (e.g., increased turbidity, sediment disturbance and downstream nearshore sedimentation, temperature alterations, or introduction of pollutants) will potentially affect oysters and the planktonic food sources that are consumed by oysters. Population success may therefore be influenced by direct disturbance (including habitat alteration due to changes in water quality), and by indirect impacts on food availability.

3.2.2 Pandalid Shrimp

Pandalid shrimp (also called humpy shrimp) (*Pandalus goniurus*) are considered a state priority species for recreational, commercial, or tribal importance, and for having vulnerable aggregations that are susceptible to population decline (WDFW 2008). There is limited information for this species with regard to habitat requirements and potential threats.

Bainbridge Island Occurrence

Information on distribution of Pandalid shrimp around Bainbridge Island is limited, however, they have been observed in Eagle Harbor on the east side of the island (Elliot Bay Trustee Council 2009). Primary harvest areas for Pandalid shrimp are mainly in Holmes Harbor, Saratoga Pass, Port Susan, and Possession Sound, which are the closest reported harvest area information to Bainbridge Island (Washington Department of Fisheries 1992).

Habitat

These shrimp are likely to be in deep embayments or the subtidal zone because they inhabit muddy substrate where their prey (worms, diatoms, detritus, algae, and various invertebrates) are present (ADFG 2010). The deeper embayments of Bainbridge Island include Eagle and Blakely

Harbors and Manzanita and Port Madison Bays where Pandalid shrimp could occur (and as stated above they have been observed in Eagle Harbor), Pandalid shrimp live mostly in the subtidal zone as adults (NMFS 2010a), usually over muddy substrate at depths up between 20 feet (6 meters) and 1200 feet (365 meters (ADFG 2010). This species captures its prey between its legs before feeding on it. It is a protandrous hermaphrodite (male first, then female later in life). It probably is a male its first year, becomes female the second year, lays eggs, and then dies. Eggs are observed from late November to April. Predators include sand sole. Pandalid shrimp eat polychaetes, small crustaceans such as amphipods and euphausiids, limpets, and other shrimp (NMFS 2010a).

Threats

Threats to Pandalid shrimp are not well documented, particular with regard to development activities. However potential threats related to development activities are likely to be similar to limiting factors for other crustaceans such as Dungeness crab to the extent that development impacts extend to deeper waters where pandalid shrimp inhabit (subtidal zone). Stressors on pandalid shrimp include bottom trawling fishing and dredging; any activities which disrupt muddy subtidal substrates, as well as chemical contamination (Fisher and Velasquez 2008). Development that reduces water quality due to contaminants, altered temperature, or other factors can affect the abundance and distribution of prey species. This, in turn, can reduce prey availability for Pandalid shrimp, as well as for other sensitive species.

3.3 Fishes

3.3.1 Forage Fish

Battelle (2003) addresses the more common species of forage fish in Puget Sound include surf smelt (*Hypomesus pretiosus*), Pacific sand lance (*Ammodytes hexapterus*), and Pacific herring (*Clupea pallasii*). All forage fish are small schooling fishes that represent a significant component of the prey base for marine mammals, sea birds, and other fish populations in the region. Likewise, forage fish are important as recreational fishing bait and contribute significantly to commercial and subsistence fisheries. Forage fish rely upon a variety of shallow and intertidal nearshore and estuarine habitats, particularly for spawning, and are a valuable indicator of the health and productivity of the marine environment.

Bainbridge Island Occurrence

Battelle (2003) provides a fish occurrence map showing locations of herring, surf smelt, and sand lance spawning habitat. Herring spawning is mapped along the northern shoreline from one mile south of Point Monroe to Battle Point on the west side of the island (Battelle 2003). Surf smelt and sand lance spawning areas are generally in the same areas and occur along Agate Point and Agate Passage, Battle Point, Eagle Harbor area, and a small beach along Port Madison Bay. Beach seine surveys reported by the Bainbridge Island Shoreline Stewardship Program (BISSP 2007) may provide additional information shoreline use and distribution of fish including forage

fish. However, the data have not yet been analyzed or published, and were unavailable for this review.

Habitat

Pacific herring use the nearshore environment for all of their life-history stages. Herring deposit their eggs almost exclusively on marine vegetation (Penttila 2007). They primarily use eelgrass and marine algal turf as a spawning substrate but may also use middle intertidal boulder/cobble rock surfaces with little or no macroalgae (Penttila 2007). Eelgrass is also important habitat for herring, surf smelt, and other forage fish species as it provides refuge (Penttila 2007).

Like Pacific herring, surf smelt use nearshore habitat for all of their life-history stages. Pacific sand lance are a common and widespread forage fish in the nearshore marine waters throughout Puget Sound. Although there is limited life history information or population data available for Pacific sand lance (EnviroVision et al. 2007), the spawning habitat of this species resembles that of surf smelt; they spawn in the upper third of the intertidal zone, in sand-sized substrate (Penttila 2007). As a result, these two species often use the same beaches and co-occurrence of eggs is common during winter when spawning seasons overlap. In general, depositional shore forms such as beaches at the far ends of drift cells and sandy spits support sand lance spawning.

Prey and Foraging

As larvae, herring exhaust their yolk sac nutritional reserves after the first week of drifting and must then feed on microplankton (Penttila 2007). Like herring, surf smelt and sand lance also feed on marine plankton.

Threats

Direct habitat modification such as dredging can destroy nearshore marine vegetation to the detriment of herring spawning habitat (Penttila 2007). Dredging alters nearshore sea-bed topography to accommodate deep-draft vessel traffic and moorage. Nearshore bottomlands are commonly dredged too deep to allow sufficient light for marine vegetation beds to re-colonize and survive, resulting in a net loss of habitat. However, dredging is prohibited in herring spawning beds by WDFW under WAC220-110-320(8). Direct modification or excavation of beaches can affect surf smelt and sand lance forage fish spawning habitat.

For summer spawning fish, the presence of over-hanging trees along the upper beach area is important for moderating wind and sun exposure, which can kill eggs (Rice 2006). The low marine riparian vegetation cover along Bainbridge Island shorelines (27 percent) indicates that this may be a limiting factor for forage fish success. Protection of the marine riparian forest along the backshore of beaches is important (EnviroVision et al. 2007) because it cools the habitat along the upper intertidal beach, which is used by summer spawning populations of surf smelt and other forage fish (Penttila 2004, Rice 2006). In addition to physical habitat needs for spawning, all life stages utilize the nearshore zone (Penttila 2007). Therefore, forage fish are vulnerable to the impacts of shoreline development, including threats from bulkheads and

shoreline hardening, overwater structures, pollution runoff, and removal of shoreline and aquatic vegetation.

No updated studies since the Battelle (2003) report regarding habitat use along Bainbridge Island shorelines by forage fish during various life stages were found. However, Beamer et al. (2008) found that pocket estuary-like habitat was most heavily used by juvenile smelt compared to other habitat types. Bainbridge Island embayments (Williams et al., 2004) are likely to provide significant habitat for forage fish. The effects of shoreline modifications in these areas and the resulting potential for long-term impacts on habitat, should therefore be considered when permitting activities in areas that are likely used by forage fish.

Eelgrass is also important habitat as it provides refuge for forage fish, and is a spawning substrate for Pacific herring (Penttila 2007). In Puget Sound, herring generally spawn on eelgrass or a fibrous red macro alga known as *Gracilariopsis* (Penttila 1999). Hence, impacts on eelgrass and macro algae habitats can also affect Pacific herring populations. For example, coincident with the loss of eelgrass from Westcott-Garrison Bays in the San Juan Islands in 2004, herring spawning was not detectable during surveys between 2004 and 2006 (Penttila 2007) indicating a direct impact to herring from eelgrass loss. Therefore, the loss of eelgrass beds around Bainbridge Island could have a direct negative effect on herring spawning.

There are no recent (since 2003) comprehensive surveys of eelgrass presence for Bainbridge Island. Therefore there is no conclusive documentation to evaluate whether or not eelgrass has declined. The Battelle (2003) report maps eelgrass beds in intermittent segments around the entire island, except from Point White to Battle Point. Herring spawning was documented in the Battelle (2003) report along the entire north end of Bainbridge Island from Battle Point to approximately 1 mile south of Point Monroe. Although herring spawning is shown continuously from Battle Point to the north end of Manzanita Bay in Battelle (2003), there is limited eelgrass mapped in this area (Battelle 2003, Ecology 2010a).

3.3.2 Salmonids

Salmonids (family Salmonidae), which include salmon, trout, and char, are an ecologically, economically, and culturally prominent group of fishes in the Pacific Northwest. All are the focus of regional research, management, and conservation efforts. The eight salmonid species found in Puget Sound include chum (*Oncorhynchus keta*), pink (*O. gorbuscha*), sockeye (*O. nerka*), chinook (*O. tshawytscha*), and coho salmon (*O. kisutch*); as well as steelhead (rainbow trout) (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*) and bull trout (*Salvelinus confluentus*).

Battelle provided a summary of the federal status of salmonids under the Endangered Species Act (ESA) at the time the 2003 BAS report was written. In 2003, Chinook salmon (within the Puget Sound Evolutionarily Significant Unit [ESU]), summer-run chum salmon (within the Hood Canal ESU), and bull trout (within the Coastal-Puget Sound DPS) had been listed as threatened under the ESA. Coho salmon (within the Puget Sound/Strait of Georgia ESU) had not been listed. In 2004, coho salmon (within the Puget Sound/Strait of Georgia ESU) was listed as a

species of concern under the ESA, and Puget Sound ESU steelhead trout was listed as threatened under the ESA on May 11, 2007.

Critical habitat has been designated throughout the nearshore areas of Puget Sound, for Puget Sound Chinook and Hood Canal summer-run chum salmon. These areas have been identified as high conservation value areas (70 FR 52630). Critical habitat has also been designated for bull trout (75 FR 2333). However, critical habitat for bull trout has not been designated along Bainbridge Island shorelines (75 FR, 2285; 75 FR 2333). Critical habitat is under development for Puget Sound steelhead, and is likely to include nearshore areas given the high value of the nearshore for the conservation of all salmonids.

Bainbridge Island Occurrence

Battelle (2003) provides a summary of salmonid local occurrence at different life stages, life history, ecology, and limiting factors to habitat and survival. All of these species use the nearshore and subtidal habitats surrounding Bainbridge Island (Williams et al. 2001). Battelle (2003) also provided an overview of streams on the island where salmonids have either been documented or presumed to be present. Thirteen streams were identified to contain fish; 12 streams contained cutthroat trout and coho; six streams were used by chum salmon and one stream, Fletcher (Springbrook) Creek, had documented use by steelhead trout. In addition to salmonid use in Bainbridge Island streams, the nearshore environment provides important habitat for juvenile rearing and migration. The Bainbridge Island nearshore provides all of the major habitat types that occur in Puget Sound including eelgrass meadows, kelp forests, flats, tidal marshes, sub-estuaries, sand spits, beaches and backshore, banks and bluffs, and marine riparian vegetation (MacLennan et al. 2010). The combination of these habitats, the natural processes which drive their formation, and the resulting environmental conditions, provide important habitat for salmonid rearing, foraging, and migration.

The nearshore environment has well documented importance for salmon. However, studies in northern Puget Sound have found juvenile Chinook are greater than 10 times more abundant in pocket estuary habitat than in other nearshore habitat (Beamer et al. 2003). There is a seasonal shift in habitat utilization by juvenile Chinook from shallow, more protected habitats, like pocket estuaries, to offshore areas later in the year (Beamer et al. 2003). Because the juvenile rearing success is one of the limiting factors for the island (Haring 2000), the protection of these features is essential to salmon recovery.

Declining salmonid populations have been a major reason for restoration efforts in Puget Sound and freshwater stream habitat in the Puget Sound region. Therefore, many recent studies have sought to better understand the threats and limiting factors to salmonids and their habitats, and to improve restoration and recovery of the species. The following is a summary of the latest science regarding salmonid habitat use and threats to the fish and their habitats within Puget Sound and the waters surrounding Bainbridge Island.

Habitat

The eight salmonid species (chum, pink, sockeye, Chinook, and coho salmon; and steelhead, coastal cutthroat, and bull trout) mentioned above are known to occur in central Puget Sound and use, to varying extents, the waters surrounding Bainbridge Island (Dorn and Best 2005). The Battelle (2003) report provided a table that described the level of use of various nearshore habitats and streams on Bainbridge Island that is provided again below (Table 2). No recent data with more detailed information about salmonid use of nearshore and estuarine habitats on Bainbridge Island were identified for this review. Many related studies focus on Chinook salmon and not the other salmonid species. Recent studies indicate that Chinook occupy the nearshore regions of East Kitsap County nearly year-round (SSPS 2007). Beach seining surveys in the shore zones of Bainbridge Island indicate that juvenile Chinook are present from March through December and most numerous from May through August (Dorn and Best 2005, SSPS 2007). Coho are present during similar window, while chum and pink salmon are found primarily between March through May (Dorn and Best 2005).

Table 2. Salmonids Summary of Nearshore and Estuarine Habitat Use and Spawning on Bainbridge Island.[a]

		Nearshore and Estuarine Use			Freshwater Use
Common Name	Scientific Name	Juvenile Rearing	Adult and Juvenile Migration	Adult Residence	Bainbridge Island Spawn
Chinook	*Oncorhynchus tshawytscha*	l	l	l	m
Chum	*Oncorhynchus keta*	l	l	m	l
Coho	*Oncorhynchus kisutch*	⊕	l	⊕	l
Sockeye	*Oncorhynchus nerka*	m	l	m	m
Pink	*Oncorhynchus gorbuscha*	l	l	m	m
Cutthroat	*Oncorhynchus clarki*	l	l	l	l
Steelhead	*Oncorhynchus mykiss*	⊕	l	m	⊕
Bull Trout	*Salvelinus confluentus*	l	l	l	m

Notes: l - extensive use; ⊕ - some use; m - no use or use not known in these areas. This table was taken directly from the Battelle (2003) report and was adapted from Williams et al. 2001.

Prey and Foraging

Chinook, like other salmonids, generally feed on terrestrial and aquatic insects, amphipods, small crustaceans, and other invertebrates as juveniles (Wydoski and Whitney 2003, Wyllie-Echeverria 2008), but with age increasingly feed on fish (Johnson and Schindler 2009, Wydoski and Whitney 2003). In nearshore waters of Puget Sound (Brennan et al. 2004), terrestrial insects have recently been shown to be a large component of the diet of juvenile salmonids (Romanuk and Levings 2010). Coastal fish species that are common Chinook prey include herring, smelt, sand lance, rockfish, and others. Steelhead and chum salmon diets are similar to that of Chinook in the marine environment. Studies have shown that juvenile fish, primarily sand lance and herring,

make up between 20 and 91 percent of juvenile chum salmon diets, and between 10 and 50 percent of adult chum salmon diets (Wydoski and Whitney 2003).

Threats

Factors affecting Puget Sound salmonids include habitat alteration, harvest practices, hatchery management, and other factors such as climate change, ocean conditions, and species interactions (SSPS 2007). Factors most relevant to land use planning and development regulation include those related to habitat alteration. Habitat alteration represents a risk to marine foraging fish including salmon due to the potential for shoreline impacts, and changes in habitat (e.g., reduced eelgrass presence) that can alter food availability and refuge. Impacts may be expected from direct vegetation removal, or indirectly through water quality impacts that effect vegetation structure in the nearshore zone. Alterations in vegetation in turn affect refuge and foraging opportunities for salmon that migrate and rear in the nearshore zone. Indirect impacts of development on habitat may also lead to altered species interactions due to changes in prey and predation opportunities.

On Bainbridge Island, human activities including increasing residential development, vegetation removal, shoreline armoring, and shoreline development have contributed to the alteration of water quality (SSPS 2007), and habitat forming processes such as erosion and shore drift (MacLennan et al 2010). These activities have subsequently impaired habitat conditions (SSPS 2007). Habitat conditions affected by these types of anthropogenic factors are important to salmonid survival and population success, and include the following (Brennan et al. 2009, Lemieux et al. 2004, MacLennan et al 2010, Puget Sound Action Team 2007, Romanuk and Levings 2010):

- Stream bank, bluff, and beach erosion
- Gravel and substrate
- Flows (high/low)
- Insects and food supply
- Water quality
- Temperature and shade
- Channel and shoreline roughness: structure complexity, cover, and refuges
- Marshes, sloughs, eelgrass, and kelp beds.

3.3.3 Rockfish

Battelle (2003) provided a summary discussion of presence for a variety of groundfish (including rockfish) for the species listed in Table 3.

Over 20 species of rockfish inhabit Puget Sound, but only three, copper, quillback, and brown rockfish, are commonly caught by recreational fisheries in nearshore marine habitats of Central and South Puget Sound (West 1997), and were the only three rockfish discussed in the Battelle (2003) report. Since the Battelle (2003) report was written, three species of rockfish were listed

by NMFS under the ESA on April 27, 2010 (75 FR 22276). Bocaccio (*Sebastes paucispinis)* was listed as endangered and canary and yelloweye rockfish (*S. pinniger* and *S. ruberrimus*) were listed as threatened. This section provides a brief discussion of the current status of brown, copper, and quillback rockfish since Battelle (2003) reported these stocks as depressed (NMFS 2001). Also, a summary of occurrence, life histories, and habitat of these newly ESA-listed species is provided. An updated discussion of the science regarding threats to rockfish as a group is also provided in under the final subheading, *Threats to Rockfish as a Group*, in Section 3.3.3.

Table 3. Groundfish species present in Bainbridge Island (including rockfish)

Common Name	Scientific Name
Pacific Cod	*Gadus macrocephalus*
Walleye Pollock	*Theragra chalcogramma*
Pacific Hake	*Merluccius productus*
Lingcod	*Ophiodon elongatus*
English Sole	*Pleuronectes vetulus*
Rock Sole	*Lepidopsetta bilineata*
Brown Rockfish	*Sebastes auriculatus*
Copper Rockfish	*Sebastes caurinus*
Quillback Rockfish	*Sebastes maliger*

Rockfish may be locally abundant in some locations in Puget Sound, but are prone to severe depletion from overfishing due to their habitat specificity (West 1997). In 2003, copper, quillback, and brown rockfish populations in both north and south Puget Sound, including Bainbridge Island, were characterized as “depressed” (Puget Sound Water Quality Action Team 2000), however, none of these species are at risk of extinction. Over the past five years, the populations of copper, brown, and quillback rockfish in the waters south of Admiralty Inlet including Bainbridge Island were stable, although their numbers had been declining prior to that time except for brown rockfish (Palsson et al. 2009, NMFS 2008c). Brown rockfish populations increased in the 1990’s likely because they are habitat generalists and eat a wider array of prey than the quillback or copper rockfish (Palsson et al. 2009, NMFS 2008c). NMFS expressed concern that changes in resource management practices (e.g., increased harvest levels) and in the ecosystem (e.g., increased numbers of marine mammals or predatory fish species), as well as increased habitat degradation, could result in increased risk of extinction for these three species of rockfish in greater Puget Sound (NMFS 2008c).

The following sections discuss the three species that are federally listed: boccacio (*Sebastis paucispinis*), canary rockfish (*S. pinniger*), and yelloweye rockfish (*S. ruberrimus*). In general, the species rely on shallow surface waters, distribution by currents, and kelp and eelgrass during their larval and juvenile stages; and then are associated with deeper rocky habitats as they mature (Wyllie-Echeverria and Sato 2005).

Bocaccio

Bainbridge Island Occurrence

In general, there is limited information on local presence and habitat use of bocaccio rockfish within Puget Sound. WDFW catch reports and Reef Environmental Education Foundation (REEF) surveys between 1994 and 2010 contain sporadic observations of bocaccio in Puget Sound (NMFS 2008c, REEF 2010), but they seem to be limited to areas around the Tacoma Narrows and Point Defiance (74 FR 18521). REEF survey data for January 1996 through October 2010 indicates that bocaccio are identified in 0.1 percent of surveys and those observed were in the Tacoma area (REEF 2010). Records show the presence of the occasional bocaccio and other rockfish during 1970's surveys throughout Puget Sound (NMFS 2009). There is no specific data for bocaccio occurrence within the waters around Bainbridge Island, but the juveniles could be present in the kelp and eelgrass beds that occur along the island's shoreline.

Habitat

Larvae are 4.0-5.0 mm (<0.2 inches) long at release, generally well-developed, have functional organs and the ability to swim and regulate buoyancy (NMFS 2009). Larvae disperse widely and are generally associated with surface waters and drifting kelp mats (74 FR 18521). The larvae metamorphose into pelagic juveniles after 3.5 to 5.5 months (typically 155 days) and settle to shallow, algae covered rocky areas or eelgrass and sand over several months (Love et al. 1991).

Tagging data indicates that juveniles will migrate as much as 92 miles (0.9-148 km) within two years of tagging (NMFS 2008c). As the juveniles age into adulthood, the fish move into deeper waters where they tend to settle near rocky reefs and oil platforms, and remain relatively localized as they age. Adults are most commonly found in waters between 164 feet and 820 feet (50 meters to 250 meters) in depth, but can inhabit waters between 39 feet to 1568 feet (12 meters to 478 meters) deep (NMFS 2009). Although rockfish are generally associated with hard substrata, bocaccio are found in nearly all types of substrate. They are typically not associated with the bottom and tend to be more pelagic than other rockfish species (74 FR 18521).

Prey and Foraging

Juvenile bocaccio consume copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010b).

Canary Rockfish

Bainbridge Island Occurrence

Canary rockfish were once considered fairly common in Puget Sound (Holmberg et al. 1967 as cited in NMFS 2008c), and most common in southern Puget Sound (74 FR 18521). Based on survey and frequency data, NMFS estimates that there are approximately 300 canary rockfish in Puget Sound Proper (south of Admiralty Inlet) where Bainbridge Island is located (74 FR

18521). No additional data for canary rockfish occurrence in the specific vicinity of Bainbridge Island were available (NMFS 2008c, REEF 2010).

REEF (2010) surveys between 1990 and 2010 suggest that canary rockfish are most consistently observed in northern waters of Puget Sound, Strait of Juan de Fuca and the outer coast. The sighting frequency (the percentage of surveys conducted that contained individuals of canary rockfish) ranged between 0.3 and 1.4 percent in the vicinity of Whidbey Island, Vashon Island, and West Seattle.

Declines in canary rockfish observations have been documented since 1965 and a decreasing abundance trend has been consistently confirmed in recent catch surveys (NMFS 2008c). REEF surveys indicate 1 to 3 percent of rockfish caught in Puget Sound proper (south of Admiralty Inlet) are canary rockfish, a slightly lower percentage than those in North Puget Sound. REEF surveys between 1996 and 2010 suggest that canary rockfish are most consistently observed in the northern waters of Puget Sound, the Strait of Juan de Fuca and the outer coast.

Habitat

Larvae and juveniles are typically found in the upper water column and surface waters. However, occasional observations of juveniles have occurred at depths up to 2750 feet (838 meters) (Love et al. 2002). The larval stage lasts for 1-4 months (typically 166 days) in the top 328 feet (100 meters) of the water column (NMFS 2009; 74 FR 18521). Juveniles settle into tide pools, rocky reefs, kelp beds, low rock and cobble areas (Miller and Geibel, 1973; Love et al. 1991; Love et al 2002). Juveniles exhibit diel migratory patterns by hanging in groups near the rock sand interface at shallow depths during the day and moving to sandy areas at night (Love et al. 2002). At approximately three years, juveniles begin to move deeper into rocky reefs.

Canary rockfish adults are generally associated with hard bottom areas and along rocky shelves and pinnacles (NMFS 2008c). They are usually found at or near the bottom (PFMC 2004). Adults tend to be in dense schools leading to patchy distribution (Stewart 2007). As adults, canary rockfish appear to be somewhat migratory and will travel as much as 435 miles over several years (NMFS 2008c). The migration is seasonal with more distance traveled in late winter over summer months (NMFS 2009).

Prey and Foraging

Canary rockfish prey and foraging is similar to that of other rockfish species. Juveniles feed on copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010c)

Yelloweye Rockfish

Yelloweye rockfish are consistently observed throughout the Salish Sea, with highest frequencies observed in North Puget Sound, including Admiralty Inlet and north (NMFS 2009). One adult

Yelloweye rockfish was recorded along with many of the common rockfish near Bainbridge Island during a 1971 survey of the Puget Sound waters (NMFS 2009). REEF (2010) reported 132 young yelloweye rockfish observations around Bainbridge Island between the years of 2004 and November 2010. Yelloweye rockfish were reported to occur at one to two percent of the recreational catch in Puget Sound proper (south of Admiralty Inlet), which has been consistently higher frequency compared to bocaccio or canary rockfish (NMFS 2008c).

Habitat

Like canary rockfish, yelloweyes are often fished for in the same habitat and at depths greater than 230 feet (70 meters) (Wyllie-Echeverria and Sato 2005). As with other rockfish species, juveniles are generally found in shallow waters and move deeper as they age. During that life stage, juveniles are found between 49 feet and 1,801 feet (15 meters and 549 meters) in depth (NMFS 2008c). As juveniles settle, they are found in high relief areas, crevices and sponge gardens (74 FR 18521; Love et al. 1991). Adults are typically found at depths between 300 feet and 590 feet (91 meters and 180 meters) (NMFS 2008c). The adult yelloweye rockfish tend also toward rocky, high relief zones (74 FR 18521). The adults have very small home ranges, generally site attached and affiliated with caves, crevices, bases of rocky pinnacles and boulder fields (Richards 1986). Rarely adult yelloweye rockfish are found in congregations, but are more commonly seen as solitary individuals (Love et al. 2002; PFMC 2004).

Prey and Foraging

Yelloweye rockfish prey and foraging is similar to that of other rockfish species. Juveniles feed on copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010d)

Threats to Rockfish as a Group

Rockfish grow slowly, are late to mature, are long-lived (up to 50 years), and have low rates of reproduction (NMFS 2010b). Typically, rockfishes mature at ages of six to 11 years old, and at about half the size of their maximum length (Palsson et al. 2009). Therefore, recovery of depressed species can take up to 50 to 75 years (Stout et. al. 2001). Palsson et al. (2009) reports that past fishing practices and derelict fishing gear are the highest impact stressors and limiting factors to rockfish population survival (Table 4). Boccaccio are fished directly and are often caught as by catch in other fisheries, including those for salmon. Currently, rockfish are commonly caught before they reach sexual maturity (Palsson et al 2009), eliminating their entire reproductive potential (WDFW 2010c). Overfishing (as either a target or a by-catch species) is likely a significant factor in the species' decline. Up to 61,000 rockfish may be caught in derelict fishing gear per year (Palsson et al. 2009). In addition, adverse environmental factors led to recruitment failures in the early- to mid-1990s (NMFS 2010b).

Table 4. Likely Stressors Limiting Rockfish Populations in Puget Sound (Source Palsson et al. 2009).

Factor	Documented[1]	Intensity[2]	Extent[3]	Relative Risk[4]
Fishery Removals	Best	High	High	High
Age Truncation	Fair	Medium	High	Moderate
Habitat Disruption	Unknown	Medium	Unknown	Unknown
Derelict Gear	Best	High	High	High
Climate	Unknown	Unknown	Unknown	Unknown
Hypoxia/Nutrients	Best	High	Medium	High
Chemical Contamination	Fair	Medium	Medium	Moderate
Species Interactions				
Food Web	Best	High	High	High
Competition	Poor	Unknown	Unknown	Unknown
Salmon Hatchery Practices	Unknown	Unknown	Unknown	Unknown
Diseases	Poor	Unknown	Unknown	Unknown
Genetic Changes	Poor	Unknown	Unknown	Unknown

[1] Best = Known references in Puget Sound, Fair = Inferred in this species from published studies in nearby areas, Poor = Inferred in Puget Sound from published studies in a proxy species, Unknown = Conceivably possible, but no publications that establish relationship.
[2] High = Stressor causes direct mortality, Medium = Stressor reduces fitness by increasing susceptibility to predation or disease or impairs reproduction, Low = Stressor is unlikely to impact health, Unknown = Intensity is unknown.
[3] High = Stressor acts continuously and over broad regions, Medium = Stressor is either episodic or acts over restricted areas within a region, Low = Stressor is infrequent or acts only over limited range, Unknown = Spatial distribution and frequency unknown.
[4] High = Overall the stressor has been documented in Puget Sound, causes direct mortality, is frequent and acts on a regional basis and dramatically limits rockfish stocks in Puget Sound, Moderate = The documented stressor causes direct mortality on episodic or local scales or continuously or episodically reduces fitness on local or regional scales, Low = The poorly documented stressor is infrequent and acts on local scales, Unknown = The stressor is possible but its intensity and extent is not documented.

Other threats (i.e., stressors) with a high relative risk of impact include those related to water quality, specifically depletion of dissolved oxygen, altered nutrients, and to a lesser extent chemical contamination; and increase in prey species such as harbor seals and California sea lion (Palsson et al. 2009). Other threats with an unknown relative risk include habitat disruption, climate change, competition from other bottomfish species, salmon hatchery practices, diseases, and genetic changes. These stressors, listed in Table 4, are detailed in *Biology and Assessment of Rockfishes in Puget Sound* (Palsson et al. 2009). That report indicates relative risk for each stressor based on three criteria. The criteria include available documentation, intensity (related to the effects of the stressor on survival, fitness, or health of the stock), and extent (related to frequency or spatial extent). An unknown condition for any criteria resulted in a relative risk of "unknown."

Stressors listed in the table that are most related to local regulation of development activities include direct habitat disruption, as well as the indirect or consequential effects of development on water quality (i.e., hypoxia/nutrients and chemical contamination) and food web dynamics. The relative risk associated with habitat disruption is unknown. This is due to limited available

documentation and a lack of knowledge on the spatial extent and frequency of the stressor affecting rockfish, meaning the risk is "conceivably possible, but [there are] no publications that establish relationship." However, habitat disruption results from filling, dumping dredge spoils, sedimentation, trawling, constructing beach bulkheads, installing pipelines and cables, sunken vessels, and constructing artificial habitats. The most vulnerable rockfish habitats are shallow-water vegetated areas and deeper rocky habitats (Palsson et al. 2009).

Rockfish vulnerability to degradation of kelp and eelgrass in the nearshore zone of Bainbridge Island is an important consideration given the species' reliance on this habitat during the larval stage, and especially considering the relatively limited coverage of kelp and eelgrass (note only 18.7 miles of eelgrass habitat, Battelle 2003) along Bainbridge Island shorelines. Development that alters substrate conditions or water quality can subsequently affect the availability of suitable habitat (see Section 3.1.2 *Eelgrass Meadows*) and associated prey species for rockfish. As indicated in Table 4, stressors related to water quality and food web dynamics, may have a higher potential for impact to rockfish than direct habitat disturbance (for which impacts are not well documented, and the relative risk remains unknown). Therefore, for future conservation of rockfish it is important to consider the relationship between specific development decisions and indirect impacts on habitat conditions or water quality, in addition to considering direct habitat disruption.

3.4 Marine Birds

Marine birds are present as breeding residents and as migrants in Puget Sound. Their distribution and relative abundance vary seasonally with highest numbers and greatest species diversity occurring during winter. There are three primary habitats that marine birds occupy – rocky shorelines, estuaries and mudflats, and open water (Buchanan 2006).

Battelle (2003) examined trends in changing density for the following species or groups of birds that commonly use open water habitats that are outside the nearshore zone:

- Goldeneye (*Bucephala islandica* and *B. clangula*)
- Scoters (*Melanitta persipcillata*, *M. fusca*, and *M. nigra*)
- Pigeon guillemot (*Cepphus columba*)
- Common murre (*Uria aalge*)
- Rhinoceros auklet (*Cerorhinca monocerata*)
- Marbled murrelet (*Brachyramphys marmoratus*)
- Western grebe (*Aechmophorus occidentalis*)
- Red-necked grebe (*Podiceps grisegena*)
- Horned grebe (*Podiceps auritus*)
- All cormorants combined (*Phalacrocorax penicillatus*, *P. pelagicus*)
- Double-crested cormorant (*Phalacrocorax auritus*)
- Brant (*Branta bernicla*)
- All gulls combined (*Larus* sp.)

- Bufflehead (*Bucephala albeola*)
- Oldsquaw (*Clangula hyemalis*)
- Greater and lesser scaup (*Aythya marila* and *A. affinis*)
- Harlequin duck (*Histrionicus histrionicus*)
- Mergansers (*Cophodytes cucullatus*, *Mergus merganser*, *M. serrator*)
- Common loon (*Gavia immer*)
- All loons combined (*Gavia immer*, *G. pacifica*, *G. stellata*, *G. arctica*)

The Battelle (2003) report provided a brief discussion of threats to marine birds. Information is limited about the threats to marine birds and the reasons for population decline. Buchanan (2006) collected information on threats and potential conservation measures for birds that use nearshore habitats. The Battelle (2003) report focused on birds that occur in open water habitats outside the nearshore zone, but did not address birds that primarily use nearshore habitats such as estuaries, mudflats, and rocky outcrops. However, Battelle (2003) did provide a list of birds sighted in Kitsap County during Audubon Christmas bird counts in 2000 and 2001. This section provides information on the primary threats and potential conservation measures for marine birds that primarily use the nearshore zone.

Three indicator nearshore shorebird species have been identified including surf scoter (*Melanitta perspicillata*), black oystercatcher (*Haematopus bachmani*) and dunlin (*Calidris alpina*) (Buchanan 2006). Surf scoters and dunlins spend much of the nonbreeding period in Puget Sound and migrate to boreal or Arctic areas to breed; the black oystercatcher is essentially a permanent resident. All of these species use the nearshore habitat along Bainbridge Island. Surf scoters use the subtidal and intertidal habitats for foraging and floating. Dunlins use beaches, estuarine habitat, and mudflats along Bainbridge Island. Other shorebirds that may commonly use the beaches along the island shoreline include sandpipers, yellow-legs, plovers, godwits, and curlews. Oystercatchers prefer rocky substrate and tide pool areas over beaches. More detailed information on each of these indicator species is provided below.

3.4.1 Surf Scoter

Bainbridge Island Occurrence

Christmas Bird Count totals from Puget Sound sites in the 1990s ranged from 2,410 (Bellingham, 1996) to 4,774 (Oak Harbor, 1993) (Nysewander 2005). Surf scoters are most abundant in Puget Sound between September and May, where they are found at highest densities in southern and central Puget Sound (Nysewander et al. 2005). Surf scoters were observed during Audubon Christmas bird counts in Kitsap County (Battelle 2003) and likely occur within subtidal waters of Bainbridge Island. No data for surf scoters were identified specific to Bainbridge Island.

Habitat

Surf scoters from Puget Sound wintering areas breed in northern Canada (Savard et al. 1998). Following the breeding season, surf scoters move away from breeding areas to molt

(Nysewander et al. 2004). In marine environments, the surf scoter is strongly associated with shallow nearshore waters. Information from Puget Sound indicates that most surf scoters use waters less than 18 meters (about 60 feet) deep (Buchanan 2006). At certain times bivalves dominate the diet (Vermeer 1981, Savard et al. 1998, Lacroix et al. 2004), especially clams and mussels (Buchanan 2006). Therefore, beaches such as those along Fletcher Bay, Manzanita Bay, Rich Passage, or other locations around Bainbridge Island that support bivalves would likely provide significant feeding opportunities for surf scoters. In spring, perhaps 50 percent of surf scoters in the region will feed on herring eggs when available (D. Nysewander personal communication cited in Buchanan 2006), and flocks of scoters regularly track the northward progression of spawning events (Vermeer 1981). Habitat that supports forage fish including herring may therefore provide additional feeding opportunities, and important habitat used by surf scoters. Surf scoters also appear to feed on a wide variety of invertebrates in late summer (e.g. shellfish, amphipods) that are associated with eelgrass habitats (D. Nysewander personal communication cited in Buchanan 2006).

Threats

Surf scoter populations have been declining although the reasons for the decline are not well understood. The potential causes of population change in surf scoters, although not definitively identified, include changes in food resources and heavy metal contaminants (Buchanan 2006). Threats may be related to habitat alteration. For example, in Prince William Sound, Alaska, numbers dropped by more than 50 percent between 1972 and the early 1990s; changes in populations of forage fish associated with increasing water temperatures in the northeastern Pacific Ocean were suggested as a contributing factor to the change in scoter abundance (Agler et al. 1999). Locally, surf scoters' reliance on organisms that are commonly associated with eelgrass, in combination with documented declines in eelgrass throughout Puget Sound (see Section 3.1.2 *Eelgrass Meadows*), are indicative that habitat alteration is a threat. Considering the important role of eelgrass in food source abundance (Murphy et al. 2000, Mumford 2007, Bostrom et al. 2006) and the limited distribution of eelgrass along Bainbridge Island shorelines, protection of this habitat during shoreline development planning and proposal review is likely to be an important conservation measure for surf scoter, as well as other species.

Declines in herring stocks, where habitat alteration is also implicated (Rice 2006, Penttila 2007), have coincided with surf scoter population changes in Puget Sound (Buchanan 2006). Studies looking at fat reserves, body mass and stable isotopes indicate that surf scoters that feed at herring spawning events are heavier and in better physical condition when northward migration begins (Anderson et al. 2005). Levels of cadmium in surf scoters from the Pacific Northwest are generally high (Henny et al. 1991), and in the Queen Charlotte Islands, British Columbia, the levels exceed those thought to cause kidney damage (Barjaktarovic et al. 2002). Oil spills are also deleterious to surf scoters (fouled plumage or actual mortality) as well as other marine birds (Kittle et al. 1987, Ford et al. 1991, Tenyo Maru Trustees 1993). The primary threats affecting surf scoters pertaining to Bainbridge Island are likely to be associated with food web relationships and losses of herring habitat or loss of eelgrass beds, and potential increased risk of oil spills or other contamination that may occur in the marine waters around the island and affect water quality and prey availability.

3.4.2 Black Oystercatchers

Bainbridge Island Occurrence

Black oystercatchers were observed during Audubon Christmas bird counts in Kitsap County (Battelle 2003) and likely occur annually on and adjacent to the beaches and rocky coasts of Bainbridge Island. No data for oystercatchers or other shorebirds were identified specific only to Bainbridge Island.

Habitat

Black oystercatchers nests are typically located on gradually sloping sand beaches (usually less than a 15 degree slope) or rock benches located above the high tide zone, on islands, small islets (Andres 1998, Andres and Falxa 1995) and rocky headlands, although the latter are not used in Puget Sound (Nysewander 1977). Foraging habitat is characterized by exposed rocky or sandy shoreline below the high tide line; sand beaches used by oystercatchers often have substantial deposits of shell and gravel (Andres 1998, Andres and Falxa 1995, Nysewander 1977). Five shoreline reaches characterized as “rocky shore” by Mac Lennan (2010) would likely contain suitable habitat for black oystercatchers.

Threats

Actual or potentially important limiting factors that have been identified include environmental conditions, predation threat, competition, or disturbance by humans and environmental contamination. Because black oystercatchers often place their nests very near the high tide line, adverse weather events, especially those associated with high tides, may produce waves capable of washing over and destroying the contents of nests (Vermeer et al. 1992, Spiegel et al. 2006). Human presence in nest and foraging areas may influence behavior or occurrence patterns (Warheit et al. 1984), although this type of disturbance has not been evaluated in Washington. Additionally, harvesting of limpets, an important component of the oystercatcher diet has been documented to affect oystercatcher population in California (Lindberg et al. 1998).

3.4.3 Dunlin

Bainbridge Island Occurrence

Dunlin were observed during Audubon Christmas bird counts in Kitsap County (Battelle 2003) and likely occur within tideflats and salt marshes within the embayments of Bainbridge Island. More recent surveys lack documentation of dunlin and other shorebird occurrences in the City of Bainbridge Island specifically (National Audubon Society 2010a, 2010b); thus the following discussion is general in scope.

Habitat

Dunlin are typically associated with estuarine tide flats during their residence in Western Washington. Preferred foraging areas are characterized by the presence of fine silts (Warnock

and Gill 1996). Dunlin forage on a wide variety of benthic invertebrates by probing with their long bills in tidal mudflats, including unidentified polychaete worms and several arthropods including *Pancolus californiensis*, *Corophium insidiosum*, and *Corophium salmonis* (Brennan et al. 1990).

Threats

Limiting factors and threats to dunlin and other shorebirds include environmental climatic factors, habitat disturbance and prey source decline, pollutants (including oil spills) and non-native species invading estuaries (Buchanan 2006). Sobocinski et. al. (2010) reports that shoreline modification and loss of beach wrack resulted in lower numbers of invertebrates, which in turn produces a reduction in prey for dunlin and other shorebirds. The most important losses or changes to important habitats include dike building and conversion of estuarine wetlands. Some modified estuaries such as Port Susan Bay and Skagit Bay currently support large aggregations of dunlin, whereas others (e.g., Budd Inlet, Commencement Bay, and Elliott Bay) no longer (or rarely) support populations of dunlin (Buchanan 2006). Estuary loss due to development would be the primary threat to dunlin on Bainbridge Island. Most of the small bays on Bainbridge Island where estuaries may be located are fully developed for residential or industrial use except Blakely Harbor and segments along the western shoreline of Bainbridge Island which remain relatively unmodified (Battelle 2003).

3.5 Marine Mammals

Battelle (2003) provided a brief summary of information on the harbor seals, but mentions other marine mammals found in Puget Sound waters, including harbor seals (*Phoca vitulina*), California sea lion (*Zalophus Californianus*), steller (Northern) sea lion (*Eumetopias jubatus*), harbor porpoise (*Phocoena phocoena*), killer whale (*Orcinus orca*) and the gray whale (*Eschrichtius robustus*).

The following section provides information on local occurrence, habitat, peray and foraging, and threats for the following marine mammals that were not covered by Battelle (2003): steller sea lion, killer whale, gray whale, and humpback whale. Also killer whale Southern Resident Distinct Population Segment (DPS) was listed as endangered in 2005, after the Battelle (2003) report was prepared. While sea otter is listed as a state endangered species, it does not occur in the waters near Bainbridge Island and therefore is not discussed below.

3.5.1 Steller Sea Lion

Steller sea lions were listed as threatened on April 10, 1990 (62 FR 30772). Critical habitat was designated for steller sea lions on March 23, 1999 (64 FR 14051), however all designated critical habitat lies outside Washington State.

Bainbridge Island Occurrence

Steller sea lions are most commonly present in the inland marine waters of Washington State, including northern and central Puget Sound (Puget Sound Action Team 2007), between January and May, and are typically absent during the June to August breeding season when they return to coastal rookeries (Personal communication with Steve Jeffries, WDFW, July 15, 2009). Steller sea lions are increasing in population in Puget Sound, by about 10 percent annually (Puget Sound Action Team 2007). On Bainbridge Island, two steller sea lion haul outs were mapped at Fort Ward State Park at the southeast end of the island and at Rich Passage near the Park (Washington State Parks and Recreation 2010).

Habitat

Terrestrial sites used by steller sea lions tend to be associated with waters that are relatively shallow and well-mixed, with average tidal speeds and gradual bottom slopes. Haul-outs (terrestrial areas used by adult sea lions during times other than the breeding season and by non-breeding adults and subadults throughout the year) and rookeries tend to be preferentially located on exposed rocky shorelines, wave-cut platforms, ledges or rocky reefs (NMFS 2010e). No known rookeries exist on Bainbridge Island. Sea lions display strong site fidelity to specific locations from year to year. Adult females with pups and juveniles generally stay within 20 km of rookeries and haulout sites while other females and males may range over much larger areas to find optimal foraging conditions (NMFS 2008b).

Although all federally designated critical habitat areas are located outside of Puget Sound, habitat that is considered “essential to the conservation of the steller sea lion” includes the “physical and biological habitat features that support reproduction, foraging, rest, and refuge” (58 FR 45269). Sites used by steller sea lions on Bainbridge Island are not considered “major haul-outs” and are therefore not designated critical habitat. However, haul out sites including those at Fort Ward State Park and Rich Passage provide steller sea lions with opportunities for rest, foraging, and refuge, and therefore they are important conservation areas.

Prey and Foraging

Steller sea lions are generalist predators that eat a variety of fish and cephalopods, and occasionally other marine mammals and birds (NMFS 2008b). They feed primarily on fish (herring, hake, salmon, cod, lamprey, rockfish, flatfish, and skates), octopus, and squid, but prey varies by season, area, and water depth. These prey species, particularly herring, salmon, and rockfish are found in the subtidal and intertidal habitats of Bainbridge Island. Steller sea lions commonly compete with other marine mammals for salmon, which are seasonally important and range from six to 33 percent of steller sea lions’ diet (Puget Sound Action Team 2007).

Data on foraging behavior are relatively limited, but suggest that adult females alternate between trips to sea to feed and periods on shore when they haul out to rest, care for pups, breed, and avoid marine predators. Territorial males may fast for extended periods during the breeding season when they mostly remain on land. Females with dependent young generally feed

relatively close to rookeries and haul-outs because they must return at regular intervals to feed their offspring (NMFS 2008b).

Threats

The primary threats to steller sea lions are environmental variability, (periodic shifts in oceanic and atmospheric conditions), reduction in the biomass and quality of sea lion prey species (generally related to fisheries impacts), and predation by transient killer whales (NMFS 2010e). Exposure to toxic substances also poses a moderate threat (NMFS 2010e). The availability of steller sea lion prey species can be influenced by habitat alteration, as discussed throughout this document. Therefore, development activities on Bainbridge Island that affect water quality, disturb substrates, or otherwise alter habitat conditions for lower trophic species will potentially affect the food web up to higher trophic species such as steller sea lions and other marine mammals. This is particularly likely when development activities are considered on a cumulative scale.

Of slightly less relevance to land use planning and development activity there are other threats to steller sea lion that include active and derelict fishing gear, illegal shooting, disease and parasites, and disturbance from marine vessels (NMFS 2008b). To the extent that development activities may influence these stressors (for example, increased vessel activity due to ferry terminal expansion or new marina development), these factors should also be considered in evaluating potential impacts from development on steller sea lion, as well as other biological resources. For example, development that leads to increased marine vessel activity not only increases the risk of direct disturbance but may also increase the potential for toxic pollutants to enter the water from oil spills or maintenance activities. Modification of habitat or water quality, entanglement in fishing gear, and vessel activity are therefore all potential threats to sea lions.

3.5.2 Orca or Killer Whale

Resident killer whales (*Orcinus orca*) in the Northeast Pacific are distributed from Alaska to California, with four distinct communities recognized: Southern Resident, Northern, Southern Alaska, and Western Alaska (Krahn et al. 2004). The Southern Resident distinct population segment (DPS) was listed as endangered under the Endangered Species Act (ESA) in 2005 (70 FR 69903). The Southern Resident population consists of three pods that numbered 87 whales in 2007 (NMFS 2008b).

Bainbridge Island Occurrence

The Whale Museum in Friday Harbor keeps a database of verified sightings by location quadrants or “quads.” Sightings may be of individual or multiple whales. Occasional sightings occur in the inland waters of the Puget Sound near Bainbridge Island. Killer whale are most common in North Puget Sound and the San Juan Islands. However, the Whale Watch Sighting Network (2010) reports relatively frequent sightings of killer whales from the Bainbridge Island ferry and from observations from shore.

Habitat

Southern Resident killer whale pods have visited coastal sites off Washington and Vancouver Island, and are known to travel as far south as central California and as far north as the Queen Charlotte Islands (NMFS 2008b). For a portion of the year the Southern Resident population of killer whale typically resides and forages in the Georgia Strait, Strait of Juan de Fuca, and the outer coastal waters of the continental shelf, principally during the late spring, summer, and fall (Krahn et al. 2004, NMFS 2008b). Winter and early spring movements and distribution are largely unknown for the population. The Bainbridge Island shoreline lies within designated critical habitat for the Southern Resident killer whale.

Prey and Foraging

Data suggest that Southern Resident killer whales have a strong preference for Chinook salmon during late spring to fall. Chum salmon are also taken in significant amounts, especially in autumn. Other prey species include coho, steelhead, sockeye, and minor numbers of non-salmonids (e.g., Pacific herring and quillback rockfish). Resident whales spend about 50-67 percent of their time foraging. Groups of killer whales often disperse over several miles while searching for salmon (NMFS 2008b). Effects on pinniped populations are also likely to be minor, except where whales remain for long periods within localized areas. For example, groups of transients are thought to have substantially reduced the harbor seal population in Hood Canal during multi-month stays in 2003 and 2005 (Puget Sound Action Team 2007). Eight salmonid species including Chinook salmon use Bainbridge Island marine shorelines for juvenile and adult migration, and several local streams are known to support coho and chum salmon (Battelle 2003, WDFW 2011). The presence of salmonid species suggests that Bainbridge Island marine waters may be used by killer whales for feeding.

Threats

The potential for development activities to impact water quality, substrate, primary production, and key habitats for food items, in turn, produce potential threats to higher trophic level species due to their indirect effects on prey availability. This relationship between development and higher trophic species is particularly applicable to killer whale due to their reliance on salmonids and the potential for bioaccumulation of toxins (Cullon et al. 2009, Puget Sound Partnership 2010).

The major threats identified in the federal listing of killer whale were prey availability, pollution and contaminants, and effects from vessels and noise. In addition, demographics, small population size, vulnerability to oil spills and other factors were considered (NMFS 2008b). The frequency of killer whale occurrences in Puget Sound and surrounding waters when salmon and other fish species are also present (Cullen et. al. 2009), suggests that waters around Bainbridge Island may be important habitat and feeding ground. There is also the potential for development activities on Bainbridge Island to impact water quality, substrate, primary production, and key habitats of killer whale prey. Another secondary, or indirect, impact of development is the potential for increased vessel activity. Increased noise and disturbance from commercial and

private vessels is a potential threat that has been shown to alter whale behavior and could adversely impact feeding behavior (Lusseau et al. 2009; Williams and Ashe 2007; Williams et al. 2002, 2009).

3.5.3 Gray Whale

The Eastern North Pacific population of gray whales was delisted from endangered status under the ESA in 1994. National Marine Fisheries Service completed a status review in 1999 NMFS (Rugh et al. 1999) and retained the unlisted status of the population based on population trends (NMFS 2010f). In October, 2010, NMFS was petitioned to conduct a status review of the Eastern North Pacific population to determine whether to list the population as "depleted" under the Marine Mammal Protection Act (75 FR 68756). Gray whales travel annually between feeding grounds in Alaska and breeding grounds in Mexico. They migrate north along the Pacific coast between mid-February and May, and return to their breeding grounds in the fall (NMFS 2010f). They are occasionally seen in the inland waters of Puget Sound.

Bainbridge Island Occurrence

There have been no documented recent sightings of gray whales immediately off Bainbridge Island shorelines. However, gray whales are increasingly sighted in the inland waters of Washington and British Columbia, and several sightings of gray whale have been noted around Vashon Island and Whidbey Island (Orca Network 2009) and in Elliot Bay (Riemer 2010). This suggests that gray whales may occur along Bainbridge Island shorelines and could utilize food sources (benthic organisms) that are influenced by local shoreline activities and subsequent environmental conditions. Gray whales often come into inner bays as they migrate up the Washington coast to feed on ghost shrimp and other small crustaceans in the shallow bottom sediments (Puget Sound Action Team 2007, Essington et. al. 2010).

Habitat

Gray whales are found mainly in shallow coastal waters in the North Pacific Ocean (NOAA 2010). Based on recent observations of gray whales and foraging patterns, Bainbridge Island marine waters, as well as Puget Sound provide suitable habitat and foraging opportunities for gray whales.

Prey and Foraging

Gray whales feed on benthic amphipods (such as ghost shrimp) by filtering sediments from the sea floor. Summer feeding grounds are primarily located offshore of Northern Alaska and the Bering Sea where there is low species diversity but high biomass and high rates of secondary production. In high use feeding areas, gray whales have been shown to disturb at least six percent of the benthos each summer, and to consume more than 10 percent of the yearly amphipod production (Rugh et al. 1999). There are indications that this resource is being stressed and that the gray whale population may be expanding its summer range in search of alternative feeding

grounds (Rugh et al. 1999). Therefore, there may be an increasing dependence on food sources in the Puget Sound region by gray whales including the vicinity of Bainbridge Island. Gray whales that have been observed in the inner waters of Puget Sound have often been emaciated and thought to be starving (Riemer 2010, Orca Network 2010). This indicates that inland marine water feeding grounds may be more important for gray whales than they were historically. In Puget Sound, gray whales have been observed feeding on ghost shrimp and tube worms between January and July (Orca Network 2010).

Threats

In the past, gray whales were threatened by commercial whaling which severely depleted both the eastern and western populations between the mid-1800s and early 1900s. Since the mid-1930s, gray whales have been protected under a ban on commercial hunting. Other current threats include collisions with vessels, entanglement in fishing gear, habitat degradation, disturbance from ecotourism and whale watching, disturbance from low-frequency noise, and illegal whaling (NMFS 2010f).

Of the above potential threats, those related to land use and development activities are most likely associated with habitat alteration, and vessel activity. The Eastern North Pacific population's annual migration along the highly populated coastline of the western United States, and their concentration in limited winter and summer areas, may make them particularly vulnerable to impacts from commercial or industrial development or local catastrophic events (NMFS 2010f). Impacts of development that affect substrate and water quality and therefore have the potential to affect important food sources may also threaten gray whale foraging opportunities.Because of the gray whale's reliance on nearshore amphipods, development activities on Bainbridge Island which affect eelgrass beds, soft substrates, lower benches of beaches, and other nearshore habitats that support the production and survival of ghost shrimp and other food sources, will likely have indirect implications on the food availability for gray whales when they occasionally enter the inner waters of Puget Sound to forage.

3.5.4 Humpback Whale

Humpback whales were listed as endangered on June 2, 1970 (35 FR 8491). Critical habitat has not been designated for this species. Humpback whales migrate to Alaska during the summer to feed. The Washington coast is a corridor for their annual migration north to feeding grounds and south to breeding grounds (Osborne et al. 1988).

Bainbridge Island Occurrence

Sightings of humpbacks in Puget Sound are infrequent; however, reported sightings have been increasing since the late 1990s. Since 2001 there have been several Puget Sound humpback whale sightings reported through the Orca Network annually. In June 2009, a humpback whale was sighted near Rolling Bay on the northeast side of Bainbridge Island (Orca Network 2009). The increase in sightings may partially result from increased local awareness and the

establishment of sighting networks such as the Orca Network where residents can easily report whale sightings, but may also reflect incremental increased use of habitat in Puget Sound.

Habitat

Humpback whales generally stay near the surface of the ocean. Feeding typically occurs in cold water summer grounds. Winter breeding grounds are generally in warmer waters at lower latitudes (between 10 degrees and 35 degrees latitude). While feeding and calving, humpbacks prefer shallow waters and prefer warmer waters during calving (NMFS 2010g). Calving grounds are commonly near offshore reef systems, islands, or continental shores. Humpback feeding grounds are in cold, productive coastal waters.

Prey and Foraging

Humpback whales feed while in their summer range (NMFS 1991). Humpbacks filter feed on small crustaceans, plankton, and small schooling fish such as herring and sand lance. They consume large amounts during the productive summer months to build up fat stores which are then utilized during the winter months. Humpbacks are known to use unique hunting methods involving columns, clouds, or nets of air bubbles to disorient and corral fish (NMFS 1991). The technique called “bubble netting” is sometimes used by multiple whales with defined roles that allow the whales to herd prey near the surface. Forage fish occurring in the marine waters around Bainbridge Island, and which depend on spawning habitat along the northern and western shorelines (Battelle 2003), and along Agate Point and Agate Passage, Battle Point, the vicinity of Eagle Harbor, and along Port Madison Bay may be important prey items for migrating humpback whales. The spawning beaches used by these species, and the kelp and eelgrass habitats that supports them (Mumford 2007) at various life stages, are therefore important factors potentially affecting the availability of prey for humpback whales.

Threats

Potential threats to humpback whales include direct injury from entanglement in fishing gear or ship strikes; stress, reduced feeding potential, or altered behavior that can result from vessel activity; and habitat degradation (NMFS 2010g). For example, as is true for other whales and described above, impacts on eelgrass beds, beaches, and other nearshore habitats that support the production and survival of food sources may reduce foraging opportunities for whales. A reduction in suitable forage fish spawning habitat would likely limit the availability of key prey species for humpback whales. Altered habitat conditions, habitat reduction, or direct disturbance and displacement of whales can occur as a result of increased vessel activity commonly associated with shipping, fisheries, or recreation (NMFS 1991, 2010d).

Ship strikes were implicated in the deaths of at least four humpback whales between 1993 and 2000 (NMFS 2005). Ship strikes are frequently unnoticed but research by Williams and O’Hara (2009) suggests that geographic “bottlenecks” where whale and boat densities are concentrated, represent higher risk areas. Although a local analysis has not been completed, the relatively high volumes of marine vessel traffic in the general vicinity of Bainbridge Island (e.g. Elliot Bay

shipping lane), and the geographic position of Bainbridge island within confined inland marine waters, is characteristic of such a bottleneck. To the extent that land use and development activities contribute to increased vessel traffic and ferry activity in Bainbridge Island marine waters could increase the risk of ship strikes.

Aquaculture development may also occupy or destroy humpback whale habitat (NMFS 2010g). Therefore, to the extent that such use is allowed, modified or expanded, aquaculture development in areas like Eagle Harbor, Fletcher Bay, Manzanita Bay, and Rich Passage could potentially affect humpback whales by reducing habitat and foraging opportunities. This can occur because impacts to habitat (e.g., water quality conditions, aquatic vegetation, and substrate) and associated food web interactions can result from aquaculture activities (Herrera 2009a).

4.0 No Net Loss

The following section discusses the no net loss standard and provides guidance to achieve this standard. Washington State Department of Ecology (2010b) defines no net loss as: Over time, the existing condition of shoreline ecological functions should remain the same as when the SMP is implemented. The standard of no net loss is intended to prevent new adverse impacts to shoreline ecological functions resulting from new or expanded development.[2]

The Shoreline Management Act (SMA) defines the baseline for measuring no net loss to be "existing shoreline conditions" which is typically defined by a nearshore characterization or more recent supplement to that characterization.

To assure no net loss of ecological functions, the Washington Administrative Code (WAC) calls for the application of development standards and mitigation measures in accordance with the mitigation sequence (WAC 173-26-201, pg. 27). The mitigation sequence prioritizes actions as follows.

1. Avoid the impact by not taking a certain action;
2. Minimize impacts by limiting actions or using appropriate technology to avoid or reduce impacts;
3. Rectify impacts by repairing, rehabilitating, or restoring the affected environment;
4. Reduce or eliminate the impact over time by preservation and maintenance operations;
5. Compensate for impacts by replacing, enhancing, or providing substitute resources or environments; and
6. Monitor the impacts and taking appropriate corrective measures.

The WAC states that when using compensatory measures "preferential consideration shall be given to measures that replace the impacted functions directly and in the immediate vicinity of the impact" (WAC 173-26-201, pg. 29). "However, alternative compensatory mitigation within the watershed that address limiting factors or identified critical needs for shoreline resource conservation … may be authorized." Thus mitigation is best implemented on-site and for the specific function(s) impacted but mitigation can occur off-site for other ecological functions that are currently limited as long as the activities would substantively benefit shoreline ecological processes or habitats.

Challenges to achieving no net loss in the City of Bainbridge Island are:

[2] See http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/Chapter4.pdf

- The City has no standardized approach for linking shoreline inventory information to shoreline master program implementation decisions;

- The City lacks funding and resources to complete the necessary monitoring and adaptive management needed to ensure no net loss.

In order to measure and achieve no net loss the City of Bainbridge will want to address the aforementioned challenges and commit to:

- Measuring ecological conditions using a shoreline characterization model such as that provided by Williams et al. (2004) as a requirement for reviewing and permitting new or expanded shoreline development;

- Compare conditions at some future time to existing conditions to determine whether the level of function has increased, decreased, or remained the same via a monitoring program; in other words examine whether the City's shoreline regulations and permit review process is adequately protecting shoreline ecosystem processes and important marine habitats, and if it is not, adaptively change what the City is doing to improve results. An assessment based on monitoring of ecological conditions (above) should be conducted, at minimum, once between SMP updates in order to inform future updates however more frequent monitoring would provide better information for decision-making.

Table 5 provides a sample of some suggested indicators for a monitoring program to measure current conditions and future conditions to evaluate no net loss. A suggested frequency for monitoring is provided but clearly such a program would depend on specific monitoring goals and the availability of resources to implement the monitoring. The sample monitoring measures were selected to evaluate buffer integrity, water quality conditions, and habitat conditions. The table outlines examples of features to be measured and provides potential indicators, methods and a suggested frequency for gathering data. The sample monitoring program is designed to be accomplished with minimal technology requirements while providing data that can be easily gathered and compared at reasonable cost.

A committed program to monitor and adapt will lessen the trend of shoreline and nearshore degradation but there is a further challenge, which is to ensure there is no continuing loss to shoreline and nearshore functions resulting from cumulative impacts. Cumulative impacts are defined as "the impacts on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions."

Table 5. Sample no net loss monitoring program.

	Feature	Indicator(s)	Suggested Method(s)	Suggested Frequency[1]
Buffer Integrity	Shoreline vegetated with native species	Area Habitat class (forest, shrub, herb/grass etc.)	GIS, Shore surveys	2 to 5 years
	Unmodified shoreline Bulkheads Over- & In-water structures	Linear Distance Area Density	GIS, Shore surveys	2 to 5 years
	Active feeder bluffs	Linear Distance	GIS, Shore surveys	2 to 5 years
	Large Woody Debris (LWD)	Distribution and abundance	GIS, Beach surveys	2 to 5 years
	LWD recruitment	Tree density Tree height Tree diameter	Shore surveys	5 years
Water Quality (samples taken in embayments and areas adjacent to streams)	Temperature	Measures temperature to support life (°C)	Grab sample (or continuous logger)	Monthly during the summer or as per site specific plan.
	Dissolved Oxygen	Measures oxygen available to support life (mg/L and percent saturation)	Grab sample	Frequency will depend on design of WQ sampling program.
	Total Nitrogen[2]	Measures nutrient supply (mg/L)	Grab sample	Frequency will depend on design of WQ sampling program.
	Nitrate+nitrate[2]	Measures available dissolved nutrients (mg/L)	Grab sample	Frequency will depend on design of WQ sampling program.
	Turbidity	Measures water clarity from suspended sediment and microbes (NTU)	Grab sample	Frequency will depend on design of WQ sampling program.
	Fecal Coliform	Measures septic and animal contributions (Number/100 ml)	Grab sample	Frequency will depend on design of WQ sampling program.
	pH	Measures acidity, a growing marine water issue (pH scale)	Grab sample	Frequency will depend on design of WQ sampling program.
	Chlorophyll a	Measures algae biomass (µg/L)	Grab sample	Frequency will depend on design of WQ sampling program.
Habitat Conditions	Eelgrass beds	Distribution, Area Density Patch Size	GIS, Marine surveys	2 to 5 years
	Kelp forests	Distribution, Area Density Patch Size	GIS, Marine surveys	2 to 5 years
	Forage fish spawning Beaches	Distribution, Area, Density	GIS, Marine surveys	2 to 5 years
	Shellfish areas	Distribution Abundance	Intertidal and subtidal Surveys	2 to 5 years
	Salmonid and marine fish	Distribution Abundance	Marine surveys Beach seines	2 to 5 years
	Depth/slope of beach and backshore	Linear distance Area	Shoreline surveys	2 to 5 years
	Substrate classes	Area	GIS, Marine surveys	2 to 5 years

[1] At minimum, monitoring should occur prior to next SMP update.
[2] The difference between total nitrogen and nitrate+nitrate is a measure of suspended particulate organic matter

Figure 4 provides a conceptual view of how to achieve no net loss given both parcel level and landscape level development impacts. It illustrates that development with no mitigation or restoration will incrementally produce a negative trend in ecological functions. Allowed development that only requires parcel specific mitigation will in most cases also produce a negative trend although the degradation trend is slower. Both of these negative trends are largely due to ongoing degradation from past activities and from violations of existing regulations. For example a bulkhead permitted in the past may continue to degrade longshore sediment transport processes even if no new bulkheads are allowed. These concepts are further described by Washington Department of Ecology in Appendix A and a different figure is provided that may be more useful to the reader's understanding.

Relying on parcel level mitigation to maintain no net loss is also unlikely to be successful because there are impacts that may appear insignificant at the parcel level but gain significance when viewed in total as they occur across a reach or a landscape and as they can begin to affect broader shoreline and nearshore functions. The site development review process looks at projects individually, which can hamper property owners and City reviewers from seeing and addressing the potential cumulative effects of some development.

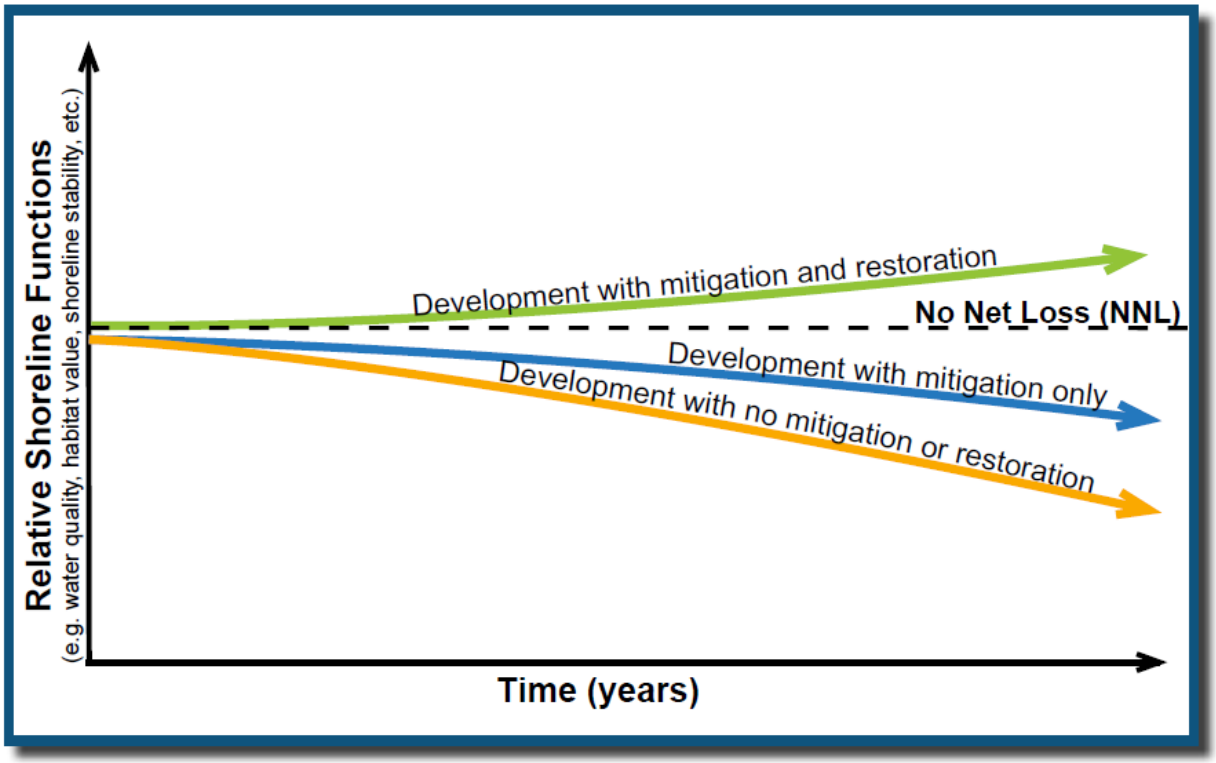

Figure 4. Conceptual view of how to achieve no net loss (source: The Watershed Company).

As illustrated in Figure 4, restoration can add benefit to parcel level mitigation measures, to offset on-going degradation, violations, and other cumulative impacts and thereby achieve no net

loss or a net ecosystem improvement. Restoration can occur on an individual lot scale such as requiring beach nourishment for existing bulkhead repairs and permitting only soft shore stabilization solutions for replacements and new bulkheads. Restoration can also occur on a larger scale with investment in focused restoration and conservation programs within the City.

For example, a residential land owner may be permitted to reconstruct a failing bulkhead because they have a *demonstrated need* (WAC 173-26- 231(3)(a)(iii)(E)) to protect principle uses or structures from erosion caused by currents, tidal action, or waves. Mitigation may or may not be required under this scenario because it is an existing condition and the no net loss standard is to maintain existing functions. A neighbor experiencing similar erosion issues (that may even have resulted from the presence of the first bulkhead) requests that a new bulkhead be permitted to protect principal uses. In this scenario mitigation would be required as it would be a new condition. A typical mitigation requirement would be to plant native shoreline vegetation to compensate for the vegetation removed as a consequence of the bulkhead installation. Now two bulkheads begins to affect other nearby properties by further cutting off sediment sources leading to increased erosion and loss of property on more parcels and a consequent loss of habitat functions for marine species.

This discussion demonstrates that achieving no net loss is very difficult and likely not attainable when efforts are confined to evaluations on a single parcel scale. No net loss is more achievable when parcel level approvals and mitigation sequencing occur in tandem with public and private efforts to enhance and restore degraded shoreline and nearshore systems, in addition to protecting high quality habitats in-perpetuity from development.

The City's Shoreline Master Program should:

- **Measure**: Systematically support quantitatively relating measures of ecological functions to shoreline master program management decisions on a parcel and a reach scale;

- **Inform**: Provide site- and reach-specific information to support shoreline master program implementation, specifically providing technical support to permit staff and educational outreach to shoreline property owners

- **Monitor**: Enable and fund quantitative and spatially explicit monitoring and assessment to document changes in ecological conditions over time.

- **Implement**: Use habitat assessment and monitoring to inform management decisions and adaptive changes in policy. Enforce the shoreline management policies.

- **Restore**: Integrate restoration activities into City's Shoreline Management Program to ensure there is no net loss over long term and cumulative scales.

A discussion of effects and recommendations for specific activities that can help the City achieve no net loss when nearshore modifications are authorized are provided in Section 5.0 *Effects of Nearshore Modifications* regarding shoreline stabilization structures, marine riparian vegetation modifications, residential development in the nearshore zone, and over-water and in-water structures.

4.1 Conservation Banking

The City might consider developing a regulatory framework to allow the use of a nearshore Conservation Bank as a way to provide compensatory mitigation for remaining or cumulative impacts to the nearshore ecosystem from a singular development. Conservation banking is an extension of the more familiar wetland mitigation banking program the Corps of Engineers has officially endorsed and operated for about a decade under Section 404 of the Clean Water Act (40 CFR Part 230). A conservation bank may be comprised of one or many (not necessarily contiguous) parcels of land containing natural resources values that are conserved and managed in perpetuity for specified listed species or ecological functions, and used to offset impacts occurring elsewhere to the same resources on non-bank lands (USFWS 2003). The values of the natural resource are translated into quantified “credits” which are purchased by project proponents. The proponents are able to complete their required mitigation needs through the one time purchase of credits. A Conservation Bank may also hold conservation easements on lands to limit development activities and protect valued shoreline and nearshore resources from development effects. Fee-in-lieu (where a party pays a fee to a Conservation Bank in lieu of providing the mitigation itself and the Bank then provides the mitigation or uses the funding to permanently protect other areas) is another variation of the same concept where the Conservation Bank can limit development in perpetuity and therefore permanently protect nearshore ecosystem functions.

Conservation banks can be used as a tool to significantly increase the ecological gain derived from compensatory mitigation activities by establishing large reserves or protecting key habitats on smaller parcels such as an important forage fish spawning beach. Large reserves are more likely to ensure greater effectiveness of nearshore ecosystem functions, foster biodiversity, and provide opportunities for linking existing habitat than small isolated mitigation sites (USFWS 2006), however both approaches can provide benefits. Assembling parcels for a Conservation Bank in a relatively built-out environment such as the City may take many years therefore banking is best viewed as a long term tool for resource protection. Nevertheless, such programs allow mitigation to take place in the most ecologically meaningful areas. A Conservation Bank would identify sites that offer the greatest environmental benefit while also providing adequate checks and balances to ensure that mitigation credits are not sold until project success standards are met (Environmental Defense 1999).

5.0 Effects of Nearshore Modifications

Over 82 percent of the parcels on Bainbridge Island are developed (Battelle 2003) and currently approximately 51 percent of the Bainbridge Island shoreline has some type of modification (MacLennan et al. 2010). Overhanging riparian vegetation covers approximately 27 percent of the entire Bainbridge Island shoreline (Williams et. al. 2004). Also, within the City's 200-foot shoreline management zone, naturally vegetated surfaces comprise 54 percent of land cover, whereas impervious surfaces represent 23 percent of the land cover (Williams et. al. 2004). Recent reports and data regarding shoreline vegetation characteristics are limited. However shoreline development since 2003, such as 34 permitted new over-water structures (which does not include structure expansions) and 48 new shoreline residential structures (Bainbridge Island 2010), indicate that the extent of developed shoreline has increased since earlier reports.

New development, ongoing maintenance of existing structures, and related shoreline alteration such as vegetation removal, described in the following sections have the potential to affect habitat and species described earlier in this document (Section 3.0 *Nearshore Biological Resources*) directly, indirectly, and cumulatively. Examples of shoreline modifications that have likely resulted in impacts on habitat is where the western end of Blakely Harbor has been altered from its original configuration with additions of fill and a dike across the head of the harbor (MacLennan et al. 2010). Also, the historical drift cell in Eagle Harbor has been significantly altered, essentially divided into two drift cells where the marina dampens wave energy and acts as a sediment sink (MacLennan et al 2010). Potential effects of shoreline modifications are further described in the following sections.

It was not within the scope of this document to include aquaculture in the analysis of the effects of nearshore modifications. Nonetheless, it should be acknowledged that aquaculture-related development may also occupy or destroy nearshore habitat (NMFS 2010g). Therefore, to the extent that such use is allowed, modified or expanded, aquaculture development in areas like Eagle Harbor, Fletcher Bay, Manzanita Bay, and Rich Passage could potentially affect species by reducing habitat and foraging opportunities. This is because aquaculture can adversely affect habitat through alterations to water quality, occurrence and extent of aquatic vegetation, substrate composition, and associated food web interactions (Herrera 2009a).

5.1 Shoreline Stabilization Structures

Bulkheads can take a large number of different forms. They are typically riprap (whether vertical or inclined), but vertical walls constructed of wood and concrete are also common (Best 2003). Not all bulkheads produce the same magnitude of environmental impact. Well-designed bulkheads that do not extend below extreme high water, do not replace shoreline vegetation, and incorporate some form of beach nourishment are expected to have reduced impacts on the nearshore environment as compared to traditional means of bank protection. However, there are

many instances when this is either not feasible or impacts have already caused modifications to the overall landscape that have compromised the habitat functions of a particular site.

Approximately 49 percent of Bainbridge Island is armored (R. Ericson, City of Bainbridge Island, personal communication with A. Azous, Herrera Environmental Consultants, December, 1, 2010). Throughout Bainbridge Island's shorelines, shoreline stabilization structures appear to have cut off a number of feeder bluffs from performing natural processes of beach formation and nourishment (MacLennan et al 2010). Due to the extent (49 percent) and location, commonly along feeder bluffs (MacLennan et al 2010) and shorelines with alongshore sediment supplies (Williams et al 2004), future impacts may be more associated with the cumulative effects (both geographic and over time) than direct impacts of a single structure. However, there is also a possibility for additional impacts associated with new shoreline armoring and development. The assessment by MacLennan et al. (2010), and future monitoring and mapping to the extent that it is conducted will likely provide a valuable asset to land management and development planning, including shoreline development review and impact assessment.

It is important to emphasize that the placement of bulkheads is often unnecessary or perhaps even counterproductive to an owner's goals (Gabriel and Terich 2005). While erosion is commonly the most often cited reason for constructing a bulkhead, it is clear from patterns of bulkheading that true risk and perceived risk are not equivalent (Gabriel and Terich 2005). For example Finlayson (2006) highlights an example from Cama Beach on Camano Island of a beach where a bulkhead was placed that was not needed. A full discussion of this situation, as well as a photograph of what this looks like is in Section 2.3.2. In that case, it was likely that temporary erosion from intermittent storms precipitated the construction of a wall on a portion of beach that was over time actually accumulating material. Therefore, in the construction or permitting of any bulkhead (new or renovated) that might be eventually qualify for an exemption, it is necessary to consider the scientific evidence and evaluate the condition of sustained erosion, rather than a particular episode.

Direct effects of shoreline stabilization structures include physical impacts to the shore and nearshore that cause consequent changes to ecological processes, encroachment on habitat and sediment sources, and beach erosion (Herrera 2005). Indirect effects include passive erosion, loss of sediment supply, shoreline simplification, loss of marine riparian zone, and contribution of chemical contaminants. These are discussed in turn below.

5.1.1 Physical Impacts and Ecological Ramifications

Numerous documents have suggested a link between armoring (particularly by bulkheads), accelerated beach and marsh erosion, and the loss or disruption of nearshore habitat of adjacent shorelines (Mulvihill et al. 1980, Kraus and McDougal 1996, Thom et al. 1994, MacDonald et al. 1994, Spaulding and Jackson 2001, Williams and Thom 2001, Sobocinski 2003, Brennan and Culverwell 2004, Herrera 2005, Finalyson 2006, Rice 2006, Herrera 2007a, 2007b, Toft et al. 2007, Bilkovic and Roggero 2008, Sobocinski et al. 2010, and Mattheus et al. 2010). While there have been some studies that argue certain aspects of these linkages (e.g., the role of wave

reflection in producing sediment erosion: Kraus and McDougal 1996), these authorities all document some array of the negative ecological impacts of bulkheads, particularly when the bulkhead is seaward of MHHW (Toft et al. 2007). While many of these studies have been performed outside of the Pacific Northwest (Kraus and McDougal 1996, Spaulding and Jackson 2001, Bilkovic and Roggero 2008, and Mattheus et al. 2010), a significant number were based on studies conducted within the confines of Puget Sound (Sobocinski 2003, Herrera 2005, Rice 2006, Finlayson 2006, Herrera 2007a&b, Toft et al. 2007, Sobocinski et al. 2010).

Sediment Supply

Sediment supply is crucial to a well functioning nearshore ecosystem, particularly on the sediment starved beaches of Bainbridge Island (Herrera 2005, Finlayson 2006, MacLennan et al. 2010). Armoring, by separating uplands from the intertidal areas, cuts off the upland supply of sediment to a beach and can lead to sediment impoundment (MacLennan et al. 2010). The impaired process of sediment transfer, indirectly leads to beach loss (Herrera 2005) thereby reducing the amount, or suitability, of habitat important to sensitive species described in Section 3.0 *Nearshore Biological Resources*. Kraus and McDougal (1996) implicate the loss of sediment supply as the primary reason that erosion occurred in their study. This effect is expected to be pronounced on Bainbridge Island, as most of the sediment supplied to the nearshore is from erosion of adjacent shorelines (MacLennan et al. 2010) unlike in many other places, where significant amounts of sediment are derived from nearby rivers (including Kraus and McDougal 1996). In a study conducted in Thurston County, the largest impacts of the loss of sediment supply were not evident at some seawall locations, but on downdrift beaches (Herrera 2005). Loss of sediment in downdrift beaches is a historical, and likely ongoing, impact of shoreline modification along Bainbridge Island shorelines where MacLennan et al. (2010) documented a 60 percent loss of sediment supply from feeder bluffs (by length of shoreline) compared to historical conditions.

Encroachment

Encroachment involves the placement of bulkheads or other structures in areas that are sedimentologically active. If a bulkhead is constructed seaward of extreme high water, it automatically narrows the beach causing habitat loss. Approximately 25 percent of Bainbridge Island’s shoreline is characterized by armoring encroachment into intertidal zone (Williams et al 2004). The loss of the upper beach and its replacement with exotic vegetation and structures causes the elimination of the ecologic services of the supratidal and intertidal (in the case of bulkheads placed below mean higher-high water). The importance of supratidal communities on the ecology of the Puget Sound nearshore has been well documented in the literature (Sobocinski 2003, Sobocinski et al. 2010). In some instances, encroachment is severe, precluding upper beach habitat. Fill and encroachment can sometimes be identified from current or historical photographs, or by the lack of wrack in front of the structure. However, even when wrack exists in front of a bulkhead, the loss of overhanging vegetation communities has a variety of impacts on nearshore physical processes and ecology (Sobocinski 2003, Romanuk and Levings 2003, Brennan and Culverwell 2004, Herrera 2005, Romanuk and Levings 2010).

Active Erosion

Active erosion is a mechanism by which armoring, particularly bulkheading, accelerates beach erosion by reflecting wave energy and increasing the rate of sediment transport offshore. Because active erosion is dependent on wave reflection, the bulkhead must encounter waves for this process to occur (such that the bulkhead is at or below the MHHW elevation). Also the frequency with which the water column encounters the bulkhead is proportional to the active erosion effect, meaning that the lower the bulkhead extends into the intertidal the more active erosion is likely to occur. It has been debated whether wave reflection is the dominant mechanism for erosion initiated by bulkhead placement. (Kraus and McDougal 1996), but it is clear that for some distance in front of the bulkhead the physical environment is altered, which has implications for habitat since this area is coincident with the tidal range associated with forage fish spawning (Spaulding and Jackson 2001, Finlayson 2006). Several grey literature observations exhibit a lower beach (though an equivalent slope) on bulkheaded shorelines as compared to adjacent shorelines (Herrera 2005, Herrera 2009b, Figure 5). Although a bulkhead may not alter the beach slope, gradual lowering of the beach elevation would alter habitat for species that depend on specific intertidal conditions, inundation frequency, and beach position.

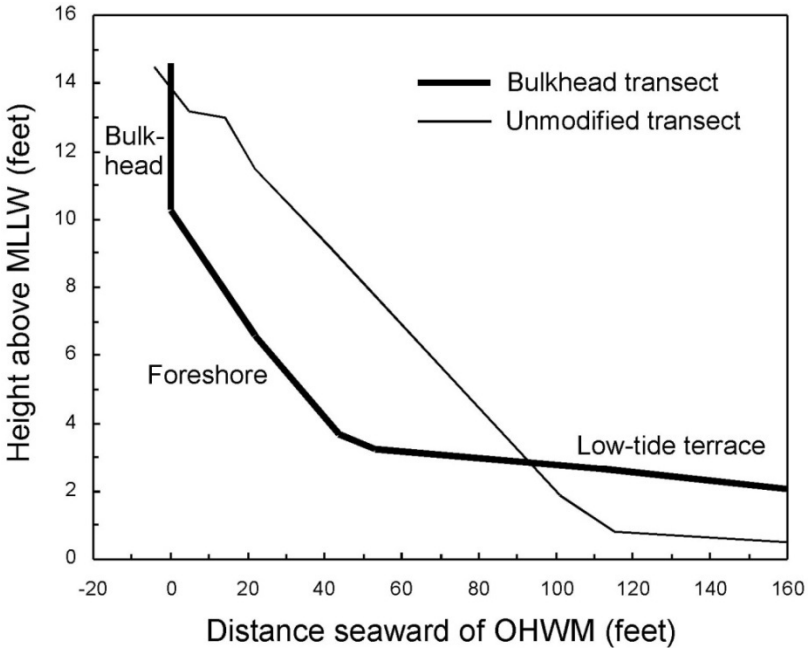

Figure 5. Comparison of beach transects from Whidbey Island (Herrera 2009b).

Alongshore variability in Puget Sound is extreme (as described in Section 2.3.2: Finlayson 2006), but the consistency of these results with observations elsewhere indicates that erosion seen in similar settings is appropriate to many places across Bainbridge island (Spaulding and Jackson 2001).There is also some doubt about the ability of bulkheads to cause active erosion on accreting shorelines, as the effects described above will be muted to non-existent. However, in these locations it is likely that a bulkhead is not needed because the shoreline is stable or aggrading – and that erosion, if observed, is an episodic, not a persistent, process (Finlayson

2006). Erosion and sediment transport on Puget Sound shorelines is discussed in detail in Section 2.3.2.

Passive Erosion

Passive erosion describes the fact that, if armoring is constructed and stabilizes a shoreline undergoing natural retreat (erosion), the armoring robs intertidal areas of the formation of new upper beach over time. Initial construction of armoring structures might leave the upper beach intact, but over time, natural erosion removes beach substrate in front of the structure eventually causing the loss of the upper beach (Figure 5). This has been pointed out in several marine settings, including in Puget Sound (Herrera 2005, Bilkovic and Roggero 2008). The migration of the shoreline can eventually cause the complete loss of the upper beach, ultimately undermining the integrity of the bulkhead.

Shoreline Simplification

Armoring, particularly a bulkhead, can reduce the physical complexity of the upper beach, such as the loss of wood debris accumulations in the upper beach. The edge habitat is effectively lost particularly if erosion lowers the beach and precludes the presence of substrate at certain tidal elevations (Herrera 2005). The loss of wrack has other implications including the loss of substrate suitable for forage fish spawning (Herrera 2005) and loss of substrate favorable to invertebrates (particularly insects), which have been shown to be important for nearshore productivity (Romanuk and Levings 2003, Sobocinski et al. 2010, Romanuk and Levings 2010) (also see the subsection *Allochthonous Input* in Section 5.2.1).

Marine Riparian Vegetation

Armoring has been documented to be associated with a significant loss of overhanging shoreline vegetation and wood debris accumulations (Gabriel and Terich 2005), thereby reducing shade and the physical complexity of the upper beach. Loss of marine riparian vegetation has a suite of impacts to the nearshore zone, which are discussed in detail in Section 5.2 *Marine Riparian Vegetation Modifications*.

Chemical Contamination

Although there are existing regulations that prohibit the placement of treated wood products in the nearshore zone, many of the bulkheads around Bainbridge Island are composed of treated wood products, particularly creosote-treated wood. These materials, regardless of age, have many relict environmental impacts that can be eliminated with the addition of requirements to mandate removal of these when older, treated bulkheads are retrofitted. To motivate compliance with this recommendation, a brief summary of the physio-chemical impacts of treated wood on nearshore biota is presented below.

Creosote and other wood preservative products used on bulkheads pose water quality and sediment contamination risks associated with contaminant leaching. The current state of

knowledge on the biological effects of creosote-treated wood routes of exposure have been summarized in three major literature reviews: Meador et al. (1995) addressed the bioaccumulation of PAHs in marine fishes and invertebrates; Poston (2001) reviewed treated wood impacts on aquatic environments; and two Stratus documents (2005a, 2005b) presented what is known about the impacts of creosote, chromated copper arsenate (CCA), and ammoniacal copper zinc arsenate (ACZA) treated wood products. The major routes of exposure for marine animals were found to be through the uptake of waterborne chemicals, including the interstitial water of sediments and through trophic transfer; while the direct uptake of sediment-bound chemicals appeared to be negligible (Meador et al. 1995).

Chromated copper arsenate treated wood, a commonly used treatment for wood in place of creosote, also has shown detrimental effects on the nearshore ecosystem (Herrera 2005). Weis et al. (1993) found that oysters growing on CCA-treated wood piles had higher metals concentrations and a greater incidence of histopathological lesions compared to oysters collected from nearby rocks. In a subsequent study, Weis and Weis (1996) fed snails algae grown on CCA-treated docks. The snails in turn suffered mortality. Finally, Weis and Weis (1994) found significantly lower biomass and diversity of sessile epifaunal communities on treated wood panels compared to untreated panels. Studies such as these indicate that the primary trophic pathway for contaminants from treated wood is through invertebrates and algae either growing on or attached to treated wood.

5.1.2 Shoreline Stabilization Measures and No Net Loss Recommendations

Battelle (2003) emphasizes avoidance of bulkheads, particularly placement of new bulkheads. However, most of the vulnerable existing structures along the shoreline of the island are already protected by bulkheads. Given the current stringent requirements for placing a new bulkhead and the inherent temporary nature of bulkheads in general (at least on actively eroding shorelines), most of the regulatory actions in the future will be related to repairs and maintenance of existing bulkheads. To address these issues, a two-pronged strategy is recommended that attempts to mitigate the past, current, and future impacts on-site, while providing for limited compensatory mitigation on off-site areas for those impacts not fully mitigated on-site. The geomorphic context (e.g., shoreform and drift cell dynamics) of a shoreline stabilization structure's location is an important consideration in defining the magnitude of its effects and the potential mitigation required. Full implementation of this strategy should ensure that City regulations with regards to shoreline armoring on individual parcels are consistent with the concept of no net loss, including consideration of cumulative impacts (see Section 4.0 *No Net Loss*).

For bulkhead replacements, soft shore stabilization techniques including beach nourishment and stable wood placement should be encouraged to minimize impacts. In addition, the following activities could be undertaken as a part of the repair of an existing bulkhead that would mitigate impacts from bulkheads on-site:

- Beach nourishment – Beach nourishment has been practiced on the East and Gulf Coast of the US and in Europe for at least 50 years (Kumar 1998;

NRC 1995). While there are impacts associated with these placements, these impacts are often minor and temporary, particularly when taken in context with the ecological benefits of nourishment (Herrera 2007c). Regardless of the geomorphic differences between these environments (Finlayson 2006), these long-term, large-scale studies provide insight into the potential physical process ramifications of expanding beach nourishment activities on Bainbridge Island. Considering that most of the impacts described above are related to the loss of sediment supply, beach nourishment represents a means to mitigate the physical impacts of a bulkhead. It is important to note that the mode of sediment supply on Bainbridge Island is primarily landsliding, not significantly different from a one-time placement of sediment from a physical process perspective. This would suggest that the ecological impacts of beach nourishment on Bainbridge Island shorelines might be less than elsewhere, and certainly not more. However, this does not preclude the need for careful assessment of potential direct and indirect impacts, and these should be assessed on a site-specific and cumulative scale when beach nourishment is considered as either mitigation or restoration.

- Revegetation – Revegetation is also a key way to mitigate the effects of a bulkhead. Many of the impacts associated with bulkhead construction can be attributed to the associated vegetation removal or maintenance (e.g., desiccation of forage fish spawn, Rice 2006). Therefore bulkhead construction could be mitigated partially by revegetating the nearshore. Revegetation may be considered in various forms including the use of vegetation in soft shore stabilization methods, incorporation into the bulkhead design (above and below the bulkhead), and/or as offsite restoration of previously impacted shorelines. Offsite restoration that may involve revegetation is likely an important element of mitigating cumulative impacts to ensure no net loss.

- Removal of treated wood – Many of the older bulkheads on the island contain treated wood. Treated wood has well known impacts to the nearshore ecosystem (see Chemical Contamination in Section 5.1.1). Removal of treated wood piling or other in-water structures is a common mitigation and restoration action taken to offset impacts of development (including bulkhead replacement or repair) on water quality. Treated wood bulkheads along the Bainbridge Island shoreline likely represent restoration opportunities to the extent they can be removed, or replaced with less impacting shoreline stabilization methods. Removing these materials and replacing them with non-toxic materials should be encouraged and required for replacements or repairs.

Considering that many of the existing bulkheads are within degraded shoreline segments, mitigation ratios greater than 1:1 is an additional means to achieve no net loss for impacts from

shoreline armoring. Requiring mitigation ratios greater than 1:1 is particularly important in areas that are more ecologically productive. Implementation of performance monitoring plans should be part of the strategy associated with the mitigation required for bulkhead repair projects. The monitoring plan should encompass physical and biological features such as beach profile, sediment characterization (type and distribution), and plant survival (if planting is included). If addressing forage fish habitat spawning habitat is part of the mitigation strategy, then forage fish spawn surveys could also be implemented. The monitoring plan should include adaptive strategies to implement corrective measures if needed. The monitoring plan implementation schedule should be flexible to allow monitoring after severe storm events.

5.2 Marine Riparian Vegetation Modifications

Marine riparian vegetation modifications were not specifically addressed as an activity in Battelle (2003), but were treated briefly in the description of marine riparian zones. The discussion in this section addresses exclusively those vegetated zones immediately adjacent to marine waters. While much of the emphasis in the past has been placed by the scientific community on analogies to freshwater systems, more work has recently been conducted directly on the role of the marine riparian zone (sometimes called supralittoral or supratidal zone) on the Salish Sea nearshore ecosystem (Sobocinski 2003, Brennan and Culverwell 2004, Romanuk and Levings 2006, Herrera 2007a, 2007b, Romanuk and Levings 2010, Sobocinski et al. 2010). Similar to placing bulkheads, Shandras (2007) found that the motivations of landowners to maintain riparian (in this case stream) vegetation are varied and typically not founded in science, and that landowner education is a key strategy to enable the public to make wise decisions about vegetation on their waterfront land.

5.2.1 Physical Impacts and Ecological Ramifications

As mentioned in Battelle (2003) and throughout the scientific literature, marine riparian zones are an essential ecosystem component to a fully functioning Puget Sound shoreline (Sobocinski 2003, Brennan and Culverwell 2004, Romanuk and Levings 2006, Herrera 2007a, 2007b, Romanuk and Levings 2010, Sobocinski et al. 2010). These studies specifically targeted shorelines that were identical in a geomorphic sense to those on Bainbridge Island. While not all of them occurred within the confines of Puget Sound, the physical conditions and ecological communities from these studies are indistinguishable from those on the island. This body of work has found that the destruction or reduction of marine riparian vegetation can result in a number of ecosystem alterations including:

- Shading and temperature
- Shoreline stability
- Allochthonous contributions
- Groundwater-surface water exchange
- Habitat structure and complexity.

These impact mechanisms and related ecological stressors are discussed below.

Shading and Temperature

The influence of shade on nearshore water quality parameters such as temperature is not as well established in marine environments, as it is for freshwater streams. In general, seasonal air temperature conditions, winds, currents, stratification, and tidal exchange play more dominant roles in determining marine water temperatures than in freshwater environments (Brennan and Culverwell 2004). However, shade may strongly influence temperatures in specific habitat types under specific circumstances, such as the upper intertidal zone, tidal pools, pocket estuaries, and other habitat types that become temporarily isolated or exposed by tidal dynamics. These systems can experience increased variability in temperature and microclimate conditions in the absence of protective shading. Microclimatic conditions in the upper intertidal zone, for example, are demonstrably influenced by marine riparian vegetation. Rice (2006) compared microclimate parameters at a bulkheaded Puget Sound beach with no overhanging marine riparian vegetation to those at an adjacent unmodified site with extensive marine riparian vegetation. He documented significant differences in light intensity, air temperature, substrate temperature, and humidity levels at the modified site, which had a strong effect on the mortality of forage fish eggs. Differences in peak substrate temperatures were particularly striking, averaging nearly 20°F (11°C) higher at the modified site.

Marine riparian shade strongly influences microclimate conditions in the upper intertidal zone. Loss of marine riparian shade is correlated with increased substrate temperatures and reduced humidity, which in turn are indicative of increased desiccation stress (Rice 2006). This is a significant finding because temperatures and desiccation are significant stressors that limit the survival of many upper intertidal organisms, including forage fish species (Brennan and Culverwell 2004). Penttila (2001) reported much higher egg mortality rates among surf smelt for eggs deposited on unshaded beaches compared to those sites with intact overhanging marine riparian vegetation. The hypothesized mechanism causing the observed higher rate of mortality was increased egg desiccation due to longer periods of direct sun exposure at sites with insufficient marine riparian vegetation to provide shade and other favorable microclimate conditions. Rice's (2006) findings comparing differences in microclimate conditions and surf smelt spawn survival on shaded versus unshaded beaches strongly support this hypothesis.

Shoreline Stability

Marine riparian vegetation clearly plays a role in stabilizing marine shorelines, particularly bluffs and steep slopes (Brennan and Culverwell 2004; Desbonnet et al. 1994; Lemieux et al. 2004; Myers 1993), but the specific mechanisms are not as well understood as they are in freshwater environments. The extent to which vegetation affects beach and slope stability varies depending on shoreline characteristics and the types of vegetation present (Lemieux et al. 2004; Myers 1993). On steeper slopes, marine riparian vegetation helps to bind the soils and protect against destabilization, slides, and cave-ins that can imperil structures and disrupt the ecology of the nearshore by increasing silt and clay sedimentation and burying vegetation (Brennan and Culverwell 2004). While natural sediment input from bluff erosion is an important physical

process that gives rise to productive nearshore habitat, accelerated erosion due to marine riparian vegetation removal can often produce sediment of a different character (i.e., fine-grained, silt, clay) that can have negative impacts to habitat. On shorelines with shallower slopes, marine riparian vegetation dissipates wave energy, thereby reducing erosion and promoting the accumulation of sediments. Fallen (but often still live) trees also act to scatter wave energy and retain sandy sediments (Herrera 2005, Herrera 2009b).

Allochthonous Input

Allochthonous contributions of organic material, leaf litter, and large wood from marine riparian systems also have demonstrable effects on nearshore habitat conditions. Allochthonous contributions extends to marine invertebrates, even those in the lower intertidal, as well, because most feed at least partially on leaf detritus (Romanuk and Levings 2010). Insects also play an important role in the nearshore food web (Sobocinski et al. 2010). Without marine riparian vegetation and beach wrack, insect density and diversity are reduced (Romanuk and Levings 2003, Romanuk and Levings 2010). Reductions of this crucial food source for nearshore fishes, such as juvenile salmon, are expected to have consequent effects on these resources (Romanuk and Levings 2006, Romanuk and Levings 2010), just as in more heavily developed environments (Sobocinski 2003, Sobocinski et al. 2010). Additionally, carbon derived from terrestrial vegetation contributes between 12.8 to 61.5 percent (mean 30 percent) of the carbon in the muscle tissue of chum salmon fry (Romanuk and Levings 2010). Thus, terrestrial vegetation in marine riparian areas is an important trophic link in supplying terrestrial carbon to nearshore food webs.

Studies suggest that the delivery of leaf and other organic matter declines at greater distances away from the water's edge, and that most contributions are made within 100 to 200 feet (30-60 meters) of the shoreline (Brennan et al. 2009). In freshwater systems it has been shown that detritus feeding organisms may not be adapted to the leaf fall patterns or the chemical characteristics of leaves from non-native trees suggesting that riparian areas are most effective when comprised of native vegetation (Karr and Schlosser 1977). This is likely the same for marine riparian areas. In addition, native plant species have adapted to local physical conditions such as soil, geology, and climate and therefore require less maintenance, are more resistant to pests and diseases, and generally require little or no irrigation or fertilizers once established. Thus maintaining native plant species in marine riparian areas can also have consequent benefits on maintaining water quality.

Groundwater-Surface Water Exchange

Alteration or removal of marine riparian vegetation would appreciably change the interface between plants, soil, and water on and near the bank surface. In freshwater settings, riparian vegetation acts as a filter for groundwater, removing sediments and taking up nutrients (Knutson and Naef 1997). The functions are likely equally important in nearshore settings as there is no evidence in the literature examined to suggest that they are absent. Conversely, there is consensus in the scientific community that marine riparian buffers are important for sustaining many of the same ecological functions (Desbonnet et al. 1994, Brennan and Culverwell 2004,

Lemieux et al 2004, Brennan et al. 2009). Reduced forest cover that results in altered flow patterns, increased sediment delivery, or reduced water quality can impact adjacent marine waters (discussed further in Section 5.4 *Recent Research on Buffer Width Requirements*). The reduction of nearshore forest cover can therefore affect nearshore and offshore marine wildlife due to affects on habitat and food web interactions (also see Section 3.0 *Nearshore Biological Resources*).

Habitat Structure and Complexity

By maintaining bank stability and contributing large wood to the aquatic environment, marine riparian vegetation forms and maintains habitat complexity. Driftwood and/or large woody debris (LWD) helps to build and maintain beach habitat structure. Documented LWD functions for beach stability include its contribution to roughness and sediment trapping (Brennan and Culverwell 2004; Gonor et al. 1988) and to contributions of organic matter, moisture, and nutrients that assist in the establishment and maintenance of dune and marsh plants (Williams and Thom 2001). Eilers (1975) found that piles of downed trees in the Nehalem (Oregon) salt marsh trapped enough sediment to support vegetation, whereby marsh islands that trapped sedge seeds provided an elevated substrate for less salt-tolerant vegetation. Herrera (2005) suggested that driftwood at the top of the beach may also slow littoral drift and reduce wave-induced erosion. It has been suggested that estuarine wood can affect water flow and the subsequent formation of bars and mudbanks (Gonor et al. 1988). The beneficial habitat structure functions of LWD along marine shorelines may be maximized if trees that fall perpendicular to beaches remain in place. A recent study in Thurston County found that local fallen trees tended to stay in place along shorelines (Herrera 2005). The perpendicular alignment of LWD across the beach provides structure for the widest possible portion of the aquatic habitat, thus maximizing the potential area for sediment trapping and organic matter contributions. Perpendicular wood pieces also have a tendency to scatter the short-period waves common in Puget Sound (Finlayson 2006).

Vertical and structural complexity of intact marine riparian forests also provides important nesting, foraging, roosting, and cover habitat for a variety of birds and mammals that inhabit the marine shoreline ecotone such as the 16 bald eagle nests that are along the shorelines of Bainbridge Island (West Sound Wildlife Shelter 2010).

5.2.2 Marine Riparian Vegetation Modifications and No Net Loss Recommendations

The link between loss of marine riparian vegetation on the productivity of ESA-listed species, such as juvenile salmon and their prey, is unequivocal (Romanuk and Levings 2010). As such, it is important to maintain existing marine riparian vegetation, as removal of this vegetation can have detrimental impacts to the nearshore ecosystem. The City already has existing code to protect large trees (i.e., significant trees) which are the most crucial riparian vegetation type due to the shade, leaf debris and shore stability they provide. Extending the notion of no net loss to forest cover of significant trees in the nearshore zone could also be pursued. Marine riparian buffers are also common measure for protecting marine riparian vegetation (see Section 5.4 *Recent Research on Buffer Width Requirements*).

5.3 Residential Development within the Nearshore Zone

As described above, much of the shoreline in Bainbridge Island has been developed for private residences. In recent years there has been a body of research that has correlated human occupation and presence with habitat degradation and destruction (Beauchamp and Gowing 1982, Brosnan and Crumrine 1994, Schiel and Taylor 1999, Jenkins et al. 2002).

Two impacts associated with residential development on the shoreline not discussed in Battelle (2003) include stormwater impacts to marine waters and physical damage from human use of the nearshore.

5.3.1 Physical Impacts and Ecological Ramifications

It has been demonstrated that stormwater runoff plays a key role in the water quality of Puget Sound (Puget Sound Partnership 2010). Stormwater impacts are pronounced in the nearshore zone because there is often little if any buffering of the quantity and quality of stormwater that enters nearshore waters. Increased impervious surface area and consequent stormwater quantity and quality impacts often accompany residential development and have nearshore ecological effects. Stormwater runoff and associated contaminants were identified as one of the leading threats to aquatic life and human health supported by the Puget Sound ecosystem (Puget Sound Partnership 2010).

In addition, where people have access to the nearshore, pedestrian traffic has been shown to have environmental impacts through trampling (Beauchamp and Gowing 1982, Brosnan and Crumrine 1994, Schiel and Taylor 1999).

Stormwater

Any permanent structure located within the nearshore zone creates some increased impervious area. This impervious surface may lead to unmanaged stormwater delivered to the nearshore zone, particularly if detention and treatment measures are inadequate to offset the impacts. Control of nearshore stormwater is crucial, as buffering by the shoreline landscape before entering marine waters tends to be more limited compared to runoff originating in locations that are further inland.

Implementing actions that are aimed to protect marine riparian vegetation (discussed further in Section 5.4 *Recent Research on Buffer Width Requirements*) will help to avoid impacts associated with pollutants, turbidity and sedimentation in the nearshore environment. Protection of marine riparian vegetation is also likely to reduce pollutants that may originate from shoreline residential uses.

Runoff from residential areas can include herbicides, pesticides, surfactants, nutrients (from fertilizers), bacteria and viruses (from animal waste) (Engstrom 2004), as well as sediment from dirt and gravel driveways. Residential areas can also contribute nutrients, viruses, bacteria and

chemicals from failing septic systems. These contaminants can enter stormwater when ponded effluent flows directly into surface runoff, or via shallow groundwater flowing directly into surface water bodies or marine environments. In addition, most standard septic systems remove very little nitrogen prior to discharge of the effluent. Some nitrogen is removed through denitrification that occurs in the soil column, but a portion of it can enter downstream receiving bodies. Nitrogen can pose a significant problem for marine receiving water bodies in cases were septic systems are close to the shore because marine waters are nitrogen limited. In addition, curtain and foundation drains often discharge to the nearshore and can contribute additional pollutants to marine waters. Zinc strips and other zinc-based products are used in residential areas to prevent and treat moss, and can add zinc to runoff. Bleach and detergents are also sometimes used for moss treatment. Other pollutants from residential areas include herbicides, insecticides, copper from copper roofs, zinc from composite roofs, and deicers.

Paved roads associated with areas of residential development can contribute runoff contaminated with pollutants from vehicles. Oil, grease, polynuclear aromatic hydrocarbons (PAHs), lead, zinc, copper, cadmium, sediments (soil particles), associated nutrients, and road salts are all typical pollutants present in road runoff (Zawlocki et al. 1981, Mar et. al. 1982, Davis et al. 2001, Horner et al. 1994). Most oil and grease comes from vehicle leakage, while PAH's are primarily from exhaust. Lead is most commonly associated with wear of metallic parts, wheel balance weights (wearing and falling from wheels), and battery leakage due to car accidents. The primarily source of zinc is wear from tires, and copper primarily comes from brake pad wear.

Frequently shoreline development is accompanied by ornamental landscaping and associated maintenance that tends to increase nutrient loading to marine waters due to the use of irrigation and fertilizers not needed for maintaining native vegetation communities. Increasing nutrient loading to Puget Sound has a variety of impacts. Considerable concern has been raised within recent years that nutrient loading has altered the balance of algal populations (Nelson et al. 2003b). Proliferation of green algae can lead to low dissolved oxygen episodes, which have been documented in Hood Canal (Peterson and Amiotte 2006), but could become common along Bainbridge Island if nutrient loading continues to increase with development. Algal blooms may also contribute to paralytic shellfish poisoning (Horner 1998).

Trampling

Trampling results from the direct pedestrian use of the nearshore zone by people. Trampling has been shown to reduce productivity of certain organisms along shorelines in the Salish Sea (Jenkins et al. 2002), as well as elsewhere (Beauchamp and Gowing 1982, Brosnan and Crumrine 1994, Schiel and Taylor 1999). All of this research has been done on rocky shorelines which are not in abundance on Bainbridge Island. It is less clear what impact increased pedestrian traffic would have on beaches or embayments, but the clarity of the research in rocky environments argues for caution in these areas as well. In particular, trampling-induced loss of forage fish spawn on the upper portions of barrier beaches has not been investigated, but could be an issue if pedestrian traffic is heavy.

5.3.2 Residential Development within the Nearshore Zone and No Net Loss Recommendations

Just as in the case of marine riparian vegetation, enforcement of existing laws is essential to moderating the effects of residential development in the shoreline zone. Requiring and enforcing buffer and setback requirements, and emphasizing adequate stormwater management during and after construction are essential to mitigating impacts of shoreline development.

Many regional stormwater manuals prescribe a site planning process for stormwater management, in addition to providing guidance for BMP design. The Stormwater Management Manual for Western Washington (Ecology 2005) is one of the most widely used stormwater guidance manuals in the region. The site planning process contained in manual includes the following steps (Ecology 2005):

- Collect and Analyze Information on Existing Conditions
- Prepare Preliminary Development Layout
- Perform Off-site Analysis (at local government's option)
- Determine Applicable Minimum Requirements
- Prepare a Permanent Stormwater Control Plan
- Prepare a Construction Stormwater Pollution Prevention Plan
- Complete the Stormwater Site Plan
- Check Compliance with All Applicable Minimum Requirements

A comprehensive stormwater site plan can help homeowners minimize impacts to stormwater quantity and quality through a holistic and thorough approach to site assessment, site layout, and stormwater planning.

Low impact development (LID) practices have been an area of recent research and growth that would be relevant to land use planning in the City of Bainbridge Island. LID refers to a range of stormwater management measures that are intended to mimic predevelopment hydrologic processes. The *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Action Team/Washington State University 2005) highlights the benefits of a comprehensive inventory and assessment of on-site and adjacent off-site conditions as the initial steps for implementing effective stormwater management plans. Evaluation of the existing hydrology, topography, soils, vegetation, and water features at a site will identify how stormwater moves through the site prior to development, providing valuable information necessary to implement proper stormwater site planning and layout as part of development (Puget Sound Action Team/Washington State University 2005). This iterative site assessment and planning process carries through the duration of the project, from inception to completion.

The *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Action Team/Washington State University 2005) contains guidance for site assessment, site planning and layout, vegetation protection and maintenance, clearing and grading, and flow control and treatment methods. It also contains information on hydrologic modeling input

parameters for LID flow control measures; this same information is also contained in the Stormwater Management Manual for Western Washington (Ecology 2005).

An increasing body of literature is promoting LID as the preferred means for managing stormwater from development (Booth 2007, Horner 2006, Horner 2007a, Horner 2007b, and Holz 2007). As with traditional stormwater management, it should be noted that the LID approach seeks to minimize disturbance and protect native vegetation as the first step, prior to resorting to BMPs to mitigate unavoidable stormwater impacts (Puget Sound Action Team/Washington State University 2005).

Washington State University is currently working on an update to the 2005 *Low Impact Development Technical Guidance Manual for Puget Sound*, anticipated to be completed in 2011. Similarly, Ecology has organized a technical advisory committee and an implementation advisory committee to assist in developing statewide guidance and requirements for future application of LID (including through future municipal National Pollutant Discharge Elimination Permit [NPDES] requirements). Regulations that require the use of LID practices under reasonable (and most) conditions will reduce the potential for impacts to water quality that would affect sensitive habitat and species.

The following menu of stormwater alternatives are suggested to be most effective at mitigating the hydrologic and water quality impacts of development particularly for residential development on the shoreline in the City of Bainbridge. These include:

- Bioretention
- Permeable Pavement
- Infiltration Facilities
- Soil Amendment
- Green Roofs
- Cisterns
- Trees or Native Growth Protection Areas
- Downspout Dispersion
- Retrofits of Roadside Ditches to Treatment Swales

5.3.3 Over-water and In-water Structures

The following sections describe impacts associated with over-water and in-water structures. In addition to bulkheads (discussed in Section 5.1 *Shoreline Stabilization Structures*), over-water and in-water structures typically associated with shoreline development can have subsequent impacts on fish and wildlife (Fresh et al. 2004, Mumford 2007, Sobocinski et al. 2010, Brennan et al. 2009).

Over-water and in-water structures are categorized into the following; marinas, boat launches, and mooring buoys. Individual docks and piers are considered within the section describing marinas. Docks and piers typically result in similar impacts as marinas (a collection of docks and piers), albeit the impacts of a single dock may be comparatively less due to the cumulative nature

of impacts that would result from a more expansive marina development. However, multiple individual docks or other shoreline structures developed across a larger geographic area would also result in cumulative impacts and potential threats to nearshore biological resources.

Marinas

Public and private marinas are found throughout Bainbridge Island. These marinas, as well as large vessel terminals, are well established and not likely to be a priority concern with respect to further degradation of shoreline functions. However, ongoing maintenance practices and proposals for facility upgrades and expansion should be carefully evaluated to ensure protection of the environment and sensitive species.

The placement and operation of structures associated with recreational and transport vessels affect aquatic ecosystems through a variety of mechanisms including the resuspension of benthic sediments, substrate and shoreline erosion, vehicle emissions, stormwater pollution, traffic-related disturbance, and direct mortality of sea life from collisions with vessels (Herrera 2007a).

Marinas (as a collection of individual piers) and ferry terminals are known to affect light availability and the aquatic habitats upon which sensitive species depend. A considerable body of literature provides evidence that shading from these structures can reduce ambient daytime aquatic light availability to levels below the light threshold levels required for aquatic plant photosynthesis and fish feeding and movement (Herrera 2007a). Marina and ferry terminal facilities can also alter ambient nighttime light through the use of artificial light. In the case of terminals that berth large vessels, documented shading includes the reflective effects of sediment resuspension and bubbles generated by high propulsion prop wash in shallow environments (Thom et al. 1994, Haas et al. 2002, Blanton et al. 2001). Boat propeller wash and benthic disturbance by ferries are well documented for ferry terminals (Haas et al. 2002; Blanton et al. 2001; Thom and Shreffler 1996), and has the potential to alter substrates and reduce habitat for numerous species dependent on specific substrate types.

Nutrient and contaminant loading from vessel discharges, engine operation, prop scouring, bottom paint sloughing, boat wash-downs, haul-outs, boat scraping, painting, and maintenance activities pose risks such as sediment contamination and water quality degradation (Herrera 2007b). Increased vessel use that may result from new or expanded ferry terminals, marinas, docks, or boat access structures increases the potential for toxic substances to enter the water due to accidental spills.

More vessel traffic in the marine environment increases the potential for underwater noise and disturbance of sensitive species, particularly marine mammals. Recent studies have shown that vessel activity can alter the behavior of whales, including foraging behavior (Lusseau et al. 2009; Williams and Ash 2007; Williams et al. 2002, 2009).

Boat Launches

Boat ramps, riprap, and other shoreline hardening structures that may be constructed in association with marinas and boat launches can function in a similar manner as described for bulkheads. These shoreline hardening structures could result in the alteration of wave energy in the surrounding area (Komar 1998), and altered sediment transport (Williams and Thom 2001), with subsequent impacts on habitat conditions and species. Regardless of the nature of the alterations, the modified relationship between topography and wave energy results in a shoreline that is out of equilibrium with natural shoreline processes (Komar 1998). As a result, wave energy artificially accumulates in some areas and is diminished in others. As previously noted, this redistribution of wave energy can have a number of interrelated indirect and direct effects on sensitive species by altering substrate and water column characteristics. These alterations can affect the movement of spawn and larvae, increase shear stress and burial, alter water column stratification, and alter the distribution of aquatic vegetation (Herrera 2008c). The effects of these disturbances can cascade to upper trophic species including salmon and marine mammals, as a consequence of impacts to marine crustaceans and beach and sediment dwelling invertebrates that are lower trophic organisms (Sobocinski et al 2010).

Mooring Buoys

Mooring buoys can differ significantly in design. Washington State DNR provides guidance for the construction of mooring buoys and requires that all mooring buoys be registered with them (DNR 2008). Since mooring buoy design effectively determines whether or not specific impacts occur, design is an important consideration for minimizing impacts on sensitive species and habitat. For instance, mid-line float buoys tethered to a well-designed helical anchor (that anchors into the bed) will not have significant construction, maintenance or operational impacts aside from encouraging vessel traffic (Betcher and Williams 1996; DNR 2008).

Betcher and Williams (1996) have documented the relative bed disturbance of different tether types. They noted that mid-line-float tethers did not disturb the bed in areas surrounding the anchor, and all-rope tethers rarely caused disturbance. Betcher and Williams (1996) also found that the extent of the disturbance of the tethers was dependent on the length of the tether with respect to the water depth, the tide range, and the strength and direction of dominant winds, waves, and currents. Bed disturbance in the vicinity of a mooring buoy may also occur due to intense vessel or dive traffic (Glynn 1994, Tratalos and Austin 2001).

The construction of an anchor for a mooring buoy directly disturbs the bed or shoreline where it is placed. In the case of screw-type or manta-ray direct-embedment anchors, the impact is limited to the anchor footprint (generally less than one square foot). However, the other types of anchors used with mooring buoys can cause bed disturbance beyond the area where the anchor is placed. Because the small footprint of screw-type or manta-ray embedment anchors minimize the adverse effects on benthic organisms, these types of anchors are recommended by the Washington State Department of Natural Resources (DNR 2008).

The disturbance of primary importance caused by mooring buoy in marine environments is related to eelgrass (Betcher and Williams 1996). Because mooring buoys are usually placed in shallow coastal settings, typical of the location of eelgrass meadows (Phillips 1984), impacts to these areas from mooring buoys are common (Betcher and Williams 1996). Mooring buoys are also often placed in more rural settings (as compared to marinas or other major shoreline development) (Jefferson County 2008a), and therefore have a higher potential for being within or near an intact eelgrass meadow.

Over-water and In-water Structures and No Net Loss Recommendations

Because the majority of shoreline development in the City of Bainbridge Island is likely to occur through incremental development and individual shoreline alterations, the cumulative impacts of multiple individual actions is of particular importance on Bainbridge Island. Although a single dock structure may have minimal direct impacts beyond localized disturbance and altered conditions, numerous structures, including their continued use and maintenance, will likely have more severe impacts on conditions on a cumulative scale. For example, beach composition that is determined in part by wave energy and sediment transport into drift cells (MacLennan et al. 2010) would be highly susceptible to alteration when the presence of multiple docks alters wave energy along the shoreline.

To minimize environmental impacts, it is recommended that the City's permit process require that proposals meet in-water and over-water structure siting and design standards. Design standards could be based on existing requirements such as those established by the US Army Corps of Engineers for residential docks (USACE 2005 or as updated), or could be developed and tailored to meet specific local conservation goals based on land use designations. Siting standards should include an evaluation of potential cumulative impacts that considers the presence of other over-water structures. More stringent siting and design criteria would likely provide better conservation, particularly on a cumulative scale.

Mooring buoys should not be placed in known eelgrass meadows, where possible. Even where eelgrass does not occur, design recommendations for anchoring (PADI 2005) and tethering systems (DNR 2008) should be followed to ensure that adjacent areas are not impacted. If an anchor is placed in or near a known eelgrass meadow it is likely that some impact to this habitat type might occur, the degree of which will depend on the type of anchor and tether.

The development and maintenance of ferry facilities in the City is managed by Washington State, and there are regulations and policies in place to ensure minimization of environmental impacts. Proposed changes to ferry and marina facilities, as well as other in-water structures, and their potential impacts on threatened and endangered species, are typically described and reviewed in a biological assessment or other documentation prepared for the project. The City should thoroughly review the project documentation for State proposed ferry facilities to ensure adequate inclusion of all sensitive habitat and species identified for protection under the City's regulations and request additional analysis or reporting if information is absent or inadequate to inform development decisions.

Due to the important ecological role of eelgrass (Section 3.1.2 *Eelgrass Meadows*) and the potential for impacts to other sensitive species that rely on this habitat, it is important to protect these areas from shoreline development activities that result in impacts to water quality and light penetration in the water column. Because there are limited recent data on eelgrass presence, site-specific surveys conducted during expected periods of growth should be required for review of individual shoreline development projects. Comprehensive surveys that contribute to a general understanding of eelgrass conditions, growth, and distribution trends would also help to inform development decisions. Long term monitoring would contribute to a better understanding of potential impacts. The City of Bainbridge Island should support long term monitoring surveys as they will likely contribute to an improved understanding of impacts, and the ability to evaluate mitigation success and whether no net loss is achieved.

5.4 Recent Research on Buffer Width Requirements

Buffers can be important to the protection of the functions and processes of the nearshore environments along marine coastlines. It is important to recognize that buffers are a tool for conserving a wide array of functions and values. One size does not necessarily fit all, especially when considering local (i.e. specific) historical and future land uses, property rights, and social values supported by marine riparian areas (e.g., cultural, human health and safety, and aesthetic benefits). These social issues combine with the need to protect ecosystem functions to complicate the process of determining adequate buffer widths for achieving a wide range of potential goals.

Many factors can influence the effectiveness of a buffer, which would depend on site-specific characteristics. Specific factors relevant to the effectiveness of a given buffer width include, for example, the type and intensity of surrounding development, influence of groundwater, stability of slopes or bluffs, types of pollutants and their sources, vegetation dynamics (such as type and density), and geomorphic functions of driftwood or other habitat features that might affect the functions and values of the buffer (Brennan et al. 2009). For example, slopes that are more susceptible to massive failure may require a larger buffer, particular if existing development is contributing to an increased rate of erosion such as from poor stormwater management, and lack of stabilizing vegetation. Likewise, feeder bluffs contributing to forage fish spawning beaches may require a larger buffer in order to prevent development that might impair sediment contribution processes as the slope seeks equilibrium. Steep slopes comprised of bedrock may require a narrower buffer as slope stability and sediment sources would not be impacted by development.

Current practices to maximize the effectiveness of buffers (by minimizing impacts to the buffer) commonly include a structure “setback.” A structure setback acts as a regulated transition area between a buffer and development. Permanent structures are prohibited in a structure setback but more limited uses such as gardens or low intensity forestry are allowed. A structure setback serves to protect buffer structure and functions while allowing for more flexibility to property

owners for property uses in areas further from the shoreline. The structure setback should be measured from the edge of the buffer.

Although information on the application and effectiveness of marine buffers is more limited than for freshwater systems, a considerable portion of the knowledge on marine buffers is founded in the science supporting stream buffers as an effective conservation tool (Lemiex et al 2004). In addition, because riparian buffers in both stream and marine environments can have implications for water quality in the marine environment some references to freshwater buffers are included in this section. Scientific research on freshwater and marine riparian environments, particularly related to safeguarding the processes that protect nearshore functions remains an active field of inquiry.

Nonetheless, as stated previously, there is consensus in the scientific community that marine riparian buffers are critical to sustaining many ecological functions (Desbonnet et al. 1994, Brennan and Culverwell 2004, Brennan et al. 2009, Lemieux et al 2004) These functions include the following (Romanuk and Levings 2010, Brennan et al. 2009, Lemieux et al 2004):

- Water quality maintenance
- Fine sediment control
- Large woody debris delivery and retention
- Microclimate moderation
- Nutrient delivery and retention
- Terrestrial carbon source to nearshore food webs
- Fish and wildlife habitat creation and maintenance
- Direct food support for juvenile salmonids
- Hydrology/slope stability
- Terrestrial carbon source to nearshore food webs
- Direct food support for juvenile salmonids

Without adequate marine riparian protection, the functions in the list above and key natural processes become degraded (Sobocinski 2003, Brennan and Culverwell 2004, Romanuk and Levings 2006, Herrera 2007a, 2007b, Romanuk and Levings 2010, Sobocinski et al. 2010).

In response to this risk, the effectiveness of various buffer widths have been established by several sources. For example, riparian buffer widths necessary for protecting functions have been developed based on site-potential tree height (SPTH). SPTH is a method for determining buffer widths that was developed by the Forest Ecosystem Management Assessment Team (FEMAT) and is sometimes called SPTH method, or FEMAT curves method. The method considers the heights that mature trees in a climax forest will reach given local conditions (FEMAT 1993). Buffer widths are then established at the distance of one SPTH or in some cases a multiple of that distance. The FEMAT curves plot the relationship between the effectiveness of a mature forested buffer at providing an ecosystem function at various buffer widths.

In addition, because much of the existing literature related to buffers is based on freshwater riparian systems, a panel of scientists was established in 2008 to assess whether the freshwater

riparian buffer science and the FEMAT curves method are applicable to marine nearshore environments (Brennan et al. 2009). The result of the literature review and the Marine Riparian Workshop Proceedings conducted by the scientific panel in 2008 was a common consensus that freshwater riparian buffer research and the FEMAT curves method is applicable to the marine environment (Brennan et al. 2009).

The panel also generally agreed marine shorelines should be viewed and managed holistically to address multiple processes and functions, at small and large spatial and temporal scales, and from a landscape-scale perspective. The literature on restoration of nearshore habitats finds that it is preferable to move to a landscape scale approach for habitat management so that interrelationships between various habitats types and processes can be maintained (Levings 1998, Simenstad and Cordell 2000, Fresh et. al. 2003, Redman et al. 2005, Shandas and Alberti 2009). As an example, the development of shrub habitat along estuaries may be dependent on emergent vegetation to trap sediments so that the marsh aggrades to an elevation that supports shrubs.

Within the context of landscape-scale management of Bainbridge Island's ecosystems, riparian buffers are an important component of the marine shoreline protection and restoration toolbox. The literature provides information on effectiveness of various buffer widths at achieving certain functions. Brennan et al. (2009) collected literature on riparian buffer widths and their effectiveness at protecting or achieving the marine riparian functions listed above. Table 6 summarizes results from the study showing three types of information: 1) the function reviewed; 2) the smallest and largest buffer widths recommended in the literature that achieved a minimum of 80 percent effectiveness for that function; and 3) buffer width recommendations to meet 80 percent effectiveness based solely on FEMAT curves.

The data from the Brennan et al. (2009) literature review suggest that buffer widths can vary from as little as 16 feet to as large as 1,969 feet in order to achieve at least 80 percent effectiveness at removing pollutants from stormwater runoff. The FEMAT curves showed the following range of minimum buffer widths to achieve 80 percent of the function: 82 feet for sediment control (retention) to 197 feet for nitrogen removal.

It is important to note that much of the existing literature addressing water quality maintenance describes buffer effectiveness based on a percentage of pollutant removed; however, the results do not indicate whether the reduction is sufficient to comply with water quality standards or protect biological resources. More focused studies that apply to marine shorelines, and that are specific to the shoreline conditions and typical land uses found in the City of Bainbridge Island, would better inform the broad range of recommendations found in the literature for removing pollutants

Buffers required for the input of organic material (such as plant litter and terrestrial insects) were limited for the marine environment, however a buffer width ranging from between 16 to 328 feet from the shoreline was indicated as effective by Bavins et al. (2000) for fish habitat in freshwater and marine environments. A range of buffers for the large woody debris function (important to habitat structure) was between 33 and 328 feet. However, given that trees located 300 feet

landward from the edge of the bluff/bank would not immediately be recruited on the nearshore, consideration should be given to the specific potential tree height and the current and expected rate of bluff/bank retreat when establishing buffers for providing large woody debris.

Table 6. Riparian buffers functions and width recommendations in the literature[a]

Riparian function	Range of buffer widths (feet) to achieve ≥ 80% effectiveness and literature cited	Minimum buffer width (approximate) based on FEMAT curve to achieve ≥ 80% effectiveness[b]
Water quality	16 ft: Schoonover and Williard (2003) for 98% removal of nitrate in a pine forest buffer 1969 ft: Desbonnet et al (1994/1995) for 99% removal	82 ft: sediment 197 ft: TSS 197 ft: nitrogen 279 ft: phosphorus
Fine sediment control	82 ft: Desbonnet et al (1994/1995) for 80% removal 299 ft Pentec Environmental (2001) for 80% removal	82 ft: (sediment) 197 ft: (TSS)
Shade/Microclimate	56 ft: Belt et al 1992 IN Eastern Canada Soil and Water Conservation Centre (2002) for 90% effectiveness 125 ft: Christensen (2000) for 80% temperature moderation	121 ft (0.6 SPTH*)
LWD	33 ft: Christensen (2000) for 80-90% effectiveness 328 ft: Christensen (2000) for 80-90% effectiveness	131 ft (0.65 SPTH*)
Litterfall & Insects	16 to 328 ft: Bavins et al (2000)	80 ft (0.4 SPTH)
Hydrology/slope stability	Consensus is that for steep slopes affecting features such as feeder bluffs, a site specific analysis by a qualified professional is necessary to determine a specific buffer width.	Recommendations are based on protecting property and not sensitive biological resources. Buffers widths are provided for a range of slope conditions.
Wildlife	73 m (240 ft): Goates (2006) for 90% of hibernation and nesting 275 m (902 ft): Burke and Gibbons 1995 IN Goates 2006 for 100% of hibernation and nesting	N/A

[a] FEMAT data in this table are based on one SPTH as equal to 200 feet. The SPTH may be different for Bainbridge Island.
[b] Table 6 is information adapted from a summary of buffer width recommendations in Protection of Marine Riparian Functions in Puget Sound, Washington (Brennan et al. 2009).

The literature did not create a FEMAT curve for wildlife habitat because the literature did not have adequate information on effectiveness of buffers for achieving wildlife habitat functions. Brennan et al. (2009) did calculate an arithmetic mean of 571 feet for buffers that were found to provide wildlife habitat functions.

To increase the effectiveness of the buffer, additional considerations should be applied. These include allowing driftwood accrual on beaches; protection, restoration, and enhancement of marine riparian forests for long term future wood recruitment, to prevent or slow shoreline

retreat, and reduce landslide potential; and use of natural means to protect shores (if protection is needed) from the impacts of climate change such as increased wave energy and sea level rise.[3]

Clearly, use of vegetated buffers, in addition to controlling and treating sediment and pollutants at their source, is critical to maintaining clean marine waters around Bainbridge Island. While stream riparian buffer research can be applied to marine shoreline environments, more research and analysis of buffer effects on marine functions is needed. Empirical studies of marine shoreline buffer effectiveness at achieving functions that are important to these areas are needed to better inform buffer establishment. For marine shorelines, site specific factors that are discussed in this section are more important than in freshwater riparian areas because of the high variability of habitat types in marine areas (Brennan et al. 2009).

Following is a more detailed discussion of marine riparian buffers by function.

5.4.1 Water Quality

Most studies have addressed the effectiveness of buffers in removing the most common pollutants from non-point pollution such as sediment, total suspended solids, nitrogen and phosphorous. Generally, the wider the buffer the more effective it is at removing pollutants. Vegetation type and density, geology, landform, and soil characteristics can affect the manner and rate at which water flows over and through the riparian area and the extent to which groundwater remains in contact with plant roots and soil particles (Klapproth and Johnson 2000). Microorganisms found in riparian soils and sediments are capable of metabolizing pesticides and transforming nutrients and other chemicals into less toxic forms (Ettema et al. 1999; Klapproth and Johnson 2000) and can also perform chemical reduction reactions such as denitrification (Adamus et al. 1991; Schoonover and Williard 2003; Rich and Myrold 2004). In addition to reducing the pollutant load to receiving waters, microorganisms cycle nutrients including carbon, nitrogen, and phosphorus. Sandy soils are more effective at draining runoff than fine sediment soils and therefore may retain greater levels of sediment (Hawes and Smith 2005).

Relative to the dynamics affecting water quality in Puget Sound at the watershed and landscape scales, undisturbed marine riparian area's contribution to maintaining water quality is limited to the area that drains directly into Puget Sound. Anthropogenic activities in marine riparian areas that can affect water quality include the generation and routing (via water) of pathogens, nutrients, toxics, and fine sediment (above normal background levels) (Brennan et al. 2009). Because the City of Bainbridge Island is primarily residential, commercial or industrial sources of pollution are limited. Sources of sediment and other pollutants are predominantly from impervious surfaces, gravel and dirt roads, septic systems, and outside household chemical use. One industrial source of pollution, the Wyckoff wood treatment plant and Bainbridge Island's

[3] Natural ways to protect shores include:

- Using stable large wood pieces without the use of cables or ecology block,
- Nourishment with sediment types appropriate for the site, and
- Revegetation (using, for example, inoculation with beneficial microorganisms and other treatments to expedite growth) with plants that respond well to site-specific conditions.

largest industry, has caused contamination of Eagle Harbor, however a toxic cleanup is underway.

5.4.2 Sediment Control

The studies cited above in Section 5.4.1 *Water Quality* typically include sediment because pollutants attach to sediment and are transported in stormwater to waterbodies. Recommendations are that an 82- to 299-foot buffer would remove approximately 80 percent of sediment loading (Brennan and Culverwell, 2004; Pentec 2001). Fine sediment is important in maintaining soil characteristics necessary for the growth and maintenance of marine riparian vegetation. However, allowing for natural erosion and sediment transport processes is critical to maintaining Puget Sound beaches and much of the sediment nourishing these beaches originates in marine riparian areas. The delivery of sediment to marine beaches is facilitated by natural driving forces (wind and wave action, bluff saturation, leading to slope failures) and it is very important to maintain these natural sediment contributions. Thus, there is a need to distinguish between "normative" sedimentation rates in marine riparian areas as opposed to human-induced changes to sediment contributions. Therefore, vegetated buffers along marine shoreline areas should be established to remove human-induced sediment (i.e., from construction or road runoff) that is not otherwise adequately controlled and treated by stormwater facilities, while allowing the natural shoreline processes to naturally feed sediment and gravel to beaches.

As discussed above in Section 5.4.1 *Water Quality*, since Bainbridge Island is dominated by residential development, human-generated sediment would primarily be associated with roads and other impervious surfaces. Twenty four percent of the Bainbridge Island's 200-foot wide shoreline zone consists of impervious surfaces and 32 percent is lawns or un-naturally vegetated areas (Williams et. al. 2004). These areas would be the largest contributors of sediment to the marine waters.

5.4.3 Shade/Microclimate

Marine riparian areas are strongly influenced by marine water temperatures during both summer and winter months (warmer in the winter and cooler in the summer than upland areas). Living riparian (overstory trees, understory shrubs, and ground) vegetation, in turn, can intercept solar contributions and affect microclimate conditions such as soil and ambient air temperature, soil moisture, wind speeds, and humidity (FEMAT 1993; Knutson and Naef 1997; May 2003; Parkyn 2004). With regard to shade, adjacent riparian vegetation may have a relatively minor affect on intertidal beaches but will provide more benefit along shorelines that lack significant back beach area. Marine riparian vegetation may also contribute to upper intertidal conditions even in the absence of providing direct shade, due to effects on humidity and wind speed. In their literature review of causes of spatial and temporal patterns in intertidal communities, Foster et al. (1986) found that desiccation is the most commonly reported factor responsible for setting the upper elevational limits of survival for intertidal animals. More recent studies (Pentilla 2001; Rice 2006) showed that a lack of shade on surf smelt spawning beaches results in higher temperatures, drier conditions, and increased egg mortality.

The FEMAT curve suggests a buffer of 121 feet to achieve 80 percent effectiveness for shade and microclimate functions. Belt et al. (1992) recommends 56 feet for 90 percent effectiveness and Christensen (2000) suggests 125 feet for 80 percent effectiveness.

Bainbridge Island shorelines have many areas of forage fish spawning. surf smelt, sand lance, and herring) spawning areas are located primarily along the shorelines of the northern half of the island with some surf smelt spawning areas recorded in Eagle Harbor (Battelle 2003), although Williams et. al. (2004) indicates that this data is incomplete and there are several areas that have not been surveyed for forage fish spawning. Additionally, juvenile salmonids utilize the nearshore habitats as discussed in Section 3.3.2 *Salmonids* and can be affected by water temperature. Therefore, ensuring buffers are adequate to provide shade and microclimate functions in these areas is important to the fish and organisms that live in these environments.

5.4.4 Large Woody Debris

Forested riparian areas are a significant source of LWD in freshwater systems (Harmon et al. 1986; Sedell et al. 1988; Bilby and Bisson 1998; Hyatt and Naiman 2001). In marine environments, LWD (also known as ‘driftwood’) originates from both freshwater and marine riparian sources. Marine riparian areas contribute LWD to shorelines through natural recruitment processes, including windstorms, fires, wave action, and landslides (NRC 2002). Most of Puget Sound’s bluffs are naturally unstable and landslides are a common occurrence throughout the region (Johannessen and MacLennan 2007).

Large woody debris provides numerous benefits to shorelines and marine riparian areas including:

- Moderation of local water temperature and soil moisture;
- Accumulation of detritus serving as a food source and habitat for invertebrates;
- Support of terrestrial vegetation (such as nurse logs);
- Structural complexity that provides habitat for fish and wildlife;
- Sediment trapping and bank erosion control.

Details about these functions and potential effects of their alteration are provided in Section 5.2 *Marine Riparian Vegetation Modifications*.

Buffer width effectiveness for LWD functions is strongly influenced by site conditions (such as slope, vegetation type and age structure, and natural disturbance regimes) (Brennan et al. 2009). The FEMAT curve suggests 80 percent effectiveness for LWD is 121 feet. The literature reviewed by Brennan et al. (2009) found a range of buffer widths between ranging from 33 to

427 feet for provision of LWD. Herrera (2005) found that about 90 percent of all LWD comes from trees growing within about 50 feet of streams.

Because most buffer recommendations have been developed for riverine systems, marine buffer requirements may need to be adjusted to account for the effects of wind, salt spray, desiccation, and general microclimatic effects (Brennan and Culverwell, 2004). These factors should be considered during the site assessment for an individual shoreline development proposal, and in the permitting review process. Potential buffer adjustments are discussed further in Section 5.5 *Buffer Approaches*.

Bainbridge Island contains primarily deciduous forests with some conifer forests along the shoreline (Williams et. al. 2004). More than 50 percent of the 200-foot wide shoreline zone of Bainbridge Island is naturally vegetated by forests, shrubs, or wetland vegetation (Williams et. al. 2004). Due to the important functions LWD provides, buffers should be adequate to provide this function. In areas where bluffs are the most unstable and prone to erosion or landslides, larger (maximum width) buffers could achieve both infrastructure protection and provision of LWD.

5.4.5 Wildlife

Provision of wildlife habitat has been well documented for freshwater riparian systems (e.g., Knutson and Naef 1997; Cederholm et al 2000; NRC 2002, Buchanan et al. 2001). Riparian areas provide the resources and structure to meet important life history requirements such as feeding, roosting, breeding, refuge, migration corridors and clean water for a variety of wildlife species. Knutson and Naef (1997) report that riparian areas contribute to high productivity and species diversity in aquatic and upland areas.

The wildlife function of marine riparian areas is not well documented, although Buchanan et al. (2001) and Brennan and Culverwell (2004) described a wide variety of fish and wildlife associations for marine riparian areas of Puget Sound. Wildlife species have adapted to the natural processes, structure, and functions of marine riparian areas and have also played an important role in shaping the structure and character of marine riparian areas. For example, many birds and mammals that breed and rear in upland areas forage in intertidal areas. Thus, these species provide marine derived nutrients to uplands in the form of feces and carcasses. These marine derived nutrients play an important role in forest ecosystem health (Cederholm et al 2000).

As mentioned previously, a FEMAT curve was not created for wildlife habitat because the studies generally did not discuss wildlife buffer requirements (Brennan et al.2009). In general, the literature states that for wildlife habitat, the larger the width of the buffer the better quality of wildlife habitat is provided (Goates 2006, Desbonnet et. al. 2005, Brennan et al. 2009, Castelle et. al. 1992). Goates (2006) found that 90 percent of hibernation and nesting of bird species could be accommodated with riparian buffers of 240 feet (73 meters), but a buffer of 902 feet (275 meters) would be required to provide 100 percent of the wildlife functions.

5.5 Buffer Approaches

Currently the City of Bainbridge Island's SMP regulations require a 100 foot marine shoreline buffer for Conservancy areas; 50 Feet for Rural, Semi-Rural, and 25 Feet for Urban Environments.

Approaches to establishing buffers vary between fixed or variable width, with the former generally being the most common (Haberstock et al. 2000). To be effective under a worst-case scenario, and to ensure success in the face of uncertainty about specific site conditions, May (2000) and Haberstock (2000) suggest that fixed-width buffers should be designed conservatively (i.e., larger than the bare minimum needed for protection).

Castelle and Johnson (2000) note that fixed buffer widths are more easily established, have a lower need for specialized personnel with knowledge of ecological principles, and require less time and money to administer. Conversely, they note that variable width buffers can potentially allow for greater flexibility, account for variation in site conditions and land management practices, and potentially achieve desired ecological goals while minimizing undue losses to landowners. Variable width buffers are considered more ecologically sound because they have the potential to reflect the true complexity of the environment and management goals (Haberstock et al. 2000; IMST 2001). Todd (2000 as cited in May 2000) suggests that variable width buffers provide the best protection while respecting property rights. Variable-width buffers may be more ecologically sound and theoretically allow landowners more flexibility.

Variable width buffer approaches have been proposed by Forman (1995) and, as cited by Castelle and Johnson (2000) by Darling et al. 1982, Steinblums et al. (1984), Barton et al. (1985), Roman and Good (1985), Budd et al. (1987), and Groffman et al. (1990). Haberstock et al. (2000) provides recommendations for a variable width two-zone approach for the protection of endangered Atlantic salmon habitat. The zone closest to the aquatic area is fixed at a certain width (e.g. 50 feet). The second zone is a variable-width area wherein limited low-impact uses (such as recreation and low-impact forestry) are allowed.

The City could use the available scientific guidance to develop variable buffers for different site conditions and the resources to be protected. Alternatively, fixed width buffers could be adopted based on the typical conditions found in Bainbridge Island. The City may also consider developing a model to determine buffer widths based on local, site-specific factors and expected effectiveness similar to Wenger (1999) and Kleinschmidt (1999). However, as previously mentioned, it is important to consider a number of factors (such as geology, soil type, slope, and vegetation) that influence buffer effectiveness for specific functions. Therefore, these and other potential factors should be considered in developing a model for determining buffer widths.

In addition to buffer width, other policies will increase the effectiveness of buffers and contribute to successful mitigation of development. These include effective on-site pollution control measures, low impervious surface, and minimizing breaks (or gaps) in buffers to increase effectiveness beyond additional buffer width (Wenger 1999). Similarly, encouraging

preservation and restoration of native vegetation may contribute to increased habitat complexity and improved functional benefits compared to non native landscapes, which typically result in a homogenous habitat structure. This could lead to a narrower buffer requirement. As mentioned previously, shoreline stability, and or the presence of a feeder bluff may dictate a larger buffer based on the observed and anticipated erosion rates (determined by a qualified professional).

5.6 Buffers Established by Other Jurisdictions

Generally, jurisdictions within the region, set their maximum buffer widths to achieve most of the functions, but not all of the functions mentioned above. However, most jurisdictions have regulations that allow jurisdictions to widen buffers in highly sensitive critical areas such as unique estuarine habitats or landslide areas. While establishment of buffer regulations have been informed by science, the buffers continue to be value driven or based on buffer regulations of adjacent jurisdictions.

Jefferson County (2008b) recently updated their SMP and undertook a BAS review of buffer science and found similar varied ranges in buffer widths by function, for example 15 feet for LWD recruitment to 328 feet for microclimate functions. Jefferson County set SMP buffers for the marine shorelines to 150 feet for Natural and Conservancy designated areas and to 50 feet for Residential and High Intensity shoreline designated areas. Jefferson County also set buffers for lake shorelines at 100 feet and river shorelines at 150 feet.

King County currently applies a 165-foot buffer to Type S shorelines outside of urban growth areas via the King County critical areas ordinance. However, buffers vary by the type of development surrounding the shoreline (e.g., high intensity, moderate, and low intensity). Buffers for high intensity development areas are 150 feet for shorelines within the urban growth area. King County provided this rationale for having smaller buffers for highly developed areas. While restoration might be possible in intensely developed areas, it would likely entail highly engineered and costly solutions. Buffers in low-intensity land-use areas can potentially better protect habitat and preserve future restoration options than buffers in highly urbanized areas. Placing a higher priority on protecting areas with high habitat restoration or species recovery potential is consistent with recommendations for protection of aquatic resources in developing areas (Booth et al. 2002; Roni et al. 2002).

Lower Kitsap County is proposing to adopt a 150-foot marine shore buffer in certain shoreline environment designations as a result of a decision by the Central Puget Sound Growth Management Hearings Board (CPSGMHB), which found that the 35-foot buffer width on shorelines considered urban, rural and semi-rural under the Kitsap County Shoreline Management Plan was insufficient.

San Juan County Marine Resources Committee has developed recommended strategies for shoreline protection with buffer regulations (SJCMRC 2010). The SJCMRC (2010) recommends a tailored approach that provides protection for each type of sensitive area and the functions and

processes that affect them. They do not recommend a one size fits all vegetated buffer, but instead an appropriate buffer for the type of habitat that exists along the shoreline. By using a fairly simple classification of shoreline types (Shipman, 2008) and incorporating ecological information, the SJCMRC proposes a suite of protection approaches that are tailored to the specifics of a site and will provide lasting protection of shoreline vegetation (trees/ground cover) and natural beach formation/erosion processes where it is most needed. For example, for rocky shorelines armoring of the shoreline has the least effect on sediment supply, so shoreline armoring, if done appropriately might be allowed in these areas compared to a beach that supports forage fish. In addition, vegetation along rocky shores does not provide slope stability, although it filters run-off and may provide important nutrient contributions to the shoreline food chain in the form of leaf litter and insects, so a smaller buffer may be adequate compared to a beach where shade is important. For beach habitats, a larger vegetated buffer is more important, especially where forage fish are present, to block beach warming solar radiation, LWD recruitment, and water quality improvement. Structural setbacks in these areas would be larger to be able to maintain the feeder bluff processes of natural erosion.

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APPENDIX A

Washington Department of Ecology Discussion of No Net Loss

Chapter 4
No Net Loss of Shoreline Ecological Functions

All phases
Shoreline Master Program Planning Process

Introduction

The Shoreline Management Act (SMA) provides a broad policy framework for protecting the natural resources and ecology of the shoreline environment. The SMP Guidelines establish the standard of "no net loss" of shoreline ecological functions as the means of implementing that framework through shoreline master programs. WAC 173-26-186(8) directs that master programs "include policies and regulations designed to achieve no net loss of those ecological functions." (The specific sections of the Guidelines addressing the NNL requirement are included at the end of this chapter.)

> *RCW 90.58.020: The legislature finds that the shorelines of the state are among the most valuable and fragile of its natural resources and that there is great concern throughout the state relating to their utilization, protection, restoration, and preservation…This policy contemplates protecting against adverse effects to the public health, the land and its vegetation and wildlife, and the waters of the state and their aquatic life...*

The SMP Guidelines, adopted in 2003, constitute the first actual rule (WAC) in Washington State to incorporate the no net loss requirement. The concept of no net loss in this State originated with earlier efforts to protect wetlands. In 1989, Governor Booth Gardner signed an Executive Order establishing a statewide goal regarding wetlands protection. "It is the interim goal...to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. It is further the long-term goal to increase the quantity and quality of Washington's wetlands resource base." (E.O. 89-10).

What does no net loss mean?

Over time, the existing condition of shoreline ecological functions should remain the same as the SMP is implemented. Simply stated, the no net loss standard is designed to halt the introduction of new impacts to shoreline ecological functions resulting from new development. Both protection and restoration are needed to achieve no net loss. Restoration activities also may result in improvements to shoreline ecological functions over time.

Local governments must achieve this standard through both the SMP planning process and by appropriately regulating individual developments as they are proposed in the future. No net loss

should be achieved over time by establishing environment designations, implementing SMP policies and regulations that protect the shoreline, and restoring sections of the shoreline. Based on past practice, current science tells us that most, if not all, shoreline development produces some impact to ecological functions. However, the recognition that future development will occur is basic to the no net loss standard. The challenge is in maintaining shoreline ecological functions while allowing appropriate new development, ensuring adequate land for preferred shoreline uses and public access. With due diligence, local governments can properly locate and design development projects and require conditions to avoid or minimize impacts.

No net loss incorporates the following concepts:

- The existing condition of shoreline ecological functions should not deteriorate due to permitted development. The existing condition or baseline is documented in the shoreline inventory and characterization. (See Chapter 7.) Shoreline functions may improve through shoreline restoration.
- New adverse impacts to the shoreline environment that result from planned development should be avoided. When this is not possible, impacts should be minimized through mitigation sequencing.
- Mitigation for development projects alone cannot prevent all cumulative adverse impacts to the shoreline environment, so restoration is also needed.

Practices that help achieve no net loss

The following SMP update practices will help to meet the no net loss requirement:

- **Locate, design and mitigate development within a watershed context**. During the SMP update process, use the characterization of ecosystem processes and functions to identify the best areas for future development and mitigation. The characterization can provide important information regarding areas that have a high potential for restoration and can be used for offsite mitigation. Such an approach can use a combination of onsite and offsite mitigation that helps restore critical processes and generates a greater “lift” in ecosystem functions.
- **Prohibit uses** that are not water-dependent or preferred shoreline uses. For example, office and multi-family housing buildings are not water-dependent or preferred uses. There is no requirement to provide a place for all types of uses within shoreline jurisdiction.
- **Require that all future shoreline development**, including water-dependent and preferred uses, is carried out in a manner that limits further degradation of the shoreline environment. No uses or activities, including preferred uses, are exempt from the requirement to protect shoreline ecological functions.
- **Require buffers and setbacks.** Vegetated buffers and building setbacks from those buffers reduce the impacts of development on the shoreline environment.
- **Establish appropriate shoreline environment designations**. The environment designations must reflect the inventory and characterization. A shoreline landscape that is relatively unaltered should be designated Natural and protected from any use that would degrade the natural character of the shoreline. (In practice, this would avoid future

impacts, the first objective of no net loss.) New shoreline development in such environs is limited, resulting in avoidance of new impacts.)

- **Establish strong policies and regulations.** Policies and regulations will define what type of development can occur in each shoreline environment designation, determine the level of review required through the type of shoreline permit, and set up mitigation measures and restoration requirements.
- **Develop policies and requirements for restoration.** These should be consistent with the shoreline restoration plan prepared for Task 4.1 of the SMP planning process.
- **Recommend actions outside shoreline jurisdiction.** The master program or an SMP supporting document can recommend actions for properties that are outside shoreline jurisdiction but have impacts on shorelands. For example, the SMP could call for improved stormwater treatment of runoff from roads, or replacement of septic systems with sewers. Recommending these actions could help create awareness of problems and provide support for them, although outside the authority of the SMP. Such recommendations could be included in the shoreline management strategy (Task 3.1) or in a brief chapter within the SMP. This would also satisfy the SMA adjacent lands policy (RCW 90-58.340) that local governments are obligated to meet.
- **In all cases, require mitigation sequencing**. The SMP must include regulations that require developers to follow mitigation sequencing: avoid impacts, minimize impacts, rectify impacts, reduce impacts over time, compensate for impacts, monitor impacts and take corrective measures. Avoiding impacts means not taking an action or part of an action in order to prevent impacts to ecological functions. Impacts can be avoided in many different ways: structures may be sited further from properly functioning shoreline areas; different landscaping plants or techniques may be used; a less impactful use may be substituted; or a proposal may be redesigned altogether.

How to demonstrate no net loss

Local governments demonstrate no net loss at two levels -- through the comprehensive SMP update planning process and over time, during the project review and permitting processes (in other words, during SMP implementation).

No net loss in the SMP planning process

The following graphic provides a visual description of the role of the SMP update in achieving no net loss. Through mitigation and restoration, a jurisdiction would achieve no net loss of shoreline ecological functions.

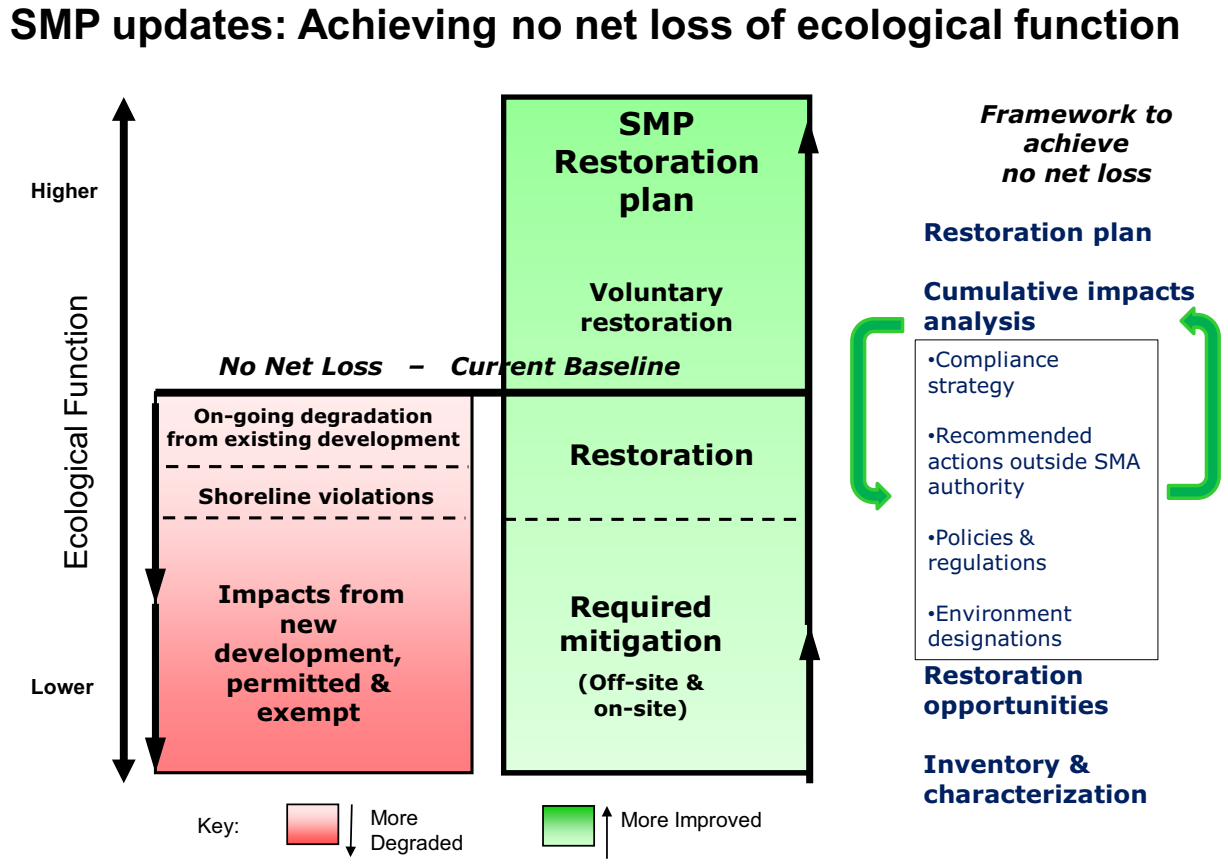


Figure 4-1: During the SMP update process, local governments should use existing shoreline conditions as the baseline for measuring no net loss of shoreline ecological functions.

Local governments show that their updated SMP will result in no net loss of ecological function by completing several tasks in the comprehensive SMP update process, including:

- **Shoreline inventory and characterization**. The shoreline inventory documents shoreline baseline conditions and the characterization analyzes shoreline functions and processes. (See SMP Handbook, Chapter 7 at http://www.ecy.wa.gov/programs/sea/sma/st_guide/SMP/inven_analysis/index.html.
- **Shoreline use analysis.** The use analysis estimates the future demand for shoreline space and potential use conflicts over a minimum 20-year planning period and projects future trends.
- **Shoreline management recommendations.** Management recommendations translate the inventory and characterization findings into SMP policies, regulations, environment designations and protection strategies for each shoreline planning unit.
- **Restoration plan.** The restoration plan includes restoration opportunities, priorities and timelines for shoreline restoration.
- **Cumulative impacts analysis.** This analysis assesses the cumulative impacts on shoreline ecological functions from "reasonably foreseeable future development" allowed

by the SMP, considering at a minimum habitat, hydrology and water quality functions. Analyzing cumulative impacts is necessary to identify and compensate for the total predictable, incremental effects on shoreline functions after applying mitigation measures and restoration.

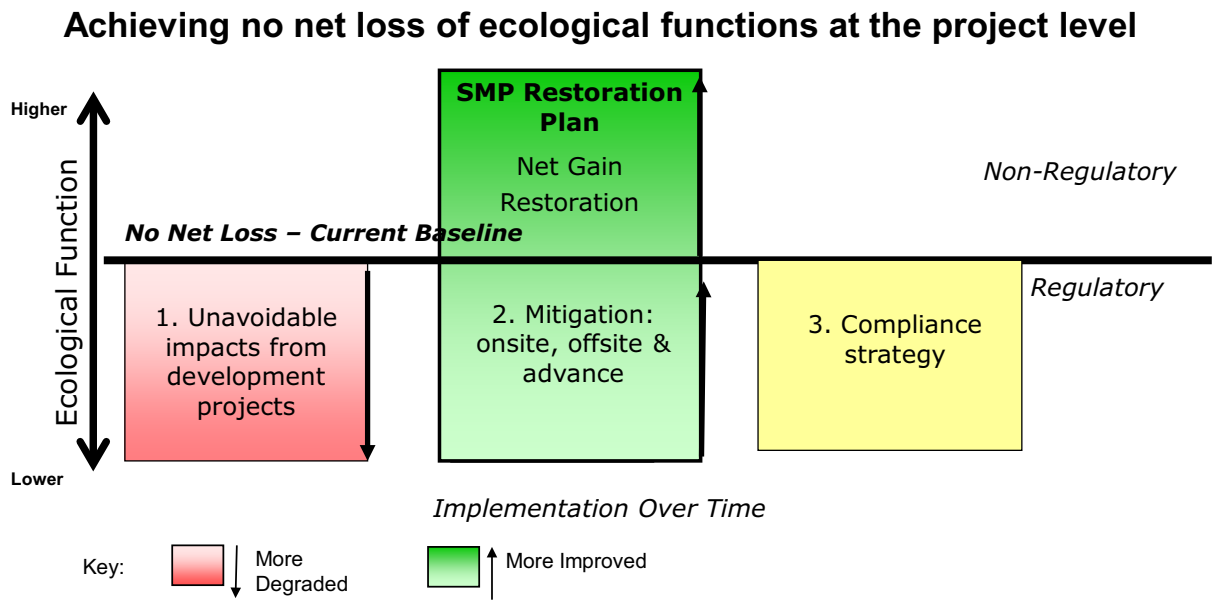
- **No net loss summary.** This narrative provides an overall picture of how the jurisdiction will meet the NNL requirement. This "executive summary" will explain how information from the supporting documents listed above was applied in developing and revising policies and regulations within the updated SMP. The summary should compare the conclusions of the supporting documents with the environment designations and use regulations to demonstrate how these provisions avoid, reduce, and mitigate reasonably foreseeable impacts in order to achieve NNL. This summary should provide a general chronology of the update while providing reference to the specific chronology captured in the SMP checklist. The purpose of this summary and other supporting documents is to ensure that the SMP environment designations, policies, regulations and shoreline restoration plan are based on the findings of the inventory and characterization and the cumulative impacts analysis and will achieve NNL. Documentation of this information will also provide a record of the jurisdiction's decisions on SMP policies and regulations in relation to NNL.

To approve a comprehensive SMP update, Ecology's Director must formally conclude that the proposed SMP, when implemented over its planning horizon, typically 20 years, will result in "no net loss of ecological functions necessary to sustain shoreline natural resources." This conclusion will be based upon the documents listed above, a completed SMP submittal checklist and supporting map portfolio.

No net loss in the permit process

When the SMP goes into effect, careful and thorough implementation will be necessary to achieve no net loss. For example, if the SMP prohibits office buildings and condominiums in the Conservancy environment, then your jurisdiction should not approve these uses in that environment. The cumulative impacts analysis would have shown that no net loss would be achieved if office buildings and condominiums are prohibited in the Conservancy environment. Allowing offices and condominiums under this scenario would result in a loss of shoreline functions.

When implementing the updated SMP, no net loss principles (first avoiding, then minimizing and compensating for ecological impacts) are applied again as individual shoreline project applications are reviewed and approved, conditioned, or denied. The following graphic demonstrates how the no net loss requirement is partially achieved during the permit process.



1. Impacts from shoreline development projects, after mitigation and restoration measures. SMP should encourage appropriate use of innovative measures such as clustering, TDRs, site specific BMPs, etc. to reduce impacts.

2. On-site, off-site and advance mitigation. SMPs should lay out the conditions when off-site mitigation will be allowed or preferred. Innovative techniques such as wetland banking (advance mitigation) should be addressed in SMPs. SMP restoration plans should help identify priority sites and types of sites for the most effective off-site restoration activities.

3. A compliance strategy should include a mechanism to document project review actions and a method to periodically evaluate the cumulative effects of authorized shoreline development. The compliance strategy should include inspection of development projects, and identify priorities for enforcement to improve protection of the most significant shoreline features and functions.

Figure 4-2: SMPs must include regulations that require developers to follow mitigation sequencing. Restoration will also be needed in order to achieve no net loss.

During the planning process, incomplete information about a potential future development and its impacts limits your ability to address no net loss. To close this information gap, unanticipated development impacts are identified through more detailed, site-specific information received at the permit review level.

Project review completes the Guidelines' combined planning and permit review framework for achieving no net loss. It assures that unanticipated impacts will still be subject to a cumulative impacts evaluation as applications for shoreline exemptions, conditional uses, and shoreline permits are reviewed.

One way to comply with the SMP Guidelines requirement is to apply an established mitigation sequence such as that in the State Environmental Policy

> *WAC 173-26-201(3)(d)(iii):For development projects that may have unanticipatable or uncommon impacts that cannot be reasonably identified at the time of master program development, the master program policies and regulations should use the permitting or conditional use permitting processes to ensure that all impacts are addressed and that there is no net loss of ecological function of the shoreline after mitigation."*

Act (*SEPA* - *WAC 197-11-768*) on a case-by-case basis during project review.

Another way is through a conditional use permit (CUP). CUPs are automatically required for unanticipated types of development ("unclassified" uses). The SMP also may require CUPS for developments in which the impacts cannot be fully known at the planning level. Through the CUP review process, "consideration shall be given to the cumulative impact of additional requests for like actions in the area" (see *WAC 173-27-160(2)*).

Potential no net loss indicators

Local planners working on SMP updates have asked for a tool to measure no net loss. In response, Ecology staff scientists and planners, with input from several state agencies and local governments, developed a list of Potential No Net Loss Indicators for Shoreline Master Programs (Table 4-1, below). This table of indicators can be used by local governments to help track the status of shoreline functions. Tracking several indicators can help to meet the "no net loss" of shoreline ecological functions standard of the SMP Guidelines.

Figure 4-3: The linear length or area of bulkheads may be used as an indicator of no net loss of shoreline ecological functions. Photo by Hugh Shipman.

The table shows 15 potential indicators and the type of measurement for each, such as acres, linear feet, number, percent cover, etc. The table shows the shoreline functions – water quality, water quantity and habitat – that are affected by the indicator, as well as specific impairments related to the indicator. Other columns include limitations for using the indicators, where the indicators are best used, and the availability of data. The indicators are limited to the area within shoreline jurisdiction where SMP regulations are implemented.

Measuring and continuing to track these indicators can give you a picture of shoreline conditions and ecological functions. The indicators can be measured to track loss or gain. For example, the length of shoreline stabilization may increase or decrease, or the acreage of riparian vegetation may increase or decrease. As conditions change over time, you may need to make changes to your SMP if tracking the indicators shows that your community is not achieving "no net loss" of shoreline ecological functions.

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
Forest cover: Acres converted from forest land to other land uses.	Water quality–sediment, nutrients & toxic filtration, conversion, and/or retention; temperature regulation. Water quantity–flow regulation. Habitat-structure for habitat life needs; input of organics & LWM*.	Reduces forest buffers and decreases filtering, conversion, and/or retention of pollutants from surface & subsurface flow; increases quantity of pollutants to aquatic habitats. Alters the delivery and timing of water to aquatic areas, increasing quantity of water delivered to aquatic habitats during high and low flows, which affects habitat structures. Increases water temperature. Loss of nesting sites, rearing, refuge & foraging areas.	Doesn't identify future land use. May be difficult to determine acres in shoreline jurisdiction without finer scale analysis.	Rural.***	Details of application available from DNR and local government. Class IV forest practice applications. CCAP data.
Shoreline stabilization: Linear length or area of bulkheads, revetments, bioengineering, seawalls, groins, retaining walls, gabions. (Includes decrease in length, change to soft structure.)	Habitat-Riparian and aquatic habitat, sediment supply. Input of organics, prey base, & LWM. Structure for habitat life needs.	Interrupts habitat-forming processes, such as beaches & channel migration, by impacting sediment supply and transport. Loss of nesting sites, rearing, refuge & foraging areas. Loss of prey base with associated loss of riparian vegetation.	Combines different types of stabilization measures into one general category; impacts may vary.	Rural, urban.	Is data available from local government, including permits & SDP exempt projects? Can locals track over time? HPA information can supplement other data, but is not sufficient on its own. Detailed aerial photos may also show stabilization changes.

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
Marine & freshwater riparian vegetation: Linear measurement of mature native riparian vegetation of a given width (buffer width) or percent cover of different vegetation classes.	Water quality–sediment, phosphorus & toxic filtration, conversion, and/or retention; temperature regulation. Water quantity–flow regulation. Habitat-input of organics, prey base, & LWM. Structure for habitat life needs.	Removes capacity of riparian vegetation to filter surface flows, sediment, phosphorous and toxics; subsurface removal or conversion of nitrogen, pathogens. Increases overland and subsurface flows. Increases water temperature. Reduces prey base. Loss of LWM that provides instream structure. Loss of nesting sites, rearing, refuge & foraging areas.	No permit, so no record of change. Focused project needed to track. Useful only if a baseline exists. Methodology needs to be able to measure change. May be difficult to measure over short time frame.	Rural, urban.	Can locals measure and track? Use sample areas, aerial photos. Puget Sound LIDAR consortium has some data.
Acres of permanently protected areas, with no or limited development: Public ownership, current use/PBRS, conservation easements, fee ownerships, NGOs.	Water quality–sediment, phosphorus & toxic filtration, conversion, and/or retention; temperature regulation. Water quantity-flow regulation. Habitat- Riparian and aquatic habitat, sediment supply. Input of organics, prey base, & LWM. Structure for habitat life needs.	Loss of nesting sites, rearing, refuge & foraging areas.	How measure degree of protection? Limit to protected areas with no development? Difficult to connect with specific functions.	Rural, urban.	Need info on ownership, PBRS, easements. Other info available from county auditor and assessor? Land trusts. NRCS and state agencies are also sources for permanently protected lands.

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
Piers/docks/floats, overwater structures: Number of structures, square footage of new and replacement. Or track grating, piling, construction materials.	Habitat. Water quality-toxics.	Increase in predation, reduction in light and aquatic vegetation and simplification of food web.	All docks not same – i.e. grating, materials vary, location affects impacts. New docks partially mitigate impacts.	Rural, urban.	Is data available from local government, including permits and SDP exempt projects? Can locals track over time? Use DNR data – number of and area over water. HPA information can supplement other data, but is not sufficient on its own. Good to monitor late spring/early summer.
Road lengths (feet) within 200 feet of water body.	Water quantity. Water quality. Habitat- connectivity.	Intercepts and changes timing of flows to aquatic habitat. Increases sediment and toxics.	Is there much new road development in shoreline jurisdiction?	Rural, urban.	Data available from DNR, local governments and WSDOT. CCAP data needs analysis to provide relevant information.
Number of road crossings of water bodies -bridges, culverts.	Habitat - Instream functions. Water quality.	Simplifies stream habitat structure, increases channel confinement and interrupts habitat forming processes. Increases delivery of pollutants.	Is there much new road development in shoreline jurisdiction? Distinguishing between fish friendly crossings and others. Combining broad range of activities.	Rural, urban.	Culvert inventories vary in quality. WDFW has fish passage barrier data, but it is incomplete. Remote sensing data? SHIAPP data? CCAP data needs analysis to provide relevant information.
Water quality: 303(d) list. All water quality	Water quality.	Impairment is specific to type of listed 303(d) issue (e.g. increased temperature, low dissolved oxygen,	How relate to functions? Some impacts from outside shoreline jurisdiction. Only	Rural, urban.	Accessible data from Ecology. Is water body on or off list? In some cases, only a portion (e.g., reach)

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
parameters such as temperature, dissolved oxygen, fecal coliform, heavy metals, toxics, organics and biological indices (e.g., Biological Index of Biotic Integrity).		increased fecal coliform, heavy metals and toxic organics.)	impaired waters are listed & measured; no WQ improvement project in place. No criteria to remove from list. Sampling methodology changes, not always comparable. Marine & fresh water lists updated in alternating 2-year cycles.		of a water body is listed. 303(d) – comprehensive,
Shellfish listings closures.			Some impacts from outside shoreline jurisdiction and municipality. Emergency closures updated regularly. Uneven data. Changes may be too frequent for NNL purposes. Limited to fecal coliform. Reflects impacts on human health, not shellfish health.		Dept of Health Shellfish Program.
Levees/dikes: Linear feet, floodplain area gained from levee setbacks.	Water quality –sediment removal, temperature regulation. Water quantity–water	Impairs natural flooding regime. Reduces floodplain sediment retention, denitrification and	Can change in habitat quality as a result of levee/dikes be easily measured?	Rural, urban.	Measure increase/decrease in lineal feet, quality of levee related to riparian

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
	storage, flooding. Habitat–structure for habitat life needs (e.g., low LWM, stream bed aggradation, river mouth progradation).	hyporheic functions. Decreases groundwater storage and base flows. Interferes with formation of habitat structure such as distributary channels in tidal and riparian and in-channel and off-channel habitat in freshwater settings. Removes habitat structure for nesting, rearing, refuge and foraging.	Various types and locations of levees & dikes are lumped together. Types of openings in levees and dikes vary; impacts may vary.		vegetation & slope. Is data from local governments or FEMA?
Floodplain area: Acres allowed to flood –tidal and river (lack of flood control and lack of other structures such as houses.)	Water quality – removal of toxics, sediment, phosphorous and pathogens through adsorption, filtration and retention. Removal of nitrogen through denitrification. Temperature regulation. Water quantity – water storage and flow regulation and reduction in downstream flooding. Habitat - formation of habitat structure from LWM, vegetation communities and sediment type/channel configuration that support habitat life	Impairment similar to that for levees & dikes with loss of floodplain from diking & filling.	Availability of data, maintenance of data.	Rural, urban.	Do local governments measure this for shoreline inventory? FEMA floodplain info available.

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
	needs. Input of organics and prey base.				
Number of bald eagle & osprey nests & roosts & great blue heron rookeries.	Habitat – structure for habitat life needs.	Indicator of impaired habitat.	More suitable for counties than cities.	Rural.	WDFW data – most up-to-date for eagles.
Percent cover of invasive species in riparian zones.	Habitat – Riparian and aquatic habitat, sediment supply. Input of organics & LWM. Structure for habitat life needs.	Overwhelms native plants, compromising ecosystem. Potential effect on physical structure and food web dynamics.	Requires field work. May be useful if data set is available. Use Noxious Weeds list to define invasive species?	Rural, urban.	Is data available? Conservation districts? WA Invasive Species Council? (working on baseline assessment due in May 2011)
Impervious surface area.	Water quality – removal of toxics, sediment, phosphorous and pathogens through adsorption, filtration and retention. Removal of nitrogen through denitrification. Temperature regulation. Water quantity – water storage and flow regulation and reduction in downstream flooding. Habitat - formation of habitat structure from LWM, vegetation communities and sediment	Reduces vegetative buffers and decreases filtering of pollutants from surface & subsurface flow. Alters the delivery and timing of water to aquatic areas, increasing quantity of water and pollutants delivered to aquatic habitats during high and low flows, which affects habitat structure. Increases water temperature Reduces prey base (by	Covered by other indicators? Percentage increase in developed urban areas would be small and may not be useful indicator. Some land surface cover layers are inaccurate, e.g. showing impervious for clearcut forest.	Urban	Aerial photos or other remote sensing techniques show impervious cover. Local governments require new impervious information in permit applications.

TABLE 4-1: POTENTIAL NO NET LOSS INDICATORS for SHORELINE MASTER PROGRAMS					
Indicator (all in shoreline jurisdiction)	**Functions affected – key categories – water quality, water quantity and habitat**	**Type of Impairment****	**Limitations of indicator**	**Where**	**Is data available or reasonable to obtain**
	type/channel configuration that support habitat life needs. Input of organics.	associated removal of vegetation) Loss of nesting sites, rearing, refuge & foraging areas.			
Wetlands acreage: Fill of natural wetlands and constructed or engineered wetlands. This includes nearshore tidal estuaries.	Water Quality – Wetlands filter pollutants and store sediment. Water Quantity – Affect groundwater storage and flow regulation. Habitat – Affects habitat structure, results in loss of wetland vegetation communities that support habitat life needs.	Changes to natural hydrological, chemical, and physical regimes affect the production and succession of a wetland's ecology, and therefore its functions and values.	Difficult to track. Could be covered in other indicators (impervious surface and water quality), however other indicators don't get at wetland conversion to non-impervious land use such as landscaping or agriculture. May require field work.	Rural, urban	Is data available? Local permit tracking? Ecology? Core of Engineers?
Area of seagrasses, kelp and emergent aquatic vegetation.	Habitat – structure for habitat life needs, including food and shelter for many species.	Decreases in aquatic vegetation such as eelgrass and kelp results in loss of food and shelter for many species.	Multiple factors affect growth and sustainability of aquatic vegetation.	Aquatic	Seagrass, kelp and emergent aquatic vegetation data along shoreline available from DNR Shorezone. (1994-2000) More recent local data available at those sites that are among the stratified randomly sampled sites.

* LWM – Large Woody Material

** For some indicators, decreasing the length or area of the indicator would result in a benefit to shoreline functions (e.g., shoreline stabilization, piers & docks.) For other indicators, increasing the length or area of the indicator would result in a benefit to functions (e.g. forest cover, riparian vegetation.)

*** Rural includes rural residential, agricultural and forestry areas.

CCAP – Coastal Change Analysis Program

PBRS – Public Benefit Rating System

NGO – Non-government organization

NRCS – National Resource Conservation Service