Little Squalicum Shoreline Restoration Feasibility Study

Bellingham, Whatcom County, WA

Prepared for:

City of Bellingham

Public Works Department

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EXECUTIVE SUMMARY

The City of Bellingham (COB) contracted Coastal Geologic Services to assess the feasibility of beach/nearshore enhancement for the shoreline from Little Squalicum beach to the southeast side of the filled coastal area referred to as the Mount Baker Plywood Peninsula shore. The objective of the feasibility study was to identify constraints and opportunities that will inform and guide the development of sustainable beach/nearshore enhancement designs. The study area includes approximately 1,500 ft of shoreline from the Lehigh Northwest Cement Company Pier eastward to the Mount Baker Plywood peninsula.

To achieve the project objectives coastal processes were analyzed and assessed, existing data and previous studies were reviewed, and field assessments were conducted by Coastal Geologic Services staff. A historical analysis of the project area shore was undertaken to place the existing conditions within their historical context. Discussions were undertaken with City of Bellingham (COB) staff and consultants throughout the project. Project constraints were assessed through discussion with COB staff and consultants under contract to the City on this site.

This report initially provides a background of the coastal processes that influence the project site. This includes a general overview of beaches and bluffs of the Puget Sound, a discussion of net shore-drift, nearshore habitats, and the general implications of sea-level rise. Specific processes at the project site are then described in more detail. Nearshore habitats within the site are then discussed. Existing conditions as seen during field visits by CGS staff are then described. Next, changes to the shoreline between 1887 and 2009 are covered in detail. Aerial photographs, historic ground photos, and oral histories from long-time residents provide historical background. The development of the design concepts outlined in this report has been carried out in close coordination with the City of Bellingham Parks Department's current park master planning effort.

After assessing the opportunities and constraints for nearshore restoration the recommended enhancement action is to create a moderate-sized pocket estuary within the southeast portion of Little Squalicum Park. With proximity of high-quality salmon habitat in the Nooksack River and Squalicum Creek, the addition of a pocket estuary in the project area would provide considerable benefits for salmon. This is the most valuable restoration/enhancement project in the study area from a habitat perspective, as explained in the document. The approximately one acre estuary/lagoon would be created in the former gravel mine area immediately landward of the BNSF trestle. The proposed estuary is larger than preliminary sketches from the early master planning work, but this is due to the need for a large enough volume of water in the basin to maintain an open inlet. This project appears much more viable in terms of landowner willingness and timing as compared to project concepts for the Mount Baker Plywood peninsula.

A large volume of mostly gravelly sand would be excavated, which could be beneficially reused on-site or nearby; providing substantial cost savings. Inlet stability analysis and examination of reference lagoons revealed that a tidal inlet is likely to remain open when constructed with specific inlet geometry. The inlet should be dynamically stable with a minimum elevation of approximately 1.5-3.5 ft below MHHW. The proposed estuary would necessitate diversion of the existing lower Little Squalicum Creek channel into the lagoon, also to increase flow. If legacy contamination in the creek as well as the source of additional

contamination is not adequately addressed, the new estuary could become contaminated. Additional coordination is required in this area.

The second opportunity is a beach enhancement project at the west edge of the Mount Baker Plywood peninsula. Approximately 310 ft of rock revetment would be removed, and a large 220 ft long, southwest-facing beach and a 90 ft long beach would be created in its place. A new groin would be required on the west end of the main beach area, which would be on the order of 115 ft long. A total of 24,000 sf of new beachface habitat could be created under this option. With application of appropriate grain sizes on the upper high-tide beach up to 4,800 sf of good potential forage fish spawning habitat could be created. This enhancement option is not supported by the landowners at this time.

The third opportunity entails creating a lagoon in the center of the triangular fill at the Mount Baker Plywood peninsula, which would be mutually exclusive with the second alternative above. This opportunity is not recommended as a high priority due an apparent lack of freshwater inputs, the unknown level of contamination of site soils, and the necessity to maintain the entire length of revetment under this alternative. The lagoon would be approximately 270 ft long by 50–140 ft wide for a total area of approximately 19,000 sf. A fringing saltmarsh (9,500 sf) would be planted, and potential forage fish habitat (1,000 sf) created in the northwest end of the project area. This enhancement option is not supported by the landowners in its present configuration.

Other restoration opportunities were briefly examined, and most were found to be more easily implemented as small, separate projects. Removal of the Cement Company pier would remove a large source of creosote contamination from the bay and provide a measurable amount of restored intertidal and subtidal habitat. Concrete debris could be removed from the intertidal area, including from around the pier and peninsula revetment. The Park trail could be relocated landward of the BNSF trestle to increase the backshore habitat area. Invasive plant removal throughout the study area with planting of salt tolerant native species should also be implemented.

The City of Bellingham Parks Department has recently endorsed the concept of a new estuary in the lower portion of the park as defined by the concept drawing in this document. Additional analysis and planning will be carried out in the design phase, set to start immediately. Designs at the 30%, 90%, and final level will be developed next.

INTRODUCTION

Purpose and Project Background

The first goal this study is to assess the feasibility of beach/nearshore enhancement for the shoreline from Little Squalicum Park beach to the southeast side of the filled coastal area referred to as the Mount Baker Plywood Peninsula. Final designs will be developed for one coastal restoration action, based on the conceptual designs produced as part of this feasibility assessment. Final design work will be completed as part of the second (later) phase of the project. The development of the design concepts outlined in this report has been carried out in close coordination with the City of Bellingham Parks Department's current park master planning effort. Several meetings were held with City staff and City Parks Department consultants during the development of this feasibility report. Additionally, recent and older work for the park area was reviewed. This included the Draft Remedial Investigation (Integral 2008), and geotechnical, wetland, and fisheries reports as referenced within.

Cleanup plans are in development now by the US Environmental Protection Agency for the Oeser site and the Little Squalicum Park area. Although the timeline for cleanup work is not certain, discussion of cleanup starting as early as the fall of 2010 has occurred. The habitat enhancement work recommended in this report has been prepared using relevant work completed to date however, uncertainties remain.

The objective of the feasibility study is to identify constraints and opportunities that will inform and guide the development of sustainable beach/nearshore enhancement designs. To achieve these objectives coastal processes were analyzed and assessed, existing data and previous studies were reviewed, and field assessments were conducted by Coastal Geologic Services staff. Key published and available unpublished sources of information on geology, coastal processes, air photos, site history, wetlands, known contaminants, and permit issues at the site were compiled and reviewed. Project constraints were assessed through discussion with City of Bellingham (COB) staff and consultants under contract to the City on this site. The scope of this work explicitly stated that land-owner willingness should not be considered in making the recommendations included in this report.

The study area includes the entire Little Squalicum marine shore, from the Cement Company pier eastward to the Mount Baker Plywood peninsula. Only part of the peninsula shore is included in the study area: the southwest facing shore located waterward of the public parking; however, the remaining shoreline (adjacent to Squalicum Creek) is not (Figure 1). The total length of shoreline encompassed within the study area measures approximately 1,500 ft long. The study area was delineated into five smaller reaches for ease in describing site characteristics (Figure 2). This report also includes some discussion and analysis of the shores adjacent to the study area, where they are applicable to local coastal processes and the condition of the nearshore. Conceptual alternatives for habitat enhancement of several specific areas include recommendations to remove some of the existing structures to increase intertidal and backshore area, excavation to create a small pocket estuary, beach nourishment, and/or vegetation enhancement.

Background on Coastal Processes

Nearshore habitats and the larger shoreforms that encompass them are created and maintained by (physical) coastal geomorphic processes. When these processes are impaired or impeded, typically as a result of anthropogenic changes to the nearshore, nearshore habitats that are formed by those processes in turn degrade or are eliminated, with resulting affects on the nearshore web of life. By understanding these key processes, and how they have been altered, scientists and resource managers can better identify ideal places to restore and the most appropriate restoration/enhancement strategies to apply.

Puget Sound and Northern Straits Bluffs and Beaches

Puget Sound and North Straits are the central features in the Puget Lowland, and consist of a complex series of generally north-south trending deep basins. The Sound and Straits were created by the repeated advance and scouring of glacial ice-sheets, the most recent of which advanced into the study area between 15,000 and 13,000 years ago (Booth 1994). Glacially derived sediment dominates the Sound and Straits (Easterbrook 1992), and along with less common interglacial sediment are exposed in coastal bluffs. Bluffs are present along the majority of the length of the Puget Sound area shores (WDNR 2001). These coastal bluffs are relatively recent landforms. Bluffs have formed in the “fresh” landscape left behind after the most recent ice-sheet advance (Vashon advance). Sea levels were generally rising with the global melting of ice-sheets up until approximately 5,000 years ago. This is thought to be the time when the current configuration of bluffs began to evolve.

Beaches are accumulations of sediment along a shore. As sediment is transported along a beach, it must be continuously replaced for the beach to maintain its integrity. The erosional nature of the majority of Puget Sound beaches is evident in that most beaches generally consist of a thin veneer of sediment that is only 3-10 inches thick vertically, atop eroding glacial deposits.

A beach serves as a buffer against direct wave attack at the bluff toe. The value of a "healthy" beach fronting a coastal bluff should not be underestimated for absorbing storm wave energy. A gravel berm can serve as a resilient landform with an ability to alter shape under different wave conditions, effectively dissipating most wave energy. Extreme waves do reach bluffs, causing erosion, which delivers sediment to the beach and is vital to maintaining the beach. Therefore, bluffs, beaches, and nearshore areas are *completely connected as integral parts of* a coastal system. Past and current management typically treated the bluffs and beaches as separate parts of the coastal system, which has resulted in substantial negative impacts to coastal erosion and nearshore habitats and wildlife.

The most basic control over beach characteristics is wave climate, which is controlled by the open water distance over which winds blow unobstructed (fetch) and the orientation of a shore relative to incoming waves. Low wave energy beaches are composed of poorly sorted sediment with a relatively narrow backshore and intermittent vegetation. Higher wave energy beaches contain areas with well-sorted sediment, often consisting of cobble, over a broad intertidal and supratidal area. Beach sediment size is strongly influenced by the available sediment coming from bluff erosion as well as wave energy, and therefore varies across the study area.

Beaches along the Little Squalicum shoreline are composed of gravel and sand with patches of cobble and bolder on the beach face. The morphology and composition of beaches within the study area are controlled by sediment input, wave climate, and shore orientation. Bluff sediment input, primarily glacially deposited units, is the primary source of beach sediment in Puget Sound. Landslides and erosion of these bluffs deliver sediment to the beach in moderate quantities. A secondary sediment source is rivers and streams. However, river and stream sediment input is thought to be responsible for on the order of

10% of beach sediment in the Sound and Straits, with the majority (90%) originating from bluff erosion (Keuler 1988). The greatest freshwater systems of influence to the study area include the Nooksack River to the north, Little Squalicum and Squalicum Creek, both of which are in close proximity to the study area.

The elevation and morphology of coastal bluffs in the study area varies due to differences in upland relief, geologic composition and stratigraphy, hydrology, orientation and exposure, erosion rates, mass wasting mechanisms, and vegetation (Shipman 2004). Bluff heights reach up to 45 ft along the Little Squalicum shoreline. Bluffs are subjected to wave attack at the toe of the slope, which contributes to intermittent bluff retreat through mass wasting events (commonly referred to as landslides).

Many of the region's landslides are initiated by hydrologic processes and land use/development changes, rather than exclusively marine-induced erosion (Johannessen and MacLennan 2007). Marine-induced erosion typically refers to landslides that are largely initiated by wave erosion, which undermines the base of the bluff, leading to its failure. Hydrologic processes that commonly lead to landslides often occur during heavy periods of precipitation and include: the occurrence of seeps mid-bluff or where bluff stratigraphy is comprised of permeable sands overlying impermeable clays (Shipman 2004). Land-use/development patterns, also referred to as human-induced erosion, often encompasses vegetation clearing, overloading the top of the bluff, grading or removing soil, and any additions of water such as excessive surface water run-off from impermeable surfaces, poor drainage design, lawn watering and septic tank leach lines (Johannessen and MacLennan 2007).

Net Shore-drift

To understand the processes controlling nearshore systems and their continued evolution, the three-dimensional sediment transport system must be examined. The basic coastal processes that control the "behavior" of the beach will be explained first and then put into the context of "drift cells". Shore drift is the combined effect of longshore drift, the sediment transported along a coast in the nearshore waters, and beach drift, the wave-induced motion of sediment on the beachface in an alongshore direction. While shore drift may vary in direction seasonally, net shore-drift is the long-term, net effect of shore drift occurring over a period of time along a particular coastal sector (Jacobsen and Schwartz 1981).

The concept of a drift cell has been employed in coastal studies to represent a sediment transport sector from source to terminus along a coast. A drift cell is defined as consisting of three components: a site (erosional feature or river mouth) that serves as the sediment source and origin of a drift cell; a zone of transport, where wave energy moves drift material alongshore; and an area of deposition that is the terminus of a drift cell. Deposition of sediment occurs where wave energy is no longer sufficient to transport the sediment in the drift cell.

Net shore-drift studies were conducted through systematic field investigations of the entire coast to identify geomorphologic and sedimentologic indicators that revealed net shore-drift cells and drift direction (Jacobsen and Schwartz 1981). The methods employed in net shore-drift mapping utilized 9-10 well-documented, isolated indicators of net shore-drift in a systematic fashion. Previous drift cell mapping efforts such as the Coastal Zone Atlas of Washington (WDOE 1979) relied exclusively on historic wind records. That method is known as wave hindcasting, where inland wind data records were used for the determination of net shore-drift, without consideration of local variations in winds, landforms, or coastal morphology. Drift directions indicated in the atlas series have commonly been proven inaccurate by extensive field reconnaissance (e.g. Jacobsen and Schwartz 1981). When the geographic complexity of the Puget Sound and North Straits, and subsequent variability of the surface winds, in addition to the seasonal variability of atmospheric circulation and the locally varying amount of drift sediment are considered, the geomorphic approach described above is better suited to the physical conditions of the region than traditional engineering methods like hindcasting.

Net shore-drift is strongly influenced by several oceanographic parameters. The most important of which are waves, which provide the primary mechanism for sediment erosion, inclusion of sediment into the littoral system, and transport. The Puget Sound and North Straits are composed of inland waters exhibiting an extreme range of wave regimes. Storm wave heights reach relatively large size during prolonged winds, in contrast to chop formed during light winds, which have little geomorphic effect on coasts (Keuler 1988).

Fetch has been proven to be the most important factor controlling net shore-drift in fetch-limited environments (Jackson and Nordstrom 1992). This has been demonstrated in the Puget Sound and North Straits by a number of scientists (Downing 1983). Due to the elimination of ocean swell in protected waters, waves generated by local winds are the primary transport agents in the littoral zone. The direction of maximum fetch that acts on a shoreline segment will correspond with the direction of the largest possible wave generation, and subsequently, the direction of greatest potential shore-drift. Where fetch is limited the wind generates the largest waves possible in fairly short time periods.

Shore Modifications

Erosion control or shore protection structures are common in the Puget Sound and within the north Bellingham Bay drift cell. Residential and industrial bulkheading (also called seawalls) are typically designed to limit the erosion of the backshore area or bluff, but have numerous direct and indirect impacts on nearshore systems. Seawalls and bulkheads have been installed more routinely in the past few decades as property values have raised and marginal lands have been developed. The effects of bulkheads and other forms of shore armoring on physical processes have been the subject of much concern in the Puget Sound region (e.g. PSAT 2003). MacDonald et al. (1994) completed studies assessing the impacts to the beach and nearshore system caused by shore armoring at a number of sites. Additional studies on impacts from shoreline armoring have quantitatively measured conditions in front of a bulkhead and at adjacent un-bulkheaded shores and showed that in front of a bulkhead the suspended sediment volume and littoral drift rate all increased substantially compared to unarmored shores, which resulted in beach scouring and lowering along the armored shores studied (Miles et al. 2001).

A bulkhead constructed near the ordinary high water mark (OHWM) in a moderate wave energy environment increases the reflectivity at the upper beach substantially, causing backwash (outgoing water after a wave strikes shore) to be more pronounced. Increased backwash velocity removes beach sediment from the beachface, thereby lowering the beach profile (MacDonald et al. 1994). A bulkhead constructed lower on the beach causes greater impacts (Pilkey and Wright 1988). Construction of a bulkhead at or below OHWM results in coarsening of beach sediment in front of the bulkhead (MacDonald et al. 1994). Relatively fine-gain size sediment is mobilized by the increased turbulence caused by the bulkhead (Miles et al. 2001), and is preferentially transported away, leaving the coarser material on the beach. This process also leads to the removal of large woody debris (LWD) from the upper beachface. Over the long term, the construction of bulkheads on an erosional coast leads to the loss of the beach (Fletcher et al. 1997, Douglass and Bradley 1999).

Of all the impacts of shore armoring in the Puget Sound and North Straits, sediment impoundment is probably the most significant negative impact (PSAT 2003). A structure such as a bulkhead, if functioning correctly, “locks up” bluff material that would otherwise be supplied to the net shore-drift system. This results in a decrease in the amount of sediment available for maintenance of down-drift beaches (Griggs 2005). The negative impact of sediment impoundment is most pronounced when armoring occurs along actively eroding bluffs (MacDonald et al. 1994, Griggs 2005). Additionally, the extent of cumulative impacts from several long runs of bulkheads is a subject of great debate in the coastal research and management communities.

Coastal Processes and Nearshore Habitat

Shore modifications, almost without exception, damage the ecological functioning of nearshore coastal systems. The proliferation of these structures has been viewed as one of the greatest threats to the ecological functioning of coastal systems in the Puget Sound region (PSAT 2003, Thom et al. 1994). Modifications often result in the loss of the very feature that attracted coastal property owners in the first place, the beach (Fletcher et al. 1997).

With bulkheading and other shore modifications such as filling and dredging, net shore-drift input from bluffs is reduced and beaches become “sediment starved.” The installation of structures typically results in the direct burial of the backshore area and portions of the beachface, resulting in reduced beach width (Griggs 2005) and loss of habitat area. Beaches would also become more coarse-grained as sand is winnowed out and transported away. When sand and finer sediment is removed from the upper intertidal beach due to bulkhead-induced impacts, the beach is often converted to a gravel beach (MacDonald et al. 1994). A gravel beach does not provide the same quality of habitat as a finer grain beach (Thom et al. 1994). Large woody debris (LWD) is usually also transported away from the shore following installation of bulkheads, with corresponding changes in habitat. This leads to a direct loss of nearshore habitats due to reduction in habitat patch area.

Habitats of particular value to the local nearshore system that may have been substantially impacted include forage fish (such as surf smelt and sand lance) spawning habitat. These habitat areas are only found in the upper intertidal portion of fine gravel and sand beaches, with a high percentage of 1-7 mm sediment (Penttila 1978). Beach sediment coarsening can also affect hardshell clam habitat, by decreasing or locally eliminating habitat.

Bulkheading also leads to reduction in epibenthic prey items, potentially increased predation of salmonids, loss of organic debris (logs, algae) and shade, and other ecological impacts (Thom et al. 1994, Rice 2006). The reduction in beach sediment supply can also lead to an increase in coastal flooding and wave-induced erosion of existing low elevation armoring structures and homes (Nordstrom 1992).

Nearshore habitat assessments in the Puget Sound and North Straits have found that large estuaries and small “pocket” estuaries provide very high value nearshore habitat for salmon as well as other species (Beamer et al. 2003, Redman and Fresh 2005). Reduction in net shore-drift volumes due to bulkheading and other modifications and site-specific impacts induced by modifications can cause partial or major loss to the (barrier) spits that form estuaries and embayments. Therefore, with consideration of all these factors, shore modifications can have substantial negative impacts on nearshore habitats.

General Implications of Climate Change and Sea Level Rise

A general discussion of the anticipated impacts of sea level rise is included here. The predicted increased rate of sea-level rise, as a result of global warming, will generally lead to higher coastal water levels, thereby altering geomorphologic configurations, displacing ecosystems and increasing the vulnerability of infrastructure (IPCC 2001, Pethick 2001).

Recent research has also reported that non-bedrock shores, such as the post-glacial material that makes up most of the region's bluffs, are likely to retreat more rapidly in the future due to an increase in toe erosion resulting from sea-level rise. Retreat rates may also be amplified in many areas due to increased precipitation, storminess (wave energy), storm frequency and higher ground water levels (Hosking and McInnis 2002, Pierre and Lahousse 2006).

Changes in sea level will also result in a spatial response of coastal geomorphology, landward and upwards, in a concept known as the Bruun law (1962). This basic idea (though its accurate application to individual beaches is not well understood) appears to apply to all coastal landforms (Pethick 2001). The landward migration of the shoreline is a response to the changes in energy inputs brought about by sea-level rise. Knowing that this translation is to occur offers resource managers a tool, allowing decisions to be made to accommodate and, where possibly, facilitate such migration (Pethick 2001).

Accommodating space to enable shoreline translation can enable salt marshes, sand dunes, and beaches to transgress (move landwards while maintaining their overall form). This concept is commonly referred to as "managed retreat" or "managed realignment" (Cooper 2003). Accommodating sea level rise prevents the diminishment and loss of natural features such as intertidal, upper beach and dune habitats, from being lost between a static backshore (such as a bulkhead or rock revetment) and rising sea level. The concept is commonly referred to as "the coastal squeeze".

As a result of these processes related to global climate change, the shores of the study area will undoubtedly incur considerable habitat loss along its many modified shores, unless managers choose to take a pro-active approach and start initiating programs focused on accommodating sea level rise and utilizing strategies such as managed realignment (e.g. removing shore armoring, relocating coastal roads). There will also be further pressure to construct emergency erosion control structures as a result of increased erosion rates, storminess and storm frequency. Permitting the building of additional bulkheads is not likely to provide a long-term solution to the erosion control, and will only amplify habitat loss caused by the coastal squeeze.

SITE CONDITIONS

Coastal Processes

The study area, which included the shore of Little Squalicum Park to the west side of the Mount Baker Plywood Peninsula, is located in Bellingham Bay in northern Puget Sound, Washington (Figure 1). The site is positioned between the Nooksack River delta to the west and heavily altered shoreline of Bellingham waterfront on the east. Little Squalicum Creek is just west of Squalicum Creek, a larger stream system. The future Little Squalicum Park property surrounding Little Squalicum Creek encompasses approximately 21 acres, but the shore of the low elevation portion of the park (approximately 370 ft) and the beach to the east of the Park to the angled shore on the west side of the Peninsula (approximately 1,100 ft) is the primary focus of the study.

Most of the Puget Sound region is isolated from the Pacific Ocean resulting in local winds being the only natural source of wave energy to the field site. As a result the Puget Sound is commonly referred to as a "fetch-limited" environment. The aspect of the study area is to the southwest. The maximum fetch (open water distance over which wind waves can form) is approximately 15 miles from the southwest, the open water distance stretches from Little Squalicum Creek to southeast Guemes Island. There is no wave fetch from the north, due to the orientation of the study area, with only 3 miles west-northwest from the mouth of the Nooksack River. Prevailing winds (most frequent) in the Bellingham region are southerly during the winter and northerly or northwesterly during the summer. Predominant (strongest) winds are southerly resulting from winter storms moving inland from the eastern Pacific. However, periodically the winter high pressure over the continent and low pressure on the coast can result in strong northerly winds as well (Finlayson 2006).

Tidal range, defined as the average difference in height between mean higher high water (MHHW) and mean lower low water (MLLW), is 8.51 ft at Bellingham (NOAA Station ID: 9449211). Because tides within the Puget Sound are predominantly mixed semi-diurnal, the typical tidal pattern has two nearly equal high waters and two largely unequal low waters. This inequality results in water levels being more commonly observed between Mean Sea Level (MSL) and Mean High Water (MHW) than any other part of the tidal range, which results in the upper portion of the beach profile being exposed to greater wave action, thus resulting in a greater potential for sediment transport (Finlayson 2006).

Net shore-drift in present day conditions is northwestward, originating at the west side of Mount Baker Plywood, at the east end of the sandy beach in the study area. The drift cell that encompasses the study area (WH-5-22) extends approximately 3 miles northwest to the west side of the Nooksack River delta (Figure 2; Schwartz et al. 1991). The historic drift cell used to be approximately 0.9 miles longer, as the origin of net shore-drift (as identified as the center of the formerly erosional divergence zone) was located near the large boat ramps in the newer portion of the Squalicum Marina (Figure 2).

Bluff sediment source areas (feeder bluffs) have not been accurately mapped in Bellingham Bay, but substantial changes in both the amount of remaining feeder bluff and the length of the drift cell have occurred over the last 150 years. The drift cell currently has limited areas that can supply sediment, as the majority of the length of the formerly longer drift cell are now covered by fill and shore armor. In addition to the reduced cell and feeder bluff length, the wave sheltering has been substantially increased from several wind directions through the creation of the Peninsula and installation of the pier, which are discussed further below. Therefore, the volume of net shore-drift being transported northwestward at the study area beach are greatly reduced since historic times (prior to Euro-American settlement).

Nearshore Habitats

The study area supports numerous habitats for nearshore species. Different species use different reaches of shore (from west to east) and at variable tidal elevations throughout the study area. The greatest number of species appears to utilize the upper beach habitats of the western portion of the study area, including Little Squalicum Creek. Far fewer species have been documented utilizing the eastern shore, adjacent to Mt Baker Plywood, which has incurred far more anthropogenic change since historic conditions (WDFW 2009, LNR 2005). Juvenile salmonids, forage fish, eelgrass and other macro algae are all known to occur in the study area.

Marine Aquatic Vegetation

Patchy *Zostera marina* (eelgrass) has been documented in this area by WDNR (2009, 2001). *Fucus spp.* (rockweed) is also known to occur along this section of shore (WDNR 2001). *Carex lyngbyei*, *Grindelia integrifolia* and other characteristic estuarine/halophytic vegetation grows along these estuarine shores.

Forage Fish

Forage fish represent a critical link in the marine food chain and constitute a major portion of the diets of other fishes, including Endangered Species Act listed Puget Sound salmonids, seabirds and marine mammals. Forage fish spawning areas have been declared “saltwater habitats of special concern” (WAC 220-110-250; WAC 1994b). The preservation of forage-fish spawning habitat is known to benefit other species that utilize nearshore habitats including hard-shell clams, juvenile salmon and shorebirds (Penttila 2007).

Two species of forage fish (surf smelt and sand lance) utilize the Little Squalicum shoreline for spawning and rearing. Surf smelt spawn in the upper intertidal beach sediment of beaches predominantly comprised of a mix of coarse sand and pebble. In the north Puget Sound region the second largest surf smelt spawning grounds (after Fidalgo Bay area) is in and adjacent to the study area in northern Bellingham Bay (Penttila 2000). As displayed in Figure 3, over half of the Little Squalicum study area is within documented surf smelt and sand lance spawning grounds (WDFW 2009). When interpreting Figure 3, be mindful of the lower level of accuracy of data points collected prior to 2000. These data points had a horizontal accuracy of 180-300 ft, which in some cases, lead to the appearance of data points being located significantly more landward than their actual sampling location. Out of 51 surveys between the years 1994-1998 surf smelt were documented as having a spawning period spanning from the end of April to the beginning of December in northern Bellingham Bay (Penttila 2000). The strongest spawning months were from June to September (Penttila 2000). Similar to most of the Puget Sound, the sand lance spawning season takes place in early November through mid-February (Penttila 2001). The greatest density of spawn activity (of both species) appears to surround the mouth of Little Squalicum Creek (Figure 3); however this is likely due to the heavily altered condition of the eastern shore.

Salmon

Salmonid presence in the Nooksack River and Squalicum Creek has been widely documented by organizations and agencies such as Nooksack Salmon Enhancement Association (NSEA), the City of Bellingham (COB) and WDFW (2009). Small drainages and tributaries located between these larger stream systems, such as Little Squalicum Creek, may offer habitat uses for various life stages of salmonids as well. The Priority Habitats and Species (PHS) dataset (a WDFW database as provided by the City of Bellingham GIS Dept) documents salmonid utilization of streams in Washington. Table 1 shows the salmonid species and type of utilization of streams between the Nooksack River and Squalicum Creek compiled from multiple documents (WDFW 2009, LaCroix pers. comm. 2009). Note that Little Squalicum Creek was not included in the PHS dataset.

Table 1. Streams and salmonid utilization east to west from Squalicum Creek to Nooksack River (WDFW 2009, LaCroix pers. comm. 2009).

Stream or drainage	**Salmonid species and type of utilization**		
	Presence/migration	**Known spawning**	**Known juvenile rearing**
Squalicum Creek	CCT, CK, CH, CO	CH, SH, CO	CO, CK
Alderwood Ave drainage	CO		
Cliffside Dr drainage	CCT, CO		
Silver Creek & east tributary	CCT, CK, CH, CO		CO
Nooksack River Mainstem	CCT, CH, CK, PK, SH, SO	CK, SH	CK, CO, BT, SO
Slater Slough	BLC		CK
West tributary of Slater Slough	CCT, CO		

*CCT=Coastal Resident Cutthroat, CH = Chum Salmon, CK = Chinook Salmon, CO = Coho Salmon, Pink Salmon = PK, Sockeye Salmon = SO, Steelhead Trout = SH, Bull Trout = BLC.

Beach seining conducted by the Lummi Natural Resources Department (2003-2007) have documented fish utilization in two different parts of the study area and along the adjacent shore including: the Mouth of Little Squalicum Creek (sample site # 201), the Beach north of Mt Baker Plywood (#202) and the Beach at the mouth of Squalicum Creek (#204). Catch results of seining these areas revealed the highest salmonid utilization at the mouth of Little Squalicum Creek (#201), where Chinook, coho, chum, surf smelt and sand lance were all documented (LNR 2003-2007). Fewer species were sampled in lower abundance at the beach at the mouth of Squalicum Creek (site #204) (and included: Chinook, chum, coho and sand lance). No salmonids or forage fish were documented along the Beach north of Mt Baker Plywood (site #202).

Local Fish Biologist Shannon Moore (pers. comm. 2009) has observed several juvenile coho utilizing Little Squalicum Creek both below and above the culvert. While checking the aquatic habitat potential of Little Squalicum Creek during the summer of 2001 or 2002, Moore observed juvenile coho from the intertidal up to about 300 ft above the culvert. Moore theorized that the juvenile coho were using Little Squalicum Creek for over-summering freshwater habitat while they readied to transition into smolt. Due to Little Squalicum Creek's proximity to the mouth of the Nooksack River, and the relatively small amount of shoreline alteration or urban impacts along this stretch of shoreline, Little Squalicum Creek could be utilized by non-natal salmonids seeking habitat for rearing, osmoregulation, foraging or refugia in the shallow, protected estuarine environment.

Beach/nearshore Conditions

Site conditions are documented in this section focusing on the beach/nearshore portion of the study area. Beach conditions are described using five subareas described below from west to east (Figure 2). Field reconnaissance was carried out on multiple days in July and early August 2009, as well on other occasions since approximately 1995. Field reconnaissance included walking the length of the shoreline and backshore areas as well as the lower portion of the future Little Squalicum Park, and investigating the surficial geologic deposits, geomorphic shoreforms, development features, and vegetation areas.

Representative field photos from summer 2009 are presented in Figure 4, photo page 1. The emphasis for these photos was on the Little Squalicum Park shore and the west side of the Mount Baker Plywood Peninsula. Additionally, field photos from late February 2006 taken by CGS following several severe southerly wind storms are presented for comparison in Figure 5, photo page 2.

Pier

The pier subarea extends from the Lehigh Northwest Cement Company pier eastward to the mouth of Little Squalicum Creek at the culvert. The intertidal beach in the pier subarea was composed of pebble with sand and cobble. Shallow-sloped stream delta deposits were present on the west side of the pier such that the mid intertidal beach extended approximately 30 ft waterward of the park beach and approximately 50 ft waterward of the beach to the west of the Cement Company pier. This is also evident in many aerial photos, presented in Figures 6 -12.

The beach west of the pier was a steeper gradient than beaches throughout the study area. This beach between the pier and the over water pipeline was composed of sand with pebble and pockets of large angular boulder that have toppled into the intertidal. A rock revetment was present along much of this reach on the upper-most beach.

The pier was supported by rows of creosote pilings, with approximately 6 pilings under the width of the pier. Rows of pilings were spaced approximately 14-15 ft apart with the gaps allowing walkers to pass beneath the pier. However, many of the intertidal piles have been buttressed with concrete near beach level. The density of the piles combined with the concrete buttresses and toppled concrete debris had trapped considerable driftwood beneath the pier. Transport of littoral sediment may also be reduced as a result of reduced beach area from the structures on the intertidal substrate as well as the wave attenuating effects of the structures. The accumulation of driftwood combined with reduced littoral transport rates have likely contributed to the wider beach configuration east of the pier. The majority of the support piles for the pier were heavily creosoted with creosote dripping to the beach in a number of locations.

The upper intertidal and backshore areas adjacent to and east of the pier contained scattered large concrete pieces, particularly at approximately + 5 to +7 ft MLLW as well as immediately above MHHW. The beach has prograded waterward adjacent to the east side of the pier partially as a result of these concrete pieces as well as the alterations mentioned above.

The backshore immediately east of the pier contained a broad depositional storm berm composed primarily of pebble with lesser amounts of cobble and sand. Numerous drift logs were present here in the summer of 2009 (Figure 4) as they were also present in late February 2006 (Figure 5). A large accumulation of large woody debris (LWD) and small woody debris was present in a storm berm landward of the primary high berm. Waterward of this, the topography rose up toward the pier base. This area was heavily colonized by dune grass with more abundant exotic species and (native) Nootka rose in the landward direction. One large clump of willow trees has persisted immediately west of the culvert outlet despite frequent winter wave attack.

Landward of the backshore was the western supports for the BNSF steel trestle. These supports occurred in sets of 4 with connecting steel bracing. Each support set was separated by 50 ft of open span.

Little Squalicum Beach

The Little Squalicum beach subarea extends from the mouth of the creek east to the end of the no-bank backshore. This area ends at the eastern end of the BNSF trestle. A broad intertidal beach was present in this area with abundant sand in the lower intertidal. The mid and upper intertidal was dominated by cobble (1.25-10 inch) with lesser amounts of pebble (0.16-1.25 inch sediment) and sand. The slope of the upper intertidal was fairly gentle.

Above MHHW the beach substrate was comprised of pebble and sand with lesser amounts of cobble. Intermittent LWD accumulations occurred throughout the Little Squalicum beach subarea that included several heavily creosoted logs. The tide channel (Little Squalicum Creek channel) meandered across small pebble and sand deposits. The channel incision was minimal on the beachface but increased up to 1 ft in depth as it passes through the storm berm. The creek passed through the backshore in a 36-inch culvert beneath the outer trail loop. The concrete culvert crosses the backshore area under the trail for a total of (approximately) 20 ft. The trail was composed of crushed gravel surface with coarser gravel beneath. The elevation of the downstream/marine outlet of the culvert was generally lower than beach level and greater than 5 ft distance from the culvert mouth. However, a scour pool was present immediately waterward of the mouth of the culvert with depths ranging from 1.1-2 ft. The culvert held an uphill gradient, which caused the creek to pond up within the area of the scour hole and inside the culvert itself.

In recent years, the beach and backshore have eroded so that the active beach now abuts the trail. The trail and culvert appeared to have experience dramatic erosion in the February 4, 2006 windstorm, as well as other windstorms in recent winters (Figure 5). The portion of the trail closest to the beach lost several feet during those storms, and the culvert became increasingly exposed as sediment was removed by wave action. Rock and logs have been placed to partially armor the waterward edge of the trail since 2006. However, no permanent repairs have been made.

The creek passed beneath one of the groups of 4 supports for the trestle landward of the trail loop. East of the creek channel, there were 3 more groups of supports for the trestle, which were surrounded by immature willows, invasive species (including Himalayan Blackberry) and other grasses and ground cover. The backshore waterward of the trestle and east of the creek was as also vegetated with numerous willow and alder trees, as well as Himalayan blackberry and a variety of other low growing species.

A small wetland that measured approximately 60 by 100 ft was present landward of the eastern portion of the trestle. Further details on this wetland and the future park subarea can be found in previous studies conducted by others including David Evans and Associates (DEA 1993) and Integral (2008). Landward and east of the trails, the lower portion of the park was dominated by immature vegetation. Trees species included: red alder, black cottonwood, willows and several big leaf maples. Species richness in the understory and groundcover vegetation was quite limited, predominantly consisting of Himalayan blackberry, exotic vines, crab apple, and several other species. Forest diversity and size classes reflect the fact that the area was an active gravel mine up to about the early 1970s as outlined in the *Shore change* section.

West Bluff

The west bluff subarea was generally characterized by a very coarse-grained beach and a bluff toe that protrudes further waterward than any other of the park subareas that are not built on fill. The lower intertidal was composed of sand to boulders at a very shallow slope. The mid and upper intertidal substrate was predominantly comprised of cobble with abundant boulder (greater than 10 inches) and smaller quantities of pebble and sand. Willow trees shaded the upper intertidal and supratidal beach. The area landward of MHHW contained finer-grained sediment including abundant pebble and sand with some scattered boulders. This area also contained a moderate amount of relatively small driftwood. Numerous seeps from the lower-most bluff produced relatively high flow even in mid summer.

The toe of the bluff was undermined in places and showed evidence of repeated toe erosion across almost the entire length of the subarea. The geology of the bank appeared to be glacial outwash of the Sumas Stade (Lapen 2000). Several very good exposures of glacial sediment were present, which consisted of deposits of sandy silt, underlain by coarse sand, beneath which were alternating units of sandy gravel, sand, and silty sand. The bluff height measured approximately 45 ft in this area. Several very large sandstone and other boulders were present along the toe of the beach in this reach. Whether these were from upslope outcrops or were dumped for rail line maintenance was unclear, although the latter may have been the case. The BNSF rail line was a minimum of 50 ft from the toe of the bank.

East Bluff

The east bluff subarea was the last stretch of relatively natural beach within the study area, extending up to the armored shores of the Mount Baker Plywood Peninsula. This area was characterized by a relatively fine-grained, broad beach. The lower intertidal was of low gradient and generally comprised of sand with a few boulders. The mid to upper intertidal beach in this reach of shore was composed of sand with pebble and some large chunks of concrete. Landward of MHHW sediment composition was dominated by sand with lesser amounts of pebble. The backshore was generally 30-45 ft wide and represented a broad sandy expanse with a subtly higher storm berm. Small volumes of driftwood occurred in the lower backshore with greater accumulations closer to the toe of the bluff.

The bluff measured approximately 40 ft high in this reach with the lower elevations present in the east end. Evidence of toe erosion could not be seen in the summer of 2009, but was likely present under vegetation. The BNSF rail line was a minimum of 45 ft from the toe of the bank.

The beach transitioned into a low erosional bank cut into gravelly fill moving eastward (Figures 4 and 5). Wood debris and some metal debris were present in this bank. The location where the trail entered the beach was the end of the subarea.

Revetment

This subarea was characterized by a large concrete rubble "revetment" running at a roughly 45 degree angle to the adjacent beach that armors a triangular shaped fill area. The public access parking lot for the adjacent beach was located in the landward-most portion of this fill triangle. The parking lot measures approximately 300 by 50 ft. The lower intertidal beach was low gradient and predominantly comprised of boulder and pebble. The upper portion of this beach contained numerous concrete pieces that appeared to have settled from the revetment. No sandy deposits were present at this subarea beach.

The large concrete rubble revetment extended approximately 380 ft. The revetment spanned from +4–5 ft MLLW to +13–14 ft MLLW. This therefore represented a large surface area measuring approximately 22 ft across and 8,400 sq ft (not counting the remainder of the Mount Baker Plywood shore such as the reach that extends directly south).

The revetment appeared to have been installed between 1963 and 1977 based on the aerial photo record. The revetment appeared to have functioned well as erosion control, although judging from the very large volume of concrete used it appeared to have been placed fairly quickly and without engineered design. Individual concrete pieces measured 3–6 ft long by 1.5–2 ft thick. Most pieces contained large diameter steel rebar potentially indicating that a large structure such as a concrete bridge was demolished and dumped in this location.

Several pockets of Himalayan blackberry, tansy ragwort, and other invasive non-native vegetation was present above the revetment. A large gravel covered surface was present on the eastern half of this backshore fill area, adjacent to the industrial buildings. A small triangular grass covered field was present in the western portion, which abutted the trail to the beach. Landward of the parking area, a largely Himalayan blackberry covered slope extended up to the BNSF rail line. Pockets of invasive species and native vegetation, such as willow, were also present landward of the trail to the beach.

SHORE CHANGE ANALYSIS

Introduction and Methods

A historic shore change analysis was conducted along the study area's shores to determine trends in beach and backshore morphology within the study area, and to gain further understanding of the history of (anthropogenic) change at the site. Results will be used to guide restoration conceptual designs and assure that recommendations do not conflict with the natural range of shoreline dynamics at the site.

Site history prior to the late 1950s is discussed here in a qualitative fashion. This era did not have good quality air photos or accessible scaled maps. Several key sources of information were the 1887 T-sheet (no. 1798, Figure 13), historic photos acquired from the Whatcom Museum, selected history presented verbally by Tim Wahl and Jeff Jewell, and an early 1940s air photo mosaic.

The quantitative shore change analysis was conducted using high resolution georeferenced and orthorectified historic aerial photographs of the study area. Aerial photographs from 6 time periods were used, including: 1950, 1963, 1977, 1988, 1997 and 2008. Images not previously orthorectified by COB were georeferenced by CGS using the 2008 City of Bellingham digital orthorectified air photo base with an average root mean square of 4.0. The georeferenced images were imported into ArcMap v.9.2. Examination of the air photos revealed that the waterward extent of driftwood, or the "logline", a commonly used feature in shoreline mapping (for examples see Stafford and Langfelder 1971, Dolan and Hayden 1983, Morton 1991), was the best feature captured in all the images within the area of interest. The vegetation line was also selected for analysis due to its visibility.

The logline and vegetation line were heads-up digitized (visually inspected) at 1:1,000 scale, which made the break between the sediment and backshore vegetation and light-colored driftlog accumulations easily discernable. The logline and the vegetation line were selected for analysis due to the ease in interpreting the location of these features in historic air photos and their value as indicators of upper beach morphology. Where features were not clearly visible breaks in the line were created. The year associated with each feature was recorded in the associated attribute table. Three transects were drawn across each shore reach and measures of change were conducted between each year. The measured length of change within each transect was averaged within each reach. Net change was also calculated across the time period of analysis; this data was also averaged for comparison of long-term change rates across all reaches.

Early Site History

General Original Conditions

The natural state of Little Squalicum Creek (predevelopment) was a narrow ravine which cut through steep bluffs and emptied out onto tide flats, as seen in the 1887 T-sheet (Figure 13). The ravine was wide enough to contain a freshwater marsh, but did not have an estuary. The entire study area beach was a sand and gravel bluff-backed beach, however the beach was described as being more sand rich in the 'old days' by Tim Wahl. The study area beach was characterized as always having a lot of LWD (T. Wahl pers comm. 2009). The beach was relatively narrow and followed the gently undulating bluff alongshore (Figure 14; late 1890s, courtesy of Whatcom Museum). The beach broadened to the east as it approached the Squalicum Creek Delta and more extensive tide flats of northeast Bellingham Bay (Figures 14 and 15, courtesy of Whatcom Museum).

The mouth of Squalicum Creek originally flowed westward into the intertidal at the approximate location of Mount Baker Plywood (Figure 16, courtesy of Whatcom Museum). The mouth of Squalicum Creek was likely rerouted around 1908 with the installation of the Bellingham Terminal rail line (Jewell pers comm. 2009; Figure 17, courtesy of Whatcom Museum). The beach along the eastern end of the study area was thus lost due to development at the mouth of Squalicum Creek. Figure 18, dated around the 1940s (courtesy of Whatcom Museum), shows a close up of the character of the west side of the study area beach.

<u>Railroad</u> - The Great Northern railroad along Bellingham Bay was installed around 1891 (Jewell pers comm. 2009). The Great Northern trestle ran from the toe of the bluffs in south Bellingham across the tide flats to the top of the bluffs just east of Squalicum Creek (Figures 14 and 19, courtesy of Whatcom Museum). A railroad spur running alongside Little Squalicum Creek was constructed after 1911 for use by Olympic Portland Cement Company (Integral 2008). The spur ran under the mainline and followed the west side of lower Little Squalicum Creek ravine (Figure 20). The railroad spur and the construction of the Marine Drive Bridge in 1956 can be seen in Figure 20 (courtesy of Whatcom Museum).

<u>Pier</u> - The long pier on the western edge of the study area was constructed some time after 1911 for use by the Olympic Portland Cement Company shipping operations (Integral 2008). The pier was well established by 1949, as seen in Figure 19. The cement plant is currently owned by the Lehigh Northwest Cement Company (Integral 2008), although it is not currently operational.

<u>Gravel Mine</u> - A gravel and sand pit was operated on the east bank of Little Squalicum Creek from the headwaters (north end of Bellingham Technical College and Oeser Company property) to the north side of the BNSF mainline trestle starting in the 1910s (Integral 2008). Mining in this area continued into the early 1970s (Wahl pers comm.). Active mining in 1956 on the east side of lower Little Squalicum Creek can be seen in Figure 20, during the installation of the Marine Drive Bridge. Figures 21-23, taken some time in the mid 1950s (courtesy of Whatcom Museum), show the widened lower creek basin as a result of mining activities. Although the lower creek basin was widened the stream remained along the original lower ravine channel. Little Squalicum Creek was later channelized upstream of Marine Drive away from its original upstream meander and along the original lower ravine channel some time between 1961 and 1962 for mining operations (Integral 2008). Tim Wahl (pers comm. 2009) remembered an open channel where Little Squalicum Creek crossed the upper beach, and not the presence of ponded water behind the beach berm. An ephemeral wetland was documented in the southeast portion of the Park (Integral 2008).

<u>Mount Baker Plywood Peninsula Fill</u> - Dredging and filling of the Bellingham Bay waterfront began in 1913 with dredging of the Whatcom Waterway in anticipation of the opening of the Panama Canal and Bellingham's potential as a 'booming port city' (Jewell pers comm. 2009). Portions of the Squalicum Creek area were filled in 1926 with the development of a resort and bathing house in the mid 1920s (Blaney's boathouse; Jewell pers comm. 2009). The Squalicum Waterway was dredged and filled with a breakwater built along its front with New Deal funds in 1933-34. The west side of the Squalicum Creek fill area was first occupied by Bellingham Furniture Manufacturers in 1933 which then became Mount Baker Plywood some time after the war (Jewell pers comm. 2009). Bellingham Shipyards occupied the Squalicum waterfront during the 1940s and built wood hull, steel vessels, minesweepers, tugs, barges, and more for

the US Navy (Jewell pers comm. 2009). The west triangle near Mount Baker Plywood was likely filled with previous dredge spoils from the activities listed above, but did not appear to be armored until the 1950s to early 1960s (Figure 13). The property is now owned by the Port of Bellingham.

Log Industry - Logs were stored by Mount Baker Plywood in the upper intertidal in 1963 (Figure 13). After cessation of gravel mining operations logs were stored in the widened lower creek channel between the Marine Drive Bridge and BNSF mainline trestle in the early 1970's (T. Wahl pers comm.). The logs were transported via the study area beach (Integral 2008).

Logline

Pier - The logline in this shore reach displayed a general trend of recession, excluding the period from 1963-1977, when a substantial volume of wood debris accumulated. As a result, the 1977 logline was considerably waterward from all years (by approximately 75-108 ft) (Table 2, Figure 24). The large accumulation of material receded after 1977 to its most recent position in 2008. Wood appears to get trapped just east of the pier resulting in a more constant deposit of LWD in the western portion of the reach. Across the period of study, the logline in this shore reach has (on average) migrated landward approximately 15 ft from its 1950s position, however considerably more erosion was observed in the eastern section of this reach where logs were not abutting the pier.

Little Squalicum Beach - The logline at the Little Squalicum beach reach exhibited a general trend of landward recession, with an average (net) change of 40 ft throughout the period of study. Similar to the Pier reach, there was a large influx of material prior to 1977, followed by continual landward recession in more recent periods. The greatest period of erosion occurred between 1977 and1988, with an average of 47.6 ft of recession across the transects. More erosion occurred along the western transects. There was also considerable erosion of the park beach between 1997 and 2008.

West Bluff - Overall the logline in this reach exhibited a general trend of landward recession on the order of 22 ft from the 1950s position. Prior to 1977, the logline was considerably waterward of its later position. The logline was advanced between 1950 and 1963 apparently due to the large volume of wood storage just up-drift of the site. The log line later receded likely due to erosion of the beach and bluff. No log accumulations were mapped along the bluff toe after 1977, or 1988 along the east end of the reach, likely due to the erosional nature of the bluff, and possibly due to overhanging vegetation.

East Bluff - The logline in this reach (also) continually receded over the period of study, excluding the period from 1950-1963, when abundant log storage occurred up-drift of the site and the upper intertidal area essentially functioned as part of the “log yard”. The recession of the logline was greatest during the period from 1977 - 1988. Overall the logline migrated landward an average (of all transect measures) 51 feet from its 1950 position. The log line was in the most waterward position in 1963 (likely due to industrial uses), then continually receded in forthcoming years.

Revetment - Log deposition in this reach has been impeded by the addition of fill and the construction of the concrete “revetment” protecting the fill area from coastal erosion. From 1950 to1963, fill placement advanced the log line waterward by approximately 130-220 ft. This shore reach was largely left out of the analysis due to the presents of multiple anthropogenic alterations of the shore. A gravel parking lot (approximately 160 ft by 50 ft) was constructed on the west side of Mount Baker Plywood by the City of Bellingham for improved access to the beach and park trails between 2002 and 2004.

Table 2. Results of shore change analysis of logline. All measurements reported in feet (ft). Avrg = Average, Park = Future Park Beach, WBlf = West Bluff, EBlf = East Bluff. Averages denote average change across all transects within each period of change. Net change represents cumulative (net) change across entire period of analysis (1950-2008) for each transect and averaged across all transects.

Period of Change	Pier-1 (ft)	Pier-2 (ft)	Pier-3 (ft)	Pier Avrg	Park-1 (ft)	Park-2 (ft)	Park-3 (ft)	Park Avrg
1950-1963	-4.9	-22.1	-26.4	-17.8	-8.4	0.25	-3.9	-4.0
1963-1977	108	86.4	75	89.8	60.23	29.7	25.2	38.4
1977-1988	-82	-65.7	-50.3	-66.0	-51.7	-50.4	-40.8	-47.6
1988-1997	-23.6	nd	nd	-23.6	-19.3	-3.28	-7.1	-9.9
1997-2008	7	-15.8	-31	-13.3	-22.4	-18.7	-10.5	-17.2
Net Change	4.5	-17.2	-32.7	-15.1	-41.57	-42.43	-37.1	-40.4
Period of Change	**WBlf-1 (ft)**	**WBlf-2 (ft)**	**WBlf-(ft)3**	**WBlf-Avrg**	**EBlf-1 (ft)**	**EBlf-2 (ft)**	**EBlf-3 (ft)**	**EBlf-Avrg**
1950-1963	3.6	-3.1	15.7	5.4	23.3	75.4	83.4	60.7
1963-1977	7.2	-9.8	-35.8	-12.8	-67.3	-32.3	-54.9	-51.5
1977-1988	0	0	-17	-5.7	-19.9	-47.3	-37.7	-35.0
1988-1997	0	0	0	0.0	-4.3	-11.8	6.7	-3.1
1997-2008	-27.9	nd	0	-14.0	-21.1	-26.6	-19	-22.2
Net Change	-17.1	-12.9	-37.1	-22.4	-89.3	-42.6	-21.5	-51.1

Vegetation Line

Pier - The vegetation line within the Pier reach of the study area displayed a general trend of erosion, followed by accretion and then again erosion. The greatest period of erosion took place from 1950-1963, with an average of 32.5 ft of (landward) recession (Table 3, Figure 25). The most recession took place in the central and western portion of the reach where logs accumulate adjacent (east) to the pier. Considerable drift logs also accumulated within the reach during this period, which could have buried and/or shaded vegetated areas (resulting in additional interpretation error). However, the mapped recession in the vegetation line was probably due to the Columbus Day storm of 1962, which had recorded winds of up to 98 mph in Bellingham. The vegetation line advanced waterward from 1963-1997 and then once again began to recede. A large portion of this section of shore did not have much vegetation due to the channel and delta of Little Squalicum Creek.

Little Squalicum Beach - The Little Squalicum beach exhibited both (net) erosion and accretion of the vegetation line across the period of study (1950-2008). The most erosion occurred along the western extent of the reach, similar to the Pier shore reach. The central portion of the shore accreted (21.4 ft) and the eastern shore was more neutral. Similar to the Pier reach each transect analyzed within the Park Beach reach eroded from 1950-1963, and then prograded from 1963-1997. Erosion of the vegetation line occurred again during the period from 1997-2008, averaging 17.2 feet of recession across the across the reach.

West Bluff - The West Bluff shore reach is one of two eroding bluffs within the study area. The results of the shore change analysis may not have accurately captured the erosion occurring at the site due to the overhanging riparian vegetation found along the bluff face. Several recent shallow landslides were observed in this shore reach during a recent field visit to the site. The limitations of (historic) air photo analysis should be kept in mind when interpreting these results. Throughout the period of study, the vegetation line eroded an average of 9.7 feet from the 1950s position. The overall trend resulting from air photo analysis and measuring change rates from 3 transects within the reach reveals that there were periods of both erosion and accretion from 1950-2008. Although it is unlikely that accretion actually occurred in this typically erosive shoretype, the waterward advance of the vegetation line was likely the result of regrowth of riparian vegetation or due to waterward migration of deciduous trees as part of a bluff failure or rotational slump. The greatest period of apparent erosion of the vegetation like was between 1997 and 2008. The greatest erosion was incurred along the east end of the reach, where over 26 feet of erosion has occurred (to the vegetation line) since 1950.

East Bluff - The vegetation line in the East Bluff reach exhibited the most erosion of any reach in the study area, with an average net change (erosion) of 28.6 feet since 1950. Considerably more erosion occurred along the western transects within the reach, which had net erosion of 42-64 feet. The vegetation line in the eastern portion of the reach, exhibited a (net) progradation of approximately 20 feet. This was likely affected by the placement of fill, log storage in the upper intertidal and the altered configuration of the shoreline resulting in more sheltered conditions.

Table 3. Results of shore change analysis of vegetation line. All measurements reported in feet (ft). Avrg = Average, Park = Park Beach, WBlf = West Bluff, EBlf = East Bluff. Averages denote average change across all transects within each period of change. Net change represents cumulative (net) change across entire period of analysis (1950-2008) for each transect and averaged across all transects.

Period of Change	Pier-1 (ft)	Pier-2 (ft)	Pier-3 (ft)	Pier Avrg	Park-1 (ft)	Park-2 (ft)	Park-3 (ft)	Park Avrg
1950-1963	-44.9	-52.5	0	-32.5	-28.3	-17.7	-11.6	-19.2
1963-1977	31.7	0	0	10.6	9.6	25.9	10.3	15.3
1977-1988	0	56.8	0	18.9	14.5	14.7	11	13.4
1988-1997	26.1	12.9	0	13.0	6.8	2.3	8	5.7
1997-2008	-25.6	-28.9	-3.5	-19.3	-29.5	-3.8	-18.2	-17.2
Net Change	-12.7	-11.7		-12.2	-26.9	21.4	-0.5	-2.0
Period of Change	**WBlf-1 (ft)**	**WBlf-2 (ft)**	**WBlf-3 (ft)**	**WBlf-Avrg**	**EBlf-1 (ft)**	**EBlf-2 (ft)**	**EBlf-3 (ft)**	**Eblf-Avrg**
1950-1963	-6.7	3.5	-27.1	-10.1	-65.8	-18	10.4	-24.5
1963-1977	-9.6	-13.3	21.6	-0.4	13.7	-16.1	-0.5	-1.0
1977-1988	22.6	16.6	-6.5	10.9	6.6	-2	24.4	9.7
1988-1997	12	12.6	13.5	12.7	8.5	11.6	-1.5	6.2
1997-2008	-20.9	-19.6	-27.7	-22.7	-26.9	-17.7	-12.5	-19.0
Net Change	-2.6	-0.2	-26.2	-9.7	-63.9	-42.2	20.3	-28.6

CONCEPTUAL RESTORATION DESIGN ANALYSIS

Overview and Synthesis

The Little Squalicum to Mount Baker Plywood Peninsula nearshore have undergone fundamental and far reaching changes due to development over different time periods. Predevelopment conditions in this portion of northern Bellingham Bay generally consisted of the large and highly productive Nooksack River estuary, the narrow ravine that contained Little Squalicum Creek, the Squalicum Creek ravine and sandy delta beach, as well as the Whatcom Creek estuary and tideflats that historically contained some 200 acres of eelgrass beds. Although little appears to be known for certain about the early history of Little Squalicum Creek, these creeks and the Nooksack River contained multiple species of natal salmon. Each of these nearshore areas have been greatly degraded over time, amounting to substantial habitat loss throughout the northeast shore of Bellingham Bay.

The large changes that have occurred outside of the study area play into the habitat and restoration analysis for the shores within the study area. In particular the Nooksack River, which is one of the major Puget Sound salmon rivers and also contains a watershed that is less developed than most Puget Sound rivers, discharges only 2 miles west of the west end of this study area. That clearly places Little Squalicum Creek within the 5 mile radius of the mouth of the Nooksack River which is forwarded to be a very important area for Nooksack River juvenile salmon for refuge and feeding, particularly in pocket estuaries (Beamer et al. 2003). In addition, Squalicum Creek is characterized as the second most important salmon stream/river in the greater Bellingham Bay area. The mouth of Squalicum Creek is located 0.25 miles east of the study area. The Squalicum Creek estuary has been severely altered and the habitat functions of the estuary are generally lost due to extensive fill and development (WADOE 2000).

WDFW, the Washington Department of Ecology, the Port of Bellingham and COB are currently exploring the feasibility of significantly altering the lower reach of Squalicum Creek to enhance stream productivity and fish passage. In addition, the same parties are proposing a significant estuary enhancement project in the embayment immediately to the northwest of Squalicum Creek. These enhancement efforts are not yet fully funded or ready to be implemented and will largely be taking place within a more urban context than the Little Squalicum shoreline restoration opportunity provides, despite the history of heavy industry at the site. Similarly, Whatcom Creek is in a highly developed urban area and there is little chance for large scale restoration, although several moderate-sized clean up and revegetation projects have occurred in the Whatcom Creek estuary. Padden Creek is another salmon-bearing stream in Bellingham Bay with a highly degraded estuary. Several small to moderate scale restoration options have been considered for the Padden Creek lagoon but the current site is constrained by existing infrastructure (available area for major restoration), unless extensive measures are taken in the former upper estuary area. In addition, all of these creeks have impaired water quality and much attention needs to be paid to addressing these water quality concerns in the future.

With this nearshore habitat framework of tremendous loss of estuarine area and the close proximity of the Nooksack River and Squalicum Creek, trying to create estuarine area opportunistically near these two natal streams seems to be a very worthy goal (as also discussed in the *Habitat* section above). The fact that the Little Squalicum Creek ravine was greatly changed through gravel and sand mining makes enhancing the estuarine habitat a possibility at this site. At present, the lower portion of the future park below Marine Drive has an immature deciduous forest in an artificially flat area that is surrounded by steep slopes on two sides. This area makes for somewhat of a blank slate for enhancement. Note that restoration is not the proper term for creating an estuary where one did not previously exist. However, a tidal marsh was mapped adjacent to the creek as evidenced by 1887 T-sheet (Figure 13) and eroded peat on the beachface (Figure 5).

Physical feasibility was of course the major element of this study. Several physical parameters were required to be within a certain range to conclude that creation of an estuary in the lower portion of (future) Little Squalicum Park is the best nearshore habitat enhancement option within the study area. The technical elements of these physical parameters are discussed and analyzed in the *Reference Lagoon/Estuary Analysis* section below. Briefly, one of the physical factors affecting feasibility was the fact that the net shore-drift cell that encompasses the study area has been considerably shortened since pre-development conditions. The cell, which exhibits northwestward drift, was shortened by 0.9 miles. Additionally, a broad sandy beach and tide flat was also lost due to development of the greater Squalicum Marina to Mount Baker Plywood Peninsula. This has greatly reduced the littoral drift rate (and the volume of sediment in transport) within the drift cell. As suggested by Bruun (1986), lower littoral drift rate increases the stability of an inlet for an estuary or creek mouth.

The second parameter was that the Little Squalicum Creek mouth was reported to be almost always open in the pre-culvert conditions (Wahl pers comm. 2009). This was potentially a result of the greatly reduced littoral drift rate, which occurred early in the first half of the twentieth century. This bodes well for an open intertidal inlet as flow would be greater with a greatly expanded tidal prism (the volume of water that a tidal basin exchange) and the added flow of tidal water in and out of a created inlet.

The third physical change to the study area that favors a mostly open inlet near the creek mouth is the presence of the Cement Company pier, which provides some degree of protection from storm wave energy in the area immediately east of the pier. This is the area where the creek mouth was at the time of the field assessment and an estuary inlet appears viable. The greatest potential wave energy was calculated using a recently created wave model for Bellingham Bay (created by Coast and Harbor Engineering for the Port of Bellingham). The model results suggest that the greatest potential wave energy is from 240 degrees (west-southwest). The pier runs at an orientation of approximately 212 degrees such that these highest velocity wind waves would first encounter the pier before reaching the shore by the present creek outlet. The density of piles supporting the pier will likely cause a moderate amount of wave dampening.

An additional beneficial feature in the lower portion of the park for potentially creating a new estuary is the very steep slopes on the east and north sides of this area. These banks represent the farthest extents of the old gravel mine and in this case provide a favorable condition in that access is generally not possible on these slopes. The natural deterrent will enable fewer disturbances (by park users) to fish and wildlife that could be using the estuary in the future.

The estuary concept in lower Little Squalicum Park was included in the early phase of park master planning as a smaller feature. The development of the design for the Little Squalicum area included in this study was carried out in consultation with the Bellingham Parks Department and the master plan consultant team. The Parks Department has now endorsed the estuary concept as forwarded in this report.

Weighed against the concept of creating an estuary in the lower portion of the park, must be other potential restoration/enhancement actions. The west edge of the Mount Baker Plywood Peninsula is clearly in a highly degraded condition in terms of nearshore habitat, which is why this site was identified as a potential enhancement area in the Bellingham Bay Comprehensive Strategy (WADOE 2000; Appendix A). Overall, although several moderately large and several small opportunities exist that should be further investigated in the future, these opportunities do not appear to offer the same degree of nearshore habitat benefit that creating a new pocket estuary would provide. The Port of Bellingham is not amenable to these proposals in their current configuration as they both entail removal of fill and usable land. Landowner input should be obtained before additional study is conducted in the area.

Two conceptual designs for the Baker Plywood Peninsula are presented in a following section. One is for a beach enhancement project at the west edge of the Mount Baker Plywood Peninsula. This beach, if it were built, could provide new potential surf smelt and possibly sand lance spawning habitat, an improved nearshore migratory corridor, and dramatically improved recreation opportunities.

The other opportunity at the Mt Baker Plywood Peninsula entails creating a lagoon in the center of the triangular fill area, which will be further discussed below. This opportunity is not recommended as a high priority for several additional reasons. There is thought to be limited freshwater input in this area, although a small damaged metal culvert was observed in 2004 with some amount of flowing water near the outlet of the path to the parking lot. Also, no lagoon occurred in this area naturally and the site geometry is not such that a lagoon would typically occur in this setting. Perhaps more importantly, in order to fit a lagoon of any size into this area, almost the entire length of the concrete rubble revetment would need to be maintained. Therefore, this option is not recommended.

Additional physical complications for the west side of the Mount Baker Plywood Peninsula design concepts are the unknown soil conditions and the potential for contaminated soils in this area. The potential for contamination does not appear to be particularly high, as it seems that this area was used for a log storage area in the past, but wood waste would need to be addressed and the total history of the site is not clear. Also, it is known that some amount of dredge spoils have been placed in this area in the past and they may have been contaminated. Also, it is unclear of the future plans for this area by the Port of Bellingham.

Other smaller opportunities for restoration or enhancement exist in this area but these are of much smaller scale and could be carried out independent of other actions. These other actions will be discussed in the last portion of this section.

Recommended Enhancement Alternatives

Lower Squalicum Park Estuary

After assessing the opportunities and constraints for nearshore restoration the recommended enhancement action is to create a moderate-sized pocket estuary within the southeast portion of Little Squalicum Park. Based on the data presented above, it appears that Little Squalicum Beach is more heavily utilized by species of concern, thus apparently providing more valuable nearshore habitat in its existing condition than the Mount Baker Plywood site. Restoration or enhancement of the Little Squalicum Creek mouth would enhance conditions for each of the species that currently utilize the nearshore habitats at the site. The proposed conceptual project presented here would provide a major nearshore habitat area that does not presently existent at this site.

Limited data on soil conditions for the lower, eastern portion of the Park was available for this feasibility analysis. However, some inferences about site geology can be made from data presented in the Draft Remedial Investigation (Integral 2008). The draft RI stated that previous geotechnical work in 1993 by Landau Associates, as sub consultants to David Evans and Associates, had completed a geotechnical evaluation of the Park for the Port of Bellingham that included the lower Park. Landau is quoted as observing that “Soil conditions were variable and included clean (low silt/clay content) sand and gravel, silty sand and gravel, and occasional silt and clay units.” No new geotechnical excavations were made in the vicinity of the lower creek for this study. The groundwater elevation was mapped in the upper and lower portions of the Park in February and May of 2006 (Integral 2008). The elevations were at least +16 ft MLLW in the northern portion of the proposed estuary and approximately +10 to +12 ft MLLW in the southern end of the proposed estuary. This suggests that seepage would occur through the upper intertidal and supratidal portions of the proposed excavation area, and should help recharge the estuary, keeping brackish water in the basin of varying salinity. This also indicates that the soils of the park should not cause the estuary to drain through infiltration during low tide periods. The high volume of seepage located at approximately +10-+12 ft MLLW along the toe of the marine bluff immediately east of the proposed estuary area demonstrate the amount of seepage above tidal levels in the vicinity. The

A clay unit of variable thickness was encountered by Integral (2008) in the course of their remedial investigation, although excavations were only performed within the upper creek area. Limited geotechnical investigations were performed in the lower creek for that study. Figure 4-5 of the Integral report shows the inferred top of clay elevation contours, which slope downward to the southwest. The lowest top surface elevation was approximately +10.5 ft MLLW in the vicinity of the Marine Drive Bridge. The groundwater surface also slopes downward to the southwest along a similar pattern as the top of clay. Projecting the contours of the top of clay layer towards the beach suggests that elevation reaches MLLW mid-way between the bridge and railroad trestle (Integral 2008). This suggests that the location of the proposed estuary consists of primarily of sand and gravel layers with a lesser amount of silt and clay and should not penetrate the clay aquatard. Soils to be excavated will be further investigated in the design phase of this project.

Soils of this type could be beneficially reused on-site as part of the remediation as well as to fill the lower creek channel during redirection of the creek into the proposed estuary. Another promising option for re-use of the remaining soils is beach nourishment west of the pier to offset the long-term effects of extensive fill and shoreline armoring. This shore is documented forage fish spawning habitat (Figure 3), which could be substantially enhanced with beach nourishment. Additional locations within the Park have been identified as possible recipients of clean fill by the COB Parks and Public Works departments. Reuse on-site represents a substantial cost savings over trucking off-site. Further investigation of soil quality and possible contamination will be necessary before plans for reuse can be made.

<u>Reference Lagoon/Estuary Analysis</u> - Several lagoon/estuaries in the Puget Sound region were selected as reference sites for the design of the proposed estuary and associated tidal inlet. The sites covered a wide area of the northern Puget Sound (Figure 26). Tidal prism for the lagoons were either derived from field data or from LiDAR data where coverage was collected at a tide level low enough to have emptied the lagoon (Table 4). For LiDAR-derived prism and cross-sectional area, the bare-earth points were

loaded into AutoCAD Civil 3D 2008 for processing, where a volume surface between the lagoon and MHHW was created. The “fill” value for the surface was used as the effective tidal prism. Additionally, the lagoon size and inlet length were calculated from aerial photographs (Tables 4 and 5).

Inlet Stability Analysis - An initial investigation was undertaken into the inlet stability of a proposed estuarine lagoon. The general principles here are that a stable intertidal inlet can be created if a sufficiently large tidal prism is created in an area with low littoral drift rates and low or moderate wave energy. Several methods have been studied to determine the stability of coastal inlets. The methods considered here are tidal prism versus wave power (Johnson 1973), tidal prism versus the inputs of shore-drift sediment (Bruun 1986), and tidal prism versus inlet gorge cross sectional area (Hughes 2002).

Table 4. Reference lagoon/estuary area and tidal prism characteristics.

Lagoon	Location	Surface Area (ft^2)	Surface Area (acres)	Tidal Prism (cy)
Shoal Bay	NE Lopez Is.	141,000	3.24	9,400
Decatur Head	NE Decatur Is.	106,000	2.43	13,000
Third Lagoon	S San Juan Is.	107,000	2.46	-
Walan Pt	Indian Is.	638,000	14.6	17,000
Gulf Rd	W. Whatcom Co.	132,000	3.4	2,300
Kala Pt	E. Jefferson Co.	605,000	13.9	40,000
Portage Island	Portage Island	26,600	0.6	530

Table 5. Reference lagoon/estuary inlet channel characteristics.

Lagoon	Location	Channel Width at MHHW (ft)	Channel Cross Section Area to MHHW (sf)	Channel Depth from MHHW (ft)	Channel Length (ft)
Shoal Bay	NE Lopez Is.	34	60	2.6	202
Decatur Head	NE Decatur Is.	38	127	3.0	207
Third Lagoon	S San Juan Is.	15	11	1.5	122
Walan Pt	Indian Is.	44	62	1.5	150
Gulf Rd	Whatcom Co.	32	65	3.0	150
Kala Pt	Jefferson Co.	65	98	2.5	300
Portage Island	Portage Island	15	17	1.9	150

Johnson (1973) developed a relationship between wave power (P_W) versus tidal prism (P) using inlets on the Pacific coast. His examination of various parameters showed that deep-water wave power appeared to be the single most important factor affecting the stability of tidal inlets. Johnson concluded that for a given wave power there is a minimum tidal prism required to keep the inlet open. By plotting the power versus prism on a graph with the equation he derived, one can qualitatively determine the stability of a given inlet. Wave power at the study area is relatively high due to the relatively long fetch of 15 miles. Insufficient data exists for full application of Johnson's equation, although modeled wave data suggests high values of P_W at the site.

Bruun (1986) proposed a relationship between tidal prism and annual input of shore-drift sediment (M_t) to an inlet. His work involved examining the inlet within the greater nearshore system, with consideration for the inputs of sediment from alongshore, which both affects and is affected by a lagoon inlet. Bruun concluded that an inlet with P/M_t ratio greater than 150 tended to maintain a fully open inlet. Given that the study area receives very little sediment via alongshore transport, the value for M_t can be considered very small, and hence the P/M_t ratio to be relatively high.

While Johnson's work would tend to show that the high wave power at the site necessitates a very large tidal prism, Bruun's analysis shows that the lack of sediment transport to the opening provides a good deal of stability. Qualitatively, these two views of inlet stability are in agreement, as Johnson's method assumes an unrestricted supply of littoral sand, which does not exist at the beach in question. Also, while the actual inputs of littoral sediment are low, the potential for sediment transport is high due to the extended fetch in the direction of predominant regional winds. Sediment that accumulates in the ebb tidal delta of a proposed lagoon would tend to be transported westward with the direction of net shore-drift and be unavailable for transport into the inlet. Additionally, inputs from fresh-water sources tend to increase the effective tidal prism, which acts to provide further inlet stability.

Much work has been done to develop a simple relationship between tidal prism and inlet geometry (Jarret 1976, Byrne 1980, Seabergh et al. 2001, Hughes 2002). Hughes' study tended to bring all of the previous data together in agreement, and provided a common relationship for the previous studies. Due to a lack of data for either Johnson's or Bruun's relationship to be feasible at this phase of design, Hughes's relationship between cross-sectional area and tidal prism will be used here.

Given the aerial coverage of the proposed lagoon at approximately 1.0 acre and an assumed difference of 3 ft between the tidal channel weir and MHHW (+8.5 ft MLLW), the effective tidal prism was proposed at 130,000 cf. The estuary mean tide level (MTL) is +7 ft MLLW. From the relationship developed by Hughes (2002), this yields a design cross-sectional area of 3.75 sf below lagoon MTL. The effective tidal prism will be larger than the lagoon volume only, as creek flow and groundwater seepage would also enter the estuary. Reference lagoon/estuary inlet channel characteristics were determined from past work by CGS (Johannessen 2009) and additional investigation for comparison (Table 5).

<u>Specific Design Elements</u> - The new estuary would be on the order of 420 ft long by approximately 160 ft wide (Figure 27). As pointed out in the previous sections, the larger the estuary area and tidal prism, the lower the chance of inlet closure would be. The conceptual level estuary design was created such that all excavation would have a small setback from the toe of the slope on the east and north sides, for slope stability reasons. The west side of the estuary would straddle the current trail location in places, and be east of the trail in other locations. A new bridge would likely be required near the north end of the estuary for a trail crossing. Likewise, a trail and bridge may be required just landward of the active beach and backshore that would cross the inlet channel just landward of the BNSF rail trestle. These areas would require coordination with Parks staff.

The deeper portions of the estuary would be excavated to an elevation of +2 to +4 ft MLLW, such that ponded water of several feet deep would be present at low tide periods (Figure 27). A gently sloped upper intertidal would be created that would maximize salt marsh area for habitat value, without going so far as to greatly reduce the needed tidal prism for keeping the inlet open. Salt marsh area would be on the order of 16,000 sf (Table 6). The area below the salt marsh elevation would be generally sandy, and have on the order of 9,000 sf exposed area when the tide is low.

Some sinuosity was introduced into the conceptual design shore to maximize shore length and add habitat and aesthetic value. Vegetation enhancement would occur in the area higher than a foot or so vertically above MHHW where salt marsh will not grow. This would have salt tolerant vegetation, as extreme high water levels would inundate the area up to approximately elevation +11 ft MLLW. Additional native vegetation would be planted on the higher elevation portions of the cut surface. Coordination with Park planners would be required relative to vegetation and land use.

The inlet channel is expected to have a minimum depth of approximately 1.5 - 3.5 ft below MHHW, but also be dynamic in response to storm waves and high creek/groundwater input. An inlet channel width of 20 ft at MHHW would produce a parabolic cross-section, which tends to maximize the hydraulic efficiency of the inlet, helping to keep it open. Since small inlets tend to toward closure, while larger inlets tend toward equilibrium (USACE 2006), a factor of 25% can be safely added in the final designs for the tidal inlet at the proposed lagoon. These calculations are preliminary at this point as additional geomorphic analysis would be required to finalize design specifications as well as collaboration with Parks, City of Bellingham staff and potentially additional consultants; if required.

Table 6. Summary of conceptual enhancement project habitat areas.

Project Concept	General Length & Width (ft)	Total Enhancement Area Below* MHHW (sf)	New Saltmarsh Area (sf)	New Beach Area (sf)	New Potential Forage Fish Spawning Area (sf)
Estuary - LSP	420, 160	43,000	16,000	9,000	0 (18,000)**
Beach - MBP	220, 75 + 80, 80	22,000 + 2,000	0 + 100	22,000 + 2,000	1,800 + 1,000
Lagoon - MBP	270, 50-140	19,000	9,500	5,000	900

Note: *Total enhancement area below MHHW represents the total area. New saltmarsh, exposed beach, and potential forage fish spawning area were summed in the total area.
**Increase in potential forage fish spawning area west of the pier assumes beneficial reuse of excavated soils on the beach west of the pier recreating an approximately 1,000 ft long by 18 ft wide of spawning area.

Mount Baker Plywood West Beach Enhancement

Habitat Overview - Anthropogenic alterations of the Mt Baker Plywood site have changed the geomorphic character of the eastern reach of the shore (adjacent to Mt Baker Plywood) from an eroding bluff that was fronted by a broad sandy beach. This beach was historically a popular bathing beach for early settlers in Bellingham, and now only the narrower beach to the west is regularly accessed by the public for its recreational value (despite its degraded condition). The historic T-sheet (No. 1798, Figure 13) shows the Squalicum Creek channel extending (southwest) across the low tide terrace waterward of Mt Baker Plywood. Currently the shore is no longer functioning from a geomorphic perspective due to the hard armoring and fill precluding natural processes including fine sediment deposition and wave-induced erosion of the bluff. It is very likely that this beach was historically a surf smelt spawning beach and possibly also utilized by sand lance, similar to the adjacent beach. Migrating juvenile salmonids likely also utilized the beach in its historic condition due to its close proximity to salmonid-bearing Squalicum Creek and the Nooksack estuary. If some of these functions and processes were restored the ecological value of the site would greatly improve and habitats would likely become utilized similar to the adjacent shore.

Specific Design Elements Mount Baker Plywood West Beach Enhancement - The design concept for the west fill triangle area at the Peninsula is to remove a significant amount of the fill area of the former log handling yard to create one larger and one smaller beach area (Figure 28). The parking lot and a small additional area (approximately 50 ft deep area) would not be altered. The larger beach area would be southwest facing. It would have a very similar aspect to the adjacent unmodified beach. An approximately 310 ft long reach of the old concrete rubble revetment would be removed from the site. Approximately 70 ft of the angled revetment would remain in place closer to the industrial area of the Peninsula. A new rockery or similar shore protection would be built setback from the existing shore on the west face of the remaining filled area, east of the new beach. A new groin would be required on the west end of the main beach area, which would be on the order of 115 ft long. A small buried revetment would run off the east side of the groin. These structures would be required as the beach would be in a much more waterward position than the natural shore was in, and the net shore-drift volume has been greatly reduced by development.

The main beach would be approximately 220 ft long (Figure 28) and would have gentle slopes to allow for installation of a mixed gravel and sand beach, using the nearby beaches as reference sites. The total enhancement area would be approximately 22,000 sf for the main beach (Table 6). Potential forage fish spawning area could be recreated here using fine grained sediment in the upper intertidal as this would be a pocket beach (approximately 3,800 sf). Direct access to the new beach would be possible from the parking lot.

A smaller beach enhancement area would be present in the lee of the north end of the groin. This would be a very small embayment with the shore curving around in a spiral shape. A small upper intertidal salt marsh area (approximately 100 sf) would be created in the south side of the spiral shore where wave energy would be very low. The total area for the smaller beach section would be approximately 2,000 sf. This area would have approximately 1,000 sf of potential forage fish spawning area. Backshore planting would be carried out wherever park user traffic would not be expected to be too high.

Specific Design Elements Mount Baker Plywood Lagoon Enhancement - The design concept for a lagoon in the fill triangle on the west side of the Peninsula would be an alternative to the above beach concept. These 2 alternatives are mutually exclusive. The idea behind the lagoon alternative would be to create an intertidal lagoon in the lee of the existing concrete ruble revetment (Figure 29). The lagoon would be approximately 270 ft long by between 50 and 140 ft wide, including all of the new sloping shore with a total area of approximately 19,000 sf (Table 6). The upper intertidal (approximately +6.5–9 ft MLLW) would become salt marsh that would wrap around the shore of the new lagoon. The total area of salt marsh is expected to be approximately 9,500 sf. Potential forage fish spawning area would be recreated in the far northwest end of the project area in the lee of the remaining revetment (approximately 1,000 sf).

Small Restoration/Enhancement Opportunities

Remove Pier - As identified in the Bellingham Bay Comprehensive Strategy (WADOE 2000; Appendix A) the Cement Company pier has been out of use for a very long time and provides a great structure removal opportunity. This pier contains upwards of 600-1000 creosoted pilings. In addition, the pipeline structure immediately west is also a derelict structure and could be removed. Removal of these structures would represent a dramatic improvement in water quality by removing this source of on-going toxic input into the environment. Additionally, removal of the structures would uncover a substantial square footage of intertidal and subtidal bottom for colonization by fish and wildlife and submerged aquatic vegetation.

Remove Concrete Debris East and West of Pier - The concrete slabs and boulders on the intertidal immediately east of the pier could be removed to free up intertidal area. The debris appears to have been in place for a long time but could be removed quite simply. Rock placed on the upper beach in the long reach west of the pier should be evaluated for removal in sections. This would include debris that has been moving down the bank at the Cement plant as well, as also recommended in the Whatcom County SMP Restoration Plan.

Move Park Trail Landward - The lower end of the loop trail at the Little Squalicum Beach is within the active upper beach/backshore area. This was evidenced by repeated storm damage. It would be best to move large sections of trail, such as this shore parallel section, landward of the BNSF trestle. This area could be restored to backshore and also allow good access for park users.

Invasive Plant Removal - The lower section of Little Squalicum Park contains large areas dominated by invasive plant species. Exotic plants here could be eradicated and appropriate salt tolerant native species could be planted in their place.

Intertidal Concrete Debris Removals in West Bluff and East Bluff Subareas - This opportunity is limited to several large concrete sections in the upper intertidal. These could be completely removed from the site and recycled.

Intertidal Debris Removal Surrounding Revetment - Portions of the upper intertidal adjacent to the west Mount Baker Plywood Peninsula revetment have concrete that has toppled to the beach. This also includes the far northwest end of the revetment where several large slabs of concrete are present in the intertidal. All of these pieces of debris outside of the primary revetment footprint could easily be removed from the intertidal and taken for recycling. This would be a simple low cost debris removal project that would have measurable uncovered intertidal beach area.

Limitations of This Report

This report was prepared for the specific conditions present within the specified study area to meet the needs of specific organizations. No one other than the client or their agents should apply this report for any purposes other than that originally contemplated without first conferring with the geologists that prepared this report. The findings and recommendations presented in this report were reached based on limited field visits and do not reflect detailed examination of sub-surface conditions present at the site, or drainage system designs, which are not known to exist. It is based on examination of surface features, bank exposures, soil characteristics, gross vegetation characteristics and beach and coastal processes. In addition, conditions may change at the site due to human influences, floods, groundwater regime changes, sea level rise, or other factors. This report may not be all that is required by contractors to carry out recommended actions. More detailed design specifications would be required prior to implementation of any conceptual design features presented herein.

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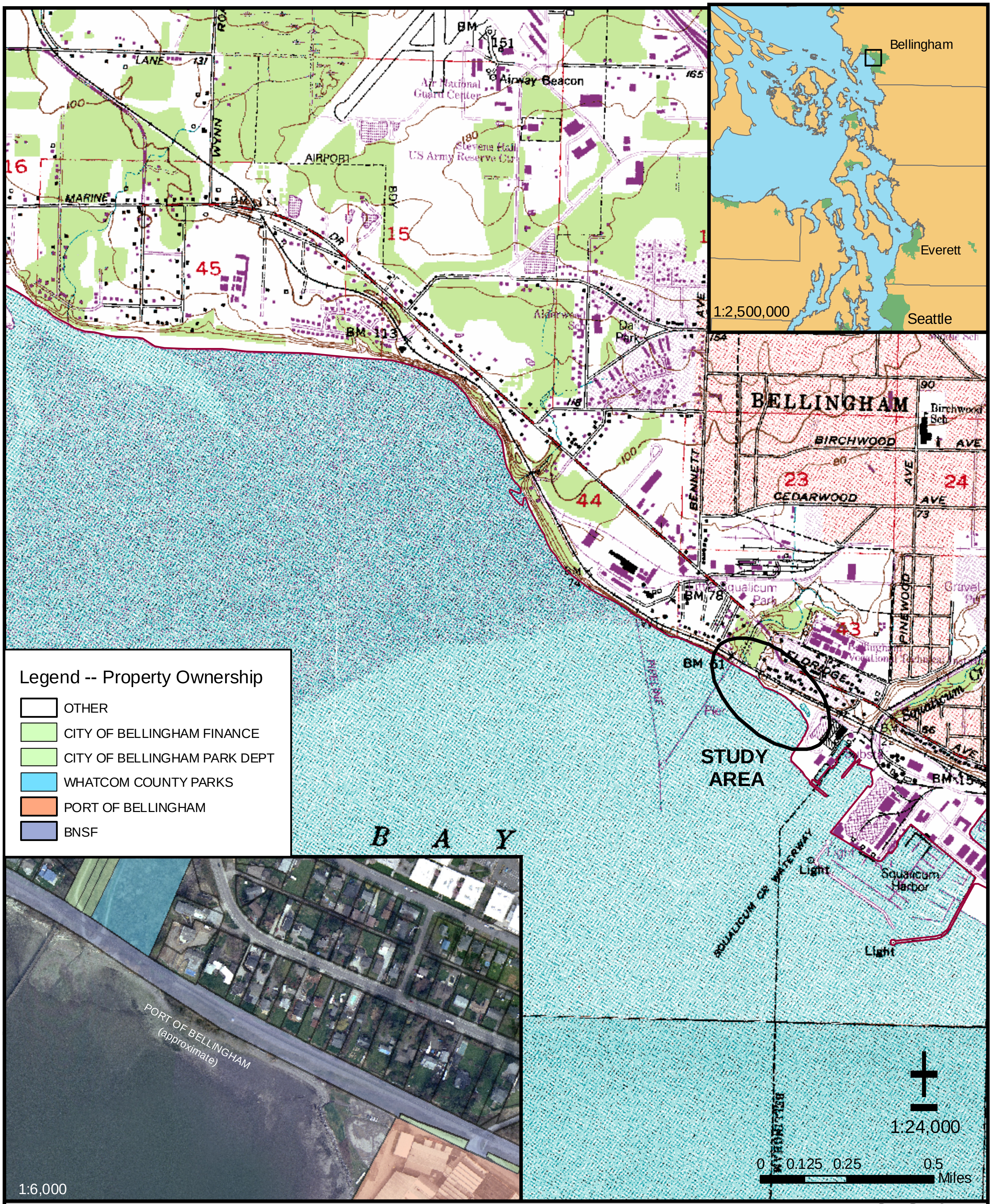

Figure 1. Location and property ownership map of the study area.

USGS Topographic Quadrangle, 2008 City of Bellingham Imagery

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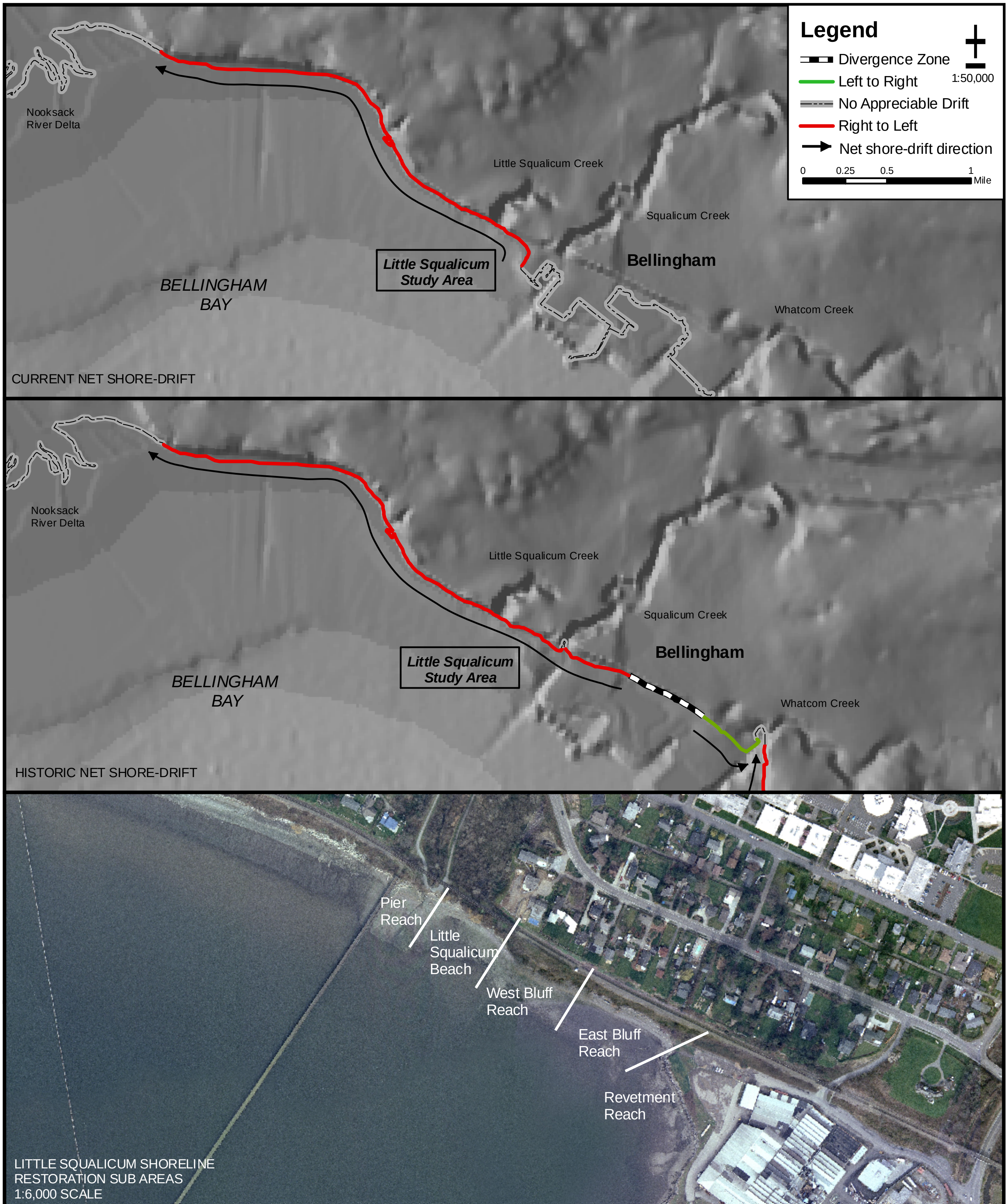

Figure 2. Historic and current net shore-drift and shoreline sub-areas.

Puget Sound LiDAR Consortium, LiDAR hillshade

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Figure 3. Surf smelt and sandlance data at Little Squalicum study area (WDFW 2009).

2008 City of Bellingham Imagery

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Figure 4. Photo page 1, summer 2009 conditions.

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Figure 5. Photo page 2, February 2006 conditions.

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Figure 6. 1944 aerial photograph (photo-mosaic) by US Army.

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Figure 7. 1977 oblique air photo (Ecology).

Figure 8. 1993 oblique air photo of the study area (Ecology).

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Figures 9. 2001 oblique air photos of study area (Ecology).

Figures 10. 2001 oblique air photos of study area (Ecology).

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Figure 11. 2006 oblique aerial photos of study area from 3/28/06 (Ecology).

Figure 12. 2006 oblique aerial photos of study area from 3/28/06 (Ecology).

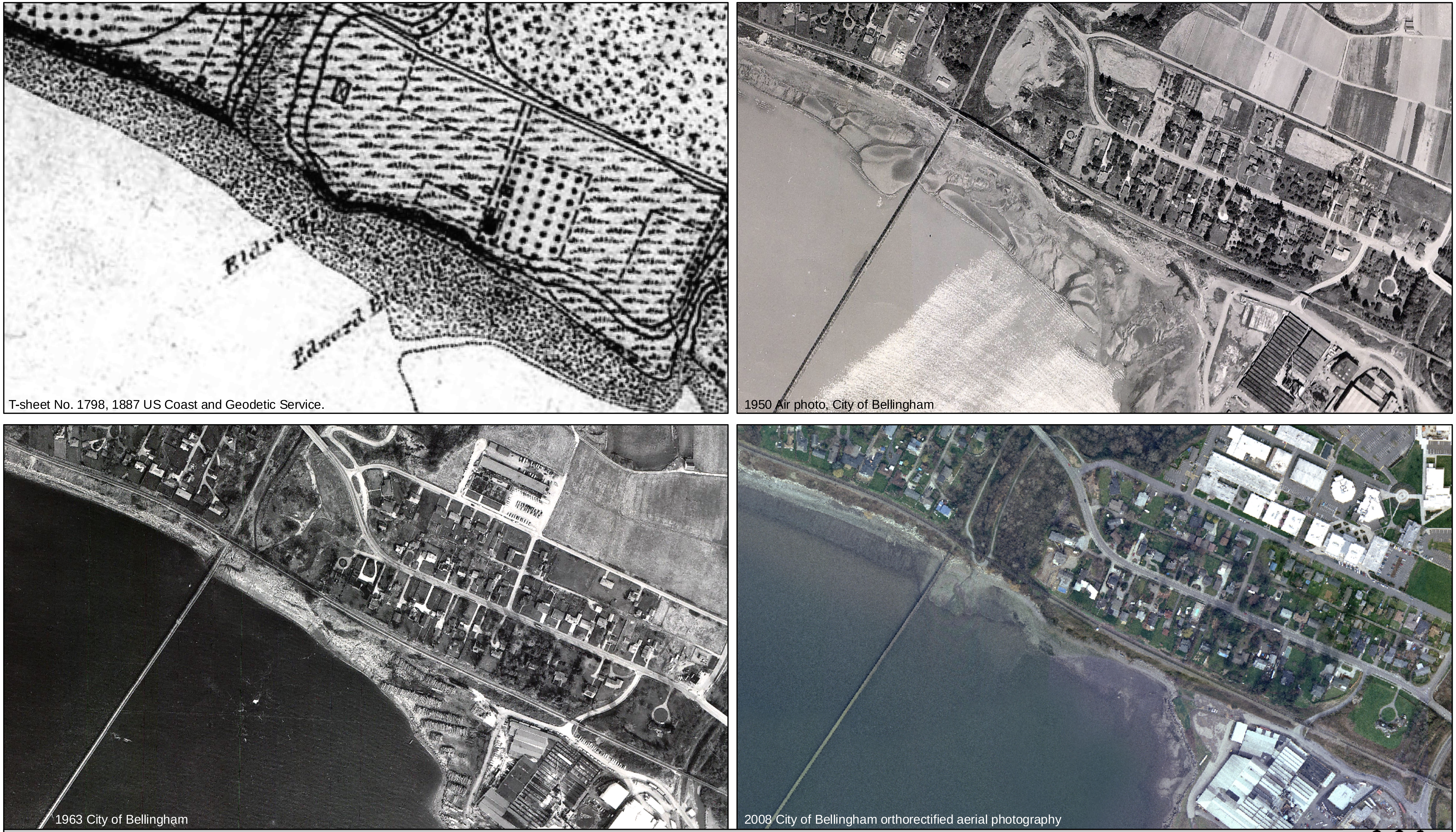

Figure 13. Images displaying contrasting configuration of study area from historic conditions to present.

0 125 250 500 750 1,000 Feet

1:5,000

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Figure 14. Northern Bellingham Bay with Squalicum Creek delta as background tideflat. Photo was taken in the late 1890s. Courtesy of Whatcom Museum.

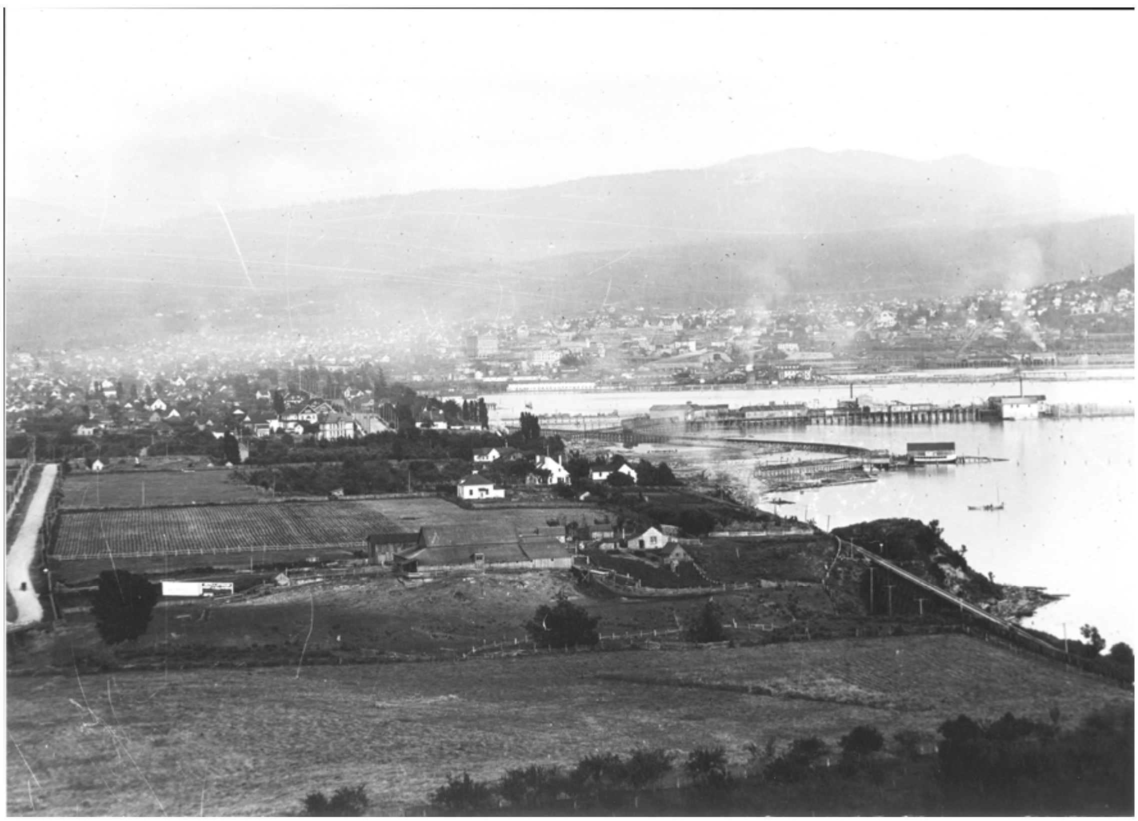

Figure 15. Northern Bellingham Bay around 1913 with Little Squalicum Creek in the bottom right. Courtesy of Whatcom Museum.

Figure 16. Squalicum Creek delta pre-development (pre-1926). Courtesy of Whatcom Museum.


Figure 17. Squalicum Creek delta development (1930s). Courtesy of Whatcom Museum.

Figure 18. Little Squalicum Creek mouth and beach conditions around the 1940s. Courtesy of Whatcom Museum.

Figure 19. Study Area beach and Squalicum Harbor development in 1949**.** Courtesy of Whatcom Museum.

Figure 20. Construction of Marine Drive bridge in 1956 over Little Squalicum Creek. Courtesy of Whatcom Museum.

Figure 21. Middle of Little Squalicum Creek mouth mid 1950s. Courtesy of Whatcom Museum.

Figure 22. East side of Little Squalicum Creek mouth mid 1950s. Courtesy of Whatcom Museum.

Figure 23. West side of Little Sqaulicum Creek mouth mid 1950s. Courtesy of Whatcom Museum.

Figure 24. Shore change analysis of driftlog line from 1950 - 2008.

2008 City of Bellingham orthorectified aerial photography

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Figure 25. Shore change analysis of vegetation line from 1950 - 2008.

2008 City of Bellingham orthorectified aerial photography

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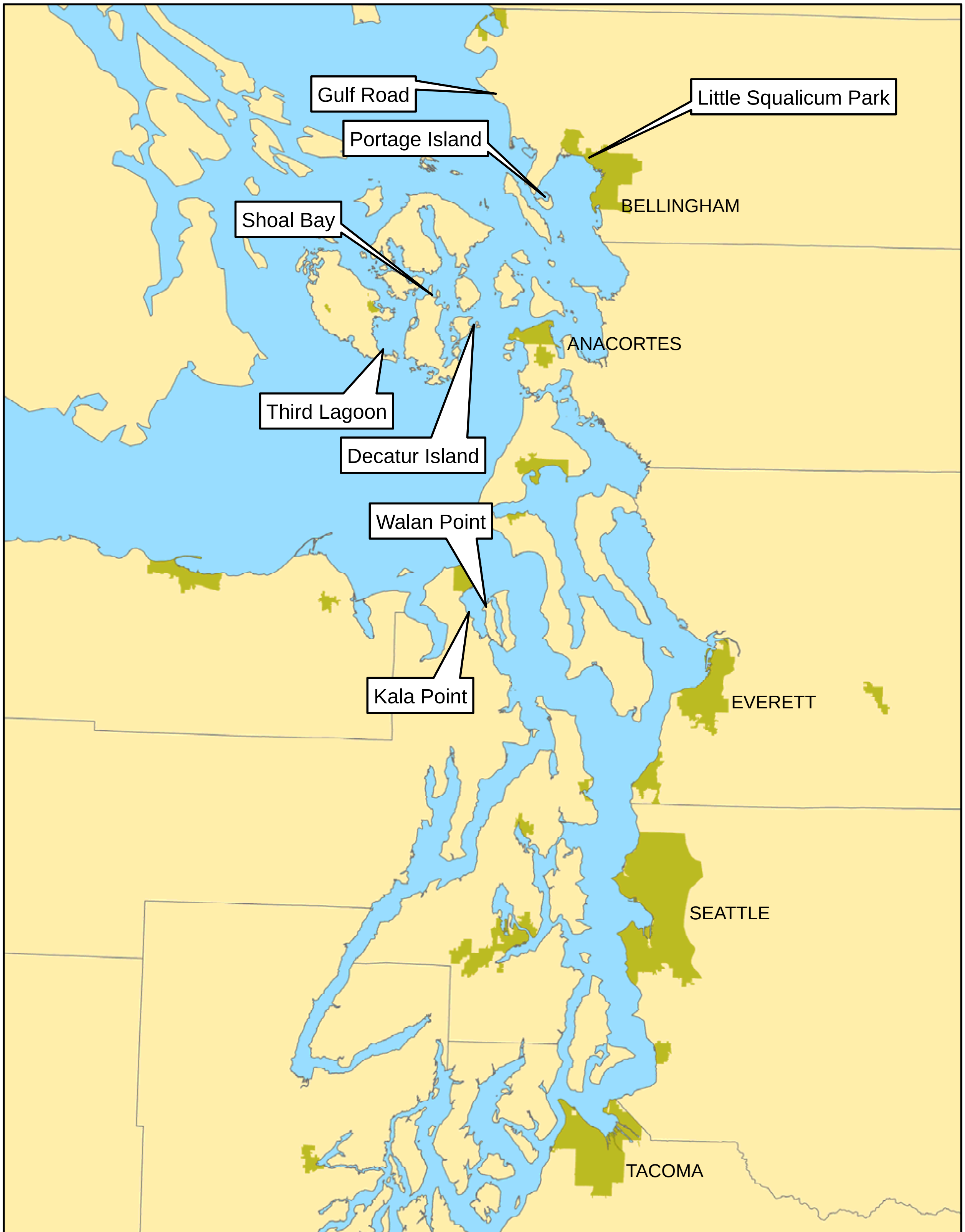

Figure 26. Location of reference sites used in tidal inlet stability analysis.

Little Squalicum Shoreline Restoration Feasibility Study

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Figure 27. Little Squalicum Park estuary conceptual design.

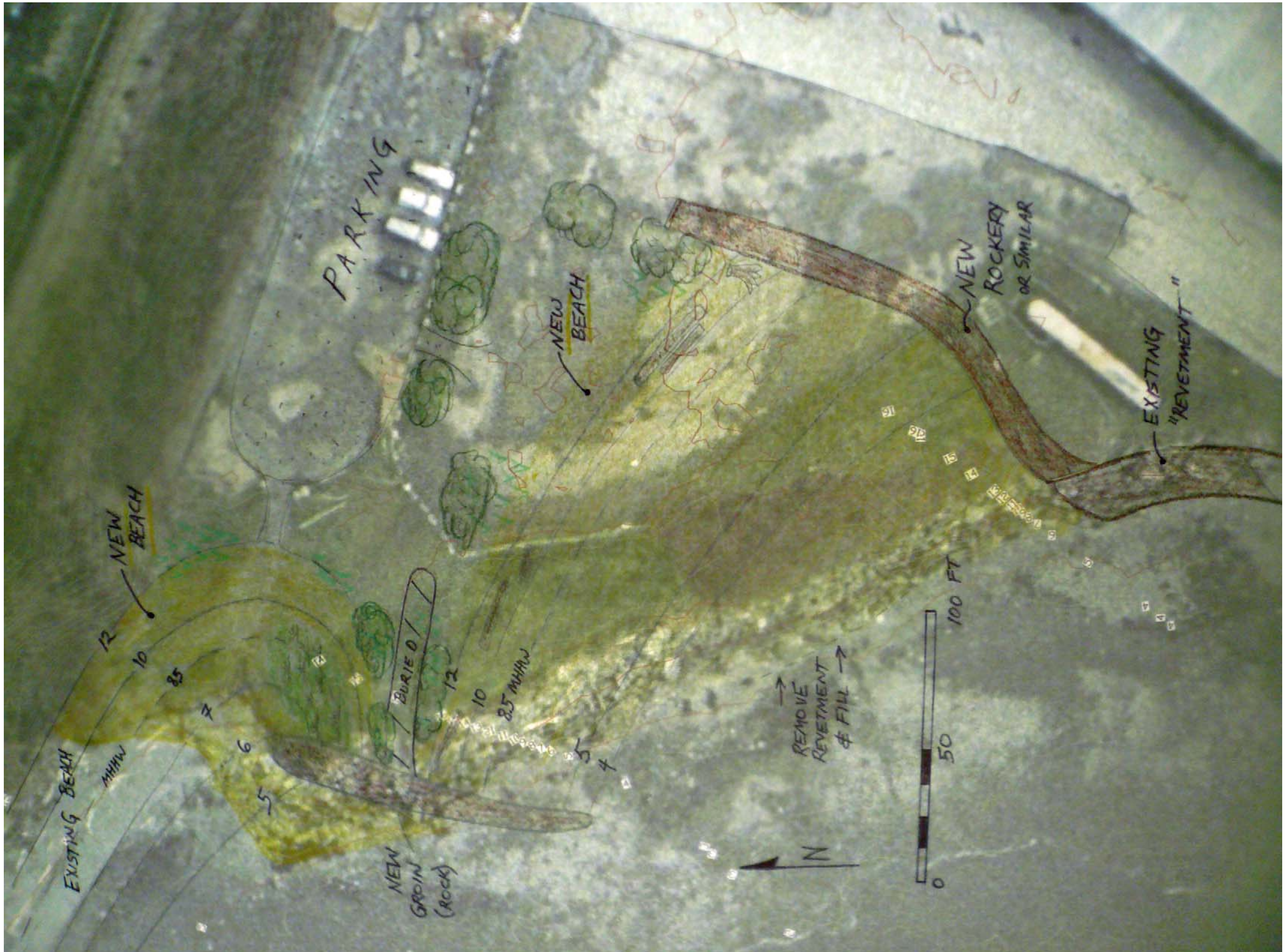

Figure 28. Mount Baker Plywood west beach enhancement conceptual design.

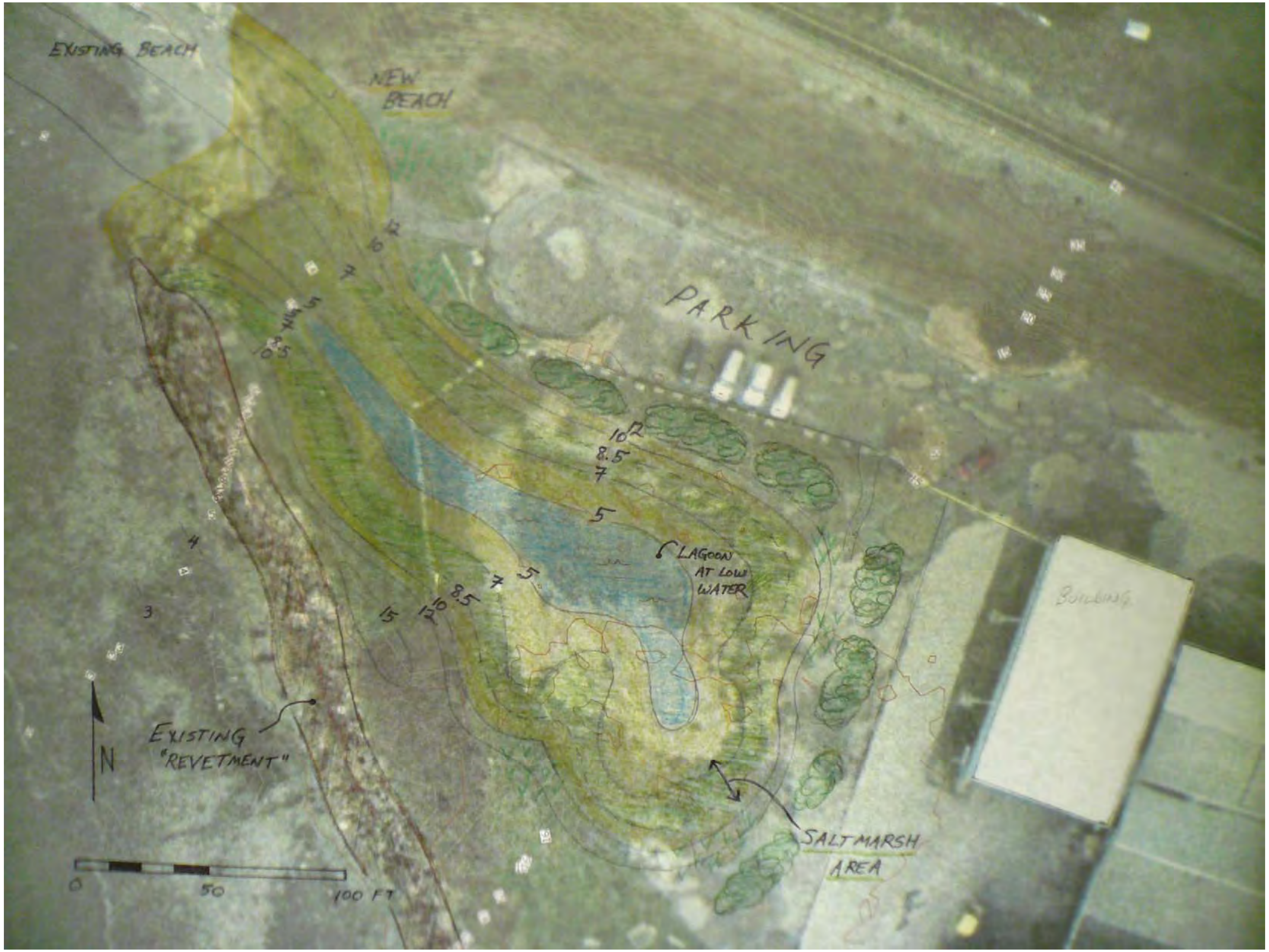

Figure 29. Mount Baker Plywood west lagoon enhancement conceptual design.

APPENDIX A:

Selected Excerpts from Bellingham Bay Comprehensive Strategy

Selected excerpts from the Bellingham Bay Comprehensive Strategy

In the Bellingham Bay Comprehensive Strategy (2000) nine subareas throughout Bellingham Bay were identified and strategies developed for each subarea pertaining to its primary use, land use, and habitat, as well as sediment sites, clean up, disposal, and source control of each subarea. Habitat actions within each subarea were listed, described, and approximate habitat area gained calculated.

The Little Squalicum Creek study area was identified as shoreline segment SI-1 within the Squalicum Industrial Subarea. Three habitat action descriptions listed in the document were encompassed by the Little Squalicum Creek study area. One habitat action in particular, coincides directly with recommendations from CGS' report. Described in CGS' report as Mount Baker Plywood West, recommendations included removing the large boulders to expose underlying sediments and adding mixed sand and gravel. An estimated 30,000 sq ft of habitat would be gained by taking this action. Relevant text from the Bellingham Bay Comprehensive Strategy is summarized below and can be found in the attached pages 3, 8-11.

Restoration opportunities identified in the Squalicum Industrial Subarea

1. Remove treated wood piles (cut below mud line) from Lehigh Northwest Cement Company Dock to remove creosote from the aquatic environment, restore substrates (38,000 sq ft), p 3.

2. Remove large boulders at Mount Baker Plywood West and nourish the newly exposed beach with sand and gravel of appropriate size (30,000 sq ft), p 3.

3. Remove fill and grade area to support marine buffer, possibly salt marsh and sand/mudflat at Mount Baker Plywood Northwest (30,000 sq ft), p 3.

Notes

- "Some **salt marsh and mudflat habitat** occurs…..these creeks and their estuaries, although relatively altered, provide some habitat function such as feeding and transitional habitat for finfish." Restore habitat associated with urban estuaries p 8.
- Shoreline segment SI-1, which encompasses the study area, states *Primary Uses* as natural resource production, **habitat protection and enhancement**, and public access as per the SMP, p 10.
- Provide for **no net loss** and/or a net gain of marine aquatic habitat area/function, p11.
- Enhance **habitat connectivity** along this shoreline, p 11.

Table A-1 Habitat Action Descriptions (Refer to the attached maps for location of numbered actions)

No.	Habitat Area to be Gained in ft² (acres)[1]	Name	Description
1	38,000 ft² (0.87)	Cement Co. Dock	The cement company dock is a relatively wooden structure near Little Squalicum Creek. It extends through intertidal and shallow subtidal water. The primary action would be removal of the treated wooden piles (probably cut below the mud line) to remove creosote from the aquatic environment and restore substrates.
2	30,000 ft² (0.68)	Mt. Baker Plywood West	The beach area west of Mt. Baker Plywood consists of large boulders and rocks. Opportunities at this site include either removing the large boulders and rocks to expose underlying sediments and supplement with finer mixed coarse gravel and sand, or placing finer mixed coarse gravel and sand over the large boulders and rocks to fill interstices.
3	30,000 ft² (0.68)	Mt. Baker Plywood Northwest	A portion of the shoreline appears to be fill. The fill could be removed and the area graded to support marine buffer, possibly salt marsh and sand/mud flat.
4	120,000 ft² (2.75)	Mt. Baker Plywood - South	The fill could be removed and the site graded to provide habitat suitable for sand/mudflat and salt marsh habitat with a marine buffer fringe.
5	20,000 ft² (0.45)	Squalicum Crk. Waterway - A	This action would involve the removal of treated wooden piles, a pier, log rafting structures, and log rafts.
6	200,000 ft² (4.6)	Squalicum Crk. Waterway – B	The elevations in this portion of the creek estuary could be raised to provide intertidal and shallow water habitat such as eelgrass, kelp or salt marsh and associated functions. Shoreline buffer could also be established.
7	50,000 ft² (1.1)	Bellingham Cold Storage	The fill could be removed and the site graded to provide estuary habitat suitable for marine buffer, saltmarsh and/or intertidal mud/sandflat.
8	640,000 ft² (14.7)	Squalicum Harbor Breakwater	Elevations off portions of the breakwater could be raised from about -18 ft MLLW to provide gently sloping intertidal and shallow subtidal habitat and functions. Side slopes on the seaward edge of the breakwater could be modified to incorporate finer grained material to provide intertidal/shallow water functions.
9	70,000 ft² (1.6)	Squalicum Marina	The substrates along the marina margins could be modified to incorporate finer grained material to provide intertidal/shallow water functions.
10	160,000 ft² (3.6) (area available outside of existing eelgrass bed)	Port-Hilton Harbor	Shallow water habitat could be established by raising the elevation next to the ASB. Marine buffer fringe habitat could be established at high elevations and/or site elevations could me modified to meet the elevations of the existing eelgrass bed. Allow for natural eelgrass colonization or do limited eelgrass transplanting.
11	280,000 ft² (6.4)	G-P ASB – East	Shallow water habitat could be established by raising the elevation next to the ASB. Marine buffer fringe habitat could be established at high elevations and the site could support either marsh plants or eelgrass at lower elevations.
12	960,000 ft² (22)	G-P ASB – South	Elevations could be raised or modified to expand the existing eelgrass bed on the west side of the ASB. About 200, 000 CY would be required to create habitat at elevations suitable for eelgrass.
13	1,430,000 ft² (33)	GP – ASB	This action would consist of removing the ASB from the water and establishing intertidal and shallow subtidal habitat, and marine buffer and/or eelgrass.

Lummi Peninsula shoreline through beach nourishment (should be implemented as a near-term action)

- Upland watershed planning efforts by the tribe and local government efforts should continue to address Nooksack River water quality, sediment, and flooding issues

Sediment Sites, Cleanup, Disposal, and Source Control

No contaminated sediment site issues occur in this subarea. Sedimentation issues are of concern due to the high volume of sediments that are carried into the bay from associated land management practices in the Nooksack River watershed.

- Upland watershed planning efforts should continue to address point and non-point source contribution to water and sediment quality degradation. The *Sediment Site and Source Control Documentation Report* further addresses the linkage between this issue and other regional efforts/programs.

SQUALICUM INDUSTRIAL SUBAREA

Subarea Description

This subarea (Figure A-3) extends from the beginning of the existing Harbor Area designation west of Little Squalicum Creek to the change in shoreline designation from Maritime Multi-Use to Maritime at the eastern boundary of the Weldcraft site. The shoreline along this subarea is predominately developed for commercial and industrial uses. The shoreline (approximately 800 feet) east of the Cement Plant Dock is gently sloped sand and gravel beach with boulders at the landward edge. The shoreline in the remainder of the subarea is primarily artificial (e.g., bulkheads, rip-rap). The Little Squalicum and Squalicum creeks drain into the bay in this subarea. Some salt marsh and mudflat habitat occurs in the Squalicum Creek estuary. These creeks and their estuaries, although relatively altered, provide some habitat function such as feeding and transitional habitat for finfish. The shoreline is designated as Conservancy west of the Cement Plant Dock, and shoreline is relatively undeveloped. East of the Cement Plant Dock, there are two shoreline designations: Public and Maritime. Characteristics of this subarea include:

- Harbor Area Designation
- Cement Plant Dock
- Public Trail System
- Mt. Baker Plywood
- Federal Navigation Channel
- Bellingham Cold Storage
- Weldcraft Sediment Site
- Squalicum Shipyard Site

Recommended Strategy

Integrate current and future land uses with habitat and natural resources occurring in the area by using innovative project and source control designs for water-dependent and maritime uses. Restore habitat associated with the two urban estuaries at Little Squalicum and Squalicum creeks (emphasis on Squalicum Creek) and balance this with the maritime and water-dependent commerce uses associated with the Squalicum Creek Waterway federal navigation channel. It is recommended that this balance be achieved

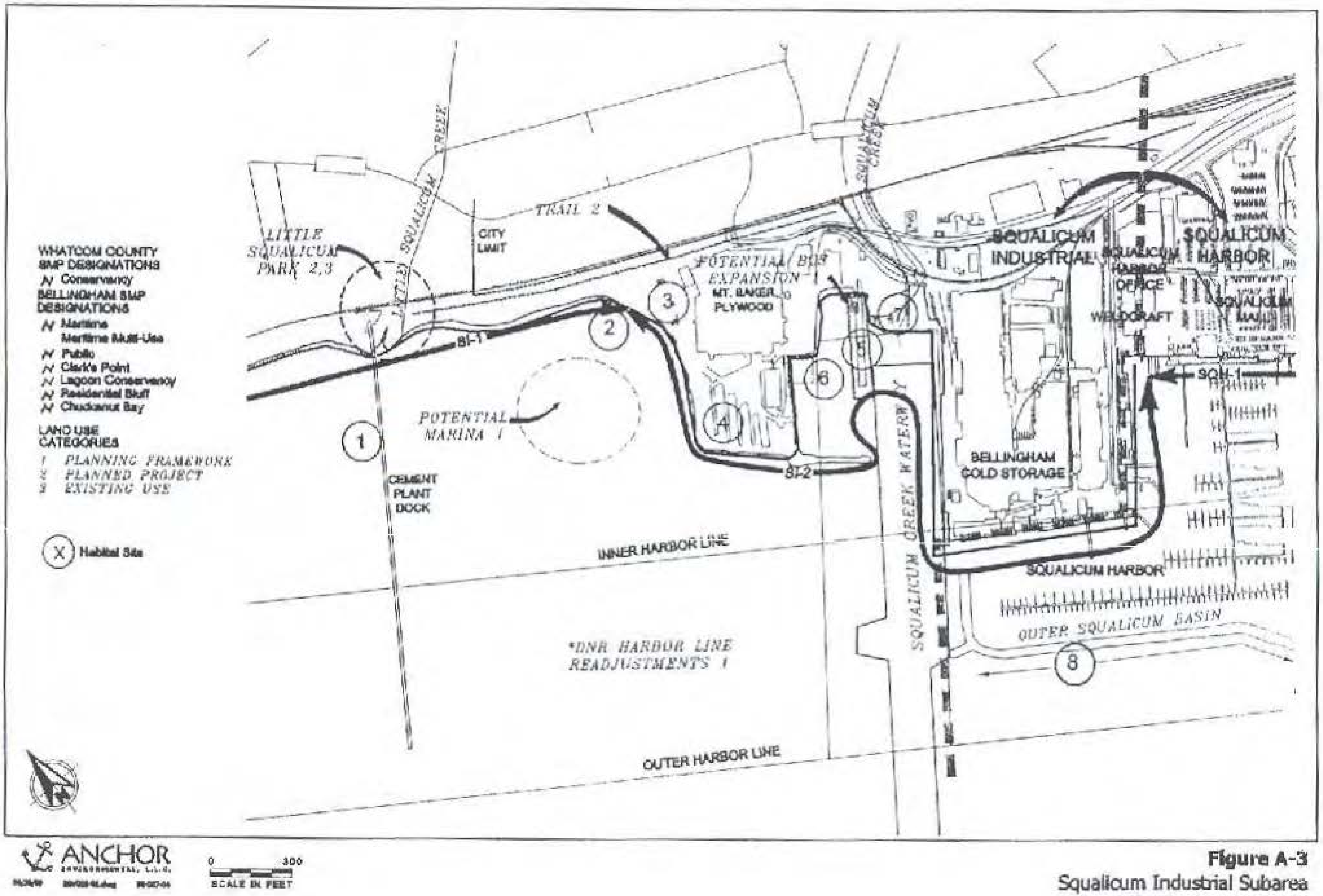

Figure A-3
Squalicum Industrial Subarea

by developing innovative projects and plans that incorporate habitat restoration and enhancements. Habitat restoration may be accomplished independent of land uses.

Primary Uses

Two distinct shoreline segments were identified within this subarea, and they have different primary uses.

- Shoreline Segment SI-1: Natural resource production, habitat protection and enhancement, and public access, consistent with the Public designation used in the SMP
- Shoreline Segment SI-2: Navigation and commerce uses consistent with the Maritime designation used in the SMP, water-dependent commerce uses associated with the federal navigation channel, ongoing maintenance dredging of the federal channel to support navigation and commerce, and protection of estuarine habitat functions associated with Squalicum Creek

Land Use

Land use activities/opportunities present in the subarea that are consistent with the recommended strategy include:

- Evaluate the option of adjusting the Harbor Area boundary to end just west of the Cement Plant Dock (should be implemented as a near-term action)
- Future uses at the Cement Plant Dock should consider a range of options that include leaving the structure for different water-dependent commercial uses, removing it to improve habitat, modifying it to accommodate public access, or a combination of the above
- Recommend future marina development that incorporates designs to avoid, or protect and enhance the nearshore marine environment
- Provide for ongoing commercial, tribal, and recreational fishing
- Provide opportunity for future public access trail that is environmentally consistent with habitat resources or improvements made in this subarea
- Recommend future upland/shoreline development proposals incorporate designs that avoid, or protect and enhance the nearshore environment through implementation of estuarine restoration goals.
- Recommend future railroad developments incorporate designs that avoid, or protect and enhance, the nearshore marine environment

Habitat

Habitat restoration and protection opportunities present in the subarea include but are not limited to:

- Restore estuary habitat functions and area at Squalicum Creek by possibly relocating the stream mouth to the northwest, through changes in shoreline or in-water land uses through proposed developments, and possibly through voluntary efforts
- Restore and protect natural processes that create/maintain habitat
- Provide for no net loss and/or a net gain of marine aquatic habitat area/function consistent with the Draft Mitigation Framework
- Protect existing smelt and sand lance spawning habitats

- Restore habitat functions by removing existing structures or fills through redevelopment projects, or through voluntary efforts
- Enhance habitat connectivity along the shoreline by incorporating habitat restoration and enhancements into proposed shoreline or in-water development projects

Sediment Sites, Cleanup, Disposal, and Source Control

Sediment sites, cleanup opportunities, and source control needs for this subarea include:

- Plan for potential need to remediate the Weldcraft site in this subarea (should be implemented as a near-term action)
- Evaluate potential woody debris in the sediments at the Squalicum Shipyard in the vicinity of Mt. Baker Plywood
- Support the evaluation of potential sources of water quality and sediment degradation associated with the Oeser site in the Little Squalicum Creek Watershed (should be implemented as a near-term action by Ecology)
- Upland watershed planning efforts in both creeks should continue to address non-point source contribution to water and sediment quality degradation. The *Sediment Site and Source Control Documentation Report* further addresses the linkage between this issue and other regional efforts/programs
- Develop stormwater treatment plan for adjacent upland areas that currently are untreated, and control sources associated with existing and proposed land uses through the use of BMPs for operations that require a discharge permit
- Evaluate the presence of phenol and 4-methylphenol in the sediments adjacent to stormwater discharges (should be implemented as a near-term action)
- Permitted NPDES discharges should remain controlled and in compliance with permit limits
- Support the evaluation of the need to modify DNR leases and uses allowed under leases if log rafting no longer occurs within the DNR lease area within this subarea

SQUALICUM HARBOR SUBAREA

Subarea Description

This subarea (Figure A-4) extends from the change in shoreline designation from Maritime Multi-use to Maritime at the eastern boundary of the Weldcraft site to the head of the I&J Waterway. Nearly the entire shoreline along this subarea is developed for commercial and industrial uses, and consists of artificial (e.g., bulkheads, rip-rap) substrate. A small mudflat occurs at the head of I&J Waterway. No creeks drain into this subarea. Despite the developed character of the shoreline in this area, it is used as a movement and migration corridor for salmonids as part of the nearshore habitat continuum, and its substrates support some feeding function for salmonids. The shoreline is designated primarily as Maritime Multi-Use and a small area around Zuanich Park is designated as Public. Characteristics of this subarea include:

- Harbor Area Designation
- Inner and Outer Squalicum basins
- Public boat launch
- USCG station