Flood Study to Determine Alternatives for Restoration and Enhancement of Marsh Habitat and Shoreline Processes for the Iverson Farm Property on Camano Island

Prepared for

Island County Public Works Department

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Services provided pursuant to this Agreement are intended for the use and benefit of the Island County Public Works Department, Washington State Department of Ecology and Washington State Department of Fish and Wildlife for the Iverson Feasibility Study.

Philip Williams & Associates, Ltd. provided services, opinions, recommendations, plans or specifications provided pursuant to this agreement, for the express use for the Iverson Feasibility Study. PWA shall not be held liable for any other use.

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1. INTRODUCTION

PWA was contracted by the Island County Public Works (ICPW) to conduct a flood study for the Iverson Farm property. The county-owned property is 300-acres in size. Approximately 120 of these acres are being considered in this study while the remaining 180 acres consist of wooded uplands. The property (Section 32, Township 32N, Range 3E and Section 5, Township 31N, Range 3E) is located on the northeastern shore of Camano Island on Livingston Bay (Figure 1). According to the Island County Wetland Compensation Plan (Sheldon & Associates, 1999) the property, one of numerous former tidal marshes in the Sound, was diked and drained for agricultural use most likely in the 1940s. It is still farmed today.

The flood study is intended to determine restoration and enhancement alternatives for tidal marsh and shoreline processes at the Iverson Farm property. Particular attention will be given to alternatives that enhance anadromous fish use. The flood study is part of a larger feasibility study for the property that is being managed by ICPW to ensure its consistency with the Island County Wetland Compensation Plan, Shoreline Management Act, Growth Management Act, and the Endangered Species Act.

Using available data PWA characterized the hydrology and geomorphology of the Iverson Farm salt marsh ecosystem. The characterization was used to develop and describe four conceptual alternatives. One of the alternatives was a “no action” alternative. The other three alternatives, bay dike removal, bay dike setback, and tide gate modification were conceptualized to maximize the habitat benefit to anadromous fish and to limit habitat impacts to high quality habitats identified by Sheldon & Associates. PWA summarized the anticipated changes in hydraulic and geomorphic parameters in each alternative and built on this to describe the evolution of the physical habitat for each alternative.

In addition to geomorphic and habitat evaluations, PWA summarized key land use changes for the alternatives. All of the alternatives, with the exception of the ‘no project’ alternative, reintroduced tidal flooding to part of the agricultural area of the site. The impact of each alternative on agriculture was described by estimating the area of agricultural land lost to restoration. In addition, possible impacts on agricultural productivity caused by changes in land drainage were evaluated qualitatively. None of the proposed alternatives increased the risk of flooding for the Long Beach residential development. Several approaches to managing this risk were explored in the alternatives.

Sheldon & Associates was contracted by the County to characterize the existing ecology and assess the potential terrestrial and aquatic habitat implications of the alternatives in a separate report. Actual costs for the restoration alternatives were not included in this contract’s scope.

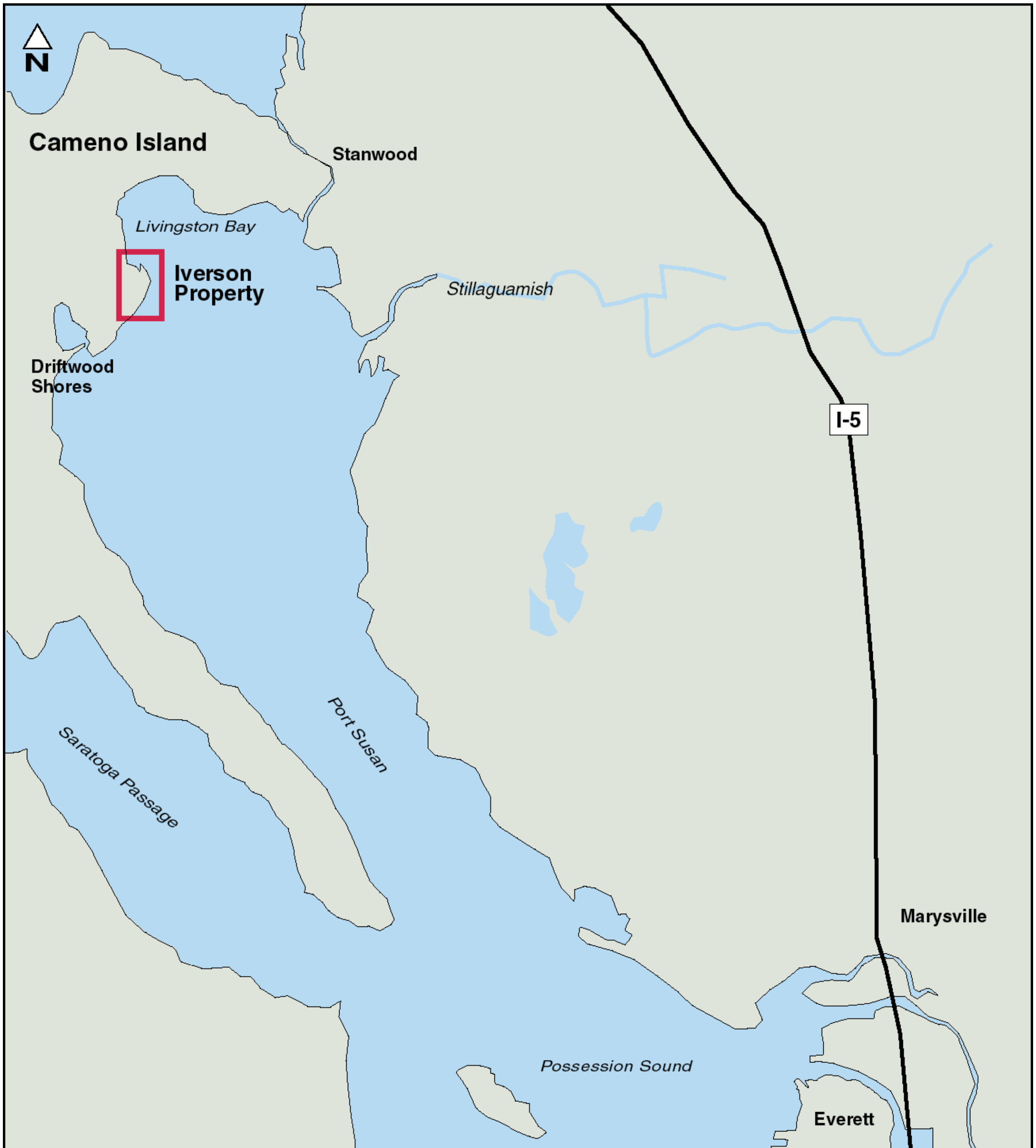

figure 1

Iverson Farm Marsh Restoration Feasibility Study

Site Location

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2. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

Approximately 100 acres of the Iverson site is currently diked and drained. This portion of the site offers opportunities to re-create tidal marsh habitat. A majority of the diked portion of the site is below the elevation of daily high tides and is therefore potentially restorable to marsh at existing grades. The diked portion of the site has only subsided about 2-feet below the average high tide elevation. Marsh vegetation colonization can be inferred from land elevation. With the restoration of tidal inundation it is likely that vegetation would quickly colonize the higher elevation perimeter of the site. It would expand to lower elevation areas as accumulating sediment raised the marshplain elevation. Even with the relatively small amount of subsidence at Iverson, it could take up to 120 years for the restored marsh to reach a mature vegetated state. However, as the tide marsh habitat evolves at Iverson it will provide salmon with food and cover by providing nearshore habitat used during the estuary to ocean transition. Food production in this habitat would include aquatic prey species and insects associated with high and low marsh vegetation and channel habitat. Evolving tidal channels would provide cover.

Existing aquatic and terrestrial habitats at the Iverson site will be changed by the restoration. There is currently about 20 acres of mudflat outside of the bay dike. Much of it colonized by *Spartina alterniflora*. The area includes one main tidal channel with a series of small tidal channel networks branching from it. The main channel and the branching networks will experience dramatic short-term changes with restoration as their contributing drainage areas increase. The main channel will deepen and widen in each of alternatives to accommodate the larger volume of water moving into and out of the restoration area with the tides. As sediment accumulates and the marshplain elevation rises the volume of water will decrease. The depth and width of the main channel will respond by decreasing. As the restored marsh reaches maturity (having established vegetation) sediment accumulation will slow and the depth and width of the channel system will stabilize or reach equilibrium geometry. It will likely take over 100 years for this process to be complete.

The proximity of the Long Beach residential development to the Iverson property makes flood hazard management a significant component of any restoration alternative at this site (Figure 4). Potential flood hazard increases can be mitigated for with dike and/or berm construction or by regulating tidal flow into the restoration area. The dike construction approach is costly but restores the largest area to tidal marsh and results in a complex channel system and vegetation mosaic. The regulation of tidal flow results in a smaller restoration area with simplified channel structure. Its altered tidal regime may result in a less complex vegetation mosaic.

2.2 RECOMMENDATIONS

PWA developed four restoration alternatives and evaluated the physical habitat characteristics of each. Sheldon & Associates summarizes the effects of these alternatives on terrestrial habitat in a separate report. The County should review both reports before determining which alternative to recommend. The County may also want to have the alternatives reviewed by a fisheries biologist to get a better understanding of the value of the restored habitat created in the alternatives to specific species of salmon.

The proximity of the Iverson site to the Long Beach residential development combined with the lack of available topographic data for that development also make recommending a specific alternative difficult without additional study.

2.3 ADDITIONAL STUDIES REQUIRED

This planning level alternative assessment was based largely on existing data. There are several areas where additional information is needed either to better evaluate the alternatives or to increase understanding of the site features and processes before selecting an alternative and finalizing a restoration design.

Additional studies should be conducted to ensure that the Long Beach residential development does not experience increased flood hazards as a result of the restoration of tidal inundation to the Iverson Property. The existing 1-foot contour interval topographic survey should be extended eastward to include the Long Beach development so that the elevations of the residential structures and other features can be determined to ensure that tidal and storm surge flooding will not result from restoration. Local tidal elevation data should be collected and extreme storm events estimated. A complete FEMA flood study could be conducted. The determination of a base flood elevation (BFE) within the project site would be prudent during subsequent restoration design work. This recommendation supports FEMA guidance that calls for developing BFE data where new development is planned to encroach on a Zone A area. In the case of this project, new development is not planned but restoration is proposed which may change flood conditions for the existing development on Long Beach. FEMA requires that within Zone A areas "substantial improvement or other development" meet the requirements of paragraphs 60.3(c-d) of the NFIP (FEMA, 1995), which includes determining the BFE. Restoration actions may be construed to be "other development".

The Long Beach water district well, on the bluff west of the development, will not likely be effected by marsh restoration. However, in 1967 an 8-inch concrete-asbestos water main was constructed across the agricultural land to deliver water to the Long Beach development. Concrete-asbestos pipe is somewhat permeable but water mains are under pressure making saltwater intrusion an insignificant issue. The alternatives for this project illustrate different approaches to maintaining access to the water main. In the full restoration alternative this main is relocated to open the entire Iverson site up to tidal inundation. In the regulated tide gate alternative the main is protected in its current location reducing the potential restoration area. The life expectancy of the water main should be determined to assess whether it will need to be replaced in the near future. If replacement will be needed in the near future it may effect the viability of alternatives that incorporate moving this main.

Tide elevations local to the Iverson site should be determined by installing a continuously recording gage and data logger at the site. The resulting data should be linked to the same vertical datum as the topographic survey, NGVD. The gage should record at 10 min. intervals for a 13-month period. These local tide elevations can then be used with site topography to refine estimates of the areas that would be inundated with each tidal cycle. Tidal prism calculations could also be refined allowing more accurate sizing of the minimum required levee breach for restoration.

Statistical relationships were used in this report to describe the channel characteristics of the evolving restoration alternatives. These relationships are based on California Marshes because limited channel data has been collected for marshes in the Puget Sound. Measurement of channel conditions in mature Puget Sound marshes should be collected to refine predictions of evolving tidal systems at Iverson and at other restoration sites in the Puget Sound.

Tidal sedimentation rates should be estimated. This can be done by measuring accumulated sediment behind failed or removed dikes near the Iverson site or by reviewing dredging records from marinas as close to the Iverson property as possible. Local sedimentation rates would refine the preliminary estimates made in this report of marsh accretion rates and the subsequent time needed for a restored marsh to reach maturity.

Additional information should be gathered to better assess the viability of farming the Iverson Property under existing conditions and those predicted in the alternatives. Several alternatives reduce the number of acres available for agriculture by about half. This may seriously effect the viability of farming at Iverson.

3. SITE CHARACTERIZATION

3.1 HISTORICAL CONDITIONS [C. 1886]

The loss of tidal channels and proximate tidal marsh vegetation is a significant habitat impact for salmonids and other species. By the 1990s 71-percent of tidal marsh in the Puget Sound had been lost (Washington State Conservation Commission, 2000). A review of maps and aerial photography of the Iverson property over time help to describe changes specific to that location.

The earliest map of the Iverson property dates from 1886 (Figure 2) (Department of Commerce, 1886). This map provides evidence that historically the 120 acres under consideration in this project was a tidal marsh. The coastal landform is a cuspate foreland, a triangular point created as sediment accumulates behind a spit forming a marsh (Downing, 1983). Unrestricted tidal flow into the Iverson Marsh resulted in two major channels that connected to Livingston Bay at the northwest corner of the site. The 1886 map is not sufficiently detailed to show smaller tidal channels branching off of the major channels. However, remaining marshes of this type have these complex channel features so we can assume that they were part of the historic marsh system at the Iverson site.

Two processes interacted to form this historic marsh. The spit was created as material was transported to the north by wind and wave action and deposited forming a barrier beach. Tidal exchange caused sediment to accumulate behind the spit and eroded tidal channels in the deposited material.

3.2 LANDSCAPE CHANGES

The interaction between sediment transport and tidal processes was disrupted by the construction of the bay dike (c. 1940s) to improve conditions for farming. To illustrate the changes to the site caused by dike construction, aerial photographs taken in 1957 and 1969 were overlain with the approximate location of

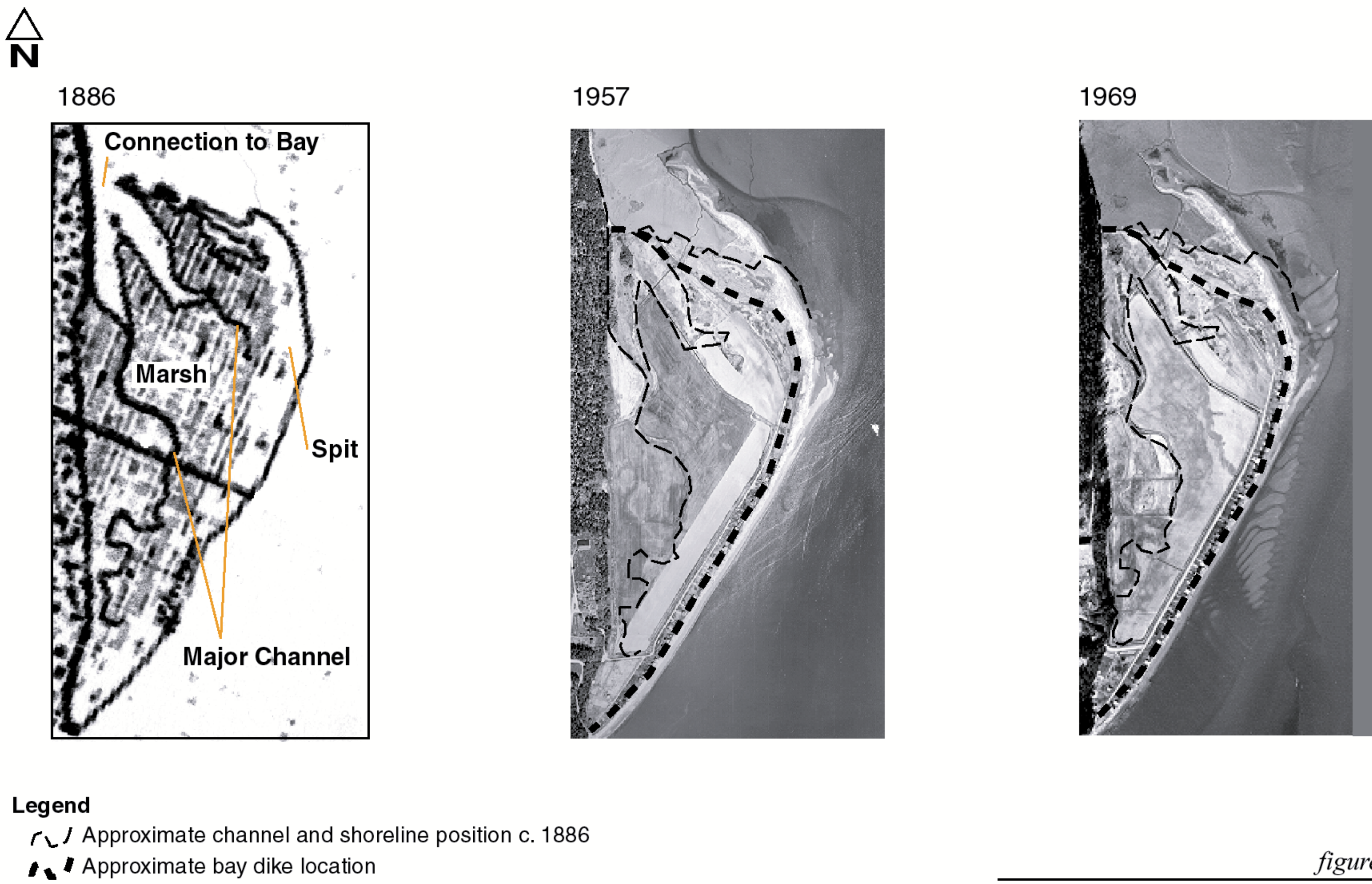

figure 2

Iverson Farm Marsh Restoration Feasibility Study

Changes in Site Conditions

PWA

the 1886 channel and shoreline and the bay dike (Figure 2). Key differences between the 1886 map and the photos are the loss of marsh and channel area behind the bay dike and the extension of the spit to the northwest. There is little difference in the channel area or the extent of the spit between 1957 and 1969.

3.3 EXISTING CONDITIONS [C. 2001]

Tidal channels are generally stable so it is not surprising that location of the main tidal channel at Iverson is in the same location in the 1957, 1969, and 2001 photos. The location of the spit is also relatively stable, though it has a more northerly orientation by 2001 (Figure 4).

3.3.1 Hydrology and Geomorphology

The disciplines of hydrology and geomorphology describe the movement of water and its effect on landform. In coastal settings, tides are the most significant hydrologic process. The power that tides have to erode and deposit sediment along shorelines is the primary mechanism for the creation of tidal marshplain and channels. These geomorphic features are colonized by marsh vegetation over time and provide habitat for aquatic and terrestrial species. Eventually, the system reaches a state of equilibrium when marsh elevation, channel complexity and inundation frequency are balanced with tidal range, sediment availability, and sea level changes.

To determine the length of time needed for a restored area at a given location to reach a mature vegetated state local tidal elevation and volume along with variations in topography, sediment availability, and the direction and strength of wave activity are taken into account (Figure 3).

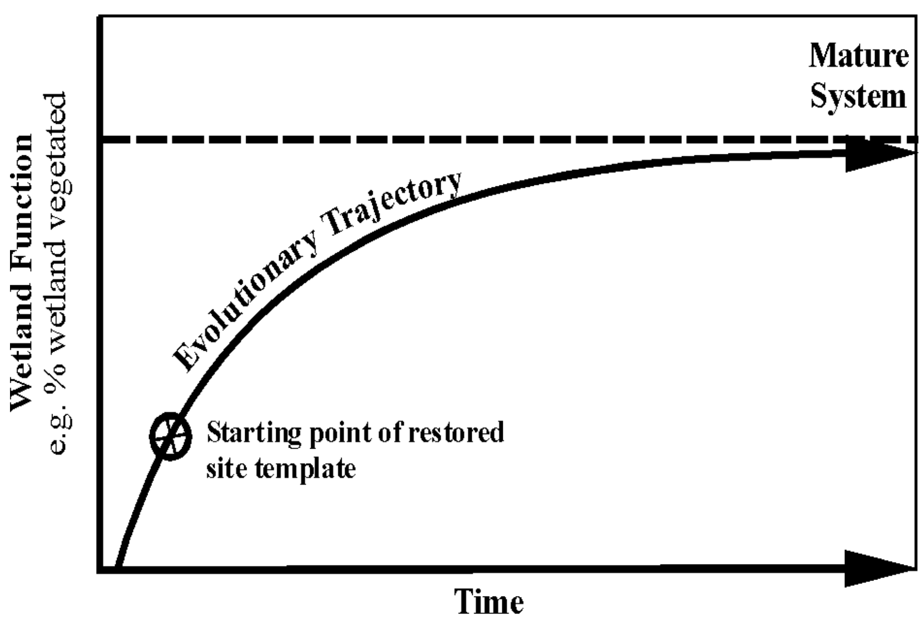

Figure 3: Conceptual Evolutionary Trajectory of a Restored Marsh (Williams, in press)

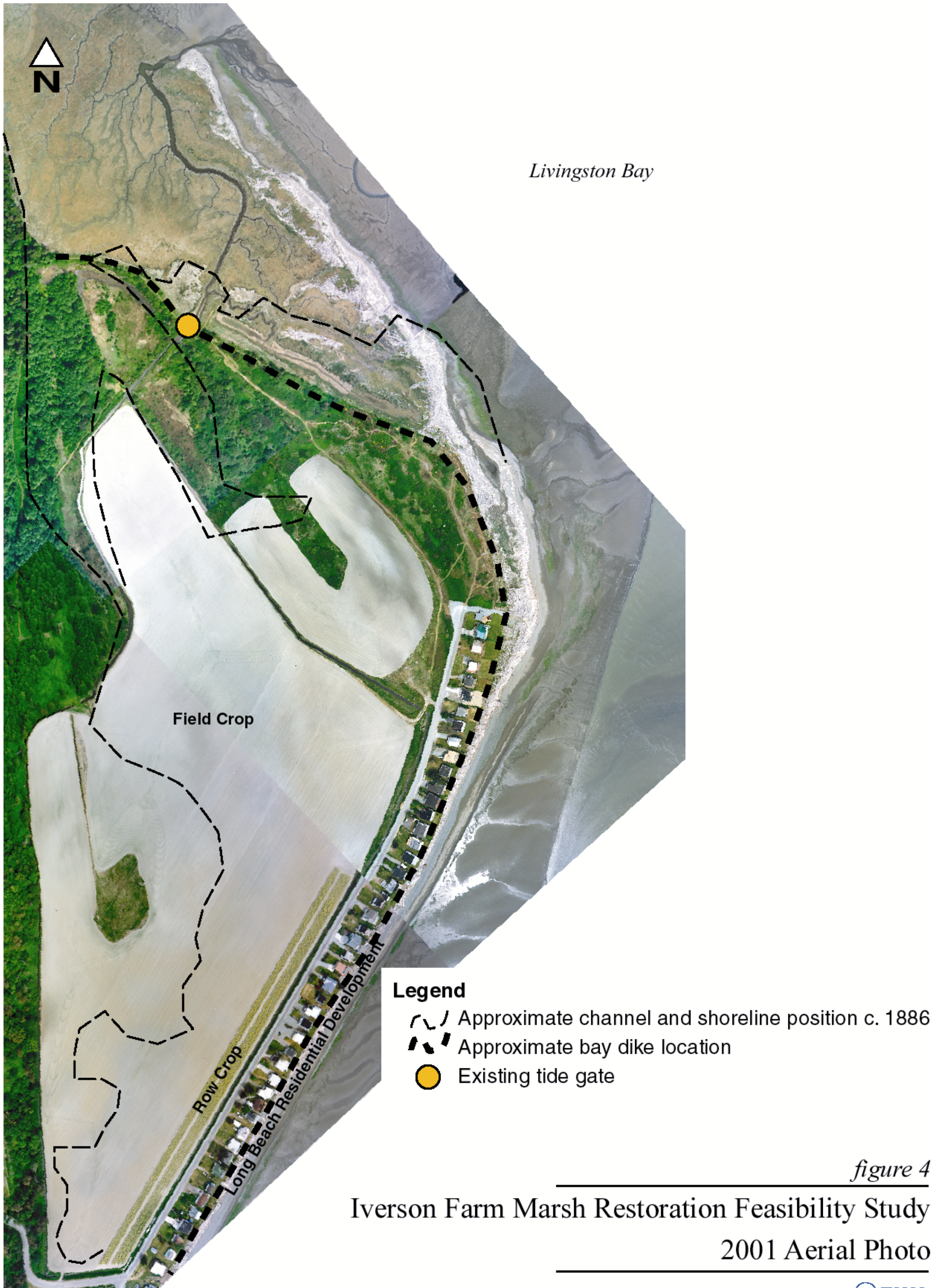

figure 4

Iverson Farm Marsh Restoration Feasibility Study

2001 Aerial Photo

PWA

Data Furnished by Walker and Associates, 2001

3.3.1.1 Tidal Characteristics

Sediment accretion is an important marsh building process. The erosion and deposition of sediment by tides is the primary mechanism for the creation and maintenance of tidal marsh habitat. Sediment is deposited during flood tides when slack water is spread out over the marshplain and tidal channels are scoured by ebb tides as water recedes from the marshplain. Tidal elevations vary daily and seasonally so arithmetic means of these different elevations are calculated and used to describe local tidal patterns. Figure 5 illustrates the relationship between a daily tidal cycle and tidal elevations. Several tidal elevations are significant in tidal marsh restoration because they define the volume of tidal water exchanged on a daily basis and the elevations at which marsh vegetation will colonize.

These tidal elevations include:

Extreme High Water (EHW), the elevation of highest estimated tide plus storm surge.
Highest Estimated Tide (HET), the highest tide predicted by tide tables.
Mean Higher High Water (MHHW), the average height of the higher high tides over a 19-year period.
Mean High Water (MHW), the average height of all high tides over a 19-year period.
Mean Lower Low Water (MLLW), the average height of the lower low tides over a 19-year period.

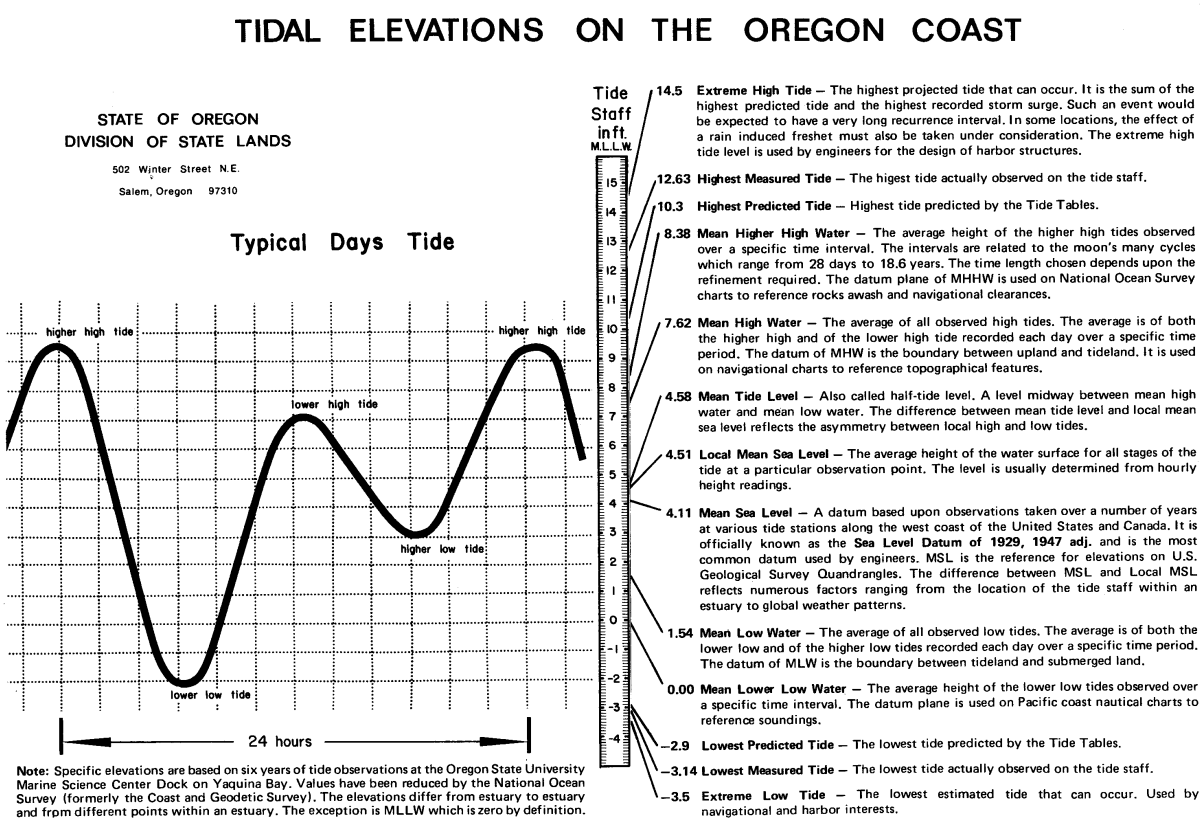

Figure 5: Daily Tidal Cycle with Definitions of Tidal Elevations (Oregon Division of State Lands, 1971)

The amount of sediment that is deposited and the rate and extent of channel scour are dependent upon sediment availability and the volume of water being exchanged with each tidal cycle (Figure 6). The volume of water exchanged in a daily tidal cycle, between mean higher high water (MHHW) and mean lower low water (MLLW), is called the diurnal tidal prism. The diurnal tidal prism has been equated to bankfull discharge in rivers – the channel forming flow (Coats *et al.*, 1995). MLLW and MHHW elevations and topography vary at different locations within Puget Sound resulting in varying tidal prism volumes. An understanding of the relationship between tide elevation and land elevation allows general predictions to be made about the size of a restored marsh and the characteristics of its tidal channels.

The Everett tide gage was used to establish tidal elevations at Iverson because it is the closest gage with a benchmark referenced to NGVD29, the vertical datum of the topographic survey of the Iverson site. Everett Washington is seventeen miles southeast of the Iverson property near the southern end of Port Susan (Figure 1).

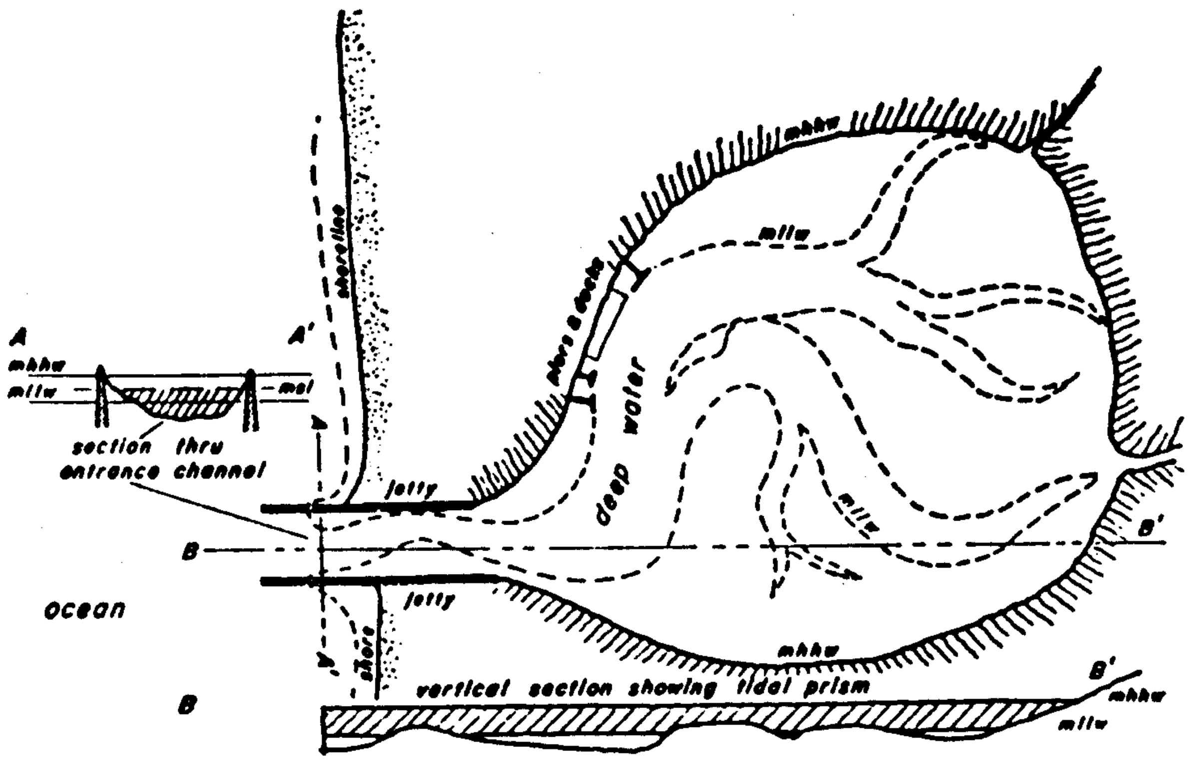

Figure 6: Illustration of Tidal Prism Between MHHW and MLLW (Bascom, 1964)

The tidal datum elevations (Table 1) were combined with land elevations from the site topography to delineate the area that would be inundated if tidal action were restored to the site (Figure 7). The potential tidal prism was also calculated. Since tidal marsh vegetation evolved to thrive under varying salinity and inundation regimes, tidal elevation can also be used to predict what plant communities will colonize at different elevations in a restored marsh. Sheldon & Associates describes existing marsh vegetation at the Iverson site and its relationship to elevation in their report.

Table 1: Everett Tide Gage Tidal Datums (http://www.nws.usace.army.mil/hh/tides/wi/wi99.htm)

Tidal Datum	MLLW	NGVD29	NAVD88
Highest Estimated Tide	14.50	8.57	12.25
Highest Observed Tide	14.35	8.42	12.10
MHHW	11.11	5.18	8.86
MHW	10.25	4.32	8.00
MTL	6.52	0.59	4.27
NGVD Zero Datum	5.93	0.00	3.68
MLW	2.70	-3.23	0.45
MLLW	0.00	-5.93	-2.25
Lowest Estimated Tide	-4.50	-10.43	-6.75
Lowest Observed Tide	-3.60	-9.53	-5.85

3.3.1.2 Topography

The available topographic survey of the property is mapped from aerial photography flown in May of this year at a scale of 1-inch = 40-feet. The survey includes the tidal marsh north of the bay dike, the portion of the property currently being farmed and most of Iverson Road. The survey has a one-foot contour interval based on the vertical datum of NGVD29. High-resolution topography is important in marsh restoration because land surface topography in marshes is generally flat. Subtle differences in elevation translate into differences in the frequency and depth of tidal inundation which in turn effect the pattern and rate of marsh development when tidal action is restored. Frequency and depth of inundation are also important habitat characteristics for salmonids (Beamer and LaRock, 1998).

A comparison of ground elevations on both sides of the bay dike indicates that 1-foot of land surface subsidence has occurred behind the bay dike. The marsh surface, or marshplain, elevation is approximately 3-feet while the agricultural land elevation is about 2-feet (Figure 7). It is common for a marsh that has been separated from tidal processes to experience subsidence. Subsidence is the result of a reduction in soil volume caused by the decomposition of organic material and soil consolidation resulting from land draining. Over time, land subsidence can also reduce the crest elevation of dikes and levees built on subsiding land. Without high-resolution topography of the pre-dike marsh, it is impossible to determine the historic elevation of the marshplain and so the exact elevation change.

The amount of subsidence at a site is significant because it directly effects the length of time that the site will take to accrete with new sediment and reach a mature vegetated state. Subsidence is related to the length of time a site has been diked and the extent to which it has been drained. The dike at Iverson was built some time in the 1940's and a tile drainage system was installed more recently, in 1986. PWA is currently working on a project on Hall Slough in the San Francisco Bay Delta that has subsided four feet. This amount of subsidence is not uncommon in diked former marshes, so the 1-foot of subsidence at Iverson is not prohibitive to restoration.

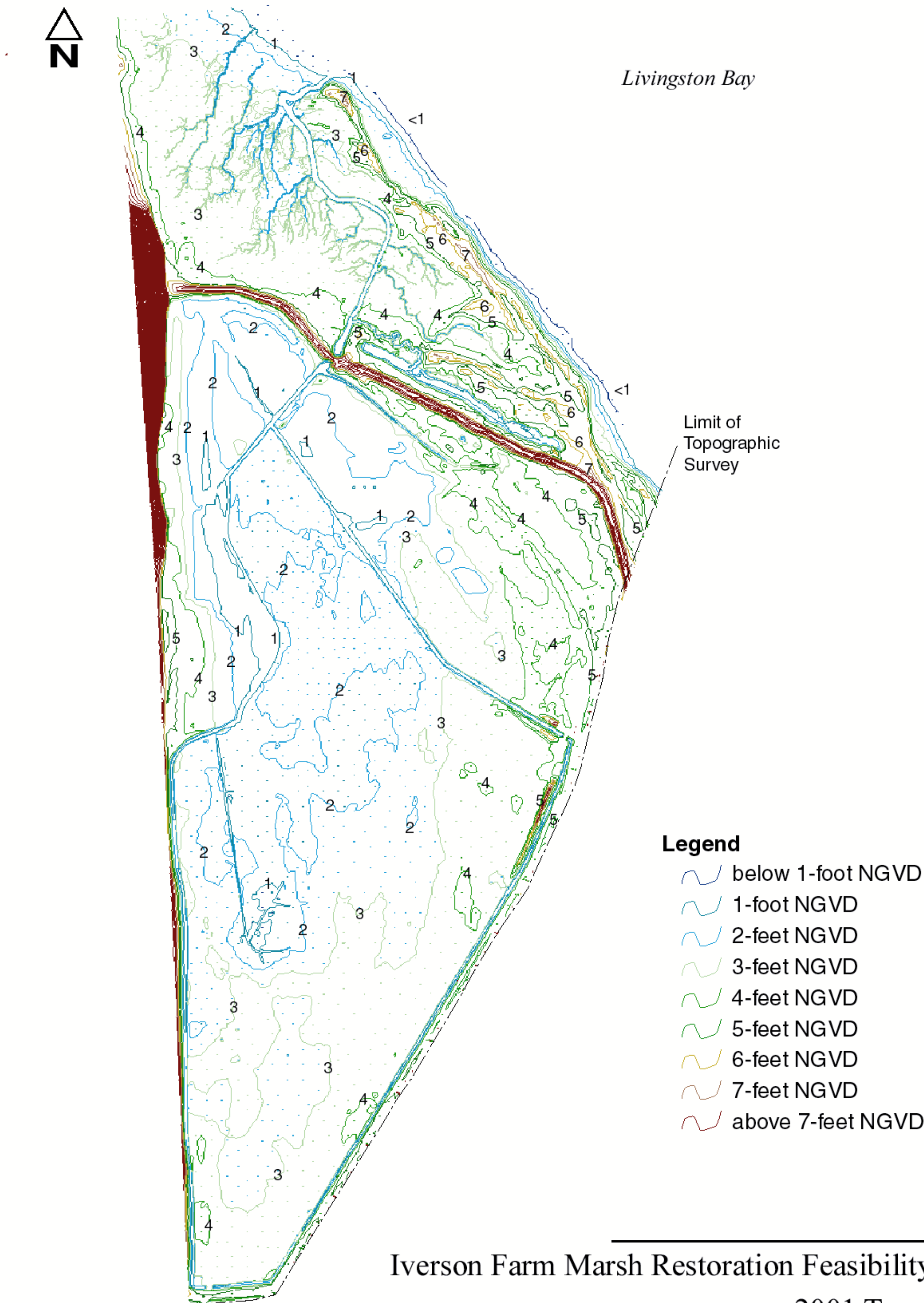

figure 7

Iverson Farm Marsh Restoration Feasibility Study

2001 Topography

Data Furnished by Walker and Associates, 2001

In addition to local land subsidence, consideration needs to be given to regional patterns of vertical land movement for tidal marsh restoration planning and design. Data indicate the landmass in the vicinity of Camano Island is subsiding at a rate of about 2 inches per century (Shipman, 1989). Recent estimates of global sea level rise indicate an [average] of 12 inches per century. By combining these data a relative sea level estimate for the project site is 14 inches in the next 100 years, or 7 inches over the 50-year planning horizon. Our experience from monitoring tidal marsh restoration projects indicates marsh accretion keeps pace with rising sea levels; however, earthen structures such as dikes may loose their design freeboard as they subside relative to a rising sea level.

3.3.1.3 Near Shore Processes

This section describes the nearshore processes adjacent to the Iverson Farm property and discusses the potential physical effects of restoration with respect to these processes. The project site is situated on coastal sedimentary deposits and has been shaped over time by the primary nearshore processes of waves, nearshore currents and littoral transport. The tidal marsh area is bounded by a cuspate foreland consisting of higher elevation deposits of sand and mixed medium materials (Washington State Department of Ecology, 1979). A similar landform is evident from maps and air photos immediately south of the project site where the Driftwood Shores spit encloses Triangle Cove. These landforms indicate a depositional environment and a predominant northerly wave direction along this portion of the Port Susan shoreline.

Wave climate is an important factor in restoration planning because it affects coastal flooding, sedimentation and the ensuing rate of marsh development. Waves making landfall at a marsh restoration site may slow the rate of sediment accretion in a developing marsh and cause it to take longer to reach maturity by either re-suspending sediment or preventing suspended sediment from coming out of suspension. Suspended or re-suspended sediment can then leave the marsh on the ebb tide. Since dike breaching or removal at Iverson would occur along the northern portion of the site, waves from the northwest, north and northeast that make landfall on the northern shore are the most significant to restoration (Figure 8).

The northern end of Port Susan is sheltered from the predominant summer westerly winds by Camano Island and results in relatively minor wave activity, while the winter wind pattern consists of southerly winds directed up the north-south alignment of Port Susan (Downing, 1983: Figure 6.1). The wave data presented in the Coastal Zone Atlas (Washington State Department of Ecology, 1979) describes the height and direction of wave activity as a percentage of the year. At the northeast tip of the project site, waves coming from the southeast account for a majority of the wave activity. Waves reaching 2-feet in height occur 20-percent of the year while waves up to four feet in height occur about 2-percent of the year (Figure 8). The waves approaching the entrance to the proposed restored marsh at Iverson Farms from the northwest, north and northeast occur only about 2-percent of the year and achieve a maximum of 2-feet in height. A 2-foot high wave entering the restored tidal marsh would break in a water depth of about 2.6 feet (U.S. Army Corps of Engineers, 1984). If this 2-foot wave were to occur at MHHW, wave action could potentially be experienced within the marsh where ground elevations are 2.6 feet, NGVD or less. However, the recurved northern extension of the Long Beach spit, that projects into Livingston Bay, has ground elevations of up to 7 feet, NGVD. This natural feature would serve to reduce the extent of open water and dissipate wave energy even for tides above MHHW.

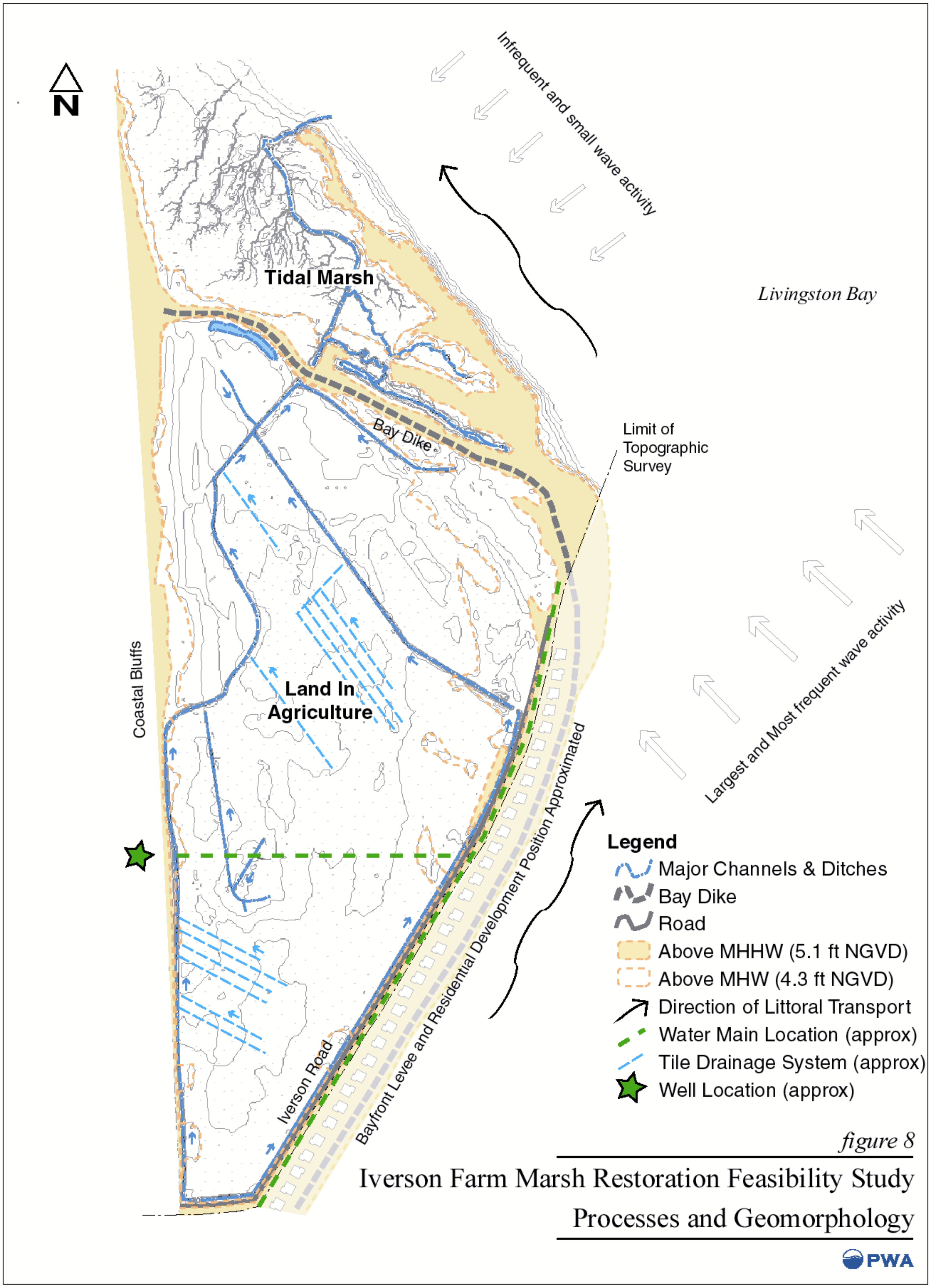

figure 8

Iverson Farm Marsh Restoration Feasibility Study

Processes and Geomorphology

The predominant northerly wave direction at Iverson corresponds to patterns of littoral transport where material moves in a clockwise direction along the western shore (Washington State Department of Ecology, 1979). The potential littoral transport rates adjacent to the project site, as shown in the Coastal Zone Atlas, indicate summer transport rates include an estimated 15,000 tons of medium fine sand transported north along Long Beach with approximately a third of this amount transported into Livingston Bay. In the winter, an estimated 100,000 tons of sand are transported north along Long Beach with approximately 15 percent of this amount transported into Livingston Bay. The predominant material transported into the bay is a sand/silt/clay mix as indicated in the Coastal Zone Atlas. An absolute drift boundary is shown at the northeast edge of the Iverson Farm property. From this point north into Livingston Bay, transport rates along the western edge of the bay increase dramatically due to the exposure of the north-south orientation of the bay shoreline to the predominant winds from the southeast. Based on these data it is assumed that the northern end of the project site may experience continued deposition of fine sand, silt and clay. These sediments tend to have a threshold erosion velocity of 20 cm/sec (Downing, 1983: Figure 4.3); i.e., the velocity at which the sediments begin to erode. Since the existing inlet channel has remained open since 1957 with low volumes of flow it is reasonable to assume that the inlet channel under restored conditions accommodating larger tidal volumes would also remain open.

3.3.1.4 Marsh Vegetation

The presence or absence of marsh vegetation largely determines the habitat function of a tidal marsh. Marsh vegetation and the insects that it supports provide food and cover for young salmon. In natural marsh systems vegetation colonization is related to tidal elevation. Idealized relationships for the Pacific Northwest show vegetation establishment between the elevations of MHW and EHW (Figure 9) with a transition between low marsh and high marsh vegetation at about MHHW. This generalized relationship is used to illustrate the evolution of restored marsh at Iverson. Elevations for MHW (4.32 feet, NGVD) and MHHW (5.18 feet, NGVD) were taken from Table 1. No gage elevation was available for EHW so the 10-year flood elevation for Driftwood Shores (10.4 feet, NGVD), which includes wave action, was assumed.

3.3.2 Land Use

3.3.2.1 Agriculture

The economy of Island County was historically agriculturally based. Over time the extent of residential development has increased while the acres of farmland have decreased. In response to this trend the County is developing incentives to keep land in agricultural production. The Iverson property is currently leased for agriculture so in light of local concern over the loss of agricultural land an assessment of the effects of the restoration alternatives on agriculture is included in the assessment of each alternative. A majority of the site is in field crops but the eastern edge, along Iverson Road, is in row crops (Figure 4). The tenant farmer on the Iverson property reports increasingly poor drainage over time (Buktenica, 2001). These problems could be caused by land subsidence due to diking which can cause fresh water ponding in depressions behind the dike. A tile drainage system was installed in 1986, presumably to address drainage problems (Figure 8). This is discussed in more detail in Section 3.3.2.5. In addition to freshwater ponding, brackish plant communities have been found on the landward side of the bay dike (Sheldon & Associates, 2001). It is difficult to determine the source of the salt water. It could be a remnant of an old overtopping event, the result of tide gate malfunction, or evidence of groundwater seepage. However, the presence of these communities indicates that salt-water intrusion is occurring at the site under existing conditions.

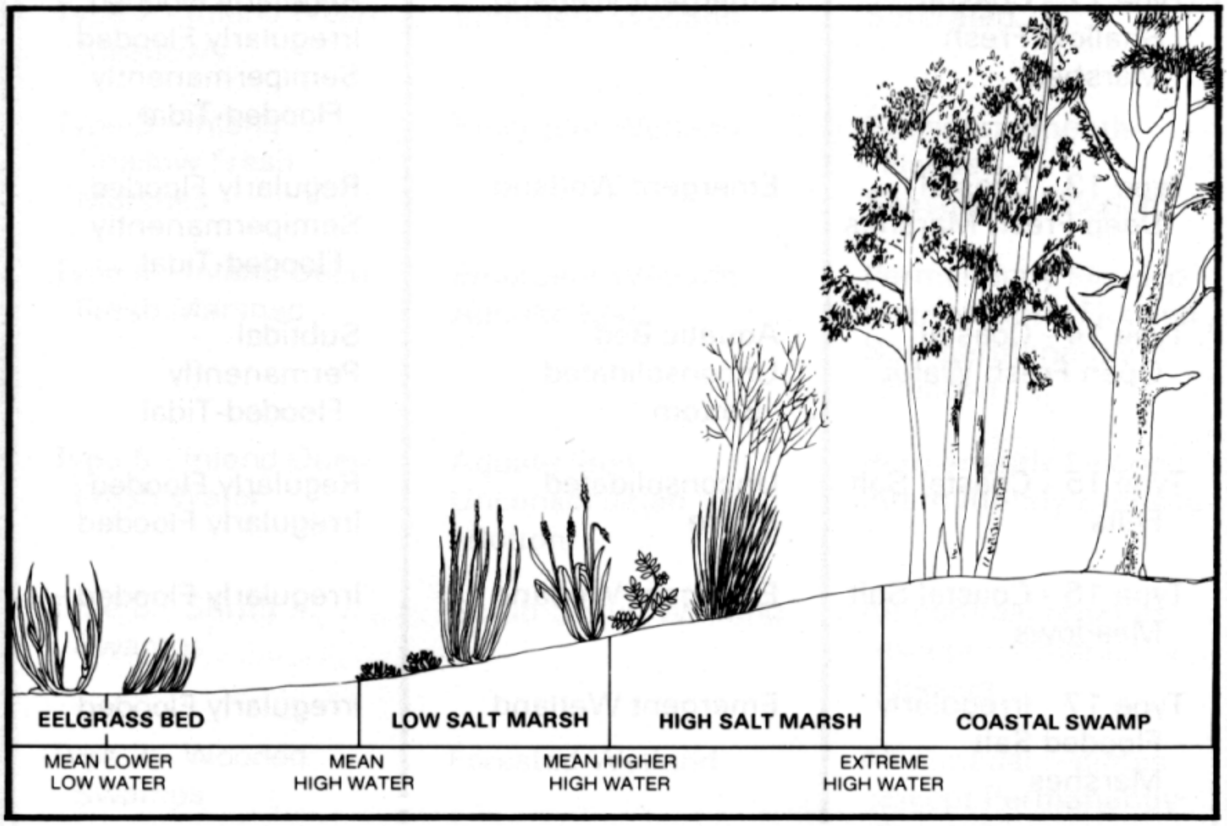

Figure 9: Idealized Pacific Northwest Marsh Vegetation Elevation Relationships (Weinmann *et. al*, 1984)

3.3.2.2 Flood Hazards

The bay dike and tide gate at the site were built to prevent salt-water intrusion into agricultural land and improve farming. The dike was built on the historic spit, taking advantage of its naturally high elevation. The dike blocked the historic marsh inlet at the northwest corner of the site and continued around the perimeter of the marsh atop the spit. Since the topographic mapping was not extended eastward to include the houses and shoreline along Long Beach, an assessment was done to estimate topographic elevations in this vicinity and evaluate flood hazards.

The crest elevation of the dike along the northern end of the project site ranges from 10 to 11 feet, NGVD. A review of the USGS quadrangle map of the Iverson Farm site indicates the dike at Long Beach is located between the houses and Port Susan. For the purposes of this flood hazard assessment, it is assumed that the crest elevation of the dike continues between 10 and 11 feet, protecting the homes at Long Beach.

The estimated base elevation of the dike was also based on the USGS quadrangle map and is at approximately the mean high water elevation. The gauge Mean High Water elevation, 4.32 feet, NGVD, corresponds reasonably well to the mapped ground elevations of 4 to 5 feet NGVD along Iverson Road indicating these elevations probably extend from the road eastward to the dike. This also corresponds to hand notations on the FEMA Flood Insurance Rate Map (FIRM) indicating an elevation of 4.09-ft, NGVD at Long Beach #2 (FEMA, 1995).

The water side of the dike surrounding the Iverson site is classified as a velocity zone, or Zone V. The Zone V designation indicates that flood elevations are estimated including additional hazards due to wave action (FEMA, 1981). Coastal flooding is typically a combination of an extreme tide elevation and wave action (wave setup and runup). No published Base Flood Elevations (BFE) are available for this zone. However, the available FEMA flood insurance study (FEMA, 1981) provides recurrence interval flood elevations for the 10-year and 100-year flood events at Driftwood Shores, approximately one mile southwest of Long Beach. The 10- and 100-year interval coastal flood elevations at Driftwood Shores are 10.4 and 11.4 feet respectively. These elevations are higher than both MHHW (5.18 NGVD) and the highest estimated tide (8.57 NGVD) from Table 1 and so were assumed to include wave action. Given these data it appears the existing bay dike at Iverson will protect inland areas from coastal flooding up to the 10-year event. Actual elevations along the Long Beach bay dike should be surveyed to confirm this assumption.

The portion of the Iverson site that is located inland of the dike is mapped on the FIRM as Zone A (FEMA, 1995). The Zone A designation relates to a Special Flood Hazard Area inundated by the 100-year flood. However, these areas are delineated by approximate methods and no regulatory Base Flood Elevation (BFE) is assigned to regulate land uses. Since wave action is not as pronounced in the sheltered waters inland of the dike, it is appropriate to assume that the regulatory 100-year tidal flood elevation would be lower than the 10-year or 100-year flood elevations cited at Driftwood Shores. For the purposes of this study, an 8.57-foot, NGVD 100-year BFE was assumed for the inland restored marsh area. This is the elevation of the highest estimated tide from Table 1. This elevation was compared to a 100-year tidal flood elevation estimated by PWA for ongoing coastal flood insurance study and mapping projects in Whatcom County (8-feet, NGVD) and deemed appropriate. If a reasonable estiamate of the 100-year stillwater elevation cannot be made upon further research, a new coastal flood study may need to be performed to establish current flood hazards on both sides of the dike system.

Table 2: Key Site Elevations

Site Feature	Minimum	Maximum	Average/estimated
100-Year Tidal Flood Elevation			8.5 feet, NGVD
10-Year Tidal Flood Elevation with Waves			10.4 feet, NGVD
Dike Elevation	10 feet, NGVD	11 feet, NGVD	10.5 feet, NGVD
Road Elevation	4.3 feet, NGVD	5.9 feet, NGVD	5.1 feet, NGVD
House Elevation			5.1 feet NGVD
Underground Utilities			3 feet, NGVD

3.3.2.3 Groundwater

The Long Beach Water District well was drilled in 1968 and is located on the bluff west of the Long Beach development (Figure 8). Well data from Island County's Hydrogeologic Database was reviewed to determine whether restoring tidal inundation would effect the water quality of this well. Soil information for the Long Beach well was not recorded by the drilling company so available stratigraphy data from several wells within a one-half-mile radius was reviewed to allows us to extrapolate to the Long Beach well. The logs for a subset of these wells, that were also located on the coastal bluffs, showed an average water level of mean sea level (local datum). The well logs indicate that risk of saltwater intrusion is low. Based on this information we assume that saltwater intrusion into the Long Beach well is not a serious concern as a result of increasing tidal inundation.

3.3.2.4 Water Delivery

The water main running from the Long Beach well to the Long Beach residential development cuts across the potential restoration area (Figure 8). This 8-inch concrete-asbestos pipe was installed in 1967. Concrete-asbestos pipe is somewhat pervious but because water mains are under pressure saltwater intrusion due to slight changes in the salinity of the ground around the water main is not a significant concern. However, access to the water main will be needed for maintenance activities.

3.3.2.5 Drainage

The agricultural portion of the site is drained by a combination tile-drainage and ditch system (Figure 8). The drain tiles were installed in 1986, presumably to mitigate for increasingly poor drainage at the site. Tile drains will need to be removed from the areas where tidal inundation is to be restored. Run-off from Iverson Road is also drained through this system of ditches. Some of the septic system drain fields for the Long Beach residential development are located between the residences and Iverson Road. The rest are on the Dike side of the development. Maintaining adequate drainage to the drain fields, the road, and land remaining in agriculture is critical in all alternatives.

4. RESTORATION GOAL AND DESIGN OBJECTIVES

4.1 GOAL

The primary goal of this project is to develop conceptual alternatives for the restoration and enhancement of wetland and shoreline processes for the Iverson Farm on Camano Island. Inherent in this goal statement is the desire to seek an ecologically valuable self-sustaining restored tidal wetland requiring a minimum of human intervention and providing high quality educational and interpretive opportunities. It is anticipated that the tidal system would reach a mature vegetated condition within 120 years for all of the alternatives.

4.2 DESIGN OBJECTIVES

Design objectives refine the goal in order to guide the design decision making process. A primary design objective is to restore tidal marsh habitat for anadromous fish. Additional design objectives include minimizing construction and ongoing operation costs and preventing increased flood risk to the Long Beach residential development. Many of the design objectives, such as flood protection, can be achieved immediately with proper design. Other objectives, such as the rate of site evolution and maintenance costs, will be influenced by design decisions. The proposed restoration alternatives were developed in response to the following design objectives that support the project goal:

- enhance tidal marsh habitat for anadromous fish
- establish a rapid timeframe for site evolution by promoting full tidal exchange;
- encourage natural tidal channel formation;
- minimize disturbances to existing habitats outside of the bay dike;
- minimize construction and ongoing operation and maintenance costs; and
- maintain current level of flood hazard protection.

4.2.1 Enhance Tidal Marsh Habitat For Anadromous Fish

Both the marshplain and tidal channels have habitat value for salmonids. The marshplain is accessed at high tides for feeding while the tidal channels provide rearing habitat and cover for fish moving to open water (Washington Department of Ecology, 2001). Habitat therefore increases with increased area of marshplain restored to tidal action and with increased linear lengths and complexity of tidal slough channels.

4.2.2 Establish a Rapid Time Frame for Site Evolution

Rapid marsh evolution can be promoted by designing bay dike breaches to accommodate full tidal exchange as soon as breaching occurs. Full tidal exchange will maximize the sedimentation rates within the restoration area thereby speeding colonization by marsh plants. However, sizing the breach and tide channel cross sections to accommodate full tidal exchange will disturb the vegetation both on and outside the bay dike as channels erode to accommodate the increased volume of water. Excavating existing channels to accommodate the greater flow conflicts with the objectives to minimize construction cost. The alternatives represent compromise between these objectives. Rapid vegetation establishment can also be encouraged by lowering or filling selected areas of the site to the elevation of MHW. The location of cut and fill areas can be selected to enhance the development of natural channels or reduce flood hazards.

4.2.3 Encourage Establishment of Natural Tidal Channels

There is a network of drainage ditches in the farmed area of the Iverson Site. If the bay dike were removed or breached these depressions would become the primary tidal channels serving the site. This channel network would be undesirable from a habitat perspective because the channels would be straighter and less complex than naturally occurring channels. For this reason the alternatives include design elements that will prevent the drainage ditches from becoming the main tidal channel system.

4.2.4 Minimize Disturbance to Existing Habitat

Some vegetation will be lost due to site inundation and the evolution of new slough channels after breaching. The alternatives seek to minimize the amount of channel excavation to reduce the short-term impacts of excavation. High elevation areas are also protected when possible to preserve scrub shrub and other non-tidal communities.

4.2.5 Minimize Construction and Maintenance Costs

The alternatives seek to minimize construction cost by balancing cut and fill volumes to avoid the use of off-site fill or disposal. Cut material can be used to elevate areas to be more readily colonized by marsh plants and to plug drainage ditches and facilitate the development of natural tidal channels. Long term O&M costs can also be minimized by letting nature do its work and allowing the initial constructed design elements to evolve naturally toward a self-sustaining ecosystem

4.2.6 Maintain Current Level of Flood Hazard Protection

The evaluation of the level of flood protection provided by the existing dike in Section 3.3.2.2 indicates that this protection extends up to the 10-year flood event including wave action (10.4 feet, NGVD) and 100-year flood event without wave action (8.5 feet NGVD). Since a design objective is to prevent increased flood risk to the residential development on Long Beach, the restoration design alternatives maintain flood protection up to these events. A variety of actions can be taken to accomplish this, while restoring the tidal marshes. These actions include setting back or connecting existing dikes to new dikes, elevating or relocating site features, and modifying the tide gated culvert to allow tidal inundation of the inland marshes up to an elevation that will not flood existing homes, utilities or emergency ingress or egress routes. The alternatives present different approaches to preventing increased hazards.

The habitat, construction and maintenance design objectives can be met most efficiently by breaching the bay dike and restoring tidal exchange. Tidal exchange will facilitate natural sediment accretion, which will raise the elevation of the marshplain over time and lead to the formation of complex tidal channels. However, full restoration and complete breaching of the bay levee will result in uncontrolled flooding of the tidal marsh and an increased exposure of existing infrastructure around the fringes of the marsh to potential flood hazards. This may result in the need to increase elevations of the land surrounding existing infrastructure or dampen the extent of tidal inundation to maintain the current level of flood protection. Vegetation will establish naturally as the marshplain elevation rises and the marsh matures. Opportunities and constraints to achieving the design objectives are addressed in the following section. The subsequent formulation of restoration alternatives builds upon findings from this comparison of desired objectives and the reality of site conditions, and present different ways to achieve these design objectives by mitigating for increased flood hazards while maximizing the area restored to tidal exchange.

5. OPPORTUNITIES AND CONSTRAINTS

The following opportunities and constraints for restoration were identified for the Iverson Farm property.

5.1 OPPORTUNITIES

- Restoring the connection between the Iverson site and Livingston Bay will provide a source of tidal water, sediment, nutrients, and colonizing plants and animals.
- The former marsh area has only subsided about 1-foot so it will take less time for the elevation of the site to increase and for vegetation to colonize. Existing elevations are within the intertidal zone.
- Small and infrequent wave activity from the north makes bay dike removal possible.
- There is adequate tidal prism to develop and sustain a marsh system.

- Use cut material as a source of fill for ditch filling and dike or berm construction.

5.2 CONSTRAINTS

- Much of the site is below natural marsh elevation and below elevations that will be rapidly colonized by vegetation.
- The low elevation of Iverson Road and the Long Beach development require them to be protected from tidal flooding.
- *Spartina alterniflora* growing outside of the bay dike will need to be controlled within the restoration area.
- Tidal action within the site may be limited until the outer tidal channels erode in response to increased tidal flows.
- Include measures to minimize mosquito production following the bay dike breach. Typical abatement measures include excavating channels to limit ponding between tidal cycles.

6. DESIGN APPROACH FOR ALTERNATIVE DEVELOPMENT

6.1 OVERVIEW OF DESIGN APPROACH

The restoration design is based on an approach that uses grading to create a template on which natural tidal processes can act. This allows a natural and self-sustaining marsh ecosystem to evolve. The approach relies upon natural physical and biological succession processes to promote gradual marsh regeneration, rather than a more aggressive approach that would entail extensive grading and/or planting.

Once tides are restored to the site, vegetation colonization usually occurs rapidly within the intertidal elevations provided that the site elevations favor local plants. In deeply subsided sites plants usually colonize the site perimeter where elevations are higher and spread toward the site interior as elevations rise. After the initial colonization of the higher areas, vegetation colonization spreads more slowly into the lower tidal zone. Sediment deposition helps facilitate this spread.

After bay dike breaching, tidal channels form quickly in unvegetated areas. Channel positions are quickly fixed as vegetation colonizes the marsh around them. The tidal channel network will evolve over time into a mature system.

6.2 RESTORATION OF NATURAL PROCESSES AT IVERSON MARSH

6.2.1 Expected Sedimentation

No sediment deposition rates, local to the Iverson site, were available at the time of this project so sediment deposition rates from the Salmon River Estuary on the Oregon Coast were used to illustrate the possible site evolution at Iverson. Measured Salmon River Estuary deposition rates were 2-to 3-inches per decade (Frenkel and Molan, 1991). PWA assumed a 2-inch per decade rate at Iverson. At this rate elevations behind the bay dike could be expected to increase by one foot in approximately 60 years with the restoration of tidal inundation. Sediment accumulation will not be uniform across the restoration area but will occur more quickly in the lower areas of the site. Since vegetation colonization is related to elevation understanding the rate at which site elevations will change is critical to predicting the spatial distribution and rate of colonization of mash vegetation.

6.2.2 Expected Vegetation Colonization

Generally, marsh vegetation colonizes between MHW and EHW. By combining general salt marsh ecology and tidal elevations local to Iverson we can generally predict the pattern of high and low salt marsh vegetation that will evolve at the site with the restoration of tidal inundation. High salt marsh species should colonize between the elevation of MHHW (5.18 feet, NGVD) and EHW (10.4-feet, NGVD) depending on local inundation frequency and soil conditions. Areas between MHW (4.32-feet, NGVD) and MHHW (5.18-feet, NGVD) should colonize with low salt marsh species. Figure 10 illustrates the potential spatial distribution of these two vegetative communities based on existing site elevations with no projected sediment accumulation. Similar illustrations were created for each alternative 50-years in the future to aid the comparison of the habitat values of the alternatives.

6.3 TARGET HABITATS

6.3.1 Relationship Between Salmonids and Marsh Habitat

The Iverson property is located across Port Susan from the delta of the Stillaguamish River, which supports one of the most productive salmon runs in the Puget Sound. A restored marsh at the Iverson property would provide nearshore habitat to salmon as they move along the coastline during their estuary to ocean transition. Nearshore habitat provides refuge from predators and is a rich food source for the fish. The two major geomorphic components of nearshore habitat are tidal marsh and channels.

6.3.2 Tidal Marsh

The tidal marsh at the Iverson site will include tidal mud flat and low and high marsh plant communities. Plants will colonize high elevation areas immediately following the restoration of tidal action. The plants will then spread to lower elevation areas over time. Eventually the site will evolve into a mature vegetated marsh. Because of the existing site elevations at Iverson this process could take over 100-years. It is important to note that while the site is evolving the changing matrix of habitats will provide a variety of prey items for salmonids of different species and life stages. For this reason the quality of the evolving habitat can be equated with the area of tidal marsh and the diversity of the habitats it includes.

6.3.3 Channels

Maximum channel widths at Iverson have the potential to vary from 70- to over 90-feet depending on the restored tidal prism volume. The tidal channel system that evolves at the Iverson site will be made up of small and large channels of varying widths and depths. Channel complexity in tidal systems can be described in terms of channel order. The channel order number describes the hierarchical relationship between the channels. First order tidal channels are small tributary drainage channels that are narrow and shallow. When two of these channels come together they form a second order channel. Two second-order channels merge to form a third order channel, and so on. The highest order channel in the system is the widest and deepest. For this reason the quality, or complexity, of the evolving channel habitat can be equated to the order of the channel system supported by the marsh and the maximum channel depth. As illustrated in Figure 11, the channel order or complexity of a mature channel network is related to the area of the marsh system. In this example four 10-acre marshes support four 3rd order systems while one 40-acre marsh supports a more complex 4th order system.

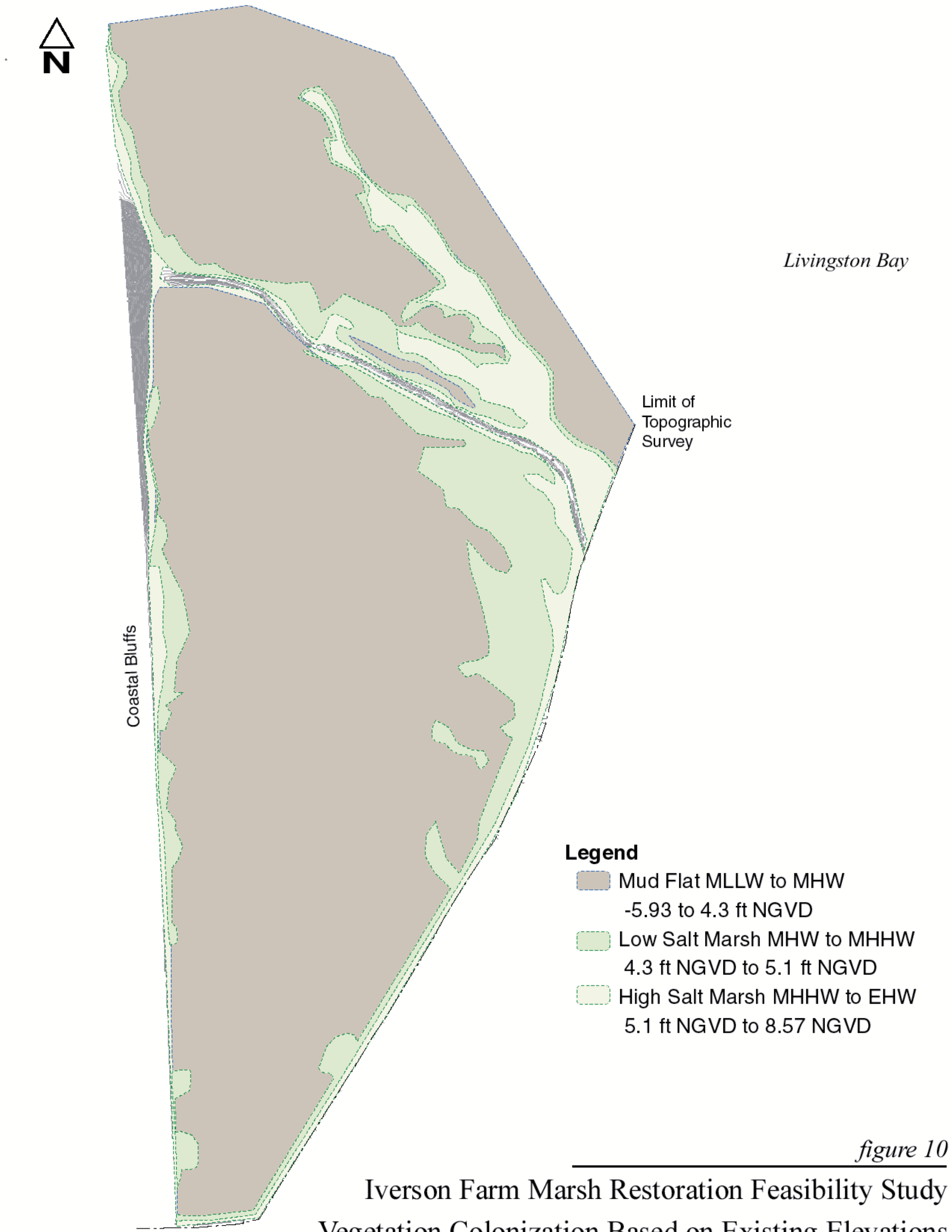

figure 10

Iverson Farm Marsh Restoration Feasibility Study

Vegetation Colonization Based on Existing Elevations

PWA

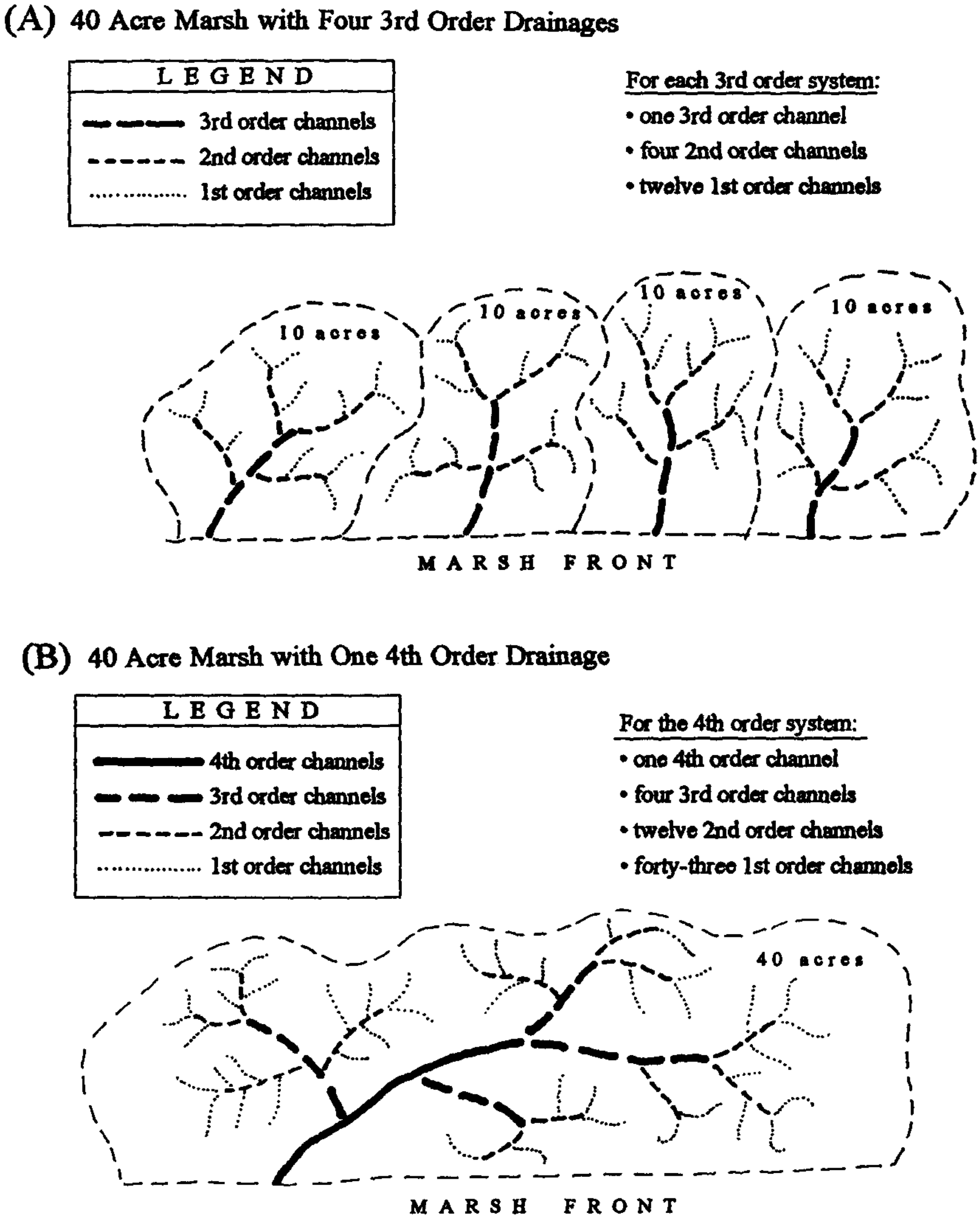

Figure 11: Tidal Channel Network Order as a Function of Marsh Size (Cotes *et al,* 1995)

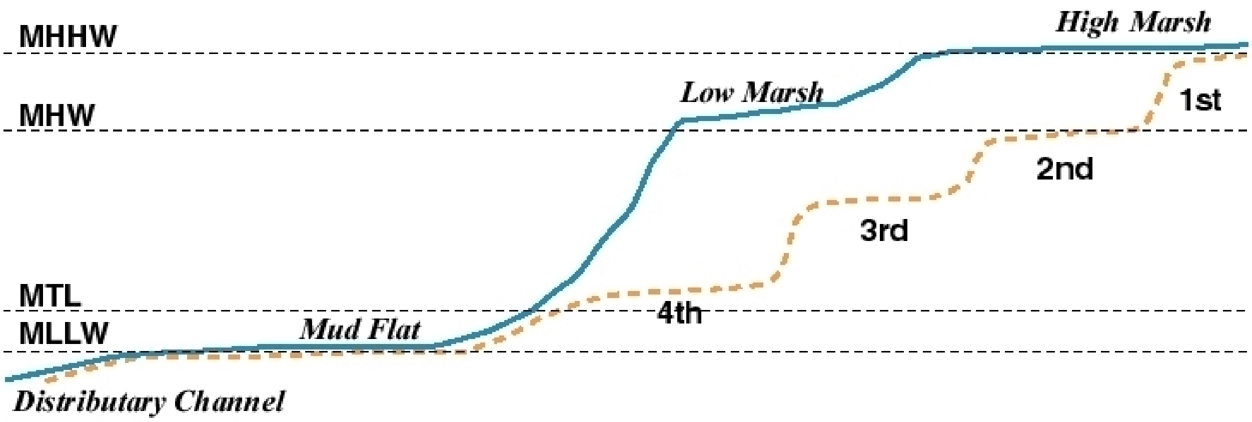

Figure 12: Relationship between Channel Order, Marsh Vegetation Type and Tidal Elevations (after Simensted, 2000)

Figure 12 illustrates the relationship between tidal elevations, marsh plant communities and channel order. The low order channels will drain at low tide elevation and expose their mudflat bottoms while the larger high order channels will contain water even at low tide and will provide sub-tidal habitat fringed with intertidal mudflat and emergent vegetation. These channels will begin to form soon after tidal action is restored. This variety of depth and width, or complexity, provides cover and rearing habitat for salmonids of different species and life stages.

6.4 FLOOD HAZARD PROTECTION

As described in Section 3.3.2.2 there are two significant flood hazard elevations used in the design approach: 1) The crest elevation of the existing bay dike is approximately 10 feet, NGVD, which generally corresponds to the published 10-year flood elevation of 10.4 feet, NGVD. Therefore, flood protection along the bay side of the dike should be maintained up to the 10-year event. This elevation includes the effects of wave action; and, 2) for the interior of the site a lower elevation of 8.5 feet, NGVD is used because this area is protected from wave action. This elevation corresponds to the estimated 100-year tide elevation.

Major site elements to be protected from flooding include the Long Beach development, access and egress roads, and utilities. Both the residences and road are located at an elevation of about 5 feet, NGVD. The topographic map shows power poles and street lights located east of Iverson Road and plans for the installation of the water main for the development indicate that it is located 14-feet east of the road centerline.

FEMA floodplain management criteria requires service facilities for building sites to be designed and/or located to “prevent water from entering or accumulating…during conditions of flooding”

[44CFR60.3(a)(3)]. Future flood damage to structures and roads may be minimized by providing physical barriers to flooding such as dikes or berms or by controlling flood elevations within the restored marsh.

New and replacement public utilities, such as water, sewer, gas and electrical systems are required to be located and constructed to "minimize or eliminate flood damage" [44CFR60.3(a)(4-6)]. PWA assumed that the underground utilities were located at a two-foot depth along the road alignment. To eliminate flood damage, this would require restored water elevations not exceed an elevation of about 2 feet, NGVD immediately adjacent to the utilities. However, it is assumed that water surface elevations could exceed 2 feet, NGVD if the inundated area was kept at a distance from the utilities. Under these conditions the maximum water elevation would only occur for a short duration on a high tide and would not result in an increase in the water table near the utilities. If sufficient distance was not available then a physical barrier could be used to lengthen the groundwater flow path and reduce the potential for seepage towards the buried utilities.

7. DESCRIPTION AND EVALUATION OF ALTERNATIVES

Four restoration alternatives for the Iverson property are described below. The discussion assumes a 50-year planning horizon. As discussed in Section 6.3.2, it will likely take over 100-years for a marsh restoration at Iverson to reach maturity. The 50-year planning horizon was selected as an interim point between this natural timeframe and a more acceptable and shorter timeframe for a public works project. It is important to note that habitat benefits for both aquatic and terrestrial species will begin soon after tidal inundation is restored to the area. The restoration alternatives include a:

1. No action alternative;
2. Bay dike removal alternative;
3. Bay dike setback alternative and;
4. Tide gate modification alternative.

The major physical changes to the site are described and mapped for each alternative, with the exception of the "no action" alternative. Qualitative estimates of the relative cost and maintenance requirements for these activities are summarized in Section 7.5.

7.1 NO ACTION ALTERNATIVE

When selecting a project alternative it is helpful to understand what might happen at the site if no project was built. This alternative consists of no change in the management of the site. Current activities, such as dike maintenance and agriculture, would continue. As the land area continues to subside relative to sea level drainage of the agricultural land protected by the dike may become more difficult because of the higher water elevations imposed at the downstream end of the drainage system. Agriculture may become less viable with a decrease in the capacity of tile drainage and ditches without installation of more drain tiles or a pumping system. The remnant slough channel leading to the tide gate may need to be dredged periodically to facilitate drainage of the agricultural areas.

In addition, the crest elevation of the existing dike may need to be increased to compensate for sea level rise accelerated by regional land subsidence. This is most likely to happen in the northwestern part of the site where the dike was built across the old tidal inlet. As a result, the site may become increasingly vulnerable to flooding from dike overtopping and dike failure. The County and the Long Beach residents may need to cooperate to rebuild the dike in its existing location. This decision would likely depend on the perceived value of the agricultural land for farming and therefore the willingness to protect it from flooding.

Another no-action scenario may develop if efforts are made to provide additional flood protection to the Long Beach development and not specifically for restoration. For example, if maintenance of the existing dike along Livingston Bay were abandoned in favor of building a new dike along the west side of Iverson Road and improving the existing dike on the bay side to protect the Long Beach development then the non-maintained northern section of the dike may eventually fail. Failure of this portion of the dike would restore tidal inundation to the site and would facilitate the restoration of tidal marsh behind the dike.

7.2 BAY DIKE REMOVAL ALTERNATIVE

In this "full restoration" alternative the northern portion of the bay dike is removed exposing the entire 100-acre area behind the dike to full tidal action (Figure 13). Relocation of the Long Beach development's water main is necessary in this alternative. Key design elements of the alternative are described below:

Dike Removal

In this alternative the western part of the bay dike is removed down to existing grades. The location of this breach corresponds to the historic entrance channel location. The eastern part of the dike is left in place to preserve the scrub shrub community on the interior of the dike and the high and low marsh communities on the exterior of the dike. This remnant dike will also preserve access for passive recreation.

Starter Channel

The historic channel inlet was located along the coastal bluff at the northwest corner of the site. However the exterior marshplain elevation at this location is 4-feet so the main path for water to enter the restoration area will remain in the existing channel. At the time of dike removal the 100-acre restoration site would have an estimated potential tidal prism of 220 acre-feet. To accommodate that volume of water the inlet channel would need to be about 95-feet wide and would have a depth of 10-ft below MHHW, or an invert elevation of about -4.8 feet, NGVD. Excavating this channel would be costly because of the saturated soil conditions on the marshplain. To keep construction costs at a minimum the natural erosion of the mud and silt sediment surrounding the existing inlet will be monitored following the breach. If barriers to erosion are encountered then channel excavation can be preformed. As sediment accumulates in the restoration area and the tidal prism decreases the equilibrium inlet dimensions will shrink to approximately 70-feet wide and 8.5 feet below MHHW, or an invert elevation of about -3.3 feet, NGVD.

Protective Berm

Since Iverson Road and the Long Beach residential development are lower than MHHW their existing level of flood protection would need to be maintained with a structural barrier along the edge of the restored area paralleling the west side of Iverson Road (Figure 13). The structural barrier could be an interior berm (Figure 14). A berm was used in this alternative because the side of the berm fronting the restoration area would slope gradually to provide a high elevation surface area for marsh vegetation to colonize once tidal inundation was restored. Cut material from the removal of the bay dike would provide some of the material needed for berm construction. The crest of the berm would be above the 100-year tidal flood elevation, which is estimated to be 8.5 feet, NGVD. This elevation is assumed to be reasonable because wave action from the north would be less than that from the southeast, along Port Susan, due to a smaller overwater fetch length and the shallow mudflats in Livingston Bay, with both conditions tending to limit wave heights. The approximate 3- to 4-foot height of the berm above the road would allow views of the restored marsh from the homes in the Long Beach development and would not present an imposing structure to residents.

Interior Drainage

The existing drainage ditch along the west side of Iverson Road would be intersected by the new berm near the north end of the road alignment. It is assumed that the ditch currently drains stormwater runoff from the Long Beach development and it would be necessary to maintain this drainage facility. Using rainfall coefficients for Everett, Washington (WSDOT, 1997), runoff for a 100-year storm event was estimated to be 10 cfs for the Long Beach development. A tide-gated culvert would be installed in the ditch at the new dike to allow the movement of water to the north and into the restored marsh. An estimate of flow capacity through a submerged 100-foot long 48-inch diameter concrete culvert pipe indicates the water level would rise about 0.1-foot in the ditch. This calculation assumes a discharge of 10 cfs and a fully submerged outlet at MHW (4.32 feet, NGVD), including head loss from a flap gate. This means drainage for this alternative could be maintained below the elevation of the road during high tide events and would be drained through the tide gated culvert on the ebb tide.

Ditch Filling

Natural tidal channels are sinuous. To ensure that a sinuous system evolves at the Iverson property, straight agricultural drainage ditches within the area to be inundated will be either filled or plugged with cut material from the site or with imported material.

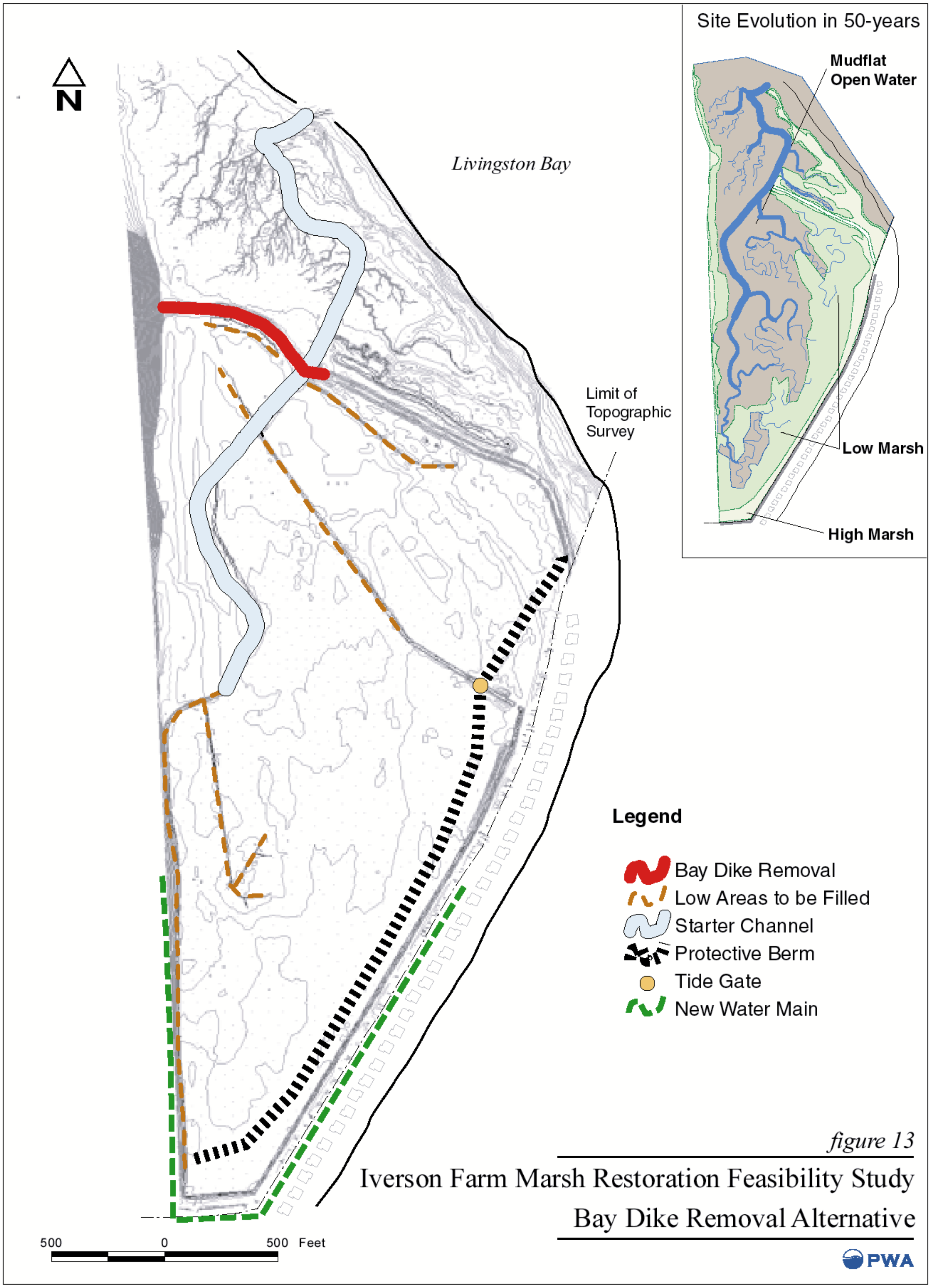

figure 13
Iverson Farm Marsh Restoration Feasibility Study
Bay Dike Removal Alternative

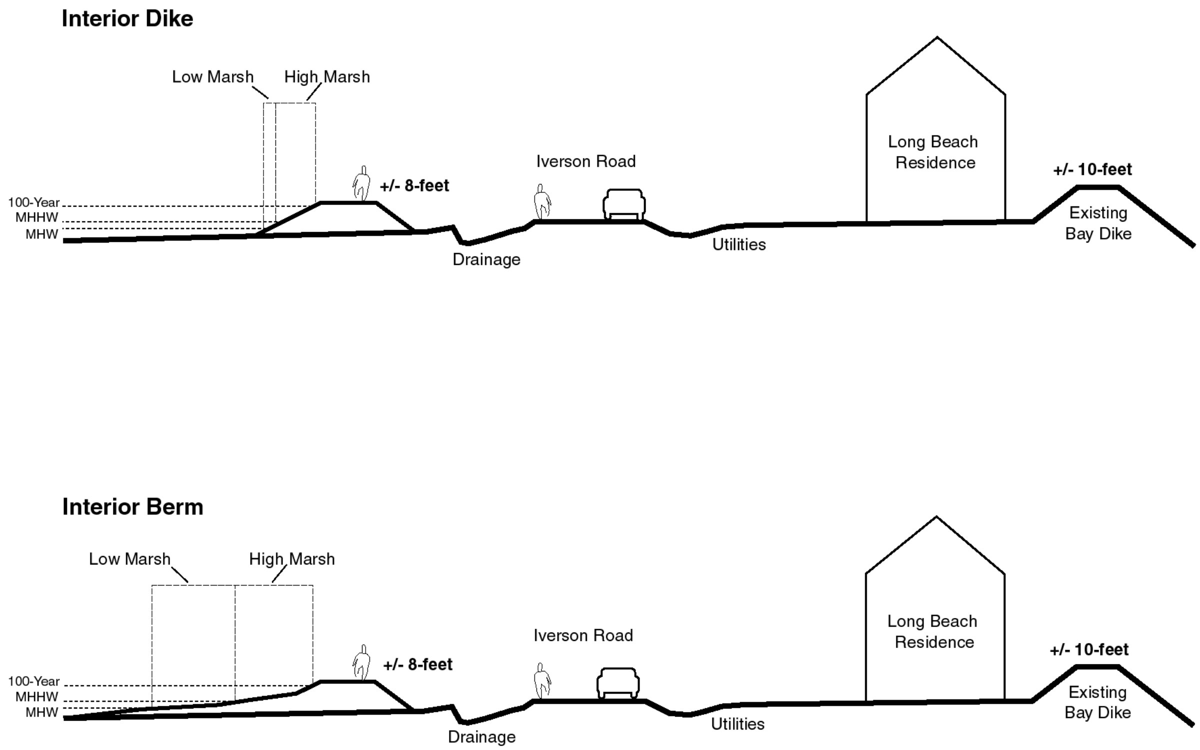

Figure 14: Dike and Berm Cross Sections

7.3 BAY DIKE SETBACK ALTERNATIVE

The bay dike setback alternative seeks to restore tidal inundation to just over half of the site, approximately 80 acres, while limiting the length of interior flood protection dike that is needed and keeping the water main in its existing location (Figure 15). Key design elements of the alternative are described below:

Dike Removal

In this alternative the existing bay dike is breached at the location of the existing tide gate. The dike to the west of this breach is lowered to the elevation of MHHW, 5.18 feet. This will preserve some of the scrub shrub community along the dike and will result in less disturbance to the tidal channel network on the exterior mudflat. The eastern part of the dike is left in place to preserve the scrub shrub community on the interior of the dike and the high and low marsh communities on the exterior of the dike. This remnant dike will also preserve access for passive recreation.

Starter Channel

At the time of dike breaching the 80-acre restoration site would have a potential tidal prism of 170 acre-feet. To accommodate that volume of water the inlet would need to be about 85-feet wide and would have a depth of 9.5-ft below MHHW, or an invert elevation of about – 4.3 feet, NGVD. To keep construction costs at a minimum the natural erosion of the mud and silt sediment surrounding the existing inlet will be monitored following the breach. If barriers to erosion are encountered then channel excavation can be preformed. As sediment accumulates in the restoration area and the tidal prism decreases the inlet dimensions will shrink to approximately 52-feet wide and 8.5-feet below MHHW, or an invert elevation of –3.3 feet, NGVD.

Protective Dike

This alternative uses a dike instead of a berm because it will require less fill material (Figure 14). A berm could be substituted for the dike in this alternative to decrease the time needed for high marsh plants to colonize. The setback dike is positioned parallel to and west of Iverson Road. The dike turns west and crosses the Iverson farm property north of the water main. In this position the dike can protect the water main from surface inundation and provide access for maintenance. Impermeable material could be placed in a trench below the new dike to reduce the potential for ground water flow beneath the dike. Cut material from the removal of the bay dike would provide some of the material needed for new dike construction. The crest of the dike would be at the 100-year tidal flood elevation, which for this level of investigation is estimated to be 8.5 feet, NGVD. This is assumed to be reasonable because wave action from the north would be less than that from the southeast, along Port Susan, due to a smaller overwater fetch length and the shallow mudflats in Livingston Bay, with both conditions tending to limit wave heights. The approximate 3- to 4-foot height of the dike above the road would allow views of the restored marsh from the homes in the Long Beach development and would not present an imposing structure to residents.

Interior Drainage

The existing drainage ditch, west of Iverson Road, would be intersected by the new dike near the north end of the road alignment. It is assumed that the ditch currently drains stormwater runoff from the Long Beach development and it would be necessary to maintain this drainage facility. Using rainfall coefficients for Everett, Washington (WSDOT, 1997), runoff for a 100-year storm event was estimated to be 10 cfs for the Long Beach development. A tide-gated culvert would be installed in the ditch at the new dike to allow the movement of water to the north and into the restored marsh. An estimate of flow capacity through a submerged 50-foot long 48-inch diameter concrete culvert pipe indicates the water level would rise less than 0.1-foot in the ditch. This calculation assumes a discharge of 10 cfs, a fully submerged outlet at MHW (4.32 feet, NGVD), and head loss from a flap gate. This means drainage for this alternative would be maintained below the elevation of the road during high tide events and would be drained through the tide gated culvert with the ebb tide.

Ditch Filling

Natural tidal channels are sinuous. To ensure that a sinuous system evolves at the Iverson property, straight agricultural drainage ditches within the area to be inundated will be either filled of plugged with cut material from the site or with imported material.

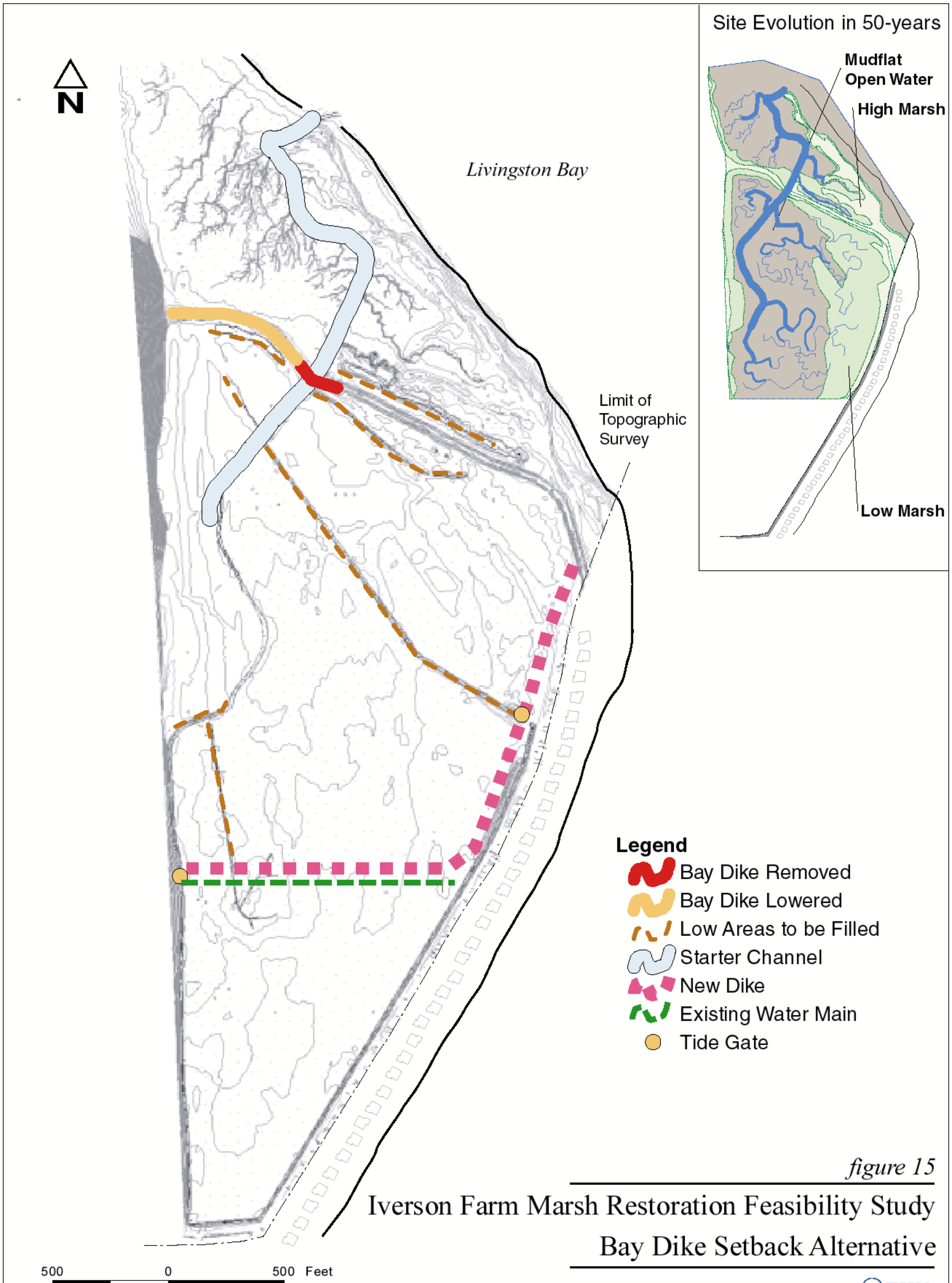

figure 15

Iverson Farm Marsh Restoration Feasibility Study

Bay Dike Setback Alternative

7.4 TIDE GATE MODIFICATION ALTERNATIVE

The tide gate modification alternative employs a self-regulating tide gate to control the elevation of tidal flows entering the site. This minimizes the need for structural barriers such as dikes or berms to protect the Long Beach development from tidal flooding while restoring tidal inundation to a 50 acre area (Figure 16). This alternative also allows the water main to remain in its existing location. Key design elements of the alternatives are described below:

Tide Gate Modification

In this alternative the existing tide gate is replaced with a self-regulating tide gate. The dike will remain in its current condition. This will preserve some of the scrub shrub community along the dike and will lessen disturbance to the tidal channel network and high and low marsh communities on the exterior of the dike. The dike will also preserve access for passive recreation. The maximum tidal elevation within the restoration area would be limited to 3-feet, NGVD by the self-regulating tide gate. This would provide for the restoration of about 90 percent of the natural diurnal tide range (between MHHW and MLLW). Restricting the upper end of the tide range would leave an uninundated buffer between the restored marsh area and the existing Long Beach development. This buffer would protect the underground utilities along Iverson Road from increased flood damage.

Starter Channel

At the time of tide gate replacement the 50-acre restoration site would have a potential tidal prism of 43 acre-feet. To accommodate that volume of water the inlet would need to be about 50-feet wide and would have a depth of 7.5-ft below MHHW, or an invert elevation of –2.3 feet, NGVD. To keep construction costs at a minimum the natural erosion of the mud and silt sediment surrounding the existing inlet will be monitored following the breach. If barriers to erosion are encountered then channel excavation can be performed. As sediment accumulates in the restoration area and the tidal prism decreases the inlet dimensions will shrink to approximately 32-feet wide and 7-feet below MHHW, or an invert elevation of –1.8 feet, NGVD.

Protective Berm

A limited length of low berm will be needed to protect the water main from inundation where land elevations are low. A berm was used in this alternative because the side of the berm fronting the restoration area would slope gradually to provide a high elevation surface area for marsh vegetation to colonize once tidal inundation was restored. Cut material from the tide gate replacement may provide some of the material needed for berm construction. The crest of the berm would be just over 3 feet in elevation. As in the dike setback alternative impermeable material could be placed in a trench below the berm to impede groundwater flow beneath it.

Interior Drainage

The existing drainage ditch west of Iverson Road would not be intersected by a physical flood protection barrier in this alternative. However, the ditch would be exposed to salt water at high tides. It is assumed that the ditch currently drains stormwater runoff from the Long Beach development and it would be necessary to maintain this drainage facility. Using rainfall coefficients for Everett, Washington (WSDOT, 1997), runoff for a 100-year storm event was estimated to be 10 cfs for the Long Beach development. To limit salt water intrusion into the ditch system a berm and tide gated culvert would be installed in the ditch at the high water elevation to allow the movement of water to the west and into the restored marsh. An estimate of flow capacity through a submerged 50-foot long 48-inch diameter concrete culvert pipe indicates the water level would rise less than 0.1-foot in the ditch. This calculation assumes a discharge of 10 cfs and a fully submerged outlet at MHW (4.32 feet, NGVD), including head loss from a flap gate. This means drainage for this alternative could be maintained below the elevation of the road during high tide events and would be drained through the tide gated culvert with the ebb tide.

Ditch Filling

Natural tidal channels are sinuous. To ensure that a sinuous system evolves at the Iverson property, straight agricultural drainage ditches within the area to be inundated will be either filled or plugged with cut material from the site or with imported material.

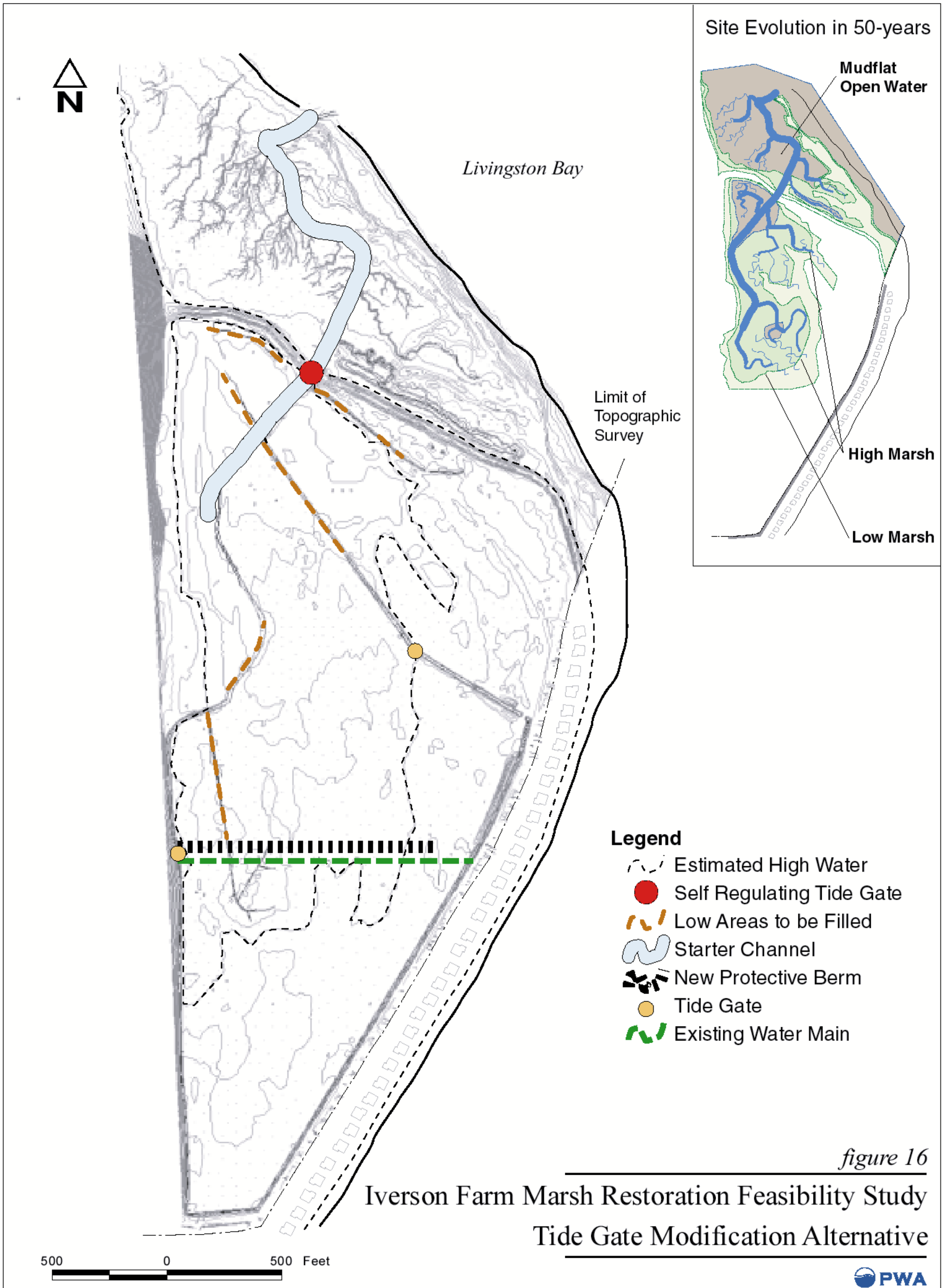

figure 16

Iverson Farm Marsh Restoration Feasibility Study

Tide Gate Modification Alternative

7.5 ALTERNATIVE EVALUATION

In order to provide information to compare the habitat benefits of the various alternatives statistical relationships developed by PWA were used to estimate the channel order, marsh area, and marsh community anticipated to evolve in the various alternatives. Statistical relationships developed from a California marsh data set were used to make predictions of channel order since similar data do not yet exist for Pacific Northwest tide marshes. The methods and relationships are described in Appendix B. In addition to these geomorphic assessments effects of the alternatives on agriculture and recreation were also evaluated qualitatively. Cost and maintenance concerns are also generally discussed.

7.5.1 No Action Alternative

Site Evolution

As in the other alternatives, marsh evolution would be driven by natural sedimentation. However, since restored tidal inundation would be the result of dike failure the restoration process begins many years in the future. The evolution of the site is further slowed by the unintentional dike breach. Since the dike would not be removed to a specified width or depth, sediment accumulation and subsequent vegetation colonization would be expected to take much longer than in the other alternatives.

Marsh Area and Communities

100 acres of tidal marsh would eventually be created in this alternative.

Channel Network

The channel network of this marsh would not be complex because it would form in the straight drainage ditches at the site and the habitat value of the marsh would not achieve its full potential.

Agriculture

Farming of the existing agricultural land would continue but would likely become less viable over time.

Construction and Maintenance Cost

There will be construction and maintenance costs associated with this alternative. Existing levels of flood protection will need to be improved to counter sea level rise and land subsidence. It is likely that additional investments will be made in tile drainage to continue farming.

Recreation

Recreation will not significantly change in this alternative.

7.5.2 Dike Removal Alternative

Site Evolution

As in the other alternatives, marsh evolution would be driven by natural sedimentation. Fully restored tidal inundation would speed optimal conditions for sediment accretion within the restoration area. In this alternative the mature vegetated marshplain would take about 120 years to evolve.

Marsh Area and Communities
100 acres of tidal marsh would be created in this alternative. At the 50 year planning horizon the marsh would be a combination of open water, intertidal mudflat and low high marsh.

Channel Network
This 100-acre marsh would likely support a 5th order channel system.

Agriculture
No land would remain in agriculture in this alternative.

Construction and Maintenance Cost
Construction cost for this alternative would be significant because of the length of new berm that would need to be built and the amount of fill material that would be needed to build it. Assuming a 15-foot crest width, a 50-foot base width, and a 5-foot height the existing dike is composed of about 6 cubic yards of material per linear foot. Assuming a 10-foot crest width, 100 foot base width and 3 foot height the berm would be composed of about 4.2 cubic yards of material per linear foot. Based on these assumptions every foot of existing dike removed could build 1.5 feet of berm. The use of the berm has the potential to reduce maintenance costs by providing additional erosion protection from small waves generated within the restoration area.

Recreation
Recreation in this alternative would change from its current condition. The trail along the dike would still be accessible but it would end at the channel inlet. Much of the trail on the inboard side of the bay dike would be inundated. Additional trails could be provided along the perimeter of the site on top of the new berm.

7.5.3 Dike Set Back Alternative

Site Evolution
As in the other alternatives, marsh evolution would be driven by natural sedimentation. Restored tidal inundation would provide conditions for sediment accretion within the restoration area. In this alternative the mature vegetated marshplain would take about 120 years to evolve.

Marsh Area and Communities
This alternative would result in 80 acres of new marsh. The existing land elevations at the northern end of the site are generally lower so there is less land in this alternative that will be readily colonized with marsh vegetation when tidal action is restored. Because of this, at the 50 year planning horizon much of the restored marsh habitat in this alternative would be open water and intertidal mudflat with a fringe of low marsh.

Channel Network
This 80-acre marsh would support a 4th or 5th order channel system.

Agriculture

In this alternative 20 acres at the southern end of the site would be available for farming. This includes part of the area currently in row crops and much of the field crop area in the southern part of the property.

Construction and Maintenance Cost

Construction cost for this alternative would be significant because of the length of new dike that would need to be built. Assuming a 15-foot crest width, a 50-foot base width, and a 5-foot height the existing dike is composed of about 6 cubic yards of material per linear foot. Assuming a 10-foot crest width, 30 foot base width and 3 foot height the dike would be composed of about 2.1 cubic yards of material per linear foot. Based on these assumptions every foot of existing dike removed could build 3 feet of interior dike. The dike does not provide additional erosion protection from small waves generated within the restoration area and so may have higher maintenance costs. It is likely that additional investments will be made in tile drainage to continue farming.

Recreation

Recreation in this alternative would change from its current condition. The trail along the dike would still be accessible but it would end at the channel inlet. If access to the western side of the inlet was critical this alternative could be modified to provide a bridged crossing. Much of the trail on the inboard side of the bay dike would be inundated. Additional trails could be provided along the perimeter of the site on top of the new dike.

7.5.4 Tide Gate Modification Alternative

Site Evolution

The self regulating tide gate essentially cuts off the top two feet of the daily tidal cycle. Because this alternative relies on modifying the natural tidal regime it is more difficult to estimate the length of time that will be required for a mature vegetated marsh to evolve. On one hand the existing marshplain elevations will be more appropriate for vegetation but the duration of inundation will be longer than normal for these depth.

Marsh Area and Communities

This alternative results in the smallest marsh area, 50 acres. Because this alternative relies on modifying the natural tidal regime vegetation colonization is more difficult to estimate. The site would be subject to generally shallow inundation but for longer periods of time than are normally found at this inundation depth. Still, a variety of communities would be expected to evolve.

Channel Network

Due to the small area restored to tidal marsh in this alternative the channel network would have less complexity than the Dike Removal or Dike Set Back alternatives. A 4th order channel system would evolve but the channel depths would be shallower than in the alternatives resulting in larger marshes. This channel size could limit access to the marsh to some fish.

Agriculture
In this alternative the perimeter of the site would be available for farming (between 40 and 50 acres). This includes the area currently in row crops and much of the field crop area in the south and east part of the property.

Construction and Maintenance Cost
Construction cost for this alternative would be lower than the Dike Removal of Dike Set Back alternatives because structural barriers to tidal inundation would not be required. However, maintenance costs would likely be higher. The self regulating tide gate would need to be monitored and maintained as needed in order to ensure that it continued to function as designed in order to provide flood protection and habitat benefits. The amount of wood on the spit outside of the dike indicates that keeping the tide gate clear of wood would be part of the ongoing maintenance.

Recreation
Recreation in this alternative would remain much as it is today. The trail along the dike would still be accessible. Much of the trail on the inboard side of the bay dike would be inundated. Additional trails could be provided in the southern and eastern portions of the site, which are not inundated.

7.5.4.1 Alternative Evaluation Summary
The matrix below is intended to provide a qualitative summary of the elements that were evaluated for the various alternatives. A higher number of asterisks indicates a greater perceived costs or benefits.

Table 3: Alternative Comparison Matrix

	Cost	Maintenance	Agriculture	Channel Complexity	Marsh Community	Marsh Area	Recreation
No Action	**	**	**	*	*	**	**
Dike Removal	***	**	*	***	***	***	*
Dike Setback	**	**	**	**	*	**	**
Tide Gate Modification	*	***	**	*	**	**	***

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