The Port Susan Bay Dike Setback Restoration is an ESRP portfolio project led by The Nature Conservancy (TNC). The Port Susan Bay (PSB) Preserve was acquired by TNC in 2001 and construction of a 150 acre ESRP funded restoration project was completed in September 2012.

PSB supports some of the finest estuarine habitats in the Puget Sound that are critical to an array of wildlife species, including several species of salmon and other fishes. PSB encompasses much of the Stillaguamish River estuary. Over the past 150 years, the Stillaguamish River has experienced significant human-induced changes in the quantity, composition, and spatial distribution of its estuarine habitats. These large-scale modifications to the physical character of the estuary have altered its ecological functioning and its capacity to support endemic estuary-dependent species. The Port Susan Bay estuary restoration project reintroduced full tidal prism and inundation regime to 150 acres of diked land in the estuary, increasing the quantity and quality of estuarine habitats for utilization by juvenile salmon, shorebirds, and other estuarine-dependent animals.

The primary objectives for the Port Susan Bay Estuary restoration project are to:

- Restore self-sustaining native tidal wetlands that support estuarine-dependent animals (site scale);
- Improve juvenile salmon access to restored rearing habitats (site scale);
- Improve connectivity between the river and northern tidal habitats, increasing the distribution of freshwater, sediment, energy and other materials (estuary scale); and
- Improve flood attenuation for neighbors in the lower river valley.

The Port Susan Bay Restoration Monitoring Plan (RMP) identifies a series of hypotheses for each project objective. The monitoring program is designed to evaluate the hypotheses in order to measure project objectives and outcomes. The project scope funded by this grant award will monitor post-restoration conditions and evaluate two of the PSB project objectives: 1) Restore self-sustaining native tidal wetlands that support estuarine-dependent animals (site scale) and 2) Improve connectivity between the river and northern tidal habitats, increasing the distribution of freshwater, sediment, energy and other materials (estuary scale).

This technical report provides an update on field activities and data management performed. The report is broken into three sections; Task 2A, Task 2B and Task 2C as described in the PSB ESRP Learning Project SOW and includes monitoring work activities from August 1, 2013 through February 28th, 2014. Each of the three sections provides an update and results (if available) on the environmental parameters measured during the respective time period.
Field work and monitoring activities during August and September 2013 included monitoring channels and channel development, Sediment Elevation Tables (SETs), and biophysical transects (vegetation species and structure and sediment). These environmental parameters are used to evaluate the hypotheses directly related to the two project objectives: 1) Restore self-sustaining native tidal wetlands that support estuarine-dependent animals (site scale) and 2) Improve connectivity between the river and northern tidal habitats, increasing the distribution of freshwater, sediment, energy and other materials (estuary scale).

**Channels**
Channels are a critical component of a healthy functioning estuary ecosystem. They are responsible for transporting nutrients and sediments to the marsh and estuary needed for native vegetation to grow and thrive as well as provide habitat for estuarine dependent species such as juvenile Chinook salmon and other fish and wildlife species. During the month of September 2013, channel cross sections were measured within the restoration project site using RTK-GPS equipment to describe the condition of the channels one year post construction. A full report including a description of the field work and results of the field measurements will be provided in January 2014.

**Sediment Elevation Tables (SETs)**
SET data along with marker horizons (marker horizons are used to assess accretion rates) can provide information on below ground processes driving elevation change. The change in sediment and elevation of the estuary are main drivers of vegetation. Elevation of the marsh in combination with hydrology and hydrodynamics influences habitat availability for fish, birds and other wildlife.

As a result of this grant award, more SET monitoring stations will be installed within the restoration site and the marsh immediately to the north. During this reporting period Equipment for the 7-9 new SETs has been ordered and is currently being manufactured. Installation of the new SETs is expected to occur prior to the end of the calendar year or soon thereafter.

**Biophysical Transects**
To further understand the complexity and interaction between vegetation and sediment accretion biophysical transects were established across the restoration site, reference site and the northern marsh of Port Susan Bay.

Primary transects have been installed and sampling of vegetation characteristics has been mostly completed for zone 2 and zone 3 (Figure 1). Sampling has begun in the other three zones as well.

To evaluate differences in sediment deposition across elevation and vegetation gradients, seven short-term sediment monitoring stations have been installed within the restoration zone, spanning the
elevation gradient. To date, two stations have been installed in zone 3 and five more will be installed in the near future. Sediment stations are being positioned on transects that will encompass the SET locations and to the extent possible will also be near sediment pin stations.

This work has involved the efforts of two Western Washington University principle investigators, two graduate student employees assisting with field work, and an undergraduate employee assisting with GIS work, as well as a self-supported University of Washington graduate student.

![Map of Port Susan Bay with study zones](image)

**Figure 1** Five study zones at Port Susan Bay for monitoring the effects of restoration.

Data Collection Log August 1 – September 31, 2013

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*Exact dates of channel monitoring work are unknown.*

Field work and monitoring activities during October and November 2013 included monitoring channels, Sediment Elevation Tables (SETs), and biophysical transects (vegetation species and structure and sediment).

Channels
Greg Hood with the Skagit River System Cooperative (SRSC), a well-known researcher in estuary restoration and channel development, collected channel cross section measurements and other data during September 2013. Data were processed and analyzed to compare channels before the restoration project (2011) to conditions one year after construction of the restoration was completed. A report of the channel morphology and development within the restoration area will be completed by the end of January 2014.

Sediment Elevation Tables (SETs)
Due to unexpected delays in the manufacture of the SET equipment, the new sediment elevation tables have not yet been installed. The sub-awardee, Western Washington University, is ready and equipment is now in place to install when appropriate weather and tides coincide.

Biophysical Transects
Vegetation structure transects have been completed in zones 1-4 and initiated in zone 5 (Figure 1). Transects consist of 10mx10m sample plots every 20 meters. Within each plot the most common species present are recorded, and the dominants and sub-dominants are noted. Five randomly selected sub-plots are sampled for vegetation height and stem density. Both current height as well as full height were measured because some plant species are senescent in the fall. For example, American bulrush stems senesce early in the fall, but their stems remain prone on the sediment surface. So the current height maybe only a few centimeters while the full height can be measured from the length of the prone stem. For the purposes of understanding sediment trapping potential and wave energy reduction, it is important to know the structural characteristics for both full growth conditions during summer, as well as during senescent periods from mid-fall through spring. The senescent periods are when river floods deliver the most sediment, and winter storms have the greatest potential to re-suspend sediment and disturb vegetation. In higher elevation areas where low growing graminoids commonly form low, dense mats of intertwining lax stems, the thickness of this mat is measured.

To evaluate differences in sediment deposition across elevation and vegetation gradients, short-term sediment monitoring stations have been installed in zones 1-3 and will be installed in zones 4-5 soon. In zone 1, south of Hatt Slough, three new feldspar stations have been installed, with 2 replicates each, to augment the two SET stations already present. The seven sites in zone 2 were completed during the previous reporting period. In zone 3, eight short term sediment sites have been installed as part of the
thesis of the University of Washington graduate student whose work was described in the last report. Six of these sites have five replicates and two have 3 replicates.

A report summarizing the results of vegetation and sediment data will be completed by May 2014.

Hydrology
There are six water level, temperature, and conductivity monitoring stations that extend from the reference marsh area south of Hatt Slough north to the old Stillaguamish river channel in Port Susan Bay. These water monitoring stations have a data logger or multiple loggers installed that are downloaded on a quarterly basis. Most recently all of the data loggers were downloaded in November 15, 2013. During the past year some of the conductivity data loggers were recalled so TNC is working with USGS-Vallejo to purchase and replace Solinst conductivity data loggers with Odyssey Conductivity and Temperature data loggers from Dataflow Systems, a New Zealand based company.
Figure 2 Location of water level, temperature and conductivity data logger sites at Port Susan Bay.

Data Collection Log October 1 – November 30, 2013

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Field work, monitoring, and data analysis activities continued through the winter months of 2013-2014 at Port Susan Bay. This work included the compilation and analysis of channel monitoring data collected in 2013, Sediment Elevation Table (SET) installation and analysis, initial analysis of findings from the biophysical transect data, work on hydrodynamic monitoring and systematic qualitative monitoring protocol.

Channel
Channel development is hugely important for restoring natural processes to the restoration site and providing critical habitat for juvenile salmon and other fish. Channel measurement and development data and analysis were included in a report prepared by Greg Hood from Skagit River System Cooperative (SRSC). This report is included at the end of this technical report. In general, new channels are developing in the restoration area. There were 12 additional small tributaries observed draining into the large historical remnant tidal channel during monitoring in the fall of 2013. The off-site channel near the northern excavated tidal channel network is widening as a result of the restoration project. The development of channels and the off-site effects of the restoration project on channels outside the restoration footprint are still in their infancy, however small changes in the channel system have been observed within a year after the restoration project was completed.

Sediment Elevation Tables (SETS)
*note: some of the work described in this section occurred in February and March 2014.*

Three additional SETS (21, 23 and 24) were installed in the mid-delta region (Figure 1), north of the restoration area in zone 4 (see Figure 2 for zone locations). Following the pattern established at other sites in the delta, two of those SETS were installed in the high marsh and one was installed in the low marsh. One more SET will be installed in the high marsh. Within the restoration area (zone 2 of Figure 2) two SETs (25 and 26) were installed along the previously established biophysical transect (Figure 1). This transect runs from the low point in the levee that borders the Stillaguamish River north to the two established breaches on the now removed dike. Two more SETs will be installed along the same transect and nearer to the river breach when water levels in the river recede.
Figure 1. Locations of five new SETS installed in the mid-delta site and in the restoration area.
Figure 2. The five study zones at Port Susan Bay for monitoring the effects of restoration.

Table 1 Mean elevation change over two years, 2011 – 2013. LE = low elevation marsh, and UT = unvegetated tide flat. See Figure 3 for SET locations.

<table>
<thead>
<tr>
<th>SET #</th>
<th>Location</th>
<th>Type</th>
<th>Location LAT/LON</th>
<th>Mean Yearly Rate of elevation change 2011-2013 (cm/year)</th>
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<td>1</td>
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<td>HE</td>
<td>N48°13'37.2&quot; W122°23'01.3&quot;</td>
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<td>2</td>
<td>South Slough</td>
<td>HE</td>
<td>N48°13'36.9&quot; W122°23'00.1&quot;</td>
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<td>3</td>
<td>South Slough</td>
<td>LE</td>
<td>N48°13'34.9&quot; W122°23'00.5&quot;</td>
<td>-0.20</td>
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<td>4</td>
<td>South Slough</td>
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<td>N48°13'34.5&quot; W122°22'59.7&quot;</td>
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<td>5</td>
<td>Mudflat</td>
<td>UT</td>
<td>N48°12'07.8&quot; W122°23'09.9&quot;</td>
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<td>7</td>
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<td>HE</td>
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Preliminary Findings: In 2011, as part of the original monitoring effort, 13 additional SETs were installed in a reference site south of the restoration area, near the Hat Slough and north of the restoration site near South Slough (Figure 3). The SETS were monitored through 2013. Generally, a positive trend in the rate of elevation change was found across the preserve, with significant elevation gains indicated at 8 of the 11 sampled sites. The mean rate of surface elevation change throughout the preserve was $0.43 \pm 0.45$ cm/year ($\pm 1$ standard deviation), elevation change ranged from -0.51 to 1.05 cm/year (Table 1). The two SETs showing losses in elevation were both of the low marsh replicate sites located in the north area, where signs of erosion were noted (terracing of the banks) during sampling (sites 3 and 4). SET site 11 revealed no substantial change in elevation (as defined by a rate of change that did not exceed variation shown amongst pins). New SETs, installed in 2014 are not included in this analysis because the first measurements of elevation change are made one year after the initial installation and baseline measurements are taken. A thorough analysis of data is underway as part of a master’s thesis, under the guidance of Western Washington University Professor, John Rybczyk. This analysis will be included in the final report in May 2014.
Figure 3. Location of SETs installed previous to the 2014 effort.

**Biophysical Transects**
Vegetation structure and sediment accretion transects (biophysical transects) have been completed for all five zones (Figure 2). Species composition and physical structure was recorded for the senescent season (fall through spring). This data will inform sediment and wave dynamics during the winter storm.
and flood season when there is the greatest delivery and distribution of sediment. Installation of several feldspar accretion monitoring stations was completed in zones 4 and 5. Zones 1-3 were completed during the previous reporting periods.

Extensive evidence of erosion was found throughout the marsh in zone 5, extending in areas up to the shrub line where there is an estuarine bluff of one to two feet (Figure 4). There was also extensive erosion in zone 4 within the seaward 50m of marsh (Figure 5). The erosion appears as proto-channels headcutting into the marsh, which is visible in the aerial of Figure 5. Landward of this zone was evidence of recent deposition of soft unconsolidated sediment. It appears that the sediment eroding from the seaward marsh edge may be depositing in the marsh interior. Overall, there is evidence of erosion of the seaward marsh edge from South Pass down to the first northerly Hatt Slough distributary channel encountered (Figure 6). An accretion monitoring guidance document is in the process of being written. The document describes various methods of monitoring, the kinds of habitat and environmental conditions for which they are most useful, and relevant logistical and analytical considerations.

Figure 4 Zone 5 erosional area.
Figure 5 Zone 4 erosion/deposition patterns. The seaward marsh edge appears to be eroding, with the sediment depositing landward in the marsh interior.

Figure 6 Area of northern marsh where there is evidence of erosion along the seaward edge of the marsh.

Hydrodynamic Monitoring

*note: some of the work described in this section occurred in February and March 2014.*

The Nature Conservancy finalized a subaward agreement with USGS to monitor wave dynamics and turbidity in Port Susan Bay. USGS and Western Washington University (WWU) have initiated the

Port Susan Bay Estuary Restoration Monitoring Progress Report, April 2014

The Nature Conservancy

WDFW Project Number: 11-1650R
monitoring of hydrodynamics at the restoration size and at boundary sites on Hatt Slough and the Old Stilly channel. WWU is working with USGS to monitoring and Equipment has been installed at all three sites to continuously monitor water level, currents, turbidity and other parameters. This equipment is stationary and measures parameters at one point, or uses acoustics to sample across a channel. In addition, synoptic sampling (discrete field sampling) was conducted to calibrate the continuous samplers, and consisted of collection of water level, current and water quality parameters across the entire channel at each location. Suspended sediment samples were collected in order to calibrate the turbidity sensors and establish an empirical relationship between suspended sediment and turbidity. This relationship will allow researchers to develop a model to estimate the volume of sediment being the delivered and entrained at the site, by comparing turbidity levels entering and leaving the site.

**Systematic Qualitative Monitoring and Database Development**

A draft protocol for systematic qualitative monitoring has been developed and restoration area photopoints resampled. The protocol is being revised and edited based on experience in the field and in processing outputs. A SQM database is in the process of being developed in conjunction with the standard database. A final report of the monitoring protocol will be completed by the end of May 2014. In addition, work has begun in developing a spatial database and user interface to house the monitoring and research data developed at Port Susan Bay. This work engages an undergraduate Advanced GIS student and a Spatial Analysis graduate student. The latter is an online tool developer who was the lead programmer for the Salish Sea Restoration Wiki, developed by Paul Cereghino (NOAA), ESRP and WWU (Roger Fuller).

Data Collection Log December 1, 2013 – February 28, 2014

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Note: 2013 Chanel Development Report is included in the PDF version of this progress report.
The purpose of this report is to describe the condition of tidal channels on the newly restored Port Susan Bay tidal marsh restoration site, one year after dikes were removed to restore tidal inundation to the site. We anticipate that an extensive tidal channel network will develop on the site over the ensuing years to efficiently convey tidal waters to and from the site. The principal question is how fast will this development occur.

Approximately 62 hectares of tidal marsh were restored through dike removal. In addition, two large channel outlets were excavated to connect an historically remnant tidal channel and the pre-existing agricultural drainage network to tidal channels seaward of the former dikes. No other channel excavation occurred. Further channel development on the site will occur through natural tidal processes.

The restoration site subsided while under agricultural management, especially the seaward portions of the site, which are now at least 1 meter lower in elevation that the natural marsh adjacent to the site. As a result, the restoration site forms a topographic bowl. This will likely affect the nature of the tidal channel network that develops on the site. While dikes have been removed, facilitating sheet flow of tidal waters, the sharp elevation difference across the site boundary will likely constrain development of new tidal channel outlets across the boundary just as remnant dikes would. Thus, the two excavated channel network outlets are likely to remain the only two outlets from the site. This could change if Hat Slough migrates northward to erode the southern site boundary and breach the high topography on that side of the site.

Tidal channels currently present on the restoration site were evaluated with field surveys using RTK-GPS (3cm horizontal and vertical accuracy), and with GIS analysis of 2013 air photos of the site and its vicinity (Fig. 1). Tidal channel cross-sections were surveyed at channel outlets from the site and at the junctions of significant tributaries. Occasionally, channel profiles were surveyed to delineate channel courses that might not be visible in air photos. Channel profiles included

![Figure 1. Restoration site (red boundary) with RTK-GPS survey points (yellow points). XS = cross-section.](image)
Channel nick points, or areas of potential head-cutting, as well as apparent channel termini. Channel profiles were not surveyed for large channels that would be clearly visible in air photos.

Results

The first, most northerly channel complex observed on the site was in early stages of development. Principal features of the network are described by the cross-sections depicted below.

Figure 2. Location of surveyed channel cross-sections 1-6, along with channel profiles (yellow points). Some profile points appear off-set from channels visible in the photos, likely due to errors in photo rectification.

Figure 3. Ground view of the location of the first and second surveyed cross-sections. The foreground consists of the steeply sloping footprint of the removed dike. The second transect was wide to reach vegetated marsh at both ends.
(Figs. 2-5). Channels were generally very shallow, suggesting their incipient nature. Except for the remnant borrow ditch, channel cross-sections for newly developing tributary channels were typically less than ~30 cm maximum depth (~1 ft).

Surveyed channel profiles generally appeared to be offset by ~2.5 meters to the west relative to the photo signatures of the tidal channels for this and the following survey sites. This is likely due to photo rectification error. Nevertheless, when used in conjunction with the air photos, the profiles provide a good indication or confirmation of the location and extent of incipient tidal channels.

The next set of channel cross-sections included the northern-most excavated channel network outlet (Figs. 6-8). Cross-section 7 describes the outlet of a tidal channel that is off-site, immediately adjacent to the remnant dike footprint. It was surveyed, because its proximity suggested that it could potentially be influenced by surface drainage (sheet flow) from the restoration site. Cross-section 8 describes the excavated tidal channel network outlet. Cross-section 9 describes a short, shallow, incipient channel located within a former borrow ditch that appears to have been mostly filled by former dike material. That fill material may be settling and producing a shallow topographic depression that may train flow and develop into a tidal channel. The points labeled "trib junction" and "nick point", above and below the cross-section refer to the downstream and upstream extents, respectively, of the channel described by cross-section 9.

Cross-sections 10 and 11 are associated with the southern excavated channel network outlet (Figs. 9-11). Cross-section 11 is located within the footprint of the former borrow ditch, but this channel drains a large historical tidal channel that was remnant on the dike site prior to restoration. There is a large difference in the elevation of the thalwegs of the two cross-sections, amounting to 0.5 m. The relatively large elevation difference and steep gradient of this short reach was so striking that the profile of this reach was surveyed (Fig. 11). The gradient of the steepest portion of the profile is 1.4%, which is about 2 orders of magnitude greater than normal for a tidal channel. There is high flow (white water) through this reach, which together with the profile form suggests this is an area of potential channel head-cutting. Thus, these two cross-sections and the profile will provide useful baseline data against which to measure future head-cutting and channel deepening.

Cross-section 12 (Figs. 12 and 13) describes a channel that borders the former dike footprint and drains two channel forks that look like they may develop further in the future. This channel is tributary to the large remnant historical channel that drains the restoration site.

Eleven additional small, incipient tributary channels were observed draining into the large historical remnant tidal channel (Figs. 14 and 15). For those channels with well-defined courses, channel profiles were surveyed to document the location and extent of the channels. Those without developed channel banks were surveyed only at their outlets to document their location and to anticipate future development of a deeper channel with well-defined banks. The large remnant tidal channel shoals very suddenly in the last third of its length, so a channel profile was surveyed in this area (Fig. 1) to confirm the channel location and document its depth in anticipation of future deepening to accommodate restored tidal prism (data not shown). This reach of the channel was typically 10-15 cm deep.
Figure 4. First three channel cross-sections from the first channel complex. Note differences in vertical and horizontal scales between sites.

Channel cross-section area, width, maximum depth ($D_{\text{max}}$) and average depth ($D_{\text{ave}}$), were calculated only from the portion of the cross-section consisting of the channel, not the adjacent marsh surface.

Note: the channels were generally less than 34 cm (~1 ft) deep on average and generally less than 70 cm maximum depth (~2 ft).
Figure 5. Cross-sections 4-6 from the first channel complex. Note similar vertical and horizontal scales within this set of cross-sections.

Channel cross-section area, width, maximum depth ($D_{\text{max}}$) and average depth ($D_{\text{ave}}$), were calculated only from the portion of the cross-section consisting of the channel, not the adjacent marsh surface.
Figure 6. Location of surveyed channel cross-sections 7-9 (yellow points). Survey points appear to be off-set from channels visible in the photo by ~2.5 m westward, likely due to photo rectification error.

Fig. 7. Ground view of cross-section 8, one of two excavated channel network outlets for the restoration site. The restoration site is on the left; the reference marsh is on the right.
Figure 8. Three channel cross-sections from the second channel complex, which included an excavated channel network outlet (cross-section 8). Cross-section 7 is the outlet of a tidal channel just outside of the restoration boundary, surveyed because of its immediate adjacency to the restoration site and thus its potential to be influenced by dike removal.

Note differences in vertical and horizontal scales between sites.

Channel cross-section area, width, maximum depth \(D_{\text{max}}\) and average depth \(D_{\text{ave}}\), were calculated only from the portion of the cross-section consisting of the channel, not the adjacent marsh surface.
Figure 9. Location of surveyed channel cross-sections 10 and 11 at the second (southerly) excavated channel network outlet, and a short profile documenting the steep gradient between the two cross-sections (yellow points). Survey points appear to be off-set from channels visible in the photo by ~2.5 m westward, likely due to photo rectification error.

Figure 10. Ground view of the second excavated channel network outlet (cross-section 10); view is oriented to the south. Reference marsh is on the right, restoration site on the left.
Figure 11. Two channel cross-sections at the southerly excavated channel network outlet (cross-section 10).

The channel profile was surveyed to document the striking grade in this part of the channel network (the observed 1.4% gradient is two orders of magnitude greater than normal).

Note differences in vertical and horizontal scales between sites.

Channel cross-section area, width, maximum depth ($D_{\text{max}}$) and average depth ($D_{\text{ave}}$), were calculated only from the portion of the cross-section consisting of the channel, not the adjacent marsh surface.
Figure 12. Location of surveyed channel cross-sections 12 and locations of channel courses, channel heads, and tributary junctions (yellow points).

Figure 13. Cross-sections 12 and locations of channel courses, channel heads, and tributary junctions (yellow points).
Figure 14. Two examples of small incipient tributary tidal channels to the large remnant tidal channel draining the restoration site: above a well-defined channel, below a poorly defined channel (no evident banks) with high flow.
Finally, off-site effects were noticed only downstream of the northern excavated tidal channel network outlet (Fig. 15). The off-site channel to which the restoration site drains widens by 6 to 14 meters for the 375 m of channel downstream from the northern restoration site outlet. Further downstream the amount of widening decreases and eventually becomes confounded with channel meandering between the 2003 and 2013 air photo time periods. Downstream changes are more likely associated with wave and tidal current erosion, while upstream changes close to the northern outlet are presumably associated with new restoration site drainage. Surprisingly, there were no changes in off-site channel width for the reach between the northern and southern restoration site outlets. One possible explanation may be that the southern outlet, where significant head-cutting appears to be occurring, may be exporting more sediment so that the effluent waters do not have further capacity to erode additional sediments from the off-site downstream channel reach. Another explanation may be that the threshold for erosion in the off-site downstream channel may not be reached until additional flow is contributed by the northern restoration site outlet.

Figure 15. Channel widening downstream from the northern excavated tidal channel network outlet. The restoration site is to the right of the red site boundary. Arrows point out areas of local channel widening. No widening was observed in the tidal channel between the southern and northern outlets. The background photo is from 2013; the yellow channel outlines were digitized from a 2003 photo.

Summary

No conclusions can be drawn at this early stage of tidal channel development. However, the abundance of apparently incipient tidal channels is encouraging. As the tidal channels mature (deepen and lengthen toward an equilibrium condition) it may be useful to compare their morphology to those of the tidal channels located in the reference marshes. Even so, it will be necessary to be guarded about the comparison because historical marsh erosion seems to have occurred over much of the
Stillaguamish Delta, so that "reference" channel morphology may reflect anthropogenic impacts to the delta, such as sea-level rise and riverine sediment by-passing the marshes as a result of anthropogenic river levees blocking historical river distributaries, preventing over-bank flooding and thereby increasing river jet momentum. Comparison with a prograding, rather than erosional system, may thus be useful as well. Such a data set of planform and cross-sectional geometry already exists for reference marshes in the erosional Stillaguamish Delta and the nearby progradational South Fork and North Fork Skagit deltas.

It is also too early to reach any conclusions regarding planform geometry of the tidal channel network draining the restoration site. From work evaluating unplanned historical dike breaches in Puget Sound (Hood, unpublished) we should expect the total length and surface area of the eventual tidal channel network to be equal to or slightly greater than that typical of the reference marshes. The bowl-like topography of the subsided site will mimic to some degree the effect of having a dike around the site, although some sheet flow at high tides will move across the site boundaries. This will confine most of the site's tidal prism to the channel outlets, still allowing full tidal channel development within the site, but constraining the number of tidal channel outlets from the site. Allometric analysis of the planform geometry of the Stillaguamish reference marshes (Hood, unpublished) indicates that a 68-ha site could be expected to have 10 tidal channel outlets, compared to the two that were excavated. However, the 80% confidence limits are 2-49 outlets, so the site just makes it within those limits. Of course the limits are so large for the Stillaguamish Delta marsh because the sample size of marsh islands available for analysis is so small, n = 6, compared to n = 48 for the South Fork Skagit Delta. However, the Skagit system provides a different allometric prediction (26 channel outlets), probably because it is a prograding system and not a mostly eroded, lower-elevation system.