Monitoring and Evaluation of the

Nisqually Delta Restoration Project

Period: June 2009 to September 30, 2010

Final Report for Agreement: DW-14-95762601-0

Environmental Protection Agency and

U.S. Fish and Wildlife Service, Nisqually National Wildlife Refuge

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Executive Summary

- We leveraged support from the EPA monitoring funds, Nisqually National Wildlife Refuge, the Nisqually Indian Tribe (Tribe), and USGS Western Ecological Research Center (WERC) to establish a monitoring framework. The monitoring framework coordinates temporal and spatial scales of biological and physical sampling locations and is scalable to address management and research goals, ranging from change detection to comparing the realized function of the restorations to reference marshes and older restorations conducted by the Tribe. WERC documented pre-restoration conditions the summer prior to the dike removal in Fall 2009 and continued to monitor physical and biological changes that focused on hydrology, geomorphology, invertebrates, vegetation and birds.

- Portions of results were funded through other sources, but are provided here for clarity.

- True color and color infra-red aerial photographs of the Nisqually Delta taken pre (June 2009) and post-dike removal (December 2009 and March 2010), show reoccupation and development of historic tidal channels that had been blocked off from tidal flow for over 100 years.

- 360 degree panoramic photographs, taken at 42 locations throughout the Nisqually NWR pre and post-dike show dieback of freshwater plants, including invasive reed canarygrass (*Phalaris arundinaceae*), as the site transitions to estuarine habitat.

- Channel scour and development tended to be greater near the mouth of the channel (i.e. almost 1 m at Unit 1 middle versus 0.3 m at Unit 1 south), likely due to greater water velocity at the mouth of the channel.

- We detected an even distribution of sediment accretion across the restoration site with a trend toward greater accumulation along the upper reaches of the restored tidal channels. Prior to dike removal, soil organic matter content ranged from 1.7% and was as high as 68.4%, which reflected the dense fibrous roots of the invasive reed canarygrass.

- We detected over 75% cover of invasive species, primarily reed canarygrass (*Phalaris arundinaceae*), along our permanent vegetation transects prior to dike removal. In 2010, post-restoration, we detected less than 1% reed canary grass along these same permanent transects.

- We detected 138 bird species after estuarine restoration. The greatest number of birds was recorded at a single high tide survey in December 2009 with > 9,000 birds, of which over 85% were dabbling ducks. Bird abundance illustrated seasonal migratory patterns with higher numbers of ducks and geese in the fall and winter and passerines in the summer.

- A partner website was developed to provide a centralized location for updates and current findings of the Nisqually delta restorations: *http://www.nisquallydeltarestoration.org*.

- WERC has participated in information sharing and knowledge transfer through workshops, shared monitoring protocols, and presentations at local and regional conferences.

Introduction

The Nisqually National Wildlife Refuge (Refuge), Nisqually Indian Tribe (Tribe), and the Washington Department of Fish and Wildlife (WDFW) protect one of the few relatively undeveloped estuaries remaining in Puget Sound along the Nisqually River. Since 1974, nearly 405 ha diked for farming in the late 1800s, had been managed by the Refuge as freshwater. In 2008, the Refuge embarked upon the tidal restoration of 283 ha of estuarine habitat on the west side of the river, consistent with the Comprehensive Conservation Plan goal to restore native habitats representative of the Puget Sound lowlands (Figure 1). The Refuge is being assisted by two key partners: Ducks Unlimited and the Tribe. This tidal restoration complements the conversion of 57 ha of diked pasture on the east side of the river undertaken by the Tribe between 1996 and 2006.

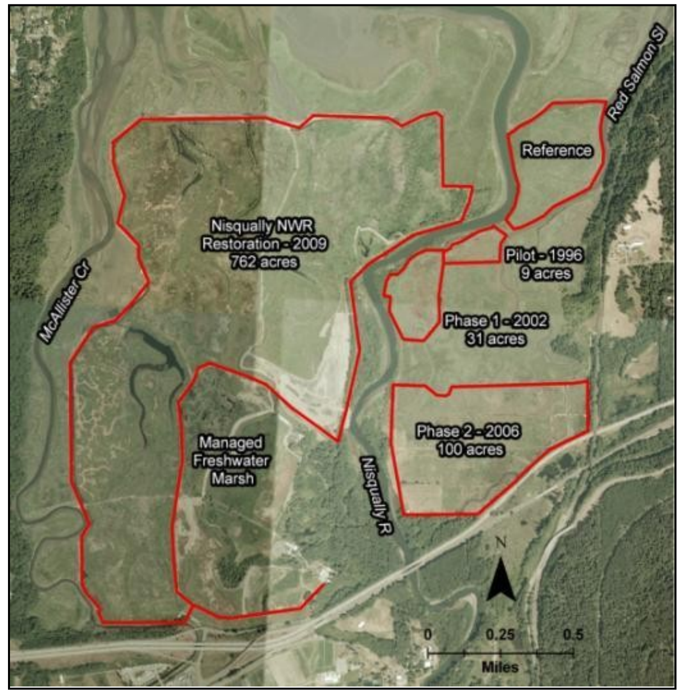


Figure 1. Nisqually Delta restorations.

The Western Ecological Research Center (WERC) received funding for restoration monitoring on the Refuge on 26 March 2009 and completed baseline conditions prior to the dike removal in Fall 2009. Following the dike removal, WERC continued monitoring physical and biological changes to document the effect of tidal restoration on the Refuge. This final report covers activities conducted under Interagency Agreement number DW-14-95762601-0 between the Environmental Protection Agency (EPA) and the U.S. Fish and Wildlife Service (USFWS) for the time period June 15, 2009 – September 30, 2010. This monitoring report focuses on Tasks A: Monitoring and Evaluation Activities for the Nisqually Estuary Restoration Project, as described in the scope of work for the memorandum of agreement between EPA and USFWS, accounts 1902-1232-13410 and 1902-1233-13530.

This report includes portions of preliminary results that were funded through other sources, but are provided here for clarity. Monitoring objectives included the following:

Task A) Monitoring and Evaluation Activities for the Nisqually Estuary Restoration Project

1. Establish baseline conditions for the Nisqually National Wildlife Refuge tidal restoration.
2. Examine initial physical and biological changes after the breach to track changes.
3. Document the effect of the tidal restoration in the Nisqually River estuary.
4. Provide support for adaptive management and public outreach through geographic information system coverages of monitoring results and a webpage with regularly updated summaries of initial restoration progress.

Tasks A1, A2, and A3. Establish baseline conditions, examine initial physical and biological changes after the breach to track changes and document the effect of the tidal restoration in the Nisqually River estuary.

Administrative progress: planning and coordination
WERC has worked closely with the Refuge, Nisqually Tribe (Tribe), Ducks Unlimited (DU) and other restoration collaborators to establish a monitoring framework that coordinates temporal and spatial scales of biological and physical sampling (Figure 2).

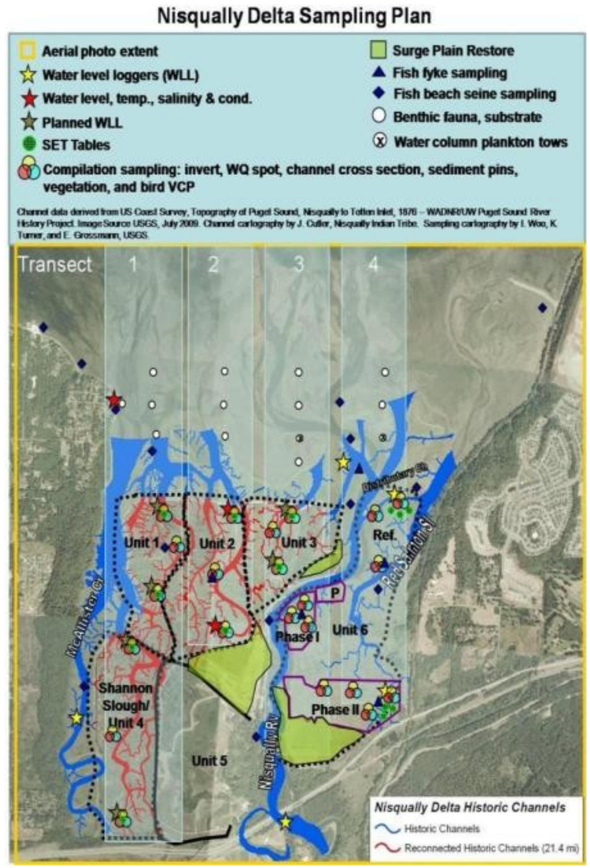


Figure 2. Nisqually Delta sampling plan.

WERC held several meetings with collaborators, and interested parties, including: USGS Patuxent Wildlife Research Center (PWRC), USGS Pacific Coastal and Marine Science Center , USGS Western Fisheries Research Center, and the Nisqually Reach Nature Center to elicit input on the need for monitoring or applied research to address management needs.

With our partners, we finalized our monitoring approach based on historic channel networks. Sampling locations were identified along the northern, middle, and southern reaches of historic channels with integrated sampling efforts along the same hydrologic gradient. Photo-interpretations, sediment and geomorphology, hydrology, vegetation, and invertebrate sampling were coordinated at the same locations so that these parameters can be directly related to each other for greater interpretive power as the restoration progresses. Bird surveys spanned across the entire restoration project area. The monitoring framework is also scalable to answer management and research goals that range from change detection to comparing the realized function of the restorations to reference sites, and older restorations conducted by the Tribe.

We leveraged funds/support from EPA, the Refuge, PWRC, and the Students In Support of Native American Relations (SISNAR) internship program, and WERC and established a monitoring framework, initiated a partner website, hired a full time restoration biologist and summer intern, established monitoring locations, installed water level loggers, and characterized pre- and post restoration condition.

Method development
WERC has over a decade of experience providing monitoring and science support for restoration of salt ponds and wetlands in the San Francisco Bay estuary. We tailored our in-house technical methods that we have adapted from our field experiences, published methods, standard operating procedures used by estuarine ecologists, and expert opinions for the Nisqually Delta.

Methods

Aerial photography and remote sensing

Aerial photography is a valuable remote sensing tool that provides information such as vegetation colonization patterns over a large area over time. A pre-restoration true color and color infra-red aerial photograph was flown on 23 June 2009 at low-tide. In December 2009 and March 2010, the first post-restoration aerial photographs were flown to examine channel morphology and the placement of the Refuge boardwalk during construction. Color infrared (IR) aerial photographs were georeferenced to UTM NAD 83 (ArcGIS, ESRI) using registered targets or landmarks. Color IR is well suited to distinguish vegetation signals from mud and bare ground than true color aerial photography. Color infrared pixels were categorized into land cover classifications (such as water, mudflat, wetland vegetation, upland vegetation, and bare ground) using GIS (ERDAS Imagine Software, Leica Geosystems) and analyzed the percent cover of each category. Vegetation colonization will be supplemented with on-the-ground vegetation surveys (below).

Photo-documentation

Photo-documentation provides an economical and effective way to qualitatively document restoration progress over time. Pre-restoration, photopoints were selected at 42 sites throughout the project area to show hydrological and vegetative changes as a result of restoration actions (Figure 3). Photos were taken from left to right, in full 360 degrees with overlapping edges, to allow the photos to later be stitched together using computer software to create unified panoramic images. By returning to the same points over time, these panoramas will provide visual documentation of large-scale changes during the restoration that provide context for describing the quantitative measures of change to the Nisqually system.

Figure 3. Photopoints selected for repeat photo-documentation during Nisqually restoration process.

Hydrology and water quality: restoration area

WERC installed six water level loggers (Solinst and Telog Instruments) and staff gauges along McAllister Creek, Nisqually River, and Red Salmon Slough prior to dike removal. Four loggers also recorded conductivity and water temperature. For each of these waterways, one logger was placed in the upper reach of the estuary and a second near the mouth where it empties into Puget Sound. Some loggers were knocked down by large algal mats, logs and debris, which required re-deployment or replacement. Water level loggers continuously monitor tide levels and staff gages referenced to NAVD88 are used to converted water level readings to NAVD88 (ft).

The Refuge and Ducks Unlimited provided existing YSI water quality meter and equipment for the installation of a YSI water level, conductivity, and temperature meter at the Nisqually Reach Nature Center (at the mouth of McAllister Creek). We dedicated a USGS field laptop solely for this water quality meter. The laptop collects and stores the data and we programmed the laptop to upload the most recent data packet to the website, where the generation of graphical displays are automated to produce graphs of real time data on the website: *www.nisquallydeltarestoration.org/monitoring*

Hydrology and water quality: estuary and nearshore

Physical processes in estuaries such as inundation, salinity variation, and water circulation patterns are dynamic. Along with freshwater inputs, the rise and fall of tides are the medium of energy exchange in estuary systems. River and tidal currents carry nutrients and sediment, create elevational and salinity gradients, and provide access to the marsh for fish and other aquatic organisms. To examine the processes that affect transport and mixing of these waters and particulates in the estuary, Acoustic Doppler Current Profilers (ADCP) were deployed at select sites across the nearshore tide flats and newly restored channels to characterize circulation patterns before and after dike removal. Conducted by our partner group USGS Pacific Coastal and Marine Science Center , the ADCP was used to measure water levels, current velocities and directions and particulate backscatter throughout the water column. These data will help characterize processes controlling sediment transport and be valuable for testing numerical circulation model simulations, including the hydrodynamic and sediment transport (HST) model developed to assess design alternatives (ENSR 1999).

Sediment and geomorphology: restoration area

Channel cross-sections provide useful information on the development and geomorphological changes to tidal channels over time. To measure channel cross sections, a line was stretched from bankfull to bankfull perpendicular to the channel flow, and depths from the line to the channel bottom are measured in 0.5 meters intervals. Channel cross sections were measured at the northern (near the water level logger), middle, and southern sections (near water level loggers) of major historic slough sections prior to dike removal and again post-restoration. During each sampling period, we obtained 12 channel cross sections along four major slough networks (Shannon, Unit 1, Leschi, and Unit 3). Channels are expected to widen and/or deepen after reconnection to Puget Sound tides.

Sediment pins are permanent depth poles used to measure sediment accretion and erosion over time. The poles are surveyed to NAVD88 so that elevation of the sediment surface can be calculated by the pole height. As sediment accretes, the length of the exposed pole will decrease and vice versa. Thirty-nine sedimentation pins (2" PVC pipe, schedule 40) were installed and measured near channel cross sections and extended perpendicular to the channel along permanent vegetation transects to measure sediment accretion/erosion patterns in relation to distance from channel. Sediment pins are measured annually to examine the sedimentation rate.

We used our integrated bathymetric system consisting of a variable frequency acoustic profiler (Navisound 210; Reson, Inc., Slangerup, Denmark), real time kinematic global positioning system unit (RTK GPS; Leica Smartpole 1200), and laptop computer mounted on a shallow-draft, flat-bottom boat (Bass Hunter; Cabelas, Sidney, NE) to map the bathymetry of channels. The echosounder determines water depth, while the RTK GPS determines location and elevation as the boat travels over shallowly inundated surfaces. Data are integrated and processed in SAS (SAS Institute 1999) and a bathymetric coverage will be generated in Geostatistical Analyst (ArcGIS; ESRI, Inc.). Annual sedimentation differences can be analyzed over surfaces using bathymetry maps.

The placement of the channel cross sections, water level loggers, sediment pins, and vegetation transects (that extend from the channel cross section into the marsh) was designed so that changes in physical properties such as elevation and hydrology, can be related to biological processes such as vegetation colonization. Bathymetry maps can be used to compare changes over time or integrated with LiDAR datasets. With elevations and water levels, inundation times can be calculated to predict the type of vegetation community that might colonize and establish at select locations. This grant supported the design and data collection of inputs for models and integrated analyses of biological responses to physical parameters.

In addition, the characterization of sediment properties is critical for colonizing benthic invertebrate communities or colonizing vegetation. We collected 27 soil samples and analyzed them for soil texture, soil pH, organic matter content, and nutrients (A&L Laboratories).

Sediment and geomorphology: estuary and nearshore

In addition to the project area itself, restoration will have effects on the greater estuary and nearshore habitats. Working in cooperation with the USGS Pacific Coastal and Marine Science Center , high-resolution terrestrial LIDAR mapping was conducted across the neashore environment of the Nisqually Delta flat on the footprint of the northern dike, which was removed in August 2009 as per the restoration plan. These data will serve as baseline data to examine geomorphic change, sediment transport, and numerical sediment transport modeling with dike removal.

Vegetation

In conjunction with aerial photography and remote sensing, on-the-ground plant surveys provide information on species composition and condition. Pre- and post-restoration vegetation surveys were conducted at the Refuge restoration area, Phase 2 Tribe restoration area and reference marsh in 2009 and 2010. Vegetation sampling at the Tribe Phase 1 restoration area was added in 2010. Vegetation sampling was conducted during summer when vegetative cover is at its maximum to track changes of species extent, species richness, plant cover of natives and exotics, and vegetative condition (height and density). Permanent, 40-m (50-m in 2010) point-intercept transects (0.5 m intervals) were established to determine the composition, height, and percent cover of plant species and to detect changes in vegetation through time. A 0.25 m^2 grid was placed at the beginning, middle, and end of each transect (3 quadrats per transect) to estimate mean stem density, height, and ocular estimates of percent cover of each species. The location of target plants or invasive species (such as reed canary grass *Phalaris arundinaceae*) were tracked with GPS ground surveys or high precision aerial photographs.

These data will allow for future development of vegetation colonization rates (given a certain inundation and salinity regime) at Tribe restorations of varying ages and a reference marsh. Colonization and establishment rates may be used to project the spatial patterns of future vegetation communities that wcould establish at the Refuge restoration, given elevation and salinity tolerances.

Invertebrates

Benthic invertebrates provide critical food resources for fish and birds that use the estuary and serve as indicators for physical characteristics such as water quality and sediment characteristics. We originally set out to characterize the benthic invertebrate community with several cores. After discussing and coordinating with research collaborators we agreed to do a much broader and wider extent of invertebrate collection that would span a longitudinal gradient from the restorations out into the tidal flats. We expended our efforts to collect and sieve these additional samples and they were archived for analyses with other funding sources.

Invertebrate sampling was coordinated with Western Fisheries Research Center (WFRC) so that their samples along the nearshore environment would be comparable to within the restoration site. Benthic invertebrates were sampled prior to dike removal from the mouth, middle, and upper reaches of four historic tidal channels (n = 36). At each location, benthic cores (10 cm diameter, 10 cm depth) were collected in August (during bird migratory season) along with physical variables such as water quality and sediment characteristics (soil texture, particle size, pH, organic matter content, and nutrients). Samples were rinsed using a 0.5 mm sieve to remove sediment and then preserved in ethanol with rose Bengal dye (a dye that stains live tissues to aid sorting).

We learned that benthic invertebrate collection, sieving, sorting, and identification procedures was greatly underestimated. Funds have been procured through the ESRP (Estuary and Salmon Restoration Program) to help process samples collected in 2010. Invertebrate collection was coordinated with WFRC so that invertebrates were collected along transects that spanned an onshore to offshore gradient, and samples were collected at the same time period with standardized methodologies.

Birds

The Refuge provides foraging, resting, and overwintering habitat for migratory waterfowl and shorebirds along the Pacific Flyway. A single pre-restoration bird survey occurred in September 2009. This survey did not represent typical pre-restoration conditions since the area was drained in preparation for restoration construction and dike removal. Nonetheless, the survey provides a snapshot of bird presence prior to restoration and repeat post-restoration bird surveys are ongoing.

Post-restoration area bird counts are conducted monthly during high tide using binoculars, spotting scopes, experienced bird observers, and numerous volunteers to detect trends in presence and abundance over time and site. A 250 m UTM grid is overlaid onto the site so observers can reference the grid in which birds are detected. Observers record grid number, bird species, number, behavior (i.e., foraging, roosting, calling, flyover, swimming), and habitat (i.e., mud flat, marsh plain, open water, aerial, upland, or levee). Birds are grouped into guilds for analyses and trends. Breeding birds or nests were recorded if encountered. Bird species richness and density will be tracked over time and related to changes in water levels. The enhanced managed freshwater marshes are also included in these surveys.

This bird dataset provides trends over time by site; differences over time can reflect changes in habitat availability (i.e., water depth). Integration of multiple datasets (water levels, elevations), along with preferred foraging depth for various avian guilds can provide a better understanding of the habitat availability by site and over time as the restorations progress. There is growing interest in the effects of estuarine restoration on waterbird productivity and habitat use, however, our data alone are insufficient to address these questions. Simple comparisons of bird abundances with current and historic datasets would be misleading because of differences in methods used to collect data, site accessibility, tide levels, and species detection probabilities. Habitat use and productivity of birds in response to estuarine restoration would require a more in-depth scientific study (i.e., telemetry, relative contribution of restoration site to diets, or carrying capacity).

Results and Discussion

Aerial photography and remote sensing

Aerial photographs from pre-restoration (July 2009) and post-restoration (December 2009, March 2010) were stitched together and distributed to partners. Using ArcGis (ESRI) and ERDAS Imagine Software (Leica Geosystems), preliminary land cover classifications were generated for December 2009 and March 2010 (Figure 4, 5). In combination with field vegetation surveys, this remote sensing data will help track vegetation colonization by estuarine plants and also document changes to the hydrological and geomorphological systems. Repeat analyses over time can show changes of vegetation extent (i.e., vegetation colonization within Refuge restoration or eelgrass beds during low tide along delta front).

Land cover classifications can be difficult to interpret because vegetation that is captured on the infrared aerial photograph cannot be distinguished by species. Basic categories include: water, dead or senescent vegetation, upland vegetation/trees, marsh vegetation, eelgrass, or algae, and impervious surfaces (Figures 4, 5). Interpretations must be made with local site knowledge and preliminary classifications are presented to illustrate the type of vegetation detection is possible over a large spatial scale. Data on percent cover of each land cover type is not presented here because we are trying to improve upon preliminary models for a more accurate spatial depiction and quantification of tidal marsh vegetation cover. In March 2010 (Figure 5), the restoration within the Refuge was dominated by dead or dying plant material (from on the ground data and observations), yet a marsh vegetation signal was detected, most likely due to algae. Further analyses using smaller patch sizes will be conducted to refine classifications with the goal to distinguish algae or submergent vegetation from emergent tidal marsh vegetation.

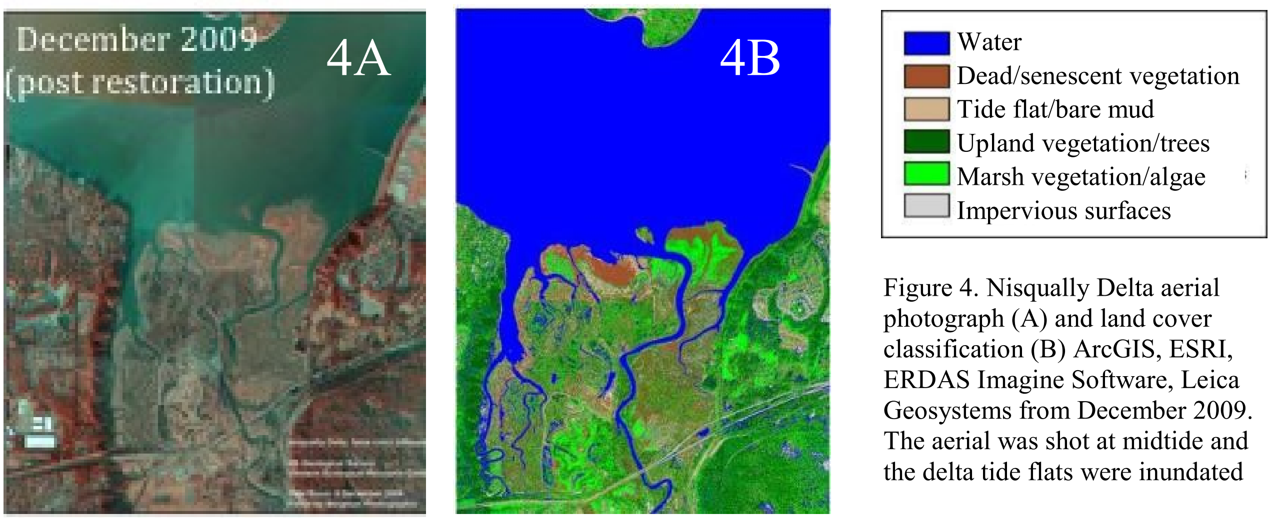


Figure 4. Nisqually Delta aerial photograph (A) and land cover classification (B) ArcGIS, ESRI, ERDAS Imagine Software, Leica Geosystems from December 2009. The aerial was shot at midtide and the delta tide flats were inundated

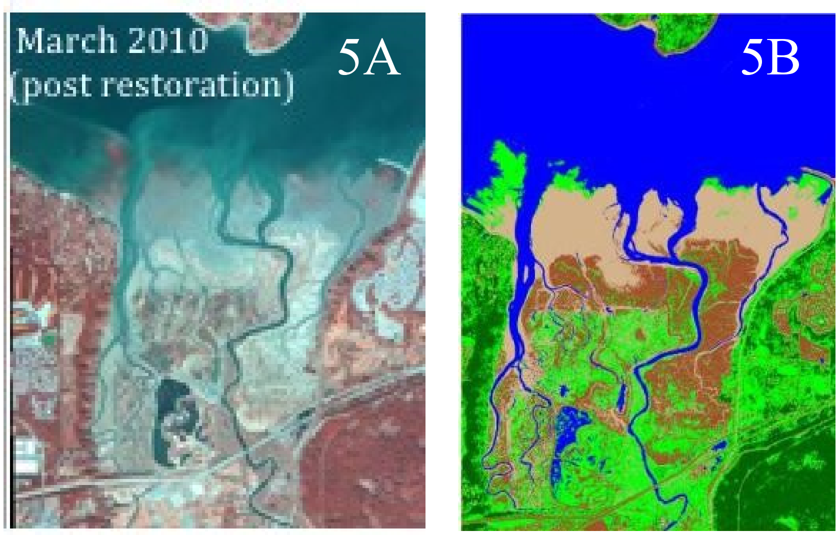


Figure 5. Nisqually Delta aerial photograph (A) and land cover classification (B) ArcGIS, ESRI, ERDAS Imagine Software, Leica Geosystems from March 2010. The aerial was shot at low tide and the delta tide flats were exposed. Eelgrass beds in the northwest of the tide flats

Photo-documentation

Pre-restoration photopoints were selected and photographed in the summer of 2009 to visually document the landscape before tidal restoration. These points were rephotographed in April and October 2010 to provide a qualitative time series of the restoration process. Figure 6 below shows an example repeated panoramaic images. The Unit 4 pre-restoration image (A) depicts the vegetation patterns of the diked landscaped during peak seasonal growth, (B) shows the site approximately seven months post-tidal restoration, and (C) captures the site a year after the dike was breached from a newly-installed public access boardwalk.

Figure 6. Example of Nisqually photodocumentation from Shannon Slough North: A) Pre-restoration (Summer 2009), B.) Post-restoration I (April 2010), and C.) Post-restoration (October 2010).

Hydrology and water quality: Restoration Area Six water level loggers (Solinst, YSI and Telog Instruments) and staff gauges were installed along McAllister Creek, Nisqually River, and Red Salmon Slough prior to the breaching of the dike. Following tidal restoration, loggers were routinely maintained and downloaded to monitor the hydrologic development of the project site. We've recorded a tidal range of 14-16 feet at our logger at the Nisqually Reach Nature Center and current data is posted on our website: *www.nisquallydeltarestoration.org* (Figure 7).

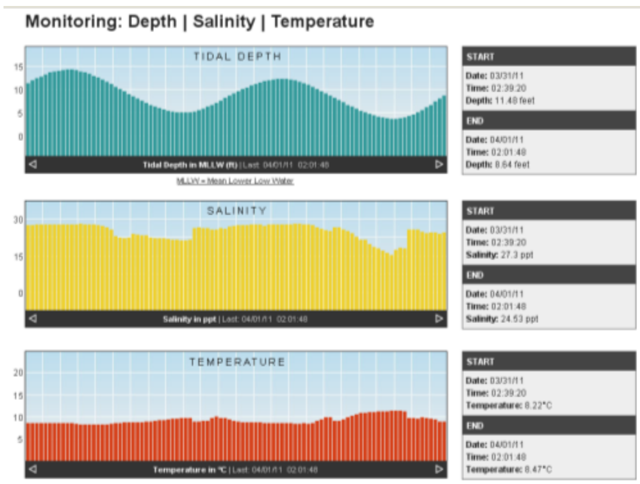


Figure 7. Real time water levels (MLLW ft), salinity, and temperature in the Nisqually Delta over a 24 hour period.

The continuation of hydrology monitoring provides trend information and will support sediment and geomorphology models, used to create inundation frequency curves for a range of elevations, establish bird or fish habitat accessible habitat times, capture extreme tidal events, and detect larger-scale changes to the system.

This funding source supported the installation, collection, and maintenance of the water level loggers and basic summary graphs of the data. Continuation and further analyses of hydrology data are partially supported through other funds.

Hydrology and water quality: estuary and nearshore

ADCP's were deployed temporarily at the mouth of Madrone Slough to characterize circulation patterns after dike removal. Average velocity in the restored Madrone Slough between May 25th and June 1st, 2010 was offshore at 22 cm/sec (Figure 8). These data will help characterize processes controlling sediment transport and be valuable for testing numerical circulation model simulations, including the hydrodynamic and sediment transport model developed to assess restoration impacts (ENSR 1999).

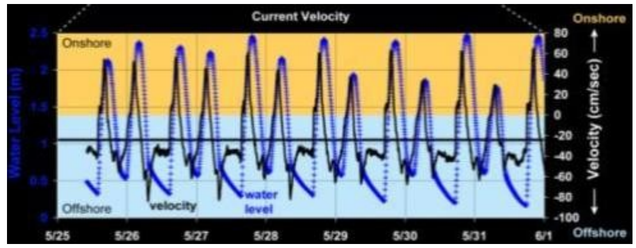


Figure 8. Water depth (blue line) and velocity (black line) at the mouth of Madrone slough between May 25th and June 1st, 2010 (USGS Pacific Coastal and Marine Science Center).

Sediment and geomorphology: restoration area

Channel cross-sections were completed pre-restoration (Summer 2009) and post-restoration (Fall 2010) at the north, middle, and southern portions of Shannon, Unit 1, Leschi, and Unit 3 tidal channels. Prior to restoration, the elevation of the channel bottom at Unit 1 middle was relatively even with approximately a 0.5 meter range between the top of the bank and channel bottom (Figure 9). After tidal restoration, the channel eroded almost 1m at the deepest point of the V-shape channel. In comparison, channel cross-sections at the southern portion of Unit 1, in the marsh interior, remained relatively unchanged. These results are likely due to greater water velocity with proximity to the channel mouth.

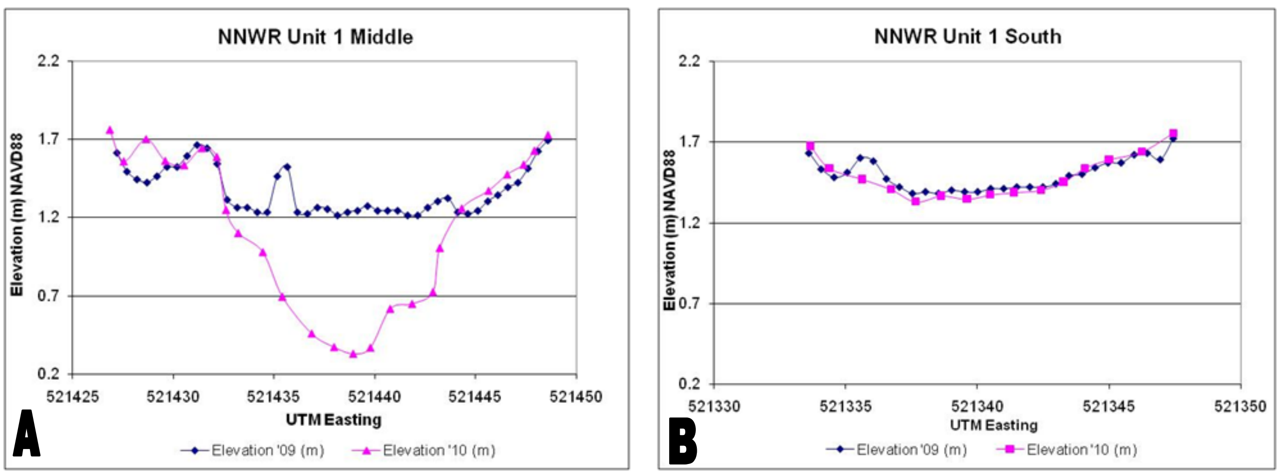


Figure 9. Channel cross-sections from Unit 1 comparing channel morphology from the middle reach of the channel (A) to the southern portion of the channel, furthese from the Dike (B) between 2009 (blue) and 2010 (pink). Moving from the west to east banks of the of the channels along the x-axis, the line represents the elevation of the channel bottom at a 0.5 m scale. The Middle location deepened by almost a meter from pre- to post-restoration while the South section remained relatively unchanged.

Sediment accretion and loss was measured at 39 sediment pins throughout the Refuge restoration site, one year after dike removal. After a the first year of the restoration of estuarine conditions, even distribution of accretion across the restoration site with a trend toward greater accumulation along the upper reaches of the restored tidal channels (Figure 10), though no statistically significant differences were detected ($F = 1.079$, $P = 0.3522$).

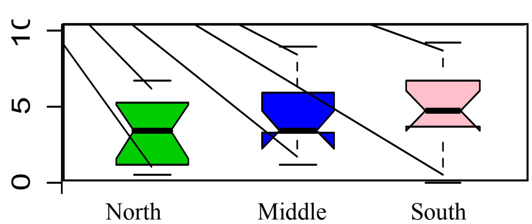


Figure 10. Sediment accumulation (cm) notched box plots of median, 25th, and 75th percentiles (boxes), and the maximum and minimum values (whiskers) at the north, middle, and southern locations of major restored channels.

Bathymetry datasets from channels are being processed and integrated into LiDAR datasets and will be made available once the data are merged. Analysis of 27 soil samples taken in conjunction with benthic invertebrate sampling show that the percent sand varied from 32% to 76%, the percent silt ranged from 11% to 60%, and percent clay ranged from 14% to 27% .

Organic matter content ranged from 1.7 and was as high as 68.4%, which was taken within a patch of reed canarygrass and reflected the dense fibrous roots.

Sediment and geomorphology: estuary and nearshore

In August 2009, terrestrial LiDAR (light detection and ranging) was surveyed along the northern dike to document pre-restoration elevations (Figure 11). From the LiDAR image, the channels (in red) on the Puget Sound side of the dike were exposed during low tide, while the channels behind the dike still held water. The highest elevation areas were the dike and vegetated edges of the historic channels within the restoration area and the western edge of McAllister Creek (blue). Future LiDAR remote sensing will allow for analysis of landscape-scale elevation changes following tidal restoration, and help inform hydrological and geomorphological modeling.

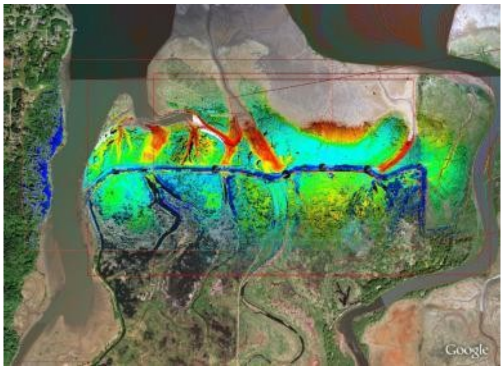


Figure 11. Terrestrial LiDAR along northern dike, August 2009. Red represents lower elevation and blue represents higher elevations (USGS Pacific Coastal and Marine Science Center).

Vegetation

We detected a total of 85 plant species in a single pre-restoration vegetation survey in 2009 and a single post restoration vegetation survey in 2010 (Appendix B). Our transect and quadrat vegetation surveys across the Refuge prior to restoration detected over 75% cover of invasive species, primarily reed canary grass (*Phalaris arundinaceae;* Figure 12), which had an average height of 1.2 m. In comparison, the Phase 2 restoration and reference marshes on the west side of the Nisqually River consisted of a mixed community of tidal marsh species such as salt grass (*Distichlis spicatum*) and perennial rye grass (*Lolium perenne*). Reed canary grass was not detected in the restored Phase 2 or Reference marshes.

One year following restoration, we detected less than 1% reed canary grass cover along permanent transects within the Refuge. The Phase 2 restoration and reference marshes continued to be represented by a mixed species community with salt grass (*Distichlis spicatum*), pickleweed (*Sarcocornia pacifica*), and baltic rush (*Juncus balticus).*

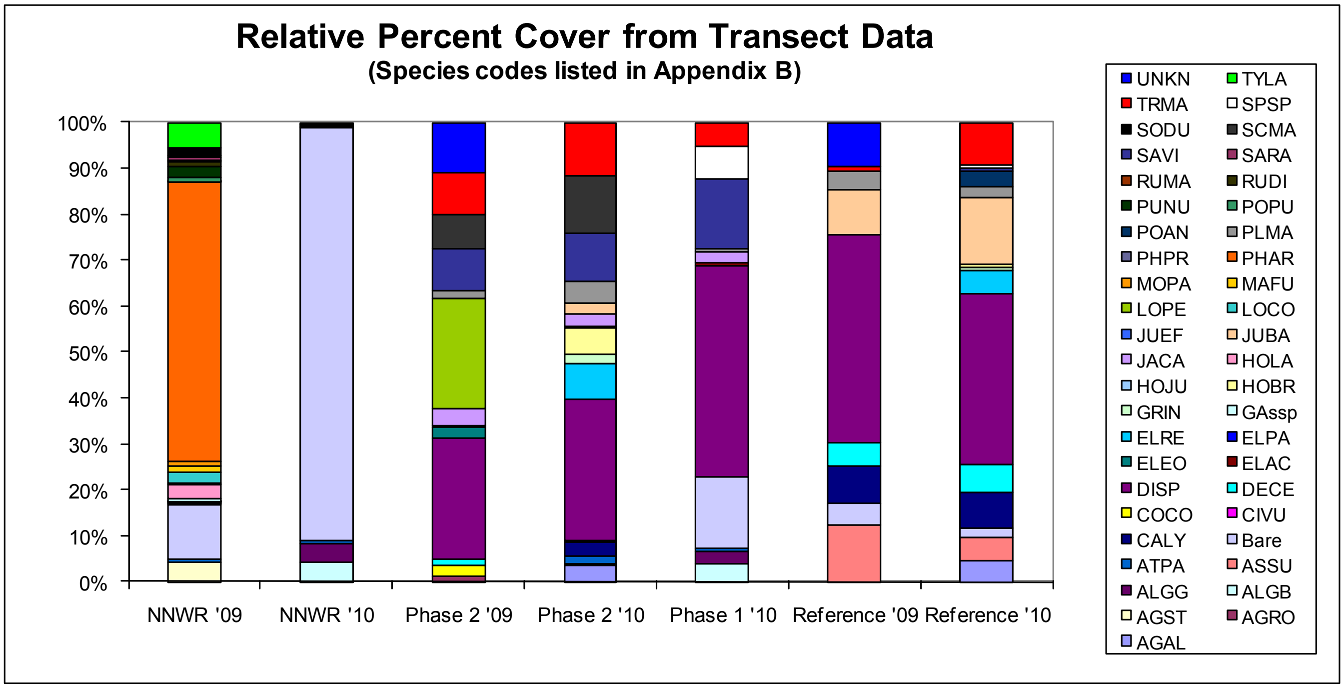


Figure 12. Relative percent cover along permanent vegetation transects in 2009 and 2010. Sites are Nisqually NWR (NNWR), Phase 2, Phase 1, and Reference.

Invertebrates

We originally set out to characterize the benthic invertebrate community with several cores. Research discussions with collaborators (WFRC) and partners led to a more ambitious invertebrate collection that would span a longitudinal gradient from the restorations out into the tidal flats. We expended our efforts to collect and sieve these additional samples and they were archived for analyses with other funding sources. We collected pre- and post-restoration in August 2009 and August 2010. Samples were sieved and preserved in 95% ethanol for later processing and identification. Funds have been procured through the ESRP (Estuary and Salmon Restoration Program) to process these samples in 2011.

Figure 13. Collecting benthic cores at Phase 2. Photo by J. Wieser.

Birds

During a single pre-restoration bird survey, less than 2,000 birds were counted in the project area and were largely composed of passerines and dabblers (dabbling ducks; Figure 14). The single pre-restoration survey represents only a snapshot of pre-restoration site conditions during a time when the interior was drained in preparation for dike removal. Thus we focus on post restoration bird trends.

We detected 138 bird species during our monthly post-restoration bird surveys. Bird abundance varied by season: dabblers, such as American wigeon (*Anas americana*) and Northern Pintail (*Anas acuta*), had the greatest abundance in December (almost 8,000 dabblers) and almost 2,000 geese (primarily Canada [*Branta canadensis*] and Cackling [*Branta hutchinsii*]) were counted in large flocks in March. During the late spring and summer, overall waterfowl abundances declined because of migration to spring/summer breeding grounds, but passerines, such as European starlings (*Sturnus vulgaris)* and cliff swallows (*Petrochelidon pyrrhonota)*, increased in spring. Overall, shorebird detection remained relatively low, compared with other guilds, largely because surveys were conducted during high tides (to allow for access by boat). Shorebirds are typically more abundance during low tide when mudflat and sediments are exposed and accessible for foraging.

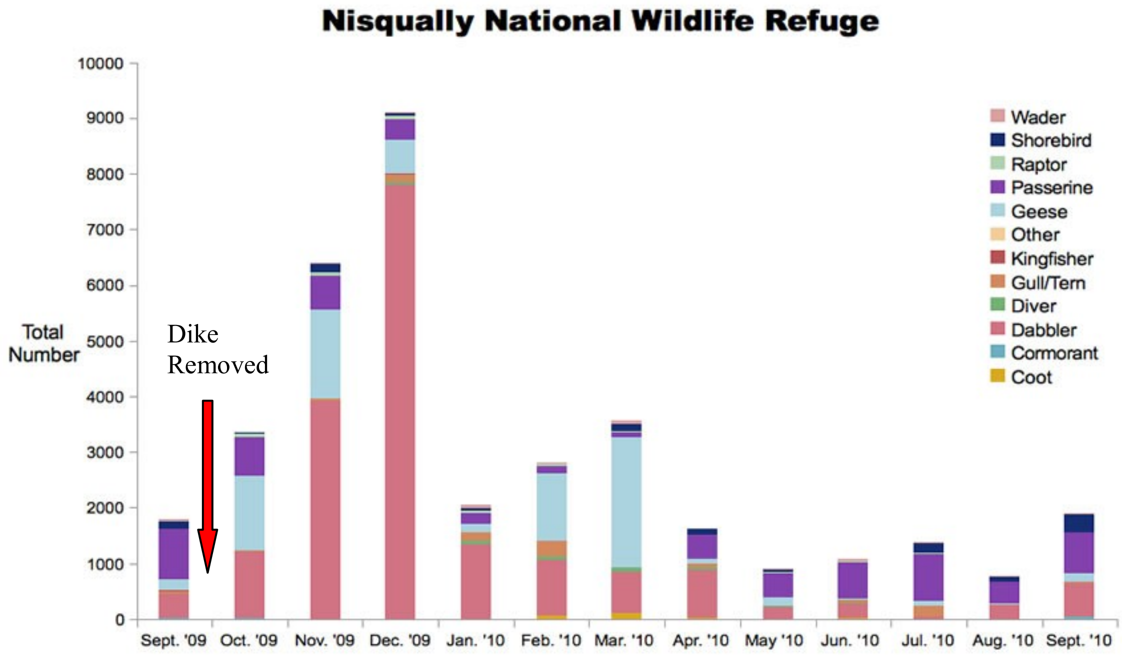


Figure 14. Total birds by foraging guild observed by month at the Nisqually Refuge from September 2009 – 2010.

Task A4. Provide support for adaptive management and public outreach.

Adaptive management

WERC participated in several coordination meetings and outlined details of a bio-physical monitoring plan to effectively track changes to the restoration after dike removal. We work closely with the Refuge to provide updates that would elicit management actions.

One example of this close partnership and resulting adaptive management strategy occurred in late summer, 2010. During the first year after dike removal, natural tidal exchange cleared out freshwater aquatic vegetation that had filled in some of the historic channels within the Refuge restoration site. Vegetation in the upper reaches of Leschi Slough, however, did not clear, resulting in channel constriction and reduced drainage even during low tides. Concerns were raised that without full tidal exchange, water temperatures and dissolved oxygen levels in the channel may not be suitable for salmonids. Water quality measurements made by the Tribe confirmed this. The Refuge took decisive action and dredged along the channel through the aquatic vegetation, creating a corridor for tidal flow. Since dredging, we have measured increases in dissolved oxygen and greater tidal range and tidal exchange in the channel in the marsh interior.

Outreach

A partner website was developed to provide a centralized location for updates of the restoration project for the public (Figure 15). WERC has coordinated with partners to establish, maintain, and provide regular science updates including real time weather data, real time water quality data, updated restoration photos, and 360 Degree Panoramic photographs of the pre-restoration conditions. The website serves as a public portal on restoration findings and provides a means for transparency of restoration progress.

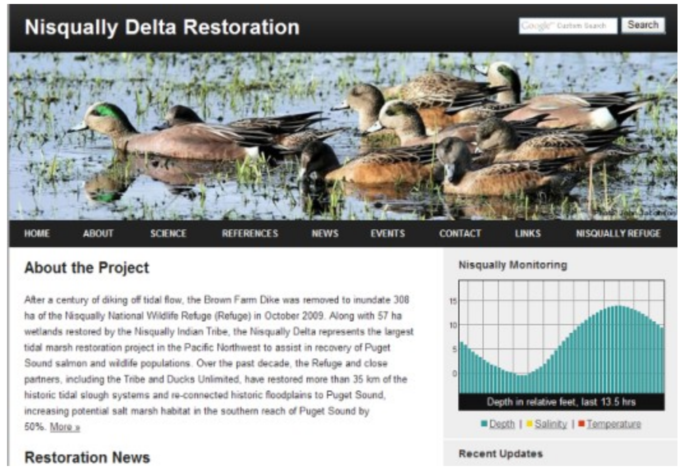


Figure 15. The Nisqually Delta Restoration website (Nisquallydeltarestoration.org).

WERC also participated in the Puget Sound River Delta Restoration and Monitoring Workshop, provided our monitoring protocols to Casey Rice (NOAA), Keith Dublanica (Mason County Conservation District), and Shannon Kirby (Skokomish Tribe), have held regular partner coordination meetings, and made several oral or poster presentations at local, regional, and national workshops and conferences (Appendix D). Regular restoration updates can be found at: *http://www.nisquallydeltarestoration.org/*

Data storage and archive

Electronic data files (i.e., imagery, spreadsheets, etc.) are provided to the Refuge and stored on USGS laptop computers at the Refuge and at an offsite location (USGS San Francisco Bay Estuary Field Station [SFBE], Vallejo, CA). Original data sheets are stored at the Refuge and hardcopies are sent to SFBE, Vallejo, CA. Data backup and data archiving occurs onto external hard drives. We've identified a need for a centralized data storage, data sharing, and data archiving system. Through additional support from ESRP, we've procured and installed a network attached storage device with three 2 TB drives with automated dual redundancy to protect data from drive failure.

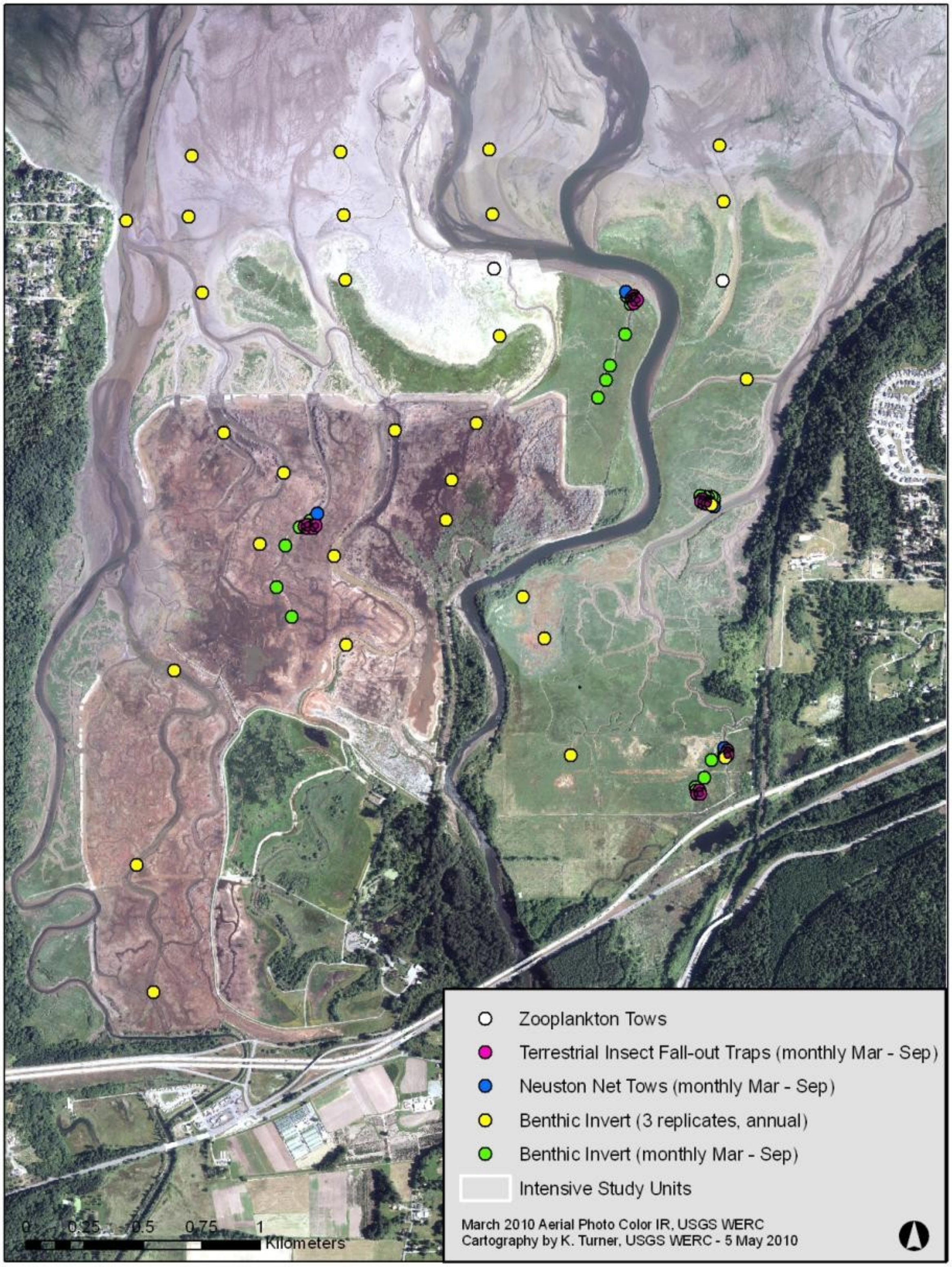
Acknowledgments

The restoration monitoring program was supported by EPA monitoring funds to the Refuge, USGS base funds and USGS intern awards (SISNAR and YIF). Portions of results were funded through other sources but are provided here for clarity. We thank the Refuge staff (J.E. Takekawa, D. Roster, M. Bailey, J. Barham, numerous Refuge volunteers) and the Nisqually Tribe (C. Ellings, F. Leischner, J. Cutler, J. Dorner) for monitoring support, USGS WERC staff/interns (A. Naljahih, L. Belleveau, H. Minella, H. Allgood, S. Bishop, K.B. Gustafson, S. Smith, E. Flynn, A. Smith, W. Chan, J. Felis, M. Iglecia,), USGS PCMG (E. Grossman, R. Kayen), Nisqually River Foundation (M. Holt, C. Iverson, A. David), Nisqually Tribe (J. Dorner, C. Ellings, F. Leischner, J. Cutler), Ducks Unlimited (S. Liske), and Nisqually Reach Nature Center (D. Hull).

Appendix A. Monitoring Maps

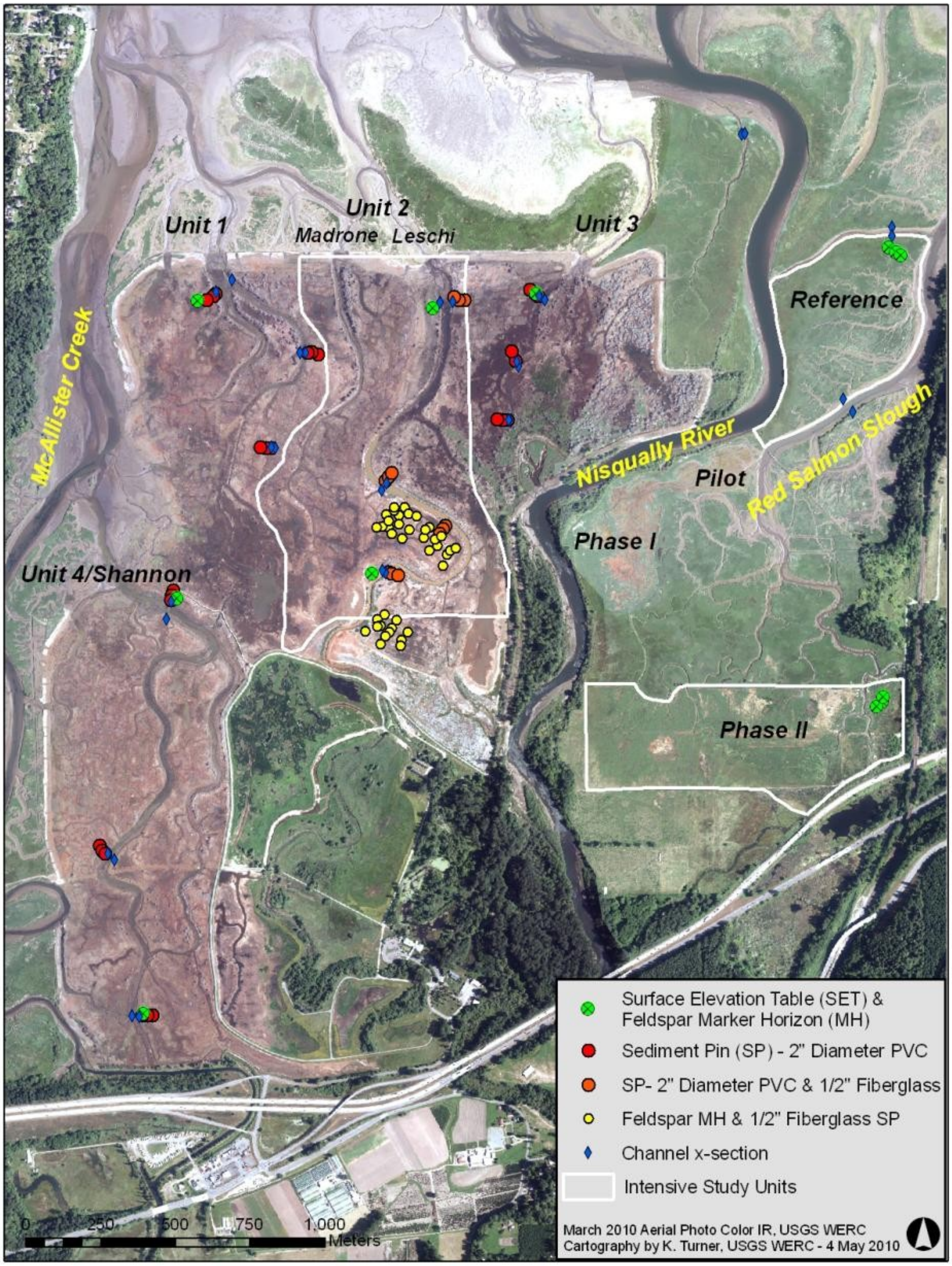
Appendix A.1. Invertebrate sampling locations throughout the Nisqually Delta.

Funds for terrestrial insect, neuston, monthly benthic samples was supplemented by multiple sources.

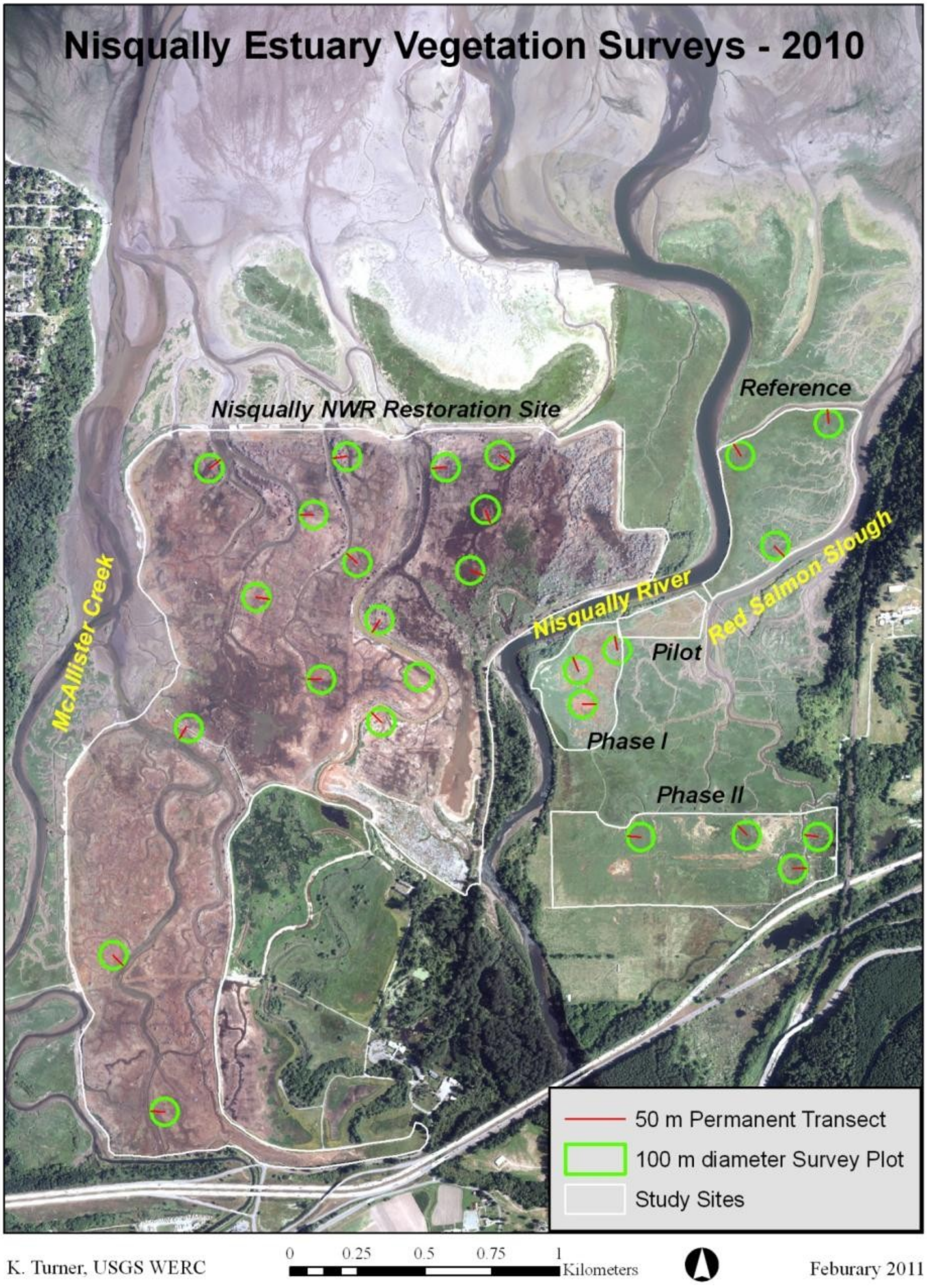


Appendix A.2. Sediment pin locations throuout the Nisqually Delta.

Surface elevation tables, feldspar marker horizons, and ½" sediment pin installation and measurements were supplemented by other funds.

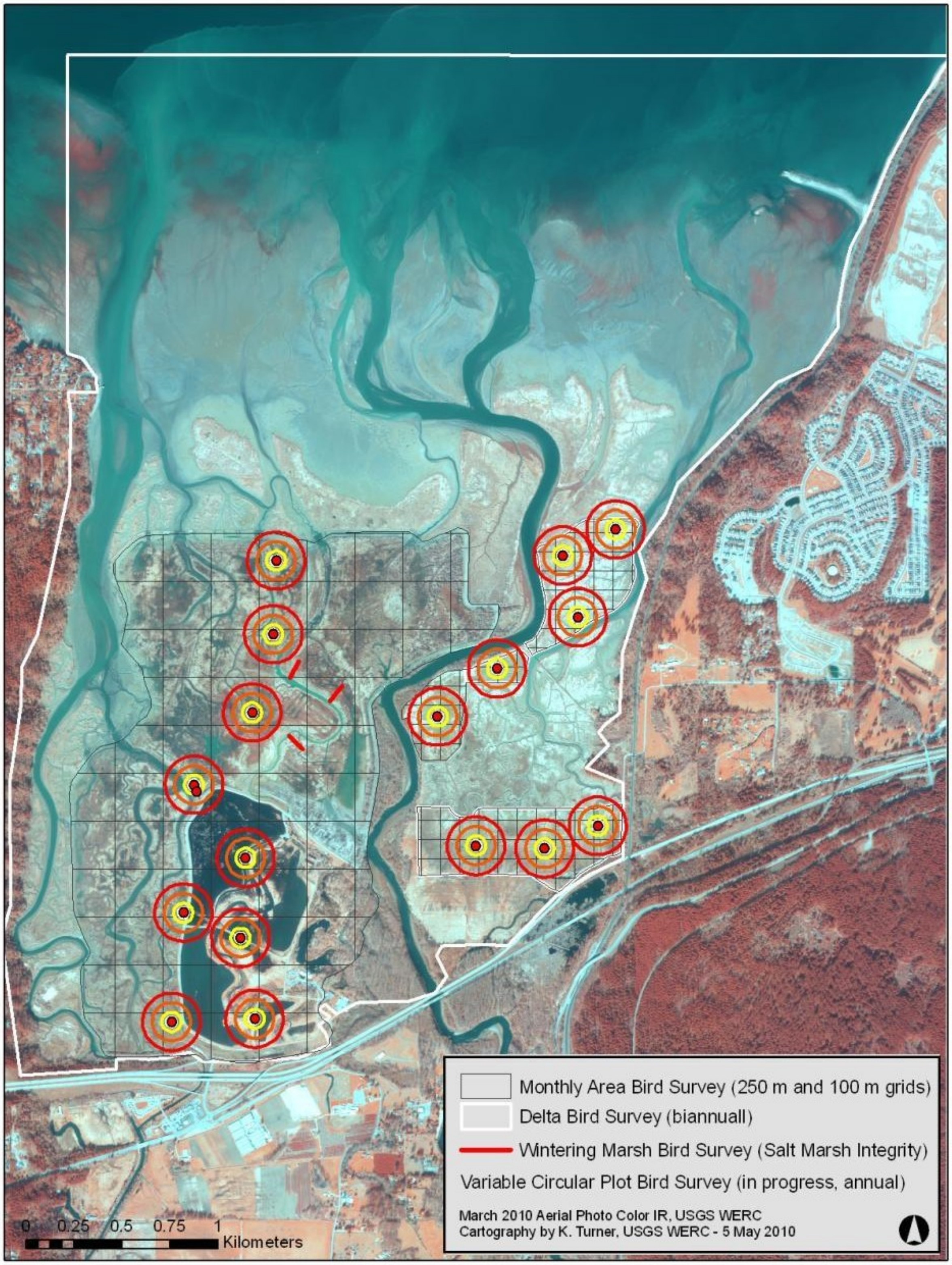


Appendix A. 3. Vegetation survey locations throughout the Nisqually Delta.



Appendix A. 4. Bird survey grid throughout the Nisqually Delta.

Point counts, winter marsh bird, and delta bird surveys were supplemented by other funds.



Appendix B. Plant species within the Nisqually Delta

Common Name	Scientific Name	Spp. Code
Colonial Bentgrass	*Agrostis alba*	AGAL
Creeping bentgrass	*Agrostis stolonifera*	AGST
Scarlet pimpernel	*Anagallis arvensis*	ANAR
Douglas' aster	*Aster subspicatus*	ASSU
Patent saltbush	*Atriplex patens*	ATPA
Australian saltbush	*Atriplex semibaccata*	ATSE
Fat hen	*Atriplex triangularis*	ATTR
Wild Oat	*Avena sativa*	AVSA
Coyotebush	*Baccharis pilularis*	BAPI
Alkali bulrush	*Bolboschoenus maritimus*	BOMA
Soft chess	*Bromus hordeaceous*	BRHO
Wild turnip	*Brassica rapa*	BRRA
Lyngby's sedge	*Carex lyngbyei*	CALY
Yellow star thistle	*Centaurea solstitialis*	CESO
Largeseed goosefoot	*Chenopodium macrospermum*	CHMA
California thistle	*Cirsium arvense*	CIAR
Bull thistle	*Cirsium vulgare*	CIVU
Brass buttons	*Cotula coronopifolia*	COCO
Salt-marsh dodder	*Cuscuta salina*	CUSA
Tufted hairgrass	*Deschampsia cespitosa*	DECE
Stinkwort	*Dittrichia graveolens*	DIGR
Salt grass	*Distichlis spicata*	DISP
Needle spikerush	*Eleocharis acicularis*	ELAC
Creeping spikerush	*Eleochris palustris*	ELPA
Ryegrass	*Elymus repens*	ELRE
Northern willow herb	*Epilobium ciliatum*	EPCI
Field horsetail	*Equisetum arvense*	EQAR
Fox tail	*Festuca myuros*	FEMY
Alkali heath	*Frankenia salina*	FRSA
Threepetal bedstraw	*Galium trifidum*	GATR
Sea milkwart	*Glaux maritima*	GLMA
Entire-leaved gumweed	*Grindelia integrifolia*	GRIN
Marsh gumplant	*Grindelia stricta*	GRST
Meadow barley	*Hordium brachyantherum*	HOBR
Foxtail barley	*Hordeum jubatum*	HOJU
Velvet grass	*Holcus lanatus*	HOLA
Mediterranean Barley	*Mordeum marinum*	HOMA
Salmarsh daisy	*Jaumea carnosa*	JACA
Common rush	*Juncus effusus*	JUEF
Baltic rush	*Juncus balticus*	JUBA
Canadian lettuce	*Lactuca canadensis*	LACA
Wild lettuce	*Lactuca serriola*	LASE

Common Name	*Scientific Name*	Spp. Code
Perennial pepperweed	*Lepidium latifolium*	LELA
Birdfoot trefoil	*Lotus corniculatus*	LOCO
Italian rye grass	*Lolium multiflorum*	LOMU
Perennial rye grass	*Lolium perenne*	LOPE
Crab apple	*Malus fusca*	MAFU
Sour clover	*Melilotus indica*	MEIN
Common reed	*Phragmites australis*	PHAU
Timothy canarygrass	*Phalaris angusta*	PHAN
Reed canary grass	*Phalaris arundinacea*	PHAR
Timothy grass	*Phleum protense*	PHPR
Bristly oxtongue	*Picris echioides*	PIEC
Sea plantain	*Plantago maritima*	PLMA
Silverweed	*Potentilla anserine*	POAN
Prostrate knotweed	*Polygonum arenastrum*	POAR
Marin knotweed	*Polygonum marinense*	POMA
Annual rabbitsfoot grass	*Polypogon monspeliensis*	POMO
Marsh cinquefoil	*Potentilla palustris*	POPA
Dotted smartweed	*Polygonum punctatum*	POPU
Pacific alkali grass	*Puccinellia nutkaensis*	PUNU
Creeping buttercup	*Ranunculus repens*	RARE
Common wild radish	*Raphanus sativus*	RASA
Curly dock	*Rumex crispus*	RUCR
Himilayian blackberry	*Rubus discolor*	RUDI
Golden dock	*Rumex maritimus*	RUMA
Pickleweed	*Sarcocornia pacifica*	SAPA
Red elderberry	*Sambucus racemosa*	SARA
Three-square bulrush	*Schoenoplectus americanus*	SCAM
Seacoast bullrush	*Scirpus maritimus*	SCMA
Common threesquare	*Scirpus pungens*	SCPU
European bittersweet	*Solanum dulcamara*	SODU
Spurrey	*Sperugula arvensis*	SPAR
Canadian sandspurry	*Spergularia canadensis*	SPCA
Cordgrass	*Spartina foliosa*	SPFO
Beach Sand spurrey	*Spergularia macrotheca*	SPMA
Red Sand spurrey	*Spergularia rubra*	SPRU
Salt-marsh chickweed	*Stellaria humifusa*	STHU
New Zealand spinach	*Tetragonia tetragonioides*	TETE
Sea arrow-grass	*Triglochin maritimum*	TRMA
Narrowleaf cattail	*Typha angustifolia*	TYAN
Broadleaf cattail	*Typha latifolia*	TYLA
Marsh violet	*Viola palustris*	VIPA
Common vetch	*Vicia sativa*	VISA
Hairy vetch	*Vicia villosa*	VIVI

Appendix C. Bird Species List

Common Name	Scientific Name	Code	Group
American Coot	*Fulica americana*	AMCO	Dabbler
American Green-winged Teal	*Anas crecca*	AGWT	Dabbler
American Wigeon	*Anas americana*	AMWI	Dabbler
Blue-winged Teal	*Anas discors*	BWTE	Dabbler
Cinnamon Teal	*Anas cyanoptera*	CITE	Dabbler
Eurasian Wigeon	*Anas penelope*	EUWI	Dabbler
Gadwall	*Anas strepara*	GADW	Dabbler
Mallard	*Anas platyrhynchos*	MALL	Dabbler
Northern Pintail	*Anas acuta*	NOPI	Dabbler
Northern Shoveler	*Anas clypeata*	NSHO	Dabbler
Ring-necked Duck	*Aythya collaris*	RNDU	Dabbler
Wood Duck	*Aix sponsa*	WODU	Dabbler
Belted Kingfisher	*Ceryle alcyon*	BEKI	Diver
Bufflehead	*Bucephala albeola*	BUFF	Diver
Common Goldeneye	*Bucephala clangula*	COGO	Diver
Common Merganser	*Mergus merganser*	COME	Diver
Double-crested Cormorant	*Phalacrocorax auritus*	DCCO	Diver
Hooded Merganser	*Lophodytes cucullatus*	HOME	Diver
Horned Grebe	*Podiceps auritus*	HOGR	Diver
Lesser Scaup	*Aythya affinis*	LESC	Diver
Pied-billed Grebe	*Podilymbus podiceps*	PBGR	Diver
Red-breasted Merganser	*Mergus serrator*	RBME	Diver
Red-necked Grebe	*Podiceps grisegena*	RNGR	Diver
Surf Scoter	*Melanitta perspicillata*	SUSC	Diver
Western Grebe	*Aechmophorus occidentalis*	WEGR	Diver
Cackling Goose and Aleutian subspp	*Branta hutchinsii leucopareia*	CACG	Goose
Canada Goose	*Branta canadensis*	CAGO	Goose
Greater White-fronted Goose	*Anser albifrons*	GWFG	Goose
Snow Goose	*Chen caerulescens*	SNGO	Goose
California Gull	*Larus californicus*	CAGU	Gull/Tern
Caspian Tern	*Sterna caspia*	CATE	Gull/Tern
Glaucous-winged Gull	*Larus glaucescens*	GWGU	Gull/Tern
Herring Gull	*Larus argentatus*	HERG	Gull/Tern
Mew Gull	*Larus canus brachyrhynchus*	MEGU	Gull/Tern
Ring-billed Gull	*Larus delawarensis*	RBGU	Gull/Tern
Thayer's Gull	*Larus thayeri*	THGU	Gull/Tern
Western Gull	*Larus occidentalis*	WEGU	Gull/Tern
American Crow	*Corvus brachyrhychos*	AMCR	Passerine
American Goldfinch	*Carduelis tristis*	AMGO	Passerine
American Pipit	*Anthus rubescens*	AMPI	Passerine
American Robin	*Turdus migratorius*	AMRO	Passerine

Common Name	Scientific Name	Code	Group
Anna's Hummingbird	*Calypte anna*	ANHU	Passerine
Band-tailed Pigeon	*Columba fasciata*	BTPI	Passerine
Barn Swallow	*Hirundo rustica*	BARS	Passerine
Bewick's Wren	*Thryomanes bewickii*	BEWR	Passerine
Black-capped Chickadee	*Poecile atricapillus*	BCCH	Passerine
Black-headed Grosbeak	*Pheuticus melanocephalus*	BHGR	Passerine
Black-throated Gray Warbler	*Dendroica nigrescens*	BTYW	Passerine
Brewer's Blackbird	*Euphagus cyanocephalus*	BRBL	Passerine
Brown Creeper	*Certhia americana*	BRCR	Passerine
Brown-headed Cowbird	*Molothrus ater*	BHCO	Passerine
Bullock's Oriole	*Icterus bullockii*	BUOR	Passerine
Bushtit	*Psaltriparus minimus*	BUSH	Passerine
Cedar Waxwing	*Bombycilla cedrorum*	CEDW	Passerine
Chestnut-backed Chickadee	*Poecile rufescens*	CBCH	Passerine
Cliff Swallow	*Petrochelidion pyrrhonata*	CLSW	Passerine
Common Raven	*Corvus corax*	CORA	Passerine
Common Yellowthroat	*Geothlypis trichas*	COYE	Passerine
Dark-eyed Junco (Oregon race)	*Junco hyemalis*	DEJU	Passerine
Downy Woodpecker	*Picoides pubescens*	DOWO	Passerine
European Starling	*Sturnus vulgaris*	EUST	Passerine
Fox Sparrow	*Passerella iliaca*	FOSP	Passerine
Golden-crowned Kinglet	*Regulus satrapa*	GCKI	Passerine
Golden-crowned Sparrow	*Zonotrichia atricapilla*	GCSP	Passerine
Hermit Thrush	*Catharus guttatus*	HETH	Passerine
House Finch	*Carpodacus mexicanus*	HOFI	Passerine
House Sparrow	*Passer domesticus*	HOSP	Passerine
Hutton's Vireo	*Vireo huttoni*	HUVI	Passerine
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	Passerine
Marsh Wren	*Cistothorus palustris*	MAWR	Passerine
Northern Flicker	*Colaptes auratus*	NOFL	Passerine
Northern Rough-winged Swallow	*Stelgidopterx serripennis*	NRWS	Passerine
Northern Shrike	*Lanius excubitor*	NSHR	Passerine
Orange-crowned Warbler	*Vermivora celata*	OCWA	Passerine
Pacific-slope Flycatcher	*Empidonax difficilis*	PSFL	Passerine
Pileated Woodpecker	*Dryocopus pileatus*	PIWO	Passerine
Pine Siskin	*Carduelis pinus*	PISI	Passerine
Purple Finch	*Carpodacus purpureus*	PUFI	Passerine
Purple Martin	*Progne subis*	PUMA	Passerine
Red Crossbill	*Loxia curvirostra*	RECR	Passerine
Red-breasted Sapsucker	*Sphyrapicus ruber*	RBSA	Passerine
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	Passerine
Rock Dove	*Columba livia*	RODO	Passerine
Ruby-crowned Kinglet	*Regulus calendula*	RCKI	Passerine
Rufous Hummingbird	*Selasphorous rufus*	RUHU	Passerine

Common Name	Scientific Name	Code	Group
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	Passerine
Song Sparrow	*Melospiza melodia*	SOSP	Passerine
Spotted Towhee	*Pipilo maculatus*	SPTO	Passerine
Swainson's Thrush	*Catharus ustulatus*	SWTH	Passerine
Tree Swallow	*Tachycineta bicolor*	TRES	Passerine
Varied Thrush	*Ixoreus naevius*	VATH	Passerine
Vaux's Swift	*Chaetura vauxi*	VASW	Passerine
Violet-green Swallow	*Tachycineta thalassina*	VGSW	Passerine
Warbling Vireo	*Vireo gilvus*	WAVI	Passerine
Western Meadowlark	*Sturnella neglecta*	WEME	Passerine
Western Wood-Pewee	*Contopus sordidulus*	WEWP	Passerine
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	Passerine
Willow Flycatcher	*Empidonax traillii*	WIFL	Passerine
Wilson's Warbler	*Wilsonia pusilla*	WIWA	Passerine
Winter Wren	*Troglodytes troglodytes*	WIWR	Passerine
Yellow Warbler	*Dendroica petechia*	YWAR	Passerine
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	Passerine
American Kestrel	*Falco sparverius*	AMKE	Raptor
Bald Eagle	*Haliaeetus leucocephalus*	BAEA	Raptor
Cooper's Hawk	*Accipiter cooperii*	COHA	Raptor
Great Horned Owl	*Bubo virginianus*	GHOW	Raptor
Merlin	*Falco columbarius*	MERL	Raptor
Northern Harrier	*Circus cyaneus*	NOHA	Raptor
Peregrine Falcon	*Falco peregrinus*	PEFA	Raptor
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	Raptor
Sharp-shinned Hawk	*Accipiter striatus*	SSHA	Raptor
Short-eared Owl	*Asio flammeus*	SEOW	Raptor
Turkey Vulture	*Cathartes aura*	TUVU	Raptor
American Golden-Plover	*Pluvialis dominica*	AMGP	Shorebird
Black-bellied Plover	*Pluvialis squatarola*	BBPL	Shorebird
Common Snipe	*Gallinago gallinago*	COSN	Shorebird
Dunlin	*Calidris alpina*	DUNL	Shorebird
Greater Yellowlegs	*Tringa melanoleuca*	GRYE	Shorebird
Killdeer	*Charadrius vociferus*	KILL	Shorebird
Least Sandpiper	*Calidris minutilla*	LESA	Shorebird
Lesser Yellowlegs	*Tringa flavipes*	LEYE	Shorebird
Long-billed Dowitcher	*Limnodromus scolopaceus*	LBDO	Shorebird
Red-necked Phalarope	*Phalaropus lobatus*	RNPH	Shorebird
Short-billed Dowitcher	*Limnodromus griseus*	SBDO	Shorebird
Sora	*Porzana carolina*	SORA	Shorebird
Spotted Sandpiper	*Actitis macuaria*	SPSA	Shorebird
Virginia Rail	*Rallus limicola*	VIRA	Shorebird
Western Sandpiper	*Calidris mauri*	WESA	Shorebird
Whimbrel	*Numenius phaeopus*	WHIM	Shorebird

Common Name	Scientific Name	Code	Group
Willet	*Catotrophorus semipalmatus*	WILL	Shorebird
Wilson's Phalarope	*Phalaropus tricolor*	WIPH	Shorebird
Wilson's Snipe	*Gallinago delicata*	WISN	Shorebird
Trumpeter Swan	*Cygnus buccinator*	TRUS	Swan
Tundra Swan	*Cygnus columbianus*	TUSW	Swan
American Bittern	*Botaurus lentiginosus*	AMBI	Wader
Great Blue Heron	*Ardea herodias herodias*	GBHE	Wader
Great Egret	*Ardea alba*	GREG	Wader
Green Heron	*Butorides virescens*	GRHE	Wader

Appendix D. Posters and presentations

Ellings, C., K. Turner, E. Grossman, K. Larsen, J. Cutler, S. Rubin, I. Woo, J.Y. Takekawa, A. Lind-Null, C. Curran, F. Leischner, S. Hodgson, A. David, J. Dorner, J. Barham and J. Takekawa. 2010. Expanding research to keep pace with extensive restoration in the Nisqually Delta. Puget Sound River Delta Restoration and Monitoring Workshop. Seattle, Washington. the Association of American Geographers. Oral Presentation. Seattle, WA

Ellings, C., K. Turner, E. Grossman, K. Larsen, J. Cutler, S. Rubin, I. Woo, A. Lind-Null, C. Curran, F. Leischner, S. Hodgson, and A. David. 2010. Expanding research to keep pace with extensive restoration in the Nisqually Delta. The 2010 South Sound Science Symposium. Poster Presentation. Shelton, Washington.

Turner, K., J.Y. Takekawa, and I. Woo. 2011. Return of the Nisqually estuary: restoration and monitoring. South Sound Estuary Association public lecture, January 2011. Oral Presentation. Olympia, Washington.

Turner, K., I. Woo, J. Y. Takekeawa, C. Ellings, F. Leischner, E. Grossman, J. Barham, and J. E. Takekawa. 2010. Restoring the Nisqually Delta: a coordinated science approach for adaptive management. Coastal and Estuarine Research Federation 20th Biennial Conference. Oral Presentation. Portland, Oregon.

Turner, K., J.Y. Takekawa, and I. Woo. 2010. Nisqually estuary restoration: monitoring the response. Spotlight on Science, October 2010. Oral Presentation. Portland, Oregon.

Woo, I., K. L. Turner, J.Y. Takekawa, C. Ellings, F. Leischner, S. Hodgson, J. Dorner, E. Grossman, S. Rubin, C. Curran, K. Larsen, A. Lind-Null, J. Barham, and J. E. Takekawa. 2011. Nisqually Delta Restorations: Integrating applied science within a monitoring framework. 9th Biennial USGS Pacific Northwest Science Conference. Oral Presentation. Vancouver, Washington.

Woo, I., K. L. Turner, J.Y. Takekawa, C. Ellings, F. Leischner, S. Hodgson, J. Dorner, E. Grossman, S. Rubin, C. Curran, K. Larsen, A. Lind-Null, J. Barham, and J. E. Takekawa. 2011. Nisqually Delta Restorations monitoring and applied research approach. Estuarine Restoration Workshop. Oral Presentation. Seattle, Washington.