U. S. DEPARTMENT OF THE INTERIOR
U. S. Geological Survey
Western Ecological Research Center

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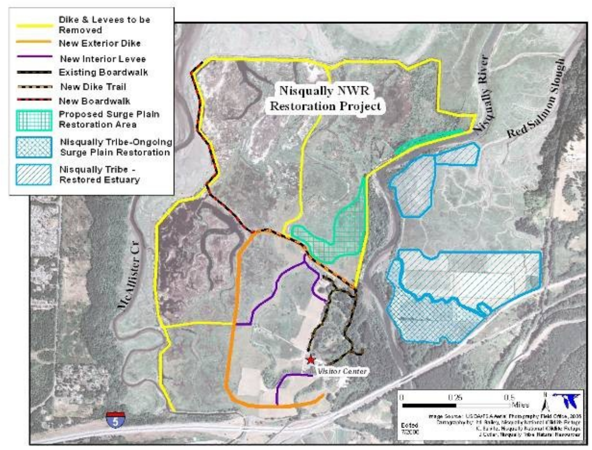
Restoration of the Nisqually Estuary: Monitoring Initial Progress of the Nisqually National Wildlife Refuge Tidal Restoration

Background and Justification:



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. Nearly 405 ha diked for farming in the late 1800s has been managed by the Refuge as freshwater wetlands since 1974. In 2008, the Refuge embarked upon the tidal restoration of 283 ha of estuarine habitat on the west side of the river (Fig. 1), consistent with the recently completed Comprehensive Conservation Plan goal to restore native habitats representative of the Puget Sound lowlands. 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 in 2002.

The Refuge tidal restoration plan was developed from an eight-year process that involved scientific and technical experts, agencies, tribes, non-government organizations, academic institutions, and public participants. It is anticipated to have widespread benefits to populations of anadromous fish and migratory birds (USFWS 2005; Ellings and Hodgson 2007), including the threatened Nisqually Fall Chinook salmon (*Oncorhynchus tshawytscha*) stock (NCRT 2001) and Nisqually winter chum salmon (*O. keta*) and many of the 275 bird species that use the Refuge, including many Pacific Flyway migrants. In 2008, a monitoring framework (Ellings 2008) was developed to document the effectiveness of the project. Monitoring in restoration projects has been called the equivalent of financial accounting in business, providing a way to track restoration progress and support adaptive management. Thus, it is critical to develop the monitoring of a restoration project in conjunction with construction to allow for immediate assessments and actions to improve its success.

In this proposal, we describe biophysical monitoring elements that will be initiated during the first year of the Refuge's tidal restoration project by the USGS Western Ecological Research Center (WERC) and its partners. WERC has over a decade of experience providing science support for restoration of salt ponds and wetlands in the San Francisco Bay estuary, working closely with federal and state management agencies (Takekawa et al. 2002, Takekawa et al. 2005, Woo et al. 2008). WERC will work closely with the Tribe, the USGS Pacific Science Center, Ducks Unlimited, and other restoration partners to document initial conditions and track physical changes as the levees are removed.

Objectives:

1. Develop specific monitoring methods and establish baseline conditions for the Nisqually National Wildlife Refuge tidal restoration.

2. Examine initial physical and biological changes after construction 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.

II. Scope of Services

The specific elements follow the monitoring framework (Ellings 2008), and we have provided a crosswalk relating the specific elements with the monitoring framework (Table 1).

Question 1: Were the processes outlined in the hydrodynamic and sediment transport (HST) model effectively restored?

The performance metrics that have been established are: a) Full Tidal Inundation: high tides inundate historical sloughs and regularly flood the restoration area and developing marsh plain; b) Full Tidal Evacuation: water evacuates restoration area during a receding tide; c) Salinity Influx: salinity in the project area is conducive to estuarine vegetation and; d) Sediment Transport /Deposition: fluvial sediments deposited during flood events cause marsh plain to aggrade.

Aerial Photography and Remote Sensing

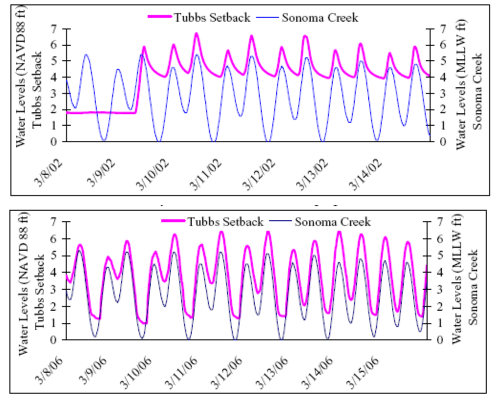
Aerial photo and land cover classification at Guadalcanal Restoration, Vallejo, CA

Aerial photographs shot at low tide when mudflats and channels are at maximum exposure are valuable tools for visual documentation of water drainage off the landscape and geomorphic change. We will take aerial photographs during the vegetative growing season. Color infrared (IR) aerial photographs will be georeferenced to UTM NAD 83 (ArcGIS, ESRI) using registered targets or landmarks. Color IR is better suited to distinguish vegetation signals from mud and bare ground than true color aerial photography. We will classify color infrared pixels into land cover classifications (such as water, mudflat, wetland vegetation, upland vegetation, and bare ground) using GIS (ERDAS Imagine Software, Leica Geosystems) and analyze the percent cover of each category. This remote sensing tool is valuable in tracking vegetation colonization over a large area over time. Vegetation colonization will be supplemented with on-the-ground vegetation surveys (below).

Photo-documentation

Photo-documentation with fixed, permanent digital photograph locations repeated over time is an economical method to qualitatively describe changes of the restoration. We will establish several locations throughout the restoration and take several digital panoramic photographs or photopoints. Photopoints will be taken seasonally at the same time as the aerial photographs and at extreme tide events to visually capture tidal extent.

Hydrology (Water levels): The rise and fall of tides are the medium of energy exchange carrying nutrients, sediment, and other materials; creating elevational and salinity gradients from mudflat to uplands; and providing access to the marsh for fish and other aquatic organisms during high tide. Characterizing tidal hydrodynamics with water level loggers will illustrate the rise and fall of tidal waters within the restoration site, compared to the adjacent sloughs outside the restoration. Patterns within a hydrograph can illustrate lag times (if present) and potentially insufficient drainage.

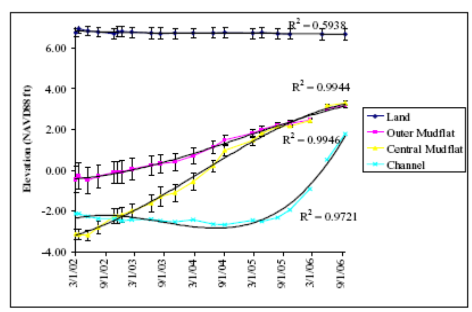


Increased tidal range through time at Tubbs Setback, San Pablo Bay NWR

Water level loggers will be installed at two locations within the restoration and one location in the adjacent slough outside the restoration for comparison. Tide levels will be monitored continuously with water level loggers (Telog Instruments) and related to NAVD88 using referenced staff gages. Water level loggers will be in continuous operation, recording mean, high, and low readings at 15-min intervals.

Water Quality: Water quality samples will be measured quarterly at established locations within channels. Temperature, pH, salinity, and dissolved oxygen will be collected with water quality meters (Hydrolab Datasonde or YSI 85 Multiprobe). Descriptive analyses will be used to characterize water quality spatial and temporal differences.

Geomorphology and Sedimentation: Tidal creeks and channels are an important drainage and habitat feature of tidal salt marshes. They influence biological and physical characteristics such as plant and avian distributions, fish and invertebrate establishment, and soil biogeochemistry (Callaway et al. 2001, Zedler 2001, Hood 2006, Hood 2007). High-resolution low tide aerial photography, along with field surveys will be used to map changes in creek and channel development. We will use our integrated bathymetric system (Takekawa et al., *submitted*; Athearn et al., *in press*) 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 determine geomorphic characteristics. The echosounder determines water depth, while the RTK GPS determines location and elevation as the boat travels over 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 and differences in elevations can be calculated in Geostatistical Analyst.



Sediment accretion by habitat: Tubbs Restoration, SPBNWR, Woo etal. 2007

Permanent depth poles or sediment pins (Takekawa et al. 2002, Woo et al. 2007) will be placed across the marsh plain to measure sediment accretion or loss over time. Sedimentation pins (2" PVC pipe, schedule 40) will be installed throughout the project to capture subtidal (channel), mudflat, marsh, and upland habitat types. Sediment pins will be measured annually to examine the sedimentation rate. The pole will be 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. In addition, the characterization of sediment properties is critical for colonizing benthic invertebrates. We will gather soil samples annually and analyze for soil particle size, soil pH, organic matter content, and nutrients.

<u>Estuary and Nearshore Changes:</u> 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 Science Center (E. Grossman), we will examine the changes in the estuary following restoration of the project site. The estuary studies will include mapping of nearshore topography and habitats, hydrologic processes controlling fluvial and tidal flow, and estuarine mixing and sediment and nutrient transport to relate to changes in ecosystem response. High-resolution LIDAR mapping will be conducted at 2-3 sites in the Nisqually Delta where dike removal is planned. These data will serve as essential baseline data to examine geomorphic change, sediment transport, and numerical sediment transport modeling with dike removal. Sediments will be collected from behind the dike and offshore areas across the tide flats, where channel formation with dike removal will erode and redistribute sediments. We will obtain a snapshot of changes in substrate type, sediment grain size, sedimentary organic matter, sedimentary nutrient and contaminant composition, micro- and macrofauna and overall rates and modes of sediment transport through repeat sampling following dike removal. Boat-mounted ADCP (Acoustic Doppler Current Profiling) will be conducted at select sites across the nearshore tide flats and newly restored channels to characterize circulation patterns before and after dike removal. 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).

Sampling of the greater estuary would include: 1) LiDAR surveys at least 1 time at 2-3 new channels behind and in front of the dike; 2) sediment sampling at 3-5 sites along a cross shore transect per new channel (n=2 or 3) before and after dike removal; and 3) current measurements, 3-5 transects repeated over the spring tide range before and after dike removal but at similar river discharge and wind conditions.

Question 2: Did the restored processes bring about habitat development trajectories towards predicted habitat structures?

The performance metrics that have been established are: a) Salt Marsh: salt marsh increases after restoration and distinct salt marsh communities develop as the physical (e.g. sediment accretion and erosion) and biological (e.g. nutrient uptake, shore crab burrowing) processes trend towards dynamic equilibrium; b) Open Channel: open channel increases after restoration and the channels diversify morphologically (i.e., channel order increases) as the physical and biological processes trend towards dynamic equilibrium; c) Mud flat: mud flat increases following the restoration of the tidal prism and then begins to reduce as salt marsh develops, channels diversify morphologically, and processes trend towards dynamic equilibrium

<u>Vegetation</u>: In conjunction with aerial photography, remote sensing, and bathymetry surveys of

the bottom substrates, on-the-ground plant surveys will provide information on species composition and condition. Vegetation sampling will be conducted during summer when vegetative cover is at its maximum. Permanent, 20-m point-intercept transects (0.5 m intervals) will be 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 will be examined 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*) will be tracked with GPS ground surveys or high precision aerial photographs. Data will be used to track changes of species extent, species richness, plant cover of natives and exotics, and vegetative condition (height and density).

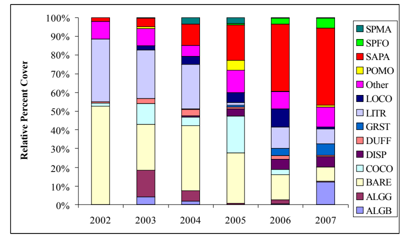


Figure 14. Relative percent cover between 2002 and 2007 transect vegetation surveys. Surveys were conducted in August with the exception of May 2005. Pickleweed (*Sarcocornia Pacifica*) cover has steadily increased until 2007. Category "other" includes: POMA, RUCR, ATTR, JACA HOBR, BAPI. Species and sampling codes follow those in Table 4.

Change in % cover, Guadalcanal Restoration: Woo et al. 2008

Question 3: Were reed canary grass and other invasive plants effectively detected and their establishment reduced, controlled, or prevented?

The performance metrics that have been established are: a) Reed Canary Grass and other Invasive Plant Occurrence: the extent of reed canary grass and other existing invasive plants within the restoration area reduce when the tidal prism and the associated physical and biological processes are restored; b) Potential Invasive Plant Establishment: the establishment of currently undetected invasive plants (e.g., *Spartina*) is prevented or controlled.

Vegetation: In addition to transects and quadrats, aerial photography, and remote sensing for vegetation cover, at each visit we will identify invasive plants and record locations and species. During each vegetation survey, field surveyors will search for target invasive plants, record GPS location of invasive plant patches, and describe condition and extent of the patch (area, density, height). For larger patches of invasive plants, such as reed canary grass, we will delineate the extent of cover with a hand-held GPS or by remote sensing, and track changes to the extent of cover annually.

Question 4: Does the ecological performance of the Nisqually NWR Estuary Restoration Project support juvenile Chinook?

The performance metrics that have been established are: a) Opportunity for Juvenile Salmon Access: juvenile Chinook readily access the restoration area sloughs throughout their season of peak abundance (May through June), as established by baseline studies; b) capacity for salmon growth and survival: The restoring salt marsh and sloughs provide habitat for insects and crustaceans that have been identified as prey for juvenile Chinook in the scientific literature; and c) Realized Function Site Specific and Ecosystem/Population Response: juvenile Chinook readily access the restoring sloughs and take advantage of the restoring area's capacity, as indicated by a similarity between their diet composition and the composition of the invertebrate community. Nisqually delta-rearing Chinook display increased estuary growth over the baseline. Nisqually delta-rearing Chinook display increased estuary residency over the baseline.

Fish: Fish sampling will be in cooperation and coordination with the Nisqually Tribe (C. Ellings, J. Dorner). The initial fish monitoring was completed with their cooperative efforts, and continued monitoring following restoration will be conducted through fyke trapping or beach seining efforts as a follow-up to the initial baseline surveys (Visintainer et al. 2006, Ellings and Hodgson 2007). The Tribe will provide continuity with the fish sampling program including detailed data analysis on estuary growth rates and residence time which they have conducted through otolith sampling (Ellings and Hodgson 2007).

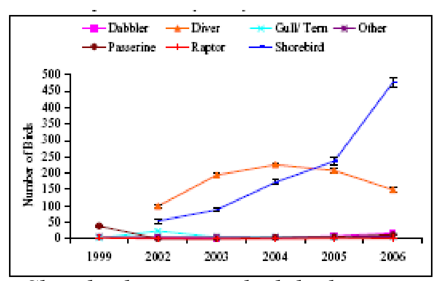
Invertebrates: Benthic invertebrates provide critical food resources for fish and birds that use the estuary. Three habitat types (slough, mudflat, and marsh edge) will be sampled at selected locations with three replicates to characterize and track the colonization of the benthic invertebrate community. At each location benthic cores (10 cm diameter, 10 cm depth) will be taken annually in the fall (during bird migratory season). In addition, physical variables that may effect invertebrate composition such as water quality, and sediment characteristics (particle size) will be taken during invertebrate collection. Samples will be screened (0.5 mm sieve) and stored in ethanol with rose Bengal dye to help distinguish organic tissues.

Surface and terrestrial invertebrates including salt marsh insects will be sampled with sweep netting (3 sweeps at each location) and fall-out traps. Invertebrates will be sieved through a 0.5 mm mesh and samples will be preserved and archived in alcohol. As additional funds become available, samples will be sorted, identified to the lowest possible taxa, enumerated, and weighed to the nearest 0.001 g (wet weight) with a high precision scale or using equations to estimate wet weight based on count data. Unidentified invertebrates will be stored in alcohol for later identification by an invertebrate specialist.

Question 5: Does the ecological performance of the Nisqually NWR Estuary Restoration Project support waterfowl, especially dabbling ducks, and shorebirds?

The performance metrics that have been established are: a) Opportunity for dabbling ducks and shorebirds to utilize habitat: Dabbling ducks and shorebirds readily utilize the restoring site during their season of historic peak abundances; b) Capacity of the site to provide conditions favorable to the growth and survival of dabbling ducks and shorebirds species: The restoring site provides structural components (established in the scientific literature) conducive to supporting feeding and resting by dabbling ducks and shorebirds; and c) Realized function, Are dabbling ducks and shorebirds taking advantage of the site's capacity: Dabbling ducks and shorebirds are observed feeding and resting at the restoring site.

Birds: Avian composition, density, and behavior can vary by tide. Thus, area counts will be completed every other month during high and low tide using binoculars and spotting scopes. The site will be partitioned into 100-250 m UTM grids so that the observer can reference the location in which birds are detected. Observers will record grid #, 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 will be grouped into foraging guilds for analyses and trends. Breeding birds or nests will be recorded if encountered. Bird



Shorebirds increased while diving ducks decreased at Tubbs Setback, SPBNWR (Woo et al. 2007) species richness, density will be tracked over time and related to changes in sediment levels. The enhanced freshwater wetlands area will also be included in these surveys.

Adaptive Management Framework: We will work closely with collaborators and the Refuge to provide monitoring data and data integration to inform managers of status and trends within an adaptive management framework. Data will be analyzed to identify uncertainties in restoration progress and to determine if project goals are being met. A public website will be developed to provide updates of the restoration. Field updates will be posted to document restoration progress through pictures, video, and ongoing data.

Question 6: What tasks should be done with construction activities?

Construction activities may not exactly follow restoration designs. Therefore, post construction surveys also form a baseline starting point from which the restoration will progress. Thus we recommend an as-built survey so that the Refuge can ensure that the project components are built to specifications.

1. An as-built survey should include a map of final elevations prior to the reintroduction to tidal flow, including the estuary restoration, riparian/surge plain restoration, freshwater wetland and grassland restoration components, and other construction tasks.
2. Riparian plantings should also be documented with species and location of planting.
3. The placement of large woody debris should also be documented with location.

Our experience has shown that integrating monitoring with construction greatly improves the accuracy of our assessments (Takekawa et al. 2002). Surveys and installation of certain monitoring tools are best handled immediately after construction and prior to breach. The following task orders will be completed during the construction phase:

4. Establishment of 6 fixed elevation benchmarks (NAVD88).
5. Installation of 2 water level loggers and staff gages (surveyed to NAVD88) within the project and installation of 1 water level logger and staff gage outside the restoration.
6. Installation of 60 PVC pipe (5 cm or 2" schedule 40) sediment pins to 0.3 m above higher high water level, 2 m deep (or driven into the substrate until no avail), surveyed to NAVD88.
7. Installation of 4 sets of PVC levee erosion pins, near areas of possible levee erosion. Erosion pins will be installed 1 m apart from the inner project to the top of the levee.

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Products: Georegistered databases will be distributed on the webpage for immediate use and long-term restoration planning processes. Data summary reports will be prepared annually. Scientific contributions including presentations and papers conducted in cooperation with the Refuge will be prepared from the collected datasets.

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Table 1. Crosswalk among questions, objectives, and performance monitoring methods.

Objective 1: Restore estuarine habitat.			
Monitoring Questions	Performance Metrics	Performance Criteria	Performance Criteria Methods
1. Were the processes outlined in the hydrodynamic and sediment transport (HST) model effectively restored?	Full Tidal Inundation	High tides inundate historical sloughs and regularly flood the restoration area and developing marsh plain.	Water level loggers.
	Full Tidal Evacuation	Water evacuates restoration area during a receding tide.	Water level loggers, aerial photography during low tide.
	Salinity Incursion	Salinity in the project area is conducive to estuarine vegetation.	Water quality parameters meter (temperature, salinity, pH, dissolved oxygen) and vegetation surveys
	Sediment Transport/Deposition	Sediment transport and deposition cause marsh plain to aggrade.	Sediment pins for erosion and deposition rates, and bathymetry
2. Did the restored processes instigate habitat development trajectories towards predicted habitat structures?	Salt Marsh (includes estuarine shrubs)	Salt marsh increases after restoration and distinct salt marsh communities develop over time.	Aerial photography/remote sensing for land cover classifications (ERDAS Imagine, GIS), photopoints, and vegetation surveys
	Open Channel	Open channel increases after restoration and the channels diversify morphologically.	Aerial photography/remote sensing for land cover classifications (ERDAS Imagine, GIS), and photopoints
	Mudflat	Mudflat increases following the restoration of the tidal prism and then begins to reduce as salt marsh develops	Aerial photography/remote sensing for land cover classifications (ERDAS Imagine, GIS), and photopoints
3. Were reed canary grass and other invasive plants effectively detected and their establishment reduced, controlled, or prevented?	Reed Canary Grass and Other Invasive Plants Occurrence	The extent of invasive plants within the restoration area reduces when the tidal prism is restored.	Aerial photography/remote sensing for land cover classifications (ERDAS Imagine, GIS), photopoints, and vegetation surveys
	Potential Invasive Plant Establishment	The establishment of currently undetected invasive plants is prevented or controlled	Rapid presence/absence invasive plant surveys
4. Does the ecological performance of the Nisqually NWR Estuary Restoration Project support juvenile Chinook?	Opportunity	Juvenile Chinook readily access the restoration area sloughs.	Fish sampling (fyke trapping and possibly beach seining)
	Capacity	The restoring salt marsh and sloughs produce invertebrates that have been identified as prey for juvenile Chinook in the scientific literature.	Invertebrate sampling (benthic cores and fallout trapping).
	Realized Function (site specific)	Juvenile Chinook readily access the restoring sloughs and take advantage of the restoring area's capacity, as indicated by a similarity between their diet composition and the composition of the invertebrate community.	Juvenile Chinook diet analysis.
	Realized Function (population)	Nisqually delta-rearing Chinook display increased estuary growth and estuary residency over the pre-project baseline.	Juvenile Chinook otolith analysis.
5. Does the ecological performance of the Nisqually NWR Estuary Restoration Project support dabbling ducks and shorebirds?	Opportunity	Dabbling ducks and shorebirds readily utilize the restoring site throughout their season of historic peak abundance.	Area bird surveys (species identification, number, behavior, habitat)
	Capacity	The restoring site provides structural components (established in the scientific literature) conducive to supporting feeding and resting by dabbling ducks and shorebirds.	Area bird surveys (species identification, number, behavior, habitat)
	Realized Function	Dabbling ducks and shorebirds are observed feeding and resting at the restoring site.	Area bird surveys (species identification, number, behavior, habitat)

Objective 2: Protect, restore, and enhance surge plain riparian habitat.			
Monitoring Questions	Performance Metrics	Performance Criteria	Performance Criteria Methods
Is the planting area on desired trajectory?	Survival of Plantings	Plant survival is >50% in first 5 years.	Vegetative transects: plant composition (dead or alive)
	Invasive and Non-Native Species	Invasive and non-native plants do not impair native plant survival.	Rapid visual survey for invasive plant species and location
	Native Species Colonization	Native riparian surge-plain plants colonize the project area.	Vegetative transects and quadrat surveys: plant composition, cover, aerial photography

Objective 3: Protect, restore, and enhance a mosaic of primarily permanent and seasonal freshwater wetlands as well as riparian forests and grasslands within the new exterior dike.			
Monitoring Questions	Performance Metrics	Performance Criteria	Performance Criteria Methods
1. Are the managed processes (e.g., hydrology) and structural changes (e.g., topography and bathymetry) of the 246 acres within the new exterior dike causing the desired mosaic of habitats to form?	Permanent Freshwater	Within the actively managed 246 acres, a habitat mosaic consisting of primarily permanent and seasonal freshwater wetlands, as well as riparian forest and grassland habitats develop. Water management within the individual cells enables the development of seasonal wetlands and other habitats.	Aerial Photography/Remote sensing for land cover classifications (ERDAS Imagine, GIS), vegetation surveys
	Seasonal Freshwater		
	Riparian		
	Grassland		
	Reed Canary Grass and Other Invasive Plants	The extent of reed canary grass and other invasive plant species are reduced.	Aerial Photography/Remote sensing for land cover classifications (ERDAS Imagine, GIS), vegetation surveys, presence/absence invasive vegetation surveys
2. Is the actively managed 246 acres providing habitat functions, like foraging, for key groups of birds, with an emphasis on dabbling ducks and raptors?	Opportunity	Dabbling ducks and raptors are observed utilizing the managed habitat.	Area bird surveys of all species observed (species identification, number, behavior, habitat)
	Capacity	The managed habitat area provides structural components (established in the scientific literature) conducive to foraging by dabbling ducks and raptors.	Benthic invertebrate sampling
	Realized Function	Dabbling ducks and raptors are observed foraging within the managed habitat.	Area bird surveys (species identification, number, behavior, habitat)