Leque
1st-year Post-Restoration
Tidal Marsh Monitoring Report

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Great Blue Heron in patchily vegetated, Bolboschoenus maritimus, *marsh one year after restoration.*

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Introduction

The Leque tidal marsh restoration site is located in the Stillaguamish River Delta opposite the mouth of the old Stillaguamish River. European-American settlement in the late 19^{th} century converted most of the Stillaguamish Delta from tidal marsh and floodplain swamp to agricultural use through the construction of dikes that prevented tidal and riverine flooding and allowed replacement of native vegetation by agricultural crops. Leque Island was diked in the 1870s and used for farming until 1990, when farming became infeasible on the site.

Since the late 19^{th} century, native populations of salmon have declined to such an extreme that Puget Sound Chinook salmon were listed as a threatened species in 1999. Because tidal marshes are critical rearing habitat for juvenile Chinook salmon, there has been significant effort addressed at restoring historical tidal marshes to recover Chinook salmon populations. This effort now includes the Leque Island marsh restoration.

The 103-ha (254.5-ac) Leque site was restored to tidal and riverine flooding in 2019 through the nearly complete removal of dikes around its perimeter. Additionally, six large tidal channels were excavated de novo or enlarged on the site to approach allometric predictions derived from nearby reference tidal marshes (Hood 2015, 2018). The channel conceptual restoration plan was modified during implementation by omitting excavation of the two smallest channels in the design, extending the excavation of some other channels, and excavating seven large ponds, located adjacent to and communicating with the three largest tidal channels. Omission of the two smallest channels was a minor modification. Excavation of the large ponds was done to provide shallow water habitat for waterfowl. These ponds, because they are directly connected to tidal channels, were also thought likely to provide significant habitat to juvenile salmon.

Dike removal and channel construction were hypothesized to be sufficient for allowing native vegetation recolonization of the site and for juvenile Chinook salmon to occupy the excavated channels and benefit from primary and secondary production on the site. Tidal marsh vegetation colonization is typically not constrained by the supply of seeds or other propagules from nearby tidal marshes, so no vegetation planting occurred as part of the restoration. This preliminary report describes the initial assessment of vegetation colonization in the first year after site restoration. It also describes the extent to which planform tidal channel geometry in the execution of restoration plans differs from the conceptual design. Future tidal channel surveys will describe channel cross-sections and planforms, and include spot measurements of excavated pond elevations.

Methods

Channel planform was digitized from aerial photographs in a GIS. Aerial photos were acquired from Google Earth; the most recent available photo dated from July 2020. Vegetation on the restoration site was monitored by point sampling with an RTK-GPS (3-cm horizontal and vertical resolution). Points were distributed along random transects that spanned most of the site, with a total of 543 points sampled, each point about 30 m apart. At each GPS point the dominant and subdominant vascular plant species were noted, while the RTK-GPS acquired the horizontal and vertical location of the point. Relative plant abundance at each point was determined by visual estimation of aerial cover within a 1-m radius from the sample point. The GPS data were transferred to a GIS for comparison of observed and predicted vegetation distributions similar to the method published in Hood (2013).

A Predictive Vegetation Model (PVM) was based on adjacent reference marshes to account for the particular salinity, soils, and tide range found in the area, and used methods described elsewhere (Hood 2013). However, it had a relatively small sample size to parameterize the model (302 sampling points distributed over 10 species), due to the small size of the reference marshes. The only species with large sample sizes in the Stillaguamish Delta were *Schoenoplectus pungens* (n = 62) and *B. maritimus* (n = 191). *Carex lyngbyei* had a sample size of 15, *Agrostis* sp. had 9; all other species were less common. Nevertheless, this PVM successfully predicted vegetation patterns in the nearby zis a ba restoration site (Hood 2019).

Results

Tidal channel planform

Tidal channel excavation resembled the conceptual planform design developed prior to restoration, but there were some significant alterations of the original design (Fig. 1). The six excavated channels amounted to a total channel area of 4.10 ha (10.13 ac) and total channel length of 6,580 m (21,589 ft). These values are greater than those of the conceptual design plan (Table 1), because although two small conceptual design channels were not excavated, one medium-sized channel was made much longer than originally planned. Overall, the total area of restored tidal channels was 19% greater than originally planned, while total channel length was 12% greater. The excavated ponds were a design modification; their area was more than twice the area of the restored tidal channels, and amounted to about 8% of the total restoration site area. The area of the shallow pans (incidental topographic depressions that tend to pond water to depths of a few inches at low tide) was comparable to that of the restored tidal channels.

Table 1. Restoration channel metrics relative to conceptual design. Total site area is 103 ha, so the total area of each feature class approximates its percentage representation in the site.

	Restoration	Conceptual design
Total channel area (ha)	4.10	3.45
Total channel length (m)	6,580	5,875
Channel outlet count	6	8
Excavated pond area (ha)	8.46	0
Shallow pan area (ha)	4.19	0

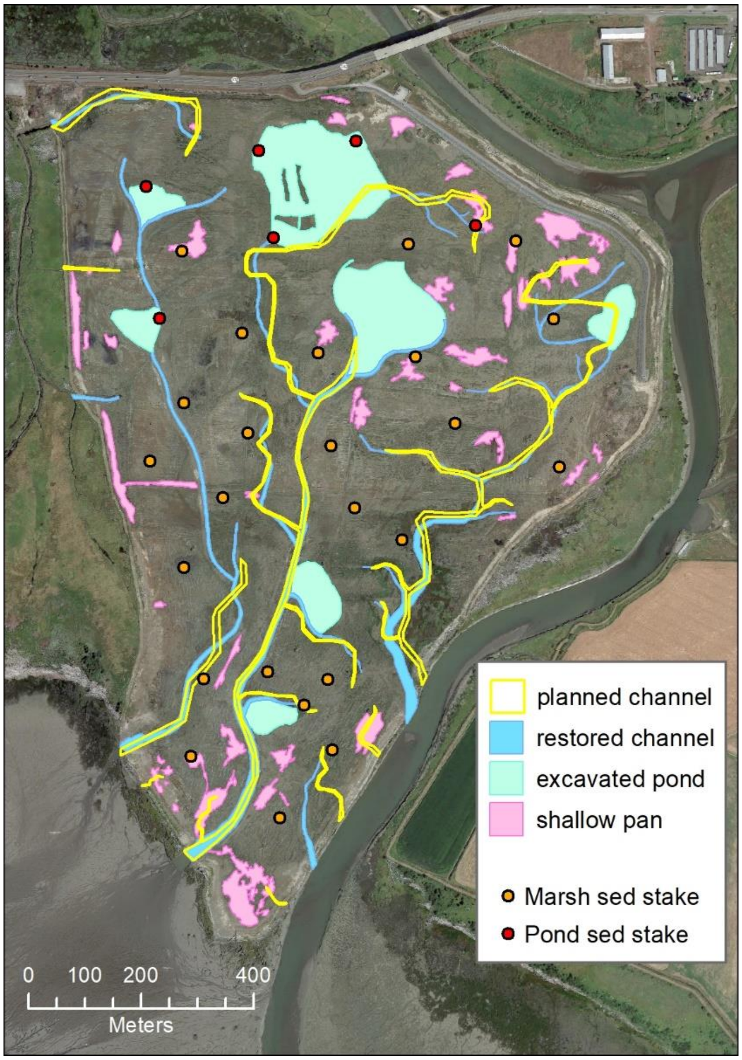

Figure 1. Location of excavated tidal channels (blue) and ponds (cyan) within the Leque restoration site, compared to conceptual plan channels (yellow outline polygons). Incidental shallow pans (pink) may also affect vegetation colonization and fish use of the marsh surface. Sediment stakes were located on marsh surfaces (orange) and in excavated ponds (red).

Tidal channel cross-sections and profiles

Tidal channel cross-sections and profiles will be surveyed in July 2021, at which point this section will be updated.

Sediment stakes

Sediment stakes have been installed in the restoration site (Fig. 1), and will be monitored on an annual basis at the end of each water-year. Five stakes are located in three excavated ponds, with three stakes in the largest pond. One stake is located in one of the deeper shallow pans. The remaining 24 stakes are dispersed throughout the marsh surface.

Vegetation colonization

One year after site restoration, the Leque Island site is just beginning to be recolonized by vegetation. Most of the site consists of bare ground; 340 of 543 RTK-GPS sample points (63%) were over bare ground. The next most frequent category sampled by RTK-GPS points was *Bolboschoenus maritimus*, 86 of 543 points (16%), followed by the non-native early colonizer, *Cotula coronopifolia*, 81 of 543 points (15%), and the high marsh grass, *Agrostis stolonifera*, 22 of 543 points (4%). Other occasionally dominant species at sampled locations included the non-native species, *Atriplex patula*, and the native species, *Distichlis spicata, Juncus balticus, Sarcocornia pacifica*, and *Triglochin maritimum*.

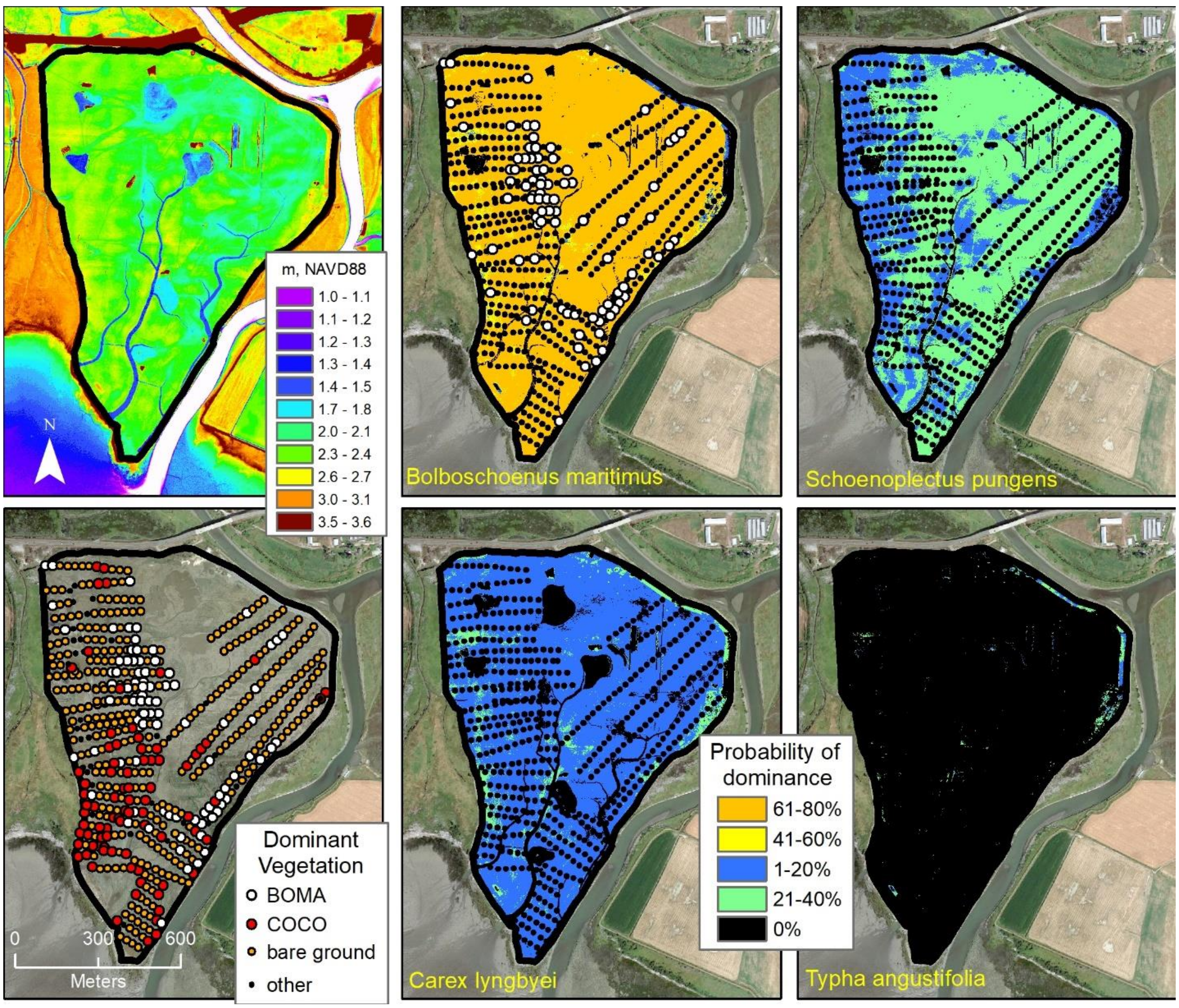

Figure 2. Observed versus predicted vegetation occurrence. The top left frame shows the general topography of the site, using 2019 lidar data. The bottom left frame shows the RTK-GPS data collection summary of dominant species encountered at each sampling point. Other frames compare RTK-GPS observations with expectations from a predictive vegetation model.

Figure 3. Two views of *Bolboschoenus maritimus*, showing typical occurrence along the margins of tidal channels.

Bare ground was distributed relatively evenly throughout the site, but *Cotula* occurred mostly in the southern, lower-elevation half of the site (70 of 81 sample points, or 86%) (Fig. 2, lower left frame). *Bolboschoenus* tended to be associated with tidal channel banks (Fig. 3), suggesting seeds or other propagules were brought onto the site with the flood tide and dropped on the nearby marsh surface. *Bolboschoenus* was particularly abundant in large patches in the north-central portion of the site, also along the margins of several tidal channels in this area. Other, less common species, were also associated with channel margins (24 of 35 sample points, or 69%), suggesting they too were brought onto the site by the flood tide.

Discussion

One of the most visually striking aspects of the Leque restoration site is the currently patchy vegetation colonization of the site. Bare ground predominates while patches of *Bolboschoenus* intermittently border tidal channels and *Cotula* is scattered at slightly lower elevations in the southern half of the Leque restoration site. Even so, the observed colonization of *Bolboschoenus* is a hopeful augury for the second year of site recovery. It seems likely that *Bolboschoenus* will continue to spread to match predictions of the vegetation model (Fig. 2, upper middle frame) of site dominance by this species. This prediction was borne out in the nearby zis a ba restoration site by the second year after site restoration, a stunningly rapid rate of vegetation establishment. It would be equally amazing if this feat were repeated for the Leque restoration site. The rapid colonization of the zis a ba site has been attributed to extensive excavation of tidal channels on that site, which diverts the energy of tidal exchange from sheet flow on the marsh surface to channelized flow in tidal channels. The lowered tidal energy on the marsh is thought to improve seed settlement and germination (Hood 2019). Since extensive tidal channel excavation also occurred on the Leque site, we should see similarly rapid vegetation recovery on the Leque site, if this hypothesis on the role of tidal energy dissipation in vegetation colonization is correct. Thus, a second year (or more) of vegetation monitoring is critical to test this hypothesis.

The PVM indicates that non-native cattail invasion and dominance of the site is unlikely to occur (Fig. 2, lower right frame). However, monitoring of the zis a ba restoration site did find scattered occurrence of *Typha angustifolia* in some areas of that restoration site. Additionally, a handful of small patches of *Phragmites* and *Spartina*, both aggressively invasive non-native species, were found on the zis a ba site, requiring immediate implementation of control measures. Continued monitoring of the Leque site will be necessary over the next several years to immediately exterminate any colonizing patches of *Phragmites* or *Spartina* before they get out of control.

The other visually striking feature of the Leque restoration site is the abundance of large excavated ponds, created to benefit waterfowl and, potentially, juvenile salmon. However, previous experience with the Wiley Slough restoration project in the South Fork Skagit Delta, suggests the excavated ponds may have a limited life span, because similar ponds in the Wiley

Slough site have experienced significant sedimentation and conversion to marsh in the 10 years since restoration of that site. On the other hand, previously excavated duck ponds in the east lobe of the Deepwater Slough site have persisted, though they are much deeper, with only modest shrinkage and conversion to marsh in the 20 years since that site was restored to tidal inundation. The likely difference between the two sites (in addition to pond depth) is the rate of sediment supply via river distributaries. Given that Leque is relatively distant from its nearest significant source of sediment, the mouth of the Stillaguamish River (i.e., Hat Slough), pond sedimentation rates may be slower than that observed for Wiley Slough, which is located immediately adjacent to the principal distributary of the South Fork Skagit Delta. On the other hand, Leque Island is exposed to significant southerly storm fetch which likely carries a lot of suspended sediment to the site during storms. This fetch effect may counter the isolation of the site from sediment sources and increase the rate of pond siltation. Thus, particular attention should be paid to monitoring the rate of pond siltation. The installed sediment stakes will be one way to monitor pond sedimentation and persistence. Another will be to use aerial photography to monitor vegetation colonization of the ponds, which can be done annually by reference to Google Earth or other contracted photos.

Surprisingly, the PVM indicates that while all of the seven excavated ponds are apparently deep enough to inhibit *Carex lyngbyei* colonization (Fig. 2, bottom middle frame), only one is predicted to inhibit *Bolboschoenus* establishment. However, comparison of the 2019 lidar with the pond and channel polygons digitized from the 2020 aerial photos suggests that further channel and pond excavation occurred after the 2019 lidar data were collected, because several ponds in the aerial photos were larger than those in the lidar data. The lidar data indicated that the one pond that was predicted to inhibit *Bolboschoenus* establishment was 20-30 cm deeper than the other ponds. If all of the other ponds continued to be excavated to the depth of this one pond, following the collection of the 2019 lidar data, then all of the ponds will likely be slow to vegetate. Otherwise, some vegetation colonization may occur. Initial field observations suggests the ponds are sufficiently deep to prevent vegetation establishment, at least for the next few years, because all ponds were entirely bare of any vegetation.

The 4 ha (10 ac) of shallow pans that were observed on the site may rapidly fill with sediment, but they may also affect early vegetation colonization by providing topographic variation that favors species diversity. As of the initial, colonizing, stage of vegetation development there is yet no indication of whether the pans will have this effect. Future vegetation monitoring should pay attention to this possibility. If the pans are shown to have a beneficial effect on vegetation diversity, future restoration designs might choose to intentionally provide such features.

Continued vegetation monitoring, particularly for the 2nd year post-restoration, is critical to determine whether the Leque site will follow a rapid recovery trajectory similar to that observed for zis a ba, or a painfully slow trajectory like that occurring on the Fir Island Farm site adjacent to Brown's Slough. Either result will have significant implications, not only for adaptive management of the Leque restoration site, but also for future design of other restoration sites. Likewise, continued monitoring of the fate of the excavated ponds (as well as their use by waterfowl and fish) will also likely influence future restoration designs.

References

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