Beneficial Re-Use of Dredged Sediment to Enhance Stillaguamish Tidal Wetlands

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Document Background

The Stillaguamish Flood Control District has proposed to dredge the Old Stilly river channel in order to reduce drainage problems on farmland. As part of the proposal, they pose the idea of using the dredged sediment to enhance tidal marshes in the estuary, to assist with Chinook recovery. This project is being considered within the context of Snohomish County's Sustainable Lands Strategy, an effort among fish and farm interests to develop strategies that generate net gains for both. With the possible exception of some small urban estuary projects, re-use of dredged sediment to enhance tidal marshes has not been done in Puget Sound. For this reason, Snohomish County hired Western Washington University to convene technical experts who could develop a conceptual framework for evaluating the potential to re-use dredged sediment in marshes. This report documents the findings of that process.

Process

Expert Workshop February 5, 2014

Twelve people met to discuss the concept of dredged sediment re-use in the Stillaguamish estuary. Attendees included eight experts in estuarine habitat, geomorphology, or modeling, as well as four representatives of Snohomish County and the Stillaguamish Flood Control District. Nine other experts were invited but not able to attend. Of these nine, three were able to attend a subsequent discussion with the Stillaguamish Technical Advisory Group and two provided additional input separately. A summary of the expert workshop and outputs is provided in **Appendix 1 (Expert Workshop Summary).** All attendees were provided the opportunity to review and approve the summary, and comments were incorporated into the final document.

The workshop began with a summary of our understanding of the current conditions of the Stillaguamish estuary as they pertain to the question of sediment re-use. A list of active researchers, research, and assessments was developed. Following this we discussed the potential different ways to use sediment in the estuary, and the general issues that would need to be considered to evaluate re-use. Lastly we discussed in detail a framework for assessing the two options of using the sediment to fill subsided restoration sites or to enhance existing wetlands.

Stillaguamish TAG Discussion February 12, 2014

The outputs of the expert workshop were presented to the Technical Advisory Group of the Stillaguamish Watershed Council. The TAG then discussed the concept of dredged sediment re-use and the general issues and concerns that would need to be addressed in any further evaluation of sediment re-use potential. The notes from this discussion are provided in **Appendix 2 (TAG Discussion Summary).**

Based on the input from the expert workshop, the TAG discussion, and additional separate input from experts unable to attend the workshop, a conceptual framework for determining how to re-use dredged sediment in the Stillaguamish estuary was developed and is presented below.

History of Dredged Sediment Re-Use

In Puget Sound, there is little history of using dredged sediment to enhance tidal wetlands. Most dredged sediment is disposed in deep water disposal sites or used to cap contaminated sediment. However, dredged sediment has been used for over a century to build Jetty Island in Everett, including construction of a sand spit behind which saltmarsh has developed. Though much of the island is covered with non-native species such as Scots broom, there are extensive areas of beach grass and dune habitat. The island continues to be maintained and enhanced with dredged sediment from the Snohomish River shipping channel. (http://www.portofeverett.com/docs/jetty_island_management_plan.pdf)

Dredged sediment has been used to enhance or create habitat for eelgrass restoration in Puget Sound (Ron Thom, personal communication). In addition, there may be a few small sites in urban estuaries where dredged sediment has been used for marshes. At the north entrance to the Swinomish Channel are what appear to be side cast dredge spoil islands where saltmarsh has developed. However, currently the sediment dredged from the Swinomish Channel is disposed in a deep water disposal site. The Port of Skagit indicates that due to heavy sedimentation, the channel requires dredging every three years.

Dredged sediment from the Columbia River has been used in numerous ways, and tidal marsh has developed on many dredge spoil islands. The Pacific Northwest National Laboratory (Battelle) has established a suite of Columbia River tidal marsh reference sites that are used in the context of restoration projects. Nineteen of these sites are on dredge spoils, though the sites were not intentionally created to support tidal marsh (Ron Thom, personal communication). These sites generally support a higher proportion of non-native plant species than other reference sites.

Though not common in Puget Sound, dredged sediment is used extensively in other regions of the world to enhance tidal wetlands. **Appendix 3 (Resources)** provides some links to a few examples from other regions where dredged sediment has been used. In the San Francisco Bay estuary, thousands of acres of tidal wetlands have been restored by using dredged sediment to fill diked and subsided farmland prior to breaching of the dikes. Due to the high peat content of the San Francisco wetland soils, diked areas have very high rates of subsidence. Agricultural working of the soil introduces oxygen and accelerates the decomposition of organic matter to rates much higher than the naturally saturated soils of wetlands. As a result, most restoration sites, where dikes are removed to restore tidal marsh, are far lower in elevation than adjacent marshes. In many cases, without the fill the sites would be too low to support tidal wetlands.

On the east and Gulf of Mexico coasts, some areas have seen very high losses of tidal wetlands due to many factors including conversion to other uses, alteration of natural processes, and sea level rise. Re-use of dredged sediment is a common mechanism used to create new wetlands, build the resilience of wetlands that are drowning due to sea level rise and other issues, build protective barrier islands, and other actions that support marshes.

Conceptual Framework for Assessing Beneficial Re-Use of Dredged Sediment in the Stillaguamish Estuary

Current Conditions in the Stillaguamish Estuary

More detail is provided in Appendix 1, but briefly, the Stillaguamish estuary has been eroding in the north and prograding in the south (**Figure 1**). These changes have resulted in the loss of hundreds of acres of wetlands in the north since the 1960's (**Figure 2A**). Some new wetlands have developed in the south (**Figure 2B**), but not nearly to the extent of the loss to the north.

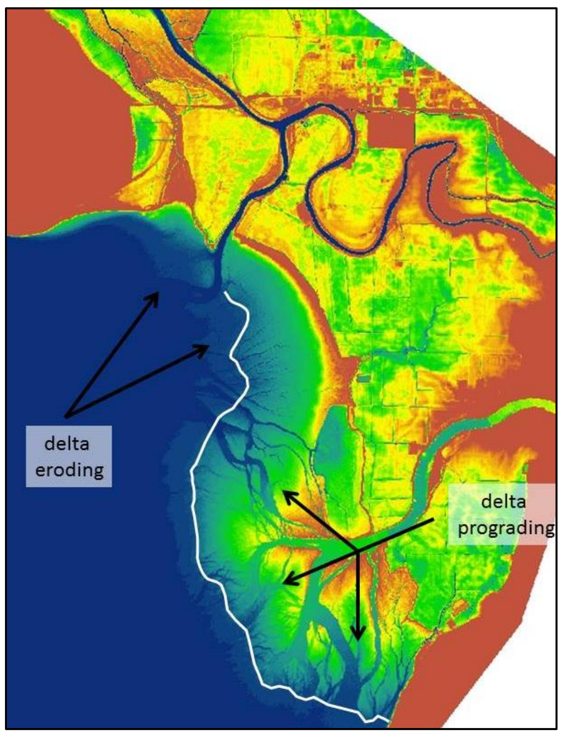

Figure 1. *The Stillaguamish delta is growing in the south, at the mouth of Hatt Slough, and shrinking in the north near South Pass.*

The loss of marsh in the north is likely due to a combination of factors including overgrazing by snow geese combined with winter wave erosion, channel changes that have reduced the flow of sediment to the north, and related changes in salinity.

The ability of marshes to keep up with sea level rise is related in part to their rate of sediment accretion. In most areas of the delta, the marsh accretion rates appear to exceed 4 mm/year, which is sufficient to keep up with moderate rates of sea level rise. At the north end, accretion rates are high in the very limited area of high marsh, but the lower marshes are losing elevation. This agrees with the evidence of erosion that occurs throughout the marsh area near the mouth of South Pass and southeast from there for ¾ mile.

Another factor that influences marsh integrity in the context of climate change is salinity. The UW Climate Impacts Group projects that the Stillaguamish summer low flows will decline by 17% in the 2020's and by 22% in the 2040's, compared to historical. A decline in summer flows will increase estuary salinity during the marsh growing season. As a result, low flow changes may have a greater effect on tidal marsh area than sea level rise over the next few decades, and areas that receive sufficient sediment to keep up with sea level, may still lose marsh due to increasing salinity.

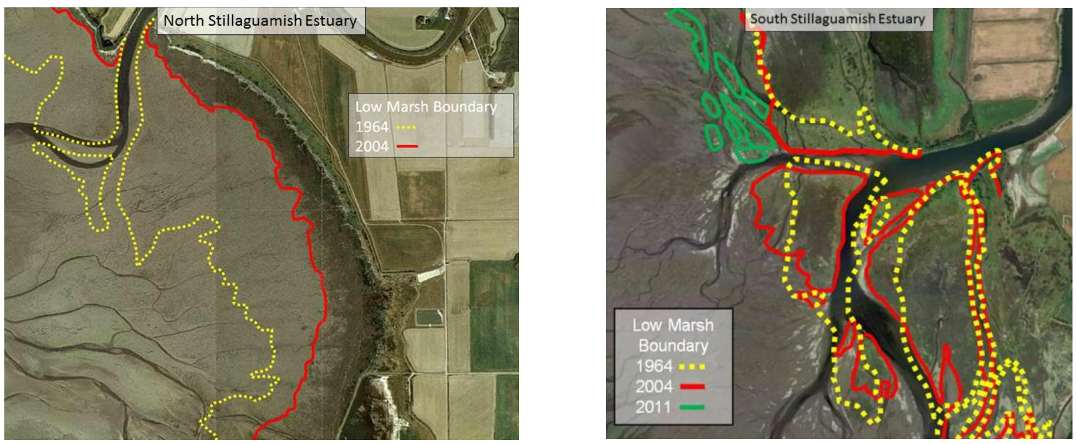

Figure 2. *Changes in Stillaguamish tidal wetlands since the 1960's. Panel A shows the northern marsh area where substantial loss has occurred. Panel B shows the southern marsh, where some marsh has been lost and some gained, with a net increase.*

<u>Three Options for Sediment Re-use</u>

The expert workshop determined that clean dredged sediment could be a beneficial tool to improve tidal wetlands in the Stillaguamish estuary under certain conditions. Re-using dredged sediment to enhance tidal wetlands does not address the underlying ecological processes that drive sediment or habitat dynamics. As such, these types of projects are not considered process-based restoration, but they may enhance or restore structural attributes of habitat.

Three broad categories of use were identified. **Appendix 1** describes the specific comments and issues identified by the experts for these options. There are many uncertainties that would need to be clarified before a decision could be made about sediment re-use, and the following recommendations provide guidance for addressing those uncertainties.

The three potential methods of re-use include:

1. ***Add the sediment to a subsided restoration site*** so that it more closely matches adjacent marsh elevations and to improve marsh and channel habitat development.
2. ***Apply sediment to existing habitat areas***

a. Apply in areas of erosion risk, to slow, reverse or prevent marsh loss due to erosion. Examples include the northern marshes where significant marsh loss has already occurred, and the north end of the "new" prograding delta in front of Hatt Slough where there has been some marsh loss, but where proximity to the TNC restoration may improve connectivity with the river mouth.
b. Increase the marsh area on the prograding delta near Hatt Slough by creating new marsh islands at the mouth, or building new marsh seaward of the existing marsh boundary. This area is not currently eroding and natural processes might therefore maintain the added sediment and continue to build elevation.
c. Add sediment to existing marshes near Hatt Slough to increase their resilience to sea level rise, and/or to accelerate development of higher marsh habitat.

3. ***Add sediment as an offshore sub-tidal berm*** and allow tidal/wave action to move the sediment up into the marshes.

Of these three broad categories, the first has the greatest potential for benefit, the least amount of uncertainty with regards to impacts and outcomes, and the lowest risk of damage to the ecosystem.

Option Three, a sub-tidal berm, has worked for feeding sand to beaches exposed to open ocean wave dynamics, but the wave dynamics in protected Port Susan Bay, combined with the energy of river flows and floods make the performance and ultimate destination of a sediment berm highly uncertain. The dredged sediment may contain high levels of fine grain material, which will perform much differently than coarser, sandier material. Fines may be carried further and in unintended directions.

Option Two, using sediment to enhance existing marsh or create new marsh islands, has potential to slow the loss of marsh in eroding areas or to expand marsh in areas where natural processes are likely to maintain the new marsh, at least under current rates of accretion. However this approach faces significant risks and uncertainties. This approach has been used extensively on the saltmarshes of the Gulf and East coasts, and there is substantial literature emerging on the best practices and effectiveness of these applications. However, Puget Sound tidal marshes are mostly brackish rather than saltmarshes, and the plant species are different than found on the other coasts. As a result, the effects of sediment addition to existing marshes could be quite different than seen elsewhere. Each plant species has its own sensitivities and thresholds with regards to environmental changes, so Puget Sound species may respond differently to sediment addition.

Sediment addition at too great a rate could smother existing plants (and animals), or weaken them to the extent that a large marsh area is destabilized and eroded by winter storms. Erosion usually triggers an irreversible state change from marsh to tide flat, due to the loss of elevation. Sediment addition could also alter soil biogeochemical processes such as gas and ion exchange, which could destabilize marshes. An approach using Option Two could be developed under a rigorous, plot-based experimental regime to test the idea on a small scale without risking large marsh areas. Applying sediment more broadly to existing tidal habitats is not recommended without first taking a very careful experimental approach on a small scale.

It is possible that beneficial re-use of sediment to enhance marshes will become an important tool in the future for Puget Sound, particularly as the effects of sea level rise unfold. In areas where marshes can't migrate landward, they may become threatened with drowning in the absence of sufficient sediment addition to keep up with rising waters. Most dredged sediment is currently disposed in deep water. At least some portion of that sediment could be used to enhance critical habitats at risk from sea level rise. Dredged sediment from the Swinomish Channel, for example, may be suitable for beneficial re-use.

However, re-use in this manner must be carefully considered, because applying sediment to existing marshes may unintentionally alter biogeochemical processes in a way that could destabilize large areas of marsh. In addition, replacing one habitat with another, such as replacing tide flat with marsh, may simply shift the impact from one group of species and ecological services to another group of equally valuable species and services. For these reasons, a controlled, small scale and experimental approach to Option 2 could be considered now, as a learning opportunity to test these ideas which may become important adaptive management tools in the future.

Option One, adding sediment to subsided restoration sites, provides the greatest immediate potential benefits with the lowest levels of uncertainty. Applying it to restoration sites that have not yet been constructed eliminates fears of destabilizing existing on-site marshes. In addition, there are target elevations that will deliver the greatest marsh and channel productivity outcomes, and where site elevations are below the target, adding sediment could substantially improve project ecological performance. In addition, re-using sediment in the context of restoration projects would likely substantially decrease the permitting complexities compared to applying in existing habitat areas.

At present there are three potential restoration sites where the sediment could be used (**Figure 3**), though future sites may also become available. The Leque, Matterand and Nature Conservancy (TNC) sites are all substantially subsided compared to marsh elevations outside the sites.

The TNC site

Of the three, the TNC site is considerably lower in elevation than the others, and includes elevations that are likely too low to support tidal marsh. Unlike the two northern sites, the TNC site has already been restored (fall of 2012), so use of sediment here would be more complicated than at the other two sites. However, it could be incorporated as part of an adaptive management program for the project.

Early monitoring at the TNC site suggests that it is not performing ecologically at a level similar to reference sites and will likely take many decades to reach that level, due to the level of subsidence relative to adjacent natural marsh. Although the old dike was completely removed, the site behaves similarly, with respect to hydrodynamics, as a diked site that has had two breaches cut in the dike. The level of subsidence at the site means that there is over-marsh flow between the old marsh and the new marsh only at higher tide levels. To facilitate tidal connectivity with the adjacent distributary channel, two breaches were carved across the marsh during the restoration, so that the site would drain completely at low tide. However, because the site is so subsided, most of the hydraulic energy of moving tides is focused through the two breach sites. As a result, this will tend to cause all new blind tidal channel systems within the site to develop as drainages through those two sites, rather than forming more frequent, smaller channel connections through the adjacent marsh area.

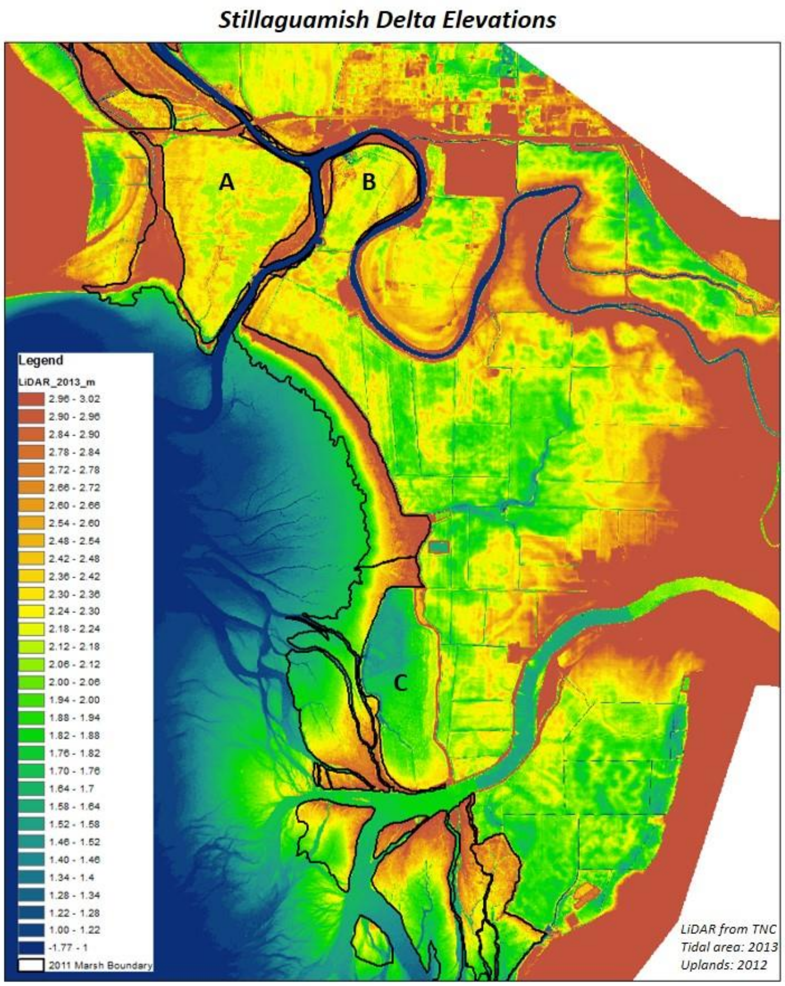

Figure 3. *Stillaguamish delta elevations. Warm colors are higher elevation, cool colors lower. The location of tidal marshes in 2011 is shown bounded by the black lines. The landward edge of these black lines is generally the location of the dike. The subsidence of the lower delta farmland relative to the adjacent tidal marshes is evident. Three restoration sites are shown as A (Leque Island), B (Matterand), and C (The Nature Conservancy).*

Leque and Matterand sites

The Leque and Matterand sites would likely be cheaper and simpler places to apply the sediment, given that they have not yet been restored and are closer to the site of proposed dredging. Both sites are subsided relative to adjacent natural marsh areas, so may benefit from sediment addition. Though subsided, both sites appear to be entirely within the expected elevation range of low marsh, which would be dominated by maritime and American bulrush. Both sites are at the north end of the bay, near the area that has been experiencing erosion over past decades. For this reason, sediment addition may be especially important to slowing or counteracting erosion. If the threat of erosion is greatest in those areas grazed by snow geese, as yet an unanswered question, it may be possible to adjust elevations in the restoration zones to emphasize vegetation more resistant to rhizome grazing, such as *Carex*, high marsh, or perhaps even some tidal transitional scrub-shrub. However, estuary topography will always adjust to the dominant hydrodynamic environment, so sustainable application of sediment must consider the processes that will ultimately determine surface elevations and slopes. Evaluation of these sites, as well as the TNC site, with respect to elevation, hydrodynamics, and projected development of vegetation and channels is necessary to determine the relative value of adding sediment.

Recommendations

1. Begin scoping the dredging proposal.
   The process and timeline for planning sediment additions at any site will depend on the likelihood and scale of the Old Stilly channel dredging. There are substantial permit hurdles to consider and knowing whether or not the regulatory agencies will permit the dredging will determine how much time to spend evaluating potential re-use sites.
   a. Initiate discussions with permitting agencies immediately. Start with WDNR, which is the state lead agency for the Dredged Material Management Program, and also the owner of aquatic bottomlands. See **Appendix 3 (Resources)** for contact information.
   b. Develop the data to support and justify dredging. Regulatory agencies will want to know this, and the TAG specifically requested this. Under what conditions is drainage to the Old Stilly channel a problem, e.g. is it after floods of a certain size, or is it drainage of high groundwater during spring planting, or some other condition? How much sediment removal is needed to alleviate the problem, would dredging significantly address the issue, how long would it be before the channel filled in and require dredging again? Modeling would likely be required to evaluate these questions. This process will also result in development of specific project objectives that will define your expected outcomes and your metrics for project success.
   c. Determine the volume of sediment that would be dredged. This will be key to determining which sites are best suited for re-use. An initial estimated range could be developed relatively quickly using straight forward geometry calculations, but a more refined estimate from the modeling may be needed to select a re-use site.
   d. Assess the sediment grain size distributions and whether different areas or strata of sediment have different grain sizes. Grain sizes may be stratified in the channel, with a shift in size happening as the channel has gradually changed from being dominated by river flow to domination by tidal flow. Surface sediment is likely very fine, but below that, and along the channel thalweg may be coarser sands. Understanding how much sediment of different grain sizes is available, and whether it is mixed or stratified, will be important to determining how the sediment can be reused. Grain size will affect which plant species will colonize and how easily the sediment may be eroded from the re-use site. The order in which sediment is applied to a site will also be determined by grain size and other sediment qualities because the top surface needs to have the sediment that is most suited for supporting the desired plant species.

2. Review the literature on sediment enhancement of tidal marshes. There is a considerable history of dredged sediment re-use in San Francisco Bay, the Gulf coast, and the east coast, and this literature should be reviewed and summarized for lessons learned and best practices. This review will guide evaluation of potential sediment re-use sites, and any future project design that emerges.

3. Seek advisory input from scientists and practitioners experienced in sediment re-use. While literature is a critical resource, the practical advice of experts doesn't always make it into the literature. In this region, learn from experts involved in sediment re-use at Jetty Island, the eelgrass beds near Bainbridge Island, and Columbia River marsh islands. In addition, experts in other regions have long experience in re-using sediment specifically in tidal marshes. Expert input will be essential to guiding the evaluation of alternative sites, and the possible development of project designs.

4. Evaluate the alternative sediment receiving sites
   The workshop determined that, at a conceptual level, there may be significant potential to improve the ecological performance of the three subsided restoration projects by raising elevations using added sediment. The key guiding principle for evaluation should be that use of sediment at a site must substantially improve ecological performance with respect to the site's restoration goals.
   Recommended Approach:
   a. Initiate conversations with the owners and project managers of the alternative sites to investigate their willingness to consider sediment enhancement. To evaluate the sites, data will be needed from each, as described in 4b below, and this evaluation process should be done in collaboration with all site owners.
   b. Develop and implement a full scope of work for evaluating each site for sediment enhancement.
      i. Determine the information that will be needed to evaluate each site. This will likely include the following.
         - Current conditions: site and adjacent marsh elevations, adjacent marsh species composition, site and adjacent marsh soil particle size distribution and soil salinity, presence of non-native species on site or nearby.
         - Accretion rates near the sites. [a network of SETs and feldspar marker horizons already exists, though additional horizons need to be installed soon in marsh areas near the two northern sites]
         - Relative climate change vulnerability. Evaluate relative vulnerability of different regions of estuary, considering rates of marsh accretion, vertical land movement, sea level rise, and potential summer low flow effects on salinity.
         - A vegetation-elevation-substrate model for the Stillaguamish estuary. Evaluate the effect of estuary region on plant elevation ranges, as species appear to have different distributions in different parts of the estuary, possibly in response to soil salinity and sediment grain size. [A veg-elevation model has been developed for the TNC site and may be under development for the other sites, a full veg-elevation-substrate model is in development for the entire estuary]. This model will inform the next task.

- Projected vegetation and elevation at each site, with and without sediment addition. Evaluate occurrence probabilities for dominant species, bare ground, and for known invasives including reed canary grass and narrow leaved cattail. Also, expected vegetation development in context of climate change. Choose a timeframe to evaluate, such as 20 or 50 years, and use the relative climate change vulnerability assessment to project future vegetation.
- Projected channel development after restoration, with and without sediment addition. [A channel model has been developed for the TNC site, and may be in development for the other sites].
- Erosional dynamics at north end of bay, and at each alternative site. There has been a high rate of marsh erosion in the north, with the seaward marsh edge moving closer to the dike at rates up to 21m/year. Some work is underway to evaluate causes. It will be important to determine which factors are playing a role, and whether the northern restoration sites will be affected. Site-scale erosion potential should also be evaluated for each potential site.
- Projected site use by Chinook with and without sediment addition. This would be based on an analysis of areas of marsh and channel habitats.

ii. Determine data gaps. Who is working on the above questions already, how much of the data is already available, and what will need to be acquired?

iii. Develop a scope of work for filling data gaps and completing analysis of potential sites.

5. If an evaluation of restoration sites suggests that sediment addition may be key to meeting the project's desired ecological performance, consider the options for obtaining sediment. If dredging the Old Stilly channel is not possible, or does not generate the right type of sediment, or will be insufficient in quantity, there may be other sources of clean dredge material.

6. Due to higher uncertainties and risks, Options 2 (adding sediment to existing marsh areas) and 3 (creating an off-shore sediment berm) are not recommended at this time, at least in any large application. However, in the context of climate change vulnerability, the use of sediment to improve the resilience of existing marshes may become an important tool in the region. For this reason, it may be worth considering a small, carefully controlled experimental project as part of this effort, to inform future adaptive management approaches in the region. Such a project must not be at a scale or location that would risk destabilizing large habitat areas. An experimental project under this option should not happen at the expense of improving the performance of one of the current restoration projects.

7. Any sediment re-use project that is implemented should take an experimental approach, based on explicit hypotheses and associated monitoring, to maximize learning opportunity. Re-use of sediment for marshes is new in Puget Sound, and the outcomes of this project would be very important to improving the design and performance of future projects.

Appendix 1
Expert Workshop Summary

Stillaguamish Estuary Beneficial Dredged Sediment Re-Use Conceptual Framework Meeting Summary

2/5/2014, 12-4pm, Everett WA

Meeting Objective:
Identify a technical and scientific framework to guide an evaluation of sediment reuse opportunities.

Meeting Context: The Stillaguamish Flood Control District has proposed to dredge the Old Stilly river channel in order to reduce drainage problems on farmland. They have proposed using dredged sediment to enhance tidal marshes in the estuary, to assist with Chinook recovery. This project is being considered within the context of Snohomish County's Sustainable Lands Strategy, an effort among fish and farm interests to develop strategies that generate net gains for both. Re-use of dredged sediment to enhance tidal marshes has been done in other regions, but is uncommon in Puget Sound. To evaluate whether re-use should be considered, a feasibility study will need to address some key issues. The purpose of this meeting was to identify those issues. This meeting was not intended to address any issues with regard to the actual dredging aspects of the project, but focused only on the concept of using dredged sediment to enhance tidal wetlands. The meeting was convened at the request of Snohomish County and was facilitated by Roger Fuller, Western Washington University.

Below is a summary of the discussion points. Individual points may not represent the consensus of all present.

Current Conditions in the Stillaguamish Estuary

The meeting began with a summary of current conditions in the estuary that are relevant to the question of the need for sediment enhancement of tidal wetlands. The purpose was to define our current assumptions about how the estuary is functioning.

- The delta is prograding at the mouth of Hatt Slough, but eroding in the north near South Pass.
- Since the 1960's, hundreds of acres of marsh have been lost in the north. There has been some marsh gain near Hatt Slough, but nothing that approaches the scale of the losses in the north. The marsh erosion rate near South Pass has approached 21m/yr since the 60's, with the most rapid rate of loss likely happening since 1990. This rate may be the highest rate of marsh erosion in Puget Sound.
- The loss of marsh in the north is the result of many interacting forces, including changes in sediment delivery as a result of channel shifts at Hatt Slough, reduced flows through the Old Stilly channel, increased salinity as channel configurations changed, and increased grazing of bulrush rhizomes by snow geese and swans, which facilitates sediment erosion by winter waves
- Local sea level rise (SLR) has been slower than global rates in the past one or two decades, as a result of Pacific Decadal Oscillation conditions. So it seems unlikely that SLR has had a significant effect on marshes recently, though it is possible that it has been a contributing factor. However, the local SLR rate could shift quickly and surpass global averages, as the dominant PDO phase

may be shifting, which would affect local sea level by altering sea surface temperatures and currents.

- Changes in the distribution of river sediment and salinity have likely occurred as the channel configuration at Hatt Slough changed. The largest channel shift occurred after the 1990 floods when a large sediment deposit at the west end of Hatt Slough shifted the main channel to the south, thereby redirecting the majority of the river flow away from the northern bay. After the 2006 flood, there was a similar, though smaller scale event which pushed even more of the flow towards the south, around the west end of "Goose Island". A recent assessment of sub-tidal bathymetry changes confirms that much of the sediment that would historically have been captured by tidal marshes at the river mouth is now building up where the sub-tidal delta shelf drops off to the deeper waters of Port Susan Bay. The current configuration of channels directs the river flow and its suspended sediment on the shortest route to the deeper water, bypassing much of the historic delta marsh area. It appears that much of the sediment delivered to the northern area of the bay is delivered by tidal action rather than direct river flow.
- The very large increase in the wintering snow goose population starting in the 90's, and their lengthening period of annual residence, has likely had a substantial effect on marsh area and erodability. Snow geese feed on the rhizomes of bulrushes, which are the dominant plant species in the Stillaguamish low marshes. This grazing reduces the volume of roots available to bind the soil against wave erosion, and the grubbing method of feeding loosens the soil surface thereby increasing the scour potential during winter storms. Fetch distance, and wave energy, is greatest at the north end of the bay. Large marsh area losses due to geese overgrazing of bulrushes has been documented for the Fraser River estuary, which co-hosts the same snow goose population.
- Recent marsh accretion rates in low and high marsh areas near Hatt Slough and in the high marsh area near South Pass are relatively high (4mm/year or greater). This rate is sufficient to keep up with moderate projections for sea level rise. However, the low marsh area near South Pass is losing elevation. This observation is consistent with the overall observation of marsh loss in the north – while accretion rates in the high marsh are adequate, implying there is sufficient delivery of sediment, the seaward edge of the low marsh is nevertheless eroding, possibly due to the combined effects of winter waves and overgrazing. It is possible that this erosion of low marsh is supplying the sediment that maintains higher accretion rates in the high marsh. A key question remains unanswered: whether the northern low marshes are limited by sediment supply from the river, by the combination of overgrazing and wind/wave fetch distance, or by all three. Work is underway to answer this.
- The presence of tidal marsh, and the slope and breadth of the intertidal zone, affect the size and energy of waves that reach the shoreline or the sea dike. Work underway suggests that the risk of erosion and overtopping of dikes in the northern area has increased with the loss of tidal wetlands.
- Current or recent research/assessment in the Stillaguamish estuary:
  - vegetation, accretion and restoration (Roger Fuller and John Rybczyk, WWU)
  - sediment and hydrodynamics including river and waves (Eric Grossman, USGS)
  - channels and vegetation-elevation models (Greg Hood, SRSC)
  - 3D hydrodynamic modeling (Tarang Khangaonkar, PNNL)
  - lower Stilly channel reach assessments and 2D hydro model (Bob Aldrich, Snohomish County)
  - hydrology, habitat, invertebrates and birds (John Takekawa and Isa Woo, USGS-Vallejo)
  - fish, shellfish and water quality monitoring (Jason Griffith, Stillaguamish Tribe)

- restoration assessments and designs (Jenny Baker et al., TNC; Curt Mykut, DU; Loren Brokaw, WDFW; Jason Griffith, Stillaguamish Tribe).

<u>Sediment re-use in the estuary: Is there a potential positive role?</u> What are the issues that need to be considered? What are some general characteristics or rules that should define a framework for considering sediment reuse?

- Subsidence in restoration areas may result in reduced habitat benefits after restoration in places where elevation is too low for development of productive tidal marsh and channel habitat. There is potential to counteract the effect of subsidence by raising site elevations to marsh elevations, and aligning them with adjacent natural marsh elevations (potential sites include TNC, Matterand, Leque, or some yet to be identified restoration project)
- Marsh areas that are eroding or at risk of eroding with sea level rise (SLR), could be recovered, or their loss could be slowed or postponed.
- In areas where there is already plenty of sediment accretion, additional sediment could sustainably expand marsh areas seaward, or could increase the resilience of the marshes to SLR.
- This approach could contribute to the Chinook recovery goals by increasing marsh area.
- Ability for self-maintenance (look for places where conditions or processes provide the potential for systems to keep or replenish the added sediment, or to adapt accretion levels as sea level rise rates change)
- Sediment composition should match that of target marshes (particle size, organic content…). Particle size is also important to whether added sediment will remain at a site with given wave energy. Sediment should be free of things that might affect plant or animal function, like toxins, excessive salts, etc.
- Work within context of controlling ecological processes such as river, tidal, wave hydrodynamics and sediment distribution – don't fight these by attempting to engineer around them
- For success, need to identify the processes that are at work at a site, how they're currently working, and how they may change with climate change
- Consider the likely longevity of applied sediment…in light of sea level rise, applying sediment in some areas may postpone marsh loss but not prevent it, so are you OK with the potential that the sediment enhancement project may be temporary, that you may just be buying a little time?
  - By doing a sediment enhancement project, are you committing to keeping it going in the future with additional sediment additions to maintain the project habitat outcomes? Will the project be a failure if the effects only last a few years or a decade or two? These expectations, either way, should be made explicit in project goals so that there is no confusion later about commitments to adaptive management.
- There is an opportunity to be experimental with this, in terms of elevation of placement, or depth of additions, etc.
- Might consider a project similar to what they have done on the SW Washington coast, using sub tidal "feeder berms" – sediment piles that are moved onshore by wave action, allowing the natural processes to move and distribute the sediment to the beaches.
- Is there a potential to focus on rare habitats?...scrub shrub, tidal forested, riparian, eelgrass? Only if you aren't replacing another valuable habitat, for example don't smother existing low marsh in trade-off for scrub shrub. If a subsided restoration site could be filled to scrub shrub elevation, might consider it.

- Engineering should be minimized and ideally avoided – if armoring is required to maintain sediment on site than it may not be sustainable economically or ecologically
- Consider the potential for harm to the system, whether temporary or long term –
  - introducing toxic materials
  - introducing invasives or creation of habitat that is more favorable to invasives than natives (in Columbia estuary, the dredge sites where marsh established host a higher proportion of non-natives than the natural reference sites)
  - replacing one habitat type with another in a way that harms certain species in favor of others
  - inadvertently destabilizing large marsh areas by adding too much sediment, burying plants
  - degrading soil gas or ion exchange in a way that destabilizes marsh plants
  - causing sediment redistribution offshore, resulting in burial of eelgrass and benthic invertebrates
- How would sediment addition interact with channels, either existing or projected – would it reduce or accelerate development, lead to filling in of channels or focus hydraulics and carve deeper or more extensive channel systems?
- If concerned about sediment accretion in the Old Stilly channel, then should avoid putting the dredged sediment someplace where tides/waves would just transport it back up the channel. How long will the desired benefits of dredging last?
- How much sediment volume are we talking about? This will be key to site and method determination.
- Evaluation of erosion potential at all sites is key.
- Macrotidal vs. microtidal conditions. In other regions where this has been done successfully, they tend to be micro/mesotidal situations. How does the macrotidal environment of Puget Sound change expectations for performance?
- How will the dredged sediment be transported to the site? How feasible is it to get the sediment to alternative sites? (are sites as far as Hatt Slough feasible)
  - One project elsewhere used old, retired wooden barges loaded with sediment and sunk on site, to reduce cost and to help anchor sediment in place.
- Other possible uses of the sediment?:
  - Would it be possible to sell the sediment to the ACOE? They may be in need of clean sediment for other mitigation projects.
  - Use it to augment dikes upstream where the levee overtopping occurs that floods the lower delta?
  - Use it to fill low lying farmland?

<u>Project Design and Feasibility - What information would be needed to determine where and how to apply sediment?</u>

- **List of the different potential project types, or ways of using sediment to enhance marshes**
  1. Add the sediment to a subsided restoration site to more closely match adjacent marsh elevations and to improve marsh and channel habitat development.
  2. Apply sediment to existing habitat areas

a. Apply in areas of erosion risk, to slow, reverse or prevent marsh loss due to erosion. For example, in northern marshes where significant marsh loss has already occurred, or near the north end of the “new” delta where there has been some marsh loss, but where proximity to the TNC restoration may improve connectivity with the river mouth.
b. Increase the marsh area on the prograding delta near Hatt Slough by creating new marsh islands at the mouth, or building new marsh seaward of the existing marsh boundary.
c. Add sediment to existing marshes near Hatt Slough to increase their resilience to sea level rise, and/or to accelerate development of higher marsh habitat.

3. Add sediment as a sub-tidal berm and allow tidal/wave action to move the sediment up into the marshes.

- **Project types: What are the assumptions, issues and questions for each project type? What do we need to know to decide?**

  1. Add sediment to a restoration site.

  Assumptions:

  - Three current sites to consider (TNC, Leque, Matterand), or a future project yet to be identified
  - If a restoration site was picked for sediment augmentation, that site would need to demonstrate that the current habitat is, or would be, lower quality compared to what would be there with higher elevations.
  - If there are large areas where there is no predicted vegetation at the site due to low elevations, this indicates that sediment could be needed to raise elevations
  - Mean Sea Level (MSL) may be the target elevation, below which you wouldn’t expect vegetation.
  - For quality habitat, avoid Typha (cattail) elevations, and favor Carex lyngbyei elevations
  - Of the 3 sites, the TNC site is the lowest elevation and may take decades or more to accrete sufficient sediment naturally to match adjacent habitats.
  - The TNC site is too low for proper ecological functioning. Even though the dikes were removed, the elevation differential between the site and adjacent marsh is so great that the site functions similar to a diked site with a couple of breaches in it. This is because there is only sheet flow across the old-to-new marsh boundary at the highest tides and otherwise all flow is through two excavated channel breaches which are inadequate in size and number. The few places where tidal or river flow can access the site means that hydraulic energy is focused towards those two sites, the ebb velocities through those sites are very high (excluding juvenile access during the ebb), areas remain inundated longer than natural, and small blind tidal channels aren’t forming that would otherwise likely form across the old-to-new marsh boundary.
    - This is not to say that broad shallow ponding is necessarily bad. At Wylie Slough (Skagit), broad shallow ponding occurs, following restoration, and these have been full of juvenile fish and appear to be very productive. So some shallow ponding is not bad. But the TNC site is not “some shallow ponding”, it’s too subsided/deep.

- If the TNC site was selected, the project should include some excavation of new/additional channels across the old/new marsh boundary

- The two northern sites may be the cheapest places to put the sediment, given proximity
- The selection of a site for sediment addition should depend on the project goals for that site, so what performance metrics are required to achieve project goals?
- Suitable sediment grain size should be used that can be maintained on site, given current and future wave energy and hydrodynamics

Sources of uncertainty

- To compare the suitability of the sites, would need to know:
  - the rate of sediment depositing (or predicted to deposit) and the time for the site to reach a "natural" elevation relative to adjacent marsh, all in the context of the rate of sea level rise (SLR)
  - the vegetation communities at the current and future elevations (given SLR, natural sediment accretion, sediment addition from re-use application, and natural subsidence)
- Projected tidal channel development and alignment – could sediment addition facilitate channel development?
- Erosional dynamics – what will keep the sediment in place within the context of site topography, wave conditions, channels, flood flows…? Are plantings needed to stabilize sediment? Other strategies like Christmas trees to provide temporary localized current attenuation?

Other issues and questions

- With restoration, the Leque/Matterand sites may capture some of the sediment that currently gets tidally pushed up into the Old Stilly channel. As a result of those projects, it may lessen the need to dredge the Old Stilly channel (if the projects decrease the future accretion rate in the channel)
- Dredged sediment is likely to be variable in particle size and other qualities as it comes from different places in the Old Stilly channel. As a result, the sorting and order of deposition of the sediment in a new place would be important, needing to get the right qualities on top where vegetation will form.
- Should plantings be incorporated into projects? E.g. to help with anchoring sediments. See some of the literature.
- For each site, are there additional actions that could be taken to enhance connectivity, sediment delivery or otherwise improve long term outcomes? For example, at the TNC site, is it worth considering a new breach along the river to stimulate formation of a new distributary towards the north and increase sediment delivery? (gradient may be too shallow for this) Or additional blind channels that would improve connectivity across old-new marsh boundaries.

2. Add sediment to existing marshes, or create new marsh islands

Assumptions

- This action would prolong marsh persistence in the face of SLR

- In areas where there is no marsh currently, there is a reason there is no marsh there. Need to understand the controlling factors for marsh there, and will those factors still be there after sediment is applied?

Sources of Uncertainty

- The erosion potential at different sites. What is the likelihood of losing the sediment to erosion?
- If there is erosion potential, how would this be overcome, how would erosion risk be reduced?
- Is there an erosion threshold, and are there areas near it? Would adding sediment in those areas prevent or substantially retard a state change in the habitat (from marsh to tide flat). This is a substantial area of uncertainty.
  - It is possible to position accretion/erosion monitoring stations to fine tune where erosion is, or may soon begin to happen.

Other issues and questions

- There are much higher uncertainties with applying sediment to existing marshes, than to a restoration area.
  - There is a risk of killing/destabilizing the marsh. How much sediment to add, how long will it stay there (next storm, next year…), will it kill existing plant (or animals such as crabs, shellfish, other benthic invertebrates)?
  - In areas where there is currently no marsh, there's a reason for that, so how can you be sure that those same reasons won't prevent, slow or alter marsh development when more sediment is added?
- Could do large plot-scale experiments to determine appropriate application depths and locations (marsh edge, marsh interior…), and to manage risk (learning opportunity without the risk of large scale marsh destabilization)
- Consider a breakwater in front of the northern marshes that are eroding? Something that would reduce wave energy…examples might be a narrow floating log boom, low rocks or blocks similar to Gulf Coast oyster reefs, engineered log jams, anchored Christmas trees, a temporary subtidal berm of sediment like they do near Long Beach Peninsula, that would temporarily reduce wave energy and provide sediment that would be pushed up into the marsh.
- There would likely be greater permitting challenges in applying sediment to existing marshes or tidelands, than in applying it to restoration sites.

Summary Discussion and Items of General Consensus

- Take an experimental approach.
  Whatever approach is taken, it should be pursued with an experimental approach, based on explicit hypotheses and associated monitoring, to maximize learning opportunity. Re-use of sediment for marshes is new in Puget Sound, and the outcomes of this project would be very important to improving the design and performance of future projects.
- Avoid risking harm to habitats. When applying sediment to restoration sites, there is less risk of harm since there is no existing marsh that could be harmed. Whereas there is

greater risk when applying to existing marsh or tide flat, and subsequently there is reason for more caution.

- Applying sediment to restoration sites is conceptually more attractive than to existing tidal habitats because of the issues of risk of harm and uncertainty, and because of potential to significantly improve performance of restoration projects.
- At this point, the TNC site seems to be the most attractive site for application because it is so low in elevation which may reduce the habitat benefits it provides for a long time in the future.

- **Next Step Recommendations**
  - Permits for both dredging and re-use will be required, so start dialogue with regulatory agencies.
  - Talk to restoration site owners.
  - General information needs: dredged sediment volume, sediment particle size fractions, sediment quality
  - Information needs for site evaluations: current and future elevations, vegetation projections, accretion/erosion rate projections, blind channel development potential, wave erosion potential,
  - Engage DNR as the state lead for dredge programs, and as owner of sub-tidal lands and some inter-tidal lands.
  - WaDOE flood hazard reduction program funding…is there someone at County who could determine whether this project may be eligible and could prepare proposals?
  - Coordinate with PSNERP and PSP as both are considering beneficial re-use at some level, in Puget Sound recovery actions. For example, NEP (EPA) funding comes through PSP, and could play a role.

<u>Participants, and relevant background:</u>

Roger Fuller, Western Washington University, landscape/spatial ecologist, research in Stilly estuary, formerly with TNC

John Rybczyk, Western Washington University, estuarine sediment dynamics, Stilly research, former colleague in LS has researched dredge spoil marshes

Greg Hood, Skagit River System Cooperative, estuarine ecologist and geomorphologist, Stilly research

Tarang Khangaonkar, PNNL, oceanographic modeling including sediment transport, Stilly 3D modeling linked with a Salish Sea hydrodynamic model

Frank Leonetti, Snohomish County, habitat specialist, fisheries biology, science/technical support to Stilly and Snohomish basins

Lara Aston, PNNL, ecologist, dredged material testing and toxicity

Ron Thom, PNNL, coastal ecologist, beneficial reuse of dredged sediment for eelgrass restoration, characterization of 53 Columbia River tidal marsh reference sites including 19 on dredge material
Bob Aldrich, Snohomish County, project specialist, geomorphology, modeling, engineering
Debbie Terwilliger, Snohomish County, director of Surface Water Management
Chuck Hazelton, Flood Control District, levee and drainage infrastructure, local knowledge of the delta
Hank Lippek, Flood Control District, attorney and planning
Sarah Lippek, Flood Control District, attorney

Invited but unable to attend:
* Kurt Nelson, Tulalip Tribe
§ Si Simenstad, UW
Paul Cereghino, NOAA
Julie Morse, The Nature Conservancy
Chris Curran, USGS
§ Eric Grossman, USGS
* Jason Griffith, Stillaguamish Tribe
Gregg Farris, Snohomish County
* Pat Stevenson, Stillaguamish Tribe

* provided input at the subsequent discussion of dredged sediment re-use at the Stillaguamish Technical Advisory Group
§ provided input separately

Appendix 2
Stillaguamish TAG Discussion Summary

Stillaguamish Watershed Council Technical Advisory Group Meeting
Discussion of Potential Use of Dredged Sediment to Enhance Tidal Marshes

2/12/2014, 9-10am, Arlington WA

Meeting Objective:
Update the TAG on the development of the concept of re-using dredged sediment to enhance tidal wetlands. Discuss with the TAG the general issues and concerns that any further evaluation of sediment reuse opportunity will need to address.

Dredged Sediment Re-use Context:
The Stillaguamish Flood Control District has proposed to dredge the Old Stilly river channel in order to reduce drainage problems on farmland. They have proposed using dredged sediment to enhance tidal marshes in the estuary, to assist with Chinook recovery. This project is being considered within the context of Snohomish County's Sustainable Lands Strategy, an effort among fish and farm interests to develop strategies that generate net gains for both. Re-use of dredged sediment to enhance tidal marshes has been done in other regions, but is uncommon in Puget Sound. To evaluate whether re-use should be considered, a feasibility study will need to address some key issues.

To identify those issues that would need to be addressed in a feasibility study, Snohomish County hired Western Washington University (Roger Fuller) to convene a workshop of estuary and sediment experts. The purpose of the workshop was to identify a technical and scientific framework to guide an evaluation of sediment reuse opportunities. Based on the input from the workshop, and from the TAG, a list of recommended next steps will be provided to the County. The County requested that this effort focus explicitly on the concept of sediment re-use, not on the channel dredging component itself. This is because the concept of sediment re-use for tidal marsh is a novel approach in Puget Sound and it was not clear that such an approach should even be considered.

Current Conditions in the Stillaguamish Estuary
Roger Fuller began by presenting an overview of current and historic conditions in the estuary, and described the research that is underway by various experts at WWU, USGS, Pacific Northwest National Laboratory (Battelle), and Skagit River System Cooperative. A summary of this information is available in the notes from the expert workshop. The workshop was held on 2/5/2014.

Expert Workshop Summary
Roger then summarized the output from the expert workshop on dredged sediment re-use, and opened the floor for input and discussion from TAG members. The workshop summary notes are available separately.

TAG Discussion

- Organic/inorganic fractions in sediment may be key to potential re-use
- Regarding potential use at the TNC site, we would want to know the current density or use of the site by chinook compared to reference marsh areas at the potential new elevations
- Invasives…is there a seed bank in the sediment to be concerned about?
- What are the benchmark accretion rates?
- For the potential use sites, what was the historical ecology of the sites?
- Need to be explicit that this is not process-based restoration, but enhancement of structure
- What would the succession of vegetation look like?
- What is the erosion potential of sites, how long will the sediment stay in place?
- Alternative method of flushing more water thru Old Stilly…let the flow move the sediment. Working to improve connection of upper end of the Old Stilly with the main Stillaguamish channel could increase flow through the Old Stilly. This would be process-based approach.
    - Tribe is working on this issue, to fix the inlet to the Old Stilly channel.
- Least disruptive opportunities – the sites that are not restored yet. Easier permitting.
- Concept of subtidal bar deposition – high uncertainty that it would go where you want. Also, can't smother eelgrass, major shellfish areas.
- The bigger issues are the channel dredging impacts, the sediment, fish impacts.
    - The drainage/flood control benefits need to be justified, particularly in the context of ongoing land subsidence…what is the real level of drainage risk, and is dredging really going to noticeably affect drainage on the farmland?

Appendix 3
Resources

Resources

The following resources provide additional background for considering beneficial re-use of sediment to enhance tidal marsh habitat. Most of these resources are also documented on the Salish Sea Restoration wiki at https://salishsearestoration.org/wiki/Beneficial_use_of_dredge_materials

Lead Agencies

The Army Corps of Engineers is the lead federal agency for sediment dredging and beneficial re-use. Their Dredge Material Management Program website can be found at
http://www.nws.usace.army.mil/Missions/CivilWorks/Dredging.aspx
Their User Manual for Dredged Material Evaluation and Disposal Procedures has been developed for Washington state. http://www.nws.usace.army.mil/Missions/CivilWorks/Dredging/UsersManual.aspx

The state agency overseeing dredging is the Department of Natural Resources.
The WDNR Dredged Material Management Program is managed by Celia Barton, at celia.barton@dnr.wa.gov, or 360-902-1735.
The program website is:
http://www.dnr.wa.gov/BusinessPermits/Topics/AquaticResources/Pages/aqr_dredged_material_program.aspx

Examples of Sediment Re-use

South Slough National Estuarine Research Reserve, Coos Bay, Oregon

- In a restoration project at the Kunz Marsh, involving dike removal, dike material was used as fill to experimentally manipulate marsh elevation of the subsided restoration site. This project did not use dredged material, but illustrates the beneficial use of fill material to improve function at a restoration site. The site was divided into four experimental zones receiving different levels of fill material. The project is described at: http://www.oregon.gov/dsl/SSNERR/docs/WTRPkunzpart1.pdf

San Francisco Bay

- Hamilton Wetlands: http://hamiltonwetlands.scc.ca.gov/ Old military air base restored to marsh using dredged sediment to raise the subsided site prior to dike breaching.
- Montezuma Wetlands Restoration Project: http://ceres.ca.gov/wetlands/projects/montezuma.html Restoring about 1,800 acres of tidal wetland by using dredged sediment to bring diked/subsided area up to natural elevation before breaching dikes.
- Sonoma Baylands: http://www.bay.org/bay-restoration/restoration-projects/sonoma-baylands Restored ~360 acres tidal wetland by using dredged sediment to fill a diked/subsided area before breaching dikes.

Chesapeake Bay

- Poplar Island – using dredge material to create 600 acres new marsh to replace marsh that had eroded away. http://www.chesapeakequarterly.net/V12N3/main1/
- Hart Miller Island – created ~180 acres wetland/mudflat from dredge material. http://www.menv.com/pages/outreach/hmi.html

Gulf of Mexico

- A detailed summary of 11 habitat restoration projects that used dredge material, including lessons learned and project references. Some, but not all involve wetland enhancement. http://www.gulfmex.org/1168/gulf-regional-sediment-management-master-plan-case-study-compilation/

Literature

The following articles provide a useful starting place for analysis of beneficial reuse of dredge materials.

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