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*Regional Sediment Management Program*

# **Site Selection and Conceptual Designs for Beneficial Use of Dredged Material Sites for Habitat Creation in the Lower Columbia River**

Chanda J. Littles, David A. Trachtenberg, Hans R. Moritz,  
Douglas C. Swanson, Ryan W. Woolbright, Kathryn M. Herzog, and  
Amy B. Borde

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## Abstract

Channel maintenance in most major rivers throughout the United States requires ongoing dredging to maintain navigability. The US Army Corps of Engineers explores several options for placement based on sediment characteristics, material quantity, cost, operational constraints, and minimization of potential adverse effects to existing resources and habitat. It is a priority to beneficially reuse dredged sediments to create habitat and retain sediments within the river system whenever possible. Nonetheless, there can be discrepancies among state and federal resource agencies, landowners, tribes, and various other stakeholders about what constitutes a benefit and how those benefits are ultimately weighed against short- and long-term tradeoffs. This work leveraged prior Regional Sediment Management efforts building consensus among stakeholders on a suite of viable strategies for in-water placement in the lower Columbia River. The goal was to identify suitable locations for applying the various strategies to maximize habitat benefits and minimize potential adverse effects. A multistep site-selection matrix was developed with criteria accounting for existing site conditions, overall placement capacity, tradeoffs, long-term maintenance, cost, stakeholder concerns, and landscape principles in the context of other habitat restoration projects implemented in the lower river. Three highly ranked sites were selected for conceptual design and exemplify results of collaborative beneficial use implementation.

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## Preface

This study was conducted for the US Army Corps of Engineers (USACE), Regional Sediment Management (RSM) Program, and the USACE Portland District (NWP), under Funding Account Code U4361199, AMSCO Code 008303. The USACE National RSM program manager at the time of publication of this report was Dr. David W. Perkey.

The work was performed by NWP of the Northwest Division, USACE. At the time of study, COL Michael D. Helton was the commander and district engineer; Mr. Keith Flowers was the deputy director of the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL); and the director of ERDC-CHL was Dr. Ty V. Wamsley.

The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

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# 1 Introduction

This report leverages input received in 2018–2019 when the Portland District actively engaged regional stakeholders in brainstorming strategies for beneficially reusing dredged material in the Lower Columbia River (LCR), specifically the approximate 100 river miles (RM) below Bonneville Dam. The interagency team began by building consensus around a set of guiding principles and concepts pertaining to the beneficial use of dredged material (BUDM) for habitat restoration. Then, three indicator species were selected to represent the habitat continuum from shallow water to vegetated uplands. Through multiple brainstorming sessions, each species' critical needs were discussed along with likely habitat characteristics meeting those needs, specific uses, and additional considerations. This first effort culminated in a list of eight BUDM management strategies for habitat restoration based on physical, hydrological, ecological, and operational constraints.<sup>1</sup> This current study flushed out conceptual designs based on the strategies identified in Studebaker et al. with a primary goal of improving habitat conditions for one or more species. The district reengaged stakeholders to select target locations for potential implementation of at least one BUDM placement strategy. This report presents those findings along with key recommendations for maximizing habitat benefits at each site.

## 1.1 Background

Over the last 150 yr,<sup>2</sup> the natural landscape in the LCR has been transformed by human activities through diking, dredging, and other river-training efforts. In addition, the hydrologic and geomorphic processes that sustained the river ecosystem have been altered by hydropower dam operation, upriver diversions, and channel deepening, resulting in the loss of 77% of tidal marshes and swamps in the floodplain (Fresh et al. 2005).

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1. C. Studebaker, R. Stolt, D. Swanson, M. Turaski, J. Norton, R. Moritz, and A. Whiting. Unpublished manuscript. "Strategies and Site Selection Criteria for Beneficial Use of Dredged Material for Ecosystem Restoration in the Lower Columbia River and Estuary," Technical Note. Portland, OR: US Army Corps of Engineers, Portland District.

2. For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–347, respectively. <https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf>.

The remaining intertidal wetlands and floodplains support 13 federally listed threatened and endangered Pacific Northwest (PNW) salmonid species (Bottom et al. 2011), and the paucity of these habitats is considered a major limiting factor to salmon recovery (NMFS 2011).

## 1.2 Objective

It was hypothesized that the BUDM strategies developed by Studebaker et al.<sup>3</sup> could be used to locate potential dredged material placement sites and strategically inform design objectives. BUDM options were sought to take advantage of natural sediment transport dynamics in the larger riverine and estuarine environments and create or enhance intertidal and floodplain habitats for the benefit of native fish and wildlife in the LCR, namely the river mouth to Bonneville Dam.

## 1.3 Approach

Several potential strategies for BUDM were considered in terms of habitat restoration potential for three focal species representing diverse species guilds, namely salmonids, Columbian white-tailed deer, and streaked horned lark. Goals included habitat improvement and minimizing long-term adverse effects to species and existing habitat. From an initial list of eight potential strategies, four were selected for incorporation into conceptual designs based on a higher presumed probability of success and the desire to have a breadth of strategies that could be implemented across a range of settings. Strategies included the (1) creation or expansion of intertidal or emergent islands, (2) use of velocity shadows to expand intertidal or emergent wetlands, (3) building bar and scroll topography, and (4) placement for targeted dispersal. Prior results from a geographic information system (GIS) framework were used to identify potential sites that were then vetted through stakeholders for further input and refinement. In the first step, seven criteria based on dredging operational needs, placement constraints, and a preliminary assessment of site characteristics were included in a site selection matrix. Sites were then evaluated using landscape principles that were developed to aid in evaluating restoration projects under the Columbia Estuary Ecosystem Restoration Program (CEERP). This secondary evaluation allowed each

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3. C. Studebaker, R. Stolt, D. Swanson, M. Turaski, J. Norton, R. Moritz, and A. Whiting. Unpublished manuscript. "Strategies and Site Selection Criteria for Beneficial Use of Dredged Material for Ecosystem Restoration in the Lower Columbia River and Estuary," Technical Note. Portland, OR: US Army Corps of Engineers, Portland District.

site to be evaluated in terms of its potential benefit to salmon at the landscape scale based on other potential restoration activities in the immediate vicinity, consideration of the hydrogeomorphic reach, and possible synergistic effects. All of these factors, along with any additional stakeholder feedback, were ultimately considered in the scoring and ranking of potential placement sites. Three of the seven sites were finally chosen for conceptual designs that included the habitat goals, estimated dredge and placement quantities, target placement elevations, aerial maps, and projected short- and long-term costs. Findings provide a solid basis for future implementation.

## 2 Site-Selection Methodology

Sites were identified by a diverse group of engineers, scientists, planners, and operations managers utilizing GIS tools developed from a systematic, structured decision-making framework for BUDM.<sup>4</sup> The Portland District's (NWP's) multiple business lines and missions (e.g., ecosystem restoration sites, 20 yr Dredged Material Management Plan, and pile-dike rehabilitation projects) were intentionally considered in charting a path forward.

Regional stakeholders were convened to build consensus on the objectives and most promising BUDM opportunities, including resource managers, regulators, and researchers from state and federal agencies: Oregon Department of Fish and Wildlife, Oregon Department of State Lands, Washington Department of Fish and Wildlife, Washington Department of Natural Resources, US Fish and Wildlife Service, NOAA Fisheries, Department of Energy–Pacific Northwest National Laboratories, and Bonneville Power Administration. The decision framework included three phases of strategic engagement with regional experts and stakeholders to help inform BUDM site selection. In Phase 1, the team reached general consensus on the principles and key concepts for the BUDM in terms of habitat restoration. During Phase 2, three indicator species were selected to reflect a habitat continuum, and the interagency team developed criteria and key constraints for both creating new habitat opportunities and avoiding potential adverse effects to existing habitat. Last, in Phase 3, the team developed and refined eight potential BUDM strategies for habitat restoration that formed the initial set of options for BUDM conceptual designs.

### 2.1 Geographic Information System (GIS) Methodology and Initial Sites

The GIS methodology for identifying potential BUDM sites was developed based on interagency discussions during workshops in 2018. Information and results from the 2018 workshops and methodology for the GIS tool are found in Studebaker et al.<sup>4</sup> Initially, eight strategies for habitat restoration were considered. Of those eight, four were prioritized based on breadth

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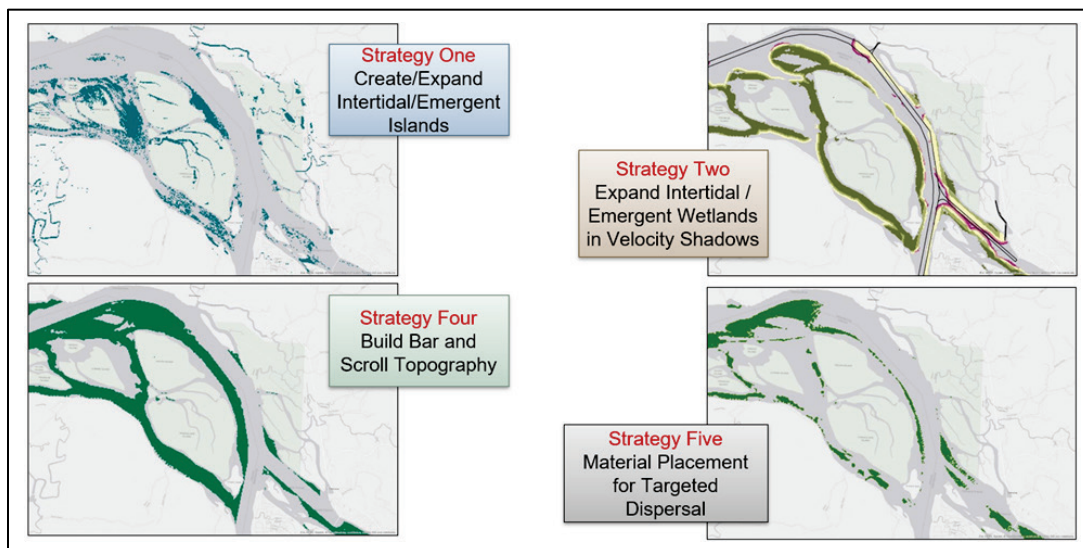
4. C. Studebaker, R. Stolt, D. Swanson, M. Turaski, J. Norton, R. Moritz, and A. Whiting. Unpublished manuscript. "Strategies and Site Selection Criteria for Beneficial Use of Dredged Material for Ecosystem Restoration in the Lower Columbia River and Estuary," Technical Note. Portland, OR: US Army Corps of Engineers, Portland District.

and probability of success and were the focus of the BUDM GIS analysis. The four strategies included in the GIS analysis and adopted for this current effort were

- Strategy 1—Create/Expand Intertidal/Emergent Islands,
- Strategy—Use Velocity Shadows to Expand Intertidal/Emergent Wetlands,
- Strategy 4—Build Bar and Scroll Topography, and
- Strategy—Place Material for Targeted Dispersal.

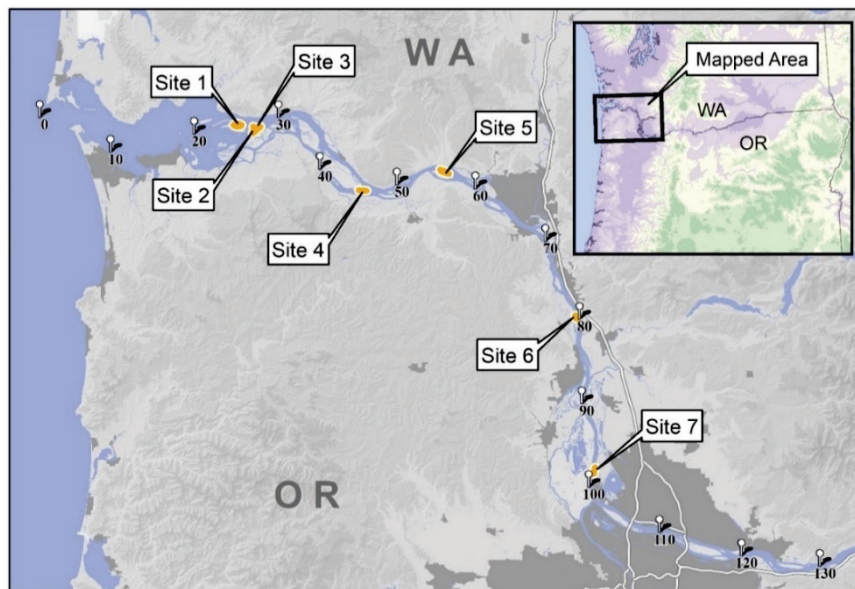
Figure 1 shows examples of the GIS analysis results, identifying where conditions exist to achieve each of the four strategies.

**Figure 1. Geographic information system (GIS) analysis results depicting possibilities for implementing the four priority strategies based on existing conditions near Tenasillahe Island.**



The project delivery team (PDT) used the BUDM GIS analysis results to identify potential sites for ecosystem creation or enhancement. Seven preliminary sites were identified in the LCR, with the most downstream site at approximately RM 25 and the most upstream site at approximately RM 98. Sites were numbered from downstream to upstream. Figure 2 shows the locations of the seven preliminary sites along the LCR. The initial sites cover a range of strategies and were initially selected based on US Army Corps of Engineers (USACE) staff professional judgement and then vetted through meetings with stakeholders for further input and refinement. Sites may be mapped in more than one strategy, but the conceptual designs typically picked one strategy as the focus of the design.

Figure 2. Locations of seven preliminary beneficial use of dredged material (BUDM) sites in the Lower Columbia River (LCR).



## 2.2 Site-Selection Criteria

To ensure a range of habitat conditions reflective of diverse locations, strategies, and reaches were considered, a two-step selection matrix with seven criteria was developed (Table 1). First, each site received a rank score from 1 to 3 under each criterion, with higher scores more desirable. The individual criterion scores were then summed to provide a total raw score per site. Next, there was an assessment of strategy, hydrogeomorphic reach, proximity to other restoration sites, likelihood of filling a habitat gap (specifically with regard to fish), and potential adverse effects to other environmental resources (Table 1). This entire process was done in consultation with stakeholders and USACE staff to arrive at a list of candidate sites that also ranked highly based on criteria in the selection matrix.

The final criteria in the site selection matrix were the following:

1. Total Area of Potential Benefit—Total area of the BUDM site based on the planned material placement in acres. The category is scored High = 3, Medium = 2, and Low = 1. Thresholds for the low score were less than 25 acres and greater than 75 acres for the high score.
2. Potential Tradeoff Area—Risk associated with the uncertainty about the potential environmental lift over baseline habitat conditions. In this context, the risk was based on expert opinion and the potential for BUDM

- placement to result in habitat degradation, instead of lift or improvement. There is at least the potential for high-value habitat in the project footprint, but more analysis and site work could be required to avoid burying highly productive habitats to achieve net environmental benefits. The category is scored opposite of the total area criterion: High = 1, Medium = 2, and Low = 3.
3. Capacity—Dredged material capacity of the BUDM site in thousands of cubic yards (kcy). Thresholds are fewer than 400 kcy for Low and greater than 1,000 kcy for High.
  4. Capacity Needs and Sediment Availability—Scores based on availability of material nearby that will be dredged from the Federal Navigation Channel (FNC) and the frequency and volume of nearby dredging relative to other proposed sites. High scores (3) would correspond to high shoaling areas with frequent dredging. Low scores (1) correspond to low shoaling areas with little dredging. Medium scores (2) correspond to intermediate shoaling areas or high shoal areas with abundant placement capacity options.
  5. Maintenance—This category considers the relative effort expected to maintain any vegetation associated with target habitat included in the site design plan. This includes any supplemental planting and augmentation of vegetated zones, along with measures needed to prevent colonization by invasive species. Planting plans and invasive species control measures were later addressed in more specific site-design plans. These measures would ultimately be developed in partnership with a local project sponsor that would be responsible for long-term site maintenance. For the preliminary scoring, vegetated zones are assumed to be the footprint of any planned berm or other area above normal high water. While this simplifying assumption facilitated an initial comparison of sites, it does not necessarily constrain the final planting plan, which could include establishing vegetated areas below normal high water. The potential need for supplemental placement of dredged sediment at a given location was not considered under this category for scoring purposes. Without further modeling and design work, it is unclear which sites could require additional placement and at what frequency. Also, additional placement actions could fall under the purview of navigational channel operation and maintenance (O&M) with no added cost to the project sponsor. The category is scored based on relative amount of effort given the projected area of vegetative cover. High = 1, Medium = 2, and Low = 3. Thresholds are less than 15 acres for Low and greater than 25 acres for High.

6. **Longevity and Stability**—This is a relative ranking of the likelihood a site would remain in place for the 50 yr planning horizon. Initial rankings are based on the average velocities the sites are exposed to as well as additional factors that could increase stability such as the placement of pile dikes or enrockments. High likelihood = 3, Medium = 2, Low likelihood = 1. Sites with associated beach nourishment would have a protected lee that would remain untouched after initial construction. The beach nourishment may need to be maintained periodically by adding material to the areas more prone to erosion.
7. **Site Evolution**—This criterion consists of two parts. First is the relative length of time (number of dredging seasons) to place material and construct the site. Second is the length of time to accrue expected benefits or establish desired habitat. Preliminary scores are based on initial construction time. The PDT requested additional input on and discernable differences in time to accrue benefits and establish habitat during workshops. Stakeholder comments reflected known habitat constraints, existing knowledge about and assumptions about the likely level of augmentation needed based on presumed habitat goals. Relative ranking based on time (assuming sooner is better): Long (1), Medium (2), and Short (3).

**Table 1. Beneficial use of dredged material (BUDM) site-selection matrix and scores.**

Site Characteristics							
Site Number	1	2 <sup>a</sup>	3	4	5 <sup>a</sup>	6 <sup>a</sup>	7
RM	25.4	27.4	27.5	45.8	55.8	79.8	98
BUDM Strategy	Strategy 1	Strategy 1	Strategy 1	Strategy 4	Strategies 2, 4, and 5	Strategy 4	Strategy 4
Step 1. Site-Selection Criteria							
Total Area of Potential Benefit	3	2	2	1	3	2	1
Potential Tradeoff Area	1	2	2	3	1	2	3
Capacity	3	2	2	2	2	2	2
Capacity Needs, Sediment Availability	2	3	3	3	3	1	1
Maintenance	2	3	1	2	3	3	2
Longevity, Stability	3	3	2	2	1	2	2
Site Evolution	1	2	2	3	3	1	1
Total Criteria Score	15	17	14	16	16	13	12

Table 1 (cont.). Beneficial use of dredged material (BUDM) site-selection matrix and scores.

Step 2. Restoration Benefits at the Landscape Scale							
Proximity to Other Sites	2	2	2	3	4	1	3
Synergy	2	5	5	4	4	3	1
Gap	1	2	2	1	1	3	4
CEERP Priority Reach	5	5	5	1	1	1	1
Step 3. Stakeholder Feedback							
Potential for Negative Effects on Other Projects or Resources Identified	Avian Predation Potential	Avian Predation Potential	Avian Predation Potential	Existing Salmonid Habitat	—	—	Sedimentation, Public Use

<sup>a</sup> Sites ultimately selected for conceptual design.

After the initial matrix was scored, sites were evaluated through the lens of the CEERP. This program recently began focusing on a site's potential contribution to habitat restoration on the broader landscape scale, which is the scale at which individual projects are likely to benefit juvenile salmon. Specific criteria were adopted from CEERP's Expert Regional Technical Group (ERTG), which applies landscape principles to compare restoration projects at multiple scales (ERTG 2020). These additional criteria enabled a consideration of how each site's location in the estuary could make it more or less favorable for migrating salmonids.

Traditionally, CEERP metrics include proximity to other completed or proposed restoration sites, synergy with existing habitats, the distance between existing habitat patches along a stretch of river (i.e., a gap reflects a greater distance), and whether a proposed restoration site occurs in one of the priority hydrogeomorphic reaches (Simenstad et al. 2011; ERTG 2020) for juvenile salmonid habitat restoration, as identified by CEERP (ERTG 2020). Priority reaches were identified by the ERTG based on important habitat transition areas that occur within them, namely the river-estuary transition below Bonneville Dam (i.e., reaches G and H) and the lower-estuary salinity transitions in reaches A and B (ERTG 2020). The proximity score reflects a potential opportunity to leverage benefits from sites by creating habitat patches that may collectively provide greater benefits to migrating salmonids, with higher scores indicative of restoration sites in closer proximity. The potential for negative effects to other projects or resources, as identified by stakeholders in the workshops, was another important consideration. BUDM strategy and hydrogeomorphic reach were also considered because there was interest in

having an array of diverse strategies and spatial heterogeneity reflected in the final suite of sites.

### **2.3 Selected Sites**

Based on the workshops and internal discussions, the PDT recommended moving forward to the conceptual design phase with Sites 2, 5, and 6. These sites then were discussed with increasing scrutiny over a series of four workshops, with final selections made during the fourth stakeholder workshop.

Site 2 received the highest score on the preliminary matrix (Table 1, Step 1). Among the three sites (i.e., Sites 1, 2, and 3) that addressed Strategy 1 (Create/Expand Intertidal/Emergent Islands), Site 2 would require the least amount of material and fewest seasons to construct. Although sediment availability and placement capacity were included in the selection matrix, these factors do not necessarily favor a greater volume of material at a particular location. A highly ranked site reflects a balance between the amount of material that needs to be dredged from a particular reach and the placement option(s) within an operational distance. The fact that Site 2 would require less material and fewer seasons to construct also means that postplacement habitat could develop sooner and with less disturbance to newly created habitat. These three sites include constructing a new berm to protect shallow-water habitat. With a smaller required berm than the other two similar sites, Site 2 would likely require less planting and maintenance as well. Site 1 is directly upstream from Miller Sands, and Site 3 would create a new berm on the leeward side of Pillar Rock Island mimicking the successful morphology generated at Miller Sands using dredged material. Of the three Strategy 1 sites, Site 2 is the farthest distance from existing landforms and known habitat and would be the least likely to impact existing habitat features.

Site 5 had the second-highest overall preliminary score and would address multiple strategies. Of the seven potential sites, Site 5 presented an opportunity for a large area of potential habitat benefits and a low potential for displacing existing high-quality habitat, as reflected in the tradeoff score and unlikely adverse effects to other projects or resources (Table 1).

Site 6 was one of three sites that fell under Strategy 4 (emulate bar and scroll topography). Of these, Site 4 had a higher preliminary score than Site 6. However, due to stakeholder concern about impacts to nearby habitat restoration projects, the team eliminated Site 4 from further consideration. Site 6 fills a habitat gap, unlike either of the other two Strategy 4 sites.

### **3 Design Considerations**

Essential design considerations were identified, discussed, and refined through iterative engagement with stakeholders; resulting in six key design considerations described below.

#### **3.1 Benefits and Tradeoffs**

Acknowledging that there are likely short-term, localized, adverse effects to habitat and associated species when placing dredged material (e.g., burial of sessile organisms), the goal of any potential BUDM site would be to create long-term benefits that outweigh any short-term adverse outcomes. Ideally, a BUDM placement action would result in a net lift to the environment (i.e., increased habitat opportunity or function) in comparison with preplacement conditions. Material dredged from the FNC can be placed within the river, at upland sites, or disposed of in an ocean dredged material disposal site in deeper water far beyond the estuary. Utilizing BUDM sites within or in close proximity to the mainstem helps keep sediments, a finite resource, in the LCR system.

While potential habitat benefits for juvenile salmon were first considered and facilitated site comparison using CEERP metrics, additional species were discussed at workshops for potential ancillary or opportunistic benefits. Ideally, BUDM projects would support a robust matrix of habitats including waters, wetlands, uplands, and riparian areas to benefit an array of species, whenever possible. However, there are habitat tradeoffs among focal Endangered Species Act (ESA)–listed species such that maximizing benefits for juvenile salmon often negates potential upland habitat for deer, especially when a BUDM alternative proposed to convert existing waters to upland berms. Specific goals for each potential site largely depended on existing conditions, proximity to other habitat, projected changes to bathymetry and water velocity, and potential constraints unique to each site. The three preferred sites, as originally configured, were anticipated to enhance aquatic habitat but with limited benefits to Columbia white-tailed deer that would require more upland habitat. A more detailed assessment and quantification of benefits would be done during a feasibility study should either of these sites be pursued with a local sponsor.

### 3.2 Desired Habitat Outcomes

In restoration ecology, reference sites are sites selected for their similarity to the target conditions or objectives of the restoration project. Habitat ratios in reference sites were used in considering how to best design BUDM sites to promote habitat development in the LCR. The percentage of various habitat types within reference sites located along elevational gradients of the LCR and estuary (LCRE) were evaluated as follows: channel or shallow water, marsh, shrub wetland, forested wetland, and upland. The goal of the engineered BUDM site designs is to create a diverse matrix of habitat types, which will provide multiple ecological benefits for focal species (e.g., juvenile salmonids in this case) by optimizing the following three objectives:

1. Wetland area (herbaceous marsh, shrub, and forested wetlands) for provision of direct benefits for juvenile salmonids such as food, shade, and refuge from predators.
2. Tidal channels to enhance the flux of prey and organic material to improve the juvenile salmonid food web in the mainstem river.
3. Upland areas to provide stability from erosive currents, create protected backwater areas, and to potentially provide habitat for Columbia white-tailed deer (deciduous forest and grassland) and streak horned lark (periodically disturbed and sparsely vegetated areas).

The purpose of identifying habitat ratios across a range of elevations is to create functional wetland and tidal channel areas to support both direct habitat use by juvenile salmonids and indirect functions of prey production and export (Weitkamp et al. 2022). The habitat ranges at the three proposed placement sites for each elevation range are shown in Table 1, and corresponding habitat ratios are provided in Tables 2 through 4.

Wetland plant community elevation boundaries for the proposed sites were estimated based on data collected at 60 reference sites throughout the LCRE, with particular focus on the reference sites located closest to the proposed BUDM sites (Borde et al. 2012, 2020; Table 2). The boundaries provided in Table 2 represent the approximate lower elevation at which each community would be found based on hydrologic conditions over the past 15 yr. The upland boundary is based on the 50% flood exceedance level for the LCRE (USACE 2012).

Table 2. Estimated wetland elevation ranges for the proposed sites (based on Borde et al. 2012, 2020).

Site	RM	Lower Boundary of Plant Community (ft, North American Vertical Datum of 1988 [NAVD88])				
		Low Marsh	High Marsh	Shrub Wetland	Forested Wetland	Upland
Site 2	27	3.3	5.0	7.3	9.3	11.8
Site 5	56	5.5	6.4	8.7	10.4	13.0
Site 6	80	6.8	8.1	11.7	12.9	16.3

To evaluate potential habitat ratios for the proposed sites, seven reference sites were selected between RM 25 and 81 that were similar in morphology to the proposed placement sites. Five of the sites have formed as a result of pile dikes or historical dredge material placement, or both (Borde et al. 2012). Two sites, Jackson Island and Bradbury Slough, were not present on historical maps from the late 1800s, and specific factors contributing to their evolution are not known. Reference sites represent a unique habitat mosaic based on their varying proportions of habitat features. All have marsh, tidal channels, shallow water, shrub or forested wetland (or both), and upland. In some areas, the upland is forested, and in others it is grassy or bare. Habitat ratios were developed using GIS to estimate the amount of each habitat occurring in a representative cross section at each reference site (Figure 3 and Figure 4; Table 2) based on land-cover classifications developed from 2009 imagery (Sanborn Mapping Company and LCEP 2011). Cross sections within reference sites were chosen to target a diverse mix of habitats (Table 3), and while not necessarily representative of the entire reference sites, the cross-section ratios give a proxy for what might be achieved in designing a BUDM site that maximizes habitat opportunity for a diverse range of species. For comparison, ratios based on the absolute area of each habitat within each reference site are also presented in Table 4.

The primary difference between the two methods is the proportion of marsh is lower and the upland habitat is higher in the area estimate compared to the cross-section estimate. This is likely because when the cross sections were chosen, a diverse mix of habitats were targeted within the seven reference sites. Several of the sites have high proportions of upland area (>50%), which precludes a more diverse habitat mix. The diverse mix represented by the cross-section method represents the more desirable outcome.

Figure 3. Maps of four reference areas (Miller Sands, Jackson Island, Prescott Slough, and Bradbury Slough) used in habitat-ratio estimation. (Map data: Google, Maxar Technologies.)

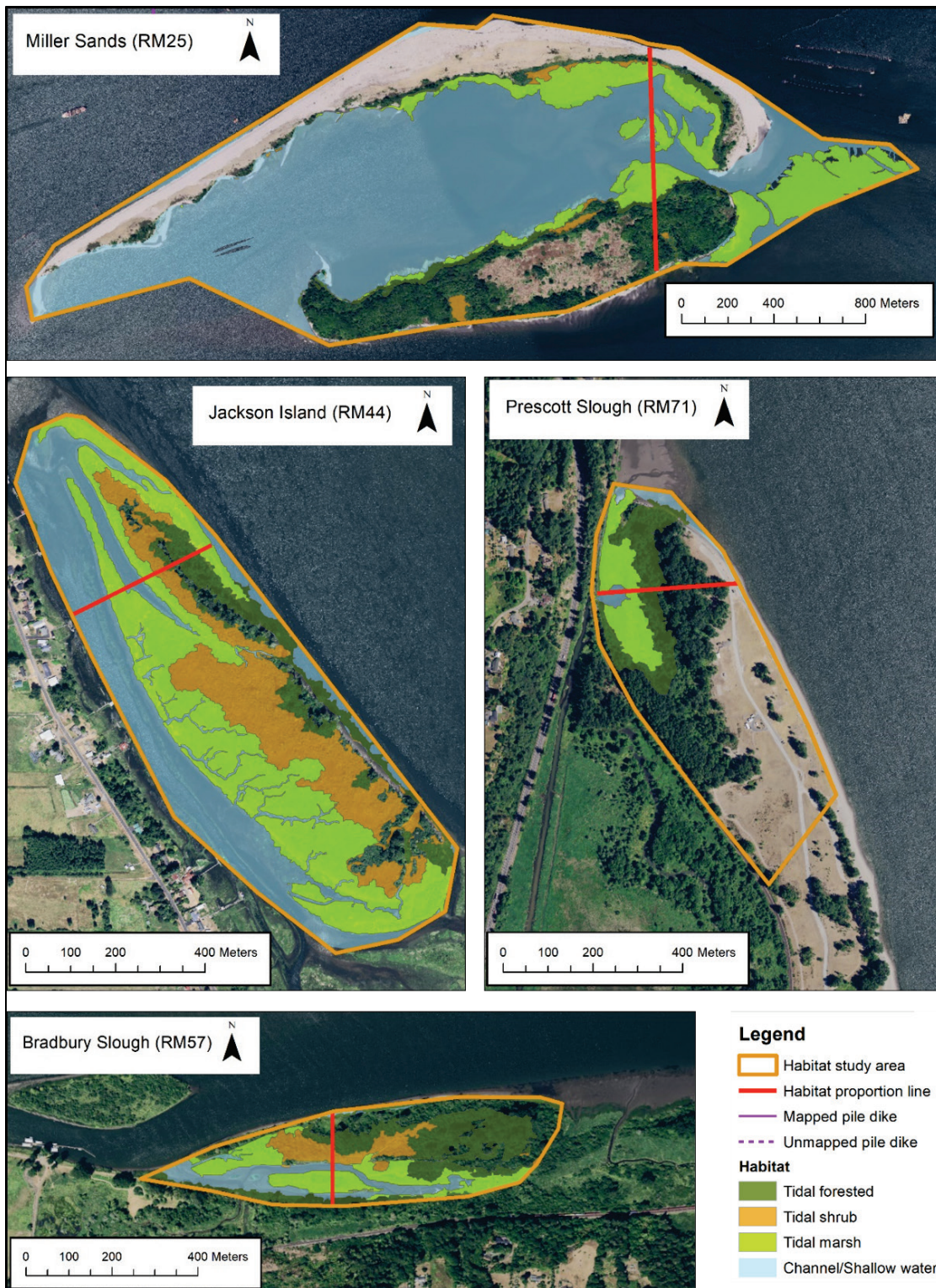


Figure 4. Maps of remaining three reference areas (Fisher Island, Lord Island, and Goat/Deer Island) used in habitat-ratio estimation. (Map data: Google, Maxar Technologies.)



**Table 3. Seven reference sites with similar morphology to the proposed placement sites. The proportions of habitat were calculated from representative cross sections in GIS.**

Site	RM	Type	Previously Monitored Reference Site <sup>a</sup> (Y/N)	Habitat Proportions				
				Channel/Shallow Water	Marsh	Shrub Wetland	Forested Wetland	Upland
Miller Sands	25	C	Y	0.23	0.35	0.02	0.02	0.39
Jackson Island	44	C?	Y	0.35	0.38	0.07	0.17	0.03
Bradbury Slough	57	C?	N	0.11	0.20	0.18	0.29	0.22
Fisher Island	59	C	N	0.58	0.09	0.00	0.10	0.23
Lord Island	62	C	Y	0.19	0.20	0.00	0.47	0.14
Prestcott Slough	71	C	N	0.14	0.15	0.00	0.14	0.57
Goat and Deer Islands	81	C	Y	0.28	0.12	0.01	0.25	0.34
<b>Average</b>	—	—	—	<b>0.27</b>	<b>0.21</b>	<b>0.04</b>	<b>0.21</b>	<b>0.28</b>

<sup>a</sup> Reference sites in the LCRE that have been monitored under CEERP and considered representative of relatively undisturbed wetland conditions (Borde et al. 2012).

C = Not present on historical maps from late 1800s and records indicate the site was created by a combination of factors including presence of pile dikes, dredge material placement, and natural sedimentary processes.

C? = Not present on historical maps from late 1800s, but factors leading to current morphology are unknown.

**Table 4. Seven reference sites with similar morphology to the proposed placement sites. The proportions of habitat were calculated from delineated site polygons in GIS.**

Site	RM	Type	Previously Monitored Reference Site (Y/N)	Habitat Proportions				
				Channel/Shallow Water	Marsh	Shrub Wetland	Forested Wetland	Upland
Miller Sands	25	C	Y	0.52	0.12	0.01	0.01	0.34
Jackson Island	44	C?	Y	0.34	0.34	0.19	0.08	0.06
Bradbury Slough	57	C?	N	0.19	0.20	0.10	0.31	0.21
Fisher Island	59	C	N	0.29	0.07	0.02	0.18	0.45
Lord Island	62	C	Y	0.16	0.09	0.00	0.33	0.42
Prescott Slough	71	C	N	0.04	0.09	0.00	0.11	0.75
Goat Island	81	C	Y	0.20	0.04	0.00	0.05	0.70
South Deer Island	81	C	Y	0.18	0.05	0.01	0.25	0.51
<b>Average</b>	—	—	—	<b>0.24</b>	<b>0.12</b>	<b>0.04</b>	<b>0.17</b>	<b>0.43</b>

C = Not present on historical maps from late 1800s and records indicate the site was created by a combination of factors including presence of pile dikes, dredge material placement, and natural sedimentary processes.

C? = Not present on historical maps from late 1800s, but factors leading to current morphology are unknown.

### 3.3 Environmental

In addition to habitat considerations for focal species, more general design considerations may be used to improve environmental conditions. A basic understanding of existing physical parameters including topography, benthic substrate composition, width of any existing channels, dominant vegetation, water depth, water velocity, and temperature are necessary to characterize existing conditions and accurately assess the potential effects of placement. For some sites, BUDM may change certain parameters (e.g., elevation) to improve habitat conditions for focal species. In other cases, BUDM may aim to avoid an ecologically significant change to certain parameters (e.g., water velocity and temperature remain below some threshold suitable for juvenile salmon). In all cases, best management practices (BMPs) will be implemented to reduce short- and long-term effects to water quality, avoid adverse effects to ESA-listed species, and minimize effects to other aspects of the human environment. Long-term monitoring goals and performance criteria are outside the scope of this work but could be developed as part of a future USACE study.

### 3.4 Construction and Operation and Maintenance (O&M)

Construction of the proposed BUDM sites will largely consist of the placement of sand dredged from the FNC using a pipeline dredge. Existing BMPs and procedures for dredging and placing material will be followed with site-specific requirements as necessary, depending on potential site-specific concerns. Standard BMPs include berms to maximize settlement of fine materials in any runoff water, limiting the footprint of access routes and any barge ramps to the smallest practicable area, and regular inspection of construction equipment to identify and address any leaks promptly.

For example, lessons learned from other habitat-creation projects in the NWP indicated that disproportionate turbidity in a project area can raise water-quality concerns. Individual project teams should evaluate the potential for turbidity during planning and design and include measures to minimize and control turbidity, such as a silt curtain where necessary.

One important consideration is the construction of wetland gradients that can allow for succession over time. For example, initial construction should target the creation of more shallow, sandy habitat, mud flats, and low-elevation wetlands (low marsh and high marsh) to maximize habitat benefits and allow succession over time to higher-elevation wetlands as

sediments accrete. Current LCRE reference wetland accretion rates indicate that wetlands are likely to keep pace with low to moderate levels of sea level rise (Diefenderfer et al. 2021).

Additional effort to actively plant or seed sites (or both) with native species in a timely manner following construction may reduce the likelihood of invasive plant species colonization. Projects may also augment predominantly coarse-grained sediments with fine sediments during construction to promote more rapid plant growth and colonization by benthic macroinvertebrates.

### **3.5 Postconstruction Monitoring**

There are outstanding uncertainties regarding how BUDM sites evolve and perform over time. To accurately capture the potential long-term ecological lift, postconstruction monitoring at each site should ideally include monitoring water surface elevation, sediment accretion, sediment composition, established photo points for better documentation of change over time, and dominant vegetation species and percent cover (when applicable). These metrics are consistent with standard restoration site monitoring and protocols implemented under the CEERP and will facilitate a more standardized assessment of how site benefits accrue over time, providing a roadmap for future BUDM efforts. In addition, site-specific postconstruction monitoring should be considered on a site-by-site basis. For example, additional monitoring metrics such as fish use (e.g., salmonids, piscine predators) should be considered where BUDM sites are designed to create a long-term beneficial lift for ESA-listed salmonids. The PDT recommends monitoring at a minimum of 1, 2, 5, and 10 yr post construction to document habitat evolution through time and for comparison with baseline data capturing preconstruction conditions.

### **3.6 Adaptive Management**

It is essential that BUDM sites allow for adaptive management and corrective actions based on lessons learned from construction, implementation, and monitoring (Lillicrop et al. 2011). Potential placement actions will be constructed in a dynamic environment, and USACE has only recently begun directly evaluating BUDM sites in the LCR to better understand how habitat conditions change over time (i.e., Woodland Islands BUDM, USACE 2020).

At the site scale, initial monitoring allows USACE and any future project sponsor to assess the degree to which placed sediments move or settle on site, likely informing the need for supplemental actions such as additional placement. Similarly, an evaluation of vegetation cover will help determine how long it takes for vegetation to establish and the extent to which invasive species may be colonizing the area and what corrective measures may be implemented to ensure sites meet long-term goals. As new sites come online, the growing body of monitoring information will also help inform ways to improve site design and implementation to maximize benefits. While the details of an adaptive management plan will be informed by the monitoring goals established at each site in coordination with a nonfederal project sponsor, USACE will leverage as much information from these sites as possible to continue to refine BUDM applications in the LCR and elsewhere.

## 4 Beneficial Use of Dredged Material (BUDM) Conceptual Design

The conceptual designs for the three sites below were developed using the GIS methodology, Site Selection Criteria, and Design Considerations described in Sections 2 and 3 of this report. The primary sources of data used during conceptual design development were GIS elevation and bathymetry data layers sourced from NWP navigation. Later phases of feasibility and design would require additional site-specific data to aid in developing detailed plans. These conceptual designs are a starting point for possible paths forward mentioned in the conclusions.

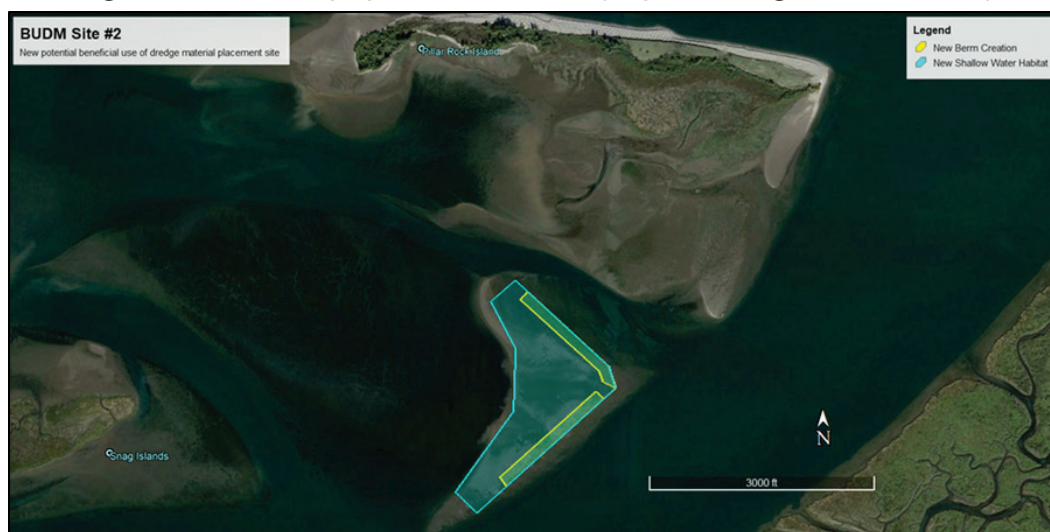
### 4.1 BUDM Site 2

Site 2 is located at approximately RM 27.4 to the south of Pillar Rock Island. Site 2 falls under Strategy 1, Create/Expand Intertidal/Emergent Islands. The intent would be to use dredged material to construct a chevron consisting of two new berms with an opening to allow flow to pass through. Additional dredged material would be placed downstream of the berms to create or expand (or both) shallow-water habitat. Conceptually, this would mimic the existing morphology and habitat at Miller Sands Island. Figure 5 shows the existing features at Miller Sands, and Figure 6 shows the proposed plan view for Site 2.

Figure 5. Aerial view of existing Miller Sands Island. (Map data: Google, Landsat 2018.)



Figure 6. Plan view of proposed BUDM Site 2. (Map data: Google, Landsat 2018.)



#### 4.1.1 Desired Habitat

The desired habitat goals for Site 2 are to increase estuarine habitat extent and diversity by building tidal marsh, emergent and forested wetlands, and by increasing channel edge density where hydraulics will supply source material in long term. This specific site is located in a shallow area where sediment appears to be accumulating. By placing dredged sediment to create protective berms, additional material could accumulate naturally or be placed in the shallow-water portion of the site with more confidence in the long-term stability. This site would likely have more channel or shallow-water area than the average sites in Table 4 and would more closely resemble the Miller Sands reference site.

#### 4.1.2 Conceptual Design

Figure 6 shows the proposed plan view for Site 2. The *yellow rectangular sections* on the plan view are the proposed berms, and the *light-blue polygon* represents proposed shallow-water habitat.

The two berms would each be approximately 1,700 ft long and 150 ft wide. The target elevations for the top of the berms would be set no higher than 11.8 ft, NAVD88, in accordance with Table 2. This assumes that they would be submerged only during the highest tides or flood conditions of the year (i.e., during the 50% flood exceedance level for the LCRE (USACE 2012)). Elevations for the downstream portions of the berms would likely be within the elevations ranges for wetlands listed in Table 2. An estimated 460 kcy of dredged sediment would be required to construct the berms

based on the current length, width, and height assumptions. It is assumed that the material would be dredged from nearby shoals and placed using a pipeline dredge. Multiple placement events would likely be needed to acquire the necessary volume of dredged material from the FNC. Information obtained from the LCR Channel Maintenance Plan PDT suggests that berm construction could take up to five placement events. Prioritization of the BUDM site and importing additional material from further away in the channel could reduce the time to construct. However, moving material from farther away would likely require different types of equipment and incur additional costs over the current assumptions.

Juvenile salmonid habitat studies throughout the PNW and in the Columbia River basin have identified a depth of 0.5–2.0 m mean lower low water as a target depth range for young juvenile salmonids that are actively rearing. An estimated 400 kcy of material would be required to construct the shallow-water habitat in the 0.5–2.0 m depth range shown in the *light-blue* area of Figure 6.

Plantings could commence once sediment placement is complete. Dredged material from the FNC typically consists of sand. Stakeholder input suggests that natural establishment of marsh vegetation in sand could take from 5 to 10 yr. Augmentation of the placed sediment could help increase the rate of colonization of desired vegetation. Stakeholders along the LCR have access to more fine materials from areas outside the FNC. Augmenting dredged sediments with these fine particles would create a more suitable substrate for supporting plants than the predominantly sandy materials that are more typically dredged from the FNC. Working with these regional stakeholders, fine materials could be placed within or upstream of the BUDM site for targeted dispersal into the BUDM site where it would be expected to settle, ultimately aiding in development of vegetation and shallow-water habitat.

#### **4.1.3 Cost**

Approximate order of magnitude costs for Site 2 are expected to be approximately \$12.2M. These costs assume 100 kcy per placement event and include mobilization and silt curtain rental for each event. Planting costs based on similar NWP projects recently completed were also included. Contingency is included, and these are assumed to be immediate costs.

## 4.2 BUDM Site 5

Site 5 is located at RM 56 along Crims Island and Gull Island. The concept for this site falls under Strategy 4, Build Bar and Scroll Topography. The intent for Site 5 is to use material dredged from the FNC to create a new berm along the riverward side of the island with a 600 ft gap between the new berm and existing shoreline as seen in Figure 7. Additional dredged material would be used to fill in the area protected by the berm, with the intent to create highly productive shallow-water habitat. Figure 7 shows a plan view of the proposed site on top of recent imagery.

Figure 7. Plan view of proposed BUDM Site 5. (Map data: Google, Landsat 2018.)



### 4.2.1 Desired Habitat

The objective for Strategy 4 is to create habitat mosaics typical of point bar landforms, including ridges, riparian berms, bars, and back-water areas with perennial or seasonal connectivity to the mainstem. The goal for this site is to meet the elevations and habitat ratios from Table 2 and Table 3. This site will likely have more channel or shallow-water area than the ideal ratio.

### 4.2.2 Conceptual Design

Site 5 would achieve the desired habitat goals by constructing a berm that is approximately 3,000 ft long by 150 ft wide and placing material to reduce the depths shoreward of the berm. Berm elevations would be optimized for upland and forested wetland plant colonization while the proposed newly created shallow-water area is expected to accumulate

sediment and evolve into tidal marsh and wetland habitats. The berm would be the upland portion of the habitat mosaic transitioning to the wetland and shallow-water habitats.

Site 5 is less than 4,000 ft from an area of the FNC with frequent shoaling. Material to construct the site is expected to be readily available during typical in-water work periods. The berm would consist of approximately 405 kcy of dredged material placed by pipeline dredge and could likely be constructed with two or more placement events. The shallow-water area could potentially hold up to 515 kcy of dredged material which would also be placed in multiple events. One critical consideration for Site 5 would be to place material in a way that maintains existing channels and hydraulic connections in and between the currently existing islands.

Targeted placement of fine materials could also be used at this site to help expedite colonization of desired wetland plant species, similar to that described for BUDM Site 2.

#### **4.2.3 Cost**

Approximate order of magnitude costs for Site 5 are expected to be approximately \$15.8M. These costs assume 100 kcy per placement event and include mobilization and silt curtain rental for each event. Planting costs based on similar NWP projects recently completed are also included.

### **4.3 BUDM Site 6**

Site 6 is located at approximately RM 80 downstream from Goat Island. The concept for this site also falls under Strategy 4, Build Bar and Scroll Topography. The intent for Site 6 is to use material dredged from the FNC to create a new berm downstream from Goat Island. Additional dredged material would be used to fill in the area protected by the berm, with the intention to create highly productive shallow-water habitat. An approximately 300 ft channel would remain between the existing island and new placement site. Figure 8 shows a plan view of the proposed site on top of recent imagery.

Due to the existing hydraulic conditions in this reach, structural elements would likely be needed to assist with the creation and maintenance of Site 6. An *orange line* in Figure 8 shows the maximum extents of the structural features. The structural features would serve to deflect flow

away from the BUDM berm during construction and hold toe of the berm post construction. The structural measures will be designed in detail in a later phase with the goal of providing the necessary hydraulic benefits with the least impact.

Figure 8. Plan view of proposed BUDM Site 6. (Map data: Google, Landsat 2018.)



#### 4.3.1 Desired Habitat

The desired habitat goals for Site 6 are similar to Site 5 in creating habitat mosaics typical of point bar landforms. Design of Site 6 should also be guided by the habitat ratios from Table 2 and Table 3. Exact ratios of habitat types to be created at this site would be determined as part of future site design efforts in coordination with the project sponsor.

#### 4.3.2 Conceptual Design

Site 6 includes a berm that is 2,200 ft long and ranges from 150 to 400 ft wide. Berm elevations again would be optimized for upland and forested wetland plant colonization. The berm would be constructed with 355 kcy of dredged material. Site 6 also includes a shallow-water area with a capacity of up to 330 kcy.

A distinct feature of Site 6 is the inclusion of structural element for additional site stability. The structural element is seen as the orange line on Figure 8. Later phases of the design process will identify the optimal structure to meet the hydraulic needs with the least impact. Designs for maintenance and repair of existing structures in the LCR are trending

towards the use of enhanced enrockment generally below the lowest water level, potentially with notches designed for juvenile fish passage were deemed beneficial or necessary (or both) (e.g., within shallow-water habitat less than 20 ft deep) and relying less on piles or other structures sticking out of the water. Cost estimates for Site 6 assume placement of rock for the structural features identified. The length of the enhanced enrockment is approximately 2,800 ft.

Site 6 is located downstream from Goat Island. Construction and material placement at Site 6 should not block the existing channel or access to the channel and habitat behind Goat Island.

#### **4.3.3 Cost**

Approximate order of magnitude costs for Site 6 are expected to be around \$43.3M. These costs assume 100 kcy per placement event and include mobilization and silt curtain rental for each event. Of the total for this site, \$31M would be the proposed enrockment (structural element). This cost includes material, placement, mobilization, and contingency. Planting costs based on similar NWP projects recently completed are also included.

## **5 Conclusions and Recommendations**

### **5.1 Conclusions**

Given the volume of material dredged from federal navigation channels on an annual basis, it is imperative that USACE makes every effort to beneficially reuse as much material as possible. In the LCR, sediments reused in the system can help create habitat that locally benefits salmonids and numerous other species, as well as aiding in long-term habitat-forming processes elsewhere in the river. The iterative engagement that allowed stakeholders to provide continuous feedback on BUDM considerations was an essential part of the process. Any future planning endeavor that strives to place large volumes of material in strategic locations to build habitat will be more successful with early buy-in from state and federal natural resource agencies, tribes, and various local entities. This report is the culmination of a multiyear process to develop placement strategies and build consensus among regional stakeholders about the benefits and potential tradeoffs when implementing those strategies at specific locations.

### **5.2 Recommendations**

The BUDM strategies presented in this report were based on broad habitat goals that are not exclusive to the LCR and could be tailored to suit other riverine settings. Similarly, the criteria included under Step 1 of the site-selection matrix (Table 1) are universal and would be relevant to a range of BUDM applications. The site-selection framework is transferable, and new criteria could be added to the matrix based on local or regional expertise.

This report culminates in a few conceptual designs for highly ranked sites to demonstrate how BUDM can be applied to habitat restoration. Having a conceptual design at the onset can help streamline the planning process and jumpstart discussions with potential sponsors. Habitat outcomes, site design, and cost are addressed because they are key decision criteria for any new project. Walking through these considerations at three sites provides readers with concrete examples of how the prescribed BUDM site selection and design moves toward implementation.

Site-selection criteria and design consideration outlined in this report could be applied to new USACE planning studies seeking to identify and

evaluate BUDM options. However, stakeholder coordination is essential, and it would be advisable to refine the final list of selection criteria proposed for any new project in conjunction with local partners. A possible next step could be to build a comprehensive list of selection criteria and design considerations that may vary regionally and incorporate the list into a database tailored to BUDM applications or develop a new USACE planning tool. Future research evaluating the realized benefits and tradeoffs at implementation sites utilizing these strategies and identifying benefits metrics that can be applied across sites are additional efforts that will help address postplacement BUDM habitat uncertainties.

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## Abbreviations

BMP	Best management practice
BUDM	Beneficial use of dredged material
CEERP	Columbia Estuary Ecosystem Restoration Program
ERTG	Expert Regional Technical Group
ESA	Endangered Species Act
FNC	Federal Navigation Channel
GIS	Geographic information system
ky	Thousands cubic yards
LCR	Lower Columbia River
LCRE	Lower Columbia River estuary
NMFS	National Marine Fisheries Service
NAVD 88	North American Vertical Datum of 1988
NWP	Portland District
O&M	Operations and maintenance
PDT	Project development team
PNW	Pacific Northwest
RM	River mile
USACE	US Army Corps of Engineers

## REPORT DOCUMENTATION PAGE

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<b>14. ABSTRACT</b> Channel maintenance in most major rivers throughout the United States requires ongoing dredging to maintain navigability. The US Army Corps of Engineers explores several options for placement based on sediment characteristics, material quantity, cost, operational constraints, and minimization of potential adverse effects to existing resources and habitat. It is a priority to beneficially reuse dredged sediments to create habitat and retain sediments within the river system whenever possible. Nonetheless, there can be discrepancies among state and federal resource agencies, landowners, tribes, and various other stakeholders about what constitutes a benefit and how those benefits are ultimately weighed against short- and long-term tradeoffs. This work leveraged prior Regional Sediment Management efforts building consensus among stakeholders on a suite of viable strategies for in-water placement in the lower Columbia River. The goal was to identify suitable locations for applying the various strategies to maximize habitat benefits and minimize potential adverse effects. A multistep site-selection matrix was developed with criteria accounting for existing site conditions, overall placement capacity, tradeoffs, long-term maintenance, cost, stakeholder concerns, and landscape principles in the context of other habitat restoration projects implemented in the lower river. Three highly ranked sites were selected for conceptual design and exemplify results of collaborative beneficial use implementation.					
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