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Urban-industrial shoreline restoration techniques: Duwamish Waterway and Elliott Bay

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Estuarine Restoration

Urban Industrial Context



George Blomberg

Port of Seattle Maritime Environment and Sustainability



South Elliott Bay

View toward northeast with Seattle urban center in middle background. Harbor Island, the East and West Waterways, and the Duwamish Waterway are visible in the foreground.

Harbor Island in South Elliott Bay

Illustrating the center of the present urban/ industrial infrastructure essential to Seattle. Note Harbor Island and adjacent industrial shoreland areas served by deep draft navigational access in the East Waterway (upper-right) and the West Waterway (upper-left).

The Duwamish Waterway extends upstream approximately five miles from the south end of Harbor Island, providing navigational access to the Duwamish industrial area.

In 1900 this area consisted entirely of intertidal mud and sand flats, estuarine marsh, forested wetland, and meandering shallow river channel estuarine floodplain, totaling approximately 5300 acres.

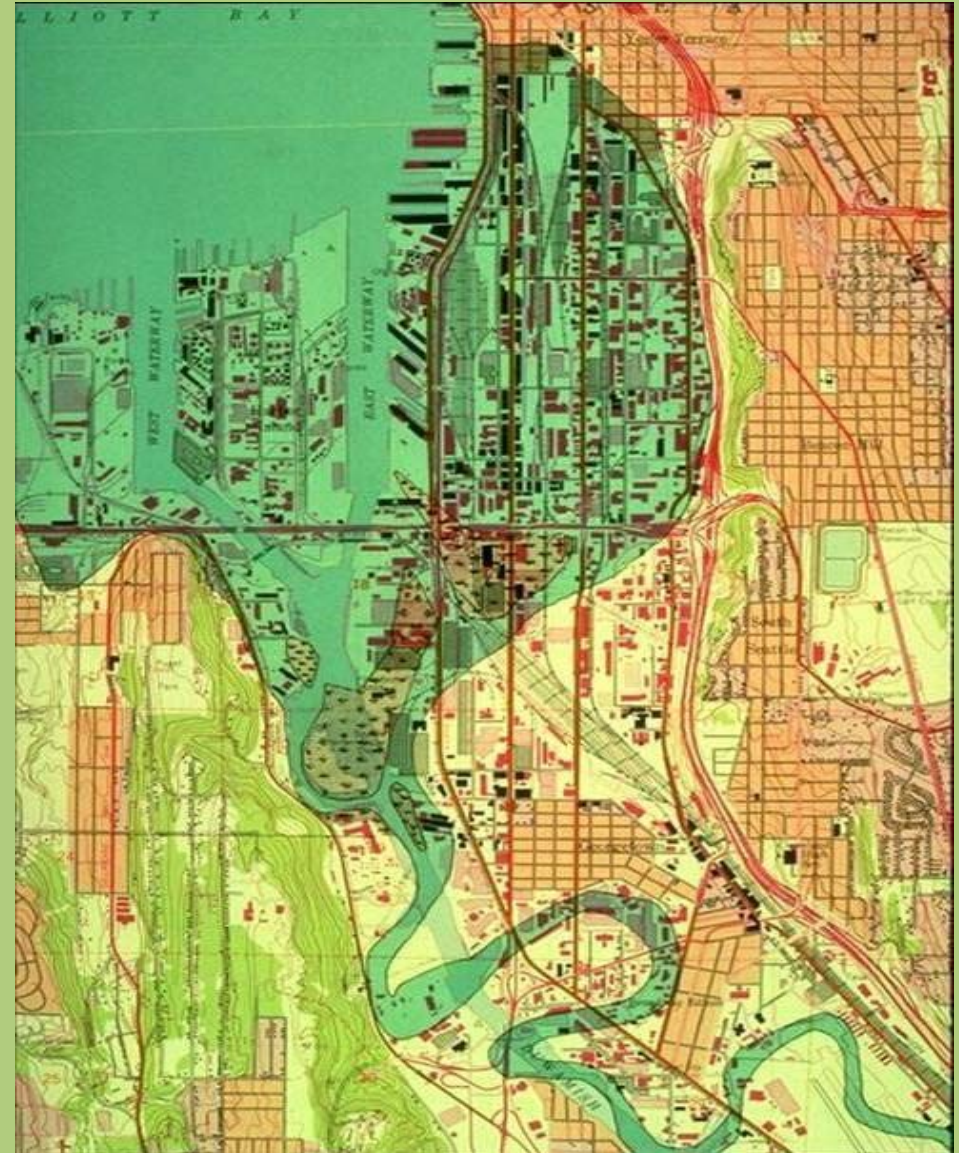
The present 8.2 square mile landscape includes 80 percent of Seattle's industrially zoned land, with approximately 19 percent as publicly-owned port property.

Approximately 12-15 million tons of cargo transshipped annually, using water-dependent marine industrial facilities located in the area, cargo value approximately \$40-45 billion.



Present industrial area and historic river channel

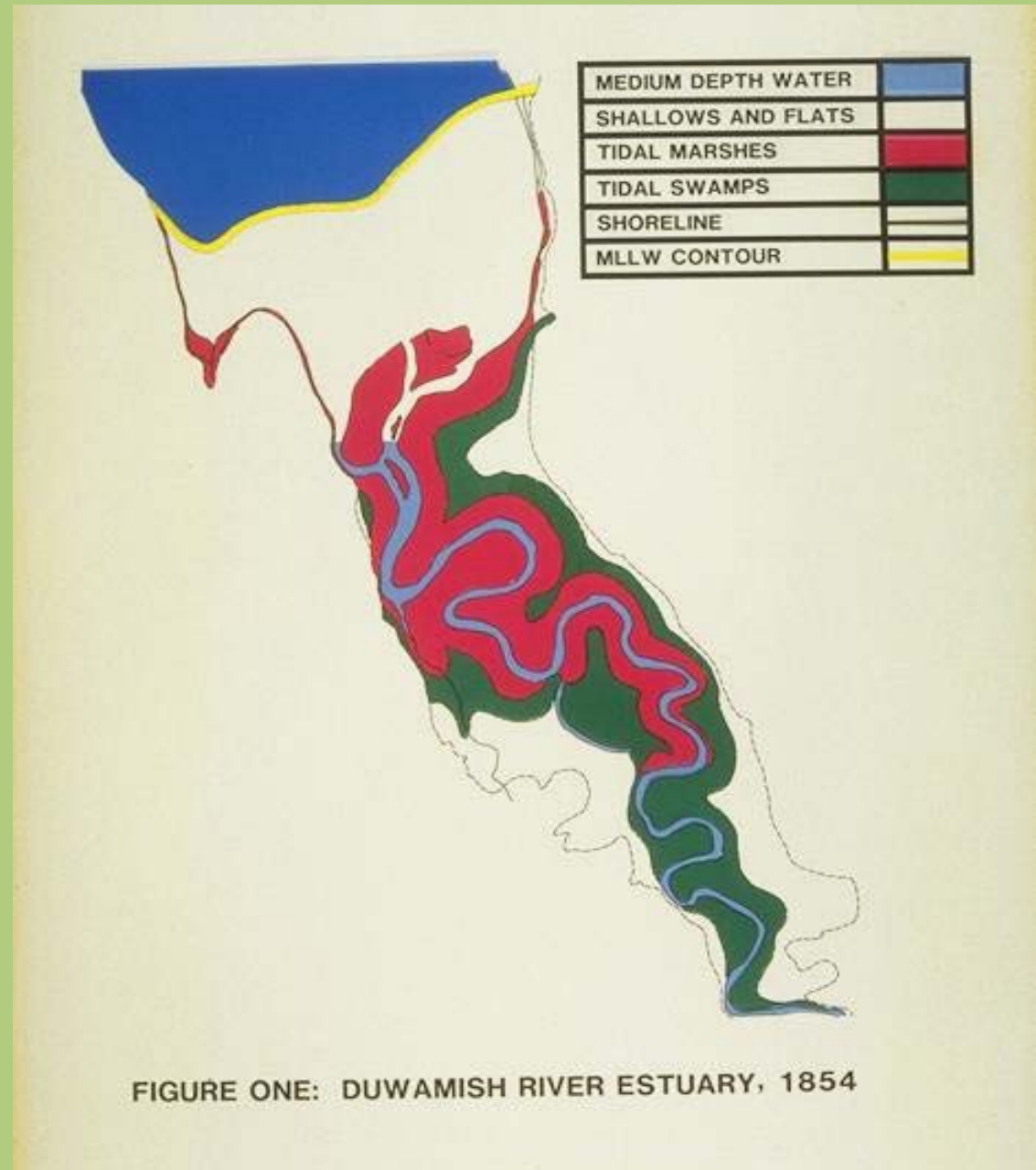
This graphic contrasts the present urban industrial shoreline in south Elliott Bay and the Duwamish Waterway with conditions recorded in 1854. All existing marine terminal area, rail and vehicle access facilities, and industrial land in south Elliott Bay and Duwamish Waterway have been constructed in former intertidal and estuarine floodplain area (identified by the dark green shading).



Historic estuarine environment in South Elliott Bay

The former estuary included approximately 1450 acres of intertidal sand and mud substrate, nearly 1300 acres of intertidal marsh, and approximately 1450 acres of tidal swamp (or forested wetland).

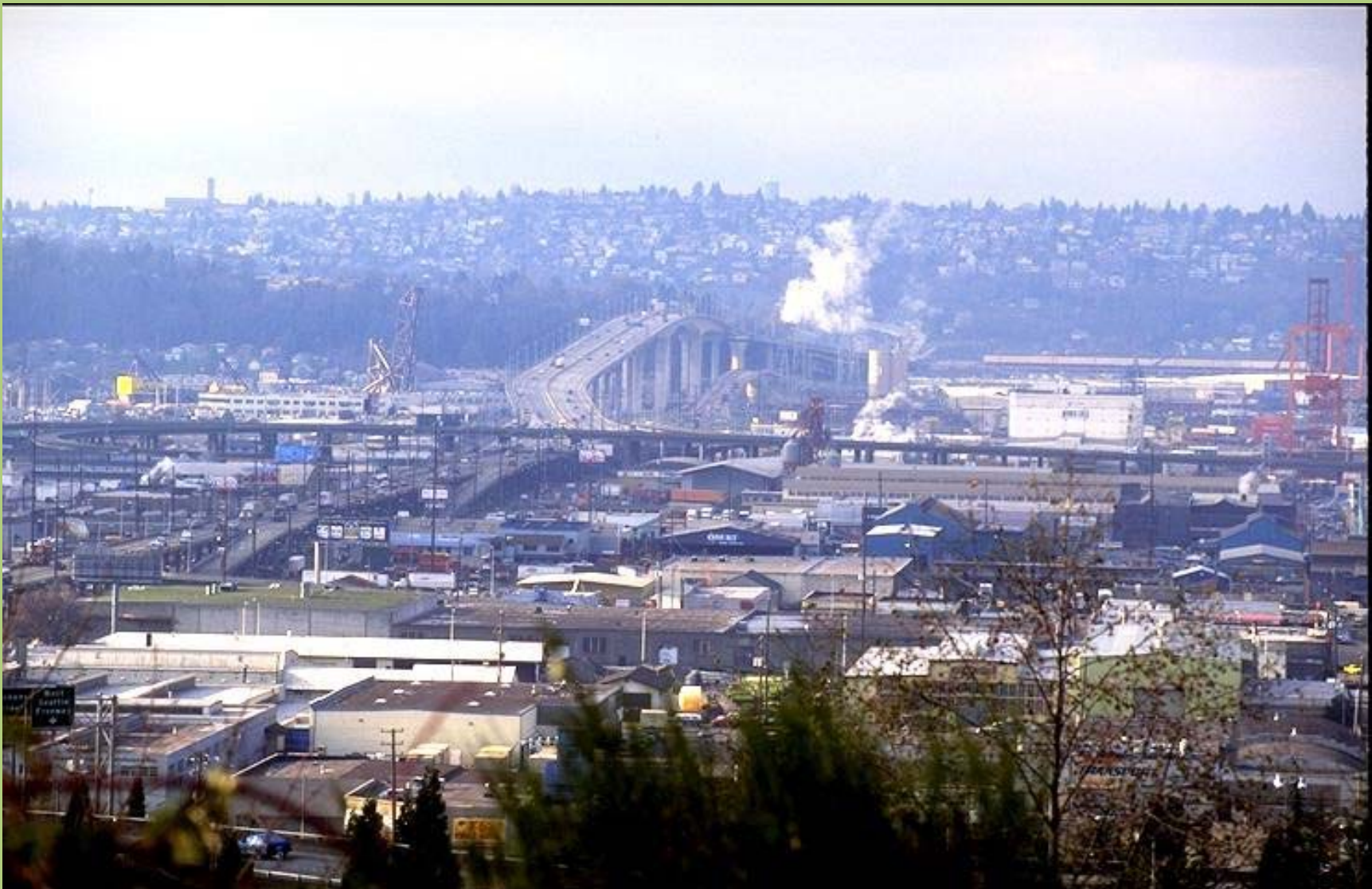
In addition, the meandering river channel included approximately 17 miles of riparian environment and estuarine floodplain. The combined intertidal and estuarine floodplain habitat area was approximately 5300 acres.





Westerly perspective, Spokane Street corridor in 1898

This figure illustrates the extent of intertidal area in south Elliott Bay prior to large scale industrial development. Note piling supported rail lines and vehicle access to west portion of south Elliott Bay.

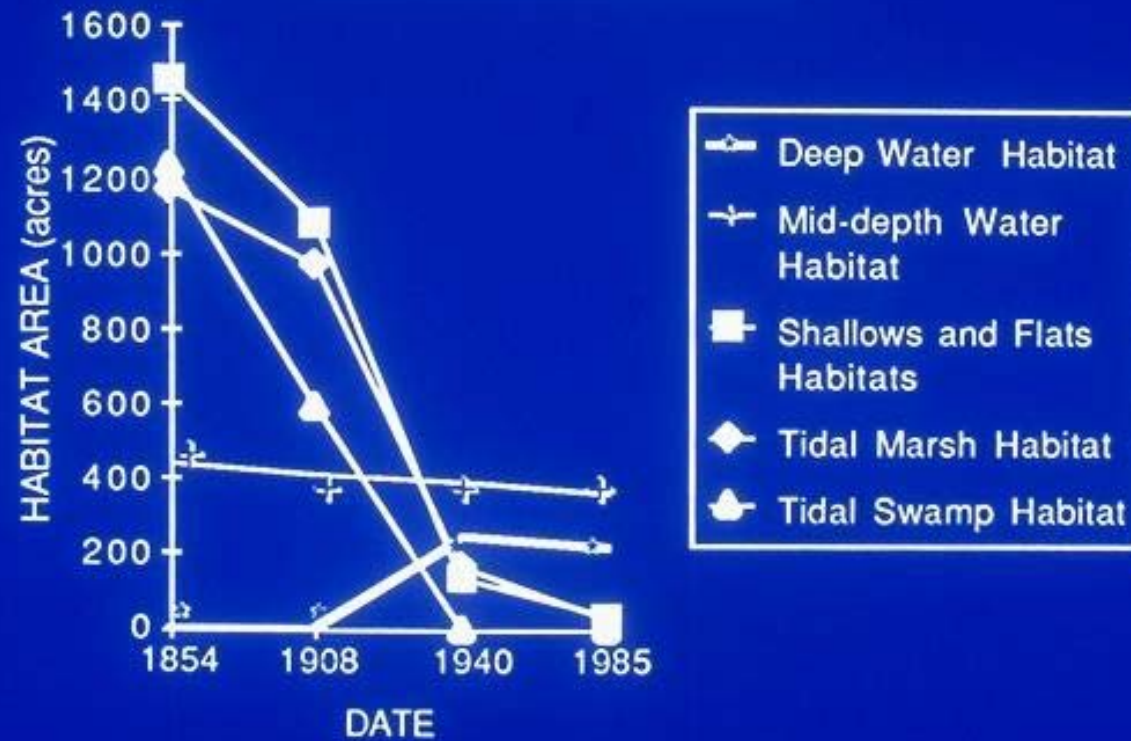


Westerly perspective, Spokane Street corridor in 1998.

This image is identical in location to the 1898 image. The elevated bridge structure, at the south end of present Harbor Island, occupies the alignment of the piling-supported trestle indicated in the 1898 photograph. The present industrial area, constructed entirely in former estuarine aquatic area, includes 75,000 to 80,000 industrial/manufacturing jobs, annual payroll approximately \$2.5 billion

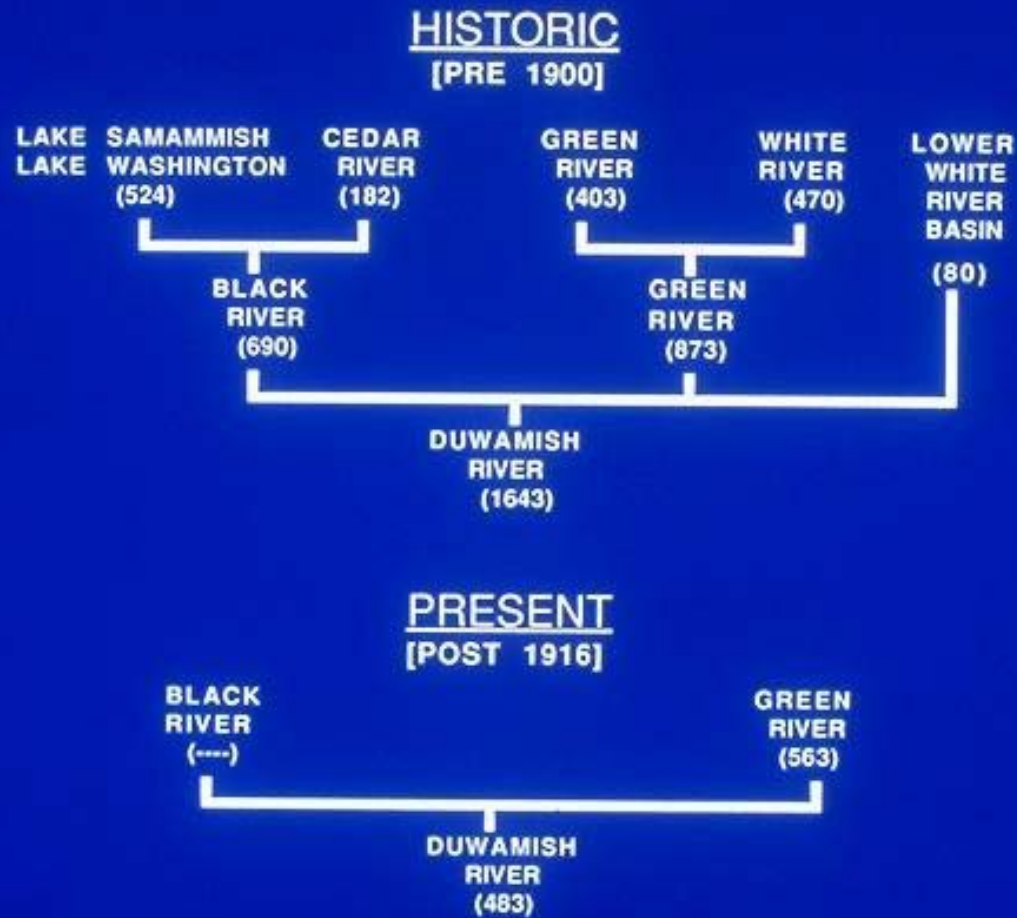
HISTORICAL CHANGES IN THE DUWAMISH RIVER ESTUARY, 1854-1973

HABITAT AREAL EXTENT



Graphic indicating scope of change in estuarine resource features—1854 to present.

HISTORIC CHANGES IN DUWAMISH RIVER WATERSHED (sq.mi.)



Graphic illustrating reduction in area of watershed discharging to Duwamish estuary.



View to northwest illustrating the Duwamish Waterway, foreground, and south Elliott Bay, upper center photograph.

This is the present environmental context for the Port's long range marine cargo and industrial infrastructure needs. The Port's objective is to redevelop existing industrial area, expanding the capability of marine terminal facilities and delivering important economic growth opportunity, while providing coincident environmental improvements - often as project-specific mitigation - in the Duwamish Waterway.



Turning Basin Number Three Demonstration Site.

Environmental conditions at the upstream end of the Duwamish Waterway (river mile 5.3) are evident in this 1995 photograph. Filled former aquatic area is occupied by industrial activities and shoreline areas include the legacy of more than 90 years of industrial use. This location became the focus for a cooperative intertidal habitat demonstration project, co-sponsored by the Environmental Protection Agency, U.S. Fish and Wildlife Service, Corps of Engineers, and the port.



Turning Basin Number Three Demonstration Site Construction Activities.

The first step in restoration work at the turning basin site was to remove derelict vessels that had been abandoned at the upstream end of the navigation channel over a period of decades.



Turning Basin Number Three Demonstration Site Grading.

Restoration of aquatic habitat functions at the turning basin site included excavation of approximately 3500 cubic yards of previously placed fill material, restoring intertidal elevations at the site.



Turning Basin Number Three Demonstration Site following construction in 1996.

This photograph illustrates restored intertidal area, marsh plantings, and recently installed riparian vegetation.



Turning Basin Number Three Demonstration site in 1999.

Intertidal marsh and native riparian plantings established at the demonstration site three years following completion of excavation and grading. Site illustrates functional fish and wildlife habitat restoration. Aquatic and riparian area provide feeding and refuge for resident and migratory fish and wildlife. Detritus and carbon export to adjacent shallow intertidal mud/sand substrate sustains benthic and epibenthic invertebrate production. Riparian vegetation supplies terrestrial insect food sources and small mammal and bird habitat.

Southwest Harbor Cleanup and Redevelopment Project: Environmental Design Elements

MINIMIZATION OF TRAFFIC IMPACTS

1. Intermodal rail cargo improvement allows container cargo to increase up to two-fold without any increase in truck traffic levels.
2. Grade-separated systems consisting container terminal with low level bridge avoids truck traffic in interconnections adjacent to site.
3. Traffic analysis indicates reduction of Florida St, SW, W. Marginal W, SW, and 20th Ave, SW, and diversion of through traffic to Harbor Ave, SW, and SW Spokane St will not degrade existing levels of activity.
4. North and south access roads and reconfiguration of traffic avoids disruption of existing services.

LANDSCAPED PUBLIC USE CORRIDORS AND BUFFER AREAS

1. Project margins adjacent to industrial, commercial, and residential areas include substantial public use improvements designed to link public use areas north, south, and east of the project area, complementing future city-initiated plans.
2. Spokane St Corridor - total area approx. 5.6 acres (approx. 1700 feet in length), with pedestrian/bicycle path, landscaping and lighting.
3. Harbor Ave Corridor - total area approx. 5.8 acres (approx. 2700 feet in length), with pedestrian/bicycle path and landscaping designed to provide habitat area and screen Harbor Ave. and adjacent to areas from industrial area to the east.

PUBLIC SHORELINE AND IMPROVEMENTS

1. Public use improvements include approx. 7.4 acres with approx. 2700 feet of paved pathways, prom and deck walkways and elevated viewing platforms, and approx. 5000 feet of recreational screen and habitat area.
2. Pathways and viewing platforms to Harbor Ave. via landscaped and lighted stairs with street parking for 30 vehicles.
3. Two parking areas, extensive interpretive information, shoreline viewing platforms, and viewing lighted observation.

ENVIRONMENTAL CLEANUP AND AQUATIC HABITAT RESTORATION

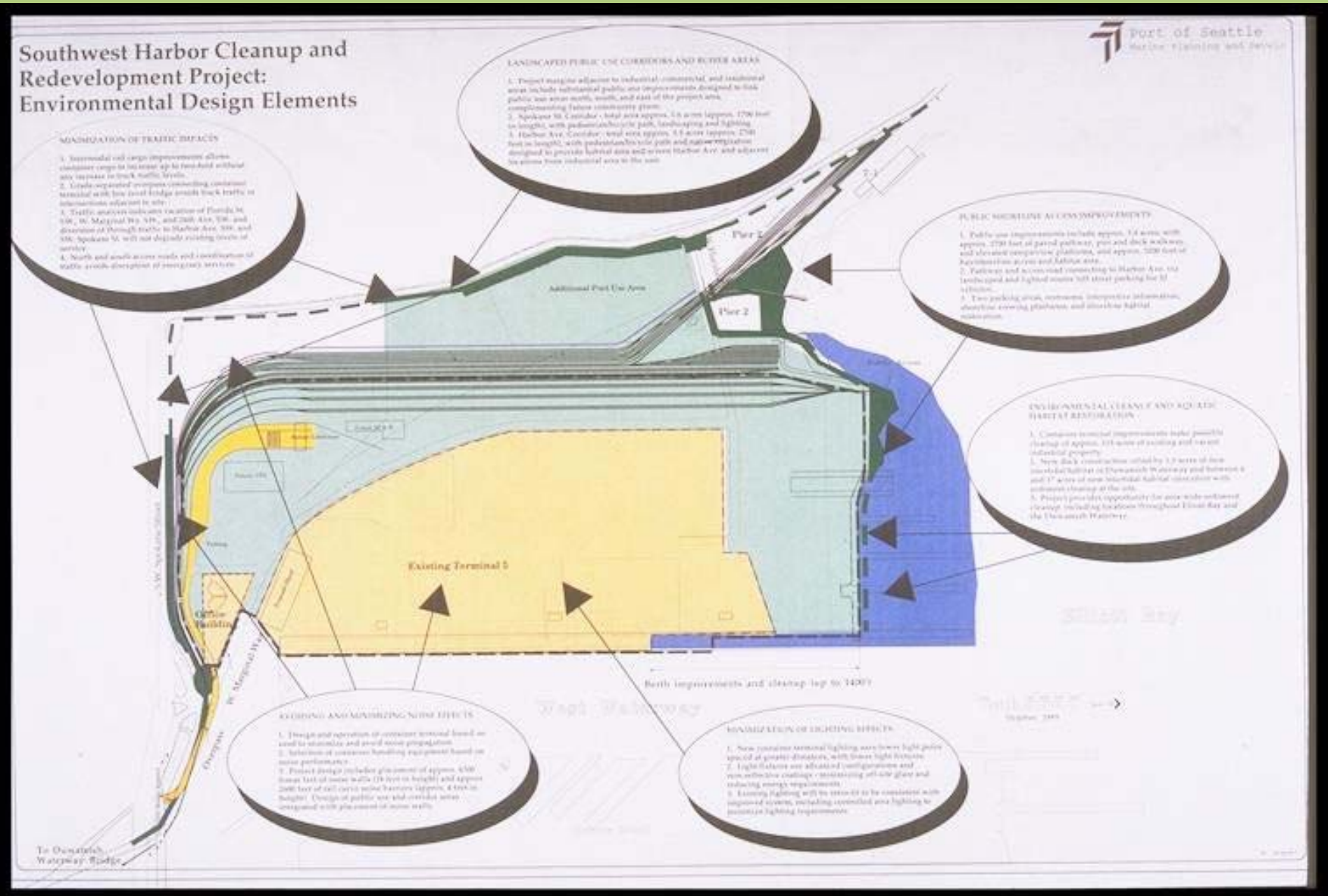
1. Container terminal improvements include possible cleanup of approx. 100 acres of existing and vacant industrial property.
2. New dock construction offset by 2.0 acres of new intertidal habitat on Duwamish Waterway and between 6 and 17 acres of new intertidal habitat construction with sediment cleanup at the site.
3. Project provides opportunity for area wide sediment cleanup, including for stream throughout Elson Bay and the Duwamish Waterway.

REDUCING AND MINIMIZING NOISE EFFECTS

1. Design and operation of container terminal based on need to minimize and avoid noise propagation.
2. Selection of container handling equipment based on noise performance.
3. Project design includes glass-pane of approx. 400 linear feet of noise walls (10 feet in height) and approx. 2000 feet of rail car noise barrier (approx. 4 feet in height). Design of public use and corridor areas incorporated with placement of noise walls.

MINIMIZATION OF LIGHTING EFFECTS

1. New container terminal lighting uses lower light poles spaced at greater intervals, with lower light fixtures.
2. Light fixtures are shielded (configurations and non-reflective coatings) minimizing spill-over and reducing energy requirements.
3. Existing lighting will be retro-fitted to be consistent with improved systems, including controlled area lighting to minimize lighting requirements.



Graphic illustrating port's emphasis on combining economic and environmental objectives as essential elements in infrastructure redevelopment at Terminal 5.

Note avoidance and minimization of potential negative effects. Project included construction of additional 400 linear feet of container cargo pier.



Removal of derelict vessel at Turning Basin Number Three, as portion of Terminal 5 redevelopment environmental restoration.



Removal of derelict vessel as portion of Terminal 5 redevelopment environmental restoration.



Site Before Fill Removal



Site After Fill Removal

Turning Basin Number Three--Estuarine Fish and Wildlife Mitigation (1999)

Illustrating restoration site excavation and grading nearly complete. Removed approximately 33,000 tons industrial fill placed in former estuarine wetland, 1915-1945.



Turning Basin Number Three--Estuarine Fish and Wildlife Mitigation (1999)

Illustrating 1.3 acre restoration site four months following grading and excavation. Restored intertidal substrate bordered with marsh and riparian vegetation planting areas.



**Turning Basin Number Three
Photograph One (Position One)**

Turning Basin Number Three—Estuarine Fish and Wildlife Habitat (southeast perspective, 2008)

Illustrating north margin of restoration site, opening to Turning Basin Number Three aquatic area. Perspective is co-linear with location of pre-construction bank line. All emergent and riparian vegetation installed as elements of restoration action. Tidal elevation approximately plus nine to ten feet MLLW.



**Turning Basin Number Three
Photograph Two (Position Two)**

Turning Basin Number Three information sign, located at the southwest entrance to the site (July 2008).



**Turning Basin Number Three
Photograph Six (Position Five)**

Turning Basin Number Three—Estuarine Fish and Wildlife Habitat (south perspective, 2008)

Illustrating marsh and riparian vegetation established at south margin of restoration site. Marsh and riparian vegetation form a continuous band at the site. Marsh vegetation in foreground planted 1999, with additional marsh plantings (background) in 2001.



**Turning Basin Number Three
Photograph Ten (Position Five)**

Turning Basin Number Three—Estuarine Fish and Wildlife Habitat (northwest perspective, 2008)

Illustrating stable marsh and exposed fine-grained, low slope substrate. Tidal elevation approximately plus nine to ten feet MLLW.



**Turning Basin Number Three
Photograph Thirteen (Position Five)**

**Turning Basin Number Three—Estuarine Fish and Wildlife Habitat
(northwest perspective—detail, 2008)**

This image also illustrates successful establishment of emergent vegetation at the restoration site. All marsh vegetation depicted is the result of the restoration project planting. Please note the continuous band of riparian vegetation immediately adjacent up-slope of the emergent planting areas. The riparian vegetation complements marsh plantings, ensuring stable bank line conditions and inhibiting Canada geese from feeding in the marsh vegetation, since the geese are prevented from entering the marsh areas from up-slope locations.



Photograph illustrating native estuarine marsh, with side channel features

Historically, marsh habitat in the Duwamish estuary included conditions similar to the photograph above. Marsh area is now utterly rare in the Duwamish estuary and side channels penetrating marsh area, once abundant, are now entirely absent. Working with federal agencies, the port designed a demonstration project as a means to re-introduce similar marsh and side channel habitat to the estuary.



Preliminary Concept for Terminal 105 Demonstration Site

This graphic illustrates an early design concept for constructing a side channel intertidal habitat area at Terminal 105. It is important to note that the environmental objective was to restore a former habitat feature to the estuary. In addition, the demonstration project tested how restored estuarine habitat areas could be configured to be compatible with industrial shoreline areas, without impeding important waterway access. Habitat restoration area oriented perpendicular to the shoreline would provide essential environmental attributes and not foreclose industrial access to adjacent shoreline areas.



Terminal 105, Estuarine Fish and Wildlife Habitat (construction 1996-1997)

Approximately 9400 cubic yards of previously placed fill was removed to create a 0.6 acre intertidal channel approximately 1300 feet in length. During construction a buried vault, filled with paint and solvent wastes was discovered, adding substantial project costs for cleanup and confirmation testing of newly exposed intertidal sediments.

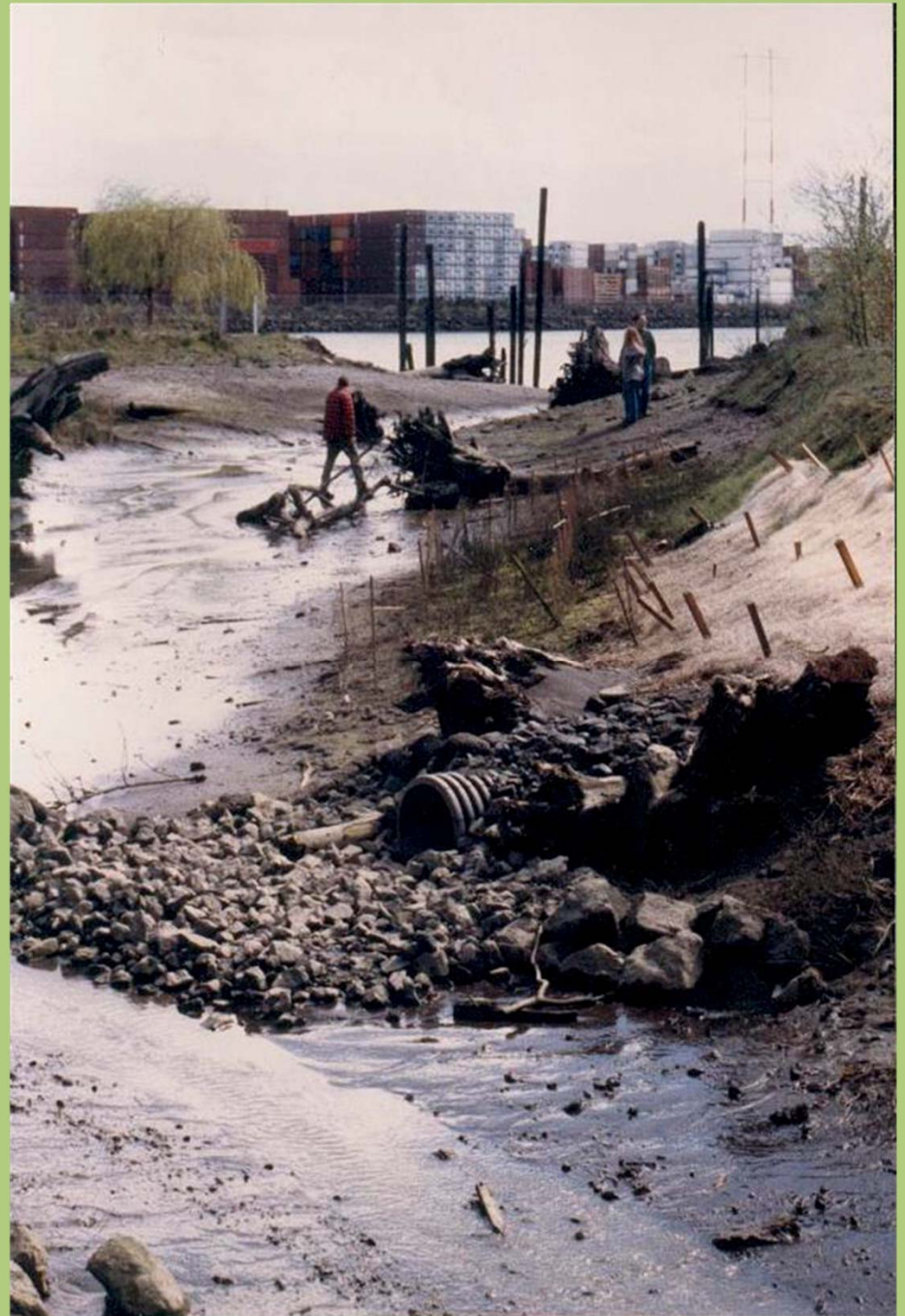


Completed Terminal 105 demonstration project site, 1997

The restoration project is illustrated at low tide – note the extent of tidal influence indicated by the wetted bank line. The site is inundated twice daily by tidal water up to five feet in depth. Following grading, the restoration site received 0.3 acres of native riparian trees and shrubs and more than 1100 marsh plants. All site vegetation work was accomplished by community participants.

Terminal 105 demonstration project site, 1998

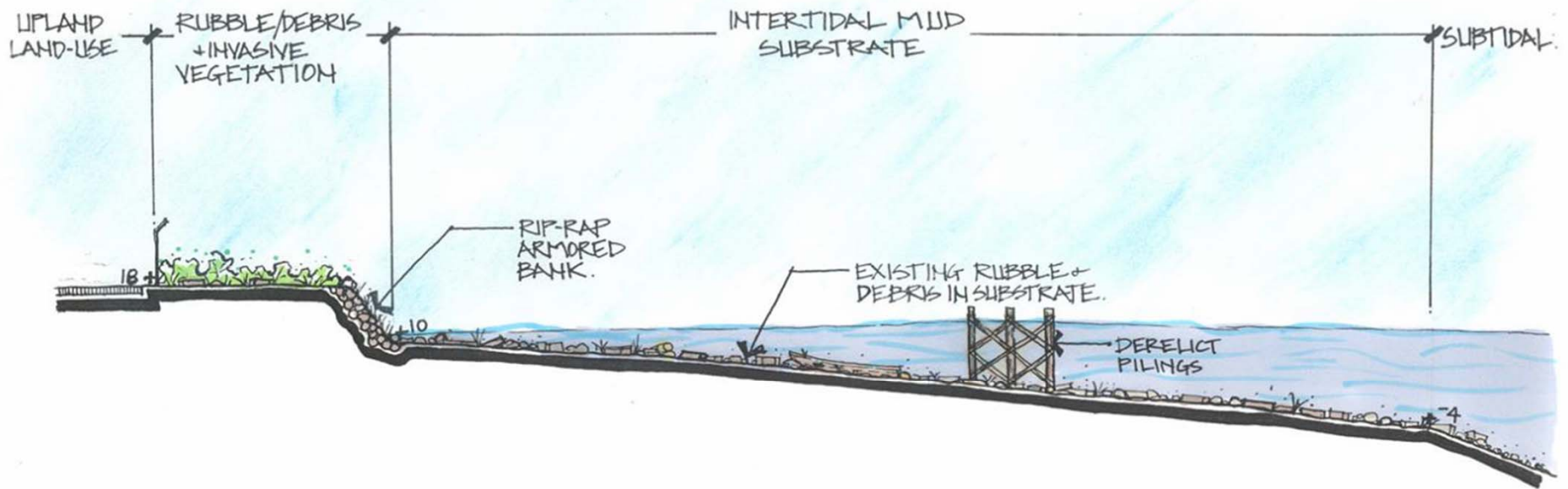
Illustrating intertidal channel following construction in 1998. Note erosion control fabric and emergent vegetation plantings. Riparian vegetation has been installed.





Completed Terminal 105 demonstration project—2006

The intertidal channel substrate is stable, with robust, sustained native marsh and riparian vegetation.



A EXISTING CONDITION SECTION A: POTENTIAL MARSH BENCH CREATION

Duwamish Waterway, Corridor Fish and Wildlife Habitat--Concept

Illustrating industrial bank line and adjacent intertidal and shallow subtidal aquatic area impeded by past industrial uses and activities



Terminal 108, Corridor Fish and Wildlife Habitat Demonstration Project (2015)

Illustrating eroding, formerly armored marine industrial bank line (upper left). Approximately 285 linear feet unstable bank line replaced with regraded riparian slope and anchored large woody debris.



Description:



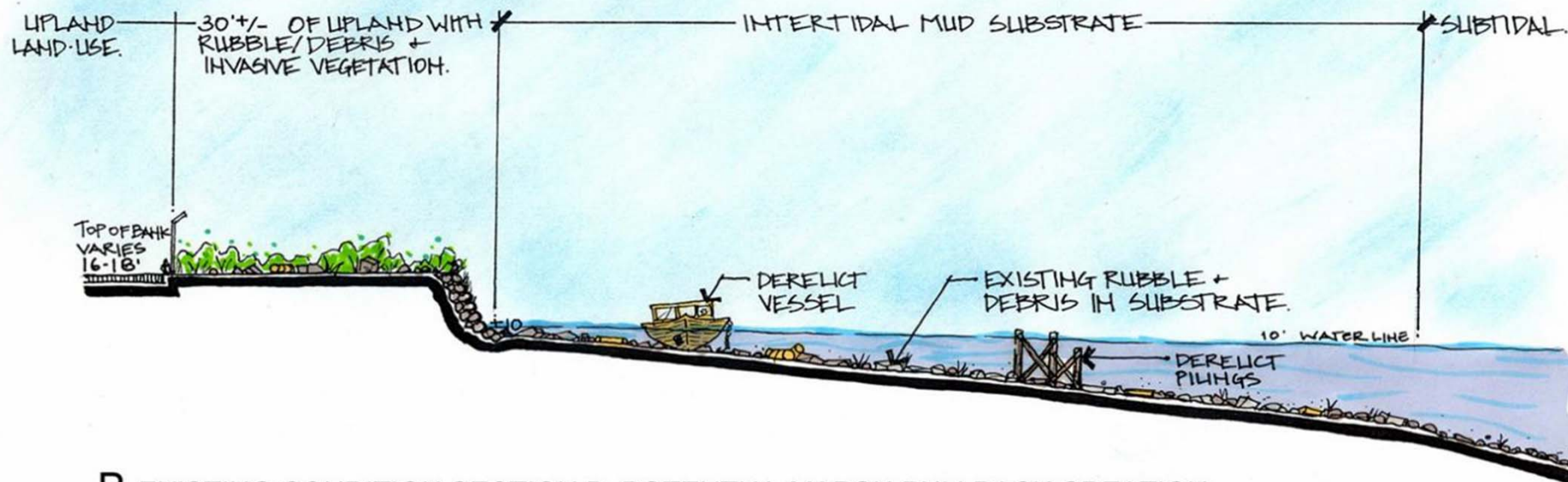
Terminal 108, Corridor Fish and Wildlife Habitat Demonstration Project (2015)

Anchored large woody debris, protecting toe-of-slope. Stable bank line conditions protect marine industrial asset while providing coincident fish and wildlife natural resource benefits.



Terminal 108, Corridor Fish and Wildlife Habitat Demonstration Project (2016)

Anchored large woody debris and native riparian vegetation, following first year riparian and upper inter-tidal vegetation growth.



B EXISTING CONDITION SECTION B: POTENTIAL MARSH PULLBACK CREATION

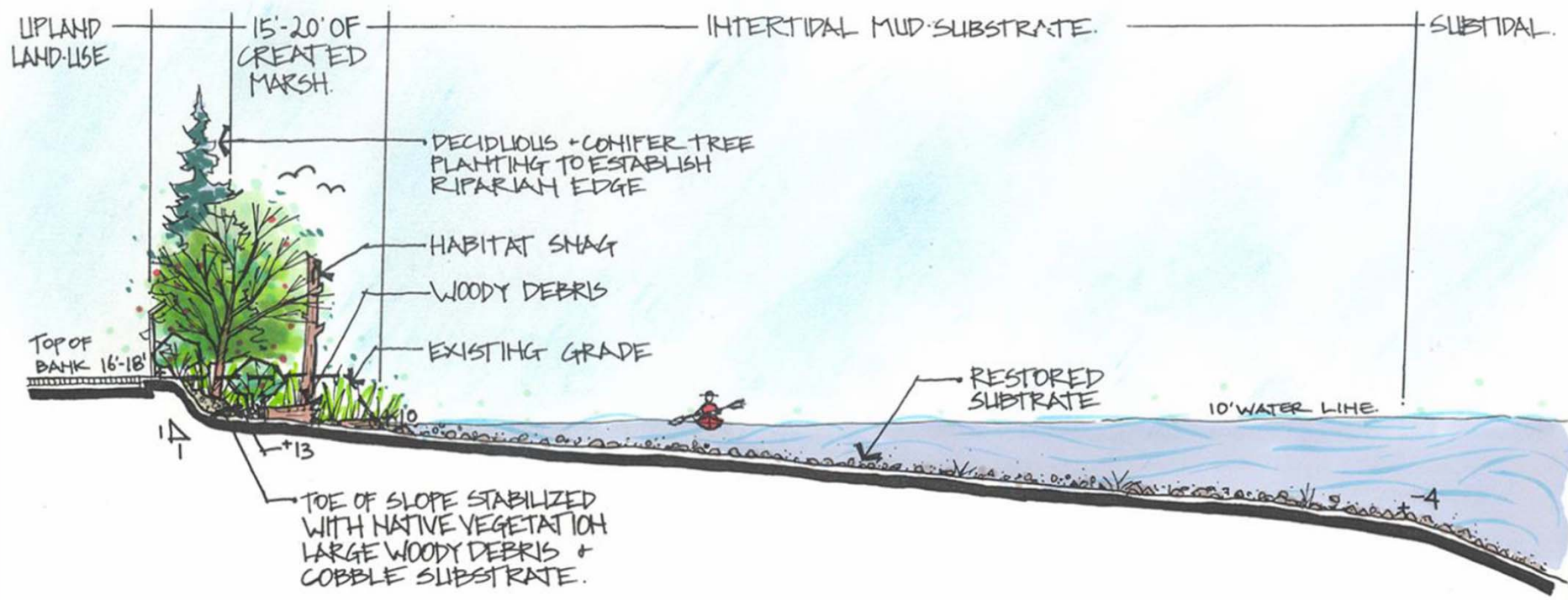
Duwamish Waterway, Corridor Fish and Wildlife Habitat--Concept

Illustrating potential for removal of derelict waterway debris and regrading eroding, rubble-filled bank line.



South Riverside Drive, Corridor Fish and Wildlife Habitat Restoration—existing conditions

Illustrating derelict waterway vessel and materials, eroding rubble fill bank line, and invasive plants. Port-owned bank line, with adjacent upland public right-of-way in use with commercial parking.



A: MARSH BENCH CONCEPT SECTION A

Duwamish Waterway, Corridor Fish and Wildlife Habitat--Concept

Illustrating elements of bank line restoration in publicly-owned Duwamish Waterway.



South Riverside Drive, Corridor Fish and Wildlife Habitat Demonstration Project (2014)

Illustrating eroding, rubble-filled bank line and industrial debris impeding intertidal area.



South Riverside Drive, Corridor Fish and Wildlife Habitat Demonstration Project (2015)

Waterway debris removal (approximately 75 tons) and bank-line regrading underway. Note toe-of-slope anchored large-woody-debris installation, coir fabric, and preparation of riparian slope planting area.



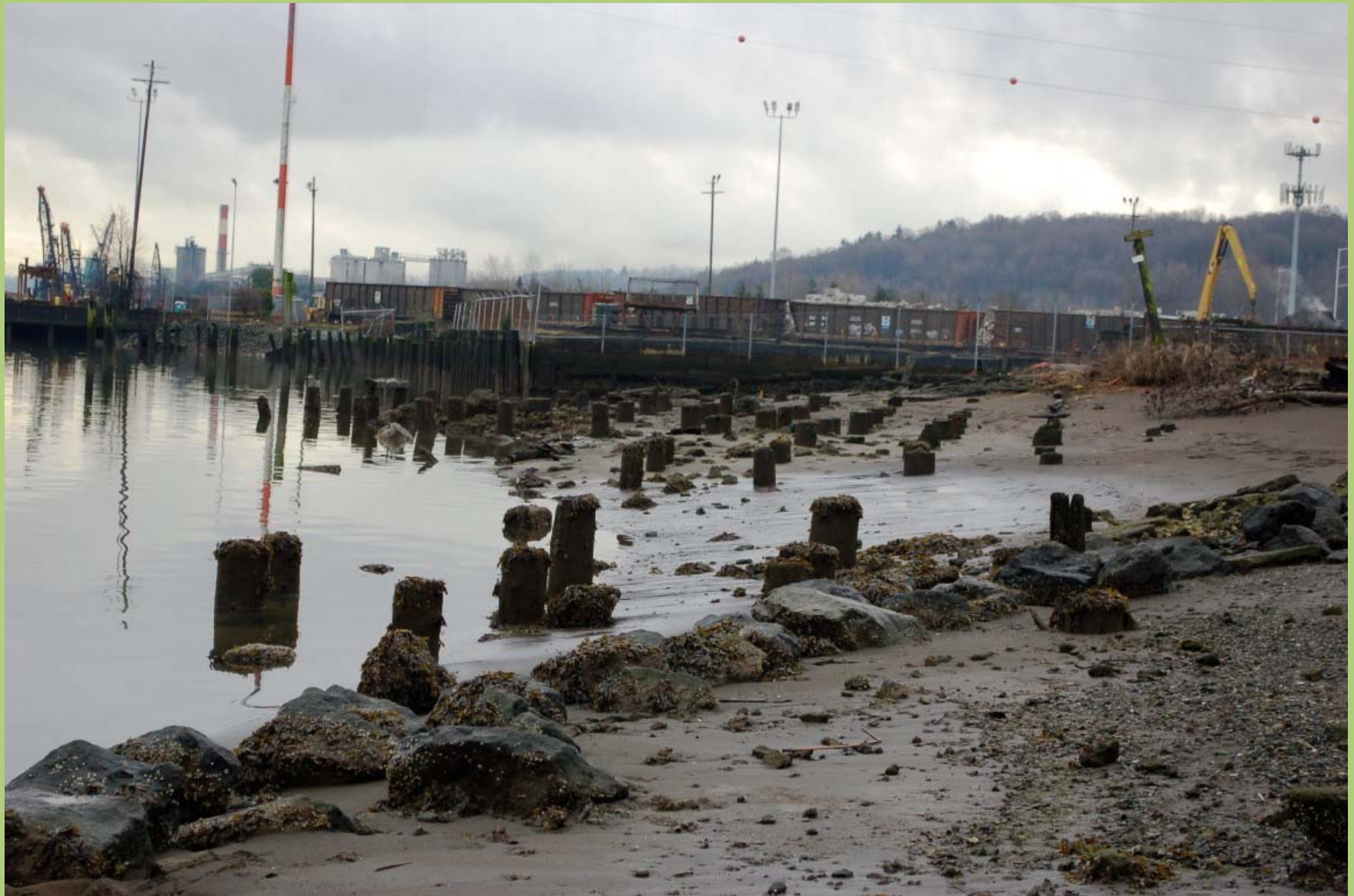
South Riverside Drive, Corridor Fish and Wildlife Habitat Demonstration Project (2015)

Approximately 310 linear feet of bank line rehabilitation completed. Approximately 6500 square feet riparian and upland native planting area prepared. Former truck parking area includes shoreline pathway connecting to adjacent port-constructed public shoreline access site. Upland area improved with passive stormwater controls.



South Riverside Drive, Corridor Fish and Wildlife Habitat Demonstration Project (2016)

Illustrating vigorous first year native riparian vegetation growth, establishing stable top-of-bank conditions.



Terminal 105, Aquatic Area and Shoreline Stabilization Project (2016)

Illustrating approximately 0.5 acres aquatic area impeded with derelict creosote piling and marine industrial debris.



Terminal 105, Aquatic Area and Shoreline Stabilization Project (2016)

Illustrating aquatic area following removal of approximately 410 creosote piling and associated industrial debris, totaling approximately 475 tons. Aquatic area received approximately 65 tons of clean sand cover.



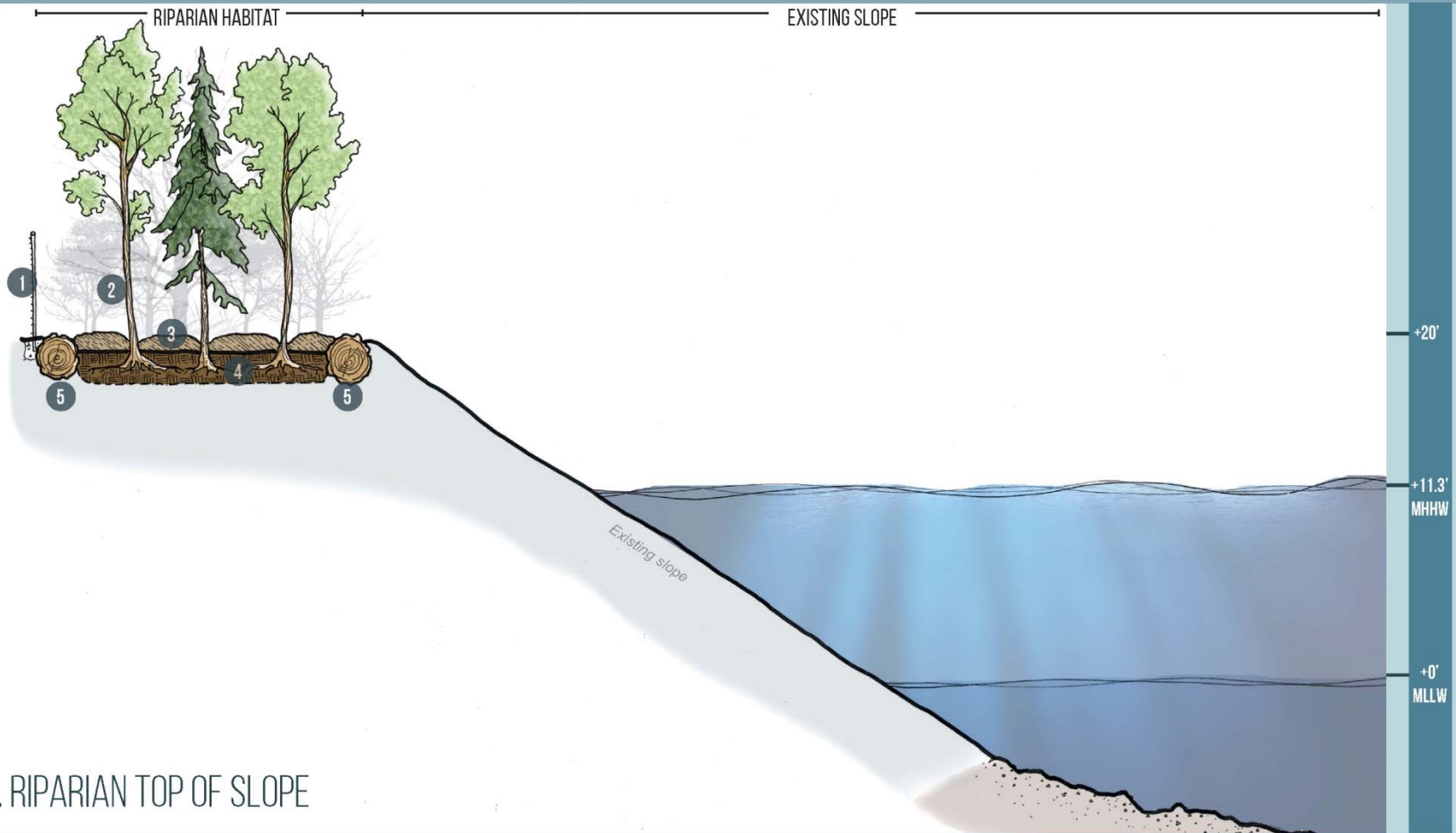
Terminal 105, Aquatic Area and Shoreline Stabilization Project (2016)

Illustrating approximately 0.3 acres, 285 linear feet, instable eroding bank-line adjacent to piling/debris removal area.



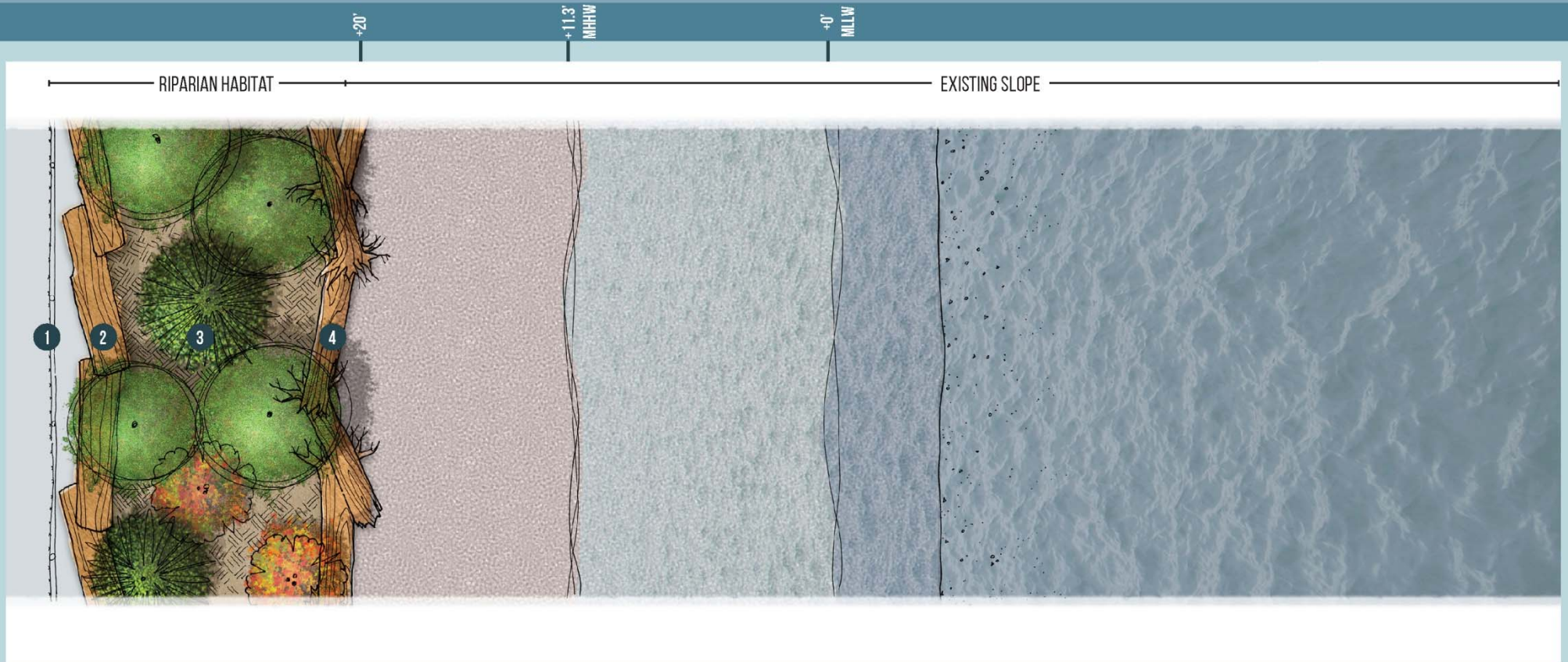
Terminal 105, Aquatic Area and Shoreline Stabilization Project (2016)

Rehabilitated bank-line, with anchored large woody debris, composted soil, and mulch cover. Large woody debris included approximately 90 logs, imbedded as “triple bundles”, secured with “duck-billed” anchors ten to 15 feet below grade. Shoreline planted in winter/spring 2017, including 600 native trees, shrubs, and upper-intertidal plants.



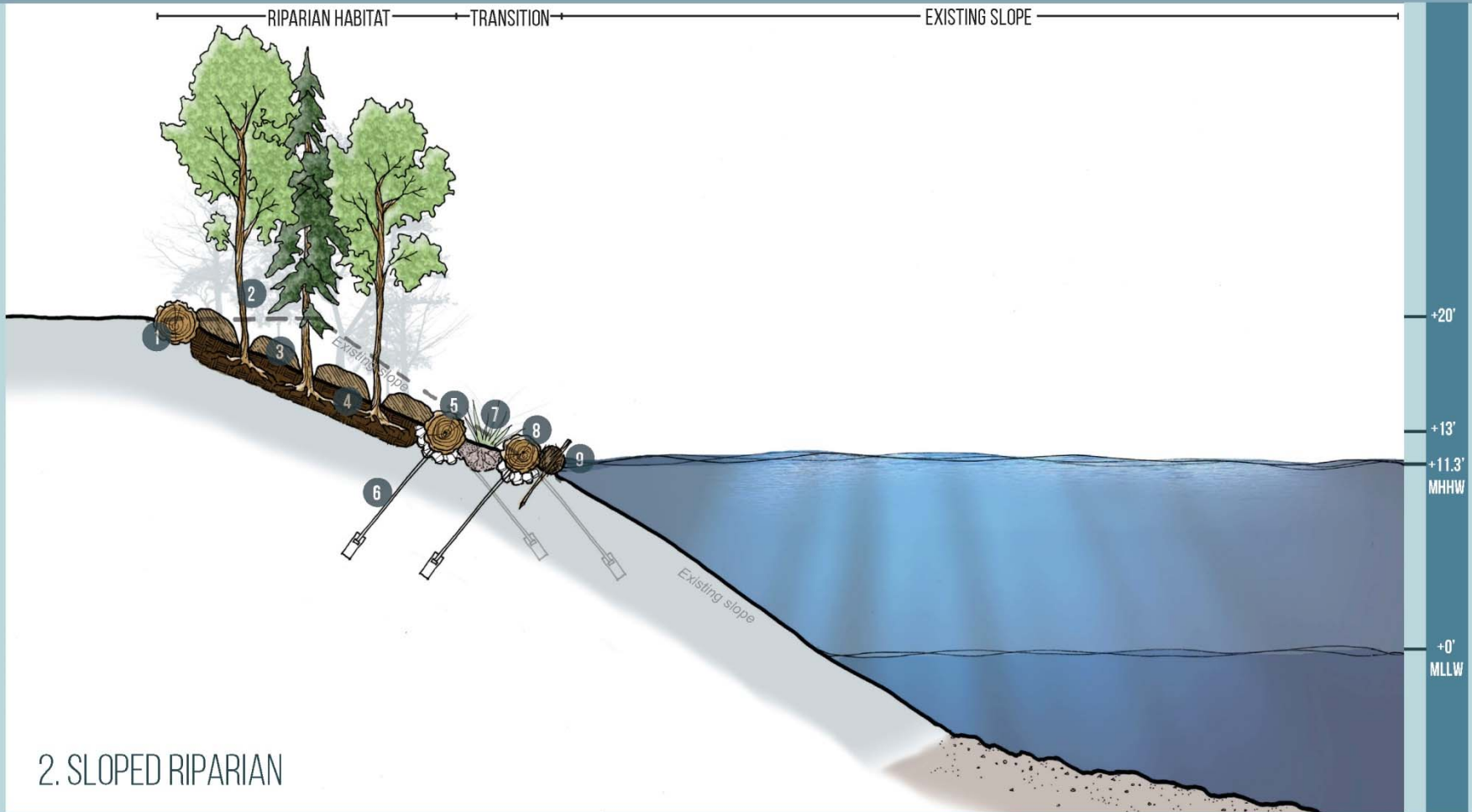
1. RIPARIAN TOP OF SLOPE

- 1 Fence
- 2 Dense riparian plantings with permanent irrigation
- 3 Twelve-inch mulch layer
- 4 Two feet imported topsoil over geotextile fabric
- 5 Large woody debris defines top of bank



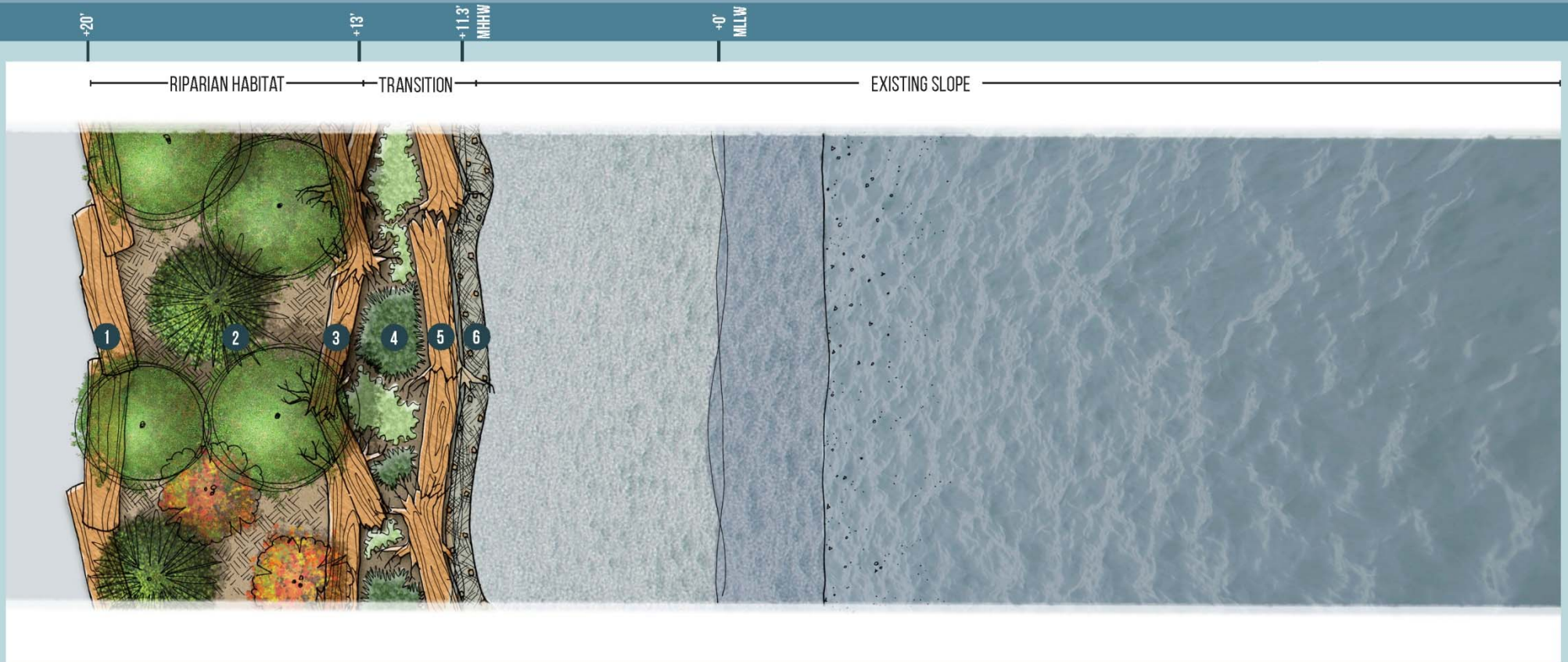
1. RIPARIAN TOP OF SLOPE

- 1 Fence
- 2 Large woody debris defines edge
- 3 Dense riparian plantings
- 4 Large woody debris defines top of bank



2. SLOPED RIPARIAN

- 1** Large woody debris
- 2** Dense riparian plantings with irrigation- 2:1 to 4:1 slope
- 3** Twelve-inch mulch layer
- 4** Two feet of imported topsoil over geotextile fabric
- 5** Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 6** Earth anchor system to secure log
- 7** Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 8** Anchored sacrificial toe log on rock bolster



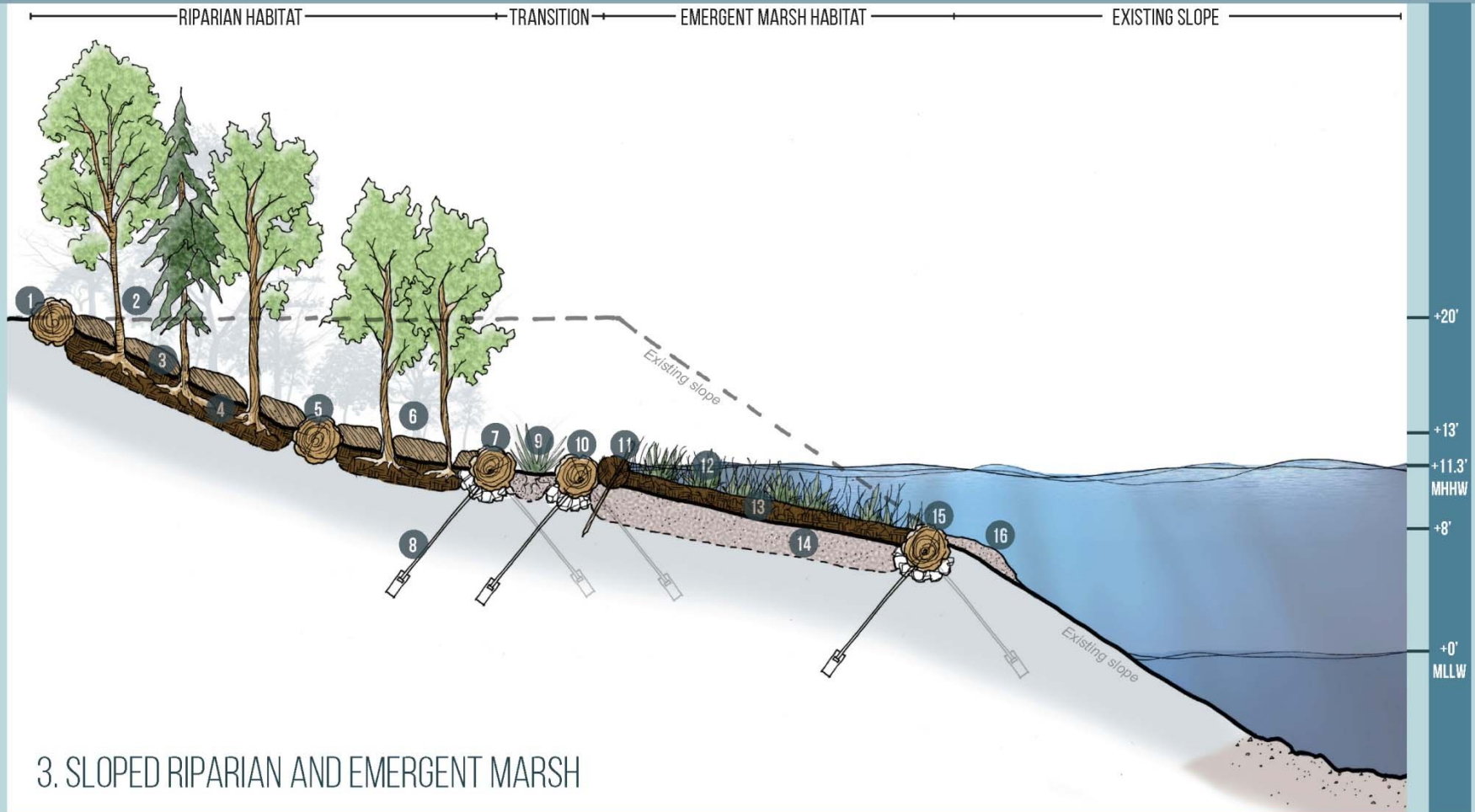
2. SLOPED RIPARIAN

- 1** Large woody debris

2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope

3 Anchored large woody debris defines edge
- 4** Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment

5 Anchored sacrificial toe log
- 6** Staked fiber roll (wattle)



3. SLOPED RIPARIAN AND EMERGENT MARSH

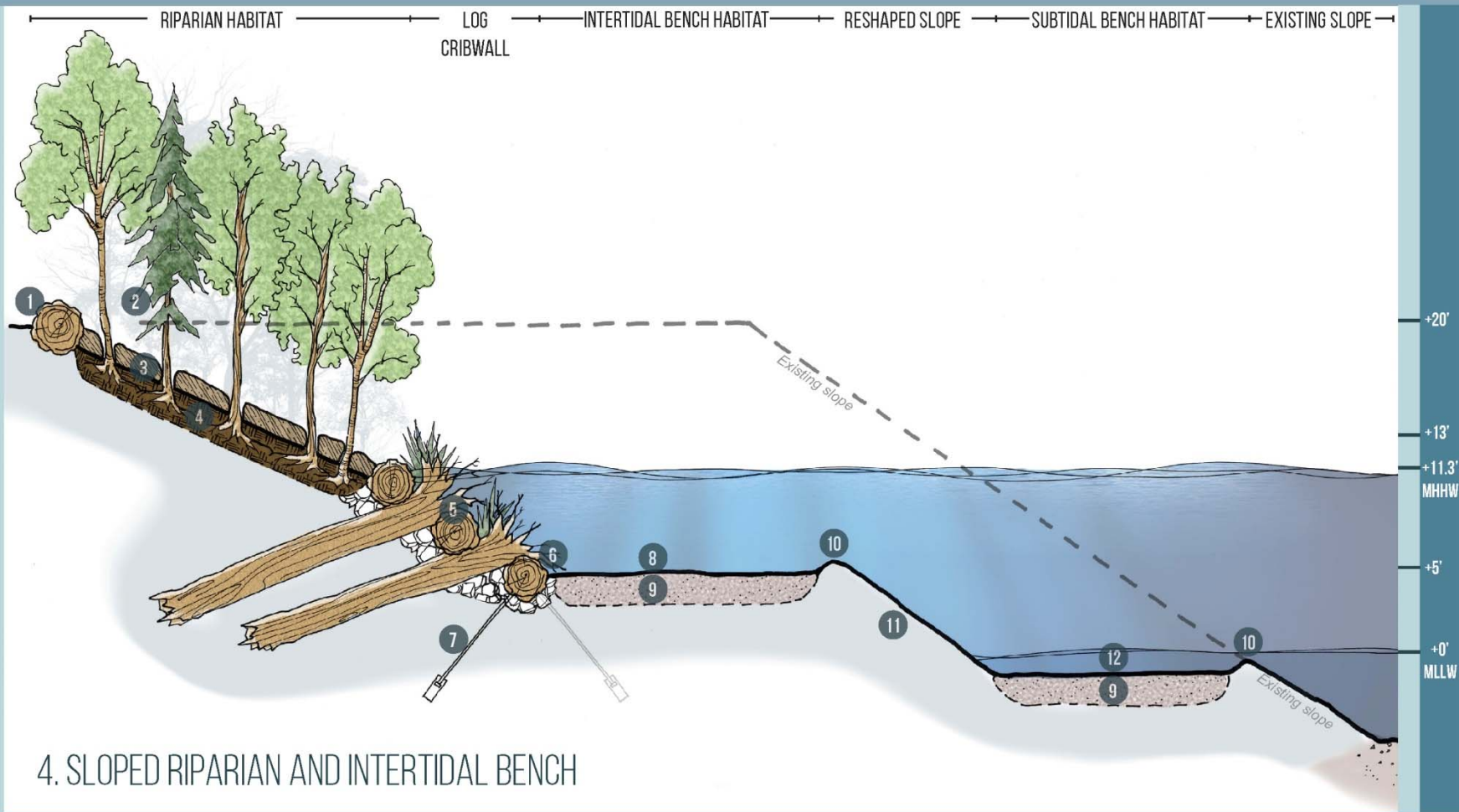
- 1 Large woody debris
- 2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope
- 3 Twelve-inch mulch layer
- 4 Two feet of imported topsoil over geotextile fabric
- 5 Large woody debris defines slope transition
- 6 Dense riparian plantings with irrigation - 4:1 or flatter slope
- 7 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 8 Earth anchor system to secure log
- 9 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 10 Anchored sacrificial toe log on rock bolster
- 11 Staked fiber roll (wattle)
- 12 Emergent marsh planted in biodegradable geotextile fabric pillow - 4:1 to 10:1 slope
- 13 Twelve-inch import topsoil layer in pillow
- 14 Two-foot fine grain sediment layer in pillow
- 15 Anchored buried log with rock bolster
- 16 Fine grain sediment veneer

PORTFOLIO RESTORATION DESIGN TYPICALS



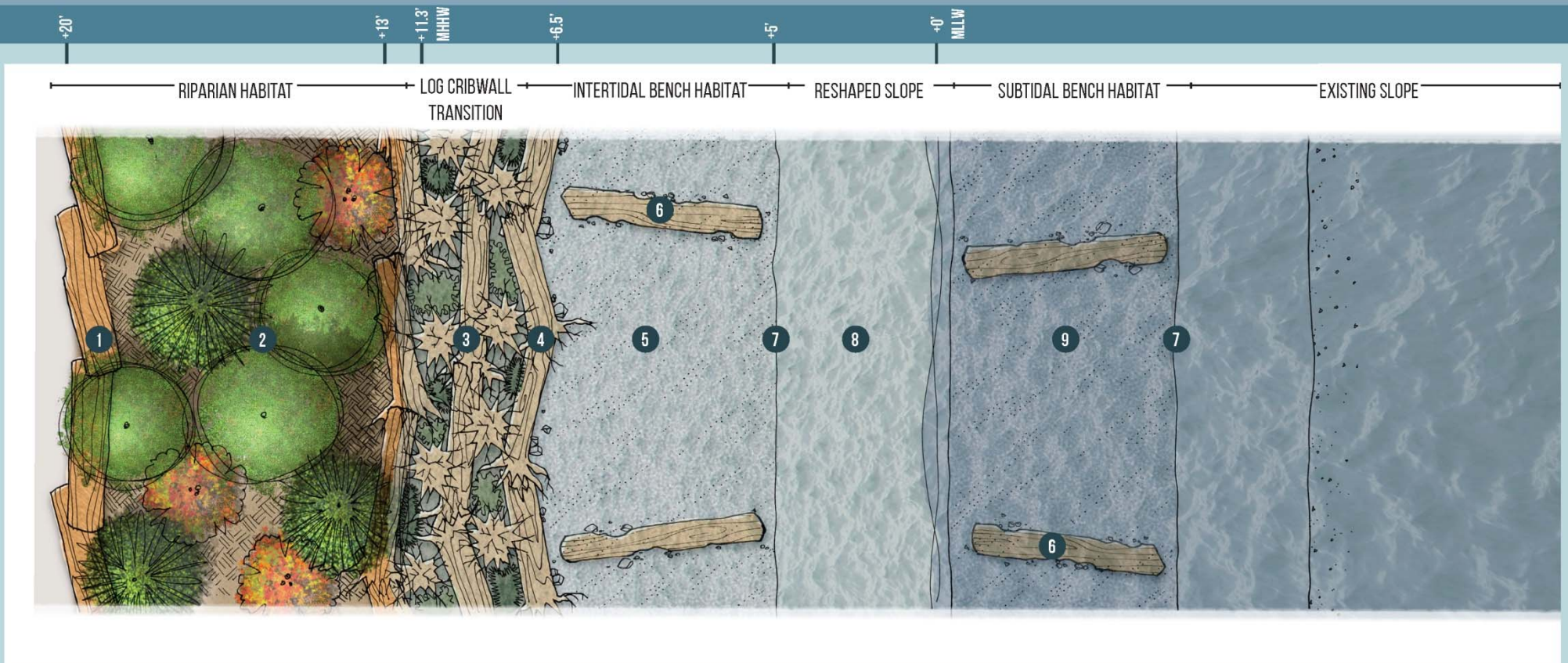
3. SLOPED RIPARIAN AND EMERGENT MARSH

- 1 Large woody debris
- 2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope
- 3 Large woody debris defines slope transition
- 4 Dense riparian plantings with irrigation - 4:1 or flatter slope
- 5 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 6 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 7 Anchored sacrificial toe log on rock bolster
- 8 Staked fiber roll (wattle)
- 9 Emergent marsh planted in biodegradable geotextile fabric pillow - 4:1 to 10:1 slope
- 10 Anchored buried log with rock bolster
- 11 Fine grain sediment veneer



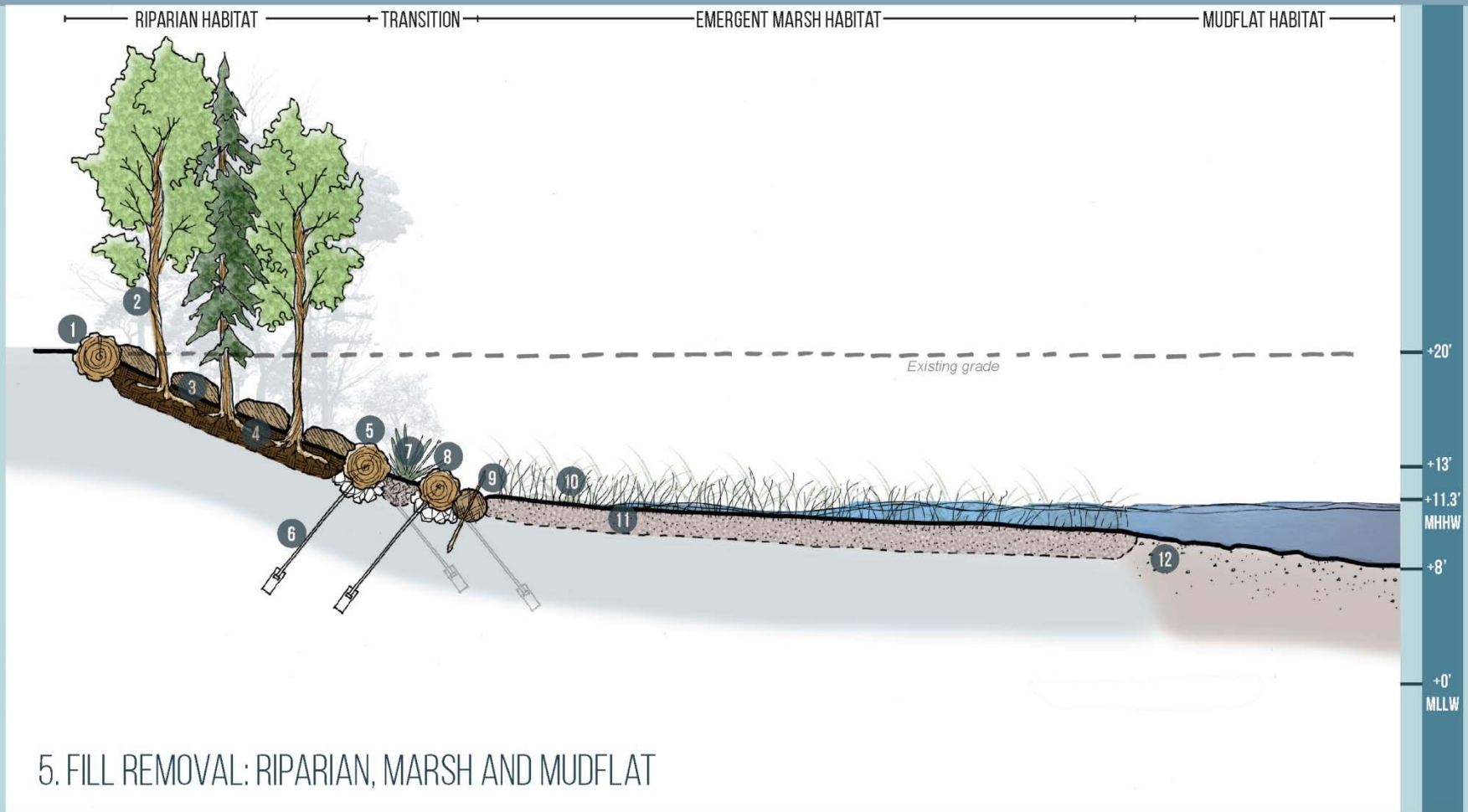
- | | | | | |
|--|--|---|--|--|
| 1 Large woody debris | 4 Two feet of imported topsoil over geotextile fabric | 6 Anchored sacrificial toe log on rock bolster | 8 Intertidal bench - slope is flat or angled up slightly | 10 Raised waterward edge |
| 2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope | 5 Log cribwall interplanted with native grasses | 7 Earth anchor system to secure log | 9 Two-foot layer fine grain sediment over geotextile fabric layer | 11 Reshaped slope - existing material |
| 3 Twelve-inch mulch layer | | | | 12 Subtidal bench - slope is flat or angled up slightly |

PORTFOLIO RESTORATION DESIGN TYPICALS



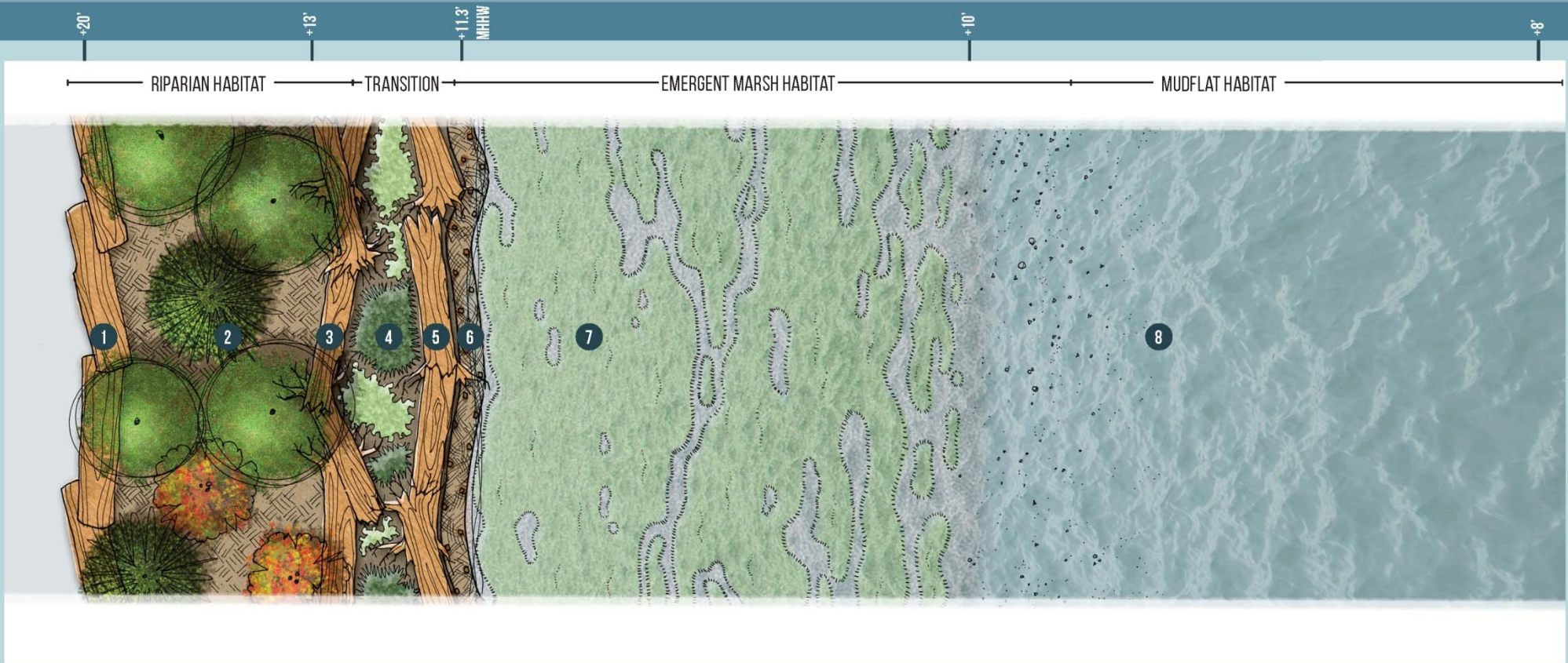
4. SLOPED RIPARIAN AND INTERTIDAL BENCH

- 1 Large woody debris
- 2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope
- 3 Log cribwall interplanted with native grasses
- 4 Anchored sacrificial toe log on rock bolster
- 5 Intertidal bench - slope is flat or angled up slightly
- 6 Transverse logs help retain sediment
- 7 Raised waterward edge
- 8 Reshaped slope - existing material
- 9 Subtidal bench - slope is flat or angled up slightly



5. FILL REMOVAL: RIPARIAN, MARSH AND MUDFLAT

- 1 Large woody debris
- 2 Dense riparian plantings - 2:1 to 4:1 slope
- 3 Twelve-inch mulch layer
- 4 Two feet of imported topsoil over geotextile fabric
- 5 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 6 Earth anchor system to secure log
- 7 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 8 Anchored sacrificial toe log on rock bolster
- 9 Staked fiber roll (wattle)
- 10 Emergent marsh in biodegradable geotextile fabric pillow - 10:1 to 25:1 slope; down to +8.5' MLLW
- 11 Twelve-inch fine grain sediment layer in pillow
- 12 Unvegetated mudflat - 20:1 or flatter slope; transition to existing slope



5. FILL REMOVAL: RIPARIAN, MARSH AND MUDFLAT

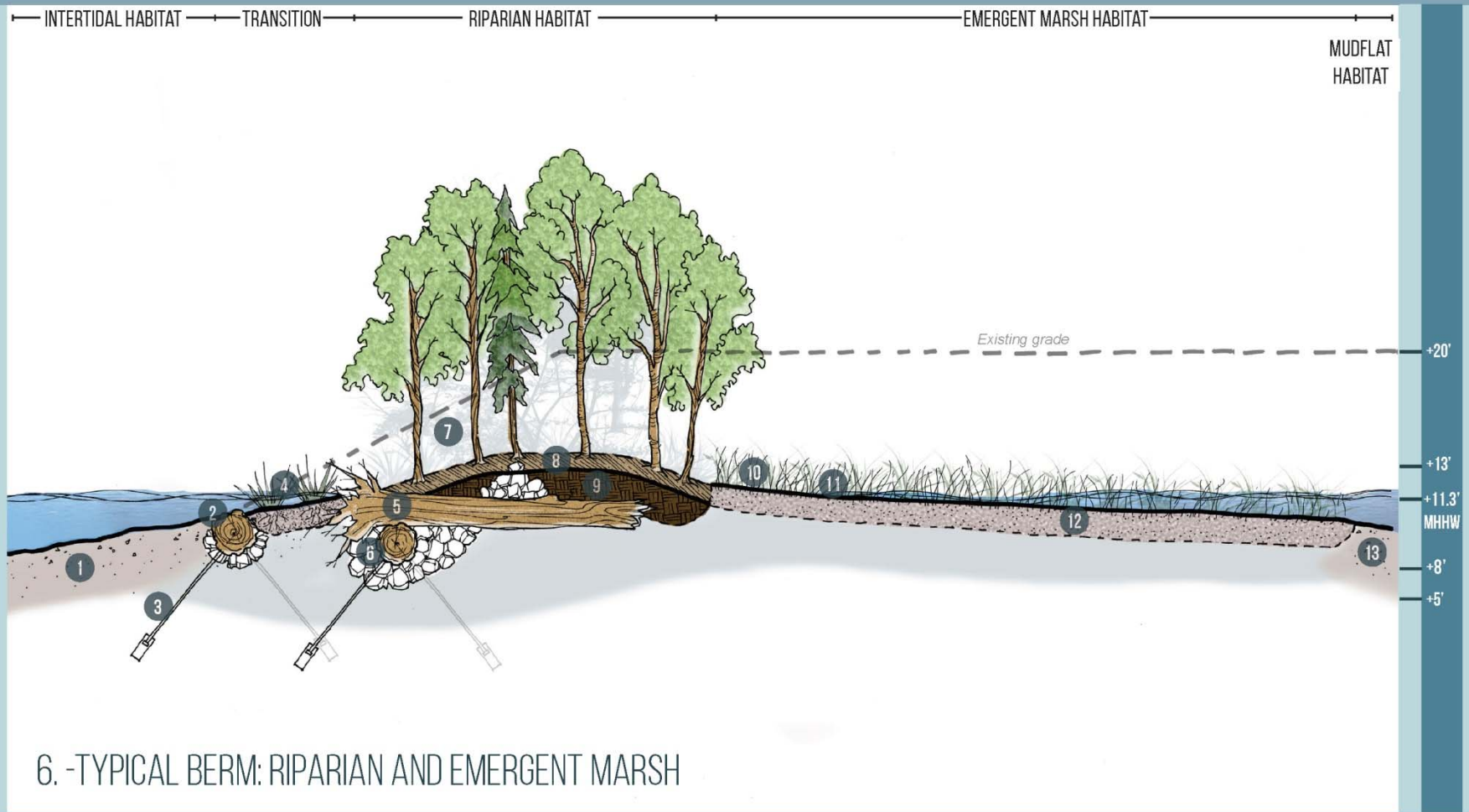
- 1 Large woody debris

2 Dense riparian plantings with irrigation - 2:1 to 4:1 slope
- 3 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat

4 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 5 Anchored sacrificial toe log on rock bolster

6 Staked fiber roll (wattle)
- 7 Emergent marsh in biodegradable geotextile fabric pillow - 10:1 to 25:1 slope, down to +8.5' MLLW

8 Unvegetated mudflat - 20:1 or flatter slope, transition to existing slope



6. -TYPICAL BERM: RIPARIAN AND EMERGENT MARSH

- 1 Unvegetated intertidal habitat
- 2 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 3 Earth anchor system to secure log
- 4 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 5 Large woody debris cross log
- 6 Anchored large woody debris footer log with rock bolster
- 7 Dense riparian plantings with irrigation - 3:1 slope
- 8 Twelve-inch mulch layer
- 9 Two-foot imported topsoil layer over geotextile fabric
- 10 Emergent marsh planted in biodegradable geotextile fabric pillow - 10:1 slope
- 11 Slope transition point - continues as 25:1 slope
- 12 Twelve-inch layer fine grain sediment
- 13 Unvegetated mudflat



6. -TYPICAL BERM: RIPARIAN AND EMERGENT MARSH

- 1 Unvegetated intertidal habitat
- 2 Anchored large woody debris on rock bolster defines waterward edge of riparian habitat
- 3 Emergent plants in biodegradable geotextile fabric pillow filled with two feet of fine grain sediment
- 4 Large woody debris cross and footer log
- 5 Dense riparian plantings with irrigation - 3:1 slope
- 6 Emergent marsh planted in geotextile fabric pillow - 10:1 slope
- 7 Slope transition point
- 8 Emergent marsh planted in biodegradable geotextile fabric pillow - 25:1 slope
- 9 Unvegetated mudflat, transition to existing slope

