Design & Application of a New Submerged Diffuser for Targeted In-Water Placement of Dredged Material within the Lower Columbia Estuary.

WEDA-Pacific Chapter 2022 Annual Meeting – San Francisco, CA

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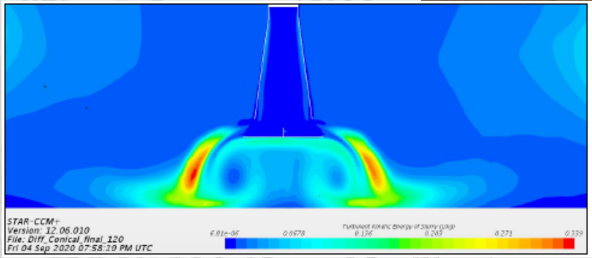

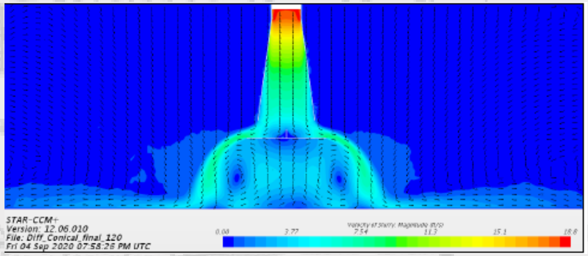

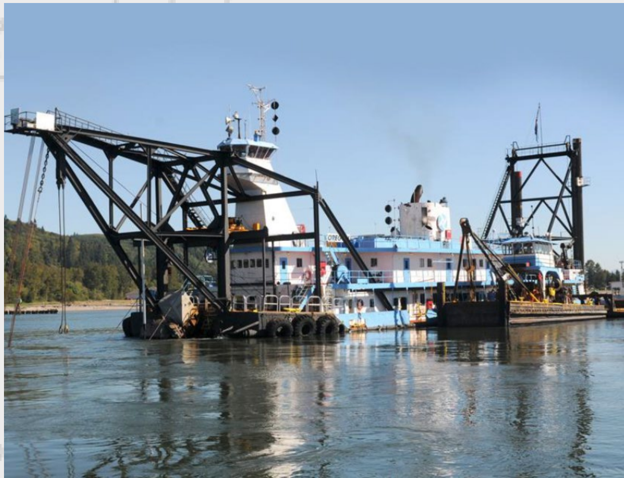

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Presentation Outline (project timeline 2018-2021)

Improve Management of Dredged Material within the Lower Columbia River (LCR)

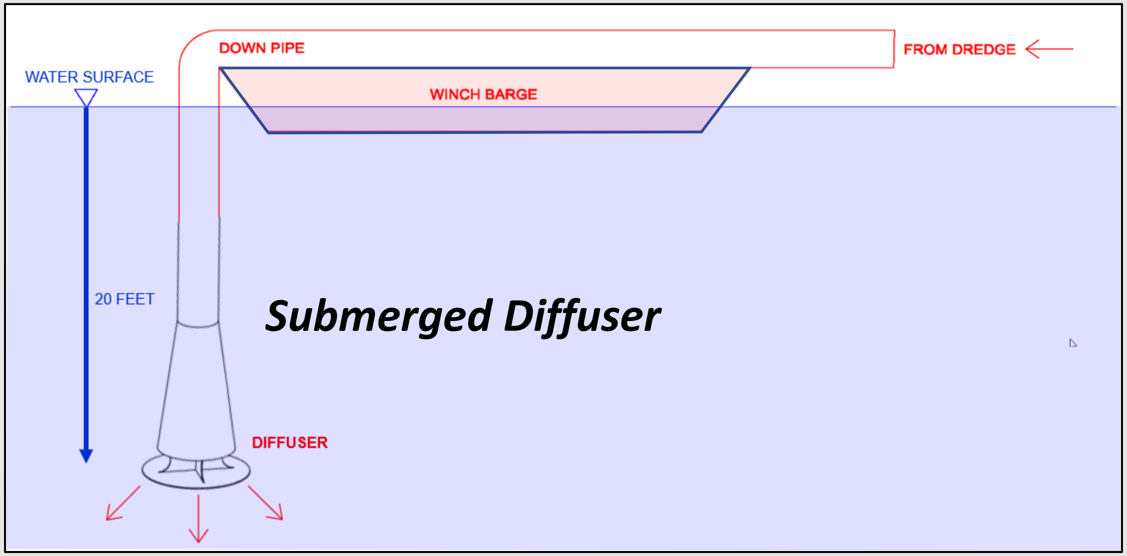
- Intersection of RSM, BUDM, EWN requires “reliable” in-water placement dredged material

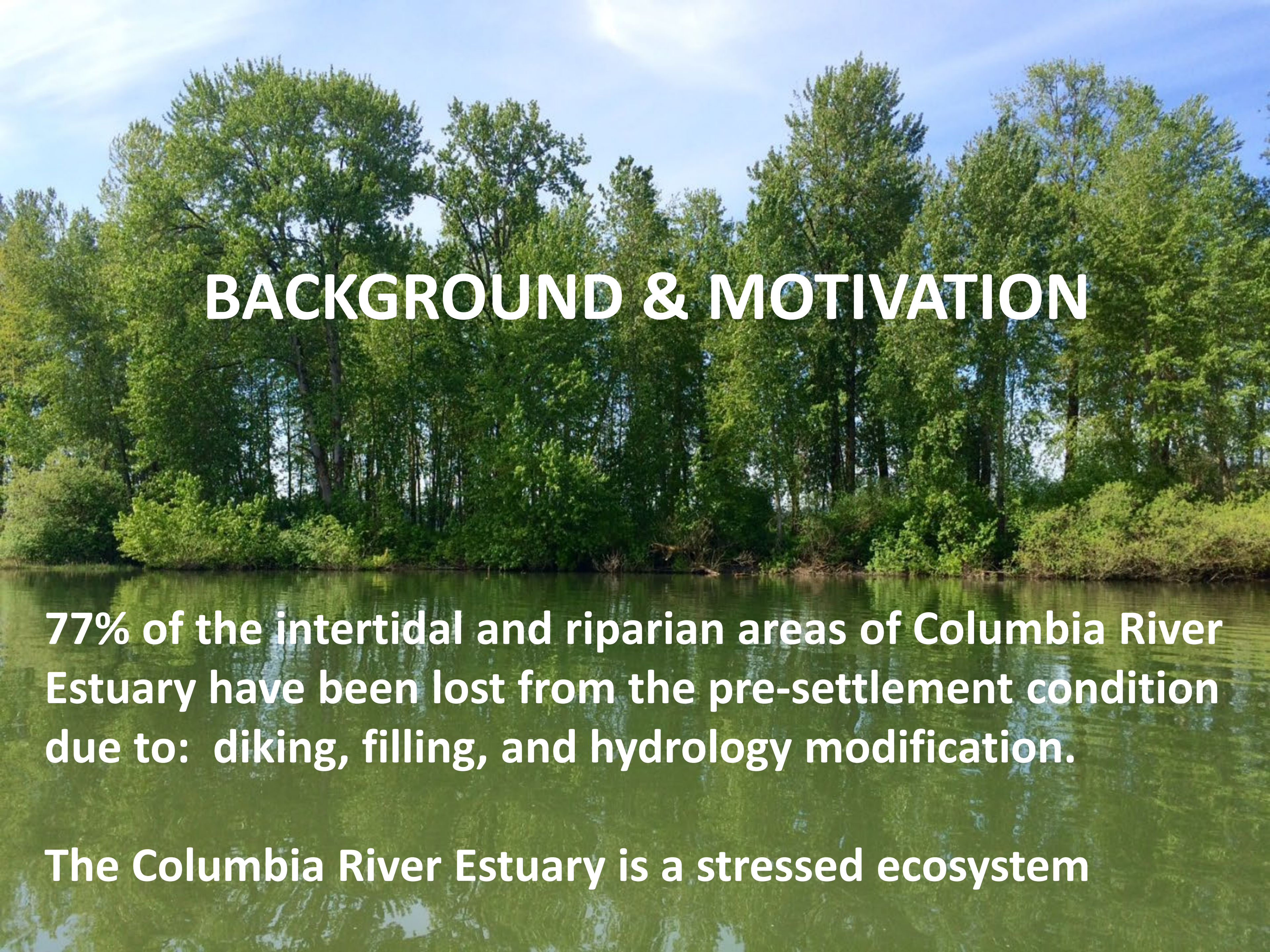
Develop an “Improved” Diffuser for Use on the LCR – For Submerged Placement

- A collaborative, slow-rolling, and iterative process

Apply the Newly Fabricated Conical Diffuser – For River Engineering

- Controlled Submerged Placement of Dredged Sand to Enable River Engineered





BACKGROUND & MOTIVATION

77% of the intertidal and riparian areas of Columbia River Estuary have been lost from the pre-settlement condition due to: diking, filling, and hydrology modification.

The Columbia River Estuary is a stressed ecosystem

LCR NAVIGATION CHANNEL: 100 miles long, 600 ft wide, 43 ft deep

River Mile 6-106

Each Year, 5 to 7 million CY of sand is dredged to maintain the channel

0.2 to 10 mm, with less than 3% fines

75 % is placed at Inwater sites > 20ft depth (feed the river-sediment system)

25% is placed as beach nourishment and upland

Objective: Implement Beneficial Use of Dredged Material (BUDM)

Improve use of dredged material to benefit the river system and restore habitat

Do a better job with Inwater Placement

Implementing BUDM within the Lower Columbia River Estuary requires precise in-water placement that does not adversely affecting the environment.

DRAFT ERDC/TN RSM-YR-21
September 2021

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

by Chanda Littles, David Trachtenbarg, Douglas Swanson, Kat Herzog, Ryan Woolbright, and Amy Borde (PNNL)

PURPOSE: This Technical Note (TN) describes the U.S. Army Corps of Engineers (USACE) Portland District (NWP) process for collaborating with interagency partners to apply a systematic, structured decision-making framework for placing dredged material to maximize ecosystem functions and benefits, i.e., beneficial use of dredged material (BUDM).

OBJECTIVES: We hypothesize that the strategies developed by Studebaker et.al. (2019) can be utilized to locate potential placement sites and inform the design objectives for strategically placing dredged material. We seek BUDM options that emulate natural sediment transport dynamics in large riverine and estuarine environments to create or enhance inter-tidal and floodplain habitats for the benefit of native fish and wildlife in the Lower Columbia River (LCR).

BACKGROUND: Over the last 150 years 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 floodplain wetland (Fresh et al. 2005). These 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 (NOAA 2011).

Since 2000, USACE and other federal agencies have invested significant resources (on the order of \$50M) to restore habitats in the LCR (primarily through levee breaches) and to evaluate the effects of ecosystem restoration. Several projects have also been completed that experimented with supplemental use of dredged material to achieve estuary and riverine benefits. While other opportunities remain, this process has broadened the range of beneficial use strategies and opened the dialogue about additional areas in the system that could be enhanced through BUDM.

SITE SELECTION METHODOLOGY: NWP's Product Delivery Team (PDT), consisting of a diverse group of engineers, scientists, planners, and operations managers, started identifying sites by utilizing the GIS tools developed based on the systematic, structured decision-making framework to select sites for the BUDM from Studebaker et.al. (2019). The PDT intentionally considered NWP's multiple business lines and missions, e.g., ecosystem restoration sites, 20-year Dredged Material Management Plan, and pile dike rehabilitation projects

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Regional Sediment Management: Integrated Solutions for Sediment Related Challenges

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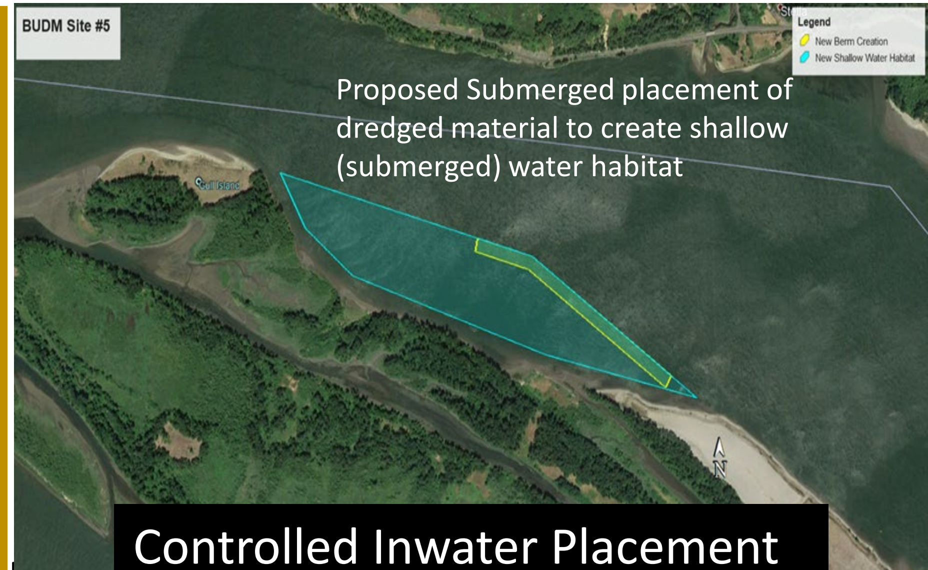


Present "tool" for In-Water placement – Dredge *Oregon* *1970s-2020*

Diffuser Barge

We need a <u>better</u> "tool" to do inwater placement of dredged material within the Columbia River: One that manages energy dissipation, minimizes turbidity, enables shallow water placement (10-20 ft deep), allows controlled deposition of placed dredged material….So that we can build restoration features, or feed the river's sediment budget w/o adverse effect.

"Present Diffuser"= 70-deg deflector with no energy dissipation.

Conical diffuser (decrease plume exit velocity)

Can we get one?

Q = VA
Discharge = Velocity x Area
Bigger discharge area = lower Velocity

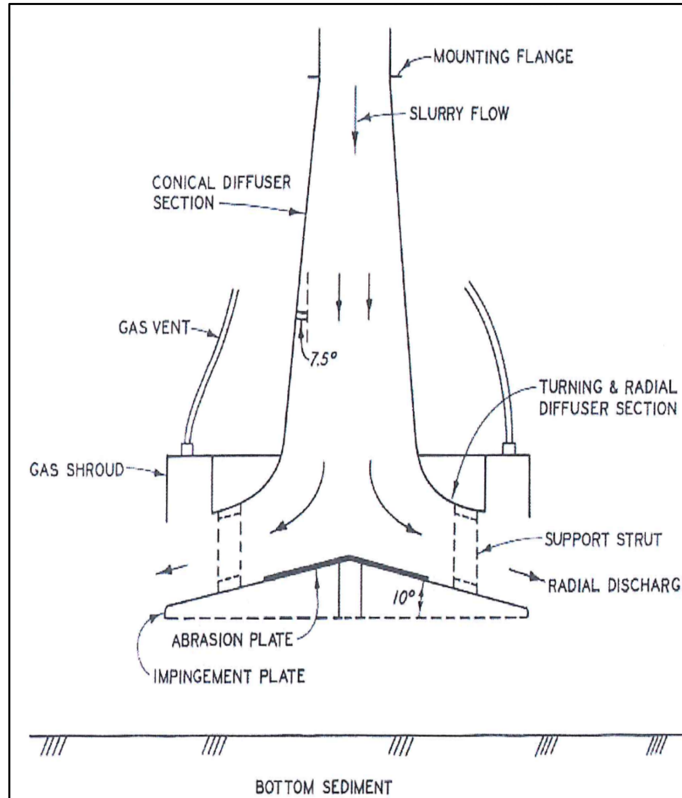


Figure 3-15. Submerged Diffuser Profile View

Development of Submerged Diffuser Concept

&

Hydraulic Evaluation of Diffuser Designs

Hydraulic Aspects: Plume encounter on riverbed, energy dissipation and pressure distribution within diffuser, slurry dispersal within diffuser

DEVELOPMENT OF SUBMERGED DIFFUSER FOR CONTROLLED DREDGED MATERIAL PLACEMENT

DREDGED MATERIAL RESEARCH PROGRAM

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

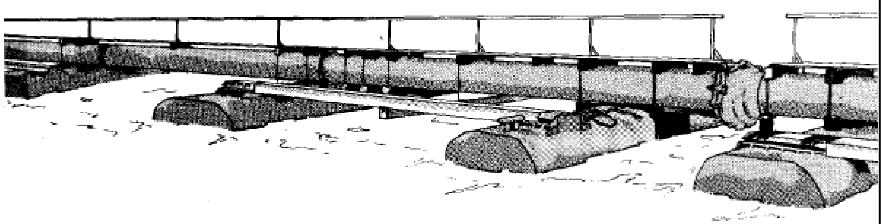
TECHNICAL REPORT D-78-44

EVALUATION OF THE SUBMERGED DISCHARGE OF DREDGED MATERIAL SLURRY DURING PIPELINE DREDGE OPERATIONS

by

Robert W. Neal, George Henry, Stephen H. Greene
JBF Scientific Corporation
2 Jewel Drive
Wilmington, Mass. 01887

August 1978
Final Report



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Washington, D. C. 20314

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Monitored by Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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Portland District

CFD Modeling Documentation Report

The Dredge *Oregon*

Diffuser Nozzle for Dredge Material Placement

Columbia River – Oregon/Washington

1

Blending Old and New: The team first consulted the olde ERDC Guidance, Engaged with ERDC via DOTS request, and then applied CFD Modeling to develop <u>“diffuser of choice”</u>

Initial Consideration focused on previously designed "smooth" diffuser concepts

DIMENSION	12"	18"	24"
A	12 5/16	18 3/8	24 3/8
B	19	25	32
C	23 5/8	35 3/8	46 7/8
D	12 3/16	18 1/4	24 3/16
E	43.4	65	86 1/8
F	9 5/16	13 15/16	18 7/16
G	7/32	9/32	9/32
H	64 7/16	96 7/16	127 3/4
I	64 1/8	96	127 1/4
J	48 1/16	72	95 7/16
K	8	12	15 7/8
L	10	15	19 7/8
M	10°	10°	10°
N	1 3/8	2	2 3/4
O	4	6	8
P	45 3/8	68	90 1/8
Q	4 1/2 (PIPE)	6 5/8 PIPE	8 5/8
R	8	12	15 7/8
S	12	18	24
T	1 1/2 NPT.	2 NPT.	2 1/2 NPT.
U	12	16	20
V	17	22 3/4	29 1/2
W	1"	1 1/4	1 3/8
X	11/16	3/4	1"
Y	1 1/2 x 1 1/2 x 1/4	2" x 2" x 3/8	2 1/2 x 2 1/2 x 1/2
Z	3/8-16	1/2-13	5/8-11
A_1	32"	48"	64"

DREDGE PIPE SIZE					
12" I.D.		18" I.D.		24" I.D.	
THICKNESS	WEIGHT *	THICKNESS	WEIGHT *	THICKNESS	WEIGHT *
3/16	800				
1/4	1066	1/4	2305	1/4	4084
5/16	1332	5/16	2880	5/16	5105
3/8	1598	3/8	3458	3/8	6126
		7/16	4034	7/16	7149
		1/2	4610	1/2	8172

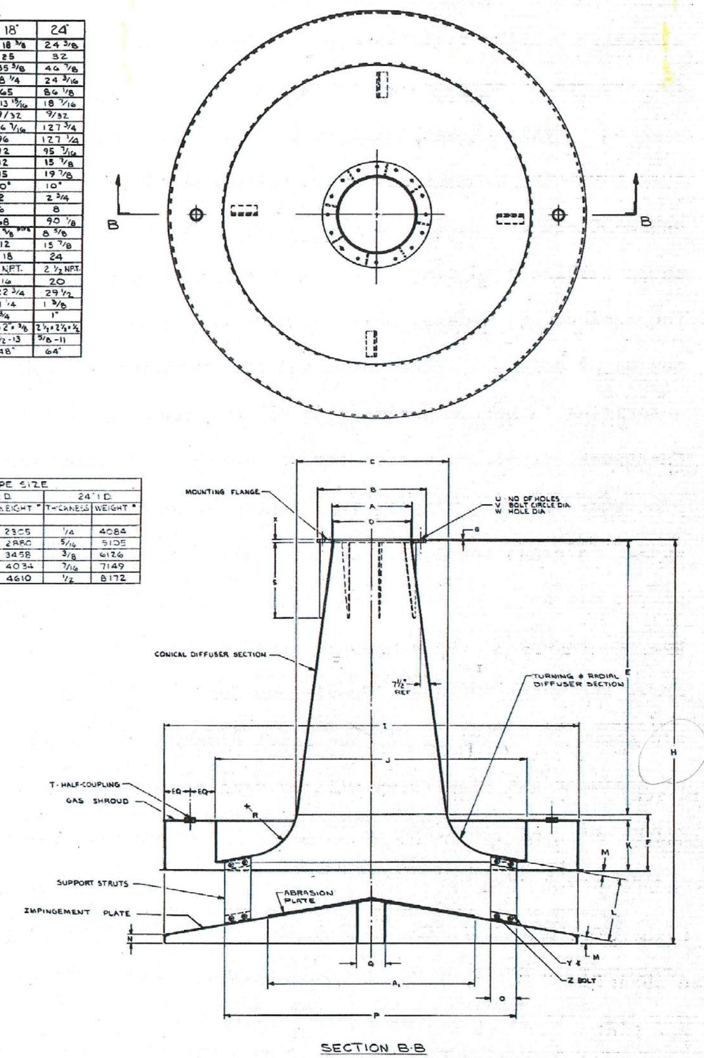
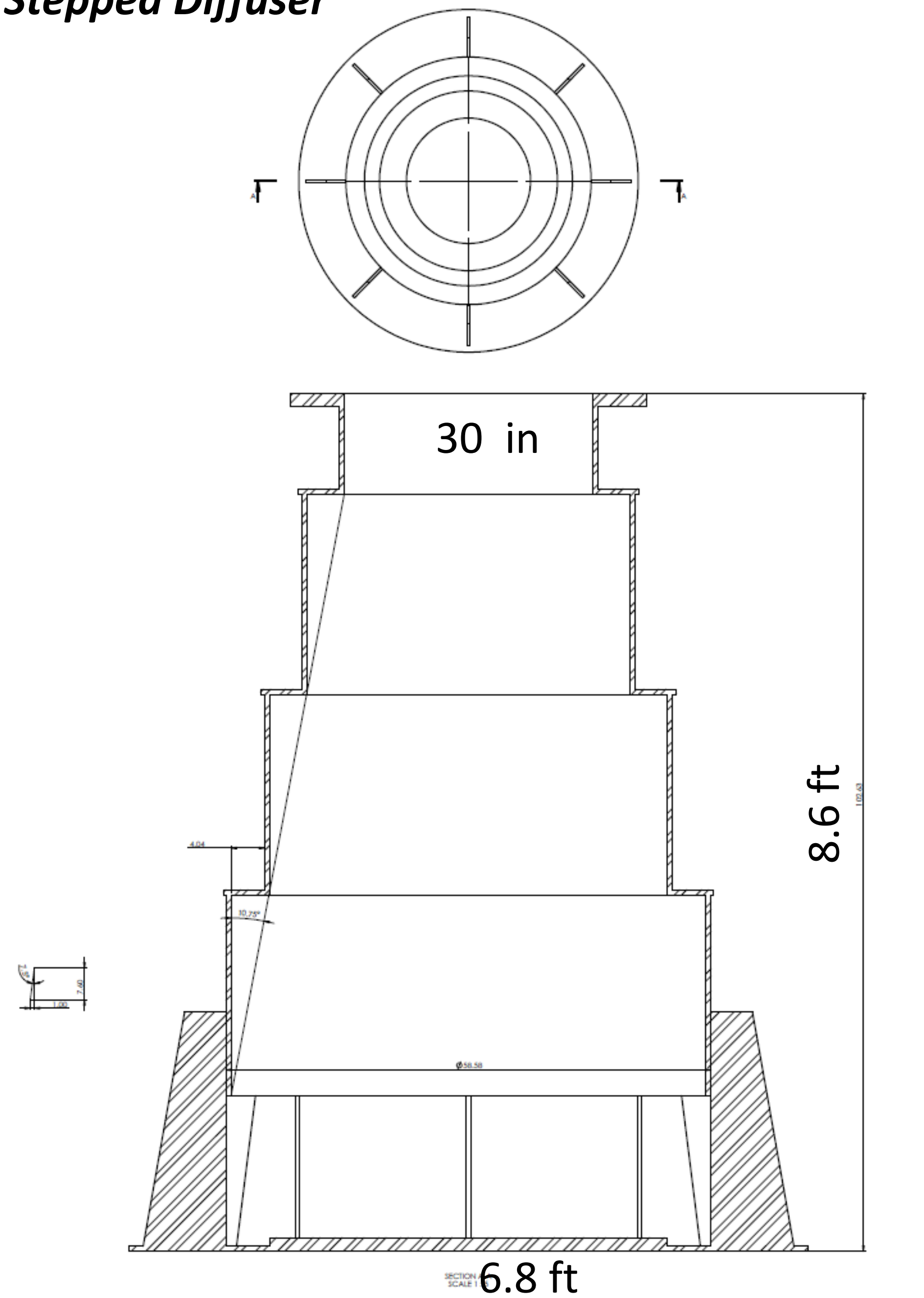


Figure 7. Full-scale diffuser processor design

The team determined that these "smooth" designs would be costly to fabricate due to curve expanding geometry----instead the team adopted a "stepped" concept

Stepped Diffuser



The stepped diffuser allows for simpler fabrication while preserving the rough shape of the smooth diffuser. Concentric cylinders, joined together, form the 'bell' with a flange at the top-most cylinder to attach to the dredging pipe. Eight fins on the bottom-most cylinder support a diffuser plate, oriented perpendicular to the flow of incoming slurry to deflect the slurry into a uniform, annular pattern as it leaves the plate.

Nominal Dredge Plant Aspects

Pipe diameter leading to diffuser = 30 in
Pipe fluid velocity = 16-20 f/s.
Maximum line pressure to diffuser = 120 psi
Typical dredge pumping rate of 40,000 gpm (83 cfs)
Solids content = 30% (by weight).
Slurry specific gravity = 1.23.
Expected dredging production = 25 Kcy/day

Expected Nominal Diffuser Operation

Diffuser located at 20 ft below water.
Baffle plate elevated 6 ft above the riverbed.
Slurry encounter velocity with riverbed is 5 f/s (max).

Nominal Diffuser Dimensions

Steel plate thickness varied from 1/2" to 9/16"
Diffuser is 8.6 ft tall.
Inlet has inside diameter = 30 inches
Baffle plate is 6.8 ft diameter.
8 fins connecting baffle plate to diffuser.
Slot clearance varied from 9 to 18 inches

The **steeped diffuser** geometry was defined within CADD and then input into a computational fluid dynamics (CFD) software; Star-CCM+ and modeled numerous times. CADD work was performed by PoP & NWP and CFD modeling was performed by Portland District (Aaron Litzenberg and Max Wilson-Fey)

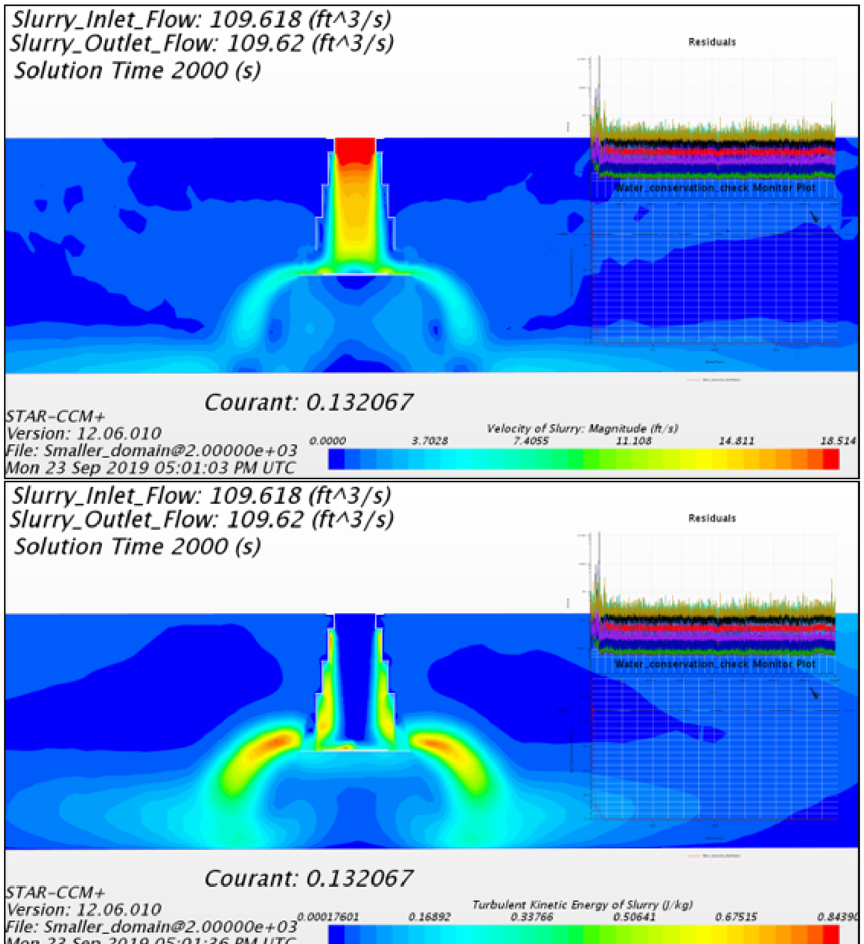


Figure 6: Run 5, steady-state slurry velocity profile (Top) and turbulent kinetic energy profile (Bottom)

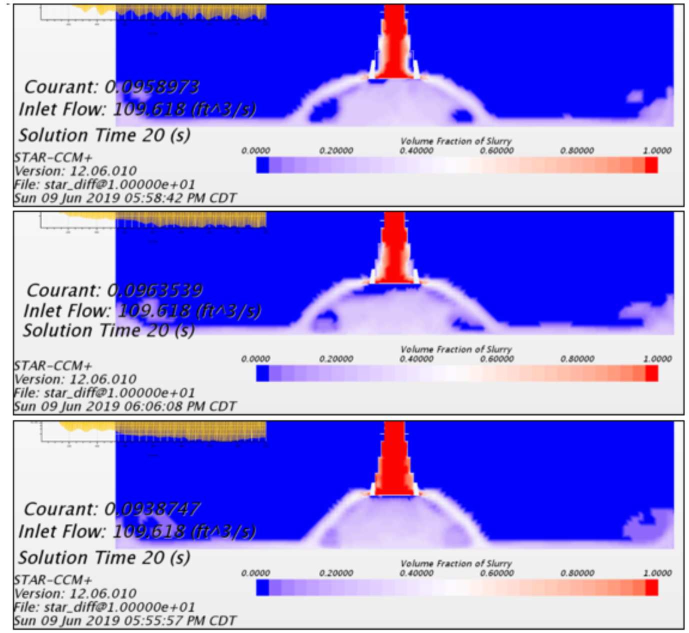


Figure 5: Run 2 at 20 model-seconds showing volume fraction profiles of slurry for original (Top), reduction of one third (Middle), and reduction of one half (Bottom) exit slot heights. Note boundary condition edge effects and how the reduction of one half configuration diffuser is 'full' of slurry.

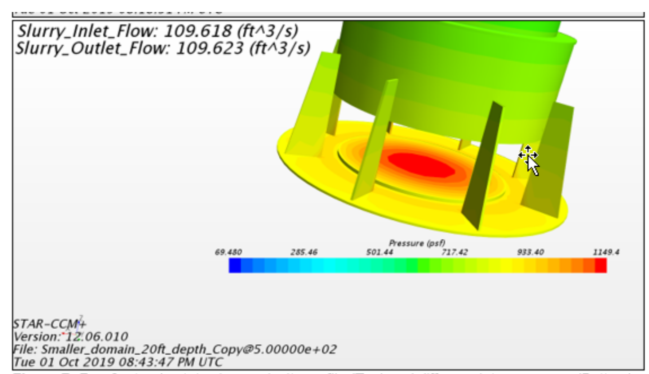
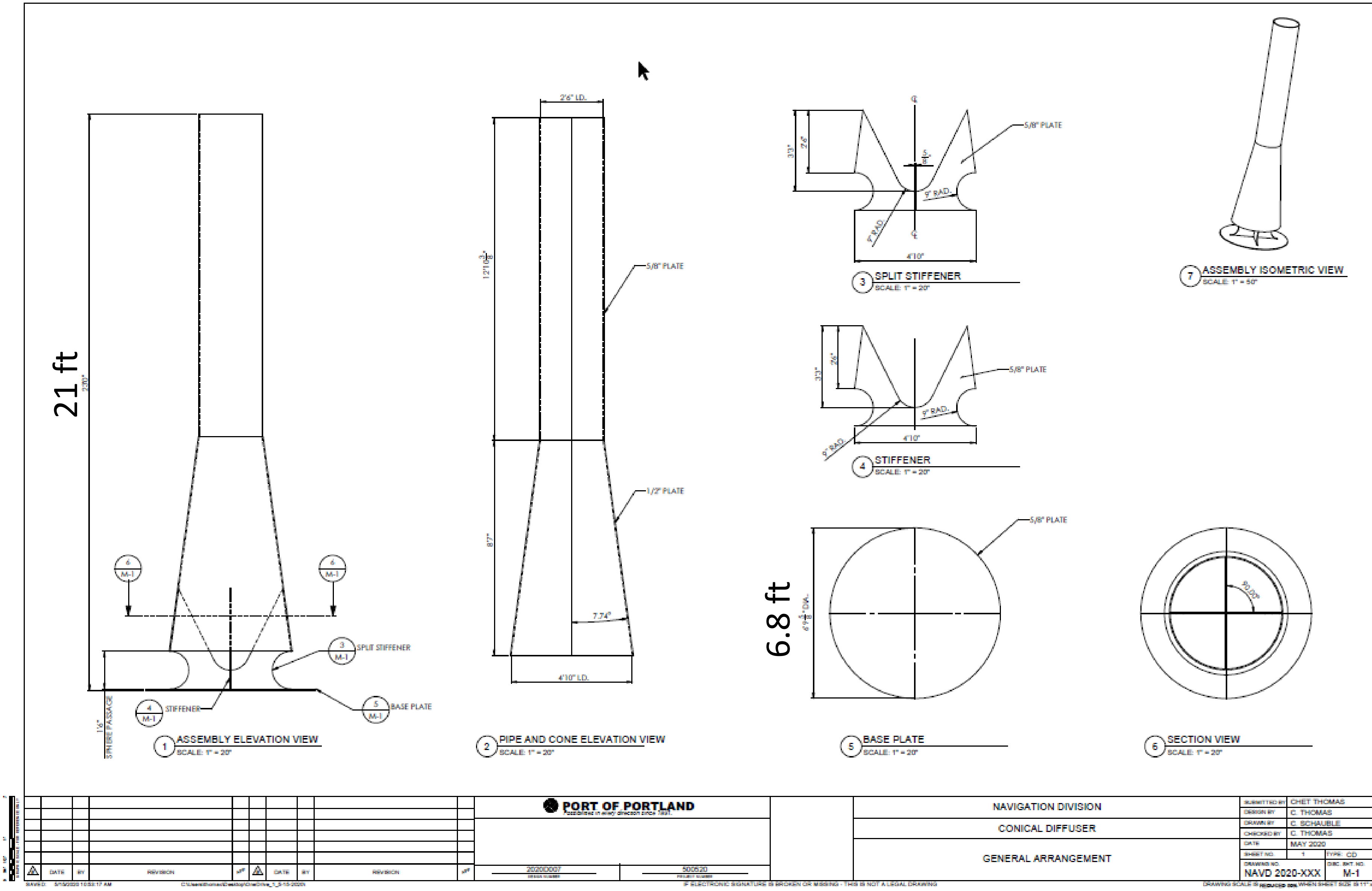


Figure 7: Run 6, steady-state slurry velocity profile (Top) and diffuser plate pressures (Bottom).

After PoP consulted with their fabricator concerning the "stepped" diffuser, the fabricator determined that a simple conical diffuser would be easier/less cost to produce.



The **conical diffuser** geometry was defined within CADD and then input into a computational fluid dynamics (CFD) software; Star-CCM+ and modeled numerous times. CADD work was performed by PoP and CFD modeling was performed by Portland District (Aaron Litzenberg and Max Wilson-Fey

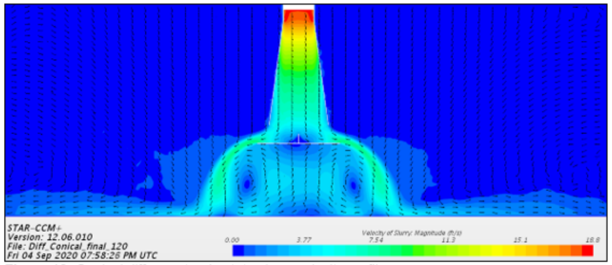


Figure 10: Conical diffuser steady-state slurry velocity profile.

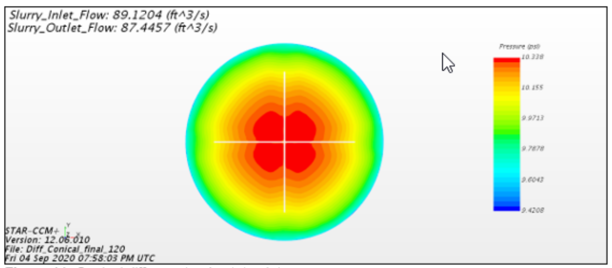


Figure 11: Conical diffuser steady-state plate pressures.

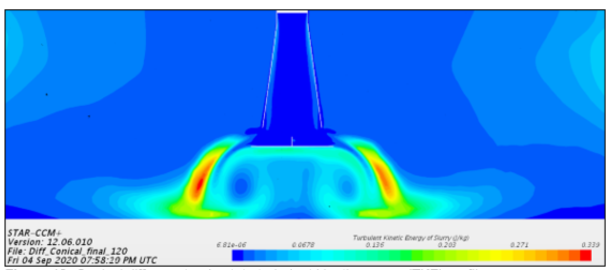


Figure 12: Conical diffuser steady-state turbulent kinetic energy (TKE) profile.

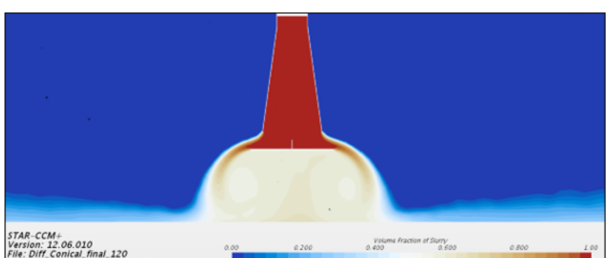


Figure 13: Conical diffuser steady-state volume fraction profile of slurry.

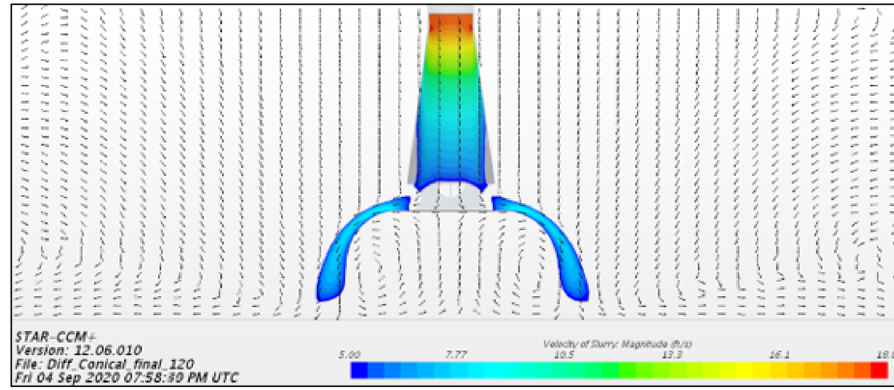


Figure 14: Conical diffuser steady-state slurry velocity profile, 5 ft/s or greater.

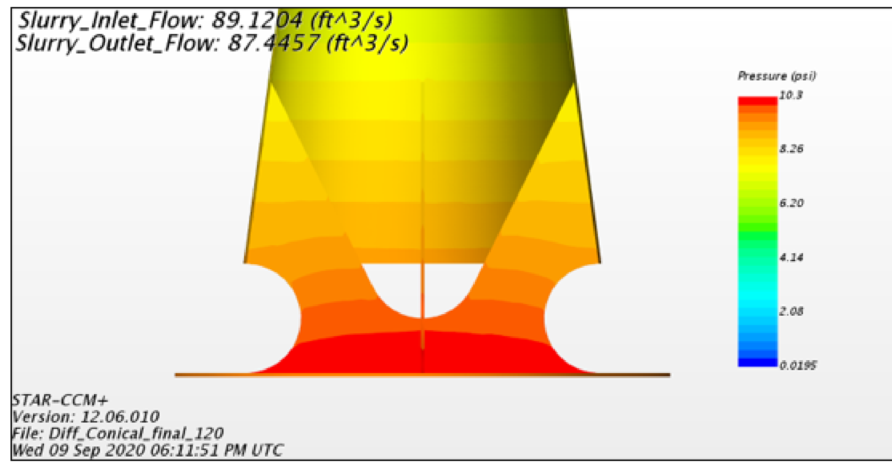


Figure 15: Conical diffuser steady-state stiffener pressures.

CFD Results: Differences Between Stepped and Conical Diffusers

there are some differences between the two designs. First, the conical diffuser appears to have more pronounced recirculation zones underneath the diffuser, which could be caused by a more pronounced downward trajectory of the slurry after it departs the edge of the plate. This is supported by the observation that the approximate diameter of the slurry plume, from the conical diffuser, along the riverbed is 15 – 20 ft, rather than 45 – 60 ft observed from the stepped diffuser (Fig. 13). Despite the pronounced downward trajectory of the slurry and recirculation zones, the maximum shear velocity along the riverbed is 4.8 ft/s, less than the 5 ft/s threshold. Fig. 14 shows how much of the slurry plume contains velocities greater than or equal to 5 ft/s but the slurry velocity dissipates to below 5 ft/s before encountering the riverbed.

Second, the stagnation dome near the center of the conical diffuser appears larger in size than the stagnation dome of the stepped diffuser. Looking at the conical diffuser's pressure on the diffuser plate (Fig. 11), the maximum is 10.3 psi, correlating to a 69% increase in pressure compared to the stepped diffuser's maximum diffuser plate pressure of 6.1 psi. In addition, for the conical diffuser, the area of influence that the maximum pressure acts upon is larger in diameter than that of the stepped diffuser. This may be due to the central stiffeners inhibiting slurry flow near the joint where the stiffeners attach to each other, trapping slurry in the corners of the stiffeners and creating a larger area of high pressure. The pressure on the stiffeners themselves is comparable to pressures on the conical diffuser plate, a maximum of 10.3 psi (Fig. 15).

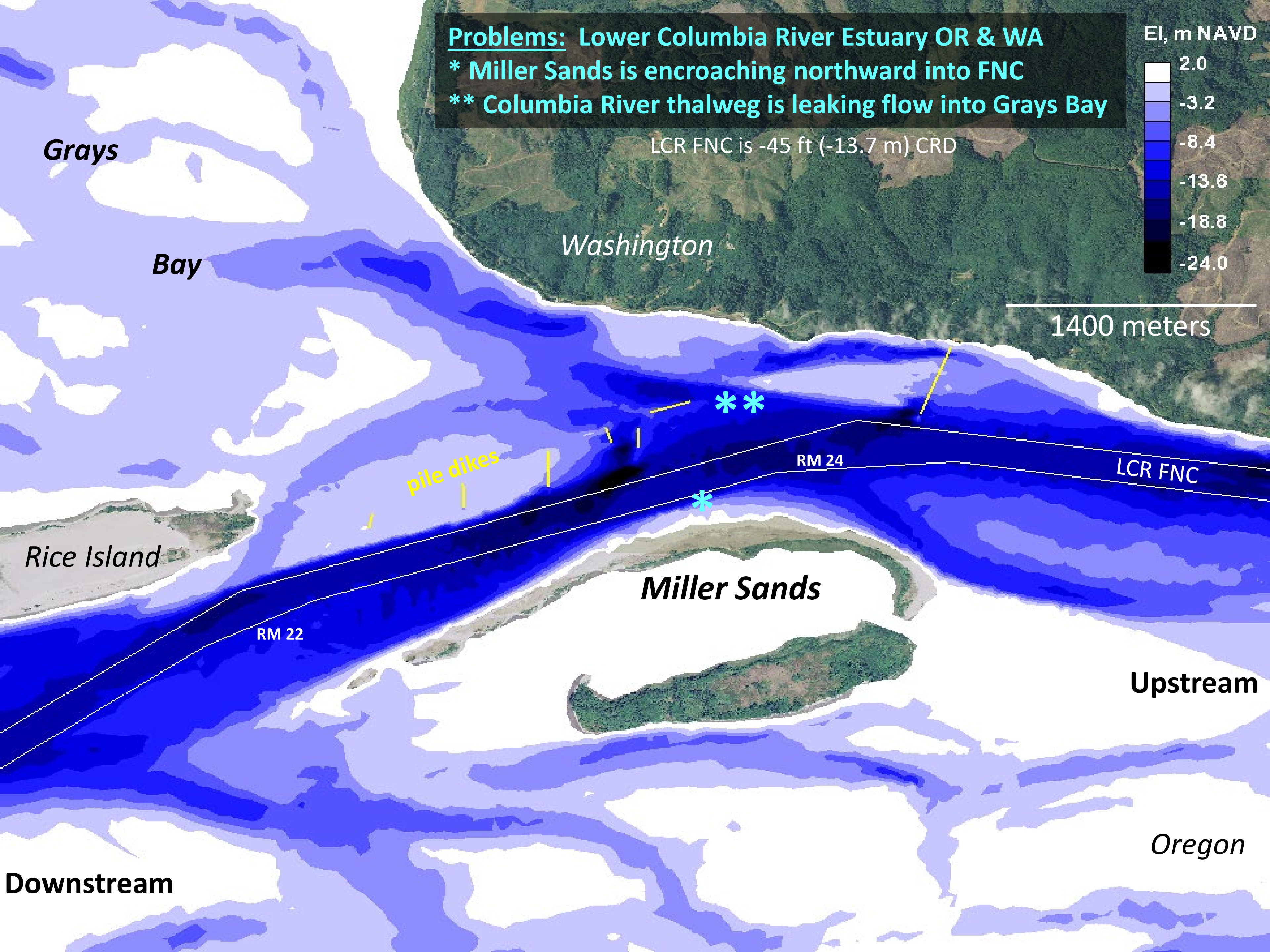
Third, the slurry velocities within the diffuser bell are generally higher for the stepped diffuser than the conical diffuser. This is likely due to the geometry of the bell. The stepped diffuser concentrates the slurry into a fast-moving column, separate from stagnation zones at the edge of the bell, whereas the conical diffuser spreads the slurry out as it moves down the bell. The stagnation zones can be clearly identified in the stepped diffuser's TKE profile (Fig. 6, Bottom) as areas where energy is dissipated. The conical diffuser's TKE profile (Fig. 12) shows little to no energy dissipation within the diffuser bell but rather the energy dissipation occurs within the slurry plume, after it exits the diffuser plate but before it impacts the riverbed.

In general, compared to the stepped diffuser, the conical diffuser slows and spreads the slurry within the diffuser bell with greater effectiveness . The diffuser plate sees higher pressures, perhaps because of the central stiffeners, and it also has a narrower slurry plume and greater zones of recirculation underneath the diffuser. The conical diffuser did not exceed the riverbed shear velocity threshold of 5 ft/s.

Use of Submerged Conical Diffuser within the Lower Columbia River Estuary
First Deployment – AUG-OCT 2021

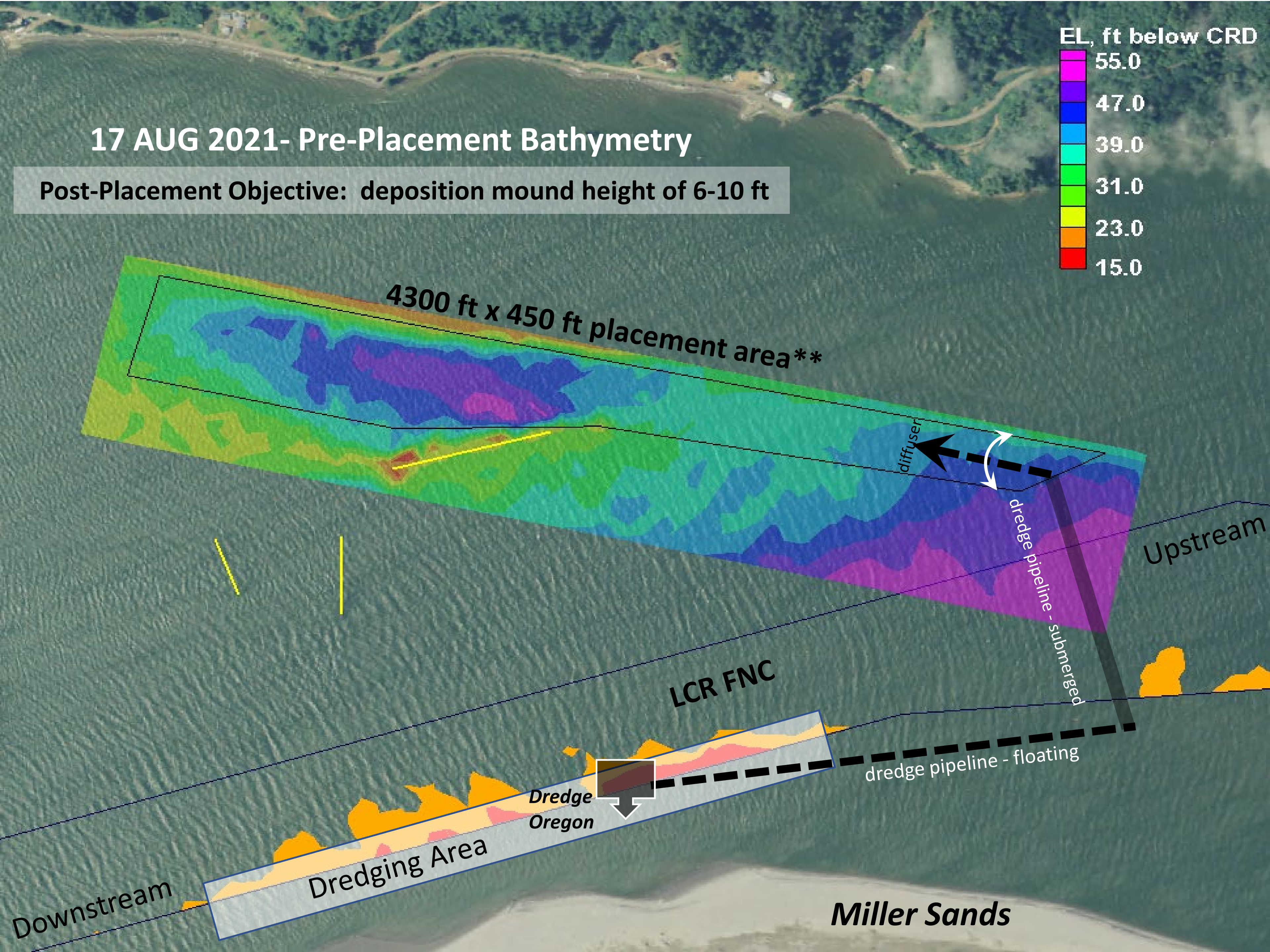
River Enginnering at <u>Miller Sands (RM25)</u>

Place 400,000 cy of dredged sand within an evolving tidal side channel to re-direct river flow (back) within the thalweg and reduce FNC shoaling



Problems: Lower Columbia River Estuary OR & WA
* Miller Sands is encroaching northward into FNC
** Columbia River thalweg is leaking flow into Grays Bay
LCR FNC is -45 ft (-13.7 m) CRD
El, m NAVD
2.0
-3.2
-8.4
-13.6
-18.8
-24.0
1400 meters
Grays
Bay
Washington
**
pile dikes
RM 24
LCR FNC
*
Rice Island
Miller Sands
RM 22
Upstream
Oregon
Downstream

During 17 Aug-3 Oct 2021, 550 Kcy of advance maintenance dredging was performed by the Port of Portland cutterhead dredge Oregon along Miller Sands to remove a northward migrating part of the shoal*. 450 Kcy of sand was precision-placed within a 4300 ft x 450 ft area** to redirect flow within the Columbia River thalweg and reduce future FNC shoaling along Miller Sands. A newly fabricated conical diffuser was used to placed the dredged sand.

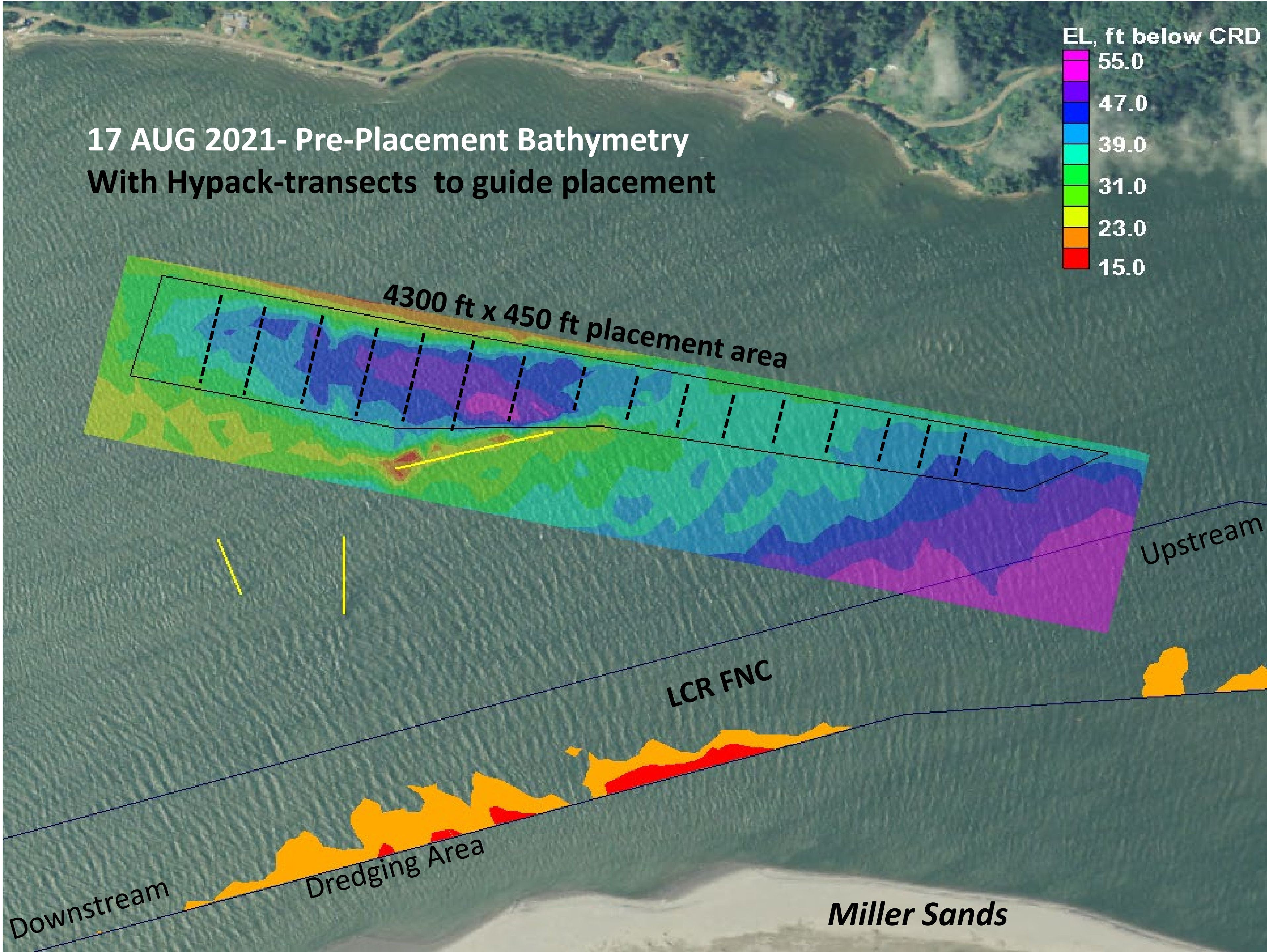

17 AUG 2021- Pre-Placement Bathymetry
Post-Placement Objective: deposition mound height of 6-10 ft
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
4300 ft x 450 ft placement area**
diffuser
dredge pipeline - submerged
Upstream
LCR FNC
dredge pipeline - floating
Dredge
Oregon
Dredging Area
Downstream
Miller Sands

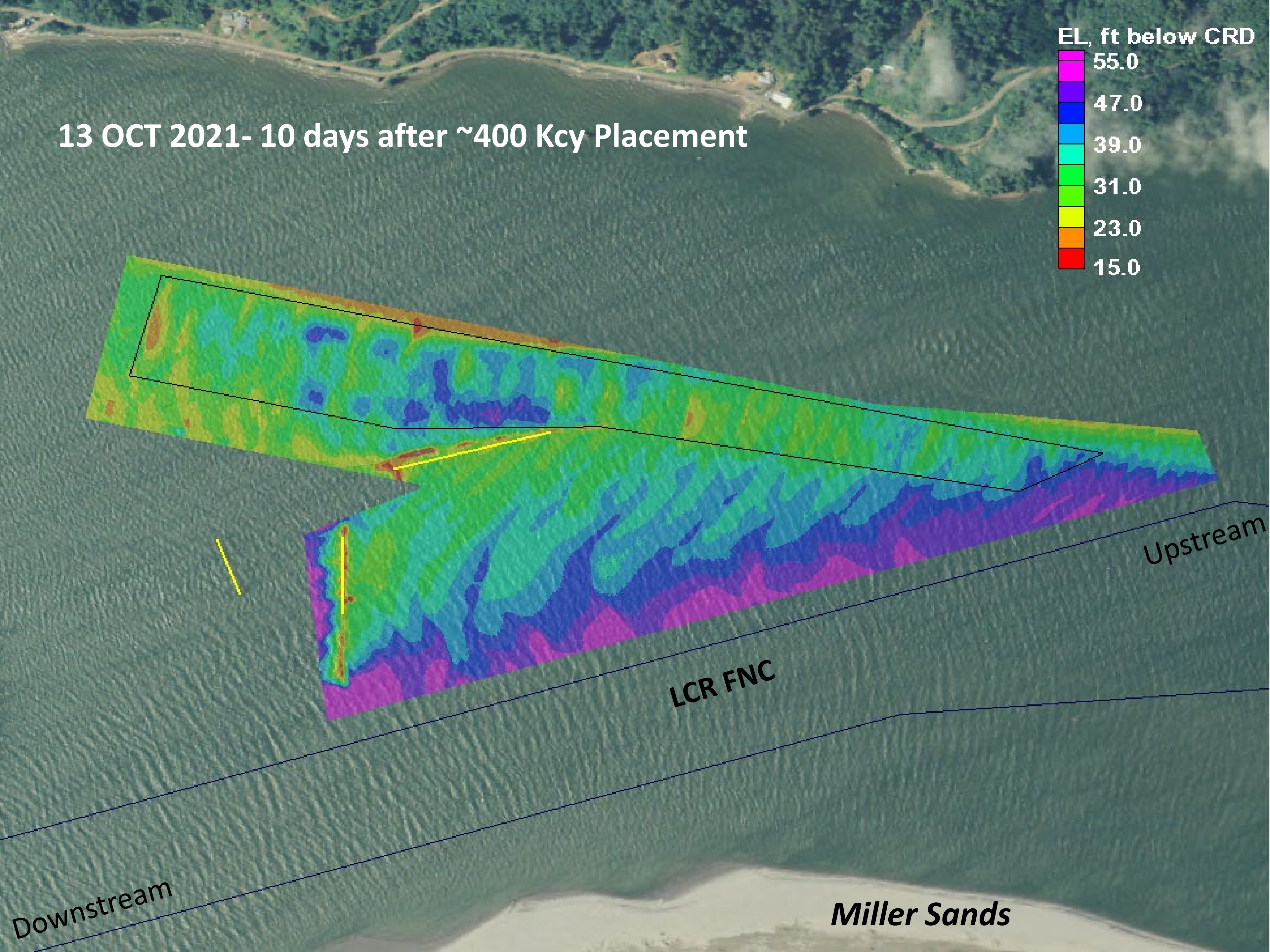
DIFFUSER OPERATION – Default Method

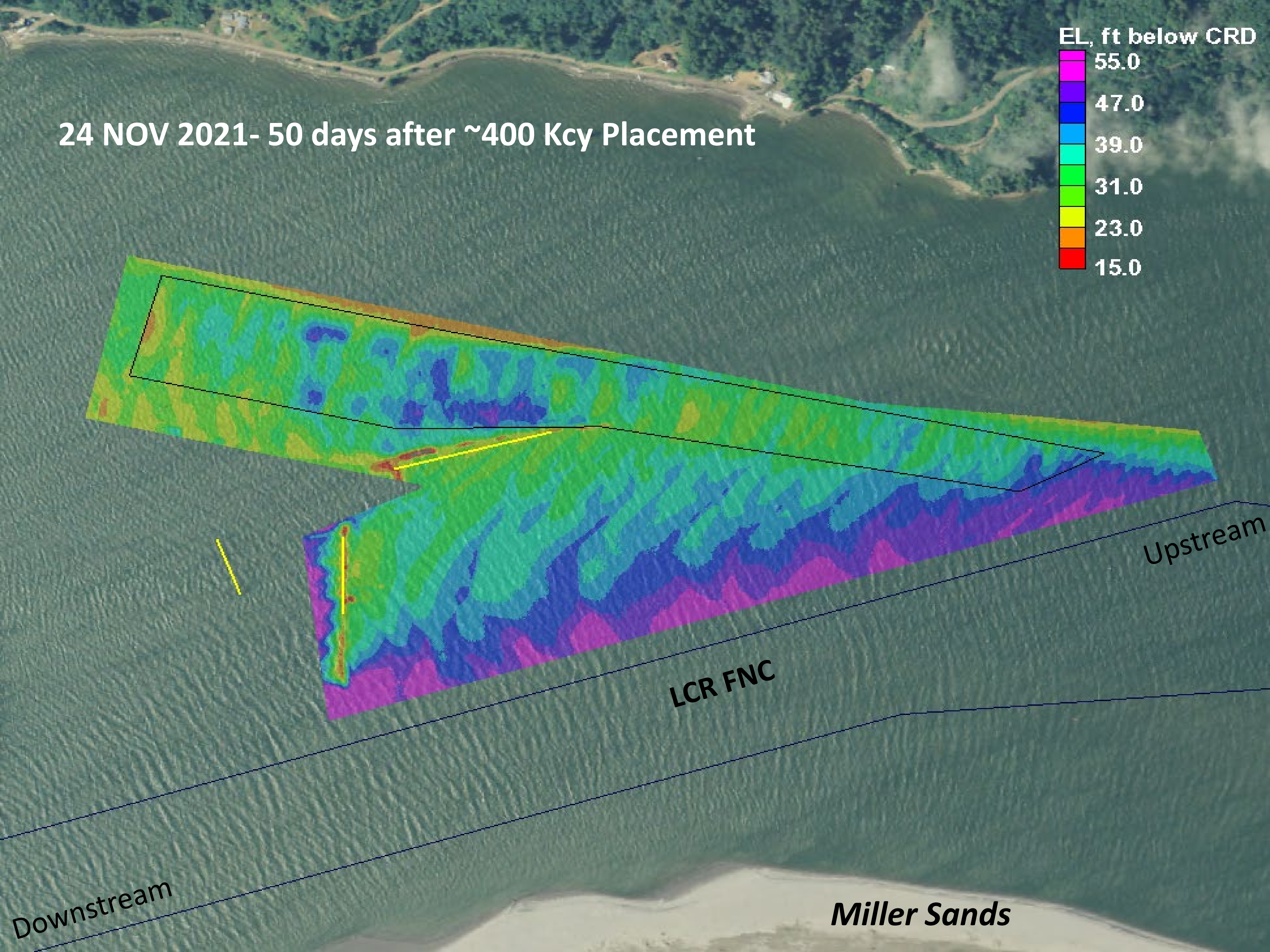
In water placement approach

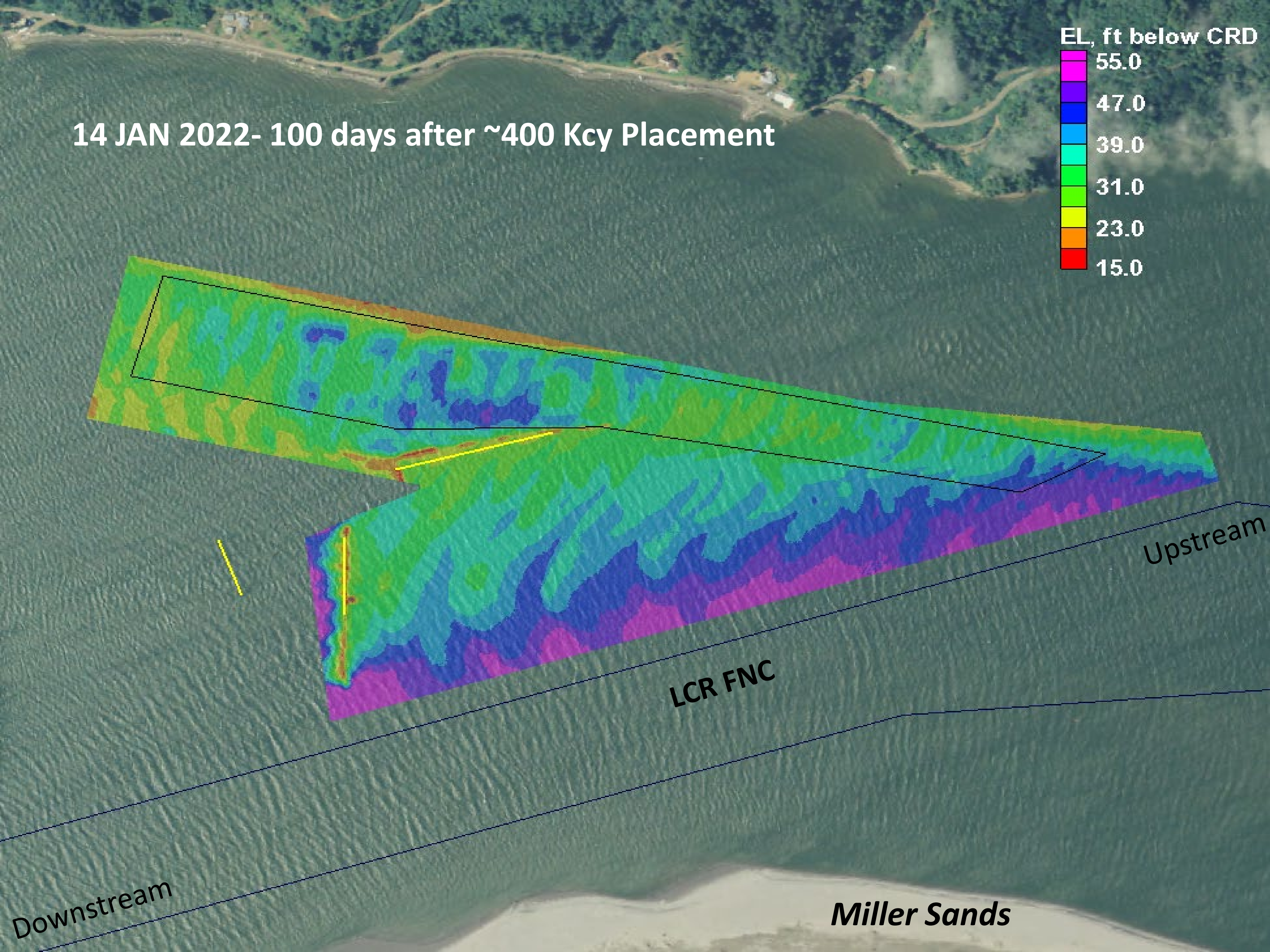
The diffuser and its accompanying end scow swing from 400’ – 700’ in the placement box. The combination was placed at the beginning of the placement area (upstream) and worked downriver. The material is placed along this arc and at the change of each tide the conditional survey of the placement area determines whether pipe is added or removed. In this way, the end scow is moved forward or retracted along the placement area. This is historically how in water placement has been done.

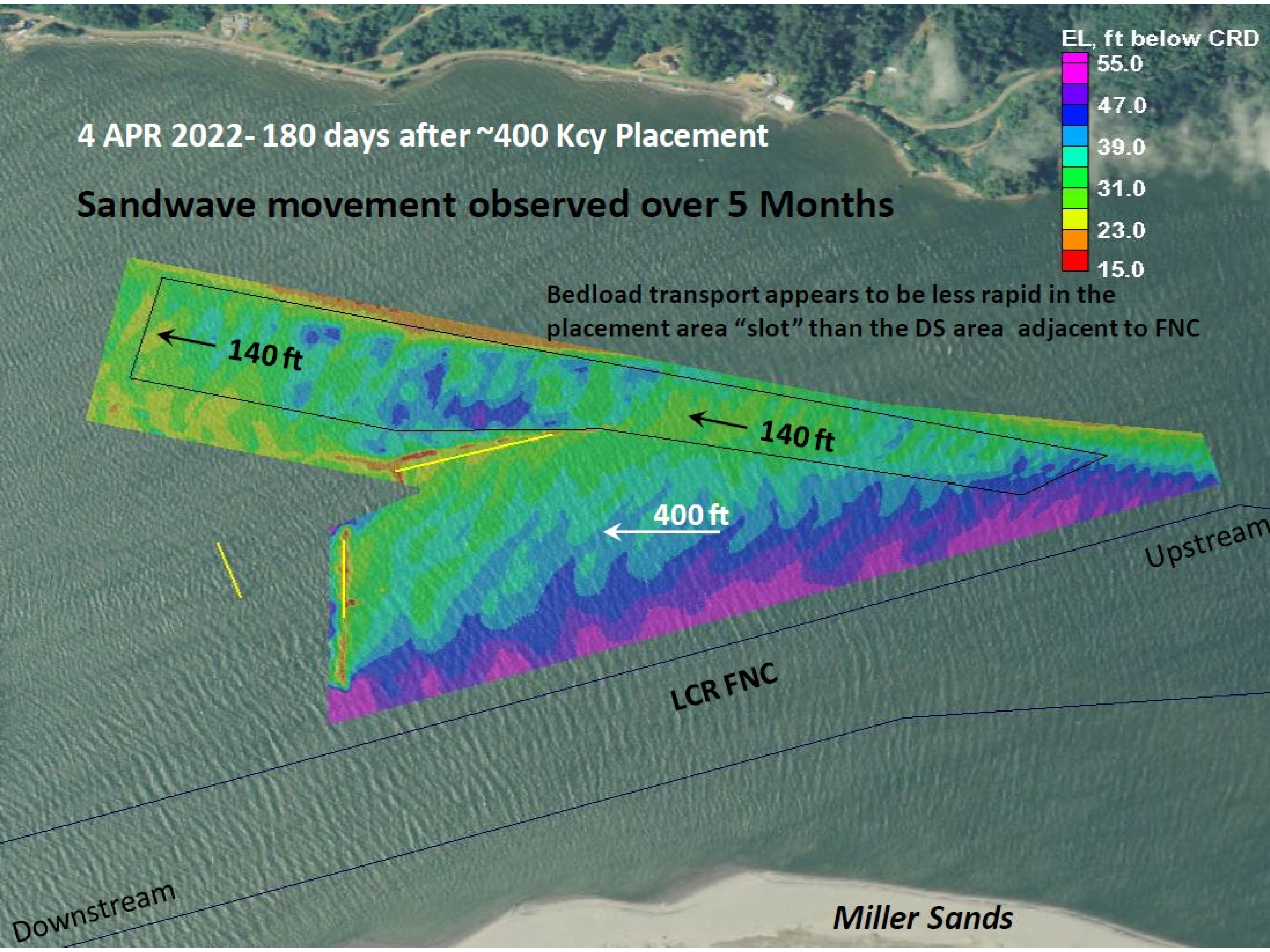
Actively move the diffuser across the placement site at 80-150 ft/hr to control mounding


17 AUG 2021- Pre-Placement Bathymetry
With Hypack-transects to guide placement
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
4300 ft x 450 ft placement area
Upstream
LCR FNC
Dredging Area
Downstream
Miller Sands

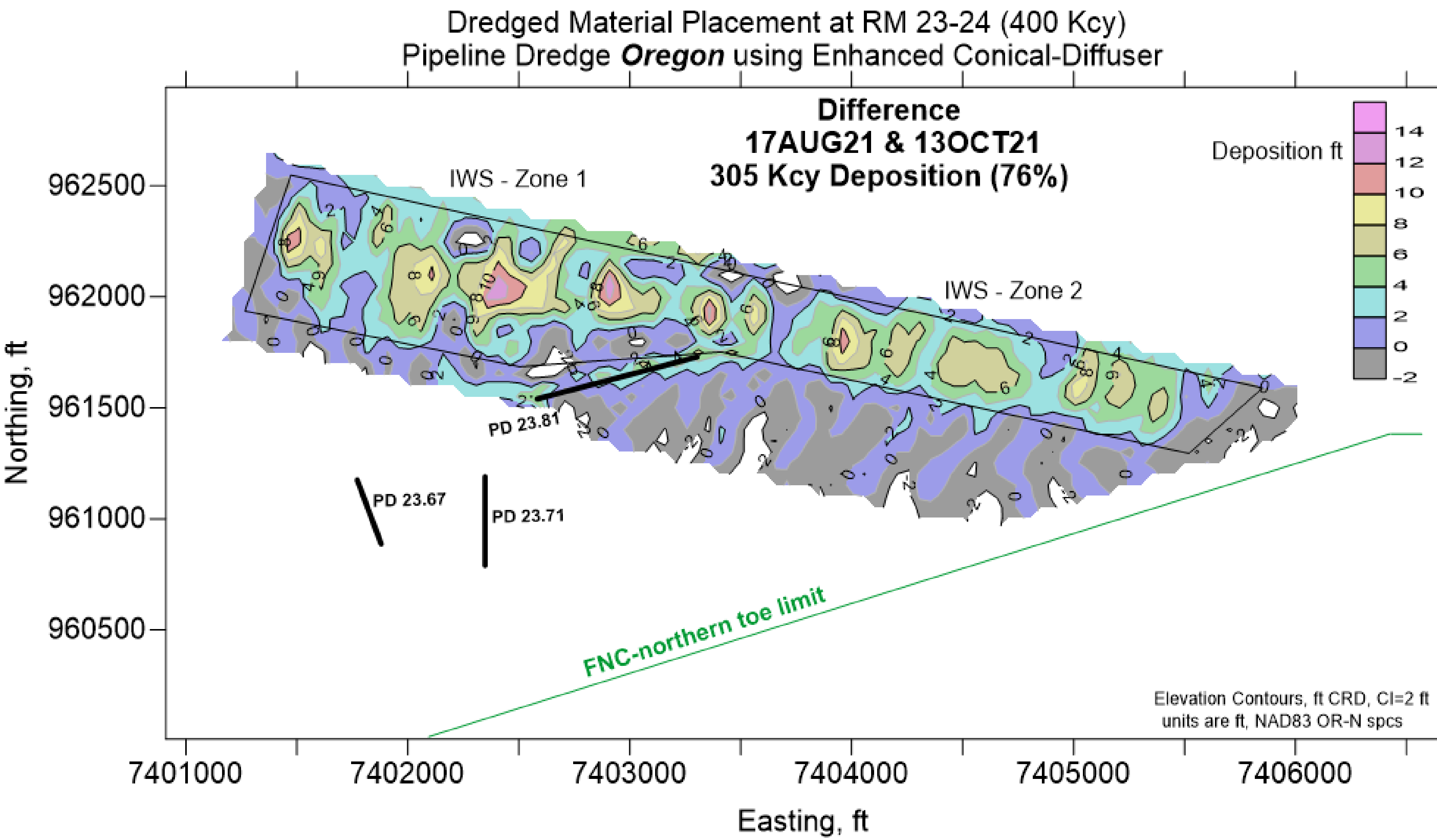

13 OCT 2021- 10 days after ~400 Kcy Placement
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
Upstream
LCR FNC
Downstream
Miller Sands


24 NOV 2021- 50 days after ~400 Kcy Placement
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
Upstream
LCR FNC
Downstream
Miller Sands

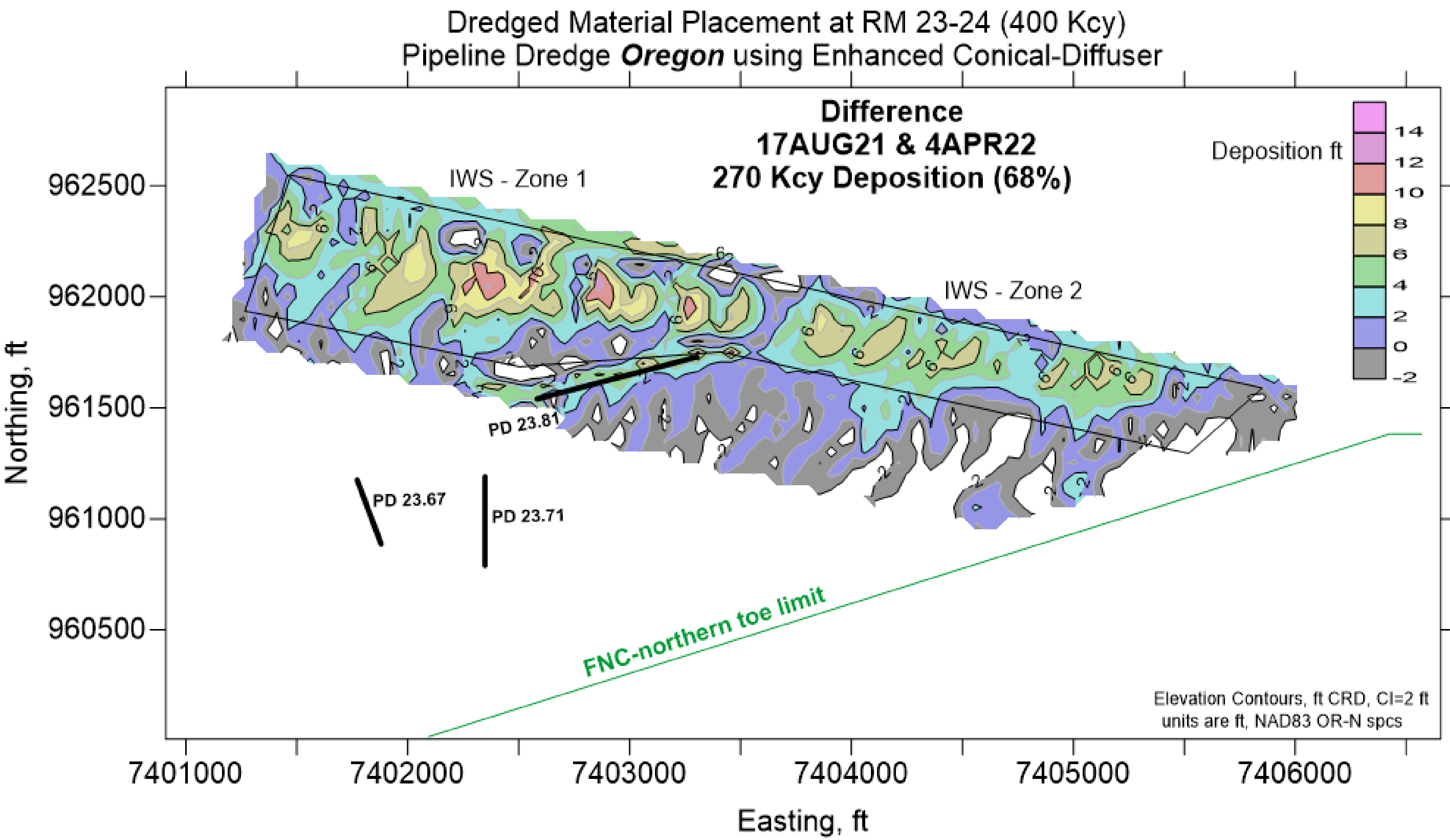

14 JAN 2022- 100 days after ~400 Kcy Placement
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
Upstream
LCR FNC
Downstream
Miller Sands



4 APR 2022- 180 days after ~400 Kcy Placement
Sandwave movement observed over 5 Months
EL, ft below CRD
55.0
47.0
39.0
31.0
23.0
15.0
Bedload transport appears to be less rapid in the placement area "slot" than the DS area adjacent to FNC
140 ft
140 ft
400 ft
Upstream
LCR FNC
Downstream
Miller Sands



Dredged Material Placement at RM 23-24 (400 Kcy)
Pipeline Dredge Oregon using Enhanced Conical-Diffuser
Difference
17AUG21 & 13OCT21
305 Kcy Deposition (76%)
IWS - Zone 1
IWS - Zone 2
Deposition ft
14
12
10
8
6
4
2
0
-2
PD 23.81
PD 23.67
PD 23.71
FNC-northern toe limit
Elevation Contours, ft CRD, CI=2 ft
units are ft, NAD83 OR-N spcs
Northing, ft
962500
962000
961500
961000
960500
Easting, ft
7401000
7402000
7403000
7404000
7405000
7406000


Dredged Material Placement at RM 23-24 (400 Kcy)
Pipeline Dredge Oregon using Enhanced Conical-Diffuser
Difference
17AUG21 & 4APR22
270 Kcy Deposition (68%)
IWS - Zone 1
IWS - Zone 2
Deposition ft
14
12
10
8
6
4
2
0
-2
PD 23.81
PD 23.67
PD 23.71
FNC-northern toe limit
Elevation Contours, ft CRD, CI=2 ft
units are ft, NAD83 OR-N spcs
Northing, ft
962500
962000
961500
961000
960500
Easting, ft
7401000
7402000
7403000
7404000
7405000
7406000

DIFFUSER OPERATION – Adaptive Improvement 1/2

Resultant summary

When the targets from Hypack survey are laid over the post placement hydro survey, it shows that the placed material has mounded along this arc in the exact same distance as the length of pipe that was changed.

This created what can be referred to as ‘corn rowing’ of the material; it effectively remained very close to where it was placed. After review of the data, it has been determined that this approach is not the most effective way to insure even distribution in the placement box.

DIFFUSER OPERATION – Adaptive Improvement 2/2

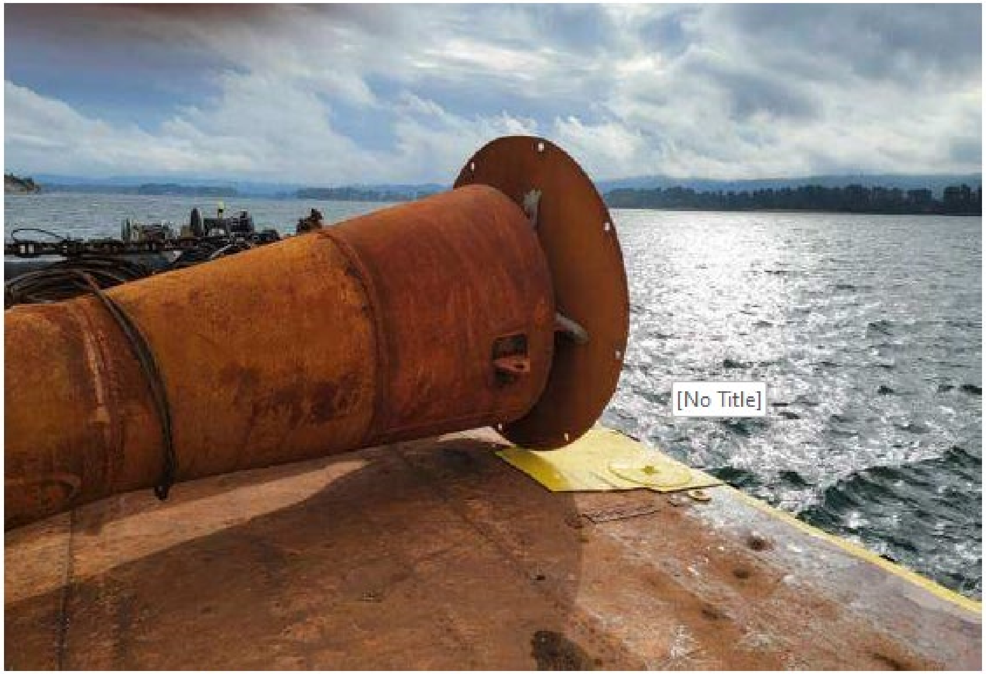
Proposed solutions

Three possible changes to the method are proposed; the placement box will be divided into sub cells, approximately 100’ by 100’ square with a known allowed quantity allowed in each. Based on this allowed cubic yardage, a timetable can be populated so it can be forecasted how long the end scow should be placing material in the cell. Once the time has lapsed a quick survey check will determine whether it is time to move to the next sub cell.

Incorporation of the swing elbow into the tail line of the pipe near the end scow would also allow more lateral movement of the end scow, as well as up/down stream. This would allow more unassisted movement within each sub cell.

Possible perforation of the diffuser plate with multiple 4”-6” holes may also provide smoother placement, rather than the current configuration.

Diffuser in final stage of fabrication, MAR 2021



Diffuser end, post placement

Diffuser Operational Summary

- New diffuser constructed for the 2021 dredge season
- Used at Miller Sands under task order F0027, WAD #12
  - Cut one from 8/2 to 8/19, cut two from 8/21 to 9/17
- Tide changes ranged from 1'-8'
- Pipe was added or removed as the tide changed
  - Pipe lengths were either 120' or 240'
- Passed approximately 400,000 cubic yards of material
- Shows little wear
- No larger debris issues; did not clog
- Maintenance does not appear to be an issue at this point
- Did not produce turbidity

Close-up view of diffuser plate and stiffener vanes, post-placement OCT 2021