

Clayton Beach Eelgrass and Dredge Hole Investigation

A Nearshore Habitat Survey for the Northwest Straits Foundation

Washington Department of Natural Resources
NWSF Contract No. 2023-09-DNR
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June 26, 2025



WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES

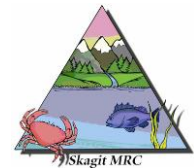
Cover Photo: Clayton Beach looking North (Photo from Washington Trails Association).

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Contents

Executive Summary	1
1 Introduction.....	2
1.1 Background and Project Description.....	2
1.2 Specific Study Objectives	5
2 Methods.....	7
2.1 Mapping Vegetation and Bathymetry.....	7
3 Results.....	17
3.1 Total Area Surveyed	17
3.2 Bathymetry	18
3.3 Eelgrass Bed Distribution – General Trends	20
3.4 Dredge Hole Volume Estimate.....	30
4 Conclusion	32
5 References	34

Executive Summary

The Northwest Straits Foundation (NWSF) and partners are currently assessing the feasibility of removing 1,300 linear ft. of armoring rock (riprap) and remnant wooding pilings from the nearshore at Clayton Beach in Skagit County, WA. In the absence of a riprap wall, eelgrass at the site is expected to move landward and fill a portion of the unvegetated intertidal at Clayton Beach. Eelgrass is an important canopy forming vegetation that countless native species rely upon for food and shelter.

In addition to the current shoreline restoration, another restoration opportunity exists just offshore from Clayton Beach. An unvegetated dredge hole, created when fill was excavated from the shallow intertidal and utilized in the construction of an interurban electric trolley at Clayton Beach (now part of Larrabee State Park in Skagit County, WA) remains as a large depression in the seafloor. While the electric trolley is long since gone, this hole remains a permanent feature of the nearshore. Due to its depth, 13.9 acres of native eelgrass that would have naturally existed in the space is absent. DNR is working with the Northwest Straits Foundation (NWSF), the Whatcom and Skagit County Marine Resource Committees (MRC), and Washington State Parks (WSP), to explore restoring the native eelgrass in this dredge hole.

In August of 2023, DNR's Aquatic Assessment and Monitoring Team surveyed a large area offshore the Clayton Beach nearshore restoration zone to understand the current distribution of native eelgrass adjacent to the current restoration zone, as well as the total volume of the unvegetated dredge hole. In total, 33 acres of the Clayton Beach nearshore were mapped with a multibeam sonar for bathymetry and eelgrass bed morphology. Sixty five acres were mapped with a single beam sonar for eelgrass canopy height and percent cover.

The Washington State Department of Natural Resources (DNR) manages 2.6 million acres of state-owned aquatic lands for the benefit of current and future citizens of Washington State. In addition to the protection of certain habitats and native species, DNR seeks to increase the opportunities for the utilization of renewable resources as well as to generate income from the use of aquatic lands when consistent with other goals.

This report was prepared by DNR using Federal funds under award NA22NMF4690358 from NOAA, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

1 Introduction

1.1 Background and Project Description

Nine miles south of the city of Bellingham WA., Larrabee State Park is a treasured recreational access point of the Chuckanut Range shoreline. Every year, tens of thousands of visitors come to the park to explore 8,100 ft of saltwater shoreline pitted with Chuckanut Sandstone features. In addition to views of the San Juan Islands and Padilla Bay, the nearshore zone provides critical habitat to countless species of important marine organisms such as forage fish, salmon, and feeding grounds for migrating seabirds.

Eelgrass, a vegetation that provides important structured habitat to these species grows abundantly along the Larrabee State Park shoreline and is especially prevalent at its southernmost portion known as Clayton Beach. Clayton Beach abuts the second largest eelgrass meadow on North America's Pacific Coast, known as Padilla Bay. Seagrasses such as the native eelgrass (*Zostera marina*) are known to increase the climate resiliency of a shoreline by capturing carbon, filtering nutrients from the water, producing oxygen, and helping to protect the coastline from floods and storm surge (Pew Charitable Trust 2023).

The Northwest Straits Foundation (NWSF) and partners are currently assessing the feasibility of removing 1,300 linear ft. of armoring rock (riprap) and remnant wooding pilings from the nearshore at Clayton Beach (Figure 1). This restoration targets the removal of structure placed at the site in the early 1900's which historically supported an electric trolley for commuter transport from Bellingham to Mt. Vernon WA. This route was known as the Bellingham and Skagit Interurban railway and operated from 1912 to 1928 (Figure 2).

The removal of riprap/pilings and re-contouring of the beach is expected to improve sediment transport processes and allow for a landward increase in the shallow edge of eelgrass back to its natural extent, which is likely impacted by rock armoring at the site (Figure 1). By itself, this restoration aims to restore nine acres of nearshore habitat, improve public access, and allow for adaptation of the shallow boundary of the eelgrass bed in the face of sea level rise (PMEP 2023).

On top of this restoration of the nearshore, another opportunity to restore an additional 13.9 acres of seagrass habitat exists only 250 ft. seaward of the existing Clayton Beach restoration zone. A large unvegetated dredge hole (hereafter called the "divot") was created in the early 1900s when sediment was excavated to support the interurban trolley trestle. This divot is currently too deep to naturally support eelgrass and is thought to exist as a bare vegetation-less hole in the subtidal. Based on sparse data from DNR's Nearshore Habitat Program, eelgrass is abundant around the periphery of the divot – indicating an exciting restoration opportunity (WADNR 2023). Restoration of this divot will involve filling it with suitable substrate and replanting with native eelgrass.

To this point, a dedicated boat based sonar survey has not been carried out to understand baseline subtidal eelgrass cover surrounding the restoration zone and divot at Clayton Beach. To further understand this distribution, the Northwest Straits Foundation contracted with the Washington State Department of Natural Resource's Aquatic Assessment and Monitoring Team (AAMT) to map the bathymetry and distribution of eelgrass at Clayton Beach.



Figure 1. Clayton Beach, 2023. Photograph taken from Larrabee State Park, looking South. Photo: Pacific Marine and Estuarine Fish Habitat Partnership.



Figure 2. Clayton Beach 1912 Trolley Trestle Construction. Photograph taken from the south, looking north. Photo from Western Washington University Heritage Resources Archive.

1.2 Specific Study Objectives

As a project partner, DNR was contracted to map the area around the Clayton Beach rip rap and piling removal project as well as surrounding the divot. Mapping was completed to delineate the following:

1. The current extent of eelgrass around the Clayton Beach nearshore restoration site to provide a baseline map of conditions which will provide a reference to determine how riprap and piling removal supports eelgrass reintroduction.
2. The current extent of eelgrass surrounding the unvegetated dredge hole or “divot”.
3. Seafloor surface morphology (or bathymetry) surrounding the nearshore restoration zone. This information will reveal how future riprap and piling restoration changes alongshore geomorphologic processes and slope profiles.
4. Bathymetry of the divot. This information will reveal the true area of the divot and the total volume of material required to fill it.

2 Methods

From August 7th to the 8th, 2023 approximately 3,380 ft. (1000 meters) of shoreline mapping for vegetation and bathymetry was carried out during two different hydrographic surveys at Clayton Beach. Both single beam and multi beam sonar were utilized to collected data that reveals the total vegetative cover as well as bathymetry of the divot and offshore of the restoration zone.

Features of each type of sonar are presented in Table 1.

Table 1. Capabilities of both single beam and multibeam sonar.

Data Type	Single Beam Sonar	Multi Beam Sonar
Eelgrass Bed Distribution (Top Down Map)_	Low resolution based on transect interval. Faster to collect.	High resolution full coverage. Slower to collect in shallow zones.
Eelgrass Percent Cover	Built in calculation.	Not capable without custom model.
Eelgrass Canopy Height	Built in calculation.	Not capable with highly vegetated sites.
Bathymetry	Low resolution. Differentiates vegetation canopy from sediment in highly vegetated sites.	High resolution, high accuracy. Full coverage. Does not differentiate vegetation canopy from sediment in highly vegetated sites.

2.1 Mapping Vegetation and Bathymetry

2.1.1 Site Description and Project Planning

The intended survey area included the riprap restoration zone, and as far to any side as impacts from restoration were expected based on predominant south to north drift cell flow (Figure 3). This area spanned 3,000 ft of nearshore at a width of 1,000 ft. and included both the unvegetated dredge hole and riprap restoration zones (Figure 3). Approximately 2000 ft of this shoreline was within Larrabee State Park (Figure 3).

Surveys were intended to extend as shallow as safely possible, and as close to the riprap shoreline to provide a thorough baseline of current shoreline conditions. The majority of this area resulted in operations within 9 ft of water or less (MLLW).

A systematic survey with a gridded design was implemented to cover the target area, which included transects spaced 65 ft. (20 meters) apart for single beam sonar. A smaller area was targeted for multibeam sonar collection which included the divot as well as zones shallower than it (Figure 3).

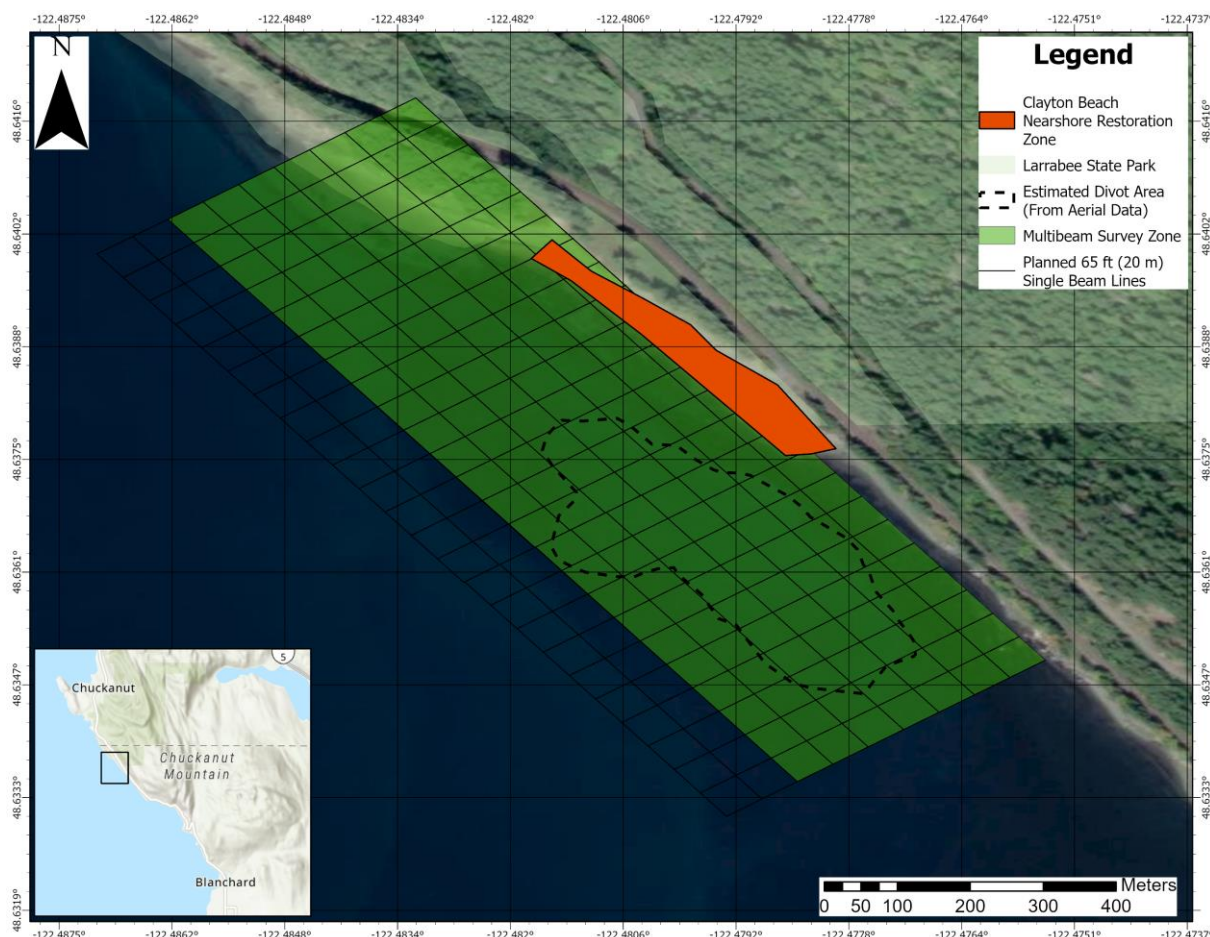


Figure 3. Approximate multibeam collection footprint at Clayton Beach, Skagit County, WA. Planned single beam transects are indicated by the hashed polygon.

2.1.2 Field Collection – Single Beam Sonar

The DNR Aquatic Assessment and Monitoring Team (AAMT) staff utilize a BioSonics DTX single beam transducer onboard AAMT's 21-foot research vessel to accurately and efficiently collect eelgrass percent cover and canopy height as well as bathymetric data (Gumusay et al., 2019).

The BioSonics DTX system is a proven and accurate platform for aquatic vegetation delineation and mapping (Gumusay et al., 2019; Stevens 2019). It emits a 420 kHz sound pulse with a width of 6 degrees, collects a sound signal reflected from the surrounding environment, and converts the signal into electrical energy. A BioSonics surface unit is used in tandem to interpret the incoming electrical signal, associate each ping to positional GPS in an interface for users to observe incoming data, adjust settings, and store raw data as digital files.

The transducer head (Figure 4A) is mounted on an aluminum pivot arm off the starboard side of the vessel and when vertically deployed sits approximately 0.39 m beneath the water's surface (Figure 4B). This pole and mounting bracket have been designed to reduce vibration and to maintain a level position while collecting data thereby minimizing distortion in backscatter readings. A Trimble Pro 6H GPS is mounted on the top of this pole and directly overhead the sonar transducer (Figure 4D). The GPS feeds position data (accurate up to 10cm) to both the Biosonics surface unit as well as a tethered towable camera.

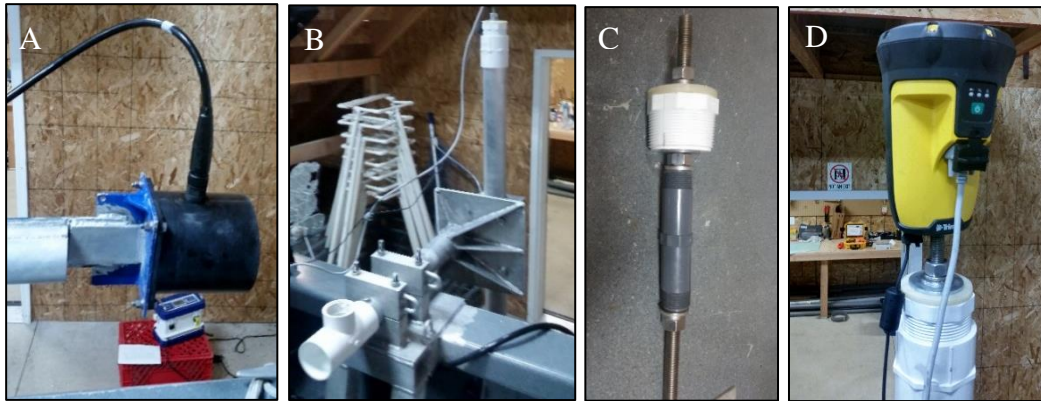


Figure 4. A) Single Beam Sonar transducer with deck cable connected. B) SBS mount in survey positions. C) GPS mount. D) GPS with RS232 and micro-USB cables attached.

Settings

A sound pulse ping rate is set at a standard of 10 pings per second and the duration for each pulse is set to 0.1 millisecond. These values have been found to be best when collecting data for eelgrass delineation (Stevens 2019). The maximum depth at which data is collected varies per site but averages 15 m - Eelgrass rarely grows beneath 12m in Puget Sound. Data is collected at a rate equal to the ping rate, 10 data points per second.

Video

BioSonics software interprets a unique sound return for eelgrass; however, there are anomalous features that may be misinterpreted as eelgrass when post-processing (Sabol et al., 2002; Shuai Xu, 2019). To verify eelgrass presence, we collect underwater video along 10% of the transects surveyed. For these transects, video can be collected while the sonar is also running by towing a SeaViewer Sea-Drop 950 video camera weighted and suspended by line off the port side of the boat. In real-time, a SeaViewer Sea-Trak GPS overlay displays time and GPS locations onto the video image (Figure 6). Video data is recorded digitally on an SD card with a SeaViewer DVR-SD.

The towed camera is housed within a PVC enclosure which orients it at a 45 degree angle to the bottom, protects the camera from potential damage, and allows the camera to track straight with the use of fins and weights (Figure 5). To maintain a constant field of view, the camera is held about 1 m from the benthos.

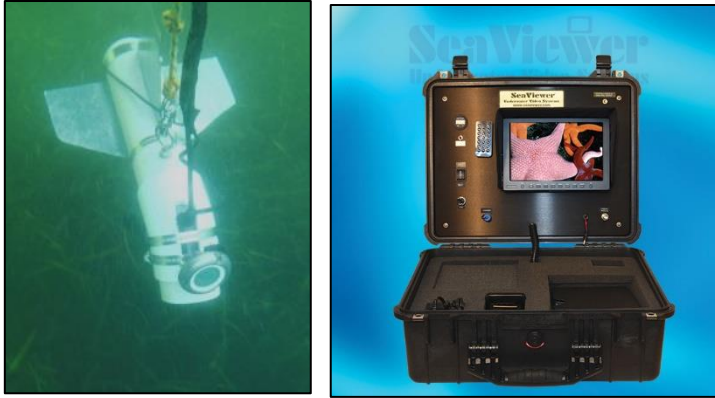


Figure 5. Left: Seaviewer Camera. Right: Seaviewer Surface Unit and Recorder Interface.



Figure 6. View of real-time video collection and attributes.

Post-processing

BioSonics data is processed for each transect using BioSonics Visual Aquatic software. This software allows a trained technician to correct inaccuracies in bottom detection and eelgrass delineation after algorithms within Visual Aquatic have been applied. These algorithms are a starting point at providing a rough classification of seafloor bathymetry and eelgrass presence or absence by sonar ping (BioSonics 2023). Eelgrass presence is determined by a unique backscatter or “bearding” pattern in the data (Figure 7). This pattern is caused by the structure of seagrass and is unique from other functional groups of marine vegetation (Shuai Xu, 2019).

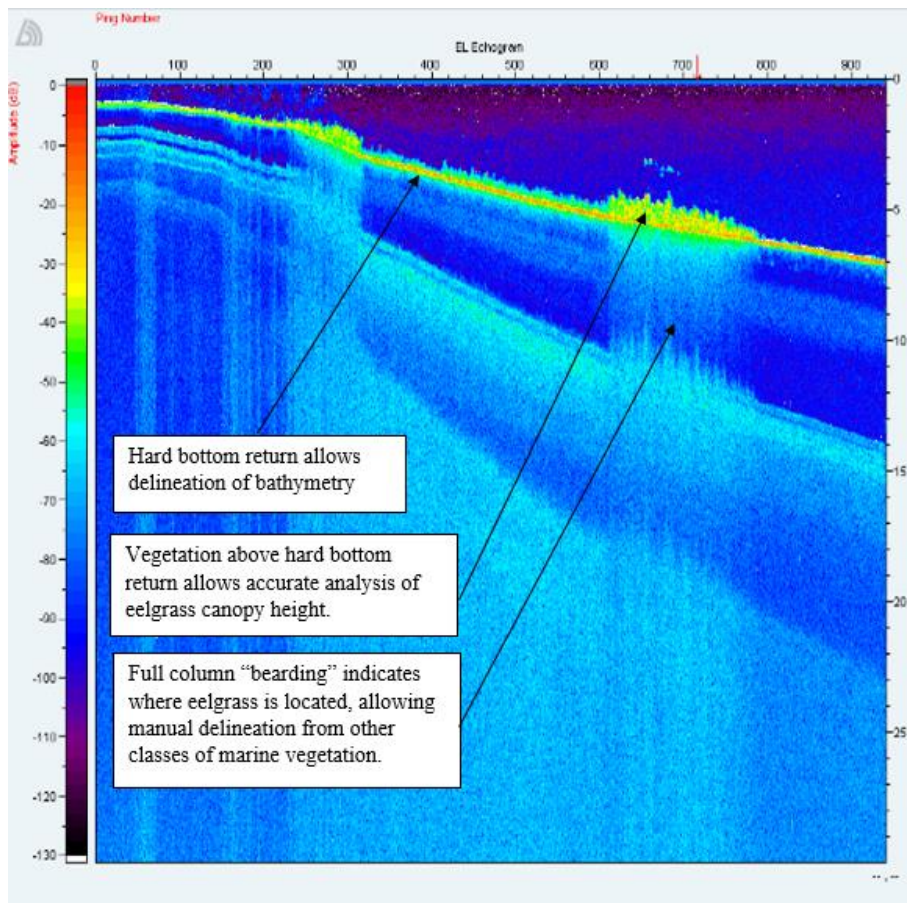


Figure 7. Image showing the distinction in the backscatter pattern unique to eelgrass.

Processed transect files are exported to a CSV format and combined into one complete dataset for further post-processing and analysis. These exported CSV files include attributes for the date, time, location (latitude, longitude), percent eelgrass cover, eelgrass canopy height, and substrate depth. Eelgrass cover for each ping is represented with a one (present) or a zero (absent), and percent cover is calculated by averaging eelgrass presence and absence over 10 pings.

GPS data collected with a Trimble Pro 6H antennae is differentially corrected with Trimble GPS Pathfinder Office (TPO). This software utilizes a network of base stations to increase accuracy of locational data by removing errors caused by various factors (e.g., cloud cover). Accuracy for data collected with the Trimble Pro 6H can be as resolute as 10 cm after post-processing.

Raw bathymetry is imported from the processed Visual Aquatic CSV and corrected for an offset to adjust for the distance between the top of the water line and the bottom of the transducer (measured before each survey). It is then transformed to Mean Lower Low Water (MLLW) vertical datum using tidal data from T-bone tides and a custom R version 4.2.2 script (University of South Carolina 2020, R Core Team 2023). A raster surface of bathymetry is created with the kriging tool in ArcGIS from corrected single beam point depths.

Video data is reviewed by a trained analyst into one-second segments. Presence and absence of marine vegetation classes (kelps, red algae, green algae, seagrass, and sargassum) as well as bottom type are determined. BioSonics data for the same transects are compared to results from processed video for quality control and to tune BioSonics edits.

2.1.3 Field Collection – Multi Beam Sonar

In addition to single beam sonar data, a multi beam was used to further establish a volume estimate of the divot and the distribution of eelgrass around it.

The bathymetry of non-vegetated surfaces is much more accurate with a multibeam sonar than a single beam, and it provides full coverage. For this reason, the multibeam was employed to target the intricacies in divot bathymetry. Additionally, it was also used to understand where eelgrass exists as it provides full coverage rather than transect data. While this “full picture” view does not provide an estimate of canopy height or percent cover, it is good supplement to the data collected with the single beam.

An R2sonic 2020 multibeam sonar and an integrated Applanix navigation system was utilized for bathymetry. The R2Sonic 2020 model is a small and light flat array multibeam unit that combines the transmitter and receiver into a single instrument. Position, heading, pitch, yaw, and roll are recorded with an Applanix Inertial Motion Unit (IMU) and Trimble GNSS positioning system. Using Applanix’s POS PAC software (Applanix Corporation 2021) DNR scientists collect raw motion and heading data in the field, process these observations in the office, and recalculate the entire survey’s data for high-accuracy three dimensional spatial locations.

Data was collected at a 400 kHz frequency, with a beam width of 130 degrees. At least fifty percent data overlap was collected between tracks. The survey was planned and carried out with QINSY software by QPS Maritime Software Solutions. Full water column sound speed measurements are collected with a Sontek CastAway CTD every two hours. The CastAway rapidly measures density, pressure, salinity, conductivity, and temperature and calibrates sound speed with the multi beam’s surface sensor.



Figure 8. R2Sonic 2020 multibeam (bottom, grey), Applanix IMU (top, black), and mount (blue)

Data Processing

Bathymetric surfaces were cleaned and processed with QPS QIMERA software. A corrected position and motion file was created with Applanix PosPac software and applied to raw bathymetric files. From these raw files, a dynamic surface was created by which point surface data anomalies were edited by hand.

Once manual edits were applied, a final dynamic surface was exported as a two band 0.25 m² resolution raster (hereafter referred to as Bathymetric Attributed Grid (BAG)). Band 1 in the BAG contains elevation data in the NAVD88 (m) vertical datum averaged from a cloud point surface. Band 2 contains CUBE uncertainty data for every band 1 cell calculated as the standard deviation of the accepted soundings that contributed to the selected surface hypothesis.

Bathymetric estimates in survey datum NAVD88 (m) were converted to MLLW (ft.) using NOAA's Vdatum tool (NOAA 2023).

The corrected BAG surface is interpolated to fill small voids in coverage using the elevation void fill function in ArcGIS Pro (creating a BAG_evf layer). Using the Benthic Terrain Modeler (BTM) package in ArcPro, the "roughness" of the Clayton BAG surface was defined using rugosity and slope. Rougher zones were extracted using a supervised classification in ArcPro and exported to a single feature class to provide a multibeam generated representation of eelgrass in the cove.

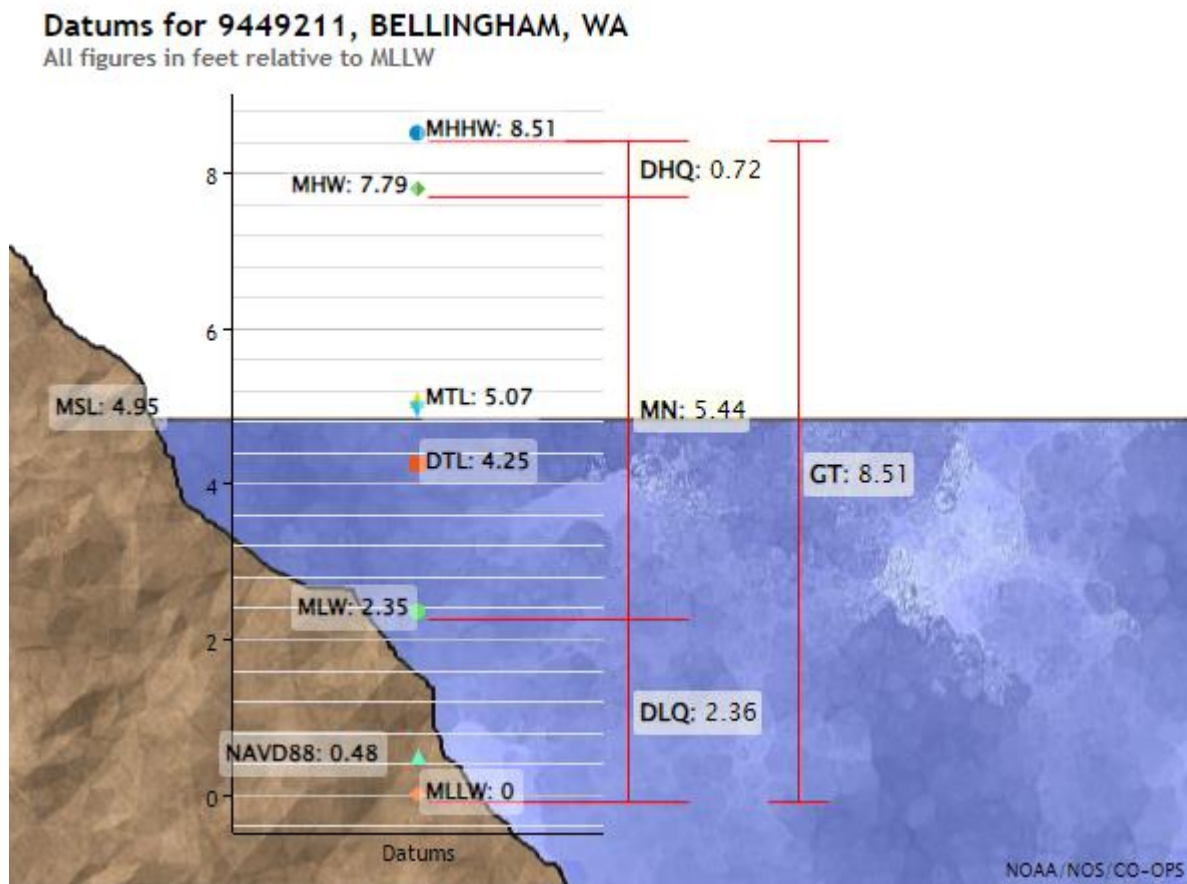


Figure 9. Datum Benchmarks for Bellingham Bay showing the difference between NAVD88 (m) and MLLW (ft.).

2.1.4 Eelgrass Bed Shape Delineation

Eelgrass bed area and size is established from multibeam data. First, a slope surface is created from the BAG with the Bathymetric Terrain Modeling (BTM) toolbox in ESRI ArcPro. Slope is the gradient, or rate of maximum change in z-value from each cell of a surface raster in degree units, and assumes that the depth or elevation units of the surface raster are the same as the x and y units (Walbridge et al. 2018).

Next, an unsupervised classification was carried out on this slope surface using the “Iso Cluster Unsupervised Classification” tool for 5 classes. The resulting classes define certain portions of the BAG that are covered in eelgrass. By comparing processed single beam data to this surface, we determine which of 5 classes include eelgrass.

The “make raster” tool is then utilized to combine eelgrass classes and remove all others. All artifacts of surveying are cleaned by hand from this surface, and the “dissolve” tool combines all separate polygons into the same feature.

2.1.5 Divot Volume Analysis

To calculate the total volume of the divot, a series of interpolations and raster masking operations were carried out. Two masks were required – the first (mask 1) was a mask of only the unvegetated area of the divot. The second (mask 2) included all area covered by multibeam data minus the unvegetated portion of the divot.

To produce mask 1 (divot extract mask) all unvegetated portions of the divot were isolated and extracted from the original BAG interpolation. The first step in this process included erasing the multibeam eelgrass layer created in the previous section from an original BAG_evf layer using the erase function. The resulting raster was converted into a polygon using the raster to polygon tool. This polygon was then edited by hand to extract the unvegetated portion of the divot, thereby producing a mask of unvegetated area of the divot, and restoration opportunity. This mask was used to extract cells of the divot using the extract by mask function.

For mask 2 (divot minus mask), a total survey mask was created with the raster to polygon tool which represented the entire multi beam sonar surveyed area (Clayton multibeam mask). The clip tool was then used to clip out the divot extract mask from the Clayton multibeam mask.

Using the extract by mask tool, both mask 1 and mask 2 were used to extract cells of the original BAG_evf raster, resulting in a raster surface without the divot included, and a raster surface with only the bathymetry of the divot. Next, the raster surface missing the divot was interpolated to establish an estimate of the natural seafloor slope prior to divot excavation.

Finally, the Cut Fill tool was used to calculate the total volume between a Clayton Beach nearshore without a divot, and the current divot bathymetry. An error estimate for this volume

calculation was produced by calculating the volume of the cube uncertainty surface within the dredge hole.

3 Results

3.1 Total Area Surveyed

On August 7th, 2023, sixty-five acres of the nearshore were mapped by single beam sonar. The next day, on August 8th, an additional 33 acres were mapped by multi beam. Coverage for both surveys extended approximately 3000 ft along the shoreline (Figure 10).

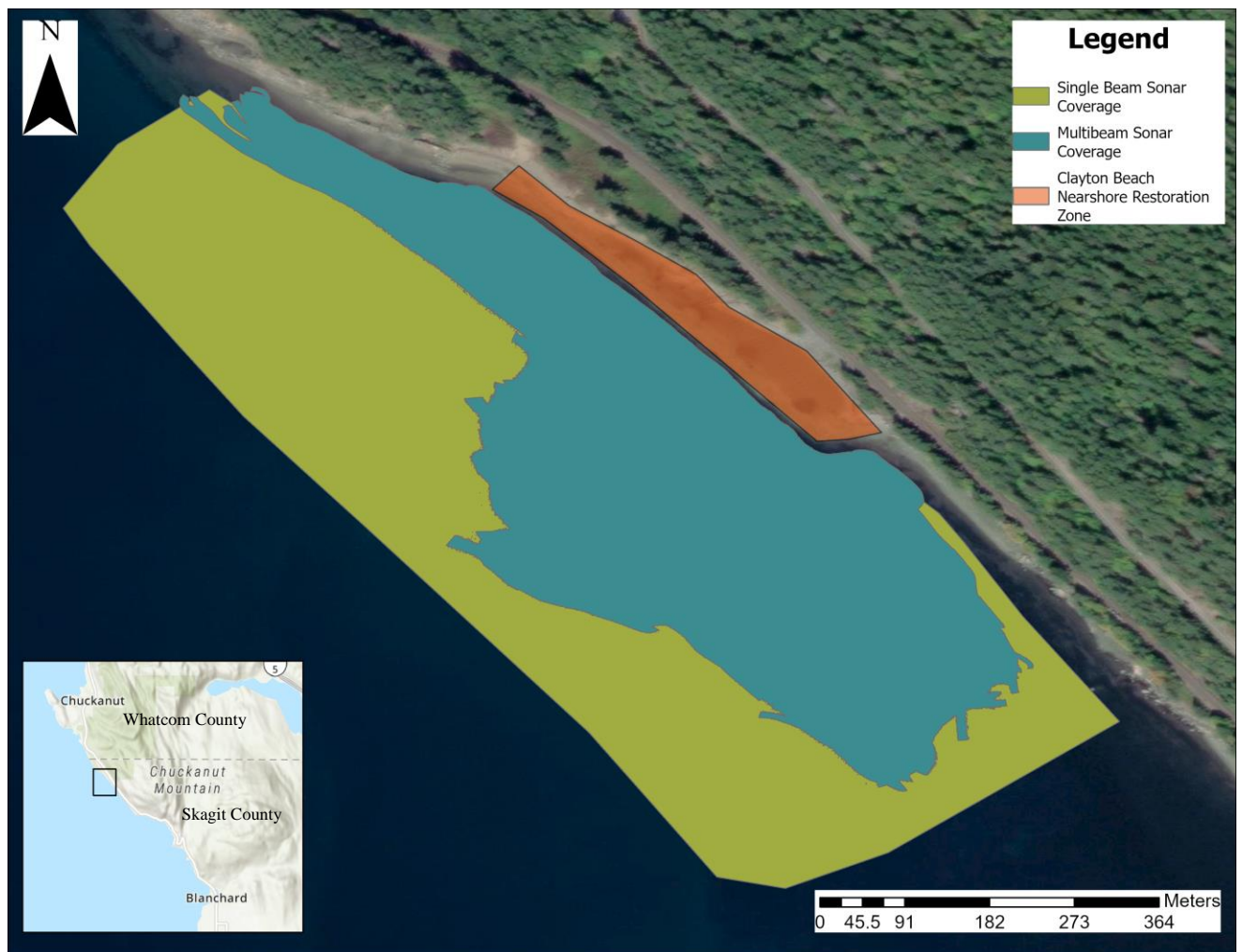


Figure 10. Survey footprints for both types of sonar applied to map the bathymetry and subtidal habitat at Clayton Beach and the offshore divot.

3.2 Bathymetry

Bathymetry from single beam depths was interpolated and is represented in (Figure 11). This surface has a low resolution of approximately 20 m², however, it indicates that in general, the sites' surface slopes steeper north of the nearshore restoration zone than it does southeast of it. To the north, the bathymetry falls from 0 ft MLLW to -8 ft. MLLW in 300 ft, is flat for 330 ft, then steeply descends out of frame (Figure 11). South of the divot, the seafloor appears to slope offshore at a shallower angle for 450 ft, falling from 0 ft. to -8ft. MLLW across that distance. The seafloor then flattens and remains at a constant depth of -9 to -10 ft. MLLW (Figure 11).

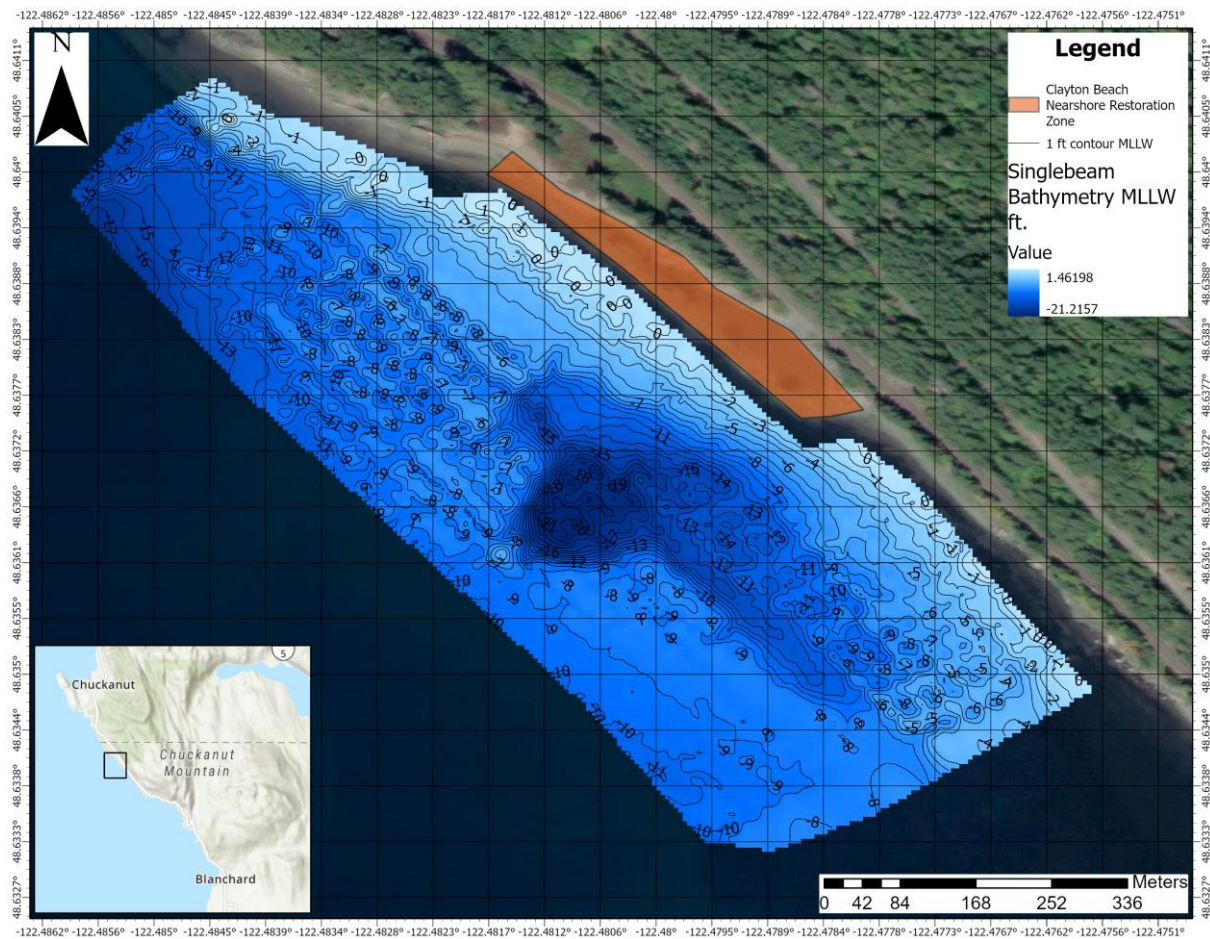


Figure 11. Bathymetric surface interpolated from single beam sonar data at Clayton Beach, Skagit County, WA.

3.2.1 Bathymetry – Nearshore Restoration Zone

The surface of the seafloor just offshore from the Clayton Beach riprap wall (at 0ft MLLW) follows a shallow slope of 0.9 degrees between the -2 and 0 ft. MLLW contour. This surface slope is more gradual than the seafloor just south of the Nearshore Restoration Zone, which slopes steeper at 1.1 degrees (Figure 11). This slope can be attributed as an influence from

the unvegetated dredge hole, as past this and at the edge of where data was collected, the slope returns to a shallower form (Figure 11).

3.2.2 *Dredge Hole Bathymetry*

Figure 12 is a surface that has been produced from multibeam sonar data. This surface accurately displays the shape and depth of the unvegetated dredge hole which is obvious as a deep depression south of the Clayton Beach nearshore restoration zone. At a resolution of 0.25 m², this surface gives a more accurate value of depth where vegetation is sparse or absent compared to the interpolation from single beam data in Figure 11. Where eelgrass was dense however, the multibeam sonar is unable to detect the true bottom depth.

Zones that are bare have a standard deviation of only 1 – 2 cm, whereas locations with eelgrass have up to 70 cm of error. In these zones, the single beam generated bathymetry surface can be used as a replacement for seafloor depth. Both bathymetric surfaces corroborate the maximum depth of the divot as -20 ft. MLLW and show that it is deepest at its northwest extent, becoming gradually shallower as one moves to the southeast. It appears to be completely void of any rock, boulder, or large feature.

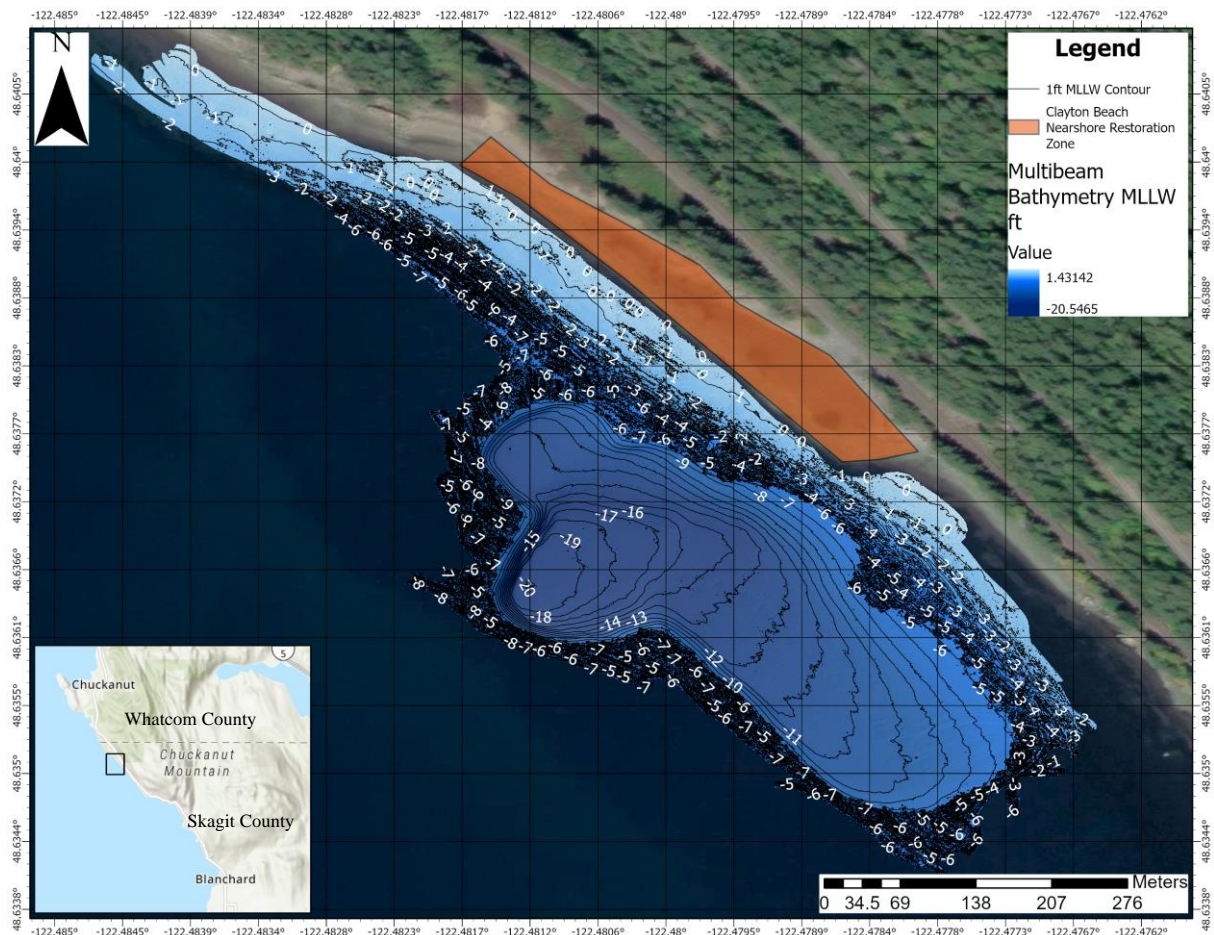


Figure 12. Bathymetry collected and produced by multibeam sonar at Clayton Beach, Skagit County, WA

3.3 Eelgrass Bed Distribution – General Trends

A dense eelgrass bed was found at depths between -1 and -10 ft. MLLW at Clayton Beach. In general, the percent cover of eelgrass is high in any zone we surveyed deeper than -1 ft. MLLW. Shallower than this, there are isolated locations where only 1- 25% cover (shoots present/m²) are found. These reductions in percent cover exist in only in localized pockets, and for the most part percent cover remains high with a mean of 60 ± 37 (SD) % cover (Figure 15).

Eelgrass canopy height is consistently long with a mean of 110 ± 21 cm (SD) up to -3 ft. MLLW (Figure 14). Shallower than this depth band, canopy height is shorter and more inconsistent– measured from 1 to 50 cm, with a mean of 31 ± 25 cm (SD) (Figure 14). The deep edge periphery of the bed at Clayton Beach is made up of shorter, less dense plants that are less than 50cm in length (Figure 14).

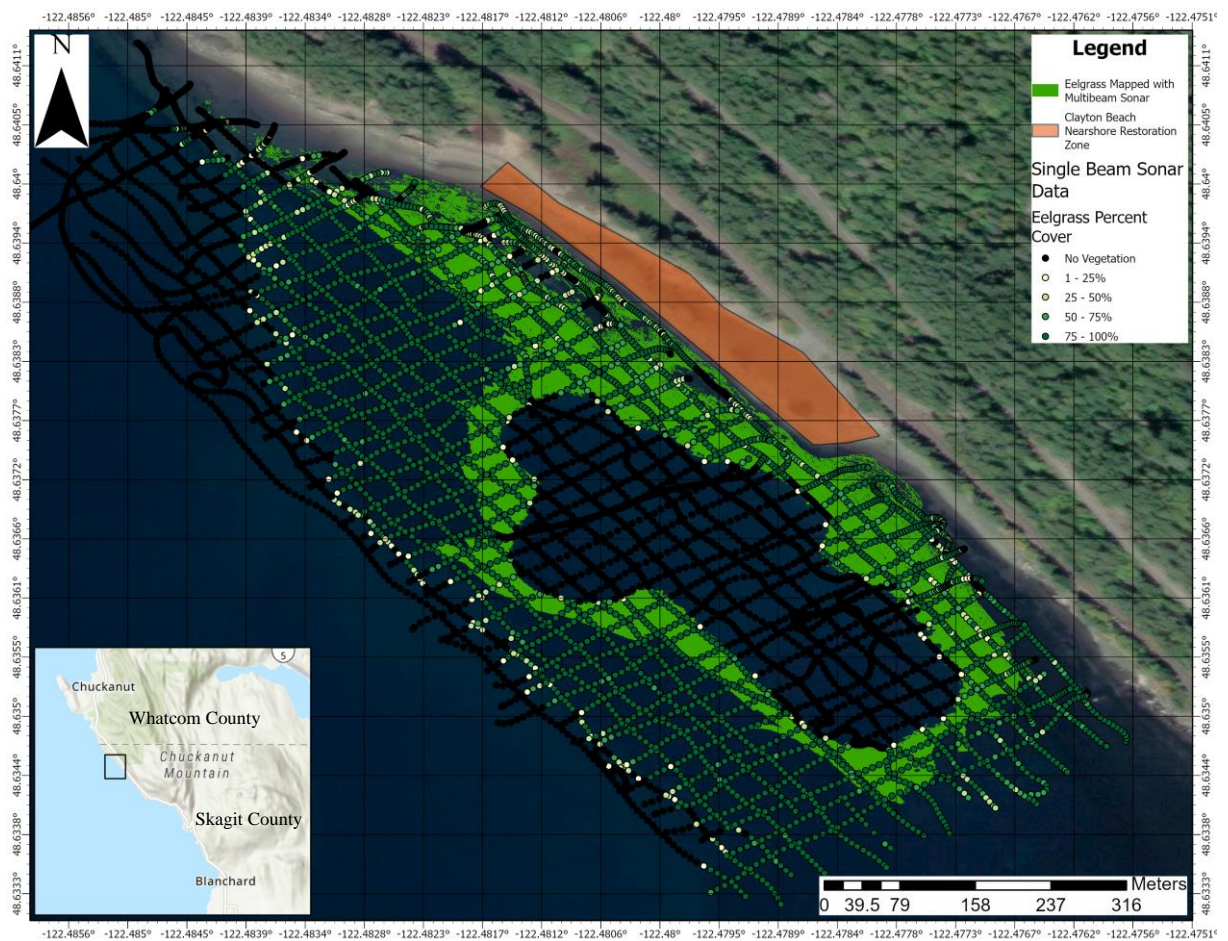


Figure 13. Eelgrass percent cover per m² from single beam sonar survey at Clayton Beach, Skagit County, WA.

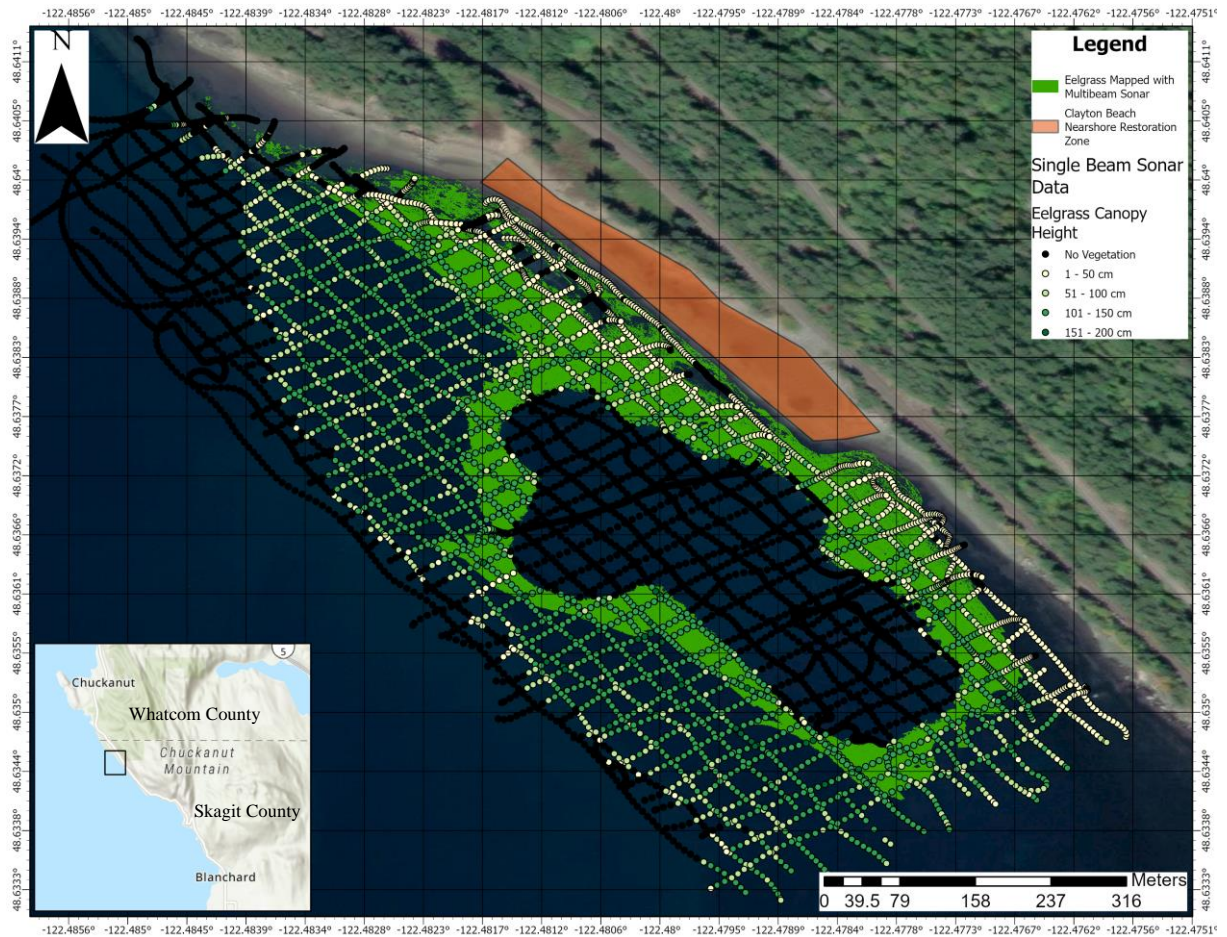


Figure 14. Eelgrass blade length from single beam sonar survey at Clayton Beach, Skagit County, WA.

3.3.1 Clayton Beach Restoration

Closer to the restoration zone, Eelgrass is patchily distributed within a buffer of approximately 130 ft. from the riprap wall, where large unvegetated patches are present and obvious in both multibeam and single beam data (Figure 17). These unvegetated patches sum to approximately .68 acres of unvegetated bed-land. The eelgrass offshore from armoring and out to approximately -1 ft. MLLW has an average percent cover of 55.4 ± 36.6 (SD). The patchy framework extends to this point (-1 MLLW ft), and deeper than this (dredge hole excluded) it becomes a more continuous bed.

Due to hazards along the shoreline, we did not extend our multibeam survey as close to shore than we did in zones with riprap armoring. This makes a comparison of the unarmored shoreline's eelgrass bed morphology difficult. Data from the single beam sonar however indicates that eelgrass in the unarmored section of our survey (hashed box Figure 17) extends shallower than -1 ft. MLLW without the large voids that are seen offshore from the armored trestle. (Figure 16). Above -1 ft. MLLW, the eelgrass in this unarmored section is also more dense (average percent cover equal to 83.4 ± 23 (SD)).

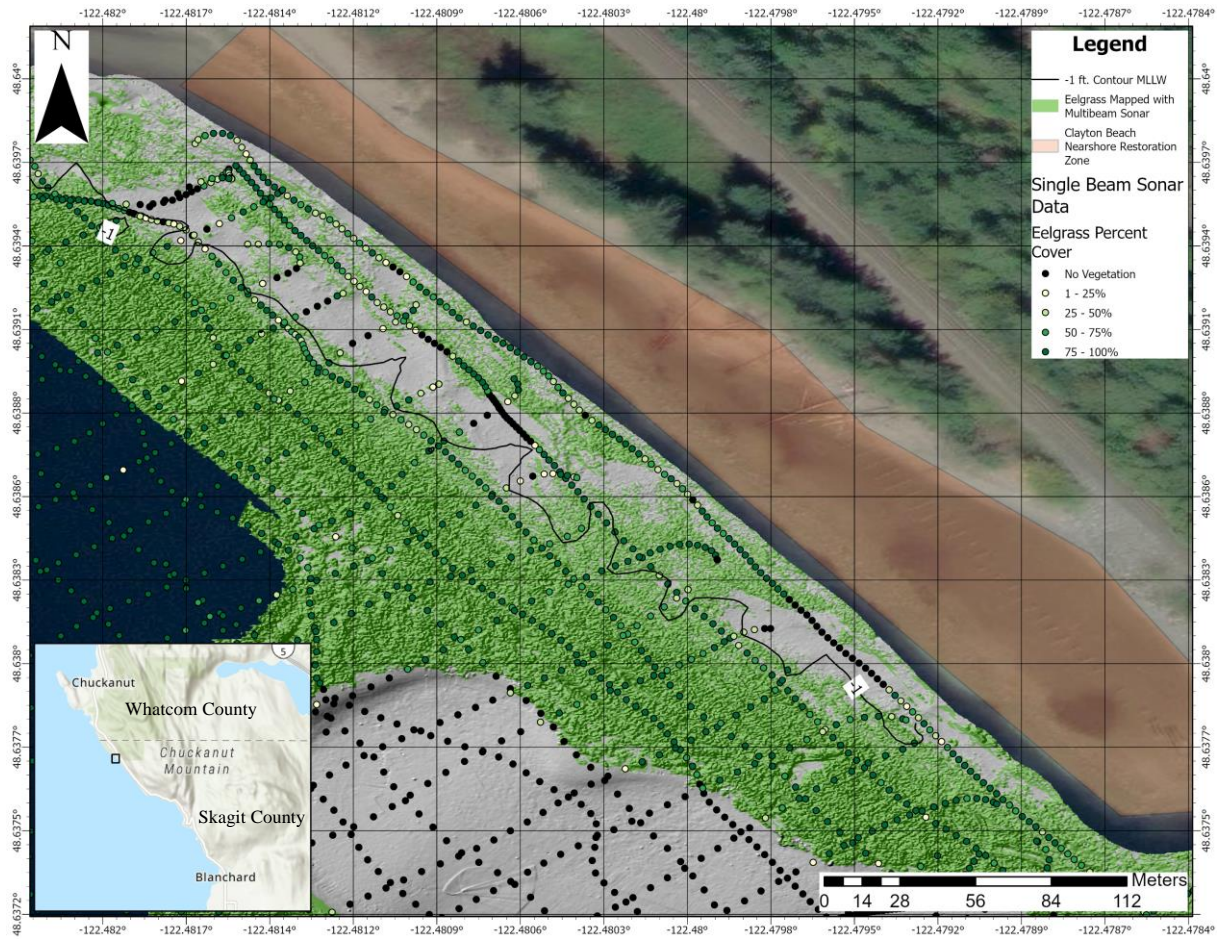


Figure 15. Eelgrass distribution offshore the Clayton Beach restoration zone.

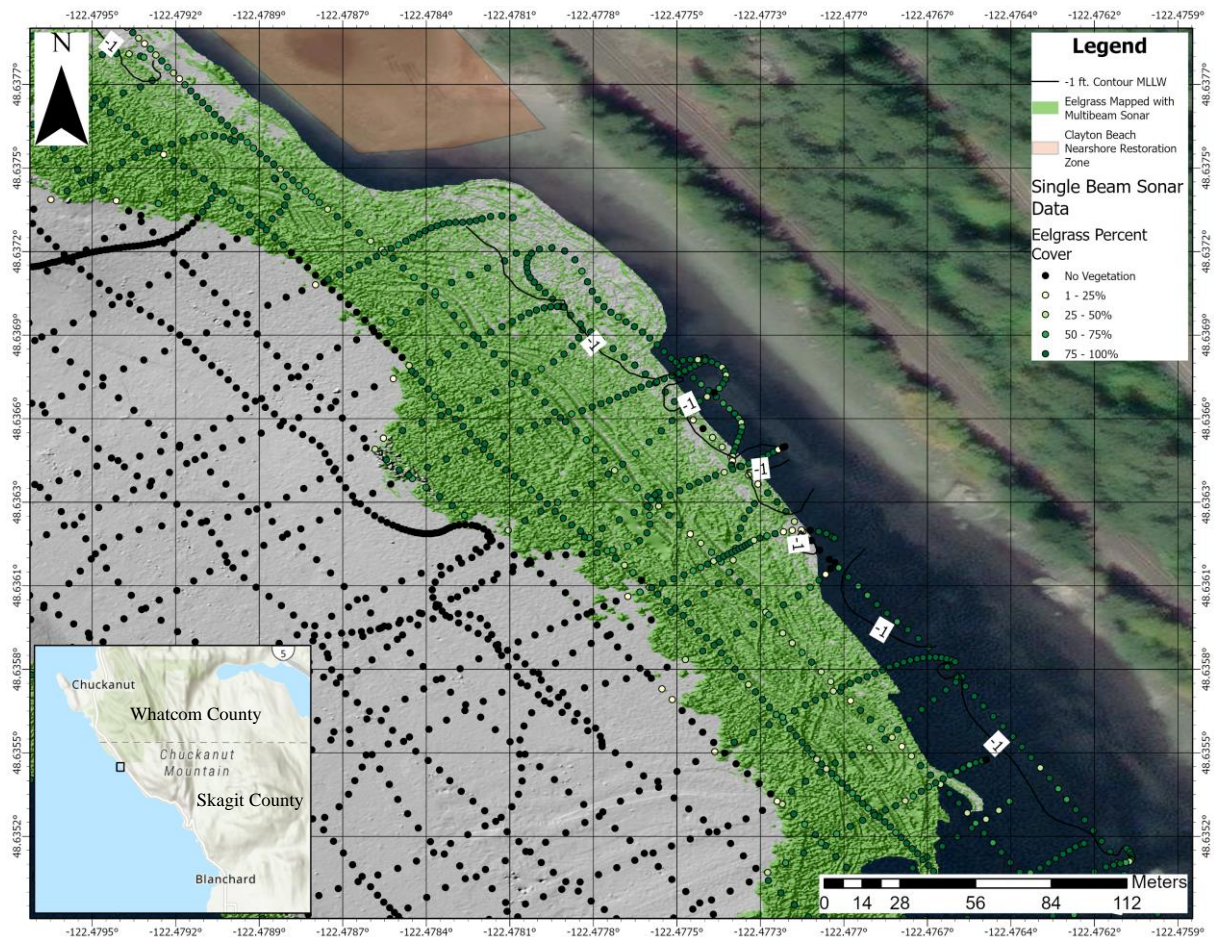


Figure 16. Eelgrass distribution south of restoration zone offshore unarmored shoreline.

3.3.2 Dredge Hole

The dredge hole yields 13.9 acres of unvegetated bed-lands, surrounded by dense eelgrass on all sides (Figure 17). Figure 18 **Error! Reference source not found.** A – D are cross sections of the divot taken from multibeam data. Eelgrass canopy appears obvious in these images as a “spiked” surface after moving from a smooth non – vegetated divot. Apparent in these cross sections is that eelgrass grows to different depths at different locations along the edge of the divot. In some locations (shallow southeast edge), it ceases to grow at approximately -5 or -6 ft. MLLW, whereas in other locations (western deep edge), eelgrass ceases to grow at the -9 ft. interface. These images corroborate previous figures and show that the divot is more steeply excavated on its west side compared to the east side (Figure 17 **Error! Reference source not found.**).

Video used to “truth” single beam and multi beam sonar identified a thin algal mat inside the dredge hole (which appeared to be decomposing at the time of this late summer survey). It is likely that the dredge hole acts as a sink for seasonal decomposition during the summer, accumulating algae and detritus (Figure 20 and Figure 21).

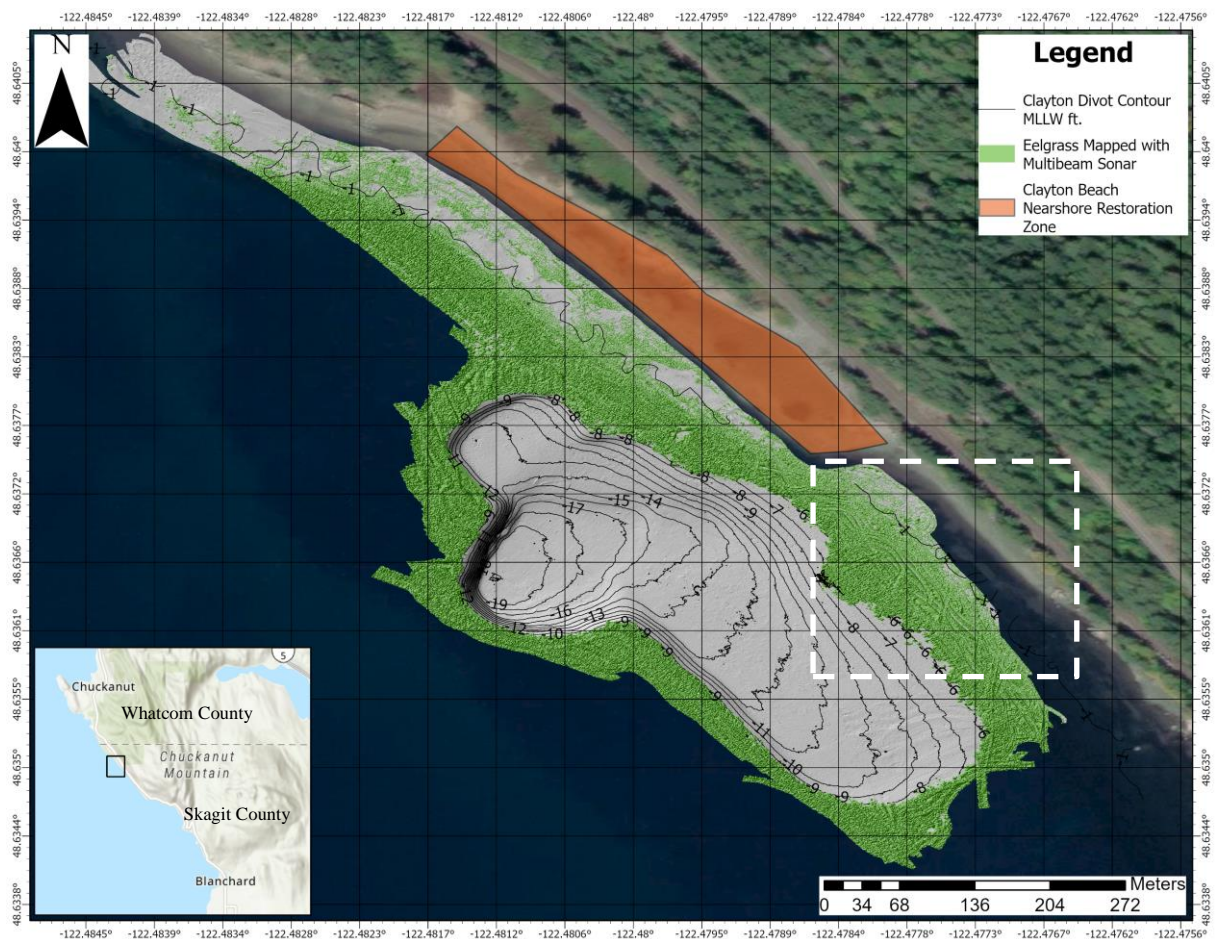
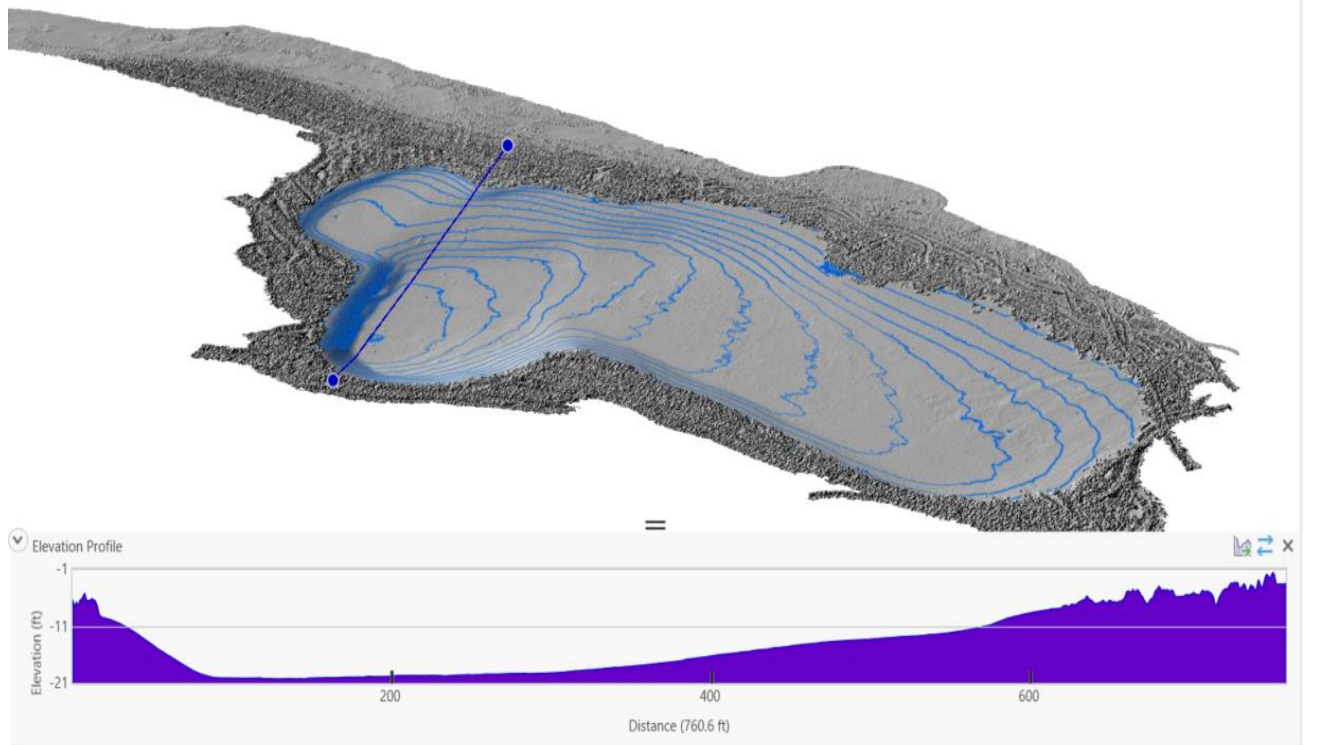
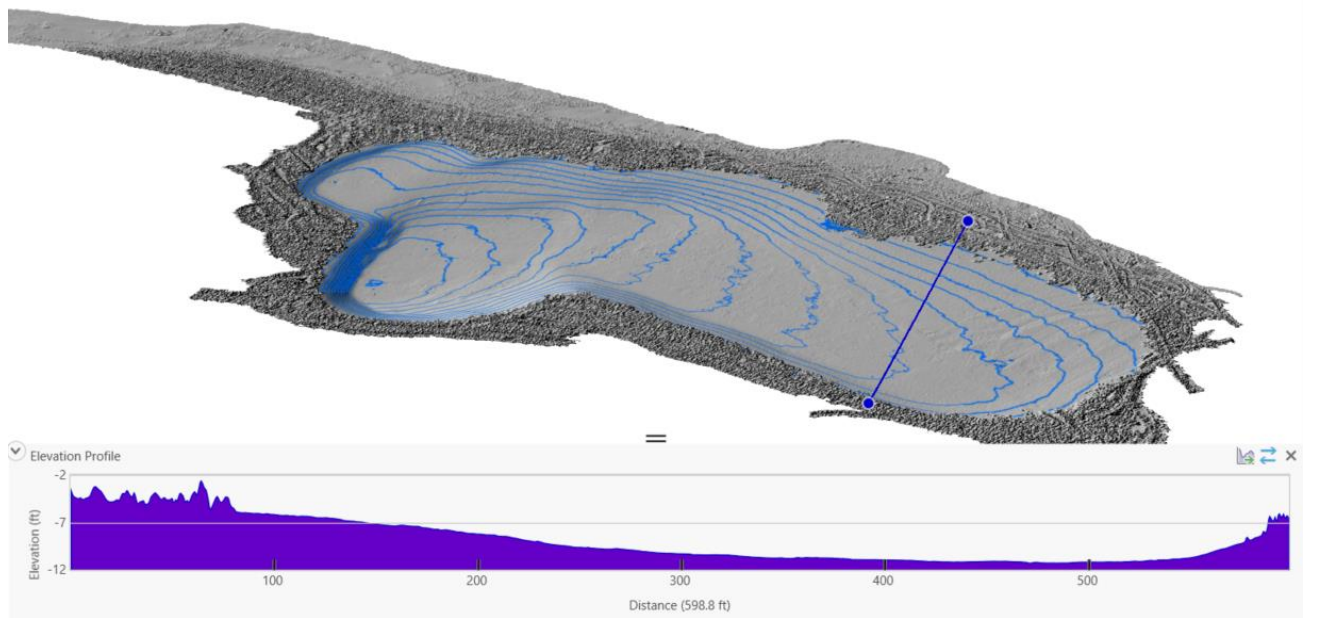


Figure 17. Bathymetry of the dredge hole and surrounding eelgrass at Clayton Beach, Skagit County, WA. Patchy eelgrass bed exists shallower of -1 ft. MLLW, whereas the eelgrass bed grows more continuous to a depth of approximately -10 ft (MLLW). The hashed white box indicates a section of the survey that was completed in front of unarmored shoreline.

A.



B.



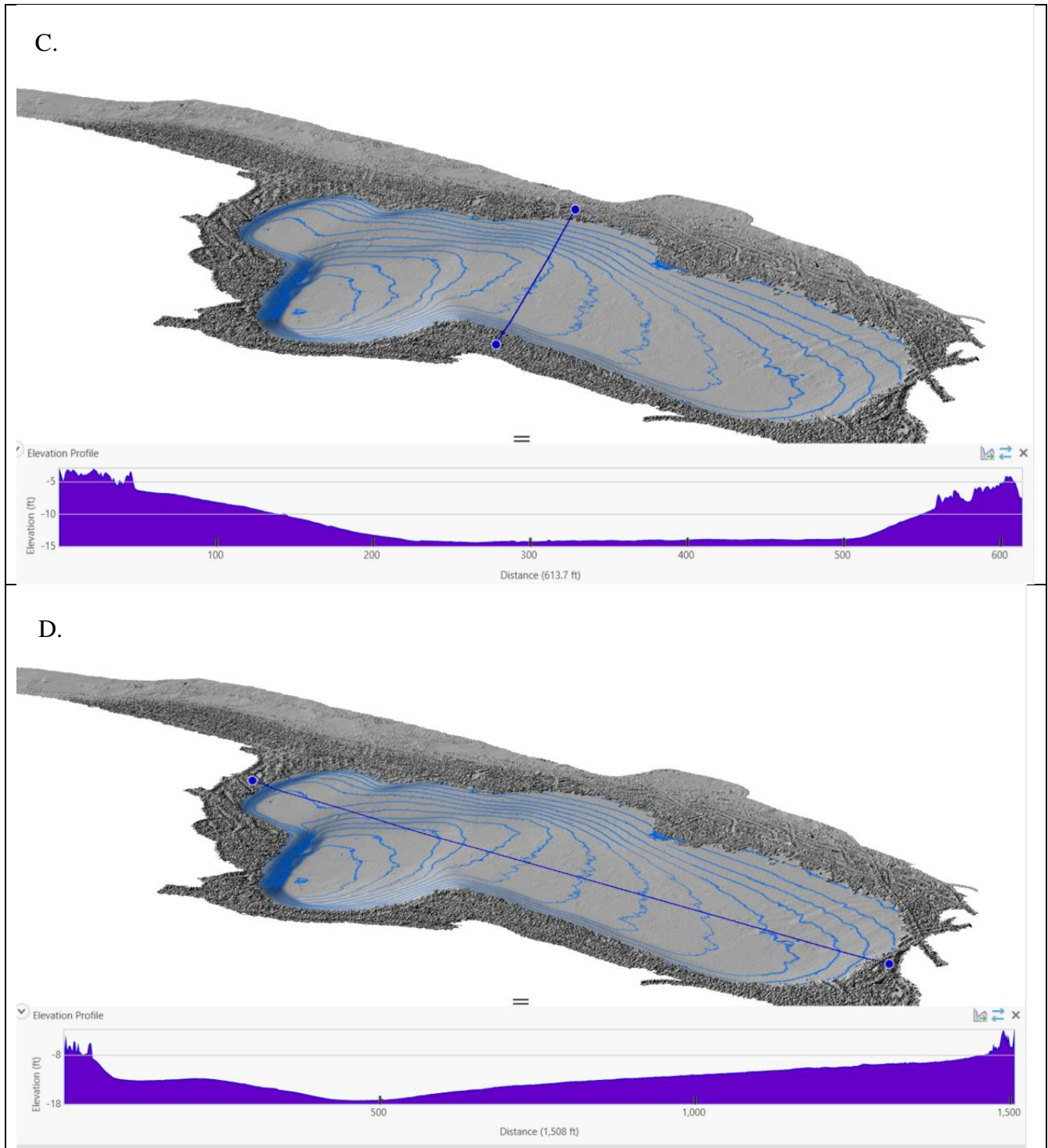


Figure 18. Cross Sections of the divot offshore from Clayton Beach, Skagit County, WA.



Figure 19. Dense eelgrass (*Zostera marina*) at Clayton Beach.



Figure 20. Video from within the Clayton Beach dredge hole, Skagit County, WA.



Figure 21. Video from within the Clayton Beach Divot, Skagit County, WA.

3.4 Dredge Hole Volume Estimate

Two raster surfaces were used to calculate the total volume of the divot. The first was an unaltered 0.25 m² resolution raster of bathymetry for all unvegetated portions of the divot (Figure 22A). The second was an interpolated surface that estimated a natural slope profile as if the divot did not exist (Figure 22B).

The volume between these two surfaces was calculated as 71,246 m³ ± 119 m³ (93,186 yd³). This is the total quantity of fill needed to bring the seafloor up to a suitable height for eelgrass restoration. For reference – this equates to roughly 97 full size school busses needed to fill the hole.

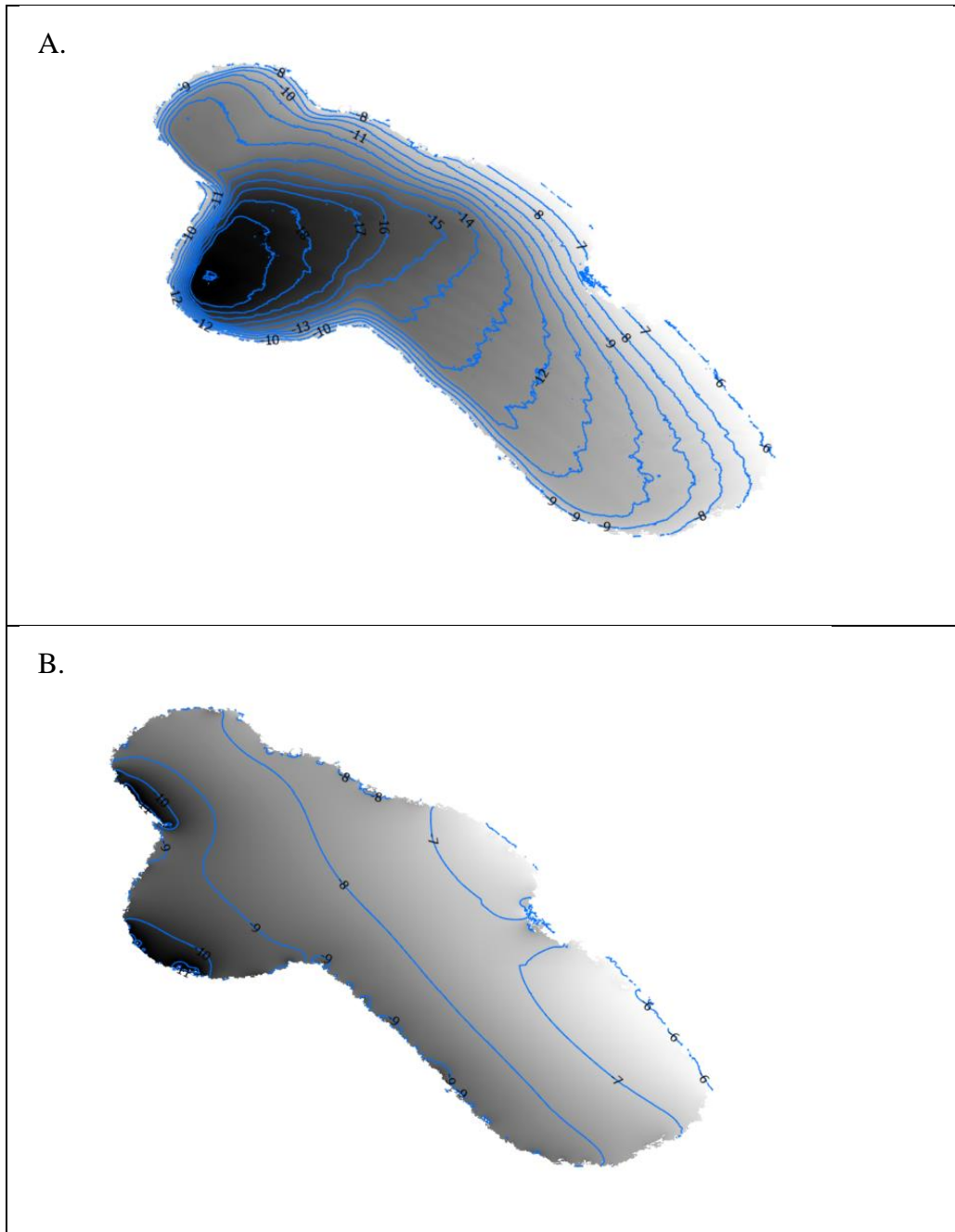


Figure 22 A. Current Clayton Beach Divot Bathymetry. Contours in MLLW ft.

Figure 19 B. Interpolated bathymetry of filled Clayton Beach Divot. Contours in MLLW ft.

4 Conclusion

In late summer of 2023, DNR's Aquatic Assessment and Monitoring Team mapped a zone surrounding a large restoration project at Clayton Beach, Larrabee State Park, WA, for bathymetry and eelgrass presence. A dense eelgrass bed surrounds the Clayton Beach restoration site and was found to abut the Clayton Beach dredge hole at bathymetric contours from -6 to -9 ft. MLLW.

This eelgrass bed was found to extend relatively high into the intertidal (up to 0 ft. MLLW), and down to -10 ft MLLW at its deep edge. Because eelgrass grows up to the riprap restoration site (at 0 ft. MLLW), it is possible that after removal and re-grading of riprap, pilings, and sediment, that eelgrass will move into this newly restored zone. Based on bathymetry and the certainty that eelgrass will grow up to 0 ft. MLLW, this may be more successful if the newly restored zone is designed like the surrounding natural shoreline and graded to remain flat until meeting the steep beach.

Our surveys detected large patches (~ .68 acres) of unvegetated seafloor in front of the trestle (riprap) restoration zone. These large patches are not evident in locations without shoreline armoring. The absence of eelgrass in localized patches could be due to several reasons, with some that are related to the presence of the current trestle. Thom et al. (2011) notes that while the impacts to eelgrass from armoring are not well studied, eelgrass will eventually be negatively affected by substrata changes associated with the reduction in fine sediment delivery to the beach. In the case of Clayton Beach, the absence of fines could be due to a scouring effect of finer sediments related to increased wave energy on the armored wall. We were not able to collect sediment samples at the base of the armored wall, and so a confirmation of this hypothesis cannot be tested. If true, the removal of armoring and recontouring of the seafloor could promote natural restoration of fine sediments back into the unvegetated patches that currently exist, making these patches more suitable for eelgrass.

In addition to this new shoreward expansion, the Clayton Beach divot presents a unique opportunity to restore 13.9 acres of eelgrass to Puget Sound. This aligns with the Statewide Kelp Forest and Eelgrass Meadow Health and Conservation initiative to conserve and restore 10,000 acres of kelp and eelgrass habitat by the year 2040 (WADNR 2023). To restore the original seafloor slope at the divot, it is estimated that approximately $71,246 \text{ m}^3 \pm 119 \text{ m}^3$ (93,186 yd³) of sediment will be needed. While it is not currently known where this large quantity of fill will come from, data from large scale dredged capping projects will identify important considerations for this restoration. A primary factor in divot restoration success will be to work around the consolidation time of deposited sediments. After sediment deposition, it will be important to allow consolidation time for successful eelgrass shoot plantings. Depending on the void ratio (the volume of voids in any sediment relative to the volume of solids) of the fill, and the total depth of deposit, the deposited sediment will consolidate

substantially. Based on data from the US Army Corps of Engineers, fill may continue to consolidate for an extended period. A report on consolidation time for different sediment void ratios indicates that subsistence and settling of material will continue for approximately 3000 days (8.2 years) post deposit regardless of sediment void ratios. Over this time, a surface may subside anywhere from 2 to 5 feet or more (Rollings 2000).

In addition to settlement time, it will be important to ensure a uniform seafloor surface is restored within the divot. Eelgrass is light limited, and the surface depth of new material should uniformly slope across the current depression at a constant from -6 to -9 ft. MLLW. It must not exceed -10 ft. MLLW in depth (the natural deep edge extent of eelgrass at the site). If a uniform slope is not achieved, a patchwork may occur where depressions in the surface exist, instead of a dense meadow of successfully restored eelgrass.

DNR plans to continually monitor the Clayton Beach restoration and divot zones for eelgrass bed distribution and seafloor bathymetry. The data compiled for this report will be included in future analyses of restoration success at the site. We thank our partners in this project – the Northwest Straits Foundation, the Whatcom County MRC, the Skagit County MRC, and Washington State Parks, and appreciate the support and opportunity to carry out this important work.

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