



Oregon

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October 19, 2023



To: Land Conservation and Development Commission

From: Brenda Ortigoza Bateman, Ph.D., Director
Lisa Phipps, Coastal Program Manager
Andy Lanier, Marine Affairs Coordinator

Subject: **Agenda Item 15, November 2-3, 2023 LCDC Meeting**

TSP Part Four – Uses of the Seafloor Rulemaking Amendment Process Briefing and Public Hearing

I. Summary

The Department of Land Conservation and Development (DLCD or department) staff will brief the Land Conservation and Development Commission (LCDC or commission) on the Territorial Sea Plan Part Four (TSP4) Amendment Process recommendations and answer any questions from the commission.

Purpose. To summarize and transmit the draft amendments that were approved through consensus of the Ocean Policy Advisory Council (OPAC) during its September 2023, meeting. These amendments would update the TSP4 – Uses of the Seafloor. Staff will ask the commission to complete the rulemaking process by incorporating the amendments to TSP4 by reference in administrative rule. This is the second public hearing for these amendments. Staff conducted the first hearing in Newport in October.

Objective. Commission adoption of the of TSP4 amendments included as Attachment A.

For further information about this report, please contact Andy Lanier, Marine Affairs Coordinator, at 503-206-2291 or Andy.Lanier@dlcd.oregon.gov.

II. Background

A network of more than 1.5 million kilometers of submarine fiber optic cables exists on the seafloor of the world's oceans. Oregon is one of the locations on the west coast of the United States where they come to shore. These cables underpin the entire global

internet and our modern information age. The first cable to land in the State of Oregon was proposed in 1998. Since then, there have been more than a dozen landed. The Ocean Policy Advisory Council (OPAC) adopted Part Four of the Territorial Sea Plan in 2000 as a formalization of the process for the management and review of cables, pipelines, and other utilities to occupy space within the territorial sea. In 2020, an accident in the installation of one of the cables led to heightened community awareness and a request for the review of the existing permitting requirements for the installation of new seafloor infrastructure. Commission may view the [Edge Cable Ocean Shore Permit website](#) for additional background information. This demand led to the passage of House Bill 2603 (2021) that legislatively mandated a review of the Part Four of the Territorial Sea Plan.

III. Background of the TSP Amendment process

House Bill 2603 (2021) directed DLCD to coordinate with other marine management agencies and lead a review of the Territorial Sea Plan Part Four: Uses of the Seafloor, and to present findings from the review to OPAC. The legislation also directed OPAC to consider the review and develop recommended amendments to Part Four (HB 2603 Section 2, subsection 2 – included as Attachment B). The review and evaluation of criteria listed took place through the formation of a Working Group, contracted studies, and presentations from various agencies and industry. Staff provided opportunities for public comment throughout the amendment process. Consistent with other amendments to the Territorial Sea Plan, OPAC served as the LCDC rulemaking advisory committee (RAC).

a. Working Group formation and composition

Staff facilitated recruitment for members of the OPAC TSP Part Four Working Group in March 2022. Working Group members represented various state and federal agencies, the undersea cable industry, the fishing industry, local government, coastal communities, conservation groups, and other affected parties. DLCD sent letters to staff and leadership of the nine federally recognized tribes of Oregon inviting them to formal consultation and to participate in the Working Group.

b. Working Group Activities

Working Group members met ten times in the period between May of 2022 and July of 2023. Discussions were informed by the completion of two supporting projects through contracts to external entities, including: a Geologic Assessment of Potential Cable Landing Sites Along the Oregon Coast (by the Oregon Department of Geology and Mineral Industries – Attachment C); and a Best Practices in the Undersea Cable Industry Report (by Ryan Wopschall – Attachment D). Between May and December 2022, DLCD and the Department of State Lands (DSL) gathered information to present

to the Working Group on the permitting processes for undersea cables within Oregon state agencies, federal agencies, and state agencies in California and Washington. The May 2, 2022 meeting included a walkthrough by state and federal agency staff on the permitting and regulatory processes for undersea cables of each agency. The December 7, 2022 meeting included an in-depth presentation on the DSL Easement granting process and an overview of the state and federal agency permitting processes related to uses of the seafloor within Oregon's Territorial Sea.

With the help of Working Group member Scott McMullen, DLCD staff also organized an experiential field trip for members to take part in site visits on the Oregon coast to undersea cable beach manholes, a cable landing station facility, the AKRON Network Operations Center and a data center of telecommunications companies in Hillsboro, Oregon. This provided members of the group a real-world perspective on the logistics and operations required for companies around the world to install, operate, and maintain the telecommunications networks, including the services and benefits provided to Oregonians through this use of ocean space.

External review of the draft amendments was coordinated by department staff with the Oregon Department of Justice (DOJ) and the National Oceanic and Atmospheric Administration (NOAA). Additionally, DLCD staff sent letters to Coastal Tribal Nations inviting them to participate in a tribal briefing and consultation. Feedback from all sources was presented to the Working Group. Recommended language amendments to the draft Part Four resulted from those efforts.

During each meeting, Working Group members discussed the current draft of the proposed amendments and provided substantive suggestions for revisions. Drafts of the proposed amendments were posted to the [Oregonocean.info website](https://www.oregonocean.info/index.php/tsp4-working-group) on the TSP Part Four Working Group page (<https://www.oregonocean.info/index.php/tsp4-working-group>). Working Group members accepted public comments by both oral and written testimony at all meetings to inform the amendment process. The Working Group operated on a consensus decision-making approach, with final recommended amendments to Part Four being supported by a consensus of the members.

c. OPAC Recommended amendments

By a consensus of the Council, OPAC adopted the Working Group recommended amendments at its meeting on September 8, 2023. The council also reviewed the required rulemaking documents at this same meeting including the draft Public Notice and Fiscal Impact Statement, Racial Equity Impact Statement, and Housing Impact Statement included in Attachment A. OPAC's recommended amendments were transmitted to the commission via letter on October 16, 2023, included as Attachment E.

DLCD staff submitted the Notice of Proposed Rulemaking on September 20, 2023 to the Secretary of State, included as Attachment A.

IV. A summary of the changes to TSP Part Four

OPAC adopted amendments to Part Four consisting of the addition of several new sections and a reworking of the sections initially included in Part Four. Included in these additions are the required formation of a Joint Agency Review Team (JART), the applicant required submission of a Resource and Use Inventory and Effects Evaluation, and decommissioning requirements. The entirety of the proposed amendment is provided in Attachment A.

A. A Coordinated Process via the JART

The JART, to be convened and led by DSL, consists of representatives from State and federal agencies with regulatory or advisory roles in the permitting process for development actions which take place on the sea floor of Oregon's territorial sea, as well as representatives of local jurisdictions, Coastal Tribes, and other parties as identified by DSL. The JART works with applicants to make sure proposed projects are sited appropriately and constructed in a way which minimizes or mitigates conflict with other ocean users and damage to natural resources.

B. Resource and Use Inventory and Effects Evaluation Requirement

Applicants proposing development actions on the seafloor within Oregon's Territorial Sea must complete a Resource and Use Inventory and Effects Evaluation in order to avoid potential conflicts and plan projects accordingly to mitigate damage to identified resources. The purpose of the Resource and Use Inventory and Effects Evaluation is to provide regulating agencies the data and information necessary to make a decision based on the project or development action's potential coastal effects. Applicants provide information and data sufficient to determine the scope, likelihood, and significance of reasonably anticipated potential effects to coastal resources and uses. The information required in the inventory and evaluation of effects ranges from logistics pertaining to the project's construction, to natural, cultural, and economic resources potentially impacted by the project.

C. Decommissioning

The proposed amendment includes decommissioning requirements for all proposed development actions within Oregon's Territorial Sea. The Plan requires the owner or operator of the seafloor infrastructure to submit a decommissioning plan to DSL for approval, based upon the terms and conditions of their easement. In cases where removal of infrastructure is more environmentally damaging than leaving it in situ, there is a process for the applicant to demonstrate that fact, secure an encroachment easement from DSL, and leave the infrastructure in place.

V. Conclusion

The final draft amendment was reviewed by OPAC, and the results are now being transmitted to LCDC for potential adoption via amendment of the TSP administrative rule - OAR 660-036-0001. After rule adoption, staff will identify and extract enforceable policies for submission to and approval by NOAA for federal consistency purposes, and list them in an update to Appendix C.

Sample Motions

Recommended motion – Approve OPAC recommendation.

I move the commission adopts as part of the Oregon Coastal Management Program, and herein incorporates by reference, an amendment to Territorial Sea Plan Part Four: Uses of the Seafloor, as recommended by the Ocean Policy Advisory Council on September 8, 2023.

Alternate motion – Remand to OPAC for further consideration.

I move the commission return the recommended amendments to TSP Part Four, OAR Chapter 660, division 36, to the Ocean Policy Advisory Council with specific revisions: [specify revisions].

VI. Attachments

A. 660-036 SOS Notice Filing, Tracked Changes

B. HB 2603 (2021) Enrolled

C. Geologic Assessment of Potential Cable Landing Sites Along the Oregon Coast

D. Best Practices in the Undersea Cable Industry Report

E. OPAC TSP Part Four transmittal letter

OFFICE OF THE SECRETARY OF STATE
LAVONNE GRIFFIN-VALADE
SECRETARY OF STATE

CHERYL MYERS
DEPUTY SECRETARY OF STATE
AND TRIBAL LIAISON



ARCHIVES DIVISION
STEPHANIE CLARK
DIRECTOR

800 SUMMER STREET NE
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NOTICE OF PROPOSED RULEMAKING
INCLUDING STATEMENT OF NEED & FISCAL IMPACT

CHAPTER 660
LAND CONSERVATION AND DEVELOPMENT DEPARTMENT

FILED

09/18/2023 1:20 PM
ARCHIVES DIVISION
SECRETARY OF STATE

FILING CAPTION: Amend Territorial Sea Plan Part Four - Uses of the Sea Floor

LAST DAY AND TIME TO OFFER COMMENT TO AGENCY: 11/03/2023 8:00 AM

The Agency requests public comment on whether other options should be considered for achieving the rule's substantive goals while reducing negative economic impact of the rule on business.

CONTACT: Casaria Taylor
971-600-7699
casaria.taylor@dlcd.oregon.gov

635 Capitol St
Ste. 150
Salem, OR 97301

Filed By:
Casaria Taylor
Rules Coordinator

HEARING(S)

Auxiliary aids for persons with disabilities are available upon advance request. Notify the contact listed above.

DATE: 11/03/2023

TIME: 7:30 AM

OFFICER: LCDC

HEARING LOCATION

ADDRESS: Medford City Hall, Council Chambers, Room 300, 411 W. 8th Street, Medford, OR 97501

SPECIAL INSTRUCTIONS:

sign-up in advance to testify at <https://www.oregon.gov/lcd/Commission/Pages/Public-Comment.aspx>

REMOTE MEETING DETAILS

MEETING URL: Click here to join the meeting

PHONE NUMBER: 1-253-205-0468

CONFERENCE ID: 766920

SPECIAL INSTRUCTIONS:

sign-up in advance to testify at <https://www.oregon.gov/lcd/Commission/Pages/Public-Comment.aspx>

DATE: 10/23/2023

TIME: 12:00 PM

OFFICER: Andy Lanier

HEARING LOCATION

ADDRESS: Hatfield Marine Science Center, 2030 SE Marine Science Drive, Library Seminar Room, Newport, OR 97365

REMOTE MEETING DETAILS

MEETING URL: Click here to join the meeting

PHONE NUMBER: 1-253-205-0468

NEED FOR THE RULE(S)

To update Part Four of the Territorial Sea Plan: Uses of the Sea Floor, originally adopted in 2001.

DOCUMENTS RELIED UPON, AND WHERE THEY ARE AVAILABLE

Statewide Land Use Planning Goal 19: Ocean Resources – <https://www.oregon.gov/lcd/OP/Documents/goal19.pdf>

Oregon Territorial Sea Plan - <https://www.oregon.gov/LCD/OCMP/Pages/Territorial-Sea-Plan.aspx>

STATEMENT IDENTIFYING HOW ADOPTION OF RULE(S) WILL AFFECT RACIAL EQUITY IN THIS STATE

The department has not identified any effect on racial equity in the state.

FISCAL AND ECONOMIC IMPACT:

State agencies (ODFW, OPRD, DSL, DLCD, DEQ) will be required to act in accordance with the policies outlined in the Plan, which may include rulemaking. Agency staff will also be necessary to be members of the Joint Agency Review Team to review project proposals for feasibility, completeness, and technical merit, which will incur the use of staff resources and personnel. In addition to proposed rulemaking for multiple divisions, DSL anticipates proposing new legislation to fully comply with the policies outlined in the plan. Moreover, DSL plans to hire a facilitator and limited duration staff to help oversee and implement proposed rulemaking. Limited duration staff will also work on drafting any necessary legislative concepts

COST OF COMPLIANCE:

(1) Identify any state agencies, units of local government, and members of the public likely to be economically affected by the rule(s). (2) Effect on Small Businesses: (a) Estimate the number and type of small businesses subject to the rule(s); (b) Describe the expected reporting, recordkeeping and administrative activities and cost required to comply with the rule(s); (c) Estimate the cost of professional services, equipment supplies, labor and increased administration required to comply with the rule(s).

1) State agencies (ODFW, OPRD, DSL, DLCD, DEQ), local governments, and industry representatives submitting project proposals will be required to act in accordance with the policies outlined in the Plan, which may include rulemaking. Agency staff will also be necessary to be members of the Joint Agency Review Team to review project proposals for feasibility, completeness, and technical merit, which will incur the use of staff resources and personnel. In addition to proposed rulemaking for multiple divisions, DSL anticipates proposing new legislation to fully comply with the policies outlined in the plan. Moreover, DSL plans to hire a facilitator and limited duration staff to help oversee and implement proposed rulemaking. Limited duration staff will also work on drafting any necessary legislative concepts. Local Governments may have increased costs associated with complying with the plan requirements.

2) (a) The department has identified small businesses such as cable owners and operators, offshore energy companies, and similar small businesses subject to the rules.

(b) Small businesses will be expected to perform additional record keeping or administrative activities outside of the requirements of current administrative rules. These additional requirements relate to the completion of the resource and use inventory and effects evaluation.

(c) The department has identified the possibility of increased cost to small businesses associated with this rule in regard to professional services, equipment supplies, labor, or increased compliance administration. The department does not have access to sufficient available information regarding the magnitude of the potential cost increase to these small businesses to make an accurate cost estimate.

DESCRIBE HOW SMALL BUSINESSES WERE INVOLVED IN THE DEVELOPMENT OF THESE RULE(S):

A number of small business entities were involved in the development of this rule through membership of the Ocean Policy Advisory Council (OPAC) and its subcommittee, the TSP Part Four Working Group as well as through public comment. The makeup of OPAC is representative of all coastal interests. The working group was made up of representatives from the telecommunications industry, conservation groups, coastal research institutions, local government, and management agencies.

WAS AN ADMINISTRATIVE RULE ADVISORY COMMITTEE CONSULTED? YES

HOUSING IMPACT STATEMENT:

Description of proposed change: (Please attach any draft or permanent rule or ordinance) This rule amendment is not expected to have any impact on housing cost.

Amend rule to read:

660-036-0001

Territorial Sea Plan: Uses of the Sea Floor

The Land Conservation and Development Commission adopts as part of the Oregon Coastal Management Program, and herein incorporates by reference, an amendment to the Territorial Sea Plan Part Four: Uses of the Sea Floor, that the Commission approved as modified on December 01, 2000 and November xx, 2023.

[Publications: Publications referenced are available from the agency.]

[ED. NOTE: To view attachments referenced in rule text, click here for PDF copy.]

Statutory/Other Authority: ORS 183.310 - 550, 196.465, 196.471 & 197

Statutes/Other Implemented: ORS 196.465, 196.471 & 197.040

History:

LCDD 1-2001, f. 1-25-01, cert. ef. 1-26-01

Description of the need for, and objectives of the rule: To update Part Four of the Territorial Sea Plan: Uses of the Sea Floor, originally adopted in 2001, and as amended in 2023 by LCDC.

List of rules adopted or amended: 660-036-0001

Materials and labor costs increase or savings: n/a

Estimated administrative construction or other costs increase or savings: n/a

Land costs increase or savings: n/a

Other costs increase or savings: n/a

*Typical-Single story 3 bedrooms, 1 ½ bathrooms, attached garage (calculated separately) on land with good soil conditions with no unusual geological hazards.

AMEND: 660-036-0001

RULE SUMMARY: This rule incorporates text amendments, by reference, for Part Four of the Oregon Territorial Sea Plan: Uses of the Sea Floor.

CHANGES TO RULE:

Telecommunication Cables, Pipelines, and Other Utilities ¶

(1) Oregon's coast is a prime landing zone for fiber-optic telecommunication cables that cross the ocean floor from sites around the Pacific Rim. Other utilities, such as natural gas pipelines, may eventually be routed across Oregon's Territorial Sea bed. Proper placement of utility easements and installation of fixtures is required to avoid damage to or conflict with other ocean uses, such as commercial fishing, and to reduce or avoid adverse effects on marine habitats. State agencies, such as the Division of State Lands, the Department of Fish and Wildlife, the Oregon Parks and Recreation Department, and the Department of Land Conservation and Development, need clear policies and standards for reviewing and approving the routing and installation of utilities on the seafloor of Oregon and adjacent federal waters.¶

(2) Policies. When making decisions to approve routing, placement, or operation of a seafloor utility or fixture, state and federal agencies shall:¶

(a) Protect ocean fisheries and other ocean uses from any adverse effects that may be caused by installation or operation of cables, pipelines, or other fixtures by requiring that such routing, placement, or operation:¶

(A) Avoid conflicts between commercial or recreational fishing or other ocean-use activities and utilities, as a first priority;¶

(B) Reduce any adverse effects when conflicts cannot be avoided; and¶

(C) Mitigate for adverse effects after first reducing them to the minimum practicable.¶

(b) Protect marine habitat, fishery areas, and other marine resources as required by Statewide Planning Goal 19, Ocean Resources, and the Oregon Territorial Sea Plan; and¶

(c) Promote direct communication between affected ocean users to resolve or avoid conflicts and require written agreements among the parties when necessary to ensure communication and memorialize agreements.¶

(3) Implementation Requirements. When approving the routing, placement, or operation of seafloor utility, state and federal agencies shall avoid or reduce conflicts or adverse effects on other ocean users through the use of one or more of the following:¶

(a) Burial:¶

(A) In state waters: All telecommunication cables, pipelines, and other fixtures, crossing or affixed to state lands of the territorial sea lying seaward of Extreme Low Water (which is the seaward boundary of the Ocean Shore Recreation Area), shall be buried so as to ensure continuous burial unless the approving state agencies make findings that burial cannot be practically achieved and all affected parties agree that adverse effects of not burying the cable, pipeline, or fixture have been reduced, avoided, or mitigated to the extent practicable.¶

(B) In federal waters: Decisions to permit burial of cables, pipelines, or other fixtures crossing or affixed to the seabed of the outer continental shelf (beneath federal waters) to a depth of 2,000 meters off Oregon, will be deemed consistent with this state policy. When a federal agency does not require burial in waters to this depth, the state may concur that the decision is consistent with state policy only if the federal agency makes findings that burial cannot be practically achieved and all affected parties agree that adverse effects of not burying the cable, pipeline, or fixture, have been reduced, avoided, or mitigated to the extent practicable.¶

(C) Burial shall be certified by the contractor to the easement-granting agency.¶

(D) The easement-granting agency shall require that cables, pipelines, or other utility fixtures shall be inspected periodically and after any major geologic event, such as subduction-zone earthquake to ensure continued burial.¶

(b) Communication and coordination. Written agreements between the applicant and fishers or other users shall be required by the easement-granting agency as evidence of communication and coordination. Such agreements may coordinate work, determine routing, identify routes, respond to emergencies, provide for mitigation of adverse effects, or specify procedures for on-going communication. Written agreements shall specify how fishers or other users and the applicant will resolve disputes over lost fishing gear, damage to seafloor utilities, or liability for such actions.¶

(c) Controlling the location of utilities. Locations for new cables, pipelines, or other utilities shall conserve areas available to ocean fisheries, prevent or avoid conflicts with other uses, protect marine habitats, and minimize adverse effects on other public resources of the seafloor or ocean shore. New rights of way may be required to be located as close to existing rights of way as possible or with sufficient capacity to enable future expansion within the approved right of way.¶

(d) Single point of contact. The Division of State Lands shall coordinate approvals of easements and permits in consultation with the Parks and Recreation Department, the Department of Fish and Wildlife, the Department of Land Conservation and Development, the Department of Geology and Mineral Industries, and coastal local governments, as appropriate. The Department of Land Conservation and Development will use its authority under the federal Coastal Zone Management Act to review federal permits to ensure that they are consistent with state requirements. The Land Conservation and Development Commission adopts as part of the Oregon Coastal Management Program, and herein incorporates by reference, an amendment to the Territorial Sea Plan Part Four:

Uses of the Sea Floor, that the Commission approved on December 1, 2000 and November xx, 2023.

Statutory/Other Authority: ORS 183.310 - 550, ORS 196.465, ORS 196.471, ORS 197

Statutes/Other Implemented: ORS 196.465, ORS 196.471, ORS 197.040

RULE ATTACHMENTS DO NOT SHOW CHANGES. PLEASE CONTACT AGENCY REGARDING CHANGES.



Oregon Territorial Sea Plan: Part Four

Uses of the Seafloor

Adopted by LCDC **Insert Date Here**

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1. The State Perspective

1.1. Purpose

Part Four of the Oregon Territorial Sea Plan provides a strategic framework for the decision-making process, partnerships, and collaborative relationships for undersea infrastructure on, affixed to, or buried under the seafloor in the state territorial sea.

1.2. Goal

This strategic framework aims to maintain the long-term protection of marine ecosystems, preservation of their ecological functions, economic and social services, and, at the same time, protection of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea from potential threats in order to preserve the services the infrastructure provides Oregonians.

1.3. Objectives

This strategic framework identifies the following objectives to be achieved:

- a. Maintain and protect marine ecosystems, biological resources, migratory species, and areas that are of economic (e.g., fisheries, navigation), aesthetic, recreational, social, or historical importance to the people of Oregon, and could be impacted by infrastructure on, affixed to, or buried under the seafloor in the state territorial sea.
- b. Implement policies and recommendations for routing, construction, operation, maintenance, and decommission, including recycling, of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea.
- c. Engage communities, ocean users, industries, research institutes, and technical experts in decision-making on a state permit, license, lease, or other authorization for infrastructure on, affixed to, or buried under the seafloor in the state territorial sea.
- d. Facilitate coordination and cooperation among federal, state, and local agencies, and tribal governments in the permitting and planning process for infrastructure on, affixed to, or buried under the seafloor in the state territorial sea, and require that the applicant develop and update mitigation and accident response plans.
- e. Promote resilience of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea to climate change, natural disasters, extreme weather events, and human-made activities.
- f. Coordinate the development and installation of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea with the growing development of



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renewable energy facilities in the Pacific Northwest (e.g., offshore wind farms, hydrokinetic, solar, and hydrogen technologies).

- g. Continue current, and promote future, compatible use of the seafloor in the state territorial sea between various ocean users.

2. Background

Oregon's coast is a prime landing zone for fiber-optic telecommunication cables that cross the ocean floor from sites around the Pacific Rim. Other types of utilities such as ocean outfall pipes also make use of the seafloor. In the future, utilities such as pipelines and power transmission cables from renewable energy facilities, may eventually be routed across the seafloor of the state territorial sea. Proper placement of easements and installation of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea is required to avoid damage to or conflict with other ocean uses, such as commercial fishing, and to avoid, minimize, and mitigate adverse effects on natural resources, marine habitats, and coastal communities.

State agencies, such as the Department of State Lands (DSL), the Department of Environmental Quality (DEQ), the Department of Fish and Wildlife (ODFW), the Oregon Parks and Recreation Department (OPRD) including the State Historic Preservation Office (SHPO), and the Department of Land Conservation and Development (DLCD), need specific policies and standards for considering the routing and installation of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea. The policies and standards within the Territorial Sea Plan can also assist federal agencies in the siting and regulation of infrastructure located in federal waters adjacent to the territorial sea.

The Land Conservation and Development Commission adopted Part Four of the Territorial Sea Plan on December 1, 2000, based on a January 28, 2000 recommendation from the Ocean Policy Advisory Council (OPAC). These amendments are consistent with administrative rules adopted by the Oregon State Land Board in August 1999, governing easements for submarine fiber-optic cables. Part Four was updated based on recommendations made from the Ocean Policy Advisory Council on September 8th, 2023. The Land Conservation and Development Commission adopted this update on **xx/xx**.

2.1. International Law & Treaty Obligations

In implementing this strategic framework, the state recognizes international agreements intended to provide adequate oversight and protection of federal and state concerns regarding seafloor development actions.

- International Convention for the Protection of Submarine Telegraph Cables (1884).
- The United Nations Convention on the Continental Shelf (1958).
- The United Nations Convention on the High Seas (1958).



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- The United Nations Convention on the Law of the Sea (1982).¹
- The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997).
- The United Nations Framework Convention on Climate Change (1992) and the Paris Agreement (2015).

In addition to those international agreements, various federal, state, and local agencies and authorities are involved in the permitting process related to seafloor development in Oregon. The routes of seafloor infrastructure can pass through many jurisdictions, and therefore, require authorizations from multiple agencies for installation and construction.

2.2. Federal

The state should consider consulting with the following (but not limited to) federal agencies with a role in permitting seafloor development: The National Oceanic and Atmospheric Administration (NOAA) and the United States Army Corps of Engineers (USACE). Additionally, for offshore renewable energy facilities addressed in Part Five: the Bureau of Ocean Energy Management (BOEM) and the Federal Energy Regulatory Commission (FERC) play roles in permitting and leasing.

In addition to the federal laws identified in Part One, subsection D.4, under federal law undersea cable systems are, and pipelines and other utilities may also be, considered vulnerable critical infrastructure. The USA PATRIOT Act of 2001 and the Critical Infrastructure Information Act of 2002 aim to protect critical infrastructure and facilitate sharing of critical infrastructure information among the owners and operators of the facilities and government agencies with infrastructure protection responsibilities.

The Cybersecurity and Infrastructure Security Agency (CISA) considers 16 critical infrastructure sectors, including communication, energy, information technology, and water and wastewater systems.²

Critical infrastructure is subject to risks associated with physical threats and natural disasters. It is also now increasingly exposed to cyber risks. In addition, connections and interdependencies between infrastructure elements and sectors mean that damage, disruption, or destruction to one infrastructure element can cause cascading effects, impacting the continued operation of another.

¹ The United States has signed the Agreement but has not ratified it. See Part One, subsection D.5 for background.

² The Department of Homeland Security Critical Infrastructure Sectors <https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors>



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A Guide to Critical Infrastructure Security and Resilience prepared by CISA³ highlights the Cascadia Subduction Zone earthquake preparedness in the Pacific Northwest as a case that requires cooperation among federal, state, local agencies, and the private sector to improve the resilience of critical infrastructure, including telecommunication cables, pipelines, and other utilities.

2.3. State

Seafloor development within the Territorial Sea may require authorizations, permits, certifications, determinations, and easements from DSL, OPRD including SHPO, DEQ, and DLCD. The enforceable policies (See Appendix C) of the Territorial Sea Plan Part Four, incorporated by NOAA's Office for Coastal Management (OCM) into the Oregon Coastal Management Program, are applicable to those federal actions that affect Oregon's coastal zone and are subject to the federal consistency requirements of the federal Coastal Zone Management Act.

2.4. Tribal

State and federal laws applicable to permitting process for seafloor development provide for communication and coordination between the state and the federally recognized tribes. Coordination with the tribal peoples native to Oregon affords the opportunity to learn traditional ecological knowledge and perspective important to the protection of tribal cultural resources. During the last glacial maximum, 19,000 years before present, Oregon's coastline was 61 kilometers west of the modern coast in some areas¹. Archaeological evidence shows people living in Oregon for at least 18,000 years and many tribal traditions say tribal people have inhabited Oregon for time immemorial²³. Ancient Oregon coastlines have moved significantly since that time. During a single generation precontact inhabitants of the coast might see the shoreline move eastward 0.5-1.35 meters/year⁴. The ancient Pacific coastline is considered by many scholars to have been a migration route and many archaeological sites are located on coastlines worldwide⁵. With the above facts in mind, the likelihood of archaeological sites along the prehistoric Oregon coast is high. According to Oregon statute, archaeological sites occurring on submerged and submersible lands or the bed of the sea within the state's jurisdiction may not be altered or excavated without a permit from the Oregon Parks and Recreation Department issued to a professional archaeologist⁶.

¹ [Inventory Pacific Submerged Archaeology Sites BOEM 2013.pdf](#)

² [Field site shows evidence of humans in Oregon 18,000 years ago | Around the O \(uoregon.edu\)](#)

³ [Essential Understandings of Native Americans in Oregon \(oregon.gov\)](#)

⁴ [Inventory Pacific Submerged Archaeology Sites BOEM 2013.pdf](#)

⁵ Loren G. Davis, David B. Madsen, The coastal migration theory: Formulation and testable hypotheses, Quaternary Science Reviews, Volume 249, 2020

⁶ ORS 390.235



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2.5. Local

Local counties, municipalities, or special districts may have jurisdiction and may have requirements for an onshore component of a seafloor development; such development actions need to be consistent with local land use planning. The most common approvals required include, but are not limited to, conditional use permits or development permits.

3. Policies

These policies and the implementation requirements of the following section are mandatory.⁴ Decisions of state agencies with respect to approvals of permits, licenses, leases or other authorizations for routing, construction, operation, maintenance, and decommission, including recycling, of any cables, pipelines, utilities or fixtures on, affixed to, or buried under the seafloor in the state territorial sea and or connected from the seafloor to the ocean shore must comply with the requirements of the Oregon Territorial Sea Plan.

An applicant for a project or development action within or affecting the Oregon Territorial Sea shall:

Design and site projects and infrastructure responsibly such that proposed seafloor development actions will maintain and protect to the maximum extent practicable, natural resources, ecosystem integrity, marine habitat, and areas important to fisheries, navigation, recreation, and aesthetic enjoyment from adverse effects that may be caused by said development actions. For purposes of this section, 'Maintain and protect' requires mitigation, in order of priority:

- 1) Avoiding the impact altogether by not taking a certain development action or parts of that action;
- 2) Minimizing impacts by limiting the degree, magnitude, or timing of the development action and its implementation;
- 3) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- 4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the development action and by monitoring and taking appropriate corrective measures; and
- 5) Compensating for the impact. Either monetary compensation or by replacing or providing comparable substitute resources or environments.

³ A Guide to Critical Infrastructure Security and Resilience
<https://www.cisa.gov/sites/default/files/publications/Guide-Critical-Infrastructure-Security-Resilience-110819-508v2.pdf>; see also CISA National Critical Functions Set
<https://www.cisa.gov/sites/default/files/publications/national-critical-functions-set-508.pdf>

⁴ Notwithstanding Territorial Sea Plan Part One, paragraph F.1.b.



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When making decisions to approve projects or development actions, regulating state agencies shall promote direct communication and collaboration between the applicant and interested and affected ocean users as identified by the Joint Agency Review Team (JART) under 4.2.2 to mitigate potential conflicts.

4. Implementation Requirements

Applicants shall adhere to these implementation requirements during all project phases related to infrastructure on, affixed to, or buried under the seafloor in the state territorial sea. This includes utility cables that transmit electrical energy from a renewable energy facility to the onshore substation, as prescribed in Part Five of the Territorial Sea Plan, Use of the Territorial Sea for the Development of Renewable Energy Facilities or Other Related Structures, Equipment or Facilities. The requirements in Part Two, Making Resource Use Decisions, sections A and B will not apply to development actions related to cables, pipelines, or other utilities or fixtures on, affixed to, or buried under the seafloor within the Oregon Territorial Sea.

When approving development actions or projects, state agencies shall mitigate (see definition in Appendix A) conflicts or adverse effects on natural resources or other ocean users through the following measures:

4.1. Agency Communication, Coordination, & Review Requirements

State agencies shall apply the policies and provisions of the Oregon Ocean Resources Management Plan, Oregon Territorial Sea Plan, and Statewide Planning Goals as required to comply with State Agency Coordination Programs (OAR chapter 660, divisions 30 and 31).

In accordance with the federal Coastal Zone Management Act, federal consistency regulations (15 CFR Part 930), and ORS 196.435, DLCD will review the consistency certification together with required necessary data and information submitted by the applicant for federal authorization for development actions related to cables, pipelines, or other utilities or fixtures on, affixed to, or buried under the seafloor within the state territorial sea to determine whether the development action is consistent with enforceable policies of the Oregon Coastal Management Program, including the Oregon Territorial Sea Plan.

DSL shall coordinate the review of applications for easements and permits in the state territorial sea in consultation with the JART as described in the next section.



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4.2. Joint Agency Review Team

The purpose of the JART is to facilitate coordination and communication between state agencies in the early stages of project planning, and between representatives of other affected jurisdictions throughout the pre-application and application process. When an applicant requests a pre-application meeting with DSL, DSL shall convene the JART for the pre-application meeting and application meeting. If the cable or fixture is associated with a renewable energy facility, the JART convened under Part Five shall also serve as the JART for purposes of Part Four coordination, with any additional membership needed to meet the requirements below. DSL may also convene the JART as necessary for follow-up meetings in order to facilitate the coordination of state and federal agencies, and local jurisdictions, as they apply their separate regulatory, proprietary, or other authorities to the review of a proposed project within the state territorial sea.

4.2.1. JART Composition

DSL shall invite representatives from the following state agencies to the coordination meetings:

- 1) ODFW, OPRD including SHPO, DEQ, DLCD, Department of Geology and Mineral Industries, and other agencies with regulatory or planning authority, or advisory expertise, applicable to the proposed project or development action and location as necessary.

The state agencies shall identify the areas affected by the proposed project or development action. Thereafter, DSL shall invite representatives from the following agencies, jurisdictions, and organizations from affected areas to the coordination meetings:

- 2) Federal agencies, with regulatory or planning authority applicable to the proposed project or development action and location;
- 3) Federally recognized Coastal Tribes in Oregon;
- 4) Local jurisdictions including representatives from affected cities, counties, and their affected communities, and affected special districts as appropriate; and,
- 5) Statewide and local organizations and advisory committees, to participate in the JART application of specific standards, including but not limited to those addressing areas important to fisheries, ecological resources, recreational and visual impacts.

4.2.2. JART Roles & Responsibilities



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- 1) The JART will coordinate with DSL on the pre-application review process, and comment on the adequacy of the resource inventories and effects evaluations required under subsection 4.3 (Resource and Use Inventory and Effects Evaluation).
- 2) The JART will make recommendations to DSL on the approval of state territorial sea easements and other authorizations, and to other applicable regulatory agencies on their decision to permit, license or authorize a proposed project or development action in the state territorial sea.
- 3) The JART comments and recommendations are advisory; regulating agencies who are members of the JART still operate in accordance with their own rules and statutory mandates.
- 4) DSL may acquire the services of technical experts at the reasonable expense of the applicant to assist the JART as necessary to conduct the application review.
- 5) The JART shall identify affected ocean users, local communities, and representatives that applicants must consult with in order to mitigate potential conflict.



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4.3. Resource & Use Inventory & Effects Evaluation

An applicant shall provide the regulating agencies the data and information to complete the Resource and Use Inventory and Effects Evaluation, prior to the regulating agencies making any decision. DSL, upon consultation with the state agencies identified in 4.2.1, may waive any information or evaluation requirement of this Section 4.3 determined to be unnecessary for evaluating the coastal effects of the development action or project under Part Four.

4.3.1. Purpose of Resource & Use Inventory & Effects Evaluation

The purpose of the Resource and Use Inventory and Effects Evaluation is to provide the regulating agencies the data and information necessary to make a decision based on the project or development action's potential coastal effects. The Resource and Use Inventory and Effects Evaluation will help identify if the applicant needs to address potential use conflicts with the proposed project or development action. The regulating agency will use the evaluation to develop specific measures for environmental protection and mitigation as well as measures to protect other ocean uses.

4.3.2. Sufficiency of Resource & Use Inventory & Effects Evaluation

An applicant must provide, during the pre-application and application phases, information and data to complete the Resource and Use Inventory and Effects Evaluation that is sufficient to identify and quantify the short-term and long-term effects of the proposed project or development action in the state territorial sea on the affected natural resources and uses.

4.3.3. Use of Available Environmental Information

Regulating agencies may allow the applicant to use existing data and information from a project application to a federal agency or other authoritative sources, when complying with the requirements for the Resource and Use Inventory and Effects Evaluation.

4.3.4. Inventory Content

The applicant shall provide information and data sufficient to determine the scope, likelihood, and significance of reasonably anticipated potential effects to coastal resources and uses. The Resource and Use Inventory and Effects Evaluation provisions listed below apply to all proposed cables, pipelines, utilities or fixtures within the territorial sea for which an applicant pursues a DSL state territorial sea easement, unless the requirements are otherwise addressed in another part of the Territorial Sea Plan or the requirements were waived as described in section 4.3.



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4.3.4.1. Information to be provided by applicants about the proposed project or development action within the Oregon Territorial Sea:

- (a) Location (using maps, charts, descriptions, etc.);
- (b) Numbers and sizes of equipment, structures;
- (c) Methods, techniques, activities to be used;
- (d) Transportation and transmission systems needed for service and support;
- (e) Materials to be disposed of and method of disposal;
- (f) Physical and chemical properties of materials, if any, to be used or produced (e.g., chemicals used in horizontal directional drilling (HDD), materials which may be transported by a pipeline, etc.); and
- (g) Proposed time schedule.

4.3.4.2. Location and description of all affected areas, including, but not limited to:

- (a) Proposed route of the cable, pipeline, or other utility; and
- (b) Onshore facilities.

Additionally for pipelines or other utilities or fixtures:

- (a) Adjacent areas that may be affected by physical changes in currents and waves caused by the project or development action;

4.3.4.3. Physical and chemical conditions including, but not limited to:

- (a) Bathymetry (bottom topography) and Shoreline Topography, including profile of water depth along the route;

Additionally for pipelines or other utilities or fixtures:

- (a) wave regime;



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- (b) typical and maximum current velocities; and
- (c) dispersal characteristics.

4.3.4.4. Geologic structure, including, but not limited to:

- (a) Geophysical imaging and geotechnical investigation of full planned HDD routes across the shoreline sufficient to characterize subsurface geotechnical properties and plan HDD construction in a way that avoids drill pipe breakage, inadvertent return, surface settlement, and other complications.
- (b) Geologic hazards, such as faults or landslides;
- (c) Mineral deposits; and
- (d) Seafloor substrate type.

4.3.4.5. Biological and ecological features affected by the project or development action, including, but not limited to:

- (a) All habitats along the proposed route, specifically including critical marine habitats (see Part Four, Appendix A)
- (b) Recreationally or commercially important finfish or shellfish species;
- (c) Benthic flora and fauna that may be affected by the project or development action; and
- (d) Other ecosystem elements that may be affected by the project or development action.

4.3.4.6. Cultural, economic, and social uses affected by the project or development action, including, but not limited to:

- (a) Commercial and sport fishing;
- (b) State or federally protected areas;
- (c) Scientific research;



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- (d) Ports, navigation, and dredge material disposal sites;
- (e) Recreation;
- (f) Coastal community economy;
- (g) Aquaculture facilities;
- (h) Wastewater or other discharge;
- (i) Utility or pipeline corridors and transmission lines;
- (j) Military uses; and
- (k) Aesthetic resources.

4.3.4.7. Significant historical, cultural or archeological resources.

4.3.4.8. Other data that the regulating agencies determine to be necessary and appropriate to evaluate the effects of the proposed project or development action.

4.3.5. Written Evaluation

An applicant shall submit a written evaluation of the reasonably foreseeable adverse effects associated with projects or development actions within or affecting the Oregon Territorial Sea. For purposes of the evaluation, the submittal shall base the determination of "reasonably foreseeable adverse effects" on scientific evidence and how the applicant mitigated any impacts in the design and siting phases of a project or development action. The evaluation shall describe the potential short-term and long-term effects of the proposed project or development action to state coastal resources and uses of the Oregon Territorial Sea, continental shelf, estuaries, onshore areas and coastal communities based on the inventory data listed above and the following considerations:

4.3.5.1. Biological and Ecological Effects:

Biological and ecological effects include those on marine habitats and on the species those habitats support. The evaluation need not discuss highly speculative consequences. However, the evaluation shall discuss possible outcomes that are either likely to occur or catastrophic environmental effects of low probability. Factors to consider include, but are not limited to:



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- (a) The time frames/periods over which the effects will occur;
- (b) The maintenance of ecosystem structure, biological productivity, biological diversity, and representative species assemblages;
- (c) Maintaining populations of threatened, endangered, or sensitive species;
- (d) Vulnerability of the species, population, community, or the habitat to the proposed actions; and
- (e) The probability of exposure of biological communities and habitats to adverse effects from construction, operating or decommissioning procedures, or accidents.

4.3.5.2. Current Uses:

Evaluate the effects of the project or development action on current uses and the continuation of a current use of ocean resources.

Factors to consider include, but are not limited to:

- (a) Local and regional economies;
- (b) Archeological and historical resources;
- (c) Transportation safety and navigation;
- (d) Recreational uses;
- (e) Fisheries;
- (f) Cultural uses; and,
- (g) Aesthetics.

4.3.5.3. Natural and Other Hazards:

Evaluate the potential risks to the project or development action, in terms of its vulnerability to certain hazards and the probability that those hazards may cause loss, dislodging, or drifting of infrastructure. Consider both the severity of the hazard and the level of exposure it poses to natural resources and coastal communities. Hazards to be considered shall include slope failures and subsurface landslides, faulting, tsunamis, variable or irregular bottom



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topography, weather related, or due to human cause. Additionally, evaluate potential for horizontal directional drilling complications that could affect natural resources and coastal communities and describe plans to minimize these hazards based on site-specific subsurface geotechnical characteristics.

4.3.5.4. Cumulative Effects:

Evaluate the cumulative effects of a project or development action, including the onshore component, in conjunction with effects of any past projects, other current projects, and probable future projects. The evaluation shall analyze the biological, ecological, physical, cultural, and socioeconomic effects of the proposed project or development action and other projects along the Oregon coast, while also taking into account the effects of existing and future human activities and the regional effects of global climate change.

In conducting the cumulative effects analysis, the applicant shall focus on the specific resources and uses, as inventoried under section 4.3.4 that may be affected by the incremental effects of the proposed project or development action and other projects in the same geographic area. The evaluation shall include but not be limited to consideration of whether:

- a. the resource and uses are especially vulnerable to incremental effects;
- b. the proposed project or development action is one of several similar projects in the same geographic area;
- c. other developments in the area have similar effects on the resources and uses;
- d. these effects have been historically significant for the resource and uses; and
- e. other analyses in the area have identified a cumulative effects concern.



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4.4. Routing & Landing

Locations for new infrastructure within the state territorial sea shall, to the extent practicable, preserve access to ocean fisheries, avoid conflicts with other uses, protect marine habitats, and minimize adverse effects on other natural resources of the seafloor or ocean shore. DSL shall consider the benefit of implementing corridors for infrastructure crossing the territorial sea while maintaining adequate distance for servicing of infrastructure and shall determine when the state territorial sea has reached carrying capacity for new easements. DSL may require new easements to be located as close to existing easements as possible or with sufficient capacity to enable future expansion within the approved right of way. DSL shall not grant easements through marine reserves, marine protected areas, rocky habitats designated as a Marine Research Area, Marine Garden, or Marine Conservation Area under Part Three, and shall not grant easements on rocky habitat areas within the state territorial sea.

4.5. Installation

4.5.1. Cable Burial: All seafloor cables shall be buried so as to achieve and maintain continuous burial unless DSL finds that burial cannot be practicably achieved and that adverse effects of not burying the cable have been avoided, minimized, or mitigated to the maximum extent practicable.

4.5.1.1. DSL may base findings for 4.5.1 on written evidence of communication between an applicant and affected ocean users.

4.5.1.2. Burial Verification: The applicant shall verify burial to DSL by written assurance. The state may require photographic or other evidence of burial from the applicant.

4.6. Maintenance

DSL shall require that cables, pipelines, utilities, or fixtures be inspected as part of installation. Inspections after installation shall occur as otherwise required by a regulatory agency, and after any major geologic event, such as subduction- zone earthquake, to confirm continued burial and or infrastructure integrity.

4.7. Decommission & Recovery

After the usable, operational, or design life of seafloor infrastructure or fixture an owner or operator shall decommission any infrastructure or fixtures, removing them from the seabed. The owner or operator of the seafloor infrastructure or



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fixture shall submit a decommissioning plan to DSL for approval pursuant to the terms and conditions of the easement.

There may be cases where the removal of discrete portions of seafloor infrastructure or fixtures is more environmentally damaging than leaving it in situ. In such cases, the owner or operator shall submit to DSL a complete application for an encroachment easement, as provided in OAR chapter 141, division 123. The application shall include a written assessment of the environmental impacts and coastal effects which demonstrates the lesser overall impact to the environment by leaving sections of seafloor infrastructure or fixtures in place and provides justification for leaving said portions of the infrastructure or fixture in place.

5. Communication & Cooperative Mechanisms

DSL may consider written agreements between the applicant and fishers or other users as evidence of communication and coordination when necessary to provide evidence that an applicant has mitigated use conflict to the maximum extent practicable. Such agreements or other documentation of coordination may coordinate work, determine preferred routing, identify routes, respond to emergencies, provide for mitigation of adverse effects, or specify procedures for on-going communication and dispute resolution.

6. Territorial Sea Plan Review

The Ocean Policy Advisory Council (OPAC) shall review the Oregon Territorial Sea Plan Part Four no longer than seven years after LCDC has adopted it. OPAC may, at any time, choose to initiate an amendment of the plan through the process described under Part One, section F.2, Changing the Plan and ORS 196.443(1)(a).

Appendix A: Definitions & Terms

The following definitions shall apply to Part Four, unless the context requires otherwise:

Affix(ed): To attach to the seafloor in a permanent way.

Archaeological Resources: Those districts, sites, buildings, structures, and artifacts which possess material evidence of human life and culture of the prehistoric and historic past. (See Historical Resources definition.)

Areas important to fisheries: (Goal 19)



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- a.) areas of high catch (e.g., high total pounds landed and high value of landed catch);
- b.) areas where highly valued fish are caught even if in low abundance or by few fishers;
- c.) areas that are important on a seasonal basis;
- d.) areas important to commercial or recreational fishing activities, including those of individual ports or particular fleets; or
- e.) habitat areas that support food or prey species important to commercially and recreationally caught fish and shellfish species.

Applicant: The person or party responsible for acquiring a state permit, license, lease or other authorization for the evaluation, siting, routing, placement, operation, or removal of a cable, pipeline, utility or fixture placed on, affixed to, or buried under the seafloor in the state territorial sea will be referred to as “the applicant”.

Avoid: To prevent or eliminate an effect from a project or development action.

Benthic: Living on or within the bottom sediments in water bodies.

Burial: To place into the seabed below the local mean surface of the ocean floor at the time of burial.

Cable(s): includes a cable used to conduct electricity or light that is placed on, affixed to, or buried under state-owned submerged or submersible lands within the territorial sea and any facilities within the territorial sea associated with the cable.

Carrying Capacity: Level of use which can be accommodated and continued without irreversible impairment of natural resources productivity, the ecosystem and the quality of air, land, and water resources.

Coastal Zone: The area lying between the Washington border on the north to the California border on the south, bounded on the west by the extent of the state's jurisdiction, and in the east by the crest of the coastal mountain range, with the exception of: (a) The Umpqua River basin, where the coastal zone shall extend to Scottsburg; (b) The Rogue River basin, where the coastal zone shall extend to Agness; (c) The Columbia River basin, where the coastal zone shall extend to the downstream end of Puget Island. (*Formerly* ORS 191.110)

Continental Shelf: The area seaward from the ocean shore to the distance when the ocean depth is 200 meters, or where the ocean floor slopes more steeply to the deep ocean floor. The area beyond the state's jurisdiction is the OUTER Continental Shelf.

Critical infrastructure: Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.



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Critical Marine Habitat: means one or more of the following areas designated within the territorial sea:

- a.) as “critical habitat” in accordance with federal laws governing threatened and endangered species;
- b.) “rocky habitat conservation areas” designated under Part Three;
- c.) areas necessary for the survival of animal or plant species listed by state or federal laws as “threatened”, “endangered”, or “sensitive”;
- d.) for scientific research or education within the territorial sea;
- e.) as essential fish habitat; or
- f.) as marine reserves or marine protected areas.

Develop: To bring about growth or availability; to construct or alter a structure, to conduct a mining operation, to make a physical change in the use or appearance of land, to divide land into parcels, or to create or terminate rights to access.

Development: The act, process or result of developing.

Development Action: Any activity related to infrastructure on, affixed to, or buried under the seafloor within or affecting the state territorial sea which is subject to regulation by local, state, or federal agencies that could result in adverse impacts to natural resources or conflict with other ocean users. Development actions also include, but are not limited to, subsequent re-permitting for activities with new impacts or continued impacts that have not been mitigated consistent with current standards.

Diversity: The variety of natural, environmental, economic, and social resources, values, benefits, and activities.

Ecosystem: the living and non-living components of the environment which interact or function together, including plant and animal organisms, the physical environment, and the energy systems in which they exist. All the components of an ecosystem are interrelated. (Oregon Statewide Planning Goals)

Fixture(s) includes any structure affixed to or permanently placed on the seafloor, not otherwise defined in this glossary, including but not limited to scientific and research devices, observation devices, or other structure requiring a Territorial Sea easement or other authorization but not otherwise governed by another section of the Territorial Sea Plan.

Geologic: Relating to the occurrence and properties of earth. Geologic hazards include faults, land and mudslides, and earthquakes.

Habitat: the environment in which an organism, species, or community lives. Just as humans live in houses, within neighborhoods, within a town or geographic area, within a certain region, and so on, marine organisms live in habitats which may be referred to at different scales. (see also “critical marine habitat”)



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Historical Resources: Those districts, sites, buildings, structures, and artifacts which have a relationship to events or conditions of the human past. (See Archaeological Resources definition.)

Impact: is the severity, intensity, or duration of the adverse effect.

Infrastructure: The physical assets that provide the foundation or basic framework for a utility (telecommunications, energy, material transfer, etc) on, affixed to, or buried under the seafloor within or affecting the state territorial sea. Examples include, but are not limited to, telecommunications cables, power transmission cables, pipelines, and fixtures.

Integrity: The quality or state of being complete and functionally unimpaired; the wholeness or entirety of a body or system, including its parts, materials, and processes. The integrity of an ecosystem emphasizes the interrelatedness of all parts and the unity of its whole.

LCDC: The Land Conservation and Development Commission of the State of Oregon. The members appointed by the Governor and confirmed by the Oregon Senate in accordance with the requirements of ORS 197.030.

Maintain: Support, keep, and continue in an existing state or condition without decline.

Minimize: to reduce or limit the effect to the maximum extent practicable.

Mitigate: taking one or more of the following actions listed in order of priority:

- (a) Avoiding the impact altogether by not taking a certain development action or parts of that action;
- (b) Minimizing impacts by limiting the degree, magnitude, or timing of the development action and its implementation
- (c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- (d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the development action and by monitoring and taking appropriate corrective measures;
- (e) Compensating for the impact. Either monetary compensation or by replacing or providing comparable substitute resources or environments.

Natural Resources: Air, land and water and the elements thereof which are valued for their existing and potential usefulness to man.

Owner or operator: Means the legal owner of the infrastructure or fixture and or long-term holder of an easement.



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Pipeline(s) includes any line of pipe, with or without equipped pumps, valves, and other control devices, used to move liquids, gasses, or slurries.

Practicable: Reasonably capable of being put into practice or of being done or accomplished.

Preserve: To save from change or loss and reserve for a special purpose.

Project: the evaluation, siting, routing, placement, operation, decommission, or removal of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea.

Protect: Save or shield from loss, destruction, or injury or for future intended use.

Provide: Prepare, plan for, and supply what is needed.

Quality: The degree of excellence or relative goodness.

Recreation: Any experience voluntarily engaged in largely during leisure (discretionary time) from which the individual derives satisfaction.

Coastal Recreation occurs in offshore ocean waters, estuaries, and streams, along beaches and bluffs, and in adjacent shorelands. It includes a variety of activities, from swimming, scuba diving, board sports, boating, fishing, hunting, and use of dune buggies, shell collecting, painting, wildlife observation, and sightseeing, to coastal resorts and water-oriented restaurants.

Low-Intensity Recreation does not require developed facilities and can be accommodated without change to the area or resource. For example, boating, hunting, hiking, wildlife photography, and beach or shore activities can be low intensity recreation.

High-Intensity Recreation uses specially built facilities, or occurs in such density or form that it requires or results in a modification of the area or resource. Campgrounds, golf courses, public beaches, and marinas are examples of high intensity recreation.

Regulating agency or regulating agencies: State agencies making decisions to authorize projects or development actions on, affixed to, or buried under the seafloor in the state territorial sea.

Restore: Revitalizing, returning, or replacing original attributes and amenities, such as natural biological productivity, aesthetic and cultural resources, which have been diminished or lost by past alterations, activities, or catastrophic events. For the purposes of Part Four of the Territorial Sea Plan restoration means to revitalize or reestablish functional characteristics and processes of the seafloor diminished or lost by past alterations, activities, or catastrophic events.

Active Restoration: involves the use of specific positive remedial actions, such as removing fills and infrastructure (cables, pipelines, other utilities or fixtures) to return a site to functional and sustainable use.

Passive Restoration: Allowing natural processes, sequences, and timing to occur in an ecosystem to return a site to functional and sustainable use.

Seafloor: The solid surface underlying the ocean. Specifically, within Part Four of the Oregon Territorial Sea Plan, the submerged or submersible lands within the boundaries of the state territorial sea.

Shoreline: The boundary line between a body of water and the land, measured on tidal waters at mean higher high water, and on non-tidal waterways at the ordinary highwater mark.

Substrate: The medium upon which an organism lives and grows. The surface of the land or bottom of a water body.

Territorial Sea: The ocean and seafloor area from mean low water seaward three nautical miles.

User: an individual, group or entity that makes use of the territorial sea and adjacent rocky intertidal, whether it is for traditional, recreational, educational, commercial or other purposes.

Utility/utilities includes any infrastructure affixed to or placed on the seafloor, not otherwise defined in this glossary, which provide the public with an essential good or service (heat, gas, electricity, water, sewage treatment, data, etc).

Appendix B: Maps

Territorial Sea Plan Part Four - Appendix B Map

Undersea Cable Routes (as of July, 2023)



Part Four Appendix C: Enforceable Policies Subject to Federal Consistency

This Appendix lists the provisions of Part Four that constitute the “enforceable policies” for Federal Consistency purposes, under the CZMA and pursuant to the Federal Consistency Regulations at 15 CFR Part 930. The federal Coastal Zone Management Act requires that certain federally permitted or licensed activities that affect coastal uses or resources must be conducted in a manner consistent with the enforceable policies of a state’s federally approved coastal management program. When reviewing federal decisions to permit or license seafloor development actions or projects for consistency with the OCMP the Department of Land Conservation and Development will apply the following sections of TSP Part Four as enforceable policies:

Note: The exact text for each of the sections will be included here once the text is finalized and approved.

81st OREGON LEGISLATIVE ASSEMBLY--2021 Regular Session

Enrolled House Bill 2603

Sponsored by Representative GOMBERG (Presession filed.)

CHAPTER

AN ACT

Relating to undersea cables; and prescribing an effective date.

Be It Enacted by the People of the State of Oregon:

SECTION 1. (1) As used in this section, “undersea cable” includes a cable used to conduct electricity or light that is placed on state-owned submerged or submersible lands within the territorial sea and any facilities associated with the cable.

(2) An applicant for an easement to place an undersea cable within the territorial sea shall acquire and maintain, until construction of the undersea cable is completed, financial assurance to ensure that the applicant constructs the undersea cable according to the terms and conditions of the easement. The amount of financial assurance required under this subsection shall be an amount determined by the Department of State Lands to be sufficient based on the scale of the project.

(3) At least 180 days before decommissioning an undersea cable, the owner or operator of the undersea cable shall submit to the department for approval a decommissioning plan that includes:

(a) A cost estimate, prepared by a person qualified by experience and knowledge to prepare the estimate, for decommissioning the cable and restoring the area authorized by the easement to a natural condition;

(b) A detailed description of and proposed schedule for the decommissioning and restoration work, including any corrective action that may be required under the easement;

(c) A detailed description of segments of bore pipe and undersea cable proposed to be left in place to avoid or minimize impacts to aquatic resources; and

(d) A proposed form of financial assurance in an amount equal to the cost estimate under paragraph (a) of this subsection.

(4) Within 30 days of receiving a decommissioning plan under subsection (3) of this section, the department shall approve the plan or request revisions to the plan or additional information. If, after receiving revisions to the decommissioning plan or additional information, the department rejects the plan, the owner or operator of the undersea cable must within 90 days submit to the department an application for an easement for the encroachment created by the undersea cable.

(5) The owner or operator of an undersea cable may not begin decommissioning and restoration work unless:

(a) The department has approved a decommissioning plan under subsection (4) of this section;

(b) The owner or operator has acquired the financial assurance required under subsection (3) of this section; and

(c) The owner or operator has provided to the department notice that the work will begin at least 60 days prior to beginning the work.

(6) The financial assurance requirements established by subsections (2) and (3) of this section may be satisfied by furnishing a financial assurance instrument that is:

(a) A surety bond, cash deposit or certificate of deposit; and

(b) In the name of the State of Oregon.

SECTION 2. (1) The Department of Land Conservation and Development, in consultation with the Department of State Lands and relevant local governments and tribal governments, shall review the part of the Territorial Sea Plan that addresses the placement of cables, pipelines and other utilities in the territorial sea. The review must consider fee structures and state and federal review processes, including permitting processes, for the placement of undersea cables on state-owned submerged or submersible land within the territorial sea and under the ocean shore and the siting of associated landing sites. The Department of Land Conservation and Development shall provide the results of the review to the Ocean Policy Advisory Council.

(2) The Ocean Policy Advisory Council shall develop recommendations for amendments to the part of the Territorial Sea Plan that addresses the placement of cables, pipelines and other utilities in the territorial sea. In developing recommendations, the council shall consider the review provided to the council under subsection (1) of this section and evaluate:

(a) A coordinated permitting process for the placement of undersea cables that allows for coordination between appropriate state agencies, tribal governments and local governments.

(b) Suitable landing sites, including a mapping analysis of opportunities, limitations and requirements for landing sites.

(c) The impact of other state agencies, laws, zoning requirements or statewide planning goals on potential undersea cable sites.

(d) Changes to fees structures and financing associated with administrative costs and the protection and management of the territorial sea and ocean shore.

(e) Requirements for public information meetings or other methods for engaging communities, tribal governments, ocean users and industries affected by a proposed undersea cable.

(f) The impact of drilling on biological resources, including migratory species, and on resources that are of economic, aesthetic, recreational, social or historic importance to the people of this state.

(g) An application process that may include:

(A) A needs analysis that takes into account the socioeconomic and environmental needs of the area;

(B) A geological study conducted by a registered professional geologist experienced in coastal processes;

(C) Consultation with Oregon sea floor experts, such as an expert affiliated with an Oregon university; and

(D) A detailed drilling, mitigation and accident response plan.

(h) Requirements for interagency preapplication process meetings.

(i) Standards for undersea cables in the States of California and Washington.

(j) Coordination with tribal governments on potential impacts of undersea cables on cultural and traditional resources.

(3) The council may consult with any of the following state agencies when developing recommendations for amendments under this section:

(a) The State Parks and Recreation Department;

(b) The Department of Environmental Quality;

(c) The State Department of Fish and Wildlife;

- (d) The State Department of Geology and Mineral Industries; or
- (e) Any other state agency with relevant expertise.

SECTION 3. The Ocean Policy Advisory Council shall develop recommendations for amendments to the Territorial Sea Plan under section 2 of this 2021 Act no later than two years after the effective date of this 2021 Act.

SECTION 4. Sections 2 and 3 of this 2021 Act are repealed on January 2, 2024.

SECTION 5. (1) Section 1 of this 2021 Act becomes operative on January 1, 2022.

(2) The Department of State Lands may take any action before the operative date specified in subsection (1) of this section that is necessary for the department to exercise, on and after the operative date specified in subsection (1) of this section, all of the duties, functions and powers conferred on the department by section 1 of this 2021 Act.

SECTION 6. Notwithstanding any other provision of law, the General Fund appropriation made to the Department of Land Conservation and Development by section 1 (1), chapter _____, Oregon Laws 2021 (Enrolled Senate Bill 5530), for the biennium beginning July 1, 2021, is increased by \$497,081 for the implementation of section 2 of this 2021 Act.

SECTION 7. Notwithstanding any other law limiting expenditures, the amount of \$196,176 is established, for the biennium beginning July 1, 2021, as the maximum limit for payment of expenses from fees, moneys or other revenues, including Miscellaneous Receipts, but excluding lottery funds, federal funds and funds described in section 2, chapter _____, Oregon Laws 2021 (Enrolled Senate Bill 5539), collected or received by the Department of State Lands, for the implementation of section 2 of this 2021 Act.

SECTION 8. This 2021 Act takes effect on the 91st day after the date on which the 2021 regular session of the Eighty-first Legislative Assembly adjourns sine die.

Passed by House June 25, 2021

Received by Governor:

.....M.,....., 2021

.....
Timothy G. Sekerak, Chief Clerk of House

Approved:

.....M.,....., 2021

.....
Tina Kotek, Speaker of House

.....
Kate Brown, Governor

Passed by Senate June 26, 2021

Filed in Office of Secretary of State:

.....
Peter Courtney, President of Senate

.....M.,....., 2021

.....
Shemia Fagan, Secretary of State

State of Oregon
Oregon Department of Geology and Mineral Industries
Ruarri J. Day-Stirrat, State Geologist

SPECIAL PAPER 54

**GEOLOGIC ASSESSMENT OF POTENTIAL CABLE LANDING SITES ALONG
THE OREGON COAST**

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2023

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Plate 2.	Detailed geology and other factors related to the suitability of potential cable landing sites in the Rockaway Beach area, northern Oregon

GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.

Geodatabase is Esri® version 10.7 format. Metadata is embedded in the geodatabase and is also provided as separate .xml format files.

SP54_Coastal_Cable_Data_Inventory.gdb:

Feature dataset: Land_sampling

feature classes:

Beaches_and_Dunes (polygon)
Coastal_Roads (polyline)
Contacts_and_Faults (polyline)
Geologic_Units (polygon)
Groundwater_Sources (polygon)
Historic_Landslides (point)
Quaternary_Faults (polyline)
Surface_Water_Sources (polygon)
Tsunami_Inundation (polygon)
Wetlands (polygon)

Feature dataset: Shoreline_Sampling

feature classes:

Bluff_Heights (point)
Coastal_Erosion (polyline)
Coastal_Geomorphology (polyline)
Headlands_Spits_Landslides (polyline)

Feature dataset: Marine_Sampling

feature classes:

Bathy_10m_Contour (polyline)
Marine_Reserves_and_MPAs (polygon)
Offshore_Faults (polyline)
Reefs (polygon)
Seafloor_Substrate (polygon)

Feature dataset: Other_Not_Sampled

feature classes:

Faults_and_Folds (polyline)
Well_Sediment_Thickness (point)

Raster data:

Landslide_Susceptibility
Lidar_Slope
Liquefaction_Susceptibility_Map

Suitability analysis data:

feature classes:

Shoreline (polyline)
Suitability_Scores (point)

EXECUTIVE SUMMARY

This report analyzes the geology of the Oregon coastal zone including the Oregon Territorial Sea to assess the siting potential of landing sites for cables that carry information and/or power from offshore. We focus on subsea cables given current uses, but much of the information we have compiled will be relevant for other uses of the seafloor that may be covered by the Oregon Territorial Sea Plan, Part 4. We review the construction of cable landing infrastructure, particularly the cable landing sites where cables cross the shoreline through subsurface conduits commonly installed with the horizontal directional drilling (HDD) method. We review best practices and challenges in HDD construction, illustrated with examples of issues that occurred during construction of recent Oregon cable landing sites. Geologic hazards and processes that should be considered during siting and construction of cable landings are summarized. We present a summary of the geologic framework of the Oregon coastal zone that extends interpretive geologic mapping offshore across the Oregon Territorial Sea and synthesizes geologic units present within an equivalent distance onshore. The geology of the coastal zone defines the material that cable infrastructure must cross in the transition from offshore locations to terrestrial fiber optic networks or the power grid. Analysis of existing and new data provides a better understanding of coastal dynamics along the Oregon Coast that should inform siting future cable landings in positions that are resilient over infrastructure life cycles. Other new data improve understanding of geologic hazards and coastal geomorphology. The major analysis is a coastwide systematic survey that leverages many geospatial data layers produced in this project and obtained from other sources to assess the suitability of potential cable landing sites along the Oregon Coast in a comprehensive way. This effort provides a consistent, regional-scale view of where future cable landings can be built with fewer construction complications and impacts on the environment and communities. A major conclusion is that detailed, site-specific investigations of the many geologic, environmental, and cultural factors are needed to bridge between this coastwide reconnaissance effort and successfully completed projects.

1.0 INTRODUCTION

1.1 Background on Submarine Cables and the Oregon Coast

Cables that traverse the seafloor are an important component of modern infrastructure. Fiber optic communication cables transmit large volumes of data with low latency around the planet. Other cables transmit power generated at offshore wind or wave energy generating equipment to the onshore power grid. The locations where cables come onshore are critical parts of these systems, as the cables cross shallow water of the coastal zone where human interaction is more likely, and dynamic geologic processes are active. The nearshore terrestrial areas where submarine cables land also host many human communities and sensitive environments where there is potential for negative effects during construction activities. We recognize other potential future uses of the seafloor such as pipelines transporting fluids for energy. Much of the information in this report is relevant for other forms of seafloor infrastructure, but we specifically focus on considerations for routing and landing cables.

Coastal Oregon hosts landings for numerous cables, and future development of power and communications infrastructure is likely to drive additional landing sites. The first submarine telecommunication cable landing in Oregon was developed in 1995 (bandoncable.org, 2023), and a total of 17 telecommunication and research cables have been constructed as of early 2023, although some have been decommissioned (**Figure 1-1**). Current cables are distributed along the coast at nine landing sites in

six areas of the Oregon Coast, from the two at Bandon in the south to Warrenton in the north (**Figure 1-1**). Demand for increased data transmission capability and system redundancy is expected to grow into the future (e.g., Wopschall, 2023). Cables transmitting power from offshore marine renewable energy facilities are likely to drive demand for additional cable landings in Oregon. A cable landing site for offshore generated power was constructed on the central Oregon Coast in 2022 (Freeman and others, 2022; PacWave, 2022). Additionally, two areas have been designated for possible offshore wind development along the southern Oregon Coast (see yellow outlined areas, **Figure 1-1**) (BOEM, 2022).

Routing of cables and construction of cable landings are dependent on the geology of the continental shelf and coastal margin when best practices are followed (Wopschall, 2023). Ideally, cables are buried in sediment across the continental shelf to protect them from being damaged by fishing activities and other human or natural processes. Following U.S. standard practice, where a cable traverses nearshore water depths less than approximately 10 m (33 ft), the cable is routed through a borehole constructed through sediment and/or rock to protect it from wave action and human interference (Wopschall, 2023). The landward termination of a submarine fiber optic cable is located in a beach manhole where it transitions to a fronthaul route cable. The fronthaul portion of the cable system is often a few kilometers long and connects to a cable landing station where telecommunication infrastructure is housed (**Figure 1-2**). Fiber optic cables connect from the cable landing station along a backhaul route to a data center or internet exchange. Power cables have analogous on-land connections from the beach manhole to local substations or other power facilities that further connect into a regional electric grid (Wopschall, 2023).

Figure 1-1. Map of existing cable landings and cables along the Oregon Coast. The seafloor geology (Goldfinger and others, 2014) is unmapped outside of the colored area in the dataset. The Oregon Territorial Sea is the 3 nautical mile-wide strip of the Pacific Ocean adjacent to the shoreline.

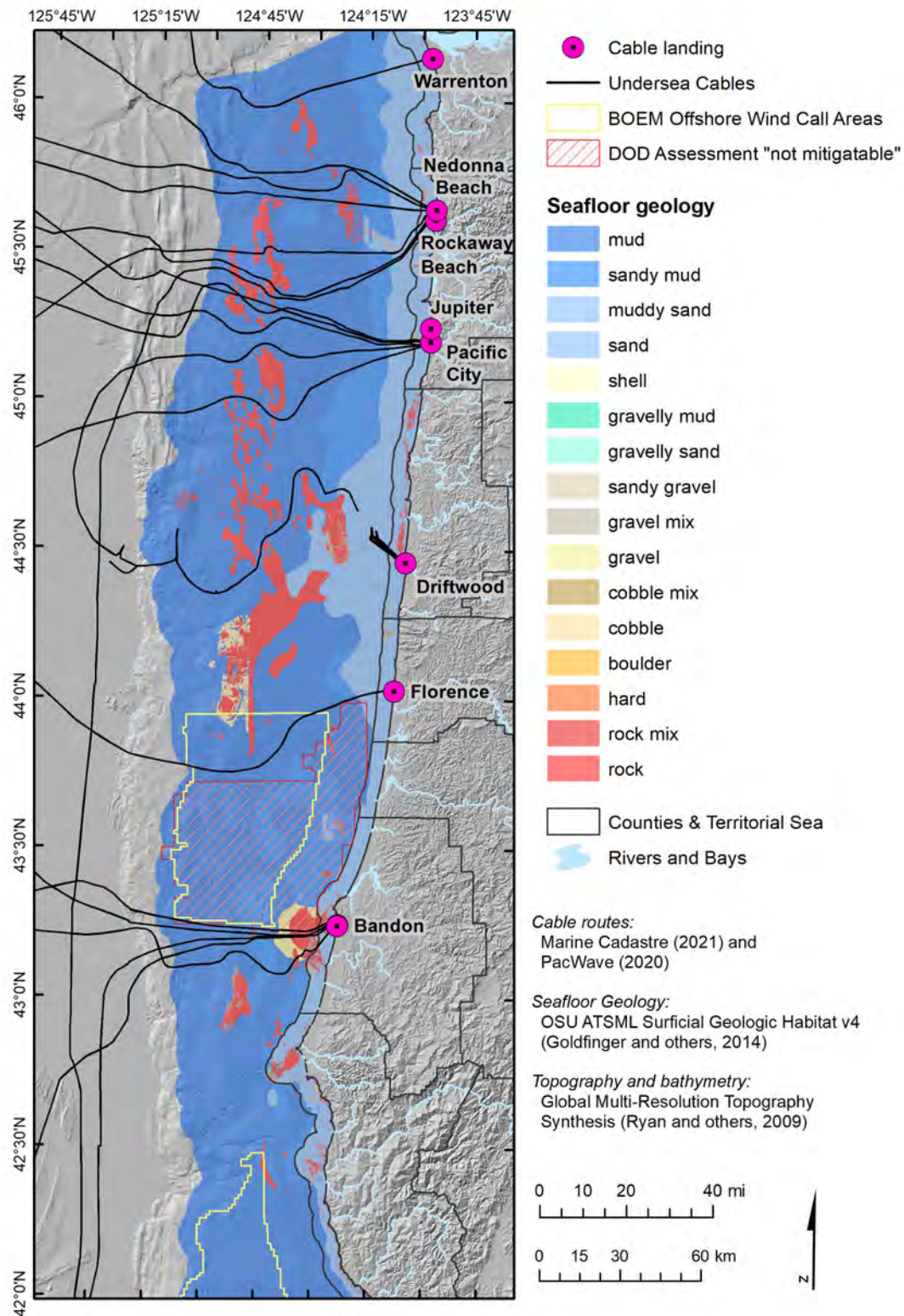
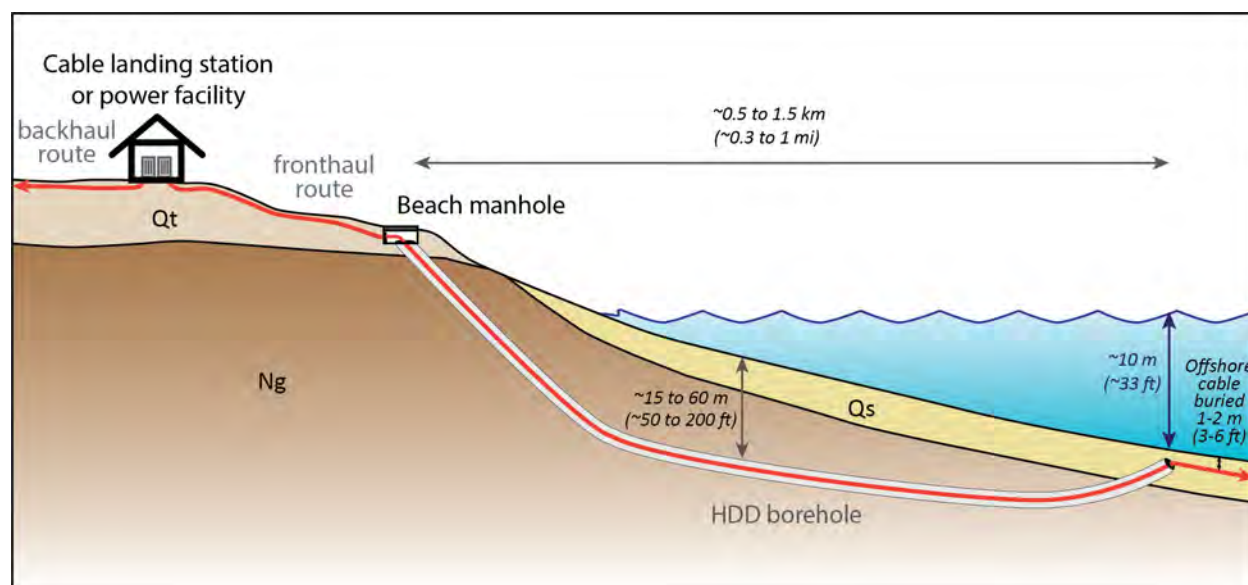


Figure 1-2. Schematic view of a cable landing showing components of a cable system in the coastal zone. Cables land at beach manholes via conduits emplaced in boreholes with horizontal directional drilling (HDD) methods. These holes are commonly drilled through the bedrock (e.g., Neogene sedimentary rock, Ng) to an offshore point where the cable is more shallowly buried in unconsolidated modern sediment, e.g., sand (Qs). From the beach manhole cables connect to other infrastructure on land (e.g. cable landing stations) that are commonly built on higher landforms such as the marine terrace depicted here (Qt).



1.2 Scope of the Report

This report synthesizes geologic information along the Oregon Coast relevant to the siting, construction, and longevity of cable infrastructure. Details of the geology and coastal processes are particularly important for construction of cable landing sites where the cable is routed through the subsurface between a beach manhole and where it emerges at the seafloor below wave base (**Figure 1-2**). Consequently, we focus on an area of interest (AOI) that encompasses the Oregon Territorial Sea and a roughly equivalent distance inland. The Territorial Sea is defined as the strip of the Pacific Ocean under state jurisdiction that extends 5.5 km (3 nautical miles; 3.4 mi) westward from the coastline (**Figure 1-1**; OPAC, 1994). For the purposes of this report, AOI extends approximately 11.11 km (6 nautical miles; 6.9 mi) eastward from the western boundary of Oregon's Territorial Sea and follows the irregular shape of the Oregon Coast. The AOI extends 588 km (365 mi) from the Washington border (46°15'41" N) to the California border (41°59'54" N). This AOI represents most of the area that controls where cables may be routed across the inner part of the continental shelf and terrestrial geology along a coastal strip that is relevant to cable landing construction and resilience.

This report summarizes how boreholes are constructed to route cables through subsurface rock and sediment and potential complications that have been experienced in coastal Oregon as well as many other locations. The subsequent section summarizes the geology of the Oregon Coast and its influence on potential cable landing sites. We provide estimates of recent coastal change along the entire Oregon Coast from repeated observations to understand potential magnitudes of future erosion and deposition. We

review seismic and landslide hazards posed to coastal infrastructure. The geologic information is combined in a comprehensive suitability analysis to identify areas along the coast that are relatively more or less amenable to construction of resilient cable landing sites with minimal complications from the physical environment.

This study has a large geographic scope, and while we have endeavored to use the best available datasets, the results are necessarily relatively coarse. Many of the issues that arise during borehole drilling involve geologic heterogeneities at a spatial scale shorter than the most detailed geologic maps, and at depths inaccessible to comprehensive mapping and analysis. Additionally, the suitability analysis applies a strategy that is effective at integrating many factors over the length of the entire coast, but it cannot assess detailed suitability for a potential individual cable that could be planned in great detail. Many of the factors addressed here can and should be considered in site-specific studies in support of locating future cables that traverse the Oregon Territorial Sea. Our study provides a regional-scale starting point for understanding promise and challenges for landing cables in different locations along the Oregon Coast.

2.0 INTERSECTION OF GEOLOGY AND COASTAL PROCESSES WITH CABLE LANDING CONSTRUCTION AND CABLE LONGEVITY

The geologic history of the Oregon Coast and active Earth system processes produce spatially varying characteristics that are relevant to both the construction phase of a cable landing project as well as its resilience over the design life of a project. The initial portion of this section provides a review of the influences of geologic materials on the construction of cable landing sites. Secondly, we review geologic processes that pose a hazard to coastal infrastructure including offshore cables and on-land portions of utility systems. Subsequent sections summarize specific characteristics along the Oregon Coast that are relevant to the issues highlighted here.

2.1 Overview of Cable Landing Construction and Potential Challenges

New cable landing sites are commonly chosen based on the availability of a suitable beach manhole site where a cable can come onshore within some proximity (<10 km; <6.2 mi) to a new or existing cable landing station that is connected to an existing or new backhaul route ([Figure 1-2](#); Wopschall, 2023). A key component of a cable landing is the construction of a subsurface conduit that connects the beach manhole to a point offshore where the cable emerges onto the seafloor. An early Oregon cable landing at Nedonna Beach was constructed using direct trenching of the beach ([Figure 1-1](#); McMullen, 1999). More recently, the most common practice in the United States involves the emplacement of conduits through boreholes constructed with the horizontal directional drilling (HDD) method (Wopschall, 2023). Recent Oregon cable landing construction has employed HDD methods to minimize impacts to the shore and to provide deeper burial and protection of cables.

HDD is a common construction practice that allows emplacement of pipes and/or cables into the subsurface over distances up to approximately 1500 m (5000 ft) from a surface endpoint. In HDD construction, a borehole is excavated as a drill head is steered through sediment and/or rock along a precise trajectory from a surface entry point to surface exit point. Conduit pipes can be pulled through a completed borehole or, as is common practice for Oregon cable landings, the conduit pipe can be used as the drill string and left in place upon intersection of the seafloor at the punchout location (Bennett and

Ariaratnam, 2017; ERM, 2020). Construction strategies are similar for both fiber optic and power cable landings, although conduits are thinner diameter (~10 to 13 cm; ~4 to 5 in) for fiber optic cables, and thicker (20 cm; 8 in or greater) for power cables (Wopschall, 2023). On land, HDD methods are commonly used where the disturbance of trenching and direct burial of cables or pipes would harm sensitive habitat or the built environment. While the HDD method generally produces minimal surface impacts, three classes of potential issues have been identified: pipe stress, inadvertent return (IR), and settlement (Bennett and Ariaratnam, 2017). Most of the existing Oregon cable landings have been constructed without publicized problems, but public records show that all three of these complications have arisen during the construction of two recent cable landings on the Oregon Coast.

2.1.1 Drilling conditions and pipe stress

Adequate geotechnical investigation and engineering design preceding an HDD project are key for successful project completion (Bennett and Ariaratnam, 2017). Understanding the properties of materials that will be encountered along the subsurface drill path is a critical component for planning the equipment and methods that are appropriate for a particular project. Methods for assessing the subsurface material include interpretation of local geology, geophysical imaging, and testing and sampling subsurface sediment or rock using vertical borings along the proposed HDD route. Subsurface information from complementary geophysical methods like seismic velocity and electrical resistivity are less invasive than drilling methods and can be applied over challenging nearshore wave environments (e.g., Alcorn and others, 2017).

HDD projects have been executed successfully through many geologic materials; however, some subsurface materials are more problematic than others. The HDD Good Practices Guidelines identifies the following materials as involving high levels of risk that may preclude HDD construction: boulders, cobbles, gravel, wood, hard or variable rock, and anthropogenic fill debris or structures (Bennett and Ariaratnam, 2017). Risks posed by these materials grow with greater size, frequency, and hardness along a proposed bore path. Subsurface voids or high artesian groundwater pressure are other problematic conditions for HDD construction.

Once the likely subsurface material has been characterized, planning the details of the borehole design and construction equipment and materials is important for successful drilling. Matching drill bits, drilling equipment, and drilling mud characteristics to the local material ensures that a project can be completed in a safe and efficient manner. The planned borehole geometry must be designed to transit from the entry point to the subsea exit point through appropriate rock and sediment, with curved segments that will not exert stress on the drill string (pipe) in excess of its strength during the dynamic drilling process. In the event of breakage of the drill string, continuity of the drilling equipment is lost, and collapse of the well bore is possible if specialized tools are not available on site to retrieve the drill head and pipe stranded in the subsurface.

Breakage of a drill string occurred during construction of the Jupiter cable landing in Tierra del Mar, Oregon in April, 2020 (**Figure 1-1**; ERM, 2020). Based on initial geologic and geophysical reconnaissance for the project, consistent soft sedimentary rock was expected along the bore path. However, the drill head encountered unexpected harder rock approximately 515 m (1690 ft) from the drill site. Drilling speed, thrust, and drill bits appropriate for soft rock were applied, the drill string experienced stress that exceeded the design specifications of the steel drill pipe, and a pipe segment broke, disconnecting ~357 m (1170 ft) of pipe and drill head assembly from the surface drilling operation (ERM 2020, Edge Cable Holdings USA LLC, 2020). Attempts to retrieve the broken drill pipe were unsuccessful, and the remaining

intact drill string and casing were removed. This resulted in the collapse of the borehole and stranding of the drill head and broken pipe along with bentonite-water drilling mud roughly 15.2 to 21.3 m (50 to 70 ft) below the seafloor (ERM, 2020). Subsequent seismic and electrical resistivity studies showed a body of rock with higher density in the offshore subsurface (SubCom, 2020). Based on the geophysical properties and geologic setting, this harder body was interpreted to be an invasive basaltic dike or a more indurated portion of sandstone trending north-south across the planned borehole route (SubCom, 2020). A revised drilling plan was formulated to deal with the harder rock portion of the borehole (Edge Cable Holdings USA LLC, 2020), and the HDD conduit portion of the cable landing was completed by March 2021 (OPRD, 2022).

2.1.2 Inadvertent return (IR)

One of the risks associated with HDD construction projects is inadvertent return (IR) that results in the loss of drilling fluid out of the borehole during construction. The pressurized drilling mud can escape into the surrounding material and can flow through a fracture or other permeable pathway onto the surface. The drilling mud is commonly a mixture of bentonite clay and water with minor additives that control gel strength, and is generally perceived as relatively environmentally benign (e.g., ERM, 2020). The most serious impacts are those associated with IRs that discharge mud into areas of sensitive habitats where ponding and burial of the land surface or seafloor will adversely affect the local organisms (Bennett and Ariaratnam, 2017). IRs are also more consequential where the drilling path underlies areas of cultural importance or the built environment. Impacts on groundwater from IR events that do not reach the surface are thought to be less impactful, with local changes in aquifer permeability as the primary effects (Nachman and others, 2021). We have not found documentation of the frequency of IRs during HDD projects in the U.S., but such issues appear to be relatively common. One study based on interviews with HDD contractors found that IR is one of the most probable complications in HDD projects (Onsarigo and others, 2014). The two most recent Oregon cable landing HDD projects both experienced IR events (HGI, 2021; PacWave Energy, 2022).

An IR occurs when the pressure of the mud that circulates during drilling and keeps the borehole from collapsing exceeds the strength of the sediment or rock being drilled. This condition can be reached in cases where the annular pressure exerted around the borehole is greater than the strength and confining stress of the intact soil or rock, producing a hydraulic fracture that propagates toward the surface (Bennett and Ariaratnam, 2017). The drilling fluid (slurry of water and clay) will follow the fracture out of the borehole and potentially reach the surface above the bore path. This fracture process has led to IRs being referred to colloquially as “frac-outs”. IRs also commonly occur in situations where heterogeneities in the permeability structure of the materials being drilled result in a lower local capacity of near-surface sediment to retain mud in the borehole. Examples of these situations include natural fractures in the soil, seepage paths along anthropogenic structures, and gravel layers with large, connected pore spaces (Bennett and Ariaratnam, 2017).

The risks of IR can be minimized by designing HDD projects so that downhole pressures will not exceed the strength of the material being drilled (Bennett and Ariaratnam, 2017). The risks of IR are greatest near the entry and exit points of boreholes, where confining pressures are low and less consolidated soil and sediment is common (e.g., Macauley Trenchless and Jacobs, 2020). Boreholes constructed with shorter lengths, wider diameters, and greater depths exert less pressure on the wall material relative to the confining pressure (Bennett and Ariaratnam, 2017). Other mitigation measures include use of conductor casing over the initial portion of the borehole, careful design of drilling fluid composition and

circulation rates, and detailed monitoring of downhole fluid pressures (Bennett and Ariaratnam, 2017). Conductor casings are larger diameter pipes emplaced into the upper part of the borehole to confine the drilling fluid in the part of the borehole most susceptible to IR. The IR issues experienced at the PacWave cable landing project (**Figure 1-1**) occurred near the downhole end of a conductor casing, and were thought to result from an imperfect seal of the casing with the stronger rock at greater depth (PacWave Energy, 2022).

The second key for mitigating IR is developing an understanding of the distribution of the types and strengths of soil and rocks that will be encountered along the boring route. This information can be found through pre-HDD vertical borings, geophysical surveys, rock property testing and knowledge of the local geology to match the technical approach of the drilling program to the specific locality (Bennett and Ariaratnam, 2017; Terracon, 2020). Broad engineering properties of Oregon coastal rocks have been described in early reconnaissance reports (e.g., Schlicker and others, 1972; 1973). However, specific behavior of rock units is generally not available in peer-reviewed literature. Informal public information regarding the PacWave energy cable landing south of Newport, Oregon, describes swelling of the Nye Mudstone when pressurized by drilling fluid, resulting in even greater annular pressures than would be predicted for most rocks (Kramer, 2022; Kezdi, 2022). Building and using knowledge of the relevant local geology will improve the success of future installations. Some irregularities in subsurface soil and rock properties, such as preexisting fractures, are unlikely to be recognized in every case prior to drilling, making IRs a risk associated even for well-planned projects. Careful monitoring for IR events and advance preparation for containing and remediating surface spills are important steps in addition to other project design considerations (Bennett and Ariaratnam, 2017). Identifying and avoiding areas where an IR spill would have unacceptable impacts on environmental or cultural features that could not be reasonably remediated may be necessary in the most sensitive areas.

2.1.3 Settlement

A third type of issue is settlement or subsidence of the land surface above the HDD borehole. Settlement issues above HDD projects have been classified as either large or systematic (Bennett and Ariaratnam, 2017). Larger amounts of settlement are generally associated with drilling larger diameter void spaces or drilling through adverse material where collapse of the overlying material during drilling produces larger cavities than the planned borehole. Systematic subsidence above HDD bores occurs due to collapse of annular space between the borehole wall and installed conduit as well as compaction of the soil due to drilling disturbance (Bennett and Ariaratnam, 2017). Geologic conditions that favor greater subsidence involve the presence of weak soils, soft clay and/or silt, or well sorted (poorly graded) loose sand, and loose gravelly sand (Bennett and Ariaratnam, 2017).

Similar to avoidance of the preceding HDD complications, one of the principal ways to minimize the risk of settlement is through a detailed understanding of the subsurface geologic material and how material properties may vary along and above the planned bore path (Bennett and Ariaratnam, 2017). Deeper bore path geometries are less likely to produce significant surface settlement. The construction of smaller diameter boreholes and smaller annular volumes around the emplaced conduits during drilling also limits effects of subsidence once the borehole collapses around the pipe. Practices that keep the borehole filled with drilling fluid during construction minimize opportunities for borehole collapse and widening during drilling. Grouting the annular space of completed HDD boreholes is another way to avoid surface subsidence (Bennett and Ariaratnam, 2017). However, standard practice for construction of cable landing boreholes that have an exit point on the seafloor is to flush the drilling fluid out of the borehole

with water during the drilling of the last ~45 m (~150 ft) prior to punchout (e.g., Edge Cable Holdings USA LLC, 2021a), which may be incompatible with filling completed boreholes with grout.

The recent Oregon case of observed settlement occurred above the HDD bore at the Jupiter cable landing site. Up to four sinkholes formed along the cable conduit route near the base of the vegetated small coastal bluff seaward of the beach manhole (OPRD, 2022; Edge Cable Holdings USA LLC, 2021b). The sinkholes were observed in April and November, 2021, following the completion of HDD construction in March 2021 (OPRD, 2022). The largest sinkhole was reported as ~0.9-1.2 m (3-4 ft) wide and ~1.5-1.8 m (~5-6 ft) deep, and the holes were filled with sand in response (OPRD, 2022). The portion of the borehole where the surface voids formed was above part of the HDD bore that had a 40.6 or 45.7 cm (16 or 18 in) conductor casing installed during construction. Upon complete installation of the ~16.5 cm (~6.5 in) fiber optic conduit, the larger pipe was removed (OPRD, 2022; Edge Cable Holdings USA LLC, 2021a; 2021b). Contractors involved with the installation interpreted these settlement features to be related to collapse of the annular space surrounding the conduit accompanied by local pit formation at the surface (Edge Cable Holdings USA LLC, 2021b). The timing of the sinkhole formation was interpreted to be related to changes in the water content of the subsurface sand due to high tides or other hydrologic changes that promoted mobility of the sediment around the HDD bore (Edge Cable Holdings USA LLC, 2021b). Electrical resistivity and seismic surface wave surveys did not show subsurface voids of resolvable size, supporting the interpretation that the sinkholes were related to settlement accompanying the removal of the guide casing (HGI, 2021). The sinkhole areas were remediated through filling with sand and compaction during high tide intervals. We are unaware of subsequent settlement associated with this project.

As with IRs the impact of settlement related to HDD construction is also coupled with the susceptibility of the overlying built and natural environment to be damaged by the process. Where HDD bores are constructed below roads, buildings, and other pipes, for example, relatively modest amounts of settlement may produce significant negative effects (Bennett and Ariaratnam, 2017). Equivalent amounts of spatially distributed subsidence in a vegetated area or area of high sediment mobility (e.g., dunes or beach) may be difficult to recognize and have minimal effects. With better understanding of the engineering properties of the soil, sediment, or rock overlying a planned borehole, the potential for localized settlement and sinkhole formation can more likely be predicted and mitigated in the design and construction phases of a project. Competing goals for cable landing boreholes need to be balanced against each other, e.g., the need to flush out drilling mud during borehole completion, the use of large diameter casing to prevent IRs, and avoiding settlement may be in conflict with one another and require careful planning and management of risk.

Overall, the reported incidents and potential for other complications during construction motivate developing a detailed understanding of the local geology along the proposed path of cables. These risks during construction may be mitigated by investigation and engineering planning, but the potential for unknown complications may motivate siting facilities where an unforeseen disruption above the cable trajectory will not damage sensitive natural areas, cultural features, or the built environment.

2.2 Resilience of Cable Infrastructure

In addition to the construction considerations for siting and emplacing a cable across the shoreline, there are other factors that control the favorability of different sites along the coast. Geologic and surficial coastal processes can damage cables on the seafloor as well as the related infrastructure onshore such as

cable landing stations. This section summarizes conditions and processes that are relevant to building cable landings that cause minimal impact to the environment and are resilient to natural hazards.

2.2.1 Rocky seafloor

The Oregon shoreline and seafloor have spatially variable rock and sediment types exposed at the surface due to the geologic history and ongoing geologic processes. Most existing cable routes that land on the Oregon Coast avoid exposed rock on the seafloor (**Figure 1-1**), for multiple reasons. First, rocky seafloor is an important habitat for sensitive species and fisheries, so avoiding rock outcrops minimizes negative impacts on the fishing industry and marine life (e.g., TSP, Part 3). Second, routing cables through sandy portions of the seafloor over the depth range where commercial fishing occurs allows subsurface burial that protects cables from accidental damage (Wopschall, 2023). Third, burial of cables in loose sediment also protects cables from being abraded on rocks when agitated by currents (Wopschall, 2023).

Rocky versus sediment-mantled seafloor reflects the geologic history of the Oregon continental shelf. Rock outcrops occur where more erosion-resistant rock types are near the surface, such as the basaltic rocks that form many of the headlands along the central and northern Oregon Coast. Other areas of rock correspond to areas of local uplift that are produced by the many faults and related folds that have grown in the recent geologic past in the forearc prism of the Cascadia subduction zone (CSZ) (e.g., McNeill and others, 2000). The distribution and types of sediment present on the seafloor are also related to inputs of clastic sediment from river systems that transport eroded geologic material from terrestrial western North America. Marine current systems redistribute sediment on the continental shelf, and farther offshore; submarine channels transport sediment to the deep seafloor and CSZ trench system via turbidity currents and other processes. Additionally, fluctuations in global sea level of ~100 m (~330 ft) over the last few million years have caused cyclic migration of the shoreline and associated progradation of terrestrial river systems and other environments across parts of the continental shelf.

Surficial geologic material types, or substrate types, have been mapped through many different surveys, and we use the most recent compilation produced by the Pacific Marine and Estuarine Fish Habitat Partnership (PMEP, 2022) that enhances mapping by Oregon State University Active Tectonics and Seafloor Mapping Laboratory (Goldfinger and others, 2014) with nearshore mapping by the Oregon Department of Land Conservation and Development. This dataset provides comprehensive coverage of the Oregon Territorial Sea and the continental shelf, with varying spatial resolution. This compilation of substrate material provides critical regional-scale information for broadly planning future cable placement in a way that will minimize conflict with other uses of the Oregon Territorial Sea and protect submarine cables from damage. A key contribution of this report is an effort to apply the lithologic mapping of rock and sediment units offshore across the Oregon Territorial Sea, integrating the substrate type with interpretations based on the more exposed and accessible geology mapped onshore.

2.2.2 Coastal dynamics

Another important consideration for how and where to site cable landing infrastructure is the action of coastal processes that erode or accrete sediment and rock to and from the seafloor and coastline. Wave energy and currents vary spatially and are changing some portions of the coast more rapidly than others. Ongoing sea-level rise will amplify these processes in predictable ways. Understanding these processes is important for ensuring that seafloor cables remain protected within boreholes below shallower water depths where wave action in storms causes erosion and deposition on interannual timescales. Resolution of the pattern of coastline change is helpful for avoiding erosion that can damage beach manhole locations (e.g., **Figure 2-1**; Wopschall, 2023). Observations of spatial patterns and magnitudes of erosion and deposition across the shallow seafloor and coastline are key to developing landing sites with suitable

setbacks. We summarize existing observations of coastal change and present new analysis for the entire Oregon Coast in Section 4.

Figure 2-1. Cable landing infrastructure exposed by coastal erosion in the Rockaway Beach, Oregon area in late 2001. Image source: J. Allan.



2.2.3 Landslides

Landslides are a common geologic hazard along the Oregon Coast. Combinations of steep slopes, large areas of weak rock, and high precipitation drive both shallow and deep-seated landslides in the mountains of coastal Oregon. Along the shoreline, unconsolidated sediment and active coastal erosion at the foot of bluffs makes many slopes unstable. This hazard is spatially variable, and therefore, we use SLIDO, the statewide compilation of landslide hazard (Franczyk and others, 2021) to assess exposure to this process. Beach manholes are commonly sited in nearshore, upland areas like marine terraces and bluff tops. Best practices that emplace the cable in the subsurface via HDD construction should largely avoid cable damage associated with landsliding, but larger, deep-seated coastal landslides could potentially damage cables where they come onshore if landings are not designed appropriately. Cable landing stations are more likely to be sited away from local steep slopes along the coast but may also be exposed to landslide hazard related to steep mountain slopes that flank the developed coastal plains.

Farther offshore, submarine landslides that produce turbidity currents pose a hazard to cables that cross the continental shelf. This hazard is faced by nearly all transoceanic cables, and damage to fiber optic cables in turbidity currents is common (Carter and others, 2014), although much less frequent than damage due to fishing vessels (Wopschall, 2023). Most major turbidity currents in the Holocene (last ~10 ka) along the continental margin offshore of Oregon have been interpreted as being triggered by CSZ earthquakes, which suggests this hazard may be linked to earthquake occurrence (e.g., Goldfinger and others, 2012), although earthquake triggering appears to vary globally (Pope and others, 2017). We do not specifically address offshore mass movement hazards given our focus on the Oregon Territorial Sea.

2.2.4 Earthquakes and associated hazards

Western Oregon is exposed to seismic hazards from two classes of faults. The most impactful source is the CSZ, which is a major plate boundary fault that accommodates relative convergence between the continental North America tectonic plate and the smaller oceanic Juan de Fuca plate to the west. The subduction zone produces large earthquakes (M8 to M9.1) that rupture part or all of the plate boundary zone from northern California to southern British Columbia (e.g., Walton and others, 2021). There are also many smaller faults within the crust of western Oregon that host smaller earthquakes ($M < 7.5$) at longer repeat intervals (Madin and others, 2021; Goldfinger and Beeson, 2023). These crustal faults pose significant hazard to local areas due to proximity of the earthquake source to people and infrastructure. There are several aspects of earthquakes that produce damage that can affect cable infrastructure.

2.2.4.1 Shaking

One of the most direct components of earthquake hazards is shaking caused by the elastic seismic waves produced when a fault experiences rapid slip. Expected levels of shaking for a CSZ earthquake, like the most recent one that occurred January 26, 1700, are predicted to be intense for the coastal fringe of Oregon (Wirth and others, 2021; Madin and others, 2021). The probability of a Cascadia earthquake in the 25-to-40-year lifecycle of an undersea cable is uncertain depending upon the details of recurrence models and interpretation of the paleoseismic and historical records (e.g., Walton and others, 2021; Melgar, 2021). However, published estimates of the probability of a large earthquake range from ~16% to 22% in the next 50 years (Goldfinger and others, 2017) to as high as 37–43% for a partial rupture of the subduction zone in southern Cascadia (Goldfinger and others, 2012), necessitating engineering and construction of the most and critical infrastructure, like cable landing stations, to survive likely levels of shaking. Lower levels of shaking are expected at the same probability threshold for crustal faults given their smaller magnitudes and slower slip rates/longer repeat times (Madin and others, 2021).

2.2.4.2 Ground rupture and vertical displacement

Another direct hazard from earthquakes is the sudden, localized displacement of the ground surface or seafloor that occurs when a fault experiences an earthquake. Cables or buildings that are anchored on two sides of a fault may experience damage as they experience high levels of strain when a fault slips. The relatively low probability of crustal faults experiencing displacement over the design life of a cable may not justify costs to mitigate this hazard, but where cable landing infrastructure and cable routes both offshore and onshore can avoid known active faults, communication or power cables will be more resilient. In the case of cables crossing the Cascadia megathrust, building in flexibility for cables to accommodate possible large (10 m/33 ft or more) displacement of the seafloor may be justified. A classic example of a well-engineered fault crossing comes from the Alaskan Pipeline that survived displacement across the Denali fault during the 2002 earthquake (Fuis and Wald, 2003).

A distributed mode of crustal displacement occurs during large earthquakes due to changes in elastic strain in the crust. Between Cascadia earthquake events, most of the Oregon Coast is rising at rates up to ~3.5 mm/yr (~0.13 in/yr) (Burgette and others, 2009). This uplift is roughly reversed during earthquake slip with most parts of the Oregon Coast experiencing coseismic subsidence of decimeters (1 dm = 3.9 in) based on marsh studies (e.g., Walton and others 2021). The details of seismic cycle deformation are more complex than this simple model; however, the likelihood of subsidence in an earthquake warrants considering the effects that would accompany the large, instantaneous rise of sea level relative to the land.

2.2.4.3 Tsunamis

Tsunamis are unusually large waves produced when the ocean water column is suddenly displaced by fault movement or a landslide. There are records of large tsunamis generated during CSZ earthquakes that have repeatedly inundated the Oregon Coast (e.g., Nelson and others, 2021; Goldfinger and others, 2017). Tsunami waves generate strong currents as seawater flows over the land that can cause large magnitudes of erosion, destruction of buildings, and exposure of buried infrastructure. In addition to the large-magnitude tsunamis triggered by local Cascadia earthquakes, the Oregon Coast is also impacted by smaller tsunami waves generated by distant sources like other subduction zones in the northern Pacific basin (Allan and others, 2018). The most hazardous distant tsunami sources are from the Aleutian area of southwestern Alaska that may produce inundation of several meters (feet) along the Oregon Coast (González and others, 2009). Modeling of potential tsunami effects has been completed for the Oregon Coast (Priest and others, 2010; Witter and others, 2013), and the best practice is to site critical facilities like cable landing stations outside of the local tsunami hazard zone (Wopschall, 2023). Beach manhole locations are necessarily closer to the coastline and many locations will be within local tsunami hazard zones, but siting these facilities at the highest elevations that permit reasonable HDD drilling distance to the desired offshore depth will make landings more resilient to tsunami damage.

2.2.4.4 Liquefaction

Liquefaction is a process that affects water-saturated, unconsolidated sediment during cyclic agitation of such as that which occurs during earthquake shaking. Some types of sediment are more susceptible to experiencing this effect during earthquakes. High levels of instability of the ground surface produce much greater levels of earthquake-related damage than that experienced by structures built on more stable geologic material. Regional-scale data are available for liquefaction susceptibility across Oregon based on geologic mapping (Madin and others, 2021). Siting infrastructure on material less prone to liquefaction improves the resilience of communication and power systems in the event of crustal or subduction zone earthquakes.

2.2.4.5 Coseismic landslides

Earthquake shaking dynamically changes the near-surface stress field, and slopes that are stable under static gravitational loads may experience landslide instability (e.g., Schulz and others, 2012). The triggering potential is further elevated if an earthquake occurs in a season when the groundwater table is high; pore-water effects seem to be the dominant trigger for landslides in the Oregon Coast Range (OCR) (LaHusen and others, 2020). Overall, the spatial patterns of earthquake-generated landslide susceptibility are similar to the relative patterns of normal landslide potential. The enhanced landslide sensitivity during earthquakes motivates greater caution when constructing infrastructure in coastal Oregon.

3.0 GEOLOGY OF OREGON'S COAST AND TERRITORIAL SEA

3.1 Geographic and Physiographic Setting of the Oregon Coast and Territorial Sea

3.1.1 Northern province

The northern province begins at the Washington/Oregon border at the mouth of the Columbia River, north of Fort Stevens State Park and extends southward to Newport and is subdivided into segments N1 and N2 ([Figure 3-2](#)). This section of the Oregon Coast is characterized by prominent headlands with steep

slopes including Tillamook Head, Cape Falcon, Cape Meares, Cape Lookout, Cascade Head, Cape Foulweather, and Yaquina Head (**Figure 3-1**). Relief from sea level through rocky sea cliffs to high points in the headlands ranges from ~60 m (~197 ft) at Yaquina Head to ~400 m (~1,312 ft) at Cascade Head. The coast between the prominent headlands is characterized by outlets of rivers, many with wide floodplains, which drain the western slope of the OCR. These include the Columbia, Nehalem, Wilson, Nestucca, Siletz, and Yaquina Rivers. The river mouths typically co-occur with sandbars and barrier spits that separate the estuaries from the open ocean. Mixing between fresh and seawater occurs in the estuaries that have formed as drowned river valleys mainly due to post-Pleistocene sea-level rise and the cycle of interseismic uplift and coseismic subsidence associated with subduction of Cascadia earthquake occurrence (e.g., Kelsey and Bockheim, 1994; Burgette and others, 2009; Walton and others, 2021). Beaches in the northern province range are variably backed by prominent foredunes and/or uplifted coastal marine terraces that connect to the higher topography of the OCR.

Population centers within the northern province include Warrenton, Gearhart, Seaside, Cannon Beach, Manzanita, Garibaldi, Rockaway Beach, Oceanside, Netarts, Pacific City, Tierra del Mar, Neskowin, Lincoln City, Depoe Bay, Beverly Beach, and Newport (**Figure 3-1**). Larger population centers such as Astoria and Tillamook are located within 12 km (~7.5 mi) of the shoreline but are outside of the Oregon Coast and Territorial Sea study area. US Highway 101 traverses the northern province from north to south starting in Warrenton in the north and stays within ~1.5 km (~1 mi) of the shoreline except where it veers inland around headlands and estuaries. The main transportation corridors that connect to the Willamette Valley include US Highway 30, which follows the south bank of the Columbia River to Portland, US Highway 26, which extends from US Highway 101 between Seaside and Cannon Beach east toward Portland, and State Highway 6, which connects Tillamook to State Highway 26 in Banks in the Tualatin Basin. State Highway 18 connects to US 101 near Lincoln City and extends east through Grand Ronde to the western Willamette Valley near Willamina. US Highway 20 connects to US Highway 101 at Newport and extends east to Philomath and Corvallis. Several small state routes and highways interconnect communities within this region of the Coast Range.

3.1.2 Central province

The central province extends from Newport in the north to Coos Bay in the south and is subdivided into segments C3 and C4 (**Figure 3-2**). This province of the Oregon Coast is characterized by generally lower topographic relief than the northern province. A few prominent basalt headlands exist in along the central Oregon Coast, in segment C3, between Newport and Florence. These include Cape Perpetua (elevation ~200 m / ~650 ft) and Heceta Head (elevation ~75 m / ~250 ft) (**Figure 3-1**). Besides these headlands, sea cliffs that occur in this province are mostly the result of wave erosion into uplifted Quaternary coastal marine terraces (Hapke and others, 2014). Between Heceta Head and Coos Bay, the distance between the shoreline and the higher topography of the OCR increases and the landscape becomes dominated by large tracts of active and inactive, vegetated sand dunes and contains intra-dune lakes such as Siltcoos Lake (Peterson and others, 2007; Hunter and others, 1983). The rivers in the Central province are the Yaquina, Alsea, Yachats, Siuslaw, Umpqua, and Coos.

The main population centers in the Central province are Newport, South Beach, Waldport, Yachats, Florence, Reedsport, and Coos Bay (**Figure 3-1**). U.S. 101 remains the main north-south transportation corridor within ~1.5 km (~0.9 mi) of the shoreline except where it veers to ~3 km (~1.9 mi) inland near Florence and Reedsport. US Highway 20 and Route 34 link Newport and Waldport to the Corvallis area, Oregon Route 126 joins Florence to the southern Willamette Valley in Eugene, and State Route 38 provides access from Reedsport to the I-5 corridor south of Cottage Grove.

Figure 3-1. Map of the Oregon Coast showing major headlands, estuaries, towns, and highways. The left panel shows northern Oregon; the right panel depicts the southern coast.



3.1.3 Southern province

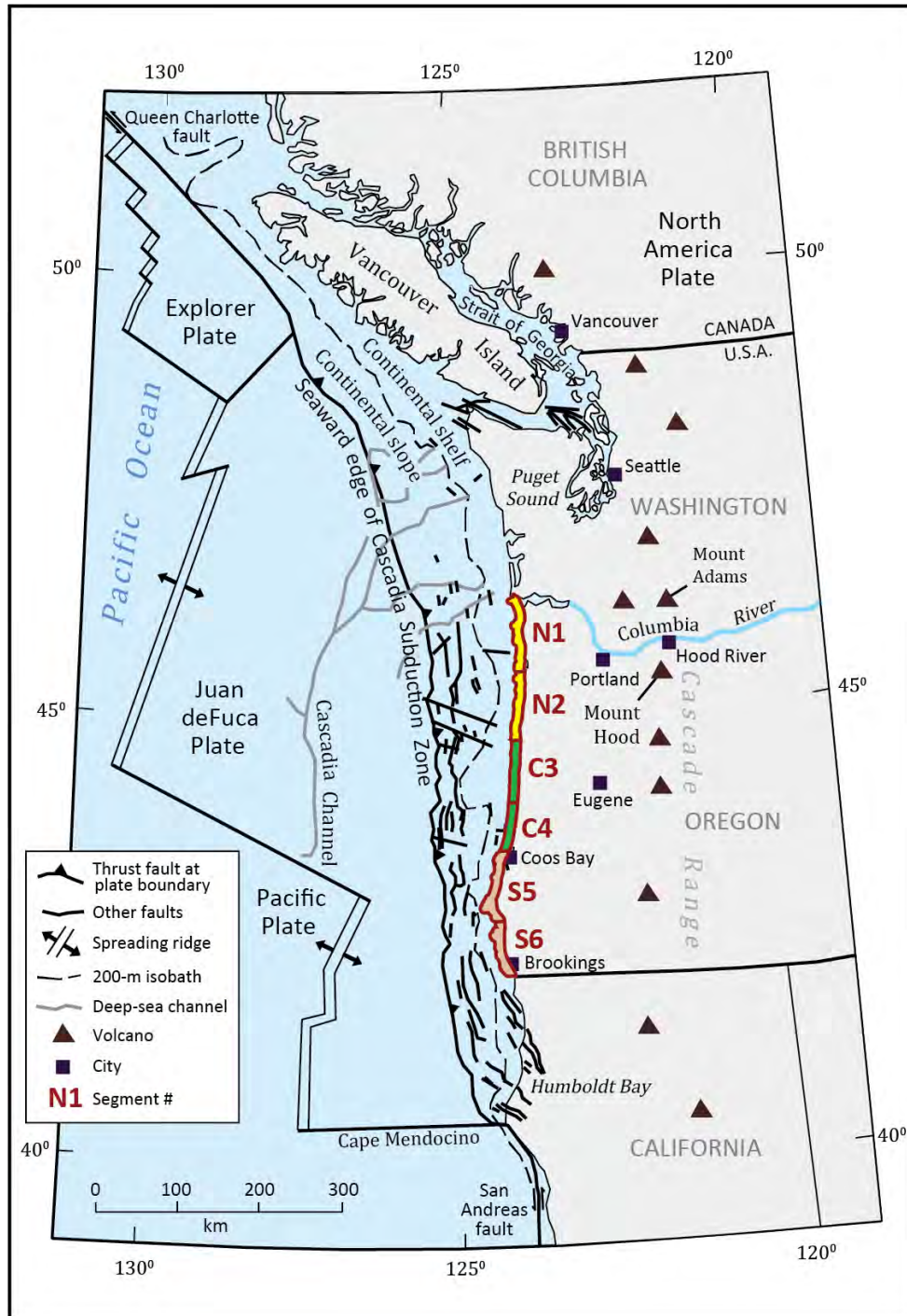
The Southern province of the Oregon Coast extends south from Coos Bay to the California border and is subdivided into segments S5 and S6 (**Figure 3-2**). The topography of this province is typified by a commonly narrow (0 to 7 km/0.0 to 4.3 mi wide) flight of marine terraces that transitions abruptly into the southern part of the Oregon Coast Range (OCR) and Klamath Mountains. The Klamath Mountains are the most rugged portion of the Oregon coastal mountains, with greater elevation, topographic relief and catchment-averaged erosion rates than the OCR to the north (Balco and others, 2013). The mountains are flanked by marine terraces which record ongoing rock and surface uplift associated with CSZ and Mendocino triple junction deformation. This province of the study area is drained by several watersheds whose rivers flow into the Pacific Ocean, including the Coos, Coquille, Sixes, Elk, Rogue, Pistol, Chetco, and Winchuk Rivers.

The main population centers south of Coos Bay include Charleston, Bandon, Port Orford, Ophir, Nesika Beach, Gold Beach, Pistol River, and Brookings (**Figure 3-1**). South of Coos Bay, US 101 reaches its farthest from the shoreline in the state of Oregon, approximately 14 km (8.7 mi), and it remains inland until it reaches Port Orford, where it continues to follow the coast. State Route 42 connects Coos Bay to the Roseburg area to the east. State Route 542 travels south from Coos Bay and connects to Gold Beach via an inland route through the OCR.

3.2 Geologic Setting of the Oregon Coast and Territorial Sea

The geologic features of the Oregon Coast and adjacent Territorial Sea (**Figure 3-2**) are the result of an active and ongoing process known as subduction, which is occurring at the westernmost edge of the North American continent at the latitude of the state. This boundary is known as the Cascadia subduction zone (CSZ), and it is where two different types of fragments of Earth's lithosphere (also known as tectonic plates) meet at a convergent margin. Subduction is the process by which the thinner and denser fragment of oceanic lithosphere that is known as the Juan de Fuca plate slides beneath the thicker and more buoyant continental lithosphere of the North America plate at the CSZ (e.g., Walton and others, 2021). The CSZ extends for more than 1,300 km (807 mi) from the northern end of Vancouver Island, British Columbia to Cape Mendocino, California (Walton and others, 2021). The Juan de Fuca plate is moving in a generally eastward direction relative to the Oregon forearc, at a rate of 30-32 mm/yr (1.2-1.3 in/yr) (McCaffrey and others, 2007; Burgette and others, 2009). The surface expression of the CSZ plate boundary between Juan de Fuca and North America off the Oregon Coast is identified by where the lower continental slope meets the abyssal plain, ~120 km (~74 mi) west of Astoria in the north and to ~77 km (~48 mi) west of Brookings in the south (**Figure 1-1**; **Figure 3-2**; Komar, 1997). The Juan de Fuca plate is overridden by the North America plate, and it dips to the east as it dives deeper into the Earth's mantle. The geological complexity of the OCR and Territorial Sea is owed to the 400-million-year geologic history of subduction-related processes. These include folding and faulting, rock and surface uplift that causes erosion and extensional faulting, subsidence that localizes sedimentation, large-scale landsliding, intrusion of molten rock into the overriding plate (notably forming volcanoes of the Cascade Range), and underplating of rock scraped from the lower plate (e.g., Darin et al., 2022). The oceanic plate transports crustal scraps to the subduction zone in a manner like a conveyor belt.

Figure 3-2. Tectonic setting of the United States, Pacific Northwest region displaying the CSZ, regional plate boundaries, and particular Quaternary faults on the North American plate (modified after Nelson and others, 2004). Barbed line is assumed to be the surface projection of the Cascadia thrust fault, where the abyssal plain meets the continental slope. Major Cascade Range volcanoes are shown as triangles. The provinces of the Oregon Coast included in this study are identified by north (N), central (C), and south (S), each one of which is subdivided into two informal segments (N1, N2, C3, C4, S5, S6).



The geology of the Oregon Coast region is best understood by dividing the region into three informal provinces that share common geologic history. We further split the maps for each province into halves that allow for a better display of units and structures along the length and narrow width of the Oregon Territorial Sea study area (**Figure 3-2**):

- Northern province (segments N1, N2) from Washington border south to Newport,
- Central province (segments C3, C4) from Newport south to Florence, and,
- Southern province (segments S5, S6) from Coos Bay south to the California border.

The emplacement, and subsequent structural modification of discrete units deposited after the accretion of Siletzia after ca. 50 million years in the northern and central provinces together with Mesozoic tectonostratigraphic terranes in the central and southern provinces largely control the morphology of the Oregon Coast. Sea cliffs make up 58% of the landforms along the Oregon Coast, with the remaining 42% of the landforms along the coast composed of wave-cut shore platforms, and wide to narrow sandy, gravel, or cobble beaches which may be backed by either sand dunes or sea cliffs (Hapke and others, 2014). The discontinuous sea cliffs may be separated by landforms such as barrier spits, estuaries, lagoons, or river deltas.

The geologic units within these provinces have been grouped throughout the study area, each having its distinct, yet interconnected geologic history. The Klamath Mountains area of the southern province is mostly Mesozoic age rocks, the geologic units are subdivided into tectonostratigraphic terranes. Tectonostratigraphic terranes are fault-bounded areas of rock that each have depositional and tectonic history, distinct from adjacent bodies of rock (Jones and others, 1983). Examples of tectonostratigraphic terranes include forearc or backarc successions of sedimentary, volcanic, and intrusive rock as well as intensely deformed complexes of geologic units (e.g., volcanic and associated intrusive rocks) that are bounded by faults (Nokleberg and others, 1994). The Siletz tectonostratigraphic terrane underlies the Central and Northern provinces of the OCR north of Coos Bay, and the geology of these areas is best understood through analysis of formal or informal stratigraphic groups that may share tectonic, sedimentary, volcanic, or intrusive environments of formation or origin (NACSN, 2005). Within each province, tectonostratigraphic terranes and groups are described in chronological order from oldest to youngest.

There are six accreted tectonostratigraphic terranes along the Oregon coast that underlie the Klamath Mountains and OCR onshore and continental shelf offshore (Blake and others, 1985): Yolla Bolly, Gold Beach, Western Klamath, Pickett Peak, Snow Camp, and Siletzia. Siletzia is the largest terrane within the study area and is overlain by post-accretion late Paleogene and early Neogene sedimentary groups that occur across the south, central, and northern provinces. A few Paleogene and Neogene sedimentary rocks can be found in the southern province, and these were deposited in a marine environment and then accreted on the smaller and more numerous tectonostratigraphic terranes in the southern province. All seem to have developed along continental and oceanic tectonic margins and each has a unique early geologic history prior to the process of accretion which added them to the North American continent. At least one of the Mesozoic terranes (Whitsett subterrane) likely developed partially or entirely in the southern hemisphere, according to fossil evidence in large blocks and studies of the remnant paleomagnetic fields of the rocks (Sliter, 1984; Blake and others, 1985; Tarduno, 1987). Recent provenance data suggest many terranes including the Western Klamath terrane may have originated near the North America continental margin (e.g., LaMaskin and others, 2022). Bedrock that is older than 58 million years (Paleocene) is intricately and intensely folded and faulted within each Mesozoic

tectonostratigraphic terrane of the Southern province unlike the Siletz terrane of the Central and northern provinces.

Faults and other structures within and between terranes affect engineering properties and can juxtapose geologic units of different strength. For example, the volcanic rocks, sandstone, and conglomerate of the Mesozoic Klamath Mountains and five tectonostratigraphic terranes are very well-cemented and form many wave-resistant sea stacks offshore for several miles between the California border north to Brookings and Bandon (McCloughry and others, 2013). Intervening highly sheared low-grade metamorphosed mudstone is landslide prone. In contrast, the post-accretion overlap sequence of Tyee Formation and younger rocks (e.g., Oligocene sandstone) in the central and northern provinces are not as well cemented, and contain smectite expandable clay (e.g., Schlicker and others, 1973), which can present challenges for HDD construction (Bennett and Ariaratnam, 2017).

3.3 Regional Geology Overview by Terranes and Groups

The geologic units and structure at the surface and subsurface coastal Oregon, and their relevant properties, reflect the unique geologic histories of different coastal provinces. Here, we summarize broad groupings of rock units from generally oldest to youngest, noting the geographic and physiographic provinces of the coast where they are exposed. We use major divisions established in the regional geologic literature, including tectonic terranes, which are coherent packages of rock that were accreted to build the crustal basement, and groups, which describe sets of rocks with related characteristics and origins. The terrane and group summary is presented in sequence from roughly oldest to youngest, and figures are also presented in a similar sequence, beginning with the oldest rocks exposed in the study area, which are in the southernmost part of the Oregon Coast and Territorial Sea ([Table 3.1](#)).

The geologic data in this report were compiled to present the best available information regarding types of rock and sediment present across the landscape of the Oregon Coast and the seascape of the Territorial Sea. South of Coos Bay, consistent, updated, and detailed geologic mapping was completed using modern lidar and geochronologic data (McCloughry and others, 2013; Wiley and others, 2014; 2015). Geologic mapping has been extended across the Territorial Sea, using seafloor substrate data (Goldfinger and others, 2014) combined with interpretations of terrestrial observations (McCloughry and others, in preparation). A major contribution of this project was continuing the strategy of McCloughry and others (in preparation) across the Territorial Sea from Coos Bay north to the mouth of the Columbia River to develop an integrated view of both onshore and offshore geology. We joined the terrestrial Oregon Geologic Data Compilation, release 7 (OGDC-7; Franczyk and others, 2020), with seafloor geology (substrate) data (Goldfinger and others, 2014; PMEP, 2022) to interpret specific geologic units where rock is exposed on the seafloor. The geologic map data in the figures of this section and the associated GIS data consist of data from McCloughry and others (in preparation) south of Coos Bay, and the extended data modified from OGDC-7 (Franczyk and others, 2020) in areas to the north. Geologic structures (faults and folds) are derived from OGDC-7 (Franczyk and others, 2020) on land, and Goldfinger and Beeson (2023) offshore.

Table 3.1. Tectonostratigraphic terranes and sedimentary groups of the Oregon Coast.

Terrane/Group	Description	Age (Period)	Abbrev.
Quaternary Surficial Deposits	Deposits of unconsolidated sediments	Quaternary	Qs
Neogene Sedimentary Rocks	Sedimentary	Neogene	Ns
Neogene Volcanic Rocks	Igneous	Neogene	Nv
Columbia River Basalt Group	Basalt and basaltic andesite lava flows	Neogene	Nc
Whalecove-Gnat Creek Group	Marine sandstone and mudstone	Paleogene/ Neogene	PNw
Astoria Group	Marine Sandstone and siltstone, including slope channel, deltaic and turbidite sandstone, and slope mudstone	Neogene	Na
Keasey-Alsea Group	Tuffaceous marine sedimentary rocks	Paleogene	Pk
Elkton-Yamhill Group	Marine slope mudstones within the Cascadia Forearc Basin.	Paleogene	Pe
Yaquina-Pittsburg Bluff Group	Tuffaceous sedimentary rocks	Paleogene/ Neogene	PNy
Coaledo-Cowlitz Group	Marine deltaic sandstone and slope mudstone, locally coal-bearing.	Paleogene	Pc
Nestucca-Hamlet	Slope mudstone and shelf sandstone.	Paleogene	Pn
Yachats-Tillamook Group	Marine sandstone and terrestrial sedimentary rocks.	Paleogene	Py
Tyee Group	Marine turbidite sandstone.	Paleogene	Pt
Umpqua Group	Marine sandstone, conglomerate, shale, and siltstone.	Paleogene	Pu
Siletzia Terrane	Submarine basalt, pillow basalt and deep marine sediments that formed as an oceanic island chain and then accreted to North America.	Paleogene	Ps
Snow Camp Terrane	Metamorphic, volcanic, intrusive and ultramafic rocks and mélange.	Jurassic/ Cretaceous	JKsc
Pickett Peak Terrane	Metamorphic and ultramafic rocks and serpentinite.	Jurassic/ Cretaceous	JKp
Western Klamath Terrane	Marine sedimentary, mafic volcanic and volcanoclastic, ultramafic, metamorphic, and mélange rocks and serpentine.	Cretaceous	Kw
Gold Beach Terrane	Severely folded and deformed marine sedimentary rocks and mafic volcanic rocks.	Jurassic/ Cretaceous	JKg
Yolla Bolly Terrane	Basaltic volcanic rocks, marine sandstone, mudstone and chert, and mélange.	Jurassic/ Cretaceous	JKy

The maps in this section of the report display simplified rock and sediment types grouped by terranes or formal and informal sedimentary and volcanic stratigraphic groups. Much greater detail of the geology of the Oregon Coast at the formation level is available in the GIS data of this report. Plates 1 and 2 show the geology in two example areas on the southern and northern Oregon Coast, respectively. In contrast to the higher resolution, consistent data of the southern coast (e.g., Plate 1) the OGDC-7 compilation (Franczyk and others, 2020) includes spatial heterogeneity in geologic unit interpretations and original map scale (e.g., Plate 2). The simplified structural features presented in the sequence of terrane and group maps presented in this section, for example **Figure 3-3b**, represent the total accumulation of faults and folds that have been identified on shore along the Oregon Coast (Franczyk and others, 2020). Offshore faults and folds emphasize structures with more recent activity (Goldfinger and Beeson, 2023).

3.3.1 Yolla Bolly terrane: southern province

The Yolla Bolly terrane (Blake and others, 1985) (**Figure 3-3**; **Figure 3-4**) contains rocks of the upper Cretaceous Dothan Formation (Dott, 1971; Wiley and others, 2017). The Dothan Formation has experienced low grade metamorphism and is characterized by sandstone that encloses large blocks of volcanic arc rocks and smaller exotic fault blocks of other lithologies. It is interpreted as structurally thickened turbidite and debris flow submarine fan sequences (Aalto, 1989). Rocks of the Dothan Formation are hard and form numerous sea stacks in the nearshore.

The Dothan Formation consists predominantly of hard, dense beds of graywacke sandstone interbedded with thick, well indurated gritty to pebbly debris flow sandstone and volcanoclastic turbidites. (Baldwin, 1974). These sedimentary units contain large (dozens of meters thick) blocks of tectonically incorporated meta-pillow lavas (greenstones) and breccias, volcanoclastic rocks, radiolarian chert, and serpentinite. Some of the blocks may have been deposited as olistostromes, which are blocks deposited by submarine landslides (Baldwin, 1974; Aalto, 1989). The environment of formation for these various units is interpreted as being deep water volcanoclastic turbidites, submarine slope, fan, and fan-channel settings adjacent to a volcanic island arc (Dott, 1971; McClaughry and others, 2013). The terrane equivalent of the Yolla Bolly/Dothan Formation across the California border is the Franciscan Group, which is also mapped as amalgamated exotic terranes (Blake and others, 1985; Seiders and Blome, 1987), *mélange* (Walker and McLeod, 1991), and a more-intact accretionary complex with exotic components (Roure and others, 1986).

3.3.2 Gold Beach terrane: southern province

The Gold Beach terrane extends in a strip from Whaleshead Island near Brookings to Ophir in the north (**Figure 3-3**, **Figure 3-4**). It is the westernmost terrane that underlies the coastal area of southwestern Oregon (Blake and others, 1985; Bourgeois and Dott, 1985; McClaughry and others, 2013). This terrane is composed of the Jurassic Otter Point Formation (Koch, 1966; Aalto and Dott, 1970), the less widespread Hostenaden Creek Formation, the Hunters Cove Formation, and the Cape Sebastian Sandstone (Dott, 1971; McClaughry and others, 2013).

Figure 3-3. Terrane/Group geologic map (A) and simplified structural features map (B) of the south-6 (S6) segment of the Oregon Coast study area. Geologic data modified from McClaughry and others (2013), McClaughry and others (in preparation), Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).

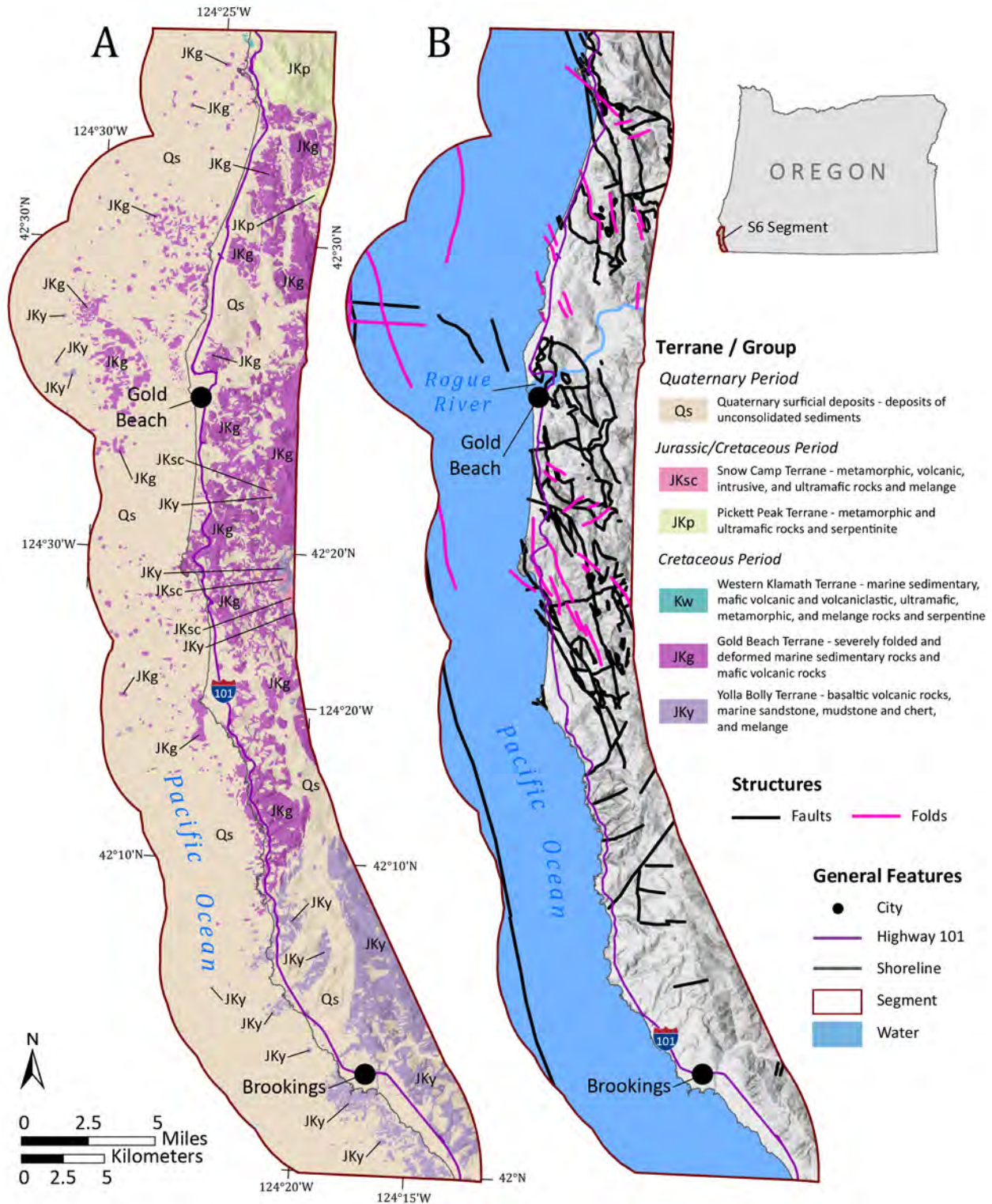
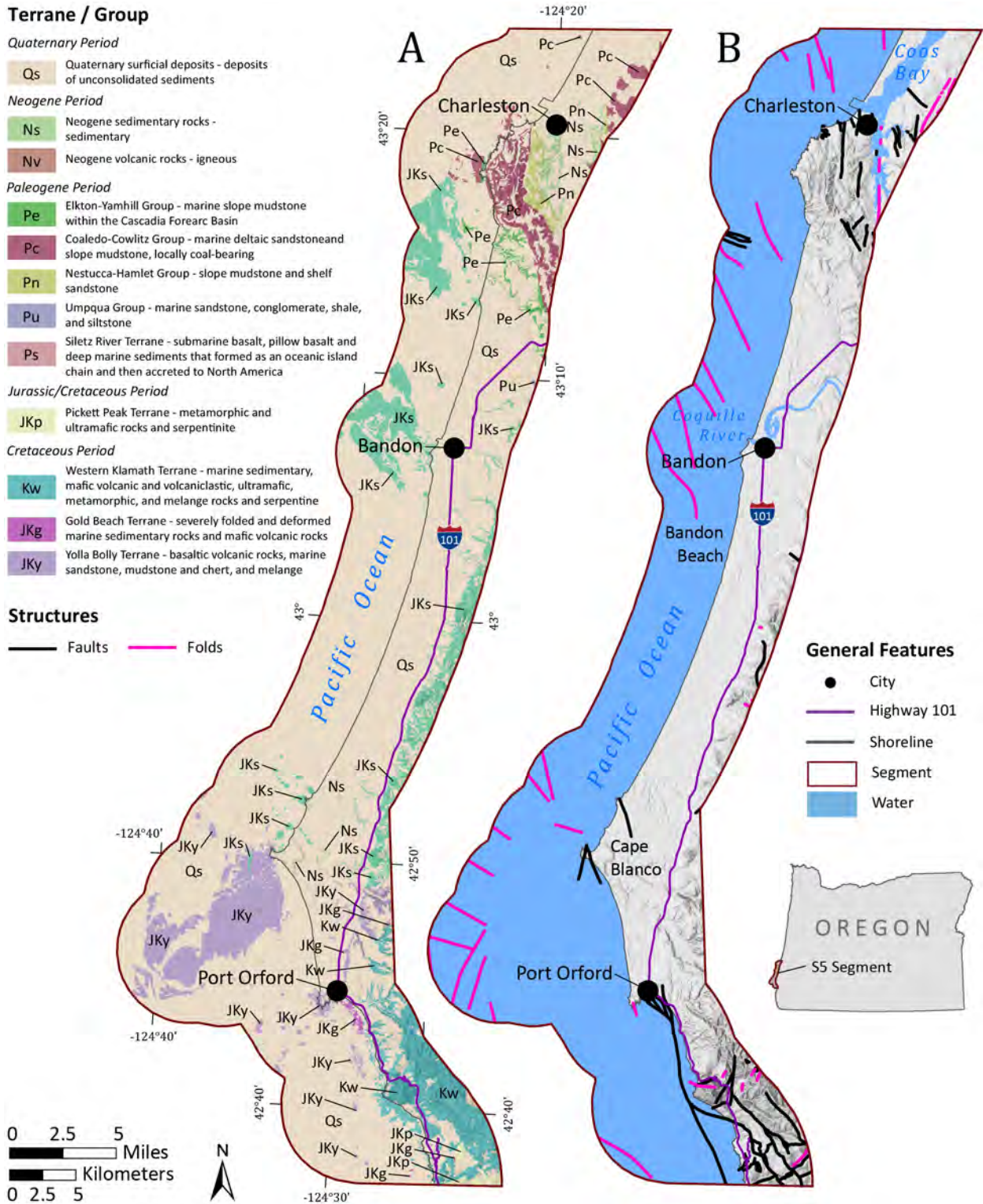


Figure 3-4. Terrane/Group geologic map (A) and simplified structural features map (B) of the south-5 (S5) segment of the Oregon Coast study area. Geologic data modified from McClaughry and others (2013), Wiley and others (2014; 2015), McClaughry and others (in preparation), Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).



The Otter Point Formation forms numerous hard, erosion-resistant sea stacks along the coastline which extend seaward a few miles and is made up of a structurally complex succession of volcanoclastic sandstone, mudstone, and conglomerate (Koch, 1966; Aalto, 1968; Aalto and Dott Jr, 1970; Dott, 1971; Walker and McLeod, 1991). Between Sundown Mountain and Sisters Rock State Park, north of Ophir, approximately 6.4 km (4 miles), inland southeast of Cape Sebastian, the formation contains north-northwest trending bands of pillow lava and volcanic breccia. There are also lines of scattered indurated blocks of volcanic rock, diorite, chert, and serpentinitized ultramafic rock, which mark the surface traces of intraformational shear zones and faults (Blake and others, 1985). The sedimentary rocks of the Otter Point Formation formed during the early Cretaceous, 145 to 100 million years ago and range from cherty mudstone to chert-pebble conglomerate near the Rogue River and chert-rich sandstone and pebbly sandstone near the Pistol River.

The youngest portion of the Houstaden Creek conglomerate and the oldest part of the Cape Sebastian Sandstone are composed of a variety of pebble- to cobble-sized clasts of fine-grained, silicic to intermediate volcanic rocks, welded tuffs, quartzite, and felsic plutonic rocks. The sedimentary units of the Hunters Cove and Cape Sebastian formations are largely composed of clasts that were eroded from the Otter Point Formation and deposited nearby as part of their respective formations. These sedimentary units are pervasively faulted; however, they are not intensely sheared, which indicates that these units did not experience metamorphism to the same degree as the underlying Otter Point Formation (McClaghry and others, 2013).

3.3.3 Western Klamath terrane: southern province

The Western Klamath terrane ([Figure 3-3](#), [Figure 3-4](#)) is the youngest part of a stack of structures known as imbricate thrust sheets, which form in convergent margin settings and cause units to thicken and repeat in vertical sequences. Much of the Western Klamath terrane is composed of the Galice Formation, which is interpreted to have formed between 157 and 152 million years ago. It is a sequence of dark slate and slaty mudstone, metagraywacke, minor greenstone, thin-bedded sandstone, and chert (Dott, 1971; MacDonald and others, 2006; Giaramita and Harper, 2006; McClaghry and others, 2013; Wiley and others, 2015; LaMaskin and others, 2022).

Along the southwestern Oregon Coast, a fragment of the Western Klamath terrane, known as the Elk subterrane, is exposed between Humbug Mountain and Port Orford. The Galice Formation is intruded by the Pearce Peak diorite which was emplaced between 148 and 144 million years ago (Dott, 1971; Giaramita and Harper, 2006). It is characterized by fault blocks and slivers of dismembered oceanic crust which range from gabbro to low grade metamorphic pillow basalt (greenstone), which is overlain by unmetamorphosed conglomerates and sandstones.

3.3.4 Pickett Peak terrane: southern province

The Pickett Peak terrane includes distinctive phyllite, schist, and gneiss that are a part of the Colebrook Schist. These rocks are exposed over an area extending from Agness on the east to Lookout Rock on the coast and from as far north as Cape Blanco to south of the Pistol River ([Figure 3-3](#), [Figure 3-4](#)). The Colebrook Schist is a collection of thinly bedded shale, turbidite sandstone, pillow lavas, tuff, and chert that underwent metamorphism to grades halfway between blueschist and greenschist facies. It commonly has serpentinite-matrix mélange beneath it (Diller 1903; Dott, 1971; Coleman, 1972; Blake and others, 1985). The Pickett Peak terrane, which structurally overlies the lower-grade metamorphic rocks of the Gold Beach and Yolla Bolly terranes, tends to occupy high terrain to the south of the Canyonville fault as

part of a complexly faulted nappe structure (Wells and others, 2017). In the Pistol and Rogue River drainages, the Pickett Peak terrane is found near exposure of sedimentary rocks that are at least 70 million years old (Late Cretaceous) and include mudstone, chert-rich sandstone, pebbly sandstone, and conglomerate. These terranes are more coherent and do not contain evidence of the high levels of deformation associated with sheared *mélange* units in the area (e.g., broken formation) (Blake and others, 1985).

3.3.5 Siletzia terrane: northern and southern provinces

The Siletzia terrane is a thick accumulation of largely tholeiitic submarine and subaerial basalt flows, diabasic and gabbroic intrusive rocks, submarine breccias, minor, deep marine sedimentary rocks, and rare silicic flows which date between 59 and 47 million years old ([Figure 3-4](#); [Figure 3-7](#)) (Howell and others, 1985; Silberling and others, 1987; Wells and others, 2014). Most outcrops of the Siletzia terrane occur as basement fault horst blocks and volcanic edifices (Snively and others, 1968; Wells and others, 2000). The Siletzia terrane extends northward from the Roseburg area in the south, across western Washington, where it is known as the Crescent Formation (Snively and others, 1968; Tabor and Cady, 1975), to the southernmost part of Vancouver Island, Canada (Wells and others, 2014). Siletzia terrane volcanic rocks are interpreted to be between 25 km and 35 km (15.5 and 21.7 mi) thick in the central part of the OCR (Trehu and others, 1994). These units are exposed at the surface in the north-central portion of the study area, where they are in depositional contact with the Elkton-Yamhill Group and the Yachats-Tillamook Group ([Figure 3-7](#)). The Siletzia terrane forms the basement rocks of the OCR and is only exposed at the surface in scattered locations (e.g., Roseburg area and along the Siletz River northeast of Newport) where rocks have experienced uplift because of the ongoing tectonic forcing associated with oblique Cascadia subduction zone (Wells and others, 2014). Volcanic units, formerly known as the Roseburg Volcanics (Baldwin; 1974), that form the Siletz terrane are thrust beneath the Mesozoic Sixes River terrane by the Wildlife Safari and associated faults in the Roseburg area. The timing of accretion of the Siletz terrane between 51 and 49 million years ago is bracketed by overlying lower-Eocene sedimentary rocks to the north of the Canyonville fault (Ryu and others, 1996; Wells and others, 2014).

Figure 3-5. Terrane/Group geologic map (A) and simplified structural features map (B) of the central-4 (C4) segment of the Oregon Coast study area. Geologic data modified from Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).

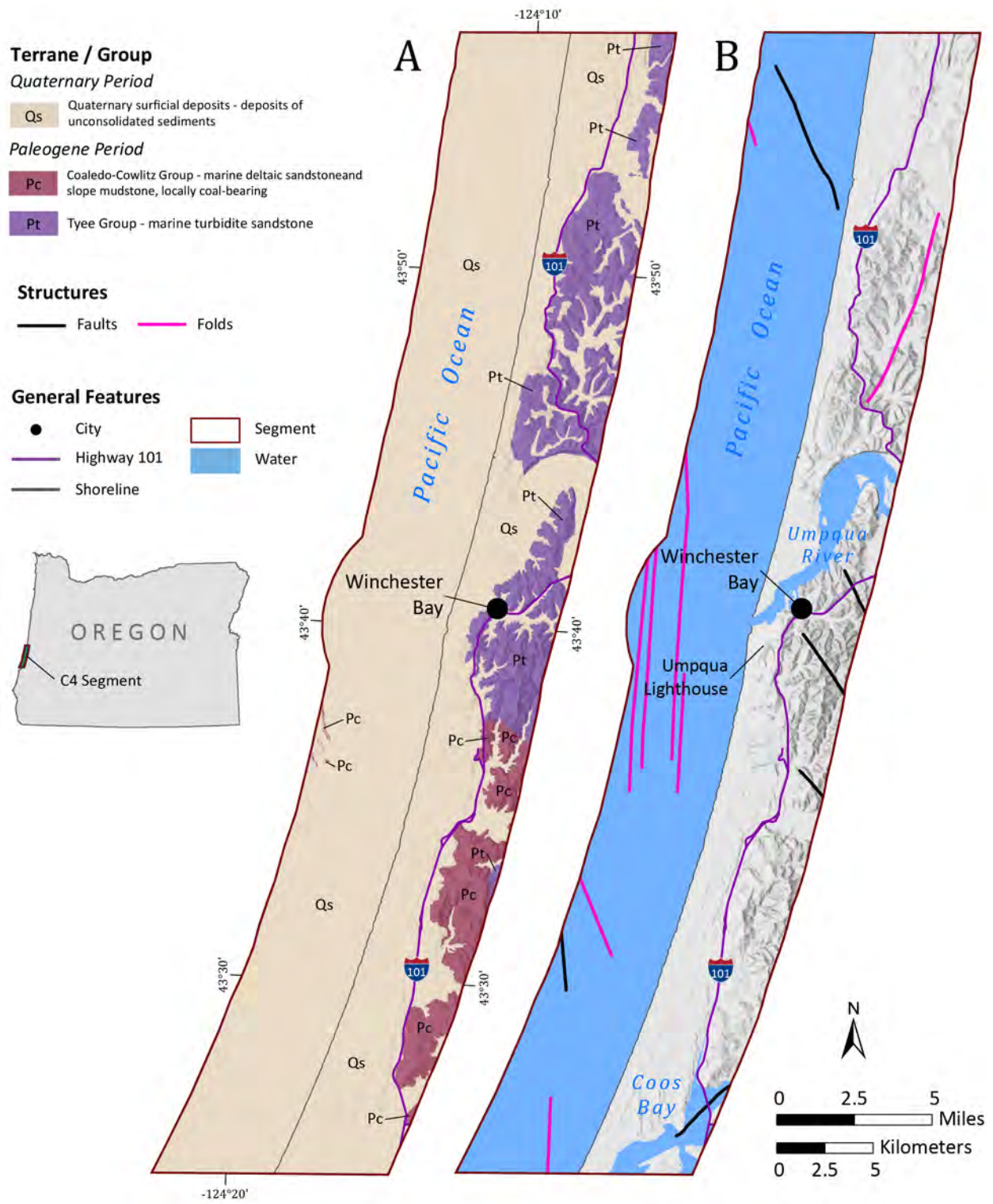
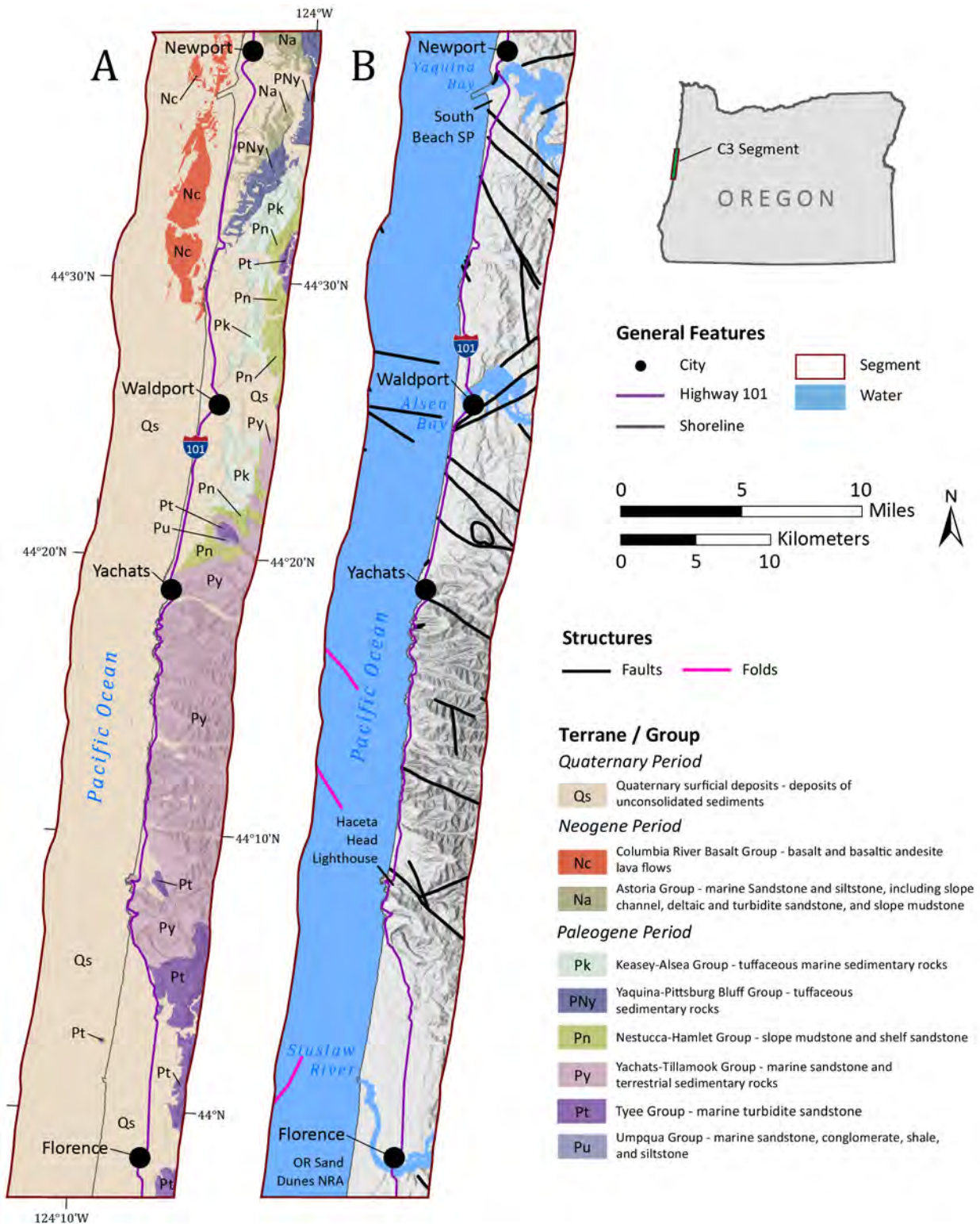


Figure 3-6. Terrane/Group geologic map (A) and simplified structural features map (B) of the central-3 (C3) segment of the Oregon Coast study area. Geologic data modified from Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).



3.3.6 Umpqua Group: northern, central, and southern provinces

The Umpqua Group is composed of thick sequences of volcanoclastic sedimentary rocks that were deposited in a marine environment during the latest eruptive stages of volcanics forming the Siletz terrane ~52-49 million years ago (**Figure 3-4, Figure 3-6, Figure 3-7, Figure 3-8**; Ryu and Niem, 1999; Darin and others, 2022). The Umpqua Group sedimentary units overlie and interfinger with Siletzia terrane basalts at the oldest/lowest part of the group (Snively and others, 1993; Wells et al., 2014). Strata that make up the Umpqua Group are well-indurated lithic turbidite sandstones largely derived from the Mesozoic Klamath Mountains and other sources. The sandstones are interbedded with deep-marine mudstone units and are interpreted to have been deposited post-accretion to the North America plate in a subduction zone setting as parts of submarine fans (Ryu and others, 1996). The oldest units of the Umpqua Group have experienced significant late middle Eocene deformation associated with the subduction zone and are tightly folded and indurated (McCroory and Wilson, 2013). Umpqua Group rocks can be found from the study area as far east and south as Roseburg (Wells and others, 2014). The units that make up the Umpqua Group record the development of a new subduction zone to the west, and closer to its present location in the early Paleogene (middle Eocene), when a very thick seamount clogged the active subduction zone during the accretion of the Siletzia terrane (Molenaar, 1985; Wells and others, 2014).

3.3.7 Tyee group: northern and central provinces

The Tyee group is made up of marine sedimentary rocks that were rapidly deposited within a 2-to-4-million-year period between 47 and 43 million years ago (Darin and others, 2022). The Tyee group comprises arkosic sandstone interbedded with mudstones and has been measured to a thickness of ~3 km (~1.8 mi) (**Figure 3-5, Figure 3-6, Figure 3-7**) (Snively and others, 1964; Heller and others, 1985; Darin and others, 2022). The average thickness of individual beds that make up the Tyee group is less than 1.7m (5 ft), however there are examples near Tillamook that can reach up to 3m (10 ft). (Schlicker and others, 1972). The total thickness of the Tyee Formation is approximately 1,828 m (6,000 ft) and is continuously exposed to the west of the coastal area of interest for ~180 km² (600 mi²) of the Coast Range (Schlicker and others, 1973).

3.3.8 Coaledo-Cowlitz group: central and southern provinces

The Coaledo-Cowlitz group includes rocks that were deposited during the middle to late Eocene between 45 and 33 million years ago in a broad coastal plain that developed adjacent to the subduction zone off the coast of North America at that time (**Figure 3-4, Figure 3-5**) (Dott Jr, 1966; Niem and others, 1989; Snively and others, 1993; Darin and others, 2022). The Coaledo-Cowlitz group are feldspar and mica-rich sandstones (Heller and Ryberg, 1983). The late Eocene Coaledo group was deposited in the Coos basin, which was adjacent to the forearc basin in which Tyee group deltaic and turbidite sediments accumulated (Newton, 1980; Ryu and others, 1996). The Cowlitz members (i.e., Spencer and Cowlitz formations) are mapped in the northern Oregon Coast Range and share similar age and lithological characteristics with the Coaledo units and have been mapped inland in the northeastern part of the Oregon Coast Range where these strata form the main storage reservoir in the Mist Gas Field, ~64 km (40 mi) northwest of Portland.

3.3.9 Paleogene, Neogene, and Pleistocene units: southern province

The Siletzia and Yolla Bolly terranes are overlain by a more gently deformed post-accretion marine overlap sequence that contains sedimentary rocks and basalts that were deposited during the Paleogene (Paleocene to Oligocene time) between 65 and 23 million years ago (**Figure 3-3, Figure 3-4**). Many of these units can be found throughout the study area, such as the Tyee, Coaledo, and Bastendorff formations

(Baldwin, 1974; Molenaar, 1985; Wiley and others, 2014, 2015). These units alternate between sandstones and mudstones and are interpreted to be the result of repeated tectonically forced sea-level rises and falls, which changed the environments of deposition for the various sedimentary units that make up this sequence (McKeel, 1984; Ryu and Niem, 1999; McClaughry and others, 2010). The characteristics of middle to late Paleogene sedimentary rocks in southwest Oregon imply that the distribution of clastic rock types was significantly influenced by worldwide changes in sea level (e.g. eustatic changes).

Exposures of younger post-accretion sedimentary rocks that formed in marine environments during Neogene time (23 to 2.6 million years ago) can be found in a few minor areas throughout the study area, specifically in Coos Bay (Allen and Baldwin, 1944), Bandon (Orr and Zaitzeff, 1970; Orr and others, 1971), and at Cape Blanco (Bandy, 1941; Fowler and others, 1971; Addicott, 1983; Emerson, 2007; Raymond and others, 2008; Wiley and others, 2014).

For example, a gently dipping local coastal unit of semi-consolidated sand, mud, sandy mud, pebbly sand, and gravel which is known as the Port Orford Formation (Baldwin, 1945) formed during the early Pleistocene (~2.53 million years ago). It lies unconformably on early Miocene rocks and forms the sea cliffs north of the Elk River. The Coquille Formation, which is composed of weakly cemented sand and gravel beds and is dated to around the same time period can be found in the subsurface under the Quaternary terrace between Bandon and Whiskey Run. This post-Siletz terrane accretion formation was unconformably deposited on the Mesozoic Sixes River tectonostratigraphic terrane and underlies Quaternary marine terrace deposits north of Bandon which have experienced rock and minor surface uplift. This unit is also in contact with older Coast Range sedimentary rocks in the subsurface either through deposition over an angular unconformity or through juxtaposition by faulting. The Coquille formation of the late Miocene-Pliocene marine diatomaceous muds could be more extensive offshore, as younger Pleistocene terrace and Holocene beach, shelf, estuarine sand and mud and river mouth gravel formed during interglacial lower sea level due to worldwide deglaciation and/or local co-seismic tectonic subsidence or uplift events.

3.3.10 Yachats-Tillamook group: northern and central provinces

The Yachats-Tillamook group refers to basalt units that occur in the northern study area province (Tillamook; [Figure 3-7](#); Plate 2) (Wells and others, 1994) and in the central province (Yachats; [Figure 3-6](#)) (Snively and MacLeod, 1974), where they intrude into the older sedimentary rocks of the Tyee and Umpqua groups. An aggregate thickness of 600 m (~1970 ft) has been interpreted for this group based on an area between Cascade Head and the Salmon River (Snively and MacLeod, 1974). In addition to lava flows, sills of diabase and gabbro have intruded the Tyee group units (Snively and others, 1976). These two units are grouped because of their post-Tyee emplacement as oceanic basalt islands, with the Tillamook basalts interpreted as erupting over a Yellowstone hotspot (Wells and others, 2014). The Tillamook basalts are dated to 46 to 43 million years ago and the Yachats basalts span a time period from 36 to 30 million years ago (Parker and others, 2010).

Figure 3-7. Terrane/Group geologic map (A) and simplified structural features map (B) of the north-2 (N2) segment of the Oregon Coast study area. Geologic data modified from Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).

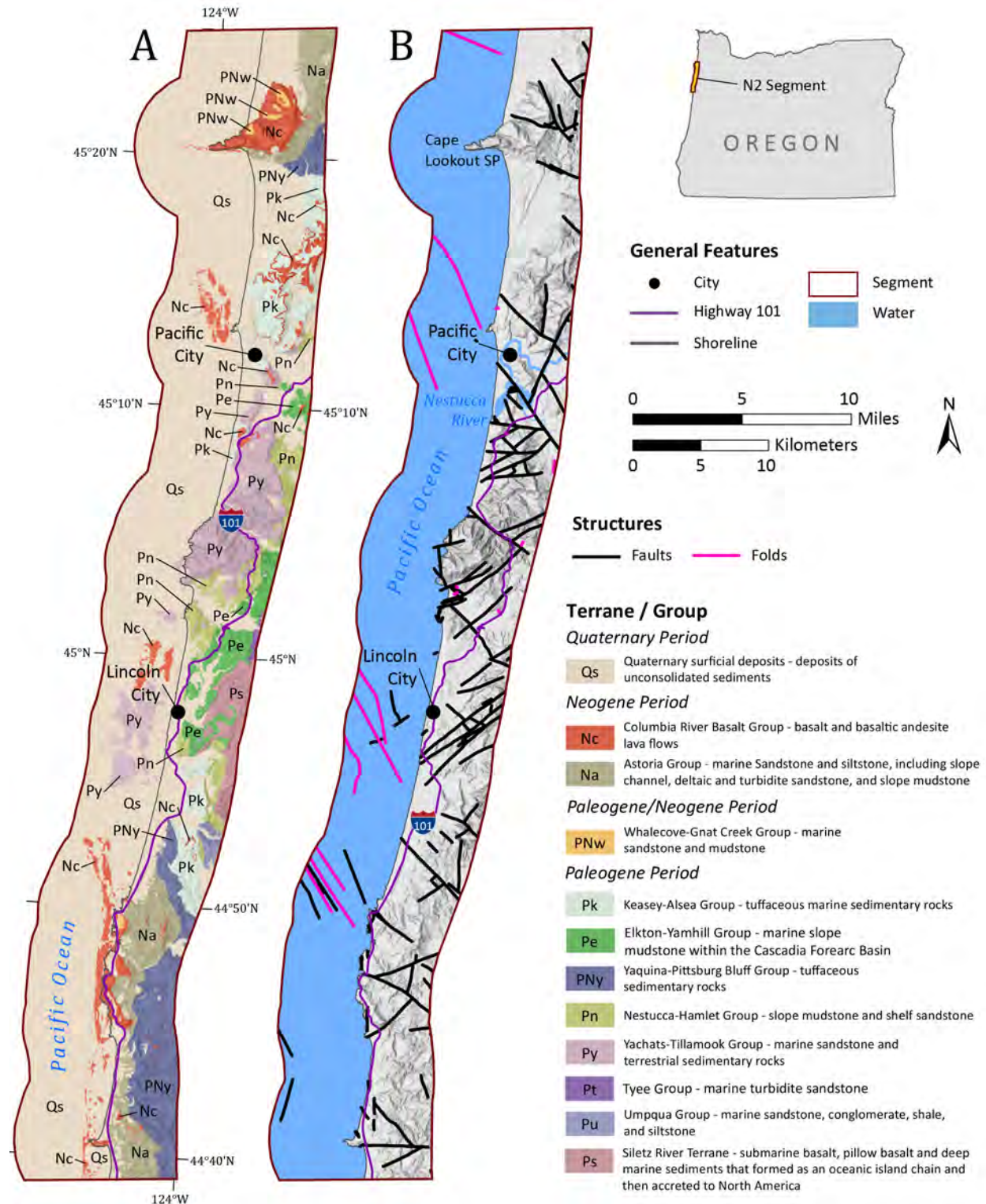
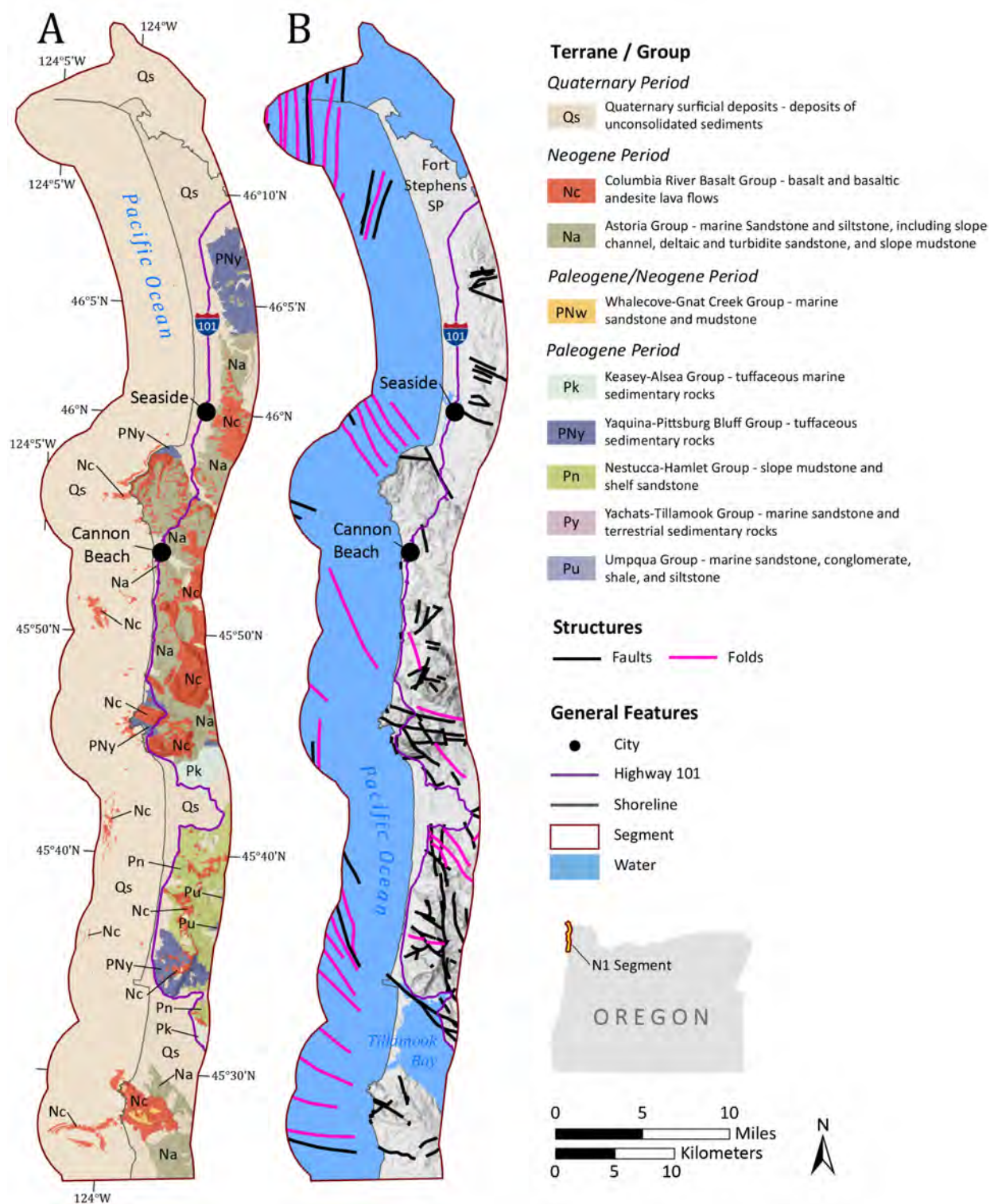


Figure 3-8. Terrane/Group geologic map (A) and simplified structural features map (B) of the north-1 (N1) segment of the Oregon Coast study area. Geologic data modified from Franczyk and others (2020), Goldfinger and others (2014), and Goldfinger and Beeson (2023).



3.3.11 Nestucca-Hamlet group: northern, central, and southern provinces

The Nestucca-Hamlet group refers to two geographically distinct groups of rocks that are equivalent in age and share similar environments of deposition but are distinct in lithology (**Figure 3-7**). The Hamlet units occur as a sequence of massive carbonaceous mudstone interbedded with basaltic conglomerates and sandstone that were deposited in a shallow marine shelf environment adjacent to a rocky coast (Niem and Niem, 1985). The late Eocene Nestucca Formation is a 450 m- (~1,500 ft-) thick sequence of deep marine sedimentary rocks. Compositionally, this formation is characterized by micaceous mudstone containing carbonaceous terrestrial matter, microfossils, thin tuff beds of reworked western Cascade-derived ash, and lenses of glauconitic and volcanic sandstone (Snively and others, 1976c). These units have been K/Ar dated as being 37 to 33 million years old (Snively and others, 1980; late Eocene-early Oligocene). The radiometric age of the Nestucca Formation is consistent with interfingering relationships with the oceanic basalts of the Yachats-Tillamook volcanics (Snively and others, 1976a, 1976b, 1976c).

3.3.12 Keasey-Alsea group: northern and central provinces

The Keasey-Alsea group refers to light yellowish-gray tuffaceous siltstone between 27 and 13 million years old (Snively and others, 1993) that contains thin tuff beds derived from the western Cascades arc (**Figure 3-6, Figure 3-7, Figure 3-8**). At the base of the Alsea Formation, basaltic sandstone beds were locally deposited around basalt headlands in a marine environment. Units of this group are referred to as the Keasey Formation in the north (Niem and Niem, 1985) and as the Alsea Formation in the Newport basin (Snively and others, 1976a, 1976b). The Keasey Formation is interpreted to have been deposited in a deep marine environment and is composed of gray tuffaceous siltstones and massive mudstones. The unit is further subdivided into three informal members: the lowest member is ~150 m (~492 ft) of micaceous laminated siltstone and mudstone, the middle member is ~500 m (~1640 ft) of light gray tuffaceous mudstones and siltstones with occasional ash layers, and the upper member is 50 m (~164 ft) of alternating light and dark siltstones and more resistant calcareous beds (Prothero and others, 2000).

3.3.13 Yaquina-Pittsburg Bluff group: northern and central provinces

The Yaquina-Pittsburg Bluff group overlies the Keasey-Alsea group and shares the shallow marine environment of deposition in the youngest parts of the Keasey-Alsea group. Changes in lithology (presence of coal and abundance of mica) and sedimentary structures indicate that the environment of deposition transitioned from shallow marine to deltaic nonmarine micaceous arkosic sandstone in the middle of the deposit (Goodwin, 1972). The shallow-marine micaceous arkosic sandstone and western Cascade pumiceous debris flow deposits of the Pittsburg Bluff Formation are resistant to weathering and erosion and can form ridges within the northern OCR. The Pittsburg Bluff Formation was deposited between 27 and 23 million years ago (Niem and Niem, 1985). The Yaquina member of the group occurs in the Central province (i.e., the Newport basin; Snively and others, 1976b) and has a measured thickness of 600 m (1,968 ft) (Goodwin, 1972). Strata of the Yaquina-Pittsburg Bluff group include re-worked volcanic clasts that were deposited in high energy environments interpreted as nearshore beach and inner shelf that experienced storm waves. Siltstones of this group are interpreted as being deposited in fluvial and coastal swamp/estuarine environments (Goodwin, 1972). The Alsea Formation is exposed in Yachats (Snively and others, 1976a), where a section of Paleogene basalt of the Yachats-Tillamook group is

overlain by a pebble to boulder conglomerate that transitions abruptly to a coarse, pebbly basaltic sandstone (Vokes, and others 1949; Lund, 1972).

3.3.14 Astoria group: northern and central provinces

The Astoria group includes sedimentary facies corresponding to two marine environments approximately 20 million years ago based on fossil assemblages (**Figure 3-6; Figure 3-7**) (Niem and Niem, 1985). The shallow water facies is a sequence of deltaic coal-bearing, cross-bedded, pumiceous and tuffaceous arkosic sandstones that are locally glauconitic. A deep marine sequence comprises mudstone that is rhythmically interbedded with fine-grained sandstone turbidites in nested channels (Niem and Niem, 1985). The Astoria group crops out along the coast in the Northern and Central province between Seaside and Newport and extends offshore in the Astoria, Tillamook, and Newport basins (**Figure 3-6; Figure 3-7; Figure 3-8**). It contains many intrusions of Columbia River Basalt Group, particularly in the northernmost outcrops of our study area (Plate 2) (Niem and Niem, 1985).

There are distinct units, or members of the Astoria Formation in the study area. First, the Angora Peak member is composed of ~335 m (1,100 ft) alternating layers of thick sandstone, dark-gray, carbon-rich siltstone, and pebble conglomerates (Smith, 1974). The Silver Point member is a ~198 m (650 ft) layer of dark, laminated mudstones that overlies the Angora Peak member and contains fossils that are interpreted as having a deep marine environment of formation based on evidence at Ecola State Park (Niem, 1975). The Netarts Bay member is made up of arkosic sandstones that can have variable grading in terms of grain size that contains large blocks of siltstone and have been interpreted as the product of deposition in a channel occurring in the transition zone between the shallow marine shelf and the slope (Parker, 1990). The Cannon Beach member of the Astoria Formation extends from the Columbia River in the north and has been identified as far south as Cape Lookout, in the Tillamook area, and overlies both Angora Peak and Netarts members, as shown in Plate 2. The Cannon Beach member is the uppermost member of the Astoria Formation and is characterized by rhythmically bedded and channelized turbidite sandstone and mudstone lithology (Parker, 1990).

Strata of the Astoria group rock have variable engineering properties, but generally tend to be weak. In the northern province, bluffs along the coast have a mean slope of ~45° in places where bare talus slopes of mostly mudstones, siltstones, and tuffs of the Astoria group are exposed to weathering and erosion. Where undercut by storm waves, landslides occur on steep cliff exposures (Niem, 1975). In some locations the Astoria units are exposed as near-vertical cliffs where wave action undercuts slopes, or where more resistant sandstone units are exposed as headlands, such as Devil's Punch Bowl (Priest and Allan, 2004).

3.3.15 Columbia River Basalt Group: northern and central provinces

The Columbia River Basalt Group (CRBG) is a succession of tholeiitic basalt and basaltic andesite lava flows erupted in eastern Oregon, eastern Washington, and western Idaho between ca. 17 and 5.5 million years ago (e.g., early to late Miocene). The flood basalts cover more than 210,000 km² (~81,000 mi²) (Reidel and others, 2013) (**Figure 3-6, Figure 3-7, Figure 3-8**). Along the Oregon Coast, these basaltic lava flows crop out from south of Newport to Astoria both onshore and offshore. CRBG occurs as subaerial lava flows and pillow lava deltas where the lava flows entered the Pacific Ocean and invasive sills and dikes. Invasive basalts are hosted by older or equivalent aged sedimentary units such as the Astoria group and Yaquina Formation (Plate 2) (Niem and Niem, 1985; Wells and others, 2009). An example of the relationship of the CRBG and older units is exposed at Seal Rock State Park, where basalt forms numerous dikes and a thick sill in the Oligocene Yaquina Formation (Snively, 1980). Very thick sills of CRBG in the

Astoria group form the headlands at Tillamook Head and Neahkahnie Mountain. This hard basalt is also present in the offshore as rock reefs and sea stacks ([Figure 3-8](#)).

3.3.16 Whale Cove-Gnat Creek group: northern segment

The Whale Cove-Gnat Creek group was deposited as thin, shallow-marine and coal-bearing fluvial to estuarine sediments during the middle to late Miocene, between 13 and 11 million years ago. These units are interbedded with CRBG lava flows. This micaceous arkosic to basaltic sandstone is poorly consolidated and consequently friable (Murphy 1981; Niem and Niem, 1985; Snively and others, 1976c).

3.3.17 Quaternary surficial deposits

By 2.5 million years ago, the position of the present CSZ was established into its present configuration (Wells, 1994). Four basins began accumulating continentally derived and marine sediments during the late Neogene: Astoria, Tillamook, Newport, and Coos. Sediments continue to be deposited in these basins and both sediments and underlying rock units are presently experiencing active deformation (e.g., [Figure 3-8b](#)). These inner and middle shelf basins are filled with ~1 km (~0.6 mi) of soft, semi-consolidated deep-marine mud, glauconitic quartzo-feldspathic sand and hemipelagic mud. The sediment sequence is broken by two major angular unconformities (Kulm and Scheidegger, 1979; Clarke and others, 1985; Niem and Niem, 1992; McNeil and others, 2000).

3.3.17.1 Northern and central provinces

Pleistocene and Holocene surficial deposits in the central and northern provinces are unconsolidated shallow-marine, estuarine, and alluvial sediments that are either in active transport or have yet to be buried to an extent where they become lithified and are the product of the last 1.8 million years of tectonic uplift and landscape evolution of the OCR. Throughout the northern and central provinces, prominent landforms include uplifted wave-cut coastal marine terraces underlain by rounded gravels and sand (up to 10 m/ 33 ft thick) (e.g., Kelsey and others, 1996; McKenzie and others, 2022). Sandy beaches, spits, and dunes are significant along many sectors of the coast (e.g., Plate 2). Inland, fluvial terraces are preserved along many streams, and along with bedrock channels, record progressive uplift and incision of the OCR (e.g., Personius, 1995; Kobor and Roering, 2004). More minor deposits include buried Pleistocene paleosols, estuarine mud beds, and layers of partially carbonized vegetation (Niem and Niem, 1985; Snively and others, 1976). There is widespread basalt colluvium which consists of thick and structureless deposits of angular to sub-rounded basalt breccias and massive basalt boulders (up to 16 m/52 ft in diameter) (Niem and Niem, 1985). Active and inactive landslides are widely distributed across the study area and are commonly recognized by hummocky topography and other morphologic signatures (e.g., Burns and Madin, 2009; Burns and Mickelson, 2016). Landslide debris consists of a chaotic mixture of soil, blocks of bedrock, and woody fragments. Active and inactive sand dunes can be found along the shoreline within the northern and central provinces. A 20 km (13 mi) stretch of foredune ridges parallels the coast from Warrenton to Seaside ([Figure 3-8](#)) and from Florence to Reedsport ([Figure 3-5](#); [Figure 3-6](#)) (Peterson, 2007). Locally, dune deposits may contain peat and lake mud deposits in and around intradune lakes.

3.3.17.2 Southern province

Much of the southern province contains Middle Pleistocene (1.8 million years old) and younger deposits of marine, fluvial, landslide, beach, dune, river, and alluvial fan deposits, all of which are unconsolidated. These deposits are highly susceptible to wave erosion along coastal bluffs and by hillslope and fluvial

processes inland often driven by heavy rainfall. Wave- and river-cut benches, along with related nearshore, fan, and river deposits, are preserved as terraces and related erosional flats (strath terraces). Groups of marine terraces are widespread along the Oregon Coast and Territorial Sea (**Figure 3-3; Figure 3-4**). They range in age from 80,000 years old to >200,000 years old and are located on wave-cut benches that rise from the sea to elevations of up to 330 m (1080 ft), respectively (McInelly and Kelsey, 1990; Kelsey and others, 1994). Fluvial terraces and strath terraces are inset into bedrock and into the youngest marine terraces along rivers and streams. The study area includes landslide deposits of varied types including rockfall deposits, debris fans, slumps, and deep-seated landslides (Niem and Niem, 1985; Burns and others, 2010; McClaghry and others, 2013; Wiley and others, 2014; 2015; Priest and Allan, 2004, Priest and others, 2004).

3.4 Structural Geology of the Oregon Coast and Territorial Sea

The movement and interaction of tectonic plates along their boundaries causes deformation of Earth's crust. In the upper ~10 to 15 km (6 to 10 mi) deformation is largely localized on faults, which are fractures that accommodate differential movement in Earth's crust. Faults can displace crustal blocks in vertical, horizontal, or oblique senses related to the orientation and magnitudes of stresses and rock properties. Faults are present throughout the Oregon Coast study area (e.g., **Figure 3-3b**) and are presented as a total accumulation, without distinguishing age or identified activity level. Faulting in western Oregon is related to the history of terrane accretion, the CSZ, and other plate boundary processes in western North America (Wells and others, 2014). Folds are a second type of structure that occurs where the crust bends in a distributed way. Anticlines are folds that are convex-upward, and synclines are concave-upward, and they generally form in pairs. In the upper crust, most folds are related to nonplanar geometries and/or slip gradients on faults present deeper in the crust (e.g., Burbank and Anderson, 2012), examples of these folds occur in sedimentary units or in the offshore region (e.g., **Figure 3-7; Figure 3-8**). Other folds exposed at the surface of the Earth today formed deeper in the crust where high temperatures allow the rocks to flow through plastic deformation at the scale of individual crystals, examples of which are in the southern province, where metamorphic units are present (e.g., **Figure 3-3; Figure 3-4**).

The distribution of mapped geologic units, faults, folds, and bedding attitudes (i.e., strikes and dips) as well as topographic lineaments as seen in high-resolution lidar, are data that describe the geologic structure along the Oregon Coast. Information such as total fault displacement can often be interpreted from offset of distinct lithologic units on either side of a fault. However, these contacts or markers are often absent across fault zones in the dense forests with deep soils of the OCR and Klamath Mountains due to nearly identical lithologies that occur on either side of the fault zones (McClaghry and others, 2013). In some cases, relative amount of offset is only locally well defined by geologic units seen along shore cutbanks or within area coal mines.

The Coast Range and Territorial Sea landscapes evolved to their present configuration because of the long-lived Mesozoic to Cenozoic geologic history of subduction of oceanic lithosphere and accretion of the various tectonostratigraphic terranes described above in **section 193.3**. The tectonic forces which moved these crustal blocks also resulted in deformation, which is generally brittle near the surface and ductile at depth. Tectonostratigraphic terranes were emplaced along major boundary faults which accommodated the movement of pieces of dismembered lithosphere into the current configuration and may juxtapose geologic units of varying hardness (sedimentary rocks with exotic greenstone, for example). There are also many joints and faults which postdate the emplacement of the tectonostratigraphic terranes and

result from the ongoing deformation associated with the subduction zone and continuing tectonic clockwise rotation as evidenced by paleomagnetism (Wells and McCaffrey, 2013). The style of faulting and magnitude of displacement of on the faults varies throughout the study area. However, the result of faulting is the juxtaposition of geologic units that do not necessarily share lithological characteristics such as sandstone, volcanic, intrusion, or metamorphic rock type and/or rock strength (e.g., Plates 1 and 2). Active faults and folds also pose hazards both as sources of seismic shaking as well as causing deformation of the ground surface above.

4.0 COASTAL DYNAMICS

This section provides information on coastal dynamics along the coast of Oregon, including descriptions of the characteristics of waves and water levels, predicted rates of sea-level rise, general beach dynamics (including closure depths), and beach and bluff change rates.

4.1 Wave Climate

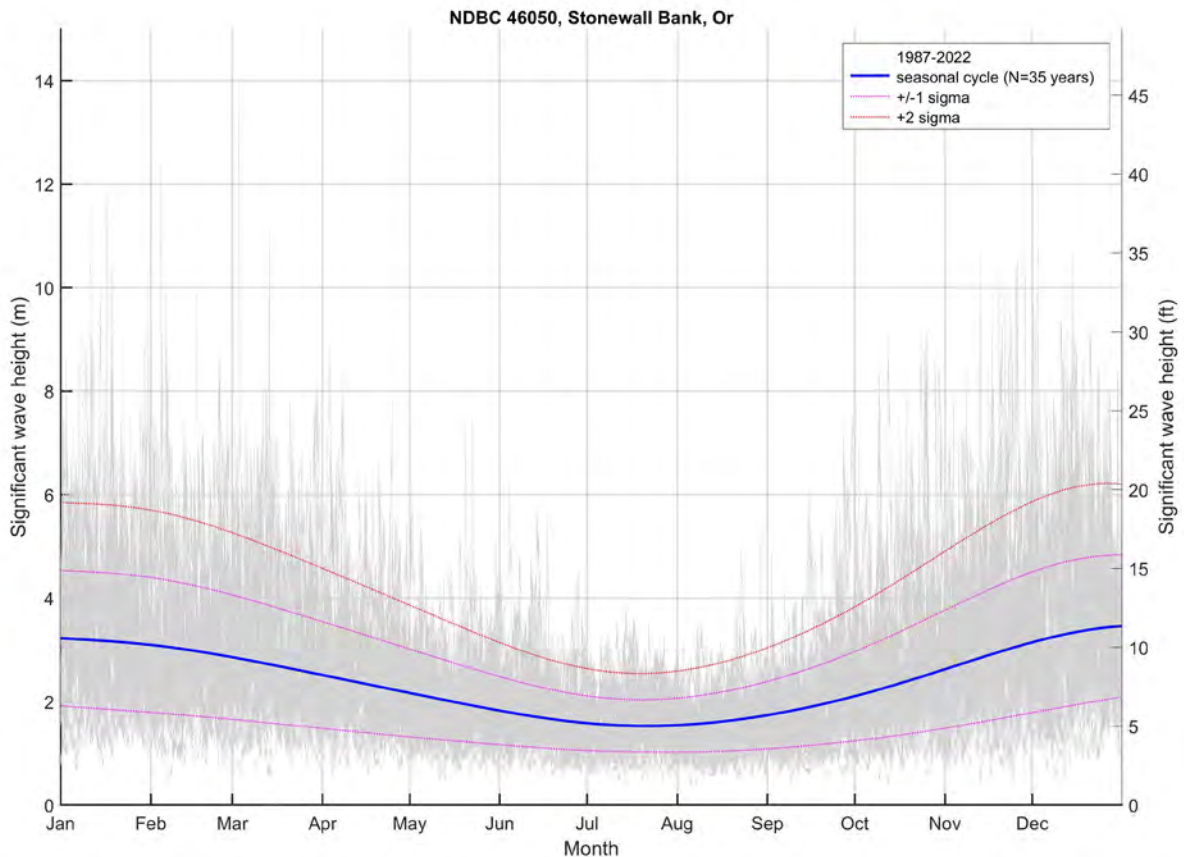
Wave action is the dominant process affecting the shape and composition of beaches. Waves transport sand onshore (toward the beach), offshore (seaward to form nearshore bars), and along the beach (longshore transport). Short-term (seasonal to interannual) beach and shoreline variability (i.e., storm-related changes) is directly dependent on the size of the waves that break along the coast, ocean water levels, and cell circulation patterns associated with rip currents. Conversely, long-term (interannual to multidecadal) shoreline changes are also forced by additional factors including the balance in the beach sediment budget (sediment inputs versus losses), changes in sea level, storm patterns, and regional tectonics.

The Oregon Coast is exposed to one of the most dynamic ocean wave climates, due to its long fetches and the strength of the extratropical storms that develop and track across the North Pacific (Allan and Komar, 2002). **Figure 4-1** presents a 35-year (1987 to 2022) summary of wave conditions measured at the Stonewall Bank (#46050) National Data Buoy Center wave buoy, located 35 km (21 mi) offshore from Newport on the central Oregon Coast. As can be seen in the figure, the offshore wave climate is characterized by a pronounced seasonal cycle (solid blue line) producing larger waves in the winter (mean significant wave height (H_s) = 3.45 m (11.3 ft)) compared with summer conditions (mean = 1.54 m (5.0 ft)). However, the most extreme winter storm waves can exceed heights greater than 10 m (33 ft), while the largest storms may produce significant wave heights in the range of 14 to 15 m (45 to 50 ft). Estimates of the 100-year or 1% extreme storm wave have been found to range from 14.4 m (47 ft) (Ruggiero and others, 2010) to 15.6 m (51 ft) (Allan and Komar, 2006). In contrast, the summer months are dominated by smaller wave heights (**Figure 4-1**), enabling beaches to rebuild and gain sand eroded in the preceding winter. Thus, there is a seasonal exchange in the volume of sand present between summer (accreted) and winter (eroded). When large waves are superimposed on high tides, they can produce total water levels that are able to reach much higher elevations at the back of the beach, contributing to significantly higher rates of coastal erosion and flood hazards (e.g., **Figure 2-1**). It is the combined effect of these latter processes that leads to the erosion of coastal dunes and bluffs, causing them to retreat landward.

4.2 Tides

Tides along the Oregon Coast are classified as mesoscale, with an average range of about 1.8 m (6 ft) and a maximum range of up to 4.3 m (14 ft) (Komar, 1997). There are two highs and two lows each day, with successive highs (or lows) usually having markedly different levels. Tidal elevations are given in reference to the mean of the lower low water levels (MLLW) and can be easily adjusted to other datums, including the North American Vertical Datum of 1988 (NAVD88). Most tidal elevations are positive numbers with only the most extreme lows having negative values. **Figure 4-2** shows various tidal elevation statistics derived from the South Beach (#9435380) tide gauge located in Yaquina Bay, Newport for the period from 1967 to 2022; the tidal patterns at South Beach are typical of gauges along the Oregon Coast. The South Beach gauge is characterized by a mean¹ range of 1.9 m (6.3 ft) and a diurnal² range of 2.5 m (8.3 ft). The highest tide measured from this record reached 3.7 m (12 ft), recorded in December 1969 during a major storm.

Figure 4-1. Seasonal variability of ocean waves measured at the Stonewall Bank (#46050) wave buoy, offshore from Newport for the period from 1987 to 2022. Gray lines define all measurements since 1987. The seasonal cycle is depicted by the solid blue line, while the range $\pm 1\sigma$ is shown by the two magenta lines accounting for 68% of the variability, and the red line shows $+2\sigma$ (accounting for 95% of the observations).



¹ The difference in height between mean high water and mean low water.

² The difference in height between mean higher high water and mean lower low water.

Tides on the Oregon Coast are enhanced during the winter months due to warmer water temperatures and the presence of northward-flowing ocean currents that raise water levels along the shore and persist throughout the winter rather than lasting for only a couple of days as is the case for a storm surge. This effect can be seen in the monthly averaged water levels derived from the combined time series (**Figure 4-3**). **Figure 4-3** indicates that, on average, monthly mean water levels during the winter are ~0.23 m (~0.75 ft) higher than in the summer. Water levels are most extreme during El Niño events, due to an intensification of these processes and enhanced sea surface temperatures offshore from the Oregon Coast. This effect was evident for the unusually strong 1982-83 and 1997-98 El Niños (Komar, 1997; Allan and Komar, 2002). As seen in **Figure 4-3**, monthly mean water levels during those climate events were approximately 0.25-0.3 m (0.8-1.0 ft) higher than the seasonal peak, and as much as 0.56 m (1.8 ft) higher than during the preceding summer, enabling wave swash processes to reach much higher elevations on the beach during the winter months, with storm surges potentially raising the water levels even further.

Figure 4-2. Daily tidal stages and elevations measured at South Beach (#9435380) tide gauge Yaquina Bay, Newport on the central Oregon Coast. Data from National Ocean Service (<https://tidesandcurrents.noaa.gov/waterlevels.html?id=9435380>).

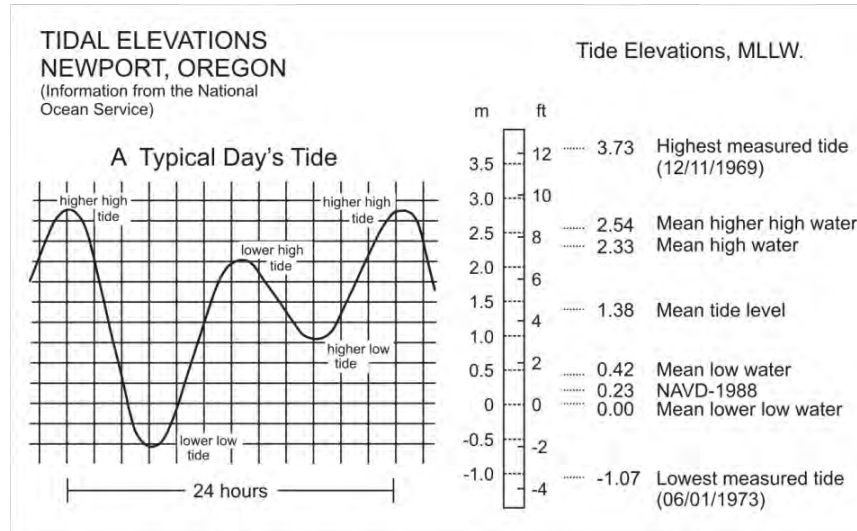
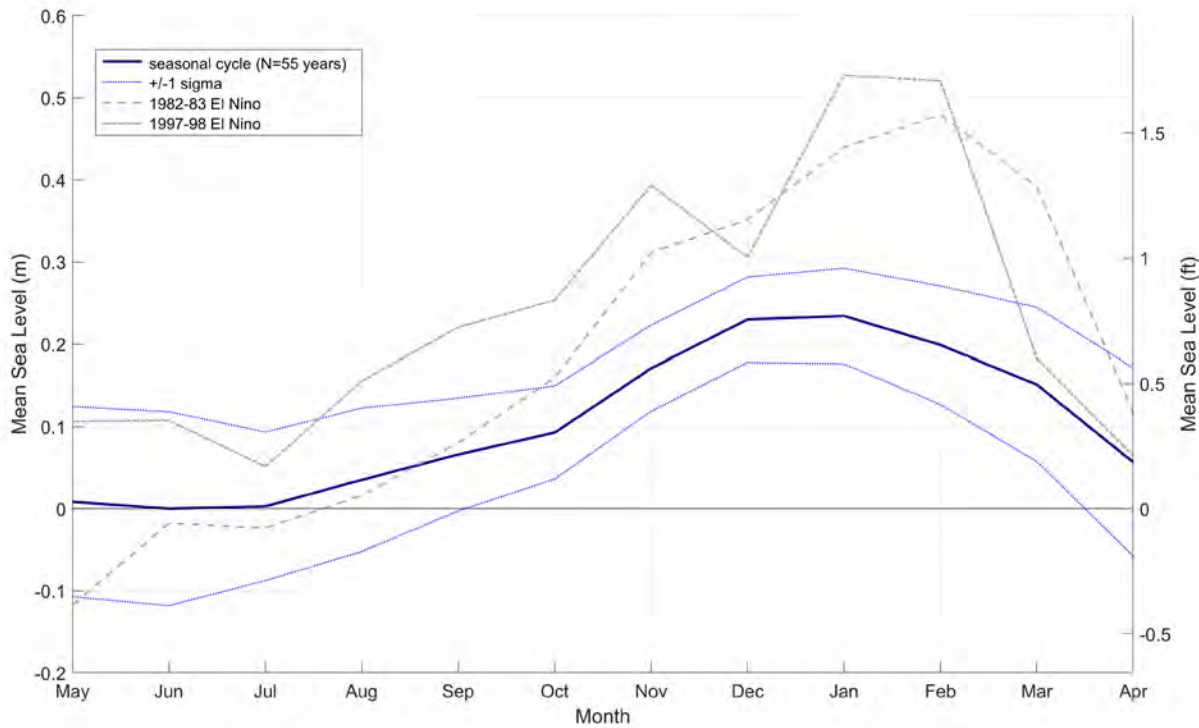


Figure 4-3. Seasonal cycles in monthly mean water levels based on data from the South Beach tide gauge (1967-2022). Data from National Ocean Service.



Aside from the seasonal and interannual effects of climate events on ocean water levels, also of interest are the long-term trends associated with relative sea-level changes on the Oregon Coast. Analyses by the NOS indicate that regional sea level at the South Beach tide gauge has risen relative to the land at a rate of $\sim 1.75 \pm 0.61$ mm/yr (0.07 ± 0.02 in/yr) which equates to a sea-level increase of ~ 0.1 m (~ 0.3 ft) since 1967. However, the rate of sea-level change along the Oregon Coast is far from uniform due to regional variations in tectonic uplift and post-glacial isostatic adjustment (e.g., Burgette and others, 2009; Komar and others, 2011; Harvey and others 2021; He and others 2022). In general, analyses of GPS, leveling data from benchmarks, and sea-level gauge trends reveal that sea level is presently falling relative to the land on the southern Oregon Coast due to higher rates of tectonic uplift (a function of the coast being closer to the CSZ). Conversely, sea level is rising when compared with the land on the central to northern Oregon Coast south of Tillamook Head; at the mouth of the Columbia River the rate of sea level rise approximately matches the rate of tectonic uplift. These spatial variations are expected to continue in the absence a major earthquake, with forecasted rates of sea-level rise increasing across the region into the future (e.g., Sweet and others 2022).

4.2.1 Projected future sea levels for the Oregon Coast

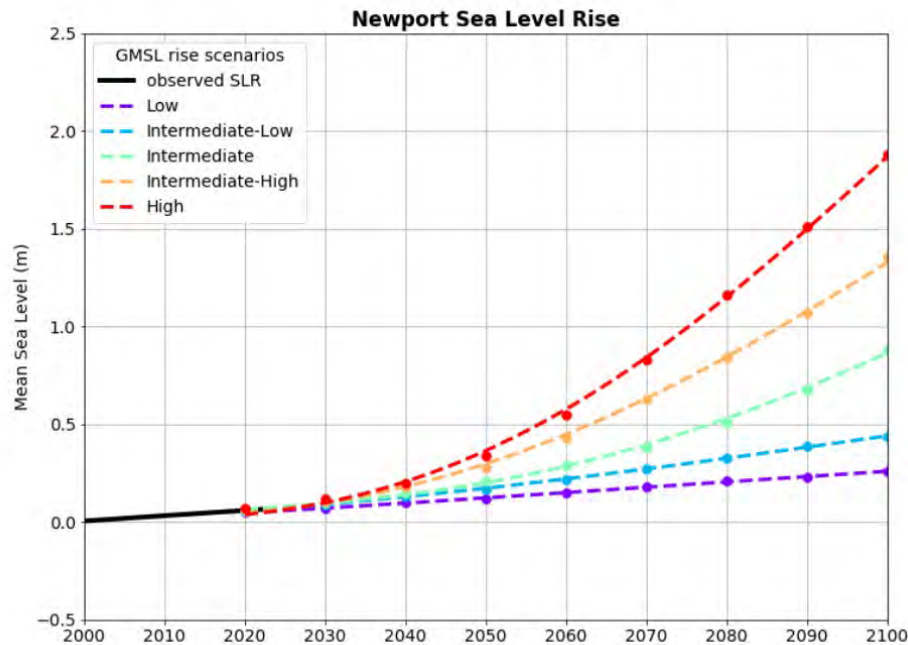
Sea-level rise driven by climate change is considered to be a clear and present danger to many coastal communities located around the shorelines of the United States and its territories (Sweet and others, 2022). Global average sea level has increased by 0.2 m (0.66 ft) between 1901 and 2018 (IPCC, 2021), and relative sea level averaged along the contiguous United States has risen by 0.28 m (0.92 ft) in the same period (Sweet and others, 2022). Evaluation of global sea-level change derived from satellite altimetry indicates an increase of 3.56 mm/yr (0.14 in/yr) since 1993, while regional estimates for the North Pacific

are slightly lower at ~3.09 mm/yr (~0.12 in/yr) (AVISO, 2023). Combining knowledge of glacial isostatic rebound (the rate at which the Earth responds to the removal of ice from the last glaciations), regional tectonics, and future temperature patterns determined from global climate models, Sweet and others (2022) provided updated low, intermediate-low, intermediate, intermediate-high, and high-range forecasts for mean sea-level changes for the United States. For the purposes of this report, we focus on increases in sea level using the midrange (intermediate) scenario, given the large uncertainties associated with future climate predictions. Based on the estimates of Sweet and others (2022), the central Oregon Coast (Newport) is predicted to experience a regional sea-level increase of ~0.87 m (2.9 ft) by 2100 (**Table 4.1**), with alongshore variations in the magnitude of sea level rise due to local vertical land motion processes (**Figure 4-4**). It is important to stress that projections of future sea level assume that sea level is uniform year-round. However, as noted previously, sea level on the Oregon Coast exhibits a pronounced seasonal cycle of about 0.23 m (0.75 ft) between summer and winter, increasing to as much as 0.5 m (1.6 ft) in response to the development of a strong El Niño. Hence, when combined with projected future regional sea-level rise, it is apparent that the potential increase in sea level could be substantially greater depending on the time of year and role of the El Niño Southern Oscillation phenomena (**Table 4-1**). For example, by 2100, sea level during an El Niño winter could raise water levels by a total of 1.37 m (4.5 ft), raising the mean shoreline position by that amount, which will shift upward and landward as beaches respond to the change in mean water levels.

Table 4-1. Projected sea-level rise (SLR) for the central Oregon Coast. Data from Sweet and others, 2022.

	SLR (m)	SLR (ft)	El Niño + SLR (m)	El Niño + SLR (ft)
2050 midrange projection	0.20	0.66	0.7	2.3
Range	0.11 to 0.33	0.36 to 1.08	0.61 to 0.83	2 to 2.47
2100 midrange projection	0.87	2.85	1.37	4.5
Range	0.25 to 1.87	0.82 to 6.14	0.75 to 2.37	2.46 to 7.8

Figure 4-4. Observed and projected regional sea-level rise from 2000 through 2100 for the Newport tide gauge in Oregon (figure from Fleischman, 2023, with the data based on Sweet and others, 2022).



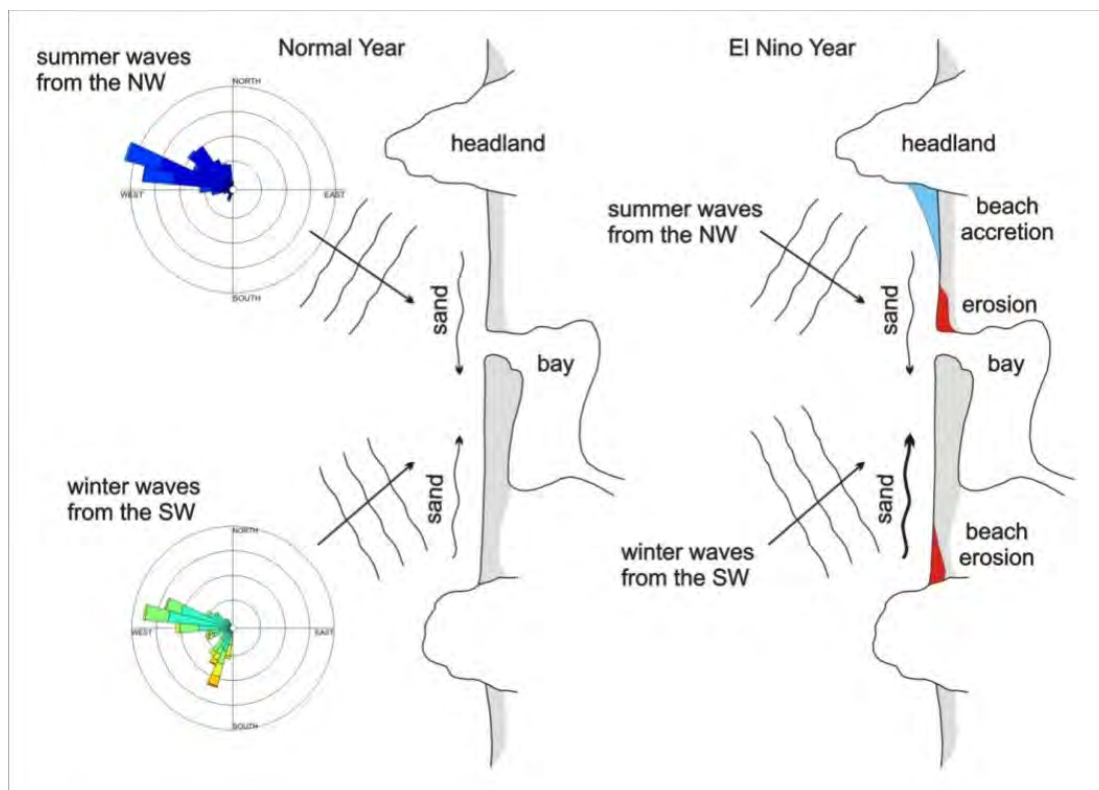
4.3 Sediment Transport

The turbulent process of wave breaking occurs across the nearshore surf zone and results in the entrainment of sediments, which are then moved about by nearshore currents. We can distinguish between those sediments that are moved in the cross-shore direction perpendicular to the beach (cross-shore sediment transport), and the movement of sediments parallel to the beach (longshore transport). Longshore transport is especially significant when waves approach the shore at oblique angles, producing strong currents confined to the breaker zone which can be responsible for the movement of substantial volumes of sediment along the shore.

On the Oregon Coast, the role of longshore currents is especially important due to seasonal variations in the directions of wave approach between summer and winter (Figure 4-5). During a “normal year,” summer waves, driven by north to northwesterly winds, approach the coast from the northwest (Figure 4-5, left, top) and transport sand onshore and toward the southern ends of the littoral cells, causing the dry part of the beach to prograde while sand may accumulate in the dunes (Komar, 1998). In contrast, the arrival of large winter waves from the southwest (Figure 4-5, left, bottom) results in a reversal in the net sediment transport direction, which is now directed toward the north. The combination of oblique wave approach and the shift to larger winter waves contributes to erosion of the beach by moving the sand back offshore. Over several “normal” years, and in some Oregon littoral cells there can be an equilibrium balance such that the net sediment transport is close to zero (i.e., there is no net long-term buildup (accretion) of sediment at either end of the littoral cells). However, this pattern may be periodically disrupted by the occurrence of major El Niño events, which can contribute to a significantly larger net northward movement of the sediment (Figure 4-5, right). In particular, El Niño events have been shown

to cause “hot spot” erosion at the southern ends of littoral cells (north of headlands and jetties) and on the northern side of estuaries.

Figure 4-5. Patterns of sediment transport during “normal” (left) and El Niño (right) years (after Komar, 1986).



One of the earliest descriptions of the effect of El Niño events on the displacement of sand in littoral cells on the Oregon Coast is that of Komar (1986). While examining the effects of the 1982-83 El Niño in the Beverly Beach littoral cell north of Newport, Komar observed an unusually high northward drift of sand in the cell, with erosion immediately north of Yaquina Head and accretion to the north at Otter Rock. Komar (1986) attributed this response to a combination of factors, including the southward displacement of the storm systems, larger waves (and hence higher wave energy levels), and more acute wave approach angles from the southwest that contribute to the development of strong northward directed currents and sediment transport within the surf zone.

Peterson and others, (1990) were also interested in the effects of the 1982-83 El Niño, focusing their study on the quantification of the northward displacement of sand between Yachats and Seal Rock on the central Oregon Coast. They estimated some $4.8 \times 10^6 \text{ m}^3$ ($6.3 \times 10^6 \text{ yd}^3$) of sand was displaced during the event along $\sim 7.4 \text{ km}$ ($\sim 4.6 \text{ mi}$) of shoreline. However, their analysis was based on only a few discrete transects, and their speculation of the thickness of the sand and beach slopes produced volume estimates that are large relative to more recent beach volume estimates (Allan and Hart, 2007; Allan and Hart, 2008) and changes observed elsewhere on the Oregon Coast. Regardless, they concluded that the sand shift was the result of a southward 10-15° latitude shift in the winter geostrophic wind, a proxy for the seasonal storm tracks. Essentially, this means that the predominant storm tracks are shifted to the south so that the storm waves arrive at relatively more acute angles relative to the shore, contributing to a stronger than normal north-directed wave energy flux.

In anticipation of potentially large erosional responses expected for the 1997-98 El Niño, airborne lidar was flown along the entire U.S. West Coast. The resultant data were subsequently analyzed in two studies in the Netarts littoral cell to assess the patterns and volume of sand transported as a result of the El Niño (Allan and others, 2003; Revell and others, 2002). In general, Revell and others found that the sand largely moved northward in the Netarts cell, with the greatest amount of erosion occurring at the south end of the cell at Cape Lookout State Park. They noted that the seasonal cycle of cross-shore sediment and beach change was about 320,000 m³ (418,500 yd³) of sand volume, while about 70,000 m³ (91,557 yd³) of sand was shifted to the north. Allan and others (2003) identified that the mean shoreline position along the southern 3 km (1.9 mi) of the Netarts cell (i.e., seaward of Cape Lookout State Park) eroded by ~20 m (~66 ft). More recently, Allan and others (2009) documented a rotational shift in the mean shoreline position in the Rockaway littoral cell located between Cape Meares and Neahkahnie Head in Tillamook County. Erosion was observed to occur at the south end of all three subcells, while accretion dominated the northern ends of the cells (Allan and others, 2009). In total, some 1.4 x 10⁶ m³ (1.9 x 10⁶ yd³) of sand was removed from the cell due to enhanced wave erosion, some of which was removed to the north where it accumulated on Nehalem Spit. These data reflect the accumulated change that took place over two winters, the 1997-98 El Niño and 1998-1999, when a series of particularly extreme storms occurred.

Anderson and others (2018) analyzed a 63-year record of hindcast waves (1950-2010) in order to calculate the monthly alongshore wave energy flux (a measure of the sediment transport potential). They found that the average monthly climatology of all 63 years results in zero net annual longshore directed wave energy flux, consistent with the hypothesis of Komar (1998). However, when individual years were examined, such as major El Niños, the northerly directed energy flux was found to be an order of magnitude greater than the climatological mean (i.e., more sand was transported to the north). Conversely, major La Niña events produced a comparable response, but in the opposite direction (Anderson and others, 2018). Incorporating a one-line shoreline change model and the long-term wave energy flux, Anderson and others (2018) identified decadal oscillations in the position of the shoreline between 1950 and 2010, which were strongly coupled to the occurrence of the El Niño/La Niña climate phenomena, as well as the longer-term Pacific Decadal Oscillation.

4.3.1 Closure depth

The seaward limit of measurable morphologic change is referred to as the depth of closure (DOC) and is a function of the nearshore wave climate and sediment characteristics (Birkemeier, 1985; Brutsché and others, 2016; Hallermeier, 1981). More specifically, the DOC reflects the depth at which there is little to no significant change in the bottom elevation. In this respect, the DOC provides a measure of the seaward extent of the littoral zone and is often thought of as the location at which repeat beach profile elevations converge through time. A second, deeper zone, was also defined that reflects the region where wave effects on the seafloor become negligible. Equations for calculating the offshore extreme surf-related effects of the littoral zone (d_l) and shoal zone (d_s) regions were originally developed by Hallermeier (1981) and modified by Birkemeier (1985). Using both sets of equations, Brutsché and others (2016) calculated DOCs for the entire US coastline, using Wave Information Study (WIS) hindcast stations. Their results are extremely useful for any coastal engineering analysis that requires an understanding of the seaward extent of significant net sediment transport in a region. Analyses of the DOCs calculated for the Oregon Coast using the Hallermeier equations indicated an average DOC of 15.9 m (52 ft), $\pm 1\sigma = 0.37$ m (1 ft); empirical calculations using Birkemeier equations indicated a mean DOC of 12 m (40 ft). Allan and others

(2005) performed similar calculations and determined a DOC for the Oregon Coast that ranges from 10 to 14 m (33 to 46 ft), varying from year to year.

Figure 4-6 presents repeat surveys of bathymetric change measured at a long-term (1998 to 2021) coastal monitoring site on Long Beach Peninsula (075), Washington State (data from Ruggiero and others, 2016). The repeat surveys show the degree of variability across the nearshore and subaerial beach, with the largest vertical envelope of change occurring at depths less than ~10 m (~33 ft). Below the 10 m (33 ft) isobath, the degree of change is much lower ($1\sigma = \sim 0.16$ m (0.5 ft)). Hence, in the Long Beach example of repeat bathymetric measurements, the DOC is close to ~10 m (~33 ft). Analyses of serial bathymetric surveys at multiple transects in the Rockaway littoral cell (2008 to 2016) (**Figure 4-7**; Allan and others, 2015d; Cohn and others, 2019) suggest a deeper DOC that is ~14 to 15 m (~46 to 49 ft). In both cases, the results from repeat bathymetric surveys are generally consistent with the simple empirical estimates of the DOC calculated by Brutsché and others (2016).

Figure 4-6. Repeat topo-bathymetric surveys performed at line 075, Long Beach peninsula, Washington State. Top plots depict the serial beach and nearshore profile surveys and the bottom plot shows the envelope of variability determined from all surveys. Data from Ruggiero and others (2016).

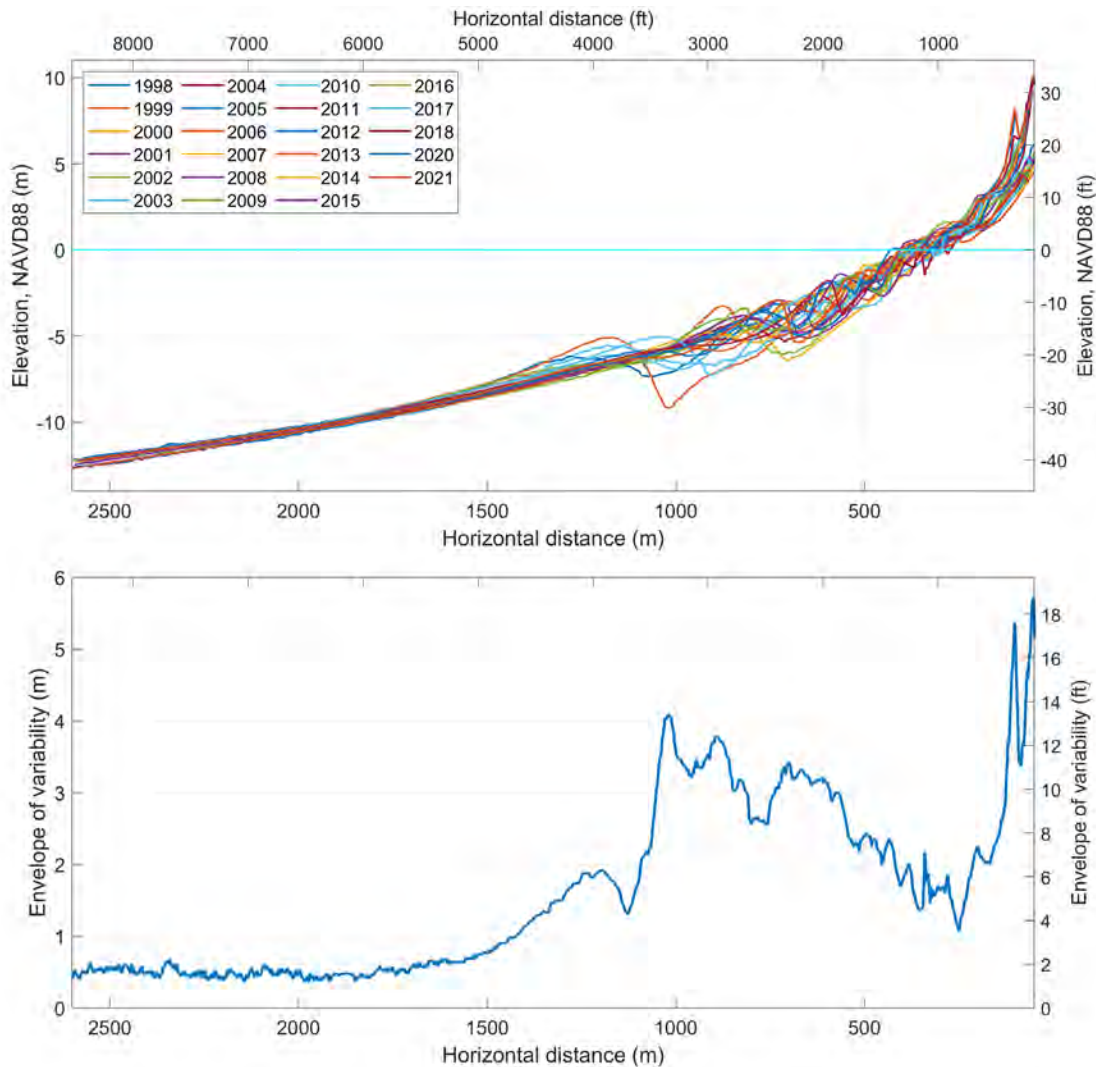
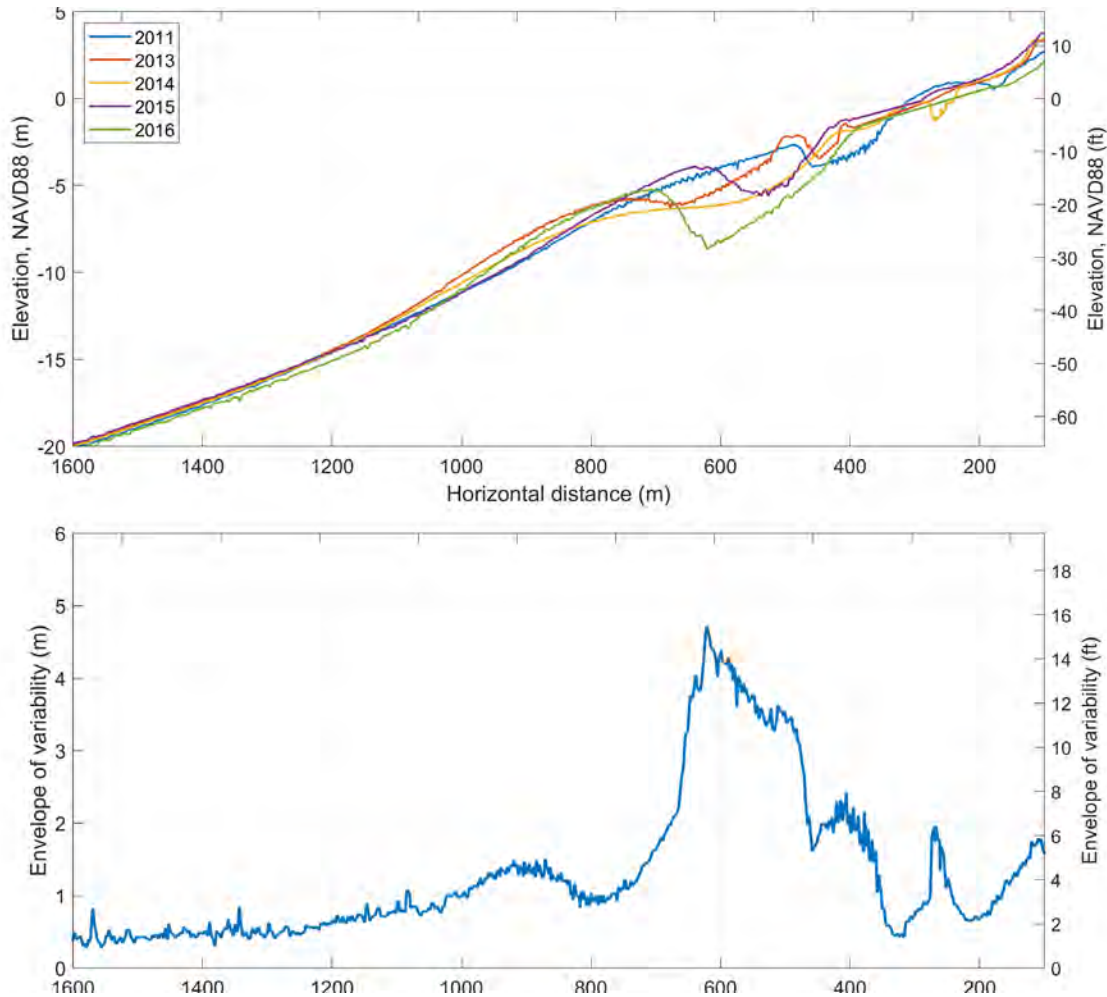


Figure 4-7. Repeat topo-bathymetric surveys performed at line 053, Rockaway Beach, Oregon. Top plots depict the serial beach and nearshore profile surveys and the bottom plot shows the envelope of variability determined from all surveys. Data from Allan and others (2015d) and Cohn and others (2019).



4.4 Coastal Change Rates and Patterns

4.4.1 Previous studies

Numerous studies have attempted to define the patterns and rates of erosion for different rock lithologies for coastal bluffs along the Oregon Coast ([Table 4-2](#)), including Lincoln County (Seal Rock to Roads End (Priest and others, 1994); Cascade Head to Seal Rock (Priest and Allan, 2004), Seal Rock to Cape Perpetua (Witter and others, 2007), Sisters Rock to North Gold Beach, Curry County (Priest and others, 2004), and southern Clatsop County (Witter and others, 2009). Erosion rates were defined using discrete measurements of identified features in serial imagery, typically a house to top of bluff measurement. Although the results from these studies are useful, they lack sufficient spatial coverage and have potentially large uncertainties in the calculated rates of change as the temporal period of observation is

limited to the period of study. For example, efforts by Priest and Allan (2004) used early 1939 aerial images where coverage was good, while other studies have used 1967 aerial images to estimate change. Unfortunately, there is no sustained effort to document the long-term rates and patterns of bluff erosion, which remains a limitation for projecting future erosion responses.

Table 4-2. Bluff erosion rates defined for different lithologic compositions with measurement errors from aerial photos (Error) and variation at multiple sites (σ). Negative rates indicate erosion; positive rates show accretion.

Location	Lithology	Erosion Rate m/yr (ft/yr)	Error m/yr (ft/yr)	σ m/yr (ft/yr)
¹ Clatsop County	Miocene Grande Ronde Basalt	-0.03 (-0.01)	0.09 (0.3)	0.02 (0.07)
	Resistant sedimentary rock	-0.03 (-0.1)	0.03 (0.1)	0.02 (0.07)
	Interbedded mudstone	-0.06 (-0.2)	0.09 (0.3)	0.04 (0.13)
	Quaternary deposits	-0.08 (-0.3)	0.08 (0.3)	0.11 (0.36)
	Basalt and hard sandstone	-0.02 (-0.07)	0.05 (0.16)	0.036 (0.12)
	Interbedded sandstone, siltstone, claystone	-0.06 (-0.2)	0.08 (0.26)	0.039 (0.128)
	Soft Quaternary sediments	-0.08 (-0.26)	0.07 (0.23)	0.081 (0.27)
³ Lincoln County				
<i>Beverly Beach</i>	Sedimentary rock (Astoria)	-0.25 (-0.82)	0.12 (0.4)	0.024 (0.08)
<i>Holiday Beach to Lost Creek</i>	Sedimentary rock (Nye Mudstone)	-0.09 (-0.3)	0.04 (0.13)	0.006 ()
<i>Lincoln City/Gleneden Beach</i>	Marine terrace sand	-0.09 (-0.3)	0.06 (0.2)	0.003 (0.01)
⁴ Curry County				
<i>Headlands/Bluffs</i>	Hard Mesozoic metamorphic rocks	-0.02 (-0.07)	0.09 (0.3)	0.028 (0.09)
<i>Nesika Beach to Gold Beach</i>	Cretaceous and Jurassic sedimentary and metamorphic rocks	-0.02 (-0.07)	0.09 (0.3)	0.028 (0.09)
<i>Euchre Creek to Nesika Beach</i>	Marine terrace deposits over Jurassic sedimentary and metamorphic rocks	-0.40 (-0.13)	0.09 (0.3)	0.003 (0.01)
<i>South Nesika Beach</i>		-0.59 (-1.9)	0.09 (0.3)	0.012 (0.04)
<i>Nesika Beach to Otter Point</i>		0.26 (0.85)	0.09 (0.3)	0.098 (0.32)
		0.16 (0.52)	0.09 (0.3)	0.064 (0.21)
<i>Otter Point to North Jetty</i>		-0.02 (-0.07)	0.09 (0.3)	

(Data sources: ¹Witter and others, 2009; ²Allan and Priest, 2001; ³Priest and Allan, 2004; ⁴Priest and others, 2004).

Change rates for sandy beaches have typically been measured by evaluating shoreline positions determined from historical National Ocean Service (NOS) topographic “T” sheets that define a mean high water (MHW) line on maps, extracting wet/dry shorelines from aerial imagery, and, more recently, by analyzing tidal datum-based shorelines (e.g., MHW or mean higher high water (MHHW)) from airborne lidar data (e.g., Allan and others, 2003; Ruggiero and others, 2013; Light, 2021). Each dataset has limitations. For example, NOS surveys of MHW shorelines of the Oregon Coast in the late 1920s mapped

at 1:20,000 scale, have large ($\sim\pm 20$ m ($\sim\pm 66$ ft)) positional uncertainties (Moore, 2000). Although the earliest coastwide aerial imagery of the Oregon Coast was collected in 1939, georeferencing these images is extremely challenging, time consuming, and often not possible due to the absence of suitable ground control points. High-quality imagery did not begin to be collected until 1967, which ultimately formed the baseline on which many recent studies of coastal change have been based. The 1967 aerial photographs were flown by the Oregon Department of Transportation for the purposes of helping to delineate a shore zone boundary (Jung and others, 2022), and were eventually used to establish the “statutory vegetation line” for determining the permitting of coastal engineering structures. The images were flown at low altitude (1:6,000 scale, ~ 900 m ($\sim 2,950$ ft) elevation) during summer months (June to October) and provide an excellent snapshot of the coastal strip at the time. These data were eventually orthorectified in 2008 using Leica Photography Suite, from which a wet/dry shoreline was digitized. Since the 1990s, high-resolution orthorectified aerial imagery specifically for the coast has been collected on a more regular basis, the most recent of which was in 2020. Beginning in 1997, high-resolution airborne lidar data have been collected along the Oregon Coast that complement the use of aerial imagery for evaluating coastal change.

Ruggiero and others (2013) analyzed a combination of aerial imagery and lidar tidal datum-based shorelines to derive both long (1920s-2002) and short-term (1967-2002) change rates for the coast of Oregon and Washington. Light (2021) provided updated rates to those of Ruggiero and others (2013), having incorporated more recent lidar collected in 2016. The challenge with these data is each of the shorelines reflect discrete “snapshots” of the position of the beach in time. Analyses of this imagery and the identified coastal changes undertaken by Allan and others (2003) reveal very large variability in the position of the shoreline snapshot due to their sensitivity to seasonal and interannual (e.g., El Niños) variations in ocean water levels and storms. This makes determining reliable erosion rates from MHW shorelines challenging, due to the large envelope of variability, and hence greater uncertainty.

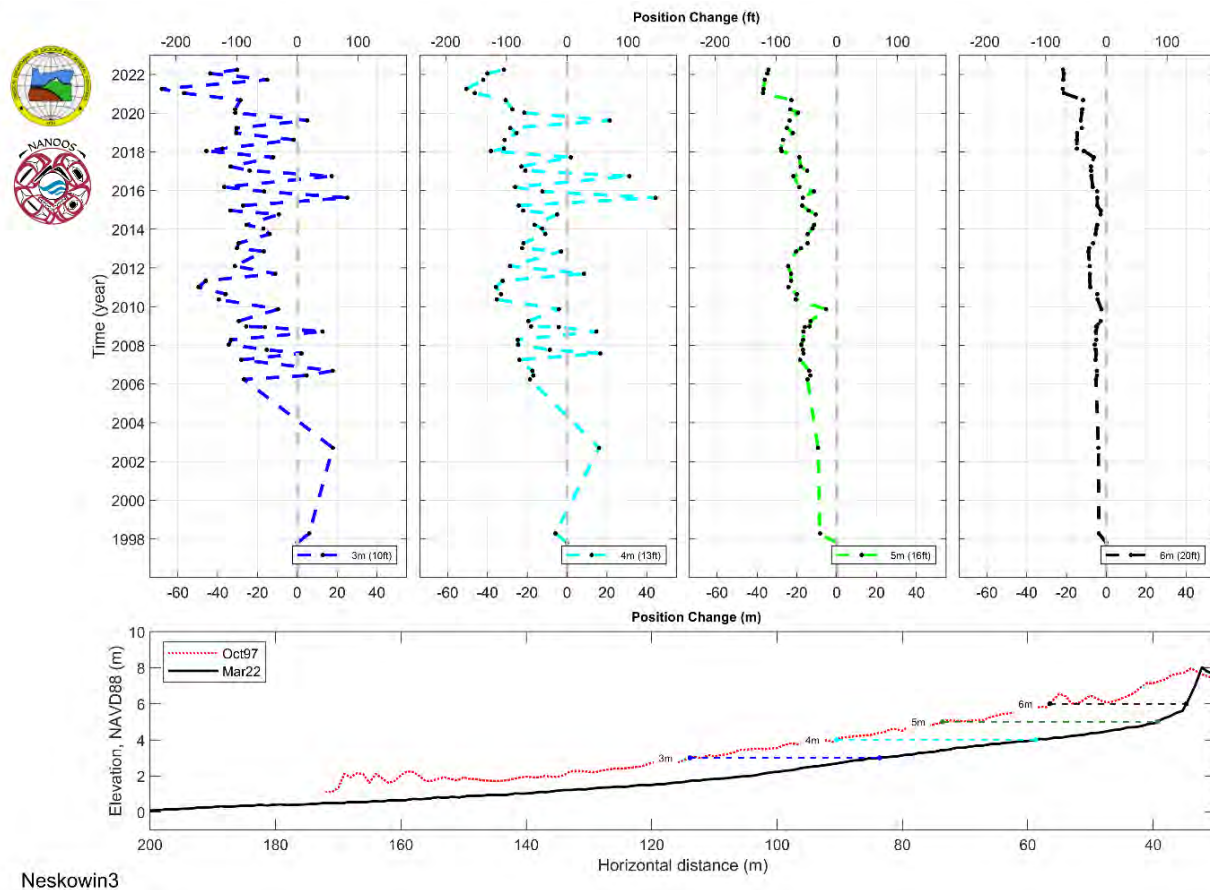
To address some of the aerial imagery and lidar challenges, the Oregon Department of Geology and Mineral Industries (DOGAMI) coastal field office implemented a coastal monitoring program in the Rockaway Beach area in October 2004 to begin documenting seasonal to interannual coastal changes. This monitoring is undertaken at discrete beach profile sites, but also involves the collection of tidal datum-based shorelines (e.g., **Figure 4-8**). Coastal change monitoring is accomplished using real-time kinematic differential GPS (RTK-DGPS) surveying and is carried out at multiple sites along the Oregon Coast, including the Rockaway and Clatsop littoral cells (Allan and others, 2008), Neskowin (Allan and Hart, 2007), Gold Beach-Nesika Beach-Netarts (Allan and Stimely, 2013), the Cannon Beach cell (Allan and others, 2018) and many other sites (<http://nvs.nanoos.org/BeachMapping>). Although a rich dataset of coastal change is now established for many north coast beach sites, with identified trends (e.g., **Figure 4-9**), regular, repeat surveys of many other sites (especially those on the south coast) do not have the same temporal sampling resolution. Nevertheless, **Figure 4-9** highlights certain important characteristics that are typical of Pacific Northwest (PNW) beach responses that provide guidance on the role of coastal processes in driving change. First, observations at the 3 m (10 ft) contour (nearest to the intertidal zone and hence the MHW shoreline) demonstrate considerable horizontal variability in the beach responses due to the strong seasonality of ocean waves and tides that characterize PNW beaches. These excursions can be very large (**Figure 4-9**), spanning $\sim\pm 10$ to 20 m ($\sim\pm 30$ to 60 ft) between summer and winter. This is further demonstrated in **Figure 4-8**, which is derived from RTK-DGPS surveys of the MHHW shoreline (light blue lines); the calculated change rate at the 3 m (10 ft) elevation at the Neskowin site is -1.21 ± 0.71 m/year (-3.94 ± 2.33 ft/year). These data highlight one of the challenges when using discrete “snapshots”

of shorelines derived from aerial imagery, where the time intervals between measurements may be long, such that the results may be strongly affected by those few discrete measurements.

Figure 4-8. MHHW shorelines (blue lines) derived from repeat surveys of the beach for Transect 3 (red line) at Neskowin.



Figure 4-9. Seasonal surveys of beach responses in the Neskowin littoral cell at station Neskowin 3 (Figure 4-8; <http://nvs.nanoos.org/BeachMapping>). Plot shows the seasonal to interannual variability at different contour elevations across the beach. Negative positions in the contours indicate erosion; positive values denote accretion.



At higher elevations on the beach, such as the 6 m (20 ft) elevation located close to the dune or bluff toe, there is much less variability (Figure 4-9) with a calculated erosion rate of -0.45 ± 0.14 m/year (-1.5 ± 0.46 ft/year). At these higher elevations, the erosion of the backshore is driven entirely by the effects of extreme total water levels, which results in periodic abrupt landward movements in the position of the contour over time (e.g., the 6 m (20 ft) contour in Figure 4-9), while highlighting a smoother long-term trend. Although monitoring efforts such as this are extremely valuable for dune-backed beaches where errors in the approach are low relative to the magnitude of changes being observed, the same cannot be said for performing RTK-DGPS measurements of sea cliff profiles given that the approach of surveying down a bluff face using GPS is prone to large errors and uncertainty due to the generally slower rates of change. Resolution of this limitation can only be achieved by establishing a monitoring program that is founded on repeat measurements of the bluff face using terrestrial lidar.

In summary, many studies have identified estimates of short to long-term coastal change rates for different areas of the Oregon Coast (Table 4-2), which have been derived from a variety of datasets, each with their own pros and cons. While it is not unreasonable to use these datasets to make projections of potential future change for the coast, we chose to undertake some additional analyses of long-term change rates for the Oregon Coast.

4.4.2 Bluff/Dune toe change rates, 1997 – 2016

Given the high variability of MHW shorelines compared with smoother trends for contours derived for the back of the beach near the dune or bluff toe, we chose to produce new change rates for the Oregon Coast by evaluating responses occurring at the back of the beach. **Figure 4-10** consists of a series of histograms of previously identified dune/bluff toe elevations undertaken for different lidar years on the northern Oregon coast (data originally from Allan and Harris, 2012). The figure indicates the wide range of dune/bluff toe elevations present on the coast, and further how these elevations can vary from year to year. For this updated change analysis, we chose to use the 6 m (18 ft) contour elevation (blue dash line in **Figure 4-10**) since it is more likely to yield a less noisy result. the 6 m (18 ft) contour elevation. For this analysis, we used lidar data that cover the period from 1997 to 2016 (**Table 4-3**). The lidar data were downloaded from the National Oceanic and Atmospheric Administration's Coastal Service Center and gridded using ArcGIS Pro. The pre 2016 lidar was gridded using a 1 m (3 ft) cell size, and 0.5 m (1.6 ft) grid cell for 2016 lidar. Although the 1 m (3 ft) grid resolution used in the pre-2008 lidar likely pushes the point density limits of those earlier flights, they are probably not unreasonable for the generally low-sloping beaches of the Oregon Coast.

Figure 4-10. Histogram showing beach dune/bluff toe elevations determined from lidar data and for different years (data originally from Allan and Harris, 2012).

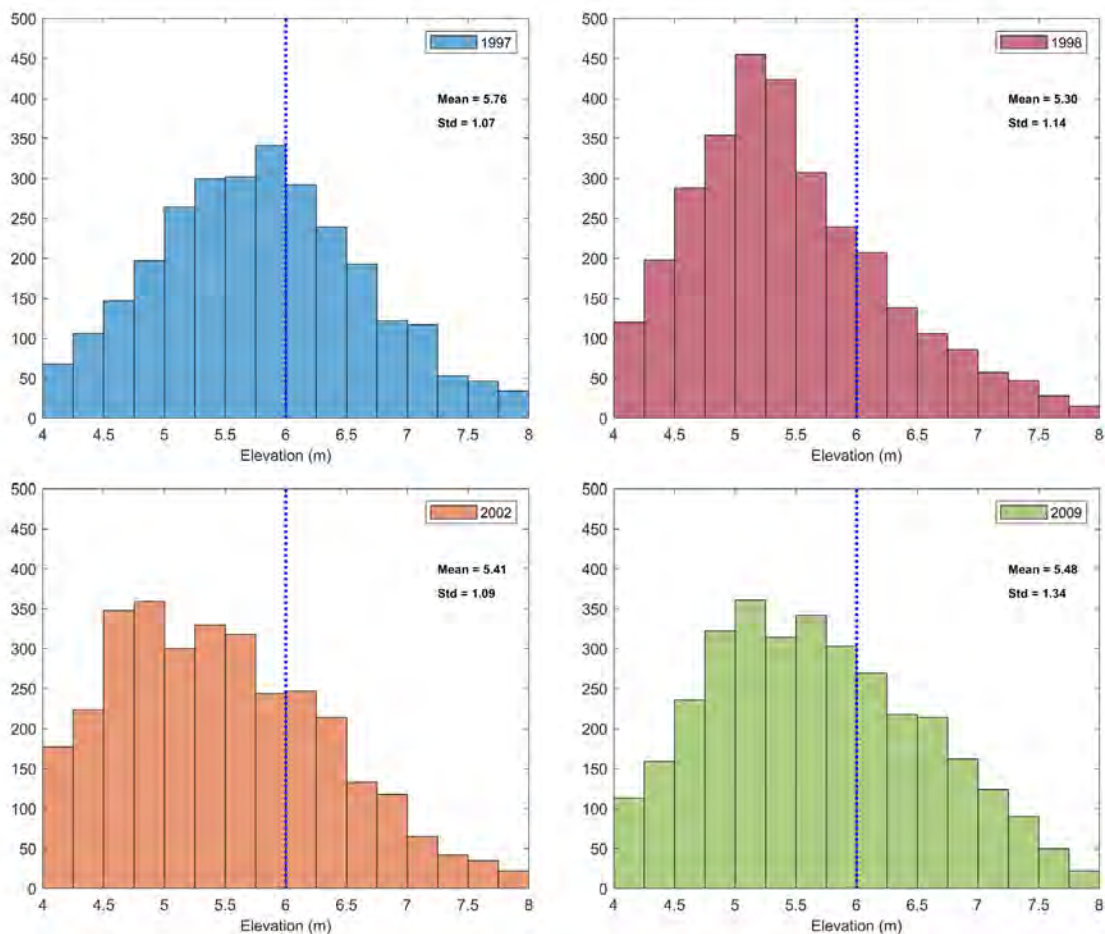


Table 4-3. Airborne lidar summary metadata.

Collection Date	Agency source	Accuracy		Typical Point density (point/m ²)	Metadata link
		Hor. (m) [ft]	Vert. (m) [ft]		
10/12/1997 – 10/26/1997	NASA/USGS ¹	0.8 (2.6)	0.15 (0.5)	3	https://www.fisheries.noaa.gov/inport/item/48150
4/8/1998 – 4/28/1998	NASA/USGS ¹	0.8 (2.6)	0.15 (0.5)	3	https://www.fisheries.noaa.gov/inport/item/48155
09/18/2002 – 10/03/2002	NASA/USGS ¹	0.8 (2.6)	0.15 (0.5)	3	https://www.fisheries.noaa.gov/inport/item/49634
04/27/2008 – 04/05/2009	DOGAMI ²	N/A	0.15 (0.5)	9	https://www.fisheries.noaa.gov/inport/item/49903
04/05/2009 – 08/09/2009	DOGAMI ²	N/A	0.15 (0.5)	9	https://www.fisheries.noaa.gov/inport/item/49906
07/30/2014 – 09/13/2014	USACE ²	1.0 (3.3)	0.1 (0.33)	9	https://www.fisheries.noaa.gov/inport/item/49456
04/28/2016 – 05/28/2016	USGS ²	0.21 (0.7)	0.06 (0.2)	9	https://www.fisheries.noaa.gov/inport/item/48222

Note: ¹single return; ²multiple return; projection used = Oregon State Plane Coordinate System (north and south), NAD83 (m); vertical datum = NAVD88.

Having developed consistent coastwide grids, we extracted various contours of interest (e.g., MHW, 6 m (20 ft)). Because the pre-2008 lidar point data exhibited considerable noise, the contours were smoothed using the Polynomial Approximation with Exponential Kernel method in ArcGIS Pro. Once the contours were produced, we performed visual checks of the contours, comparing the results against lidar hillshades to identify additional spurious noise; noise can be attributed to a combination of insufficient points or spikes in the lidar returns. Noise in the contours were removed by either clipping out portions of the lines or deleting select vertices.

The derived contours were then processed to identify temporal change using the Digital Shoreline Analysis System (DSAS) tool developed by the U.S. Geological Survey (Himmelstoss and others, 2018). The DSAS tool is an add-in to Esri ArcGIS Desktop version 10.4–10.7 that enables a user to calculate rate-of-change statistics from a time series of vector shoreline positions. DSAS includes an automated method to establish measurement locations and perform rate calculations and evaluates the statistical data necessary to assess the reliability of the change rate calculations (Himmelstoss and others, 2018). To operate the tool, a user first defines a series of baselines along a coastline of interest. For the purposes of this study, we developed baselines that spanned individual counties. Transects are then automatically cast by DSAS seaward and perpendicular to each baseline of interest. Although DSAS provides several functional controls that help account for areas subject to large shoreline curvature, we typically created shorter baselines, and manipulated the DSAS controls to ensure the transects were aligned shore-normal (perpendicular to the coast) and addressed moderate scale coastline curvature at alongshore scales of 200 m (~650 ft). For the purposes of this study, we chose to cast transects spaced 10 m (33 ft) apart for the entire coast. The tool then requires input of the shoreline “contour” features for change detection along with various metadata, which includes specification of any errors associated with each line feature. For this study, we determined a contour uncertainty of 3 m (10 ft) for pre-2008 lidar data, and 1 m (3 ft) for post-2008 data. Once the necessary data are input into the tool, DSAS is then run to define the rate-of-

change statistics for the period of interest. This is accomplished by querying the position of each shoreline feature (with assigned dates) and its intersection with every transect line. Several statistics are then output from the tool, including net shoreline movement, endpoint rate calculations, linear regression rates, and weighted linear regression rates (e.g., see Table 10 in Himmelstoss and others, 2021).

Having processed the individual transect change rates, discrete shore reaches were identified in ArcGIS and compiled in an Excel worksheet. Additional processing was performed in Mathworks Matlab (vR2022b) in order to smooth the 10 m (33 ft) spaced transect data; we used a 50 m (164 ft) smoothing function to reduce the noise in the change data. Each reach was defined based on a combination of the dominant coastal geomorphology (e.g., dune- and bluff-backed beaches, cobble shorelines, rock coast, etc.) and the identified change rates. An example of the compiled results is presented in **Table 4-4** for Clatsop County, which includes the net shoreline movement for the study period, endpoint rate calculation and standard deviation, percent of transects eroding or accreting, calculated 1% (100-year) storm-induced erosion (dune-backed beaches only), and projected future erosion due to sea-level rise by 2050 and 2100. For the latter, we used a simple 2D geometric response that accounts for the slope of the beach at ~MHW (defined for each shore reach based on 2016 lidar) and the projected sea-level rise (Bruun, 1988; Dean and Houston, 2016) defined in **Table 4-1**. Storm-induced dune erosion defined in **Table 4-1** (and for subsequent counties) is based on analyses of the calculated erosion associated with a 1% storm and is fully described in Allan and others (2012), Allan and others, (2015a), Allan and others (2015b), Allan and others (2015c), Allan and others (2015d), Allan and others (2017).

Table 4-4. Example DSAS change information for select reaches in Clatsop County.

Site Name	Transect Id	Net Shoreline Movement 1997-2016 (m) [ft]	Endpoint Rate (m/year) [ft/year]	Sigma (m) [ft]	Transects Eroding %	Transects Accreting %	¹ Storm Induced Erosion 1% event (m) [ft]	Sea-Level Rise Erosion 2050 (m) [ft]	Sea-Level Rise Erosion 2100 (m) [ft]
South jetty dynamic revetment	1 – 34	3.69 (12.1)	0.20 (0.7)	0.18 (0.59)	12	88	-17.9 (-58.7)	-11.9 (-39.0)	-51.9 (-170.3)
East jetty	35 – 108	-3.62 (-11.9)	-0.20 (-0.7)	0.23 (0.75)	89	11	-17.9 (-58.7)	-6.3 (-20.7)	-27.2 (-89.3)
Clatsop Spit	109 – 163	1.68 (5.5)	0.09 (0.3)	0.05 (0.16)	0	100	-17.9 (-58.7)	-5.4 (-17.7)	-23.5 (-77.1)
Iredale	226 – 1039	9.24 (30.3)	0.50 (1.6)	0.33 (1.08)	3	97	-9.5 (-31.2)	-5.7 (-18.7)	-25.0 (-82.0)
Rilea	1040 – 1507	35.78 (117.4)	1.93 (6.3)	0.44 (1.44)	0	100	-10.8 (-35.4)	-6.4 (-21.0)	-27.7 (-9.09)
Delray	1508 – 2076	40.06 (131.4)	2.16 (7.08)	0.45 (1.48)	0	100	-10.9 (-35.8)	-6.0 (-19.7)	-26.2 (-86.0)
Gearhart	2077 – 2430	27.29 (89.5)	1.47 (4.82)	0.40 (1.31)	1	99	-13.7 (-44.9)	-5.9 (-19.4)	-25.8 (-84.6)
Necanicum estuary	2431 – 2448	-44.90 (-147.3)	-5.91 (-19.4)	3.87 (12.7)	94	6	-19.8 (-65.0)	-12.5 (-41.0)	-54.5 (-178.8)
Seaside	2465 – 2810	42.40 (139.1)	2.28 (7.48)	1.93 (6.33)	5	95	-9.8 (-32.2)	-7.5 (-24.6)	-32.6 (-106.9)

(¹100-year storm erosion data is derived from Allan and others, 2017; Allan and others, 2015a; Allan and others, 2015b; Allan and others, 2015c; Allan and others, 2015d; Allan and others, 2012)

Figure 4-11 to Figure 4-16 present the smoothed change results for all seven coastal counties. Overall, the figures demonstrate significant variability along the Oregon Coast, from extreme erosion to areas undergoing considerable accretion. Overall, we note the following general observations by county:

Clatsop

- The coast north of Tillamook Head is experiencing relatively high rates of accretion (Figure 4-11). For example, our change analyses indicate that Seaside is experiencing rates of accretion of ~2 to 3 m/year (~6 to 10 ft/year), and ~0.5 to 2.5 m/year (1.6 to 8 ft/year) along the Clatsop Plains.
- Significant accretion also dominates the area north of Ecola Creek in Cannon Beach.
- South of Cannon Beach, the coastline is experiencing gradual erosion.

Tillamook

- Change analysis along the Tillamook County coast exhibits significant alongshore variability that ranges from high rates of erosion to high rates of accretion (Figure 4-12). Overall, the identified rates and patterns are entirely consistent with GPS measurements of discrete beach profile sites monitored by DOGAMI staff (<https://nvs.nanoos.org/BeachMapping>).

- Accretion dominates much of Nehalem (~0.5 to >2 m/year (~1.6 to >6 ft/year)) and Bayocean Spits (~0.5 to >3 m/year (~1.6 to >10 ft/year)), north of the Sand Lake estuary (~0.5 to 1 m/year (~1.6 to 3 ft/year)) and along Sitka Sedge Spit (>1.5 m/year (>5 ft/year)).
- Significant erosion dominates areas such as Neskowin to Nestucca estuary (~-1 m/year (~-3 ft/year)), Netarts Spit (~-1 to -2 m/year (~-3 to -6 ft/year)), and Twin Rocks and Rockaway Beach shore (~-1 to -3 m/year (~-3 to -10 ft/year)).

Lincoln

- Gradual rates of erosion are dominant along the length of the Lincoln County coastline (**Figure 4-13**), where average rates of change are in the range of -0.1 to -0.2 m/year (-0.3 to -0.6 ft/year). These rates are consistent with long-term measurements derived from aerial imagery and provided in **Table 4-2**.
- Exceptions to the above include significant accretion taking place at the mouths of Alsea Bay, Yaquina Bay, and at the tip of Siletz Spit.

Lane and Douglas

- Accretion dominates much of the Lane and Douglas County shoreline (**Figure 4-14**). In particular, we note relatively high rates of accretion in the vicinity of Heceta Beach and the mouth of the Siuslaw estuary (~1 to >2 m/year (~3 to >6 ft/year)).
- Low rates of erosion dominate the coastline north of Heceta Head.

Coos

- Relatively low to moderate rates of erosion (~-0.1 to -1 m/year (~-0.3 to -3 ft/year)) dominate much of the Coos North Spit (**Figure 4-15**).
- The shoreline south of the Coquille estuary exhibits significant variability that ranges from relatively low rates of erosion (~-0.1 to -1 m/year (~-0.3 to -3 ft/year)), to significant accretion in places such as at Johnson Creek and along the New River Spit (~1 to >2 m/year (~3 to >6 ft/year)).
- Variability along the New River Spit is likely being affected by periodic river mouth breaching.

Curry

- Much of the Curry County coastline is characterized by relatively low to moderate rates of erosion (~-0.1 to -1 m/year (~-0.3 to -3 ft/year)). The main exception is Gold Beach, where relatively high rates of erosion (~-2 m/year (~-6 ft/year)) are dominating the current coastal response (**Figure 4-16**).
- Accretion is largely occurring in a few isolated areas such as at Garrison Lake, south of Hunter Creek, and along the Pistol River.
- Accretionary responses occurring along the Garrison Lake coastline should be viewed with caution as Allan and others (2003) documented the effects of extreme erosion along that shore following the 1997-98 El Niño.

Figure 4-11. Coastal change rates (m/year) and patterns for the period 1997 to 2016 for Clatsop County. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.

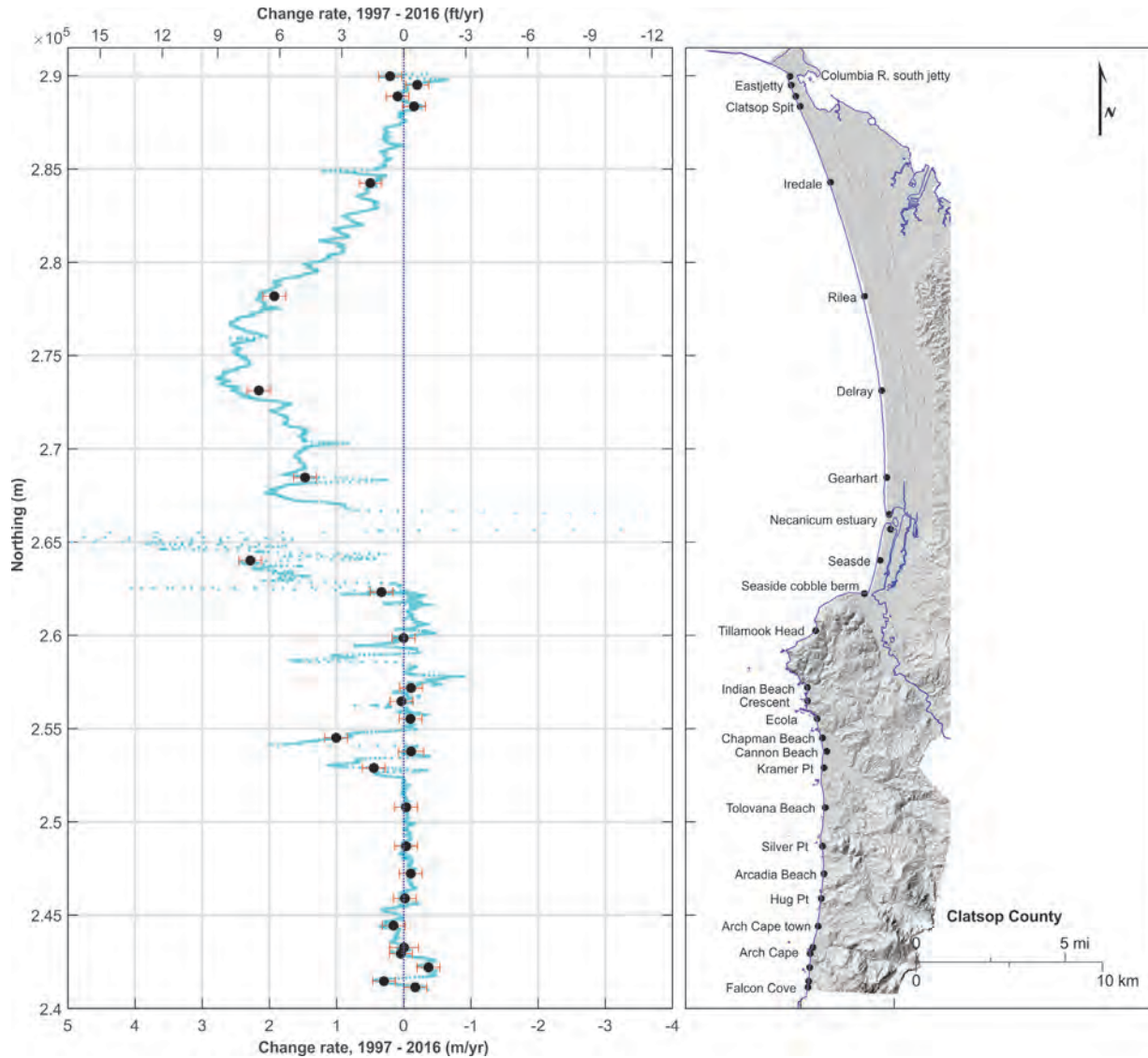


Figure 4-12. Coastal change rates (m/year) and patterns for the period 1997 to 2016 for Tillamook County. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.

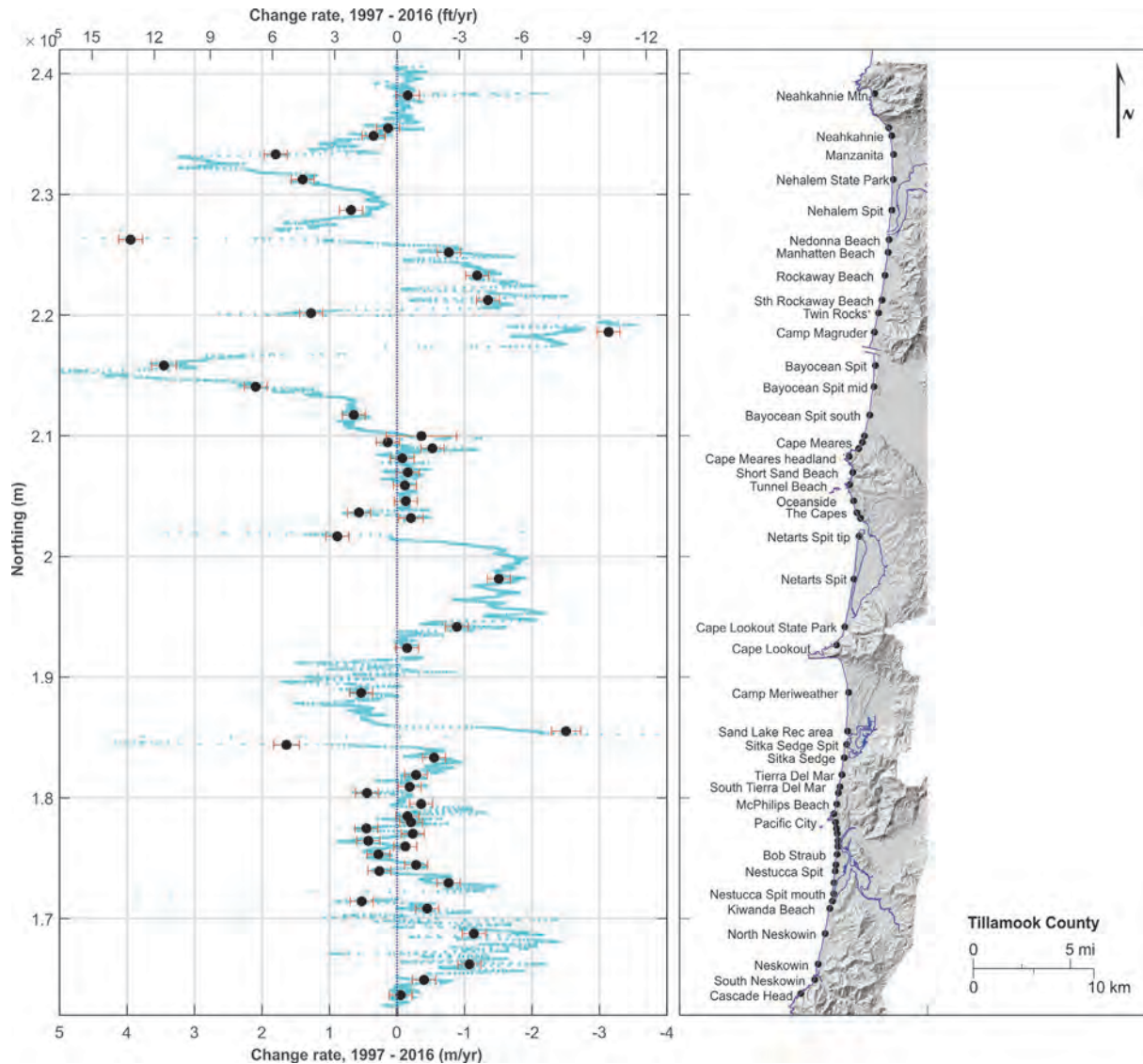


Figure 4-13. Coastal change rates (m/year) and patterns for the period 1997 to 2016 for Lincoln County. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.

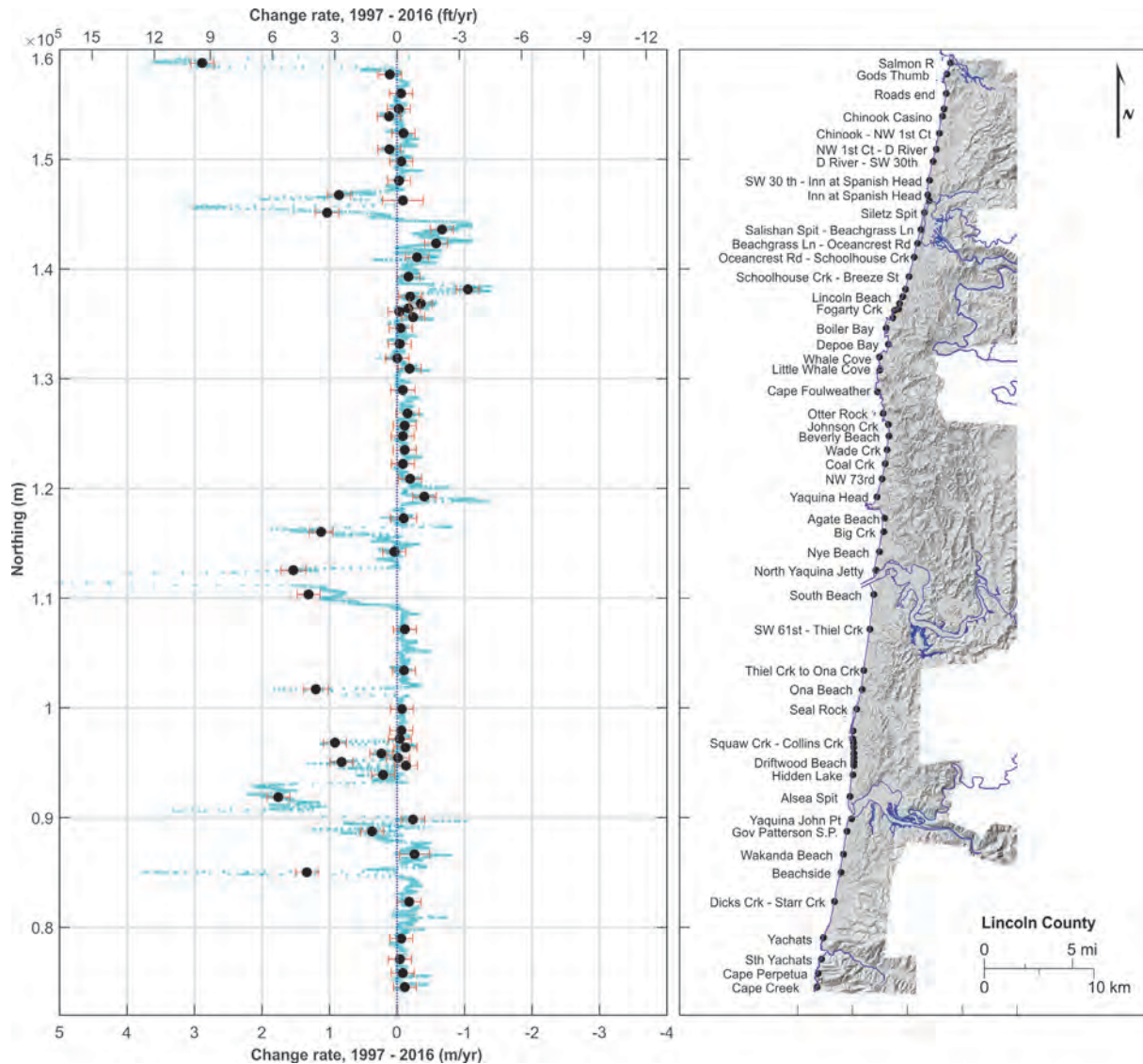


Figure 4-14. Coastal change rates (m/year) and patterns for the period 1997 to 2016 for Lane and Douglas Counties. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.

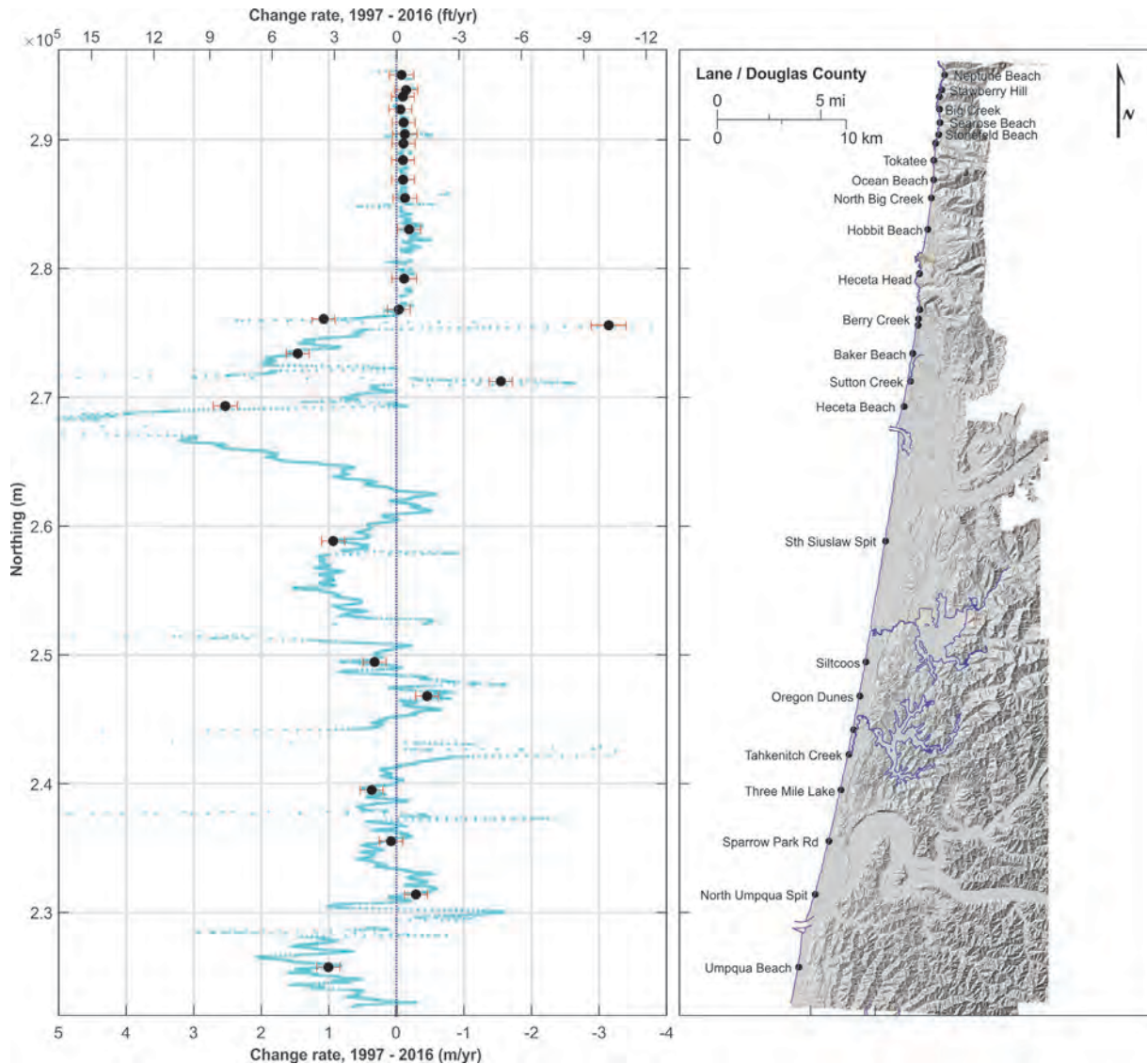


Figure 4-15. Coastal change rates (m/year) and patterns for the period 1997 to 2016 for Lane and Coos Counties. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.

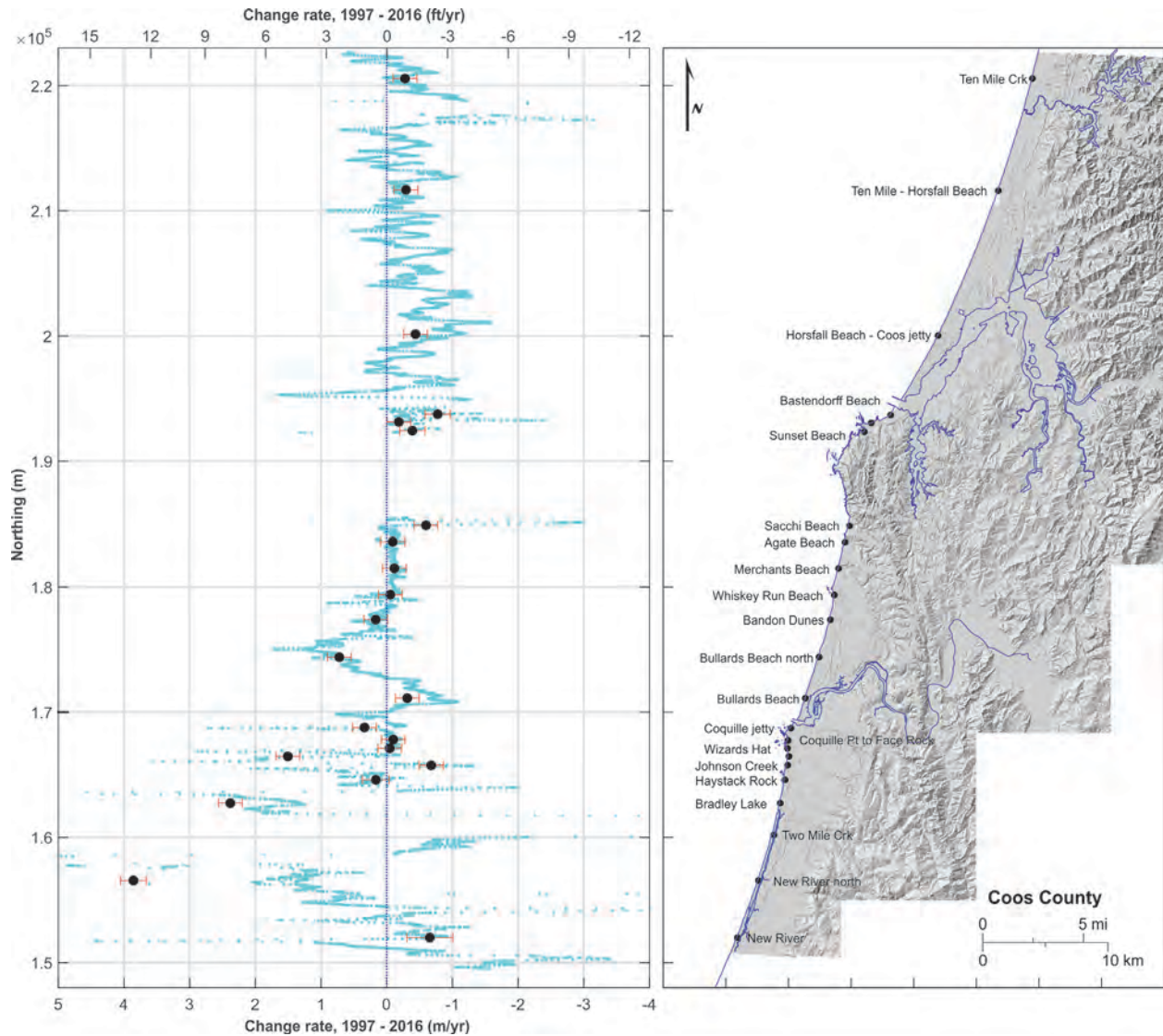
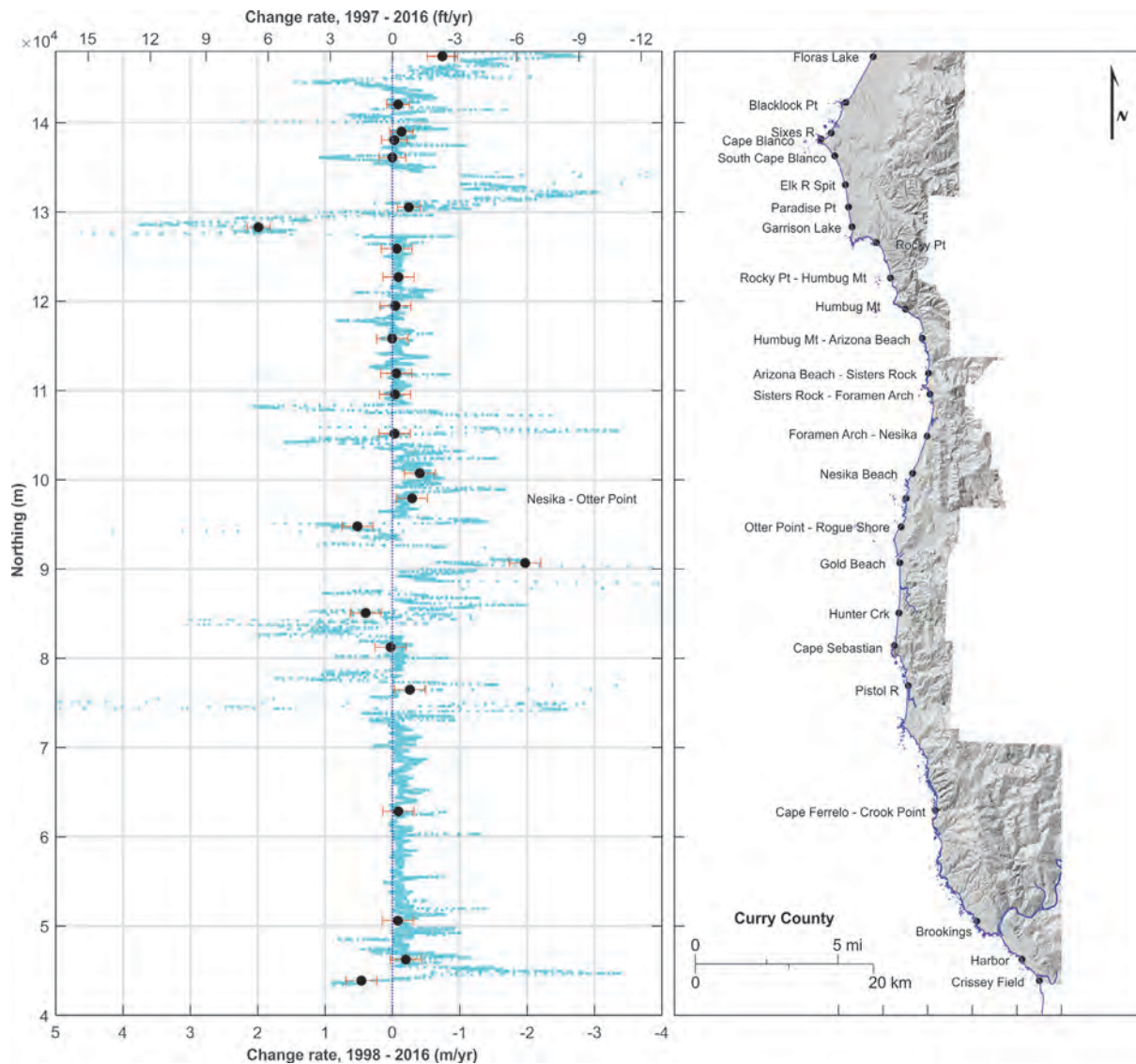


Figure 4-16. Coastal change rates (m/year) and patterns for the period 1998 to 2016 for Curry County. Cyan line reflects a 50 m (164 ft) smoothing of the individual transects, while the solid circles with uncertainty depicts the mean change for the identified study reach. Negative values indicate erosion, while positive values denote accretion.



4.5 Final Projected Shoreline Change Index

For every study reach, we defined a mean change rate and projected future erosion associated with SLR in a table (e.g., Clatsop County example, ([Table 4-4](#)). The mean change rate is only used to project coastal retreat along coastal bluffs where shoreline migration rate is controlled by resistance of rock to erosion ([Table 4-2](#)). In contrast, along dune-backed beaches, particularly those beaches presently experiencing accretion, historical patterns and rates of shoreline change are unlikely to reflect future patterns under a rising sea level. Thus, for the dune-backed beaches it is simpler to account for the storm-induced erosion, as this is less likely to change significantly in the future, and then separately account for the long-term erosion trend using a simple Bruun type expression (final two columns in the example [Table 4-4](#)).

To produce projections of future erosion along the entire Oregon Coast, we divided the 6 m (18 ft), 2016 lidar elevation contour into segments of 10 m (33 ft) length. Shoreline change projections were transferred to the shoreline segments using GIS based on the geomorphic setting and projections for the nearest observational transect. We made projections of future shoreline migration for each shoreline segment based on estimated storm-induced erosion and sea level at two time horizons: 2050 CE and 2100 CE. For each future time, our script estimated future shoreline change using either SLR-derived projections for dune areas or extrapolated change rates for bluffs.

Finally, we generated an index of erosion susceptibility relevant to coastal infrastructure such as cable landings. For each shore segment, the three projected erosion calculations were combined using the following weights: storm erosion = 1; 2050 CE sea-level rise erosion = 0.5; 2100 CE sea-level rise erosion = 0.1. The decision to use reduced weights over time accounts for the fact that existing cable landings have a limited lifespan (~25 years), such that future effects of SLR (beyond ~2050) are less important when compared with erosion events taking place today or in the next two decades. The three weighted projected erosion distances were then summed to give a final score. The units of these scores are not meaningful as they are weighted and summed over multiple time periods. From these scores, we then defined a final erosion category based on the following criteria: a zero score = no projected erosion; $0 < \text{Score} \leq 5$: Low; $5 < \text{Score} \leq 15$: Medium; $15 < \text{Score} \leq 25$: High; and $25 < \text{Score}$: Extreme. These scores provide a coastwide, consistent assessment of future erosion potential and we used the information to assess suitability of the coastline for cable landing sites (Section 6.0).

5.0 UPDATED COASTAL GEOLOGIC DATASETS

In this section we describe data relevant to cable landings that were produced or updated through this project. We combined the best available landslide susceptibility information to generate a comprehensive layer for the coastal zone in an internally consistent framework. Rocky reefs identified through high-resolution nearshore bathymetric surveys provided new information on the geomorphology and substrate of the seafloor. We generated estimates of bluff heights along the entire Oregon Coast from high-resolution lidar topographic data to assess the nearest extensive low-relief land surfaces that exist above the shoreline.

5.1 Oregon Coastal Landslide Hazard

Exposure to landslide hazards is relevant to resilient coastal infrastructure, and we compiled datasets that integrate best available data for coastwide landslide hazards. The Statewide Landslide Information Database for Oregon (SLIDO) assesses hazard from landslides across the state (Franczyk and others, 2021). The susceptibility layer is a grid that was produced at 10 m (33 ft) resolution based on gridded topography and the statewide geologic map (Burns and others, 2016). The areas most susceptible to future landslide activity are those with geomorphic evidence of observed historic and prehistoric landslides (e.g., Sears and others, 2019). We use more detailed landslide inventories based on 1 m (3 ft) resolution topographic data (Burns and Madin, 2009; Burns and Mickelson, 2016) to improve the statewide susceptibility grid. These inventories were completed for the entire Oregon Coastal zone, with the exception of the Coos County section of the coast and are included in the SLIDO v4.4. compilation (Franczyk and others, 2021). Additionally, a detailed susceptibility analysis was completed for western Tillamook County based on high-resolution lidar data (Calhoun and others, 2020).

5.1.1 Deep-seated landslide hazard

We developed a susceptibility layer for the nominal 3 NM (5.6 km/3.5 mi) inland coastal project area that combines the best available landslide hazard in a seamless mosaic with internally consistent hazard classes. Our approach follows other recent work that integrated the detailed information from the landslide inventory with the full spatial coverage of the statewide layer (Williams and Burns, 2022). Additionally, we integrated information from the detailed landslide susceptibility analysis where it has been completed within portions of Tillamook County (Calhoun and others, 2020).

The strategy for combining the landslide inventory data into the statewide susceptibility layer involved reclassification of the existing layer. Susceptibility is rated in four classes: low, moderate, high, and very high (Burns and others, 2016; Franczyk and others, 2021). Following Williams and Burns (2022), we use the observed landslide occurrences (Franczyk and others, 2021) as better estimates of the “very high” hazard classification. The existing “very high” class was converted to “high,” and the areas corresponding to mapped landslide occurrences became the new highest susceptibility class. By definition, the inventoried landslides are the areas assigned the highest hazard classification (Burns and others, 2016); this process sharpened the resolution of where slopes are most likely to fail.

Integration of the detailed landslide susceptibility mapping for the Tillamook County area required additional processing to produce consistency. The new assessment addresses the susceptibility of deep and shallow landslides in separate layers (Calhoun and others, 2020). The statewide susceptibility map of SLIDO v4.4 is most relevant to the hazard of deep-seated landsliding (Burns and others, 2016; Franczyk and others, 2021). Thus, we used the polygon-based deep landslide component of the new data to integrate into the previous layer. Whereas the statewide layer has four susceptibility classes, the detailed layer divides potential into three classes of low to high. The detailed “high” category generally corresponds to the extent of inventoried deep-seated landslides (like the “very high” category of the statewide grid) with additional area added to encompass hazard associated with future downhill movement and uphill growth in landslide extent (Burns and Mickelson, 2016). The detailed-assessment medium-hazard polygons are most similar to the “high” category of the SLIDO layer. Where our coastal polygon intersected the new detailed mapping, we retained the statewide SLIDO categories “low” and “moderate” in areas of lowest hazard in the detailed compilation. The new areas of “high” and “very high” are defined by the two highest hazard classes in the detailed polygon layer. Full resolution examples of the landslide susceptibility layer are provided for the Gold Beach and Rockaway Beach areas (Plates 1 and 2)

5.1.2 Slope, shallow landslide hazard, and constructability

Detailed shallow landslide susceptibility has not yet been assessed for the majority of the coastal counties of Oregon. However, high-resolution topographic data exist for the entirety of the coastal focus area quantifying surface slope, which is one of the strongest predictor variables for assessing shallow landslide occurrence. Steep slopes also pose challenges for general construction, and we view flatter areas as being more suitable for building cable landing infrastructure.

We assessed four general classes for slope stability based on observed shallow landslide occurrence in Oregon and geotechnical construction standards. There are 6,725 shallow landslides in the SLIDO v4.4 compilation (Franczyk and others, 2021). Of the observed landslides, only 2% occurred on slopes less than 10°, and we use this category as the lowest susceptibility. Approximately 11% of shallow landslides occurred on slopes of less than 15°, and this slope value also corresponds to a threshold commonly used in Oregon for land-use planning (Sears and others, 2019). Nearly 40% of the shallow landslides occurred on slopes between 15° and 26°. Slopes of 26° have slope ratios of 2 horizontal units to 1 vertical unit, and

represent a commonly used threshold in geotechnical engineering for most types of soil and geologic materials (Burns and others, 2011; Sears and others, 2019). Roughly half of the shallow slope failures occurred on slopes greater than 26° (Burns and others, 2011; Franczyk and others, 2021), and we use this range to represent areas most susceptible to shallow landsliding and most challenging for safe construction.

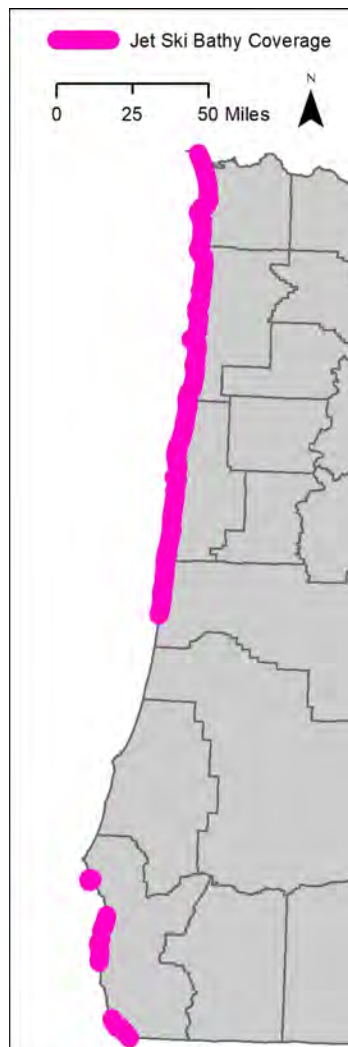
We use the 1 m (3 ft) resolution bare-earth lidar topography collected from 2008 to 2020 to produce a slope map for the coastal polygon (OLC, 2023). Slope values are calculated in degrees and rounded to the nearest integer. The slope map does not correspond to shallow landslide hazard directly, as it does not include information about surficial geologic materials or other factors that influence slope stability (e.g., Calhoun and others, 2020). We use the slope map and the classes described above to assess relative suitability of potential cable landing sites in terms of general constructability and slope stability.

5.1.3 Observed historic landslide locations

The third source of landslide data that we use is the record of historically observed landsliding included in SLIDO v4.4 (Franczyk and others, 2021). The occurrence of landslides in the very recent geologic past indicates that an area has characteristics that may promote future slope instability in the same location or adjacent areas. Plates 1 and 2 show examples of the detailed landslide point inventory.

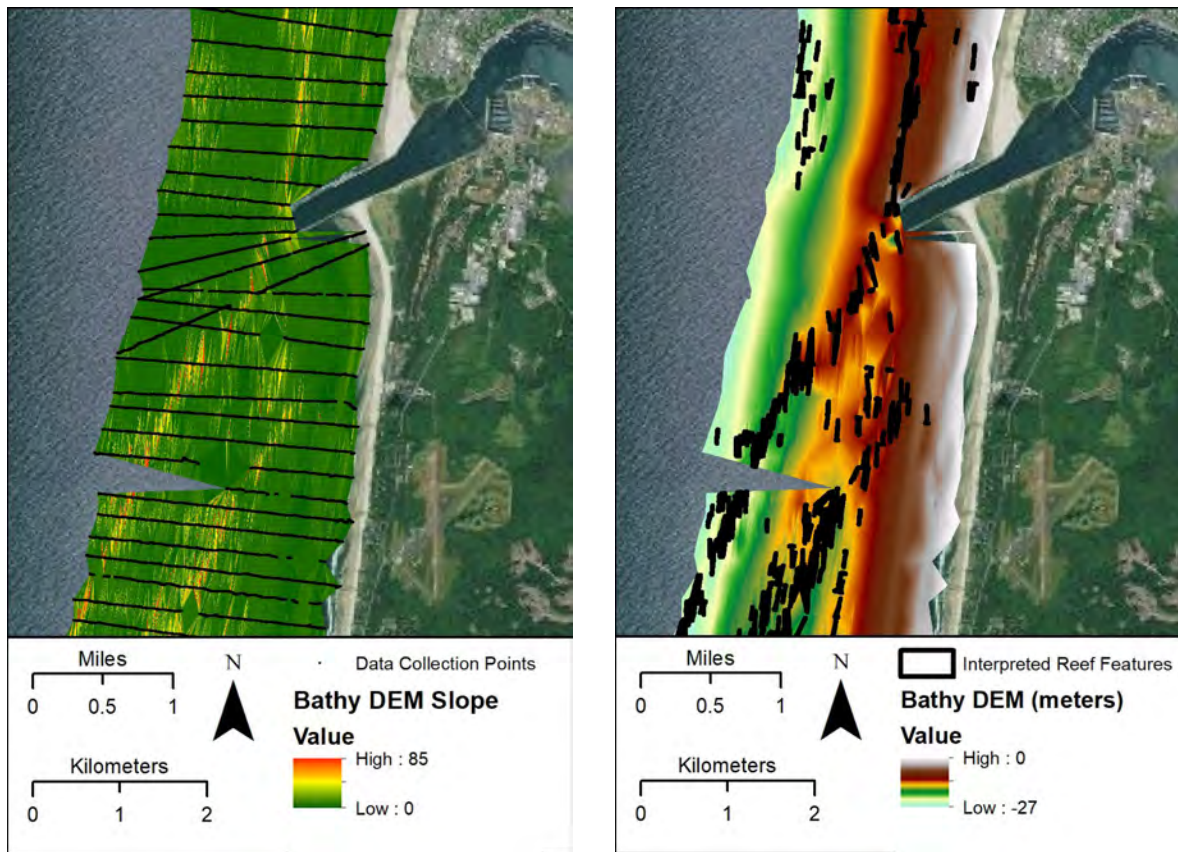
5.2 Nearshore Reef Geomorphology

Areas of rocky seafloor are generally avoided for cable routes to avoid negative impacts on marine life and damage to cables. Additionally, the presence of rocky reefs in nearshore environments is indicative of variations in the erosional resistance of rocks and may indicate the presence of lithologic variations that would be challenging for HDD construction. We supplemented previous mapping of the seafloor (e.g., Goldfinger and others, 2014) with information from high-resolution bathymetric surveys covering roughly 60% of the Oregon coast (**Figure 5-1**).

Figure 5-1. Map showing extent of jet ski bathymetric surveys.

The high-resolution bathymetric data were collected through a set of surveys conducted from a jet ski platform, spaced at roughly 0.5 km (0.3 mi) intervals along the coast. The transects extend through the surf zone to an offshore distance of 2 to 3 km (1.2 to 1.9 mi). Bathymetric elevation data were interpolated in GIS to derive an elevation raster spanning the extent of the transect lines (**Figure 5-2**). We used the presence of spatially extensive, high gradient portions of the seafloor to define likely extents of rocky reefs in the nearshore zone. Candidate reefs were identified from a slope raster calculated from the elevation data using a 10° threshold for defining rocky seafloor. Reefs identified in this project have areas of slope greater than 10° that cover 200 m^2 (2153 ft^2) or more. Laterally extensive features that meet these criteria were extracted as polygon features. In many cases, the reefs correspond to areas of mapped rock substrate (PMEP, 2022) in areas where the two datasets overlap. However, in other locations, reefs are identified in areas previously thought to be unconsolidated sediment (Plates 1 and 2). These complementary data strengthen our understanding of high relief rocky habitat in the nearshore environment.

Figure 5-2. left) Jet ski transects and bathymetric slope map for a sample location. Right) bathymetric elevation with rocky reefs identified using criteria described in text.

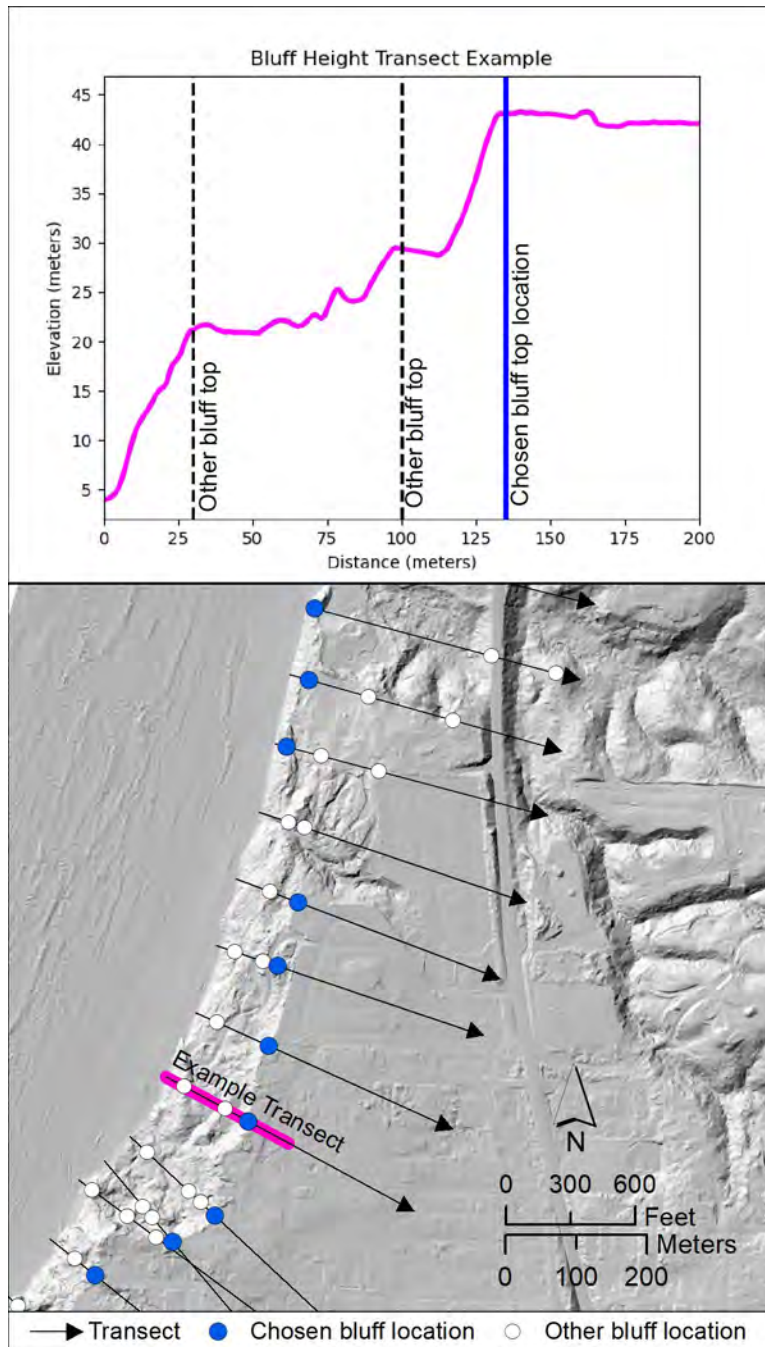


5.3 Coastal Bluff Height

Bluffs capping sea cliffs and steeper hillslopes form prominent features of the Oregon Coast landscape. The heights of bluffs vary widely, reflecting spatial variation in surface geology, erosional processes, and Quaternary uplift rates. Low-relief bluff tops comprise a common setting for building towns, roads, and other infrastructure. Coastal bluffs host some cable landing infrastructure currently, and represent locations elevated above some coastal hazards. However, higher bluffs create challenges for HDD construction across the shoreline. We produced systematic measurements of bluff heights using gridded airborne lidar data along portions of the coast classified as bluff-backed or rocky shore in the coastal geomorphology layer.

Bluff heights were determined semi-automatically using transects spaced at 100 m (328 ft) intervals along relevant portions of the Oregon shoreline. Transect lines were oriented perpendicular to the shoreline extending 400 m (1312 ft) landward (**Figure 5-3**). Elevation values from lidar digital elevation models (OLC, 2023) were extracted at points spaced along the lines at a 1 m (3.3 ft) interval. Profiles based on paired elevation and landward distance values are the basis of the bluff identification process.

Figure 5-3. Example of measuring bluff height from topographic profile data.



We defined bluff tops as low relief areas with cumulative elevation change of 3 m (10 ft) or less over a horizontal profile distance of 10 m (33 ft). Candidate bluff edges are defined as the seaward point on a 10 m window of low relief topography. Multiple bluff heights were considered using 7 different minimum heights at intervals of 5 m (16 ft) from 10 m (33 ft) to 40 m (131 ft) to identify the most appropriate bluff top location and avoid biases resulting from obliquity of profile lines to the topographic slope. In instances where two or more candidate bluff edge points were identified along a profile, the point that best

represents the topography was chosen manually. In cases where the automatic processing did not yield meaningful bluff locations, bluff top locations were digitized manually.

Our data provide a comprehensive view of cliff and hillslope heights along the Oregon Coast and are available in full detail in the GIS data of this report. Map examples of the locations and heights of bluff tops are illustrated in Plates 1 and 2 for the Gold Beach and Rockaway Beach areas.

5.4 Sediment Thickness above Bedrock

Quaternary surficial sediment mantles much of the coastal margin. One consideration for HDD construction is the depth at which unconsolidated sediment lies in contact with indurated rock below. Geophysical surveys for past subsurface construction projects are limited in scope and often not published. Widespread observations of subsurface geologic materials have been made during construction for water and geotechnical wells. Logs showing depths at which different geologic units were encountered during well drilling are archived and distributed by the Oregon Water Resources Department (OWRD, 2023). We used coastal well completion reports to build a database of well locations with depth intervals of consistent sediment and rock types in built wells. Most of the wells are not precisely located in the well reports, with many locations based on Public Land Survey System section notation that carries ambiguity up to ~1.1 km (~0.7 mi). Along the southern coast wells without precise coordinates were more precisely located based on property addresses and inspection of georeferenced aerial and satellite imagery (McClaghry and others, 2013; Wiley and others, 2014; 2015).

During this study we extended the database of subsurface well information (McClaghry and others, 2013; Wiley and others, 2014; 2015) to include wells north of Coos Bay. We only included wells with locations defined by GPS surveys that have location accuracy ~10 m (~33 ft) or better. This resulted in coastwide coverage of subsurface well information, although the well density is lower in northern Oregon counties than along the southern coast. For this study we focus on the thickness of sediment above bedrock. Of the 2039 wells in our dataset, bedrock was not encountered at the bottom of 269 wells, and these points provide only a minimum estimate of the total sediment thickness in those locations. Plates 1 and 2 show examples of the well sediment thickness measurements in areas of the southern and northern Oregon Coast, and the accompanying GIS data provide the full dataset. Given the variable spatial density of wells along the coast and short-scale spatial variation in the depth to bedrock, we did not use these data to assess suitability for cable landings. The well data provide a useful guide to understanding the depth to bedrock where the spatial density of located wells is higher that will inform future subsurface construction projects. Additionally, this dataset contributes to understanding the history of erosion and sedimentation during the Quaternary along the Oregon Coast.

6.0 SUITABILITY ANALYSIS FOR CABLE LANDINGS ALONG THE OREGON COAST

We analyzed the suitability of cable landings along the full Oregon Coast to systematically integrate the factors that the Territorial Sea Plan, Part 4 Working Group and ourselves have identified as relevant for constructing resilient cable infrastructure that crosses the Oregon Territorial Sea with minimal impact on the environment and coastal communities. Our analysis emphasized geologic and geomorphic factors and did not consider many biological, cultural, or logistical factors that may be relevant to holistic consideration of potential cable landing sites. To this end, we have sought to integrate the best available data that spans the entirety of the state coastal zone. We focused specifically on assessing suitability at

points where prospective cables would cross the shoreline at a beach manhole (**Figure 1-2**), as those locations are viewed as most pivotal by the cable industry (Wopschall, 2023). Cable landing stations and electrical substations likely have greater flexibility in positioning within some radius of a cable landing site (**Figure 1-2**), although many of the terrestrial layers that we have compiled within a three nautical mile distance of the shoreline are relevant background for future detailed siting studies. We note that our analysis is necessarily broad and is not a substitute for detailed, site-specific studies that will confirm or deny the most important details of prospective sites. Additionally, our analysis does not identify good sites that may exist in small pockets of the coastline or that may be accessed through more complex cable routing through areas of otherwise less desirable seafloor. Based on the diversity of settings in existing Oregon cable landings, different settings may be used successfully if engineering and construction practices are aligned with the particular characteristics of the specific sites.

6.1 Suitability Analysis Methodology

We developed a flexible framework for scoring the suitability of small sectors of the coastline based on the available spatial layers relevant to the question of constructing new cable landings. All of the layers used in our analysis are available along the full coast to minimize spatial biases in data availability. We integrated diverse types of geospatial data ranging from raster (gridded) data to vector features including data represented with polygons, lines, and points. Scores were calculated based on the various layer feature characteristics or raster values, and with different strategies based on spatial coincidence, line lengths, or proximity to candidate sites, depending upon the relationship of a factor to the siting and construction of a cable landing. Additionally, we applied a weighting strategy to emphasize the factors that are most important for siting cable landings. The scoring strategy is necessarily subjective, and all of the layers are available publicly, enabling others with different priorities to make independent assessments.

6.1.1 Spatial framework

The core of our analysis is a linear representation of the shoreline along the Oregon Coast. We found no existing shoreline dataset that described the boundary between more active areas of the beach and upland areas that are rarely impacted by even the largest storms in a detailed way consistent with high-resolution lidar topographic data. High-resolution shorelines based on tidal datums such as MHHW exist for the Oregon Coast, but in areas of more gently sloping beaches without large dunes or bluffs, the shoreline may regularly be crossed by distances of tens of meters (tens to hundreds of feet) by storm waves. Consequently, the horizontal setbacks from MHHW necessary for best practices of beach manhole siting vary widely depending upon the geomorphic setting of candidate sites along the coast. We developed a shoreline for this project based on a combination of different tidal and lidar elevation datums and interpretation of modern aerial orthophotography imagery. The line has gaps across stream mouths and bays, and has a total length of 583 km (362 mi). We seeded the shoreline with a series of 5,817 points placed every 100 m (328 ft) of line distance. These points represent potential locations where cables could cross the shoreline in the vicinity of hypothetical beach manholes.

Sampling of the geospatial data that represent the different factors is accomplished using multiple linear transects that extend seaward and landward of each shoreline point. Most of the input suitability factors are sampled by rectangular polygons that are centered on each transect line. Each rectangle extends 50 m (164 ft) to either side of its associated transect line, ensuring roughly complete spatial sampling of the relevant coastal zone. We consider three seaward distances from each point

corresponding to different aspects of siting and construction (**Figure 6-1**). The shortest distance increment is from the shoreline point to the local 10-meter (33-foot) water depth bathymetric contour as derived from a bathymetric grid for DOGAMI tsunami studies. This zone is relevant to HDD construction between the shoreline and the nominal seafloor punchout depth of ~10 m (~33 ft) (Wopschall, 2023), and its outer edge approximates the observed sediment closure depth along the Oregon Coast (Section **4.3.1**). The second distance increment corresponds to the distance between the 10 m (33 ft) water depth and the outer edge of the Oregon Territorial Sea at a nominal 3 nautical mile distance from a spatially smooth shoreline (OPAC, 1994). The third distance extends from the edge of the Territorial Sea to a distance of 15 km (9.3 mi) from the shoreline point to provide additional information on the characteristics of the seafloor that must be traversed by cables across the continental shelf seaward of Oregon territorial waters.

The marine transects associated with each shoreline point sample a limited area of seafloor on a defined azimuth. At a broad scale, the Oregon shoreline is oriented north-south, although in detail it is much more irregular. To account for the broad similarity in the orientation of depth contours on the offshore shelf, and to avoid biases from projecting lines from the local shoreline geometry, we choose a primary due-west orientation for sample transects from the shoreline points (**Figure 6-1**). However, we note that many existing cables approach the shoreline obliquely, so for each point we consider two alternative sample rectangles that are oriented 30° north and south of west (**Figure 6-2**), roughly guided by the obliquity of some existing cables (**Figure 1-1**). The oblique rectangles are of greater length to reach equivalent offshore distances measured straight west of each point as the corresponding west-oriented sample rectangles.

Figure 6-1. Map showing examples of west-oriented marine transect lines colored by the three offshore zones and the land sample interval. The marine sample windows are particularly variable in southern Oregon as depicted here based on bathymetry and width of the Territorial Sea. Individual lines are spaced 100 m (330 ft) apart and are absent where the shoreline crosses mouths of major streams.

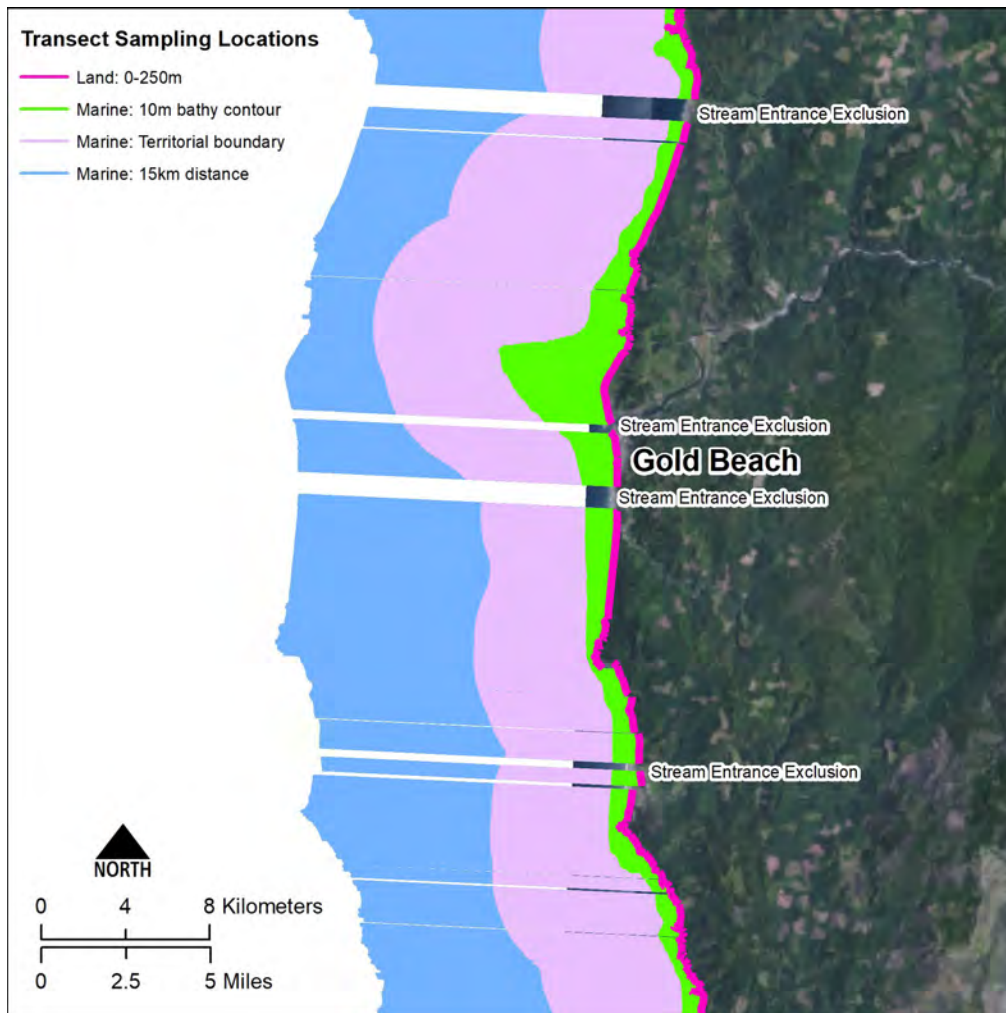
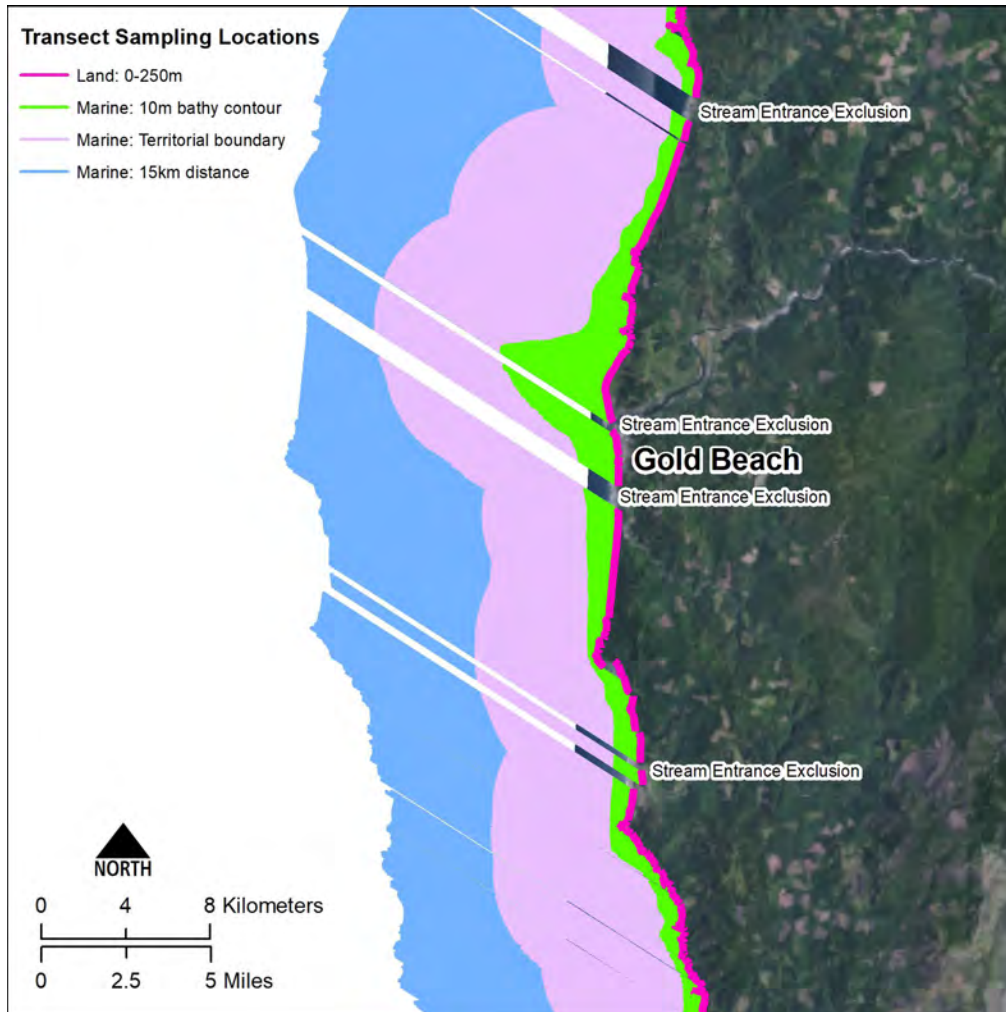


Figure 6-2. Map showing examples of alternative northwest-oriented marine transect lines colored by the three offshore zones and the land sample interval for the same area as Figure 6-1. We also sampled the marine data with a set of analogous oblique lines that trend southwest from each shoreline point (not depicted).



The landward factors of potential sites are sampled by rectangles of the same 100 m (330 ft) widths centered on each sample point (Figure 6-2). The land transects extend inland 250 m (820 ft) from the shoreline points to encompass the distance range where most of the existing cable beach manholes are located along the Oregon Coast (Figure 1-1; Wopschall, 2023). Given the shorter distance of the landward sample rectangles and local topography that better corresponds to the adjacent shoreline orientation, we oriented these polygons normal to the local shoreline.

6.1.2 Spatial data sampling and factor scoring

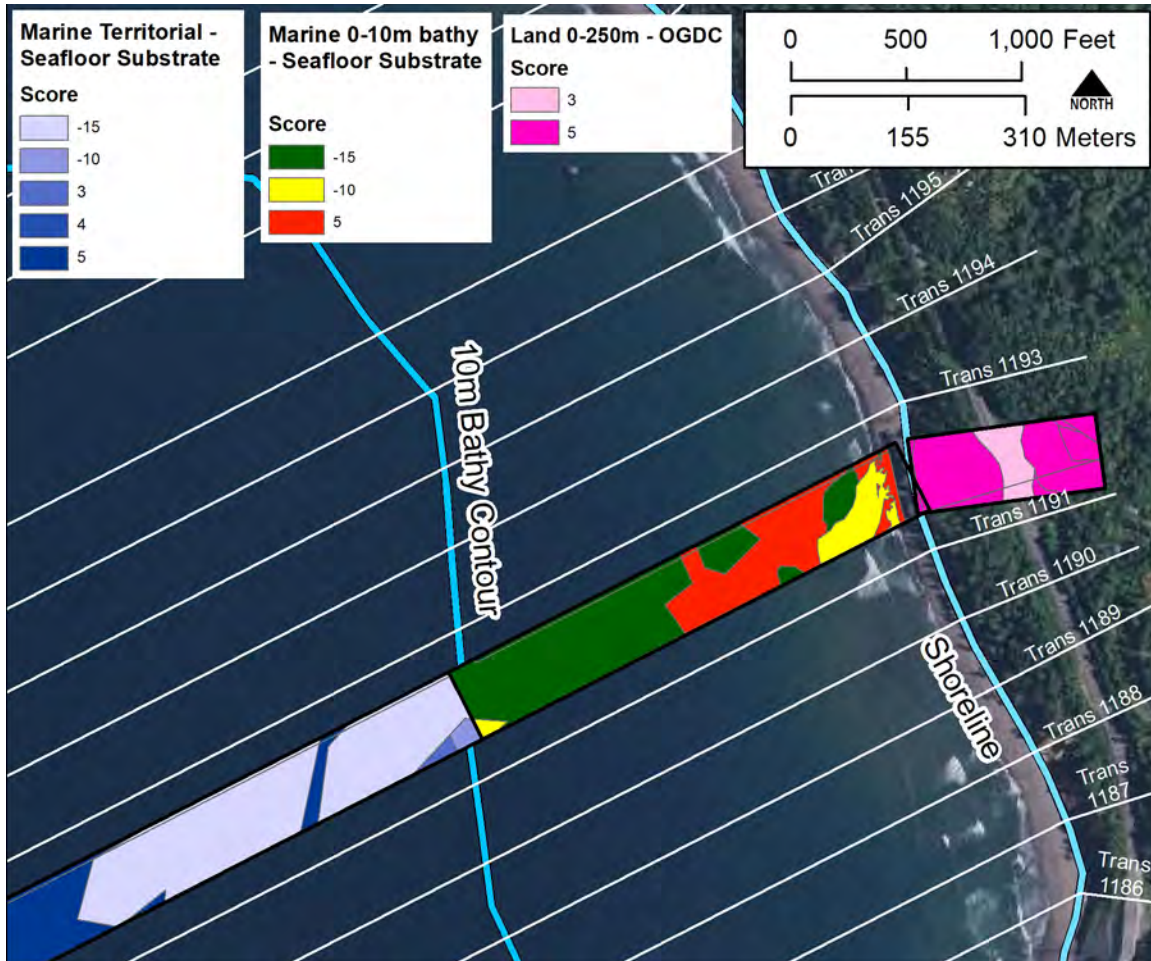
On both the land and ocean side of each shoreline point, relevant geospatial layers are sampled using one of three general strategies: area sampling, distance sampling, or proximity sampling; scores are calculated in a consistent framework. Each factor is scored on a relative scale where negative values are worst and higher positive values are more suitable. More neutral characteristics are typically assigned a zero value. This convention allows effective weighting and does not produce a favorable bias if any site is missing

factor data. The most definitive negative factors (marine protected areas, rocky headlands, and actively moving landslides) are used to set relevant shoreline points to have zero final total scores. Marine suitability factors are sampled over the relevant distance range(s) along each of the three transect orientations from each point. Shoreline points where complex shoreline geometry did not allow a straight-line path to the open ocean were assigned zero score. The sample line orientation with the highest total score for all of the combined marine factors is retained for scoring each shoreline point. The following section describes the methods used to score varying types of criteria.

6.1.2.1 Area sampling

Factor datasets that are represented with spatially continuous raster or polygon data are sampled using an area strategy (**Figure 6-3**). Examples of such layers include seafloor substrate types offshore, geologic rock types onshore, and the gridded landslide susceptibility data on land. The input data are subset to each candidate sampling rectangle, scores are applied to each factor, and the factor score is calculated as the area-weighted score for the full sample rectangle.

Figure 6-3. Example of area sampling of offshore geology data using rectangular polygons along the southwest-oriented marine sample transect and onshore geology from an example candidate shoreline point. Different colors show the underlying geologic unit polygons transformed to scores on the relevant scoring system for each layer. Scores for each spatial sample interval (e.g., Marine 0-10 m (0-30 ft) bathymetry) are the area-weighted average of all of the scored input polygons that intersect this sample rectangle.



6.1.2.2 Line distance sampling

Other datasets are lines such as faults that have impact on construction considerations and/or longer-term hazards. We calculate the spatial density of such mapped features and corresponding inferred impacts on a potential cable route as the cumulative line length contained within each sampling polygon. Scores are assigned in proportion to the frequency of each line type within each sampling region.

6.1.2.3 Proximity sampling

Other datasets are sampled according to the distance between the sampling rectangle or shoreline point to factors of interest. For example, HDD construction is generally capable of making boreholes that span about 1.5 km (0.9 mi) from an entry point to the punchout location on the seafloor (Wopschall, 2023). The punchout depth is commonly about 10 m (33 ft) deep to protect the cables in the subsurface where the seafloor is shallow enough to be affected by wave energy and currents (Wopschall, 2023). We calculate horizontal distance from each shoreline point to the 10 m (33 ft) depth contour and score sites to favor

shorter drilling distances. Other datasets are scored as being present or absent within the sample rectangle, such as shallow, linear reef structures or marine reserves. Finally, on-land features are scored as either favorable (roads) or unfavorable (wetlands or observed landslides) based on their nearest proximity to the boundaries of the sampling rectangles.

6.1.3 Score weighting

The final score is calculated by summing the individual factor scores, scaled by the weights assigned to each factor. The summed weighted scores are transformed to the range of zero (worst) to 100 (best) by normalizing all of the scores to the numerical score of the most favorable site in the analysis and reporting percentages. The impact of each factor on total score is determined by both the weight for the factor and the possible range of scores that vary between factors as described in the following section. Sites with negative total numerical scores are assigned a zero score in the final dataset.

6.2 Suitability Analysis Inputs and Scoring Details

In this section we provide details on the specific layers used, what sampling strategies were used for each layer, and how the different factors are scored and weighted. **Table 6-1** shows all of the layers grouped by spatial zones from land through the shore to the marine zones. This table also provides references to subsequent tables that give details of how scores are assigned to the data in our analysis. The final column of **Table 6-1** lists the weights applied to the overall score for each dataset. **Table 6-2** provides details on the GIS layer names that correspond to each dataset, the dataset availabilities, and data origins. We distribute all of the new datasets generated for this project, as well as versions of most of the preexisting datasets. Further information on the datasets can be found in the metadata included with the geodatabase produced for this project.

We used 13 different layers for the land area that are relevant to HDD construction and hazards and infrastructure longevity (**Table 6-1**). Four layers describe the shoreline characteristics and potential for shoreline change. Seven layers are sampled in the three marine zones. Two of the layers are sampled in only one zone each, and the remaining layers are sampled in all three of the marine zones. Sampling in the three marine zones allowed us to emphasize the importance of factors nearer to shore in the Oregon Territorial Sea as well as using different weights for the same layers for the different spatial zones (**Table 6-1**).

Table 6-1. List of datasets used in suitability scoring analysis with relevant value tables and weights.

Transect Sampling Area	Sample Method	Dataset	Value Table	Weight
Land 0-250 m (0-820 ft)	Proximity	Coastal Roads	Proximity Roads	3
		Historic Landslides	Proximity Miscellaneous	0.5
		Groundwater Sources	Proximity Miscellaneous	1
		Surface Water Sources	Proximity Miscellaneous	1
		Wetlands	Proximity Miscellaneous	3
	Line Length	Contacts and Faults	Land Faults	2
		Quaternary Faults	Land Faults	1
	Area	Liquefaction Susceptibility	Liquefaction Susceptibility	1
		Landslide Susceptibility	Landslide Susceptibility	2.5
		Topographic Slope	Topographic Slope	2
		Tsunami Inundation	Tsunami Zones	2
		Geologic Units	Geologic Units	4
		Beaches and Dunes	Beaches & Dunes	2
Shoreline	Shoreline Attributes	Coastal Geomorphology	Coastal Geomorphology	3
		Headlands Spits Landslides	Headlands, Spits, & Landslides	2*
		Bluff Heights	Bluff Heights	2
		Coastal Erosion	Coastal Erosion	3
10m (30 ft) bathymetric depth	Proximity	Reefs	Reefs	1
		Marine Reserves and MPAs	Marine Reserves	1†
		10m bathy distance	10m bathy contour	2
	Line Length	Offshore Faults	Offshore Structures	2
		Offshore Folds	Offshore Structures	0.75
	Area	Seafloor Substrate	Seafloor Substrate	1
Territorial Sea	Proximity	Reefs	Reefs	2
		Marine Reserves and MPAs	Marine Reserves	1†
	Line Length	Offshore Faults	Offshore Structures	1
		Offshore Folds	Offshore Structures	0.5
	Area	Seafloor Substrate	Seafloor Substrate	3
15km (9.3 mi) Distance	Proximity	Marine Reserves and MPAs	Marine Reserves	1†
	Line Length	Offshore Faults	Offshore Structures	0.5
		Offshore Folds	Offshore Structures	0.25
	Area	Seafloor Substrate	Seafloor Substrate	2
		DOD Offshore Assessment	DOD Assessment	1

*Headlands and landslides: if a headland or active landslide is present in this layer, the final score is set to zero

†Marine Reserves: If any marine sampling zone intersects a reserve or marine protected area, the final score is set to zero

Table 6-2. Layers used with specific filenames, sources, and relevant value fields.

GIS Layer Name (SP54_Coastal_Cable_Data_Inventory.gdb)	Data Type	Source	Value Field (with subset)
Land Sampling			
Beaches_and_Dunes	Polygon	DOGAMI	Suitability
Coastal_Roads	Line	DOGAMI	
Groundwater_Sources	Polygon	DEQ	
Surface_Water_Sources	Polygon	DEQ	
Tsunami_Inundation	Polygon	DOGAMI	Tsunami_Region
Wetlands	Polygon	NWI	WETLAND_TY
Contacts_and_Faults	Line	DOGAMI	LTYPE
Quaternary_Faults	Line	USGS	
Historic_Landslides	Point	DOGAMI	MOVE_CLASS
Geologic_Units	Polygon	DOGAMI	ThematicRockType
Lidar_Slope	Raster	DOGAMI	
Liquefaction_Susceptibility_Map	Raster	DOGAMI	
Landslide_Susceptibility	Raster	DOGAMI	
Shoreline Sampling			
Bluff_Heights	Point	DOGAMI	Bluff_Elev_m
Coastal_Erosion	Line	DOGAMI	Coastal_Erosion
Coastal_Geomorphology	Line	DOGAMI	Coastal_Geomorph
Headlands_Spits_Landslides	Line	DOGAMI	Category
Marine sampling			
Reefs	Polygon	OSU/ DOGAMI	
Bathy_10m_Contour	Line	DOGAMI	
Marine_Reserves_and_MPAs	Polygon	DLCD	
Offshore_Faults	Line	Goldfinger and others (2023)	struc_type
Seafloor_Substrate	Polygon	PMEP/ DLCD/ OSU	CMECS_SC_Name
DOD Offshore Assessment*	Polygon	DOD/BOEM	Color
Other layers not sampled			
Shoreline	Line	DOGAMI	
Well_Sediment_Thickness	Point	OWRD/ DOGAMI	

* The Department of Defense/Bureau of Ocean Energy Management Combined Wind Assessment for the Oregon Offshore, was not available for redistribution. GIS data exist online at <https://offshorewind.westcoastoceans.org/>.

6.2.1 Scoring systems

We used three scoring systems to assign relative score values to the information sampled from each dataset. The score system strategy was dependent upon the dataset structure as well as our sampling methodologies. The first class of scoring system applies to layers that are assessed based on numerical values (**Table 6-3**). We applied this scoring to layers that were assessed based on proximity, cumulative line distance, and layers with numerical values like bluff height and slope (**Table 6-3**).

Table 6-3. Scoring systems for layers with quantified numerical results. See Table 6-1 for which layers these score systems are applied.

Score	Min	Max	Units	Min	Max	Units
Proximity Roads						
5	0	0	km	0	0	mi
4	0	0.15	km	0	0.09	mi
3	0.15	0.25	km	0.09	0.16	mi
2	0.25	0.5	km	0.16	0.31	mi
0	0.5	1	km	0.31	0.62	mi
-5	1	+	km	0.62	+	mi
Proximity Miscellaneous						
5	1	+	km	0.62	+	mi
4	0.5	1	km	0.31	0.62	mi
3	0.25	0.5	km	0.16	0.31	mi
2	0.1	0.25	km	0.06	0.16	mi
-2	0	0.1	km	0	0.06	mi
-5	0	0	km	0	0	mi
Land Faults						
5	0	0	m	0	0	ft
4	0	50	m	0	164	ft
2	50	100	m	164	328	ft
0	100	150	m	328	492	ft
-2	150	200	m	492	656	ft
-5	200	+	m	656	+	ft
Bluff heights						
5	0	15	m	0	49	ft
3	15	25	m	49	82	ft
2	25	35	m	82	115	ft
1	35	45	m	115	148	ft
0	45	+	m	148	+	ft
Topographic slope						
5	0	10	degrees			
3	10	15	degrees			
0	15	26	degrees			
-5	26	90	degrees			
10 m bathy contour						
5	0	0.5	km	0	0.31	mi
3	0.5	1	km	0.31	0.62	mi
0	1	1.5	km	0.62	0.93	mi
-5	1.5	+	km	0.93	+	mi
Offshore Structures						
5	0	0	meters	m	0	0
4	0	75	meters	m	0	246
3	75	150	meters	m	246	492
2	150	250	meters	m	492	820
1	250	500	meters	m	820	1640
0	500	+	meters	m	1640	+

The other two types of scoring systems are for layers that have information represented by a limited number of categorical values. We divide the categorical scores into **Table 6-4** for non-numerical data such as geology or seafloor substrate, and **Table 6-5** for factors scored based on limited number of possible numerical values or presence or absence of features. In the case of the Beaches and Dunes layer, many categorical values were grouped into numerical classes that represent our assessment of relative suitability for this project. More descriptive information is retained in a field in the geodatabase layer.

Table 6-4. Scoring systems for layers with non-numerical categorical information.

Score	Value List
Tsunami Zones	
5	Outside Hazard Area
3	Local Tsunami Evacuation Zone, OPTIONAL – Outside Hazard Area
0	Distant Tsunami Evacuation Zone
Geologic Units	
5	sediments, mud, muddy sand, sand
3	gravel, terrestrial sedimentary rocks, marine sedimentary rocks
-5	melange rocks
-15	intrusive volcanic rocks, volcanic rocks, marine volcanic rocks, invasive extrusive rock
Coastal Geomorphology	
5	Dune-backed beach, Gravel beach
4	Cobble beach, Low bluff-backed beach
3	Bluff-backed beach
1	Bluff-backed cobble beach
-5	Rocky shore (Bluffs & Cliffs), Jetties, Estuary
Headlands, Spits, & Landslides	
0	Normal
-50	Spit
*	Headland, Landslide
Coastal Erosion	
5	None
4	Low
2	Medium
-3	High
-5	Extreme
Seafloor Substrate	
5	Coarse Sand, Sand, Fine Sand, Fine Unconsolidated Substrate, Medium Sand
4	Muddy Sand, Sandy Mud
3	Mud, Shell Hash, Slightly Gravelly Sand
0	Very Coarse Woody Debris, Sandy Gravel, Slightly Gravelly Mud, Unconsolidated Mineral Substrate
-10	Cobble, Coarse Unconsolidated Substrate, Gravel, Gravel Mixes
-15	Anthropogenic Rock Rubble, Bedrock, Boulder, Unclassified, Rock Substrate
DOD Assessment	
0	Green
-5	Red

*Headlands and landslides: if a headland or active landslide is present in this layer, the final score is set to zero

Table 6-5. Scoring systems for layers with numerical categories or presence/absence.

Score	Value
Liquefaction Susceptibility	
5	0
4	1
2	2
0	3
-2	4
-5	5
Landslide Susceptibility	
5	1
3	2
0	3
-5	4
Beaches & Dunes	
5	Absent
5	3
2	2
-5	1
Reefs	
0	Absent
-5	Present
Marine Reserves	
0	Absent
*	Present

*Marine Reserves: If any marine sampling zone intersects a reserve or marine protected area, the final score is set to zero

6.3 Suitability Analysis Results

6.3.1 Summary of full results

Application of the strategy described in the previous section provides relative suitability scores for cable landing construction at 5,817 shoreline points along the Oregon Coast. Summary histograms of all the scores show the distribution of the favorability at the scale of the entire state coastline and the impacts of implementing the weighting strategy (**Figure 6-4**). Approximately 36% of the total candidate points have a zero score (completely unfavorable) due to complex shoreline geometry, headlands, active landslides, or being landward of marine protected areas or reserves. Overall, use of weights provides greater resolution of differences between the most suitable sites and less favorable locations, but the effect is relatively modest (**Figure 6-4**). Excluding the points with zero scores, the histogram is bimodal, with peaks at ~ 67% and ~18%. The lower peak generally corresponds to areas of spits and areas where multiple factors with negative scores coincide. The median nonzero score is 67% and the top 40% of points have scores greater than ~70%, corresponding to shades of orange to red in the color scheme used here (**Figure 6-4**). We consider the upper 40% of scores to represent relatively favorable characteristics. The top 10% of nonzero scores are ~83% or higher.

Figure 6-4. Histograms of the statewide cable landing suitability scores using unweighted and weighted strategies. The weighted histogram is colored using the same scheme as the suitability map figures.

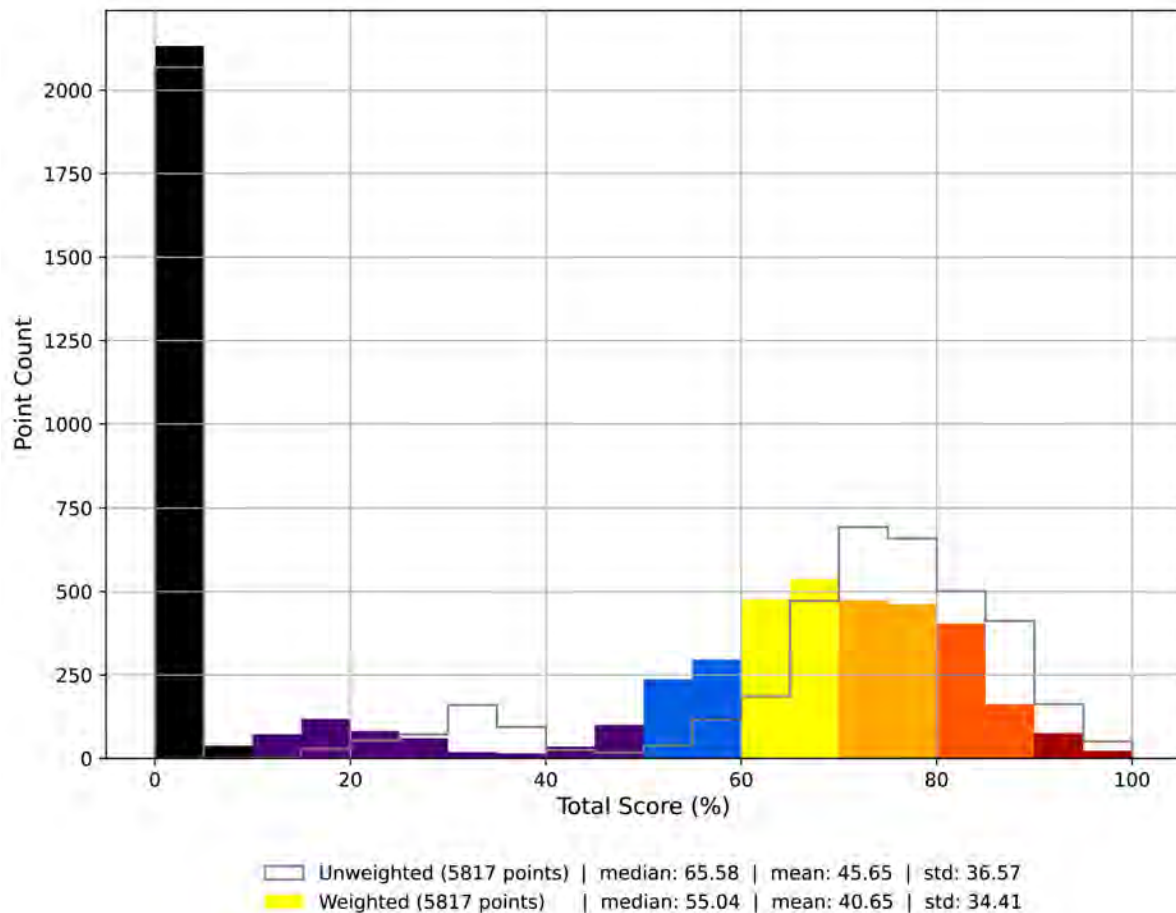
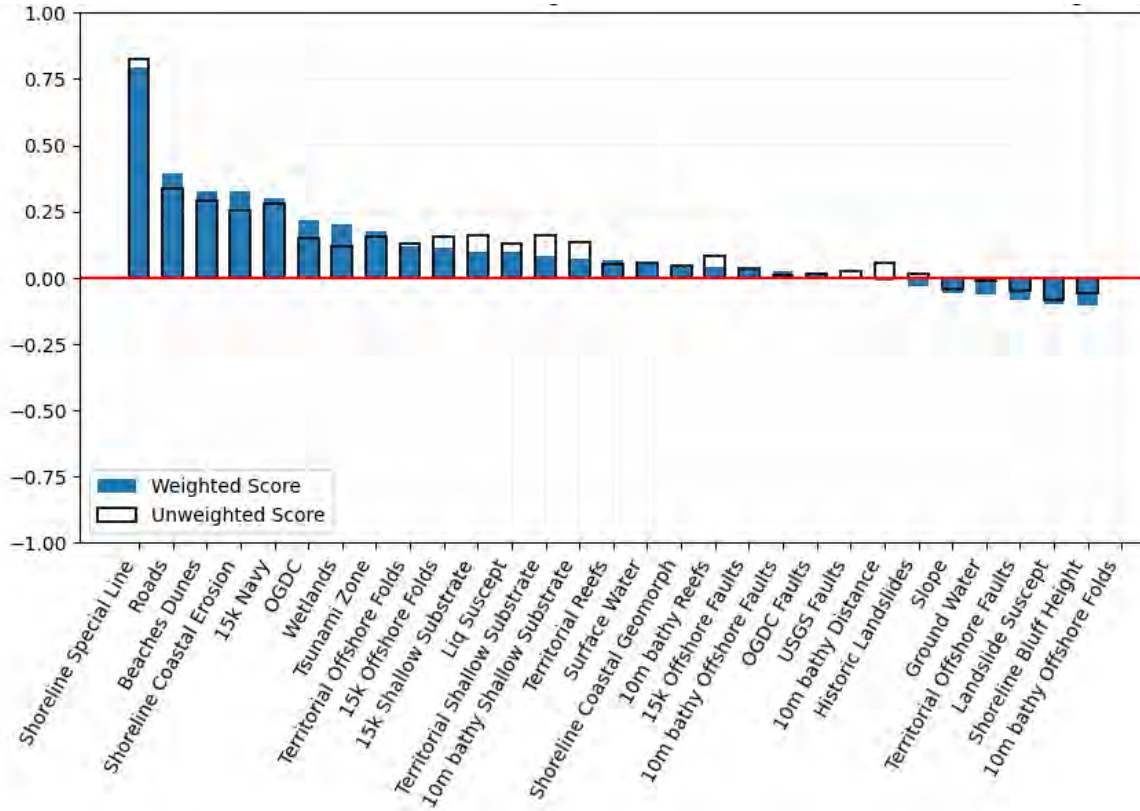


Figure 6-5 shows the influence of each of the factors on the total score through the Pearson correlation coefficient. Aside from the “Special Line” (Headlands, Spits, Landslides) factor that includes the heavily penalized spit category, the correlation values are weak ($\sim \pm 0.3$ or less). The influences of individual factors on the total score reflect a combination of the factor scores and weights as well as spatial correlations between characteristics that are scored either positively or negatively. The subsequent section presents the spatial pattern of cable landing suitability we calculated in six sectors of the coast.

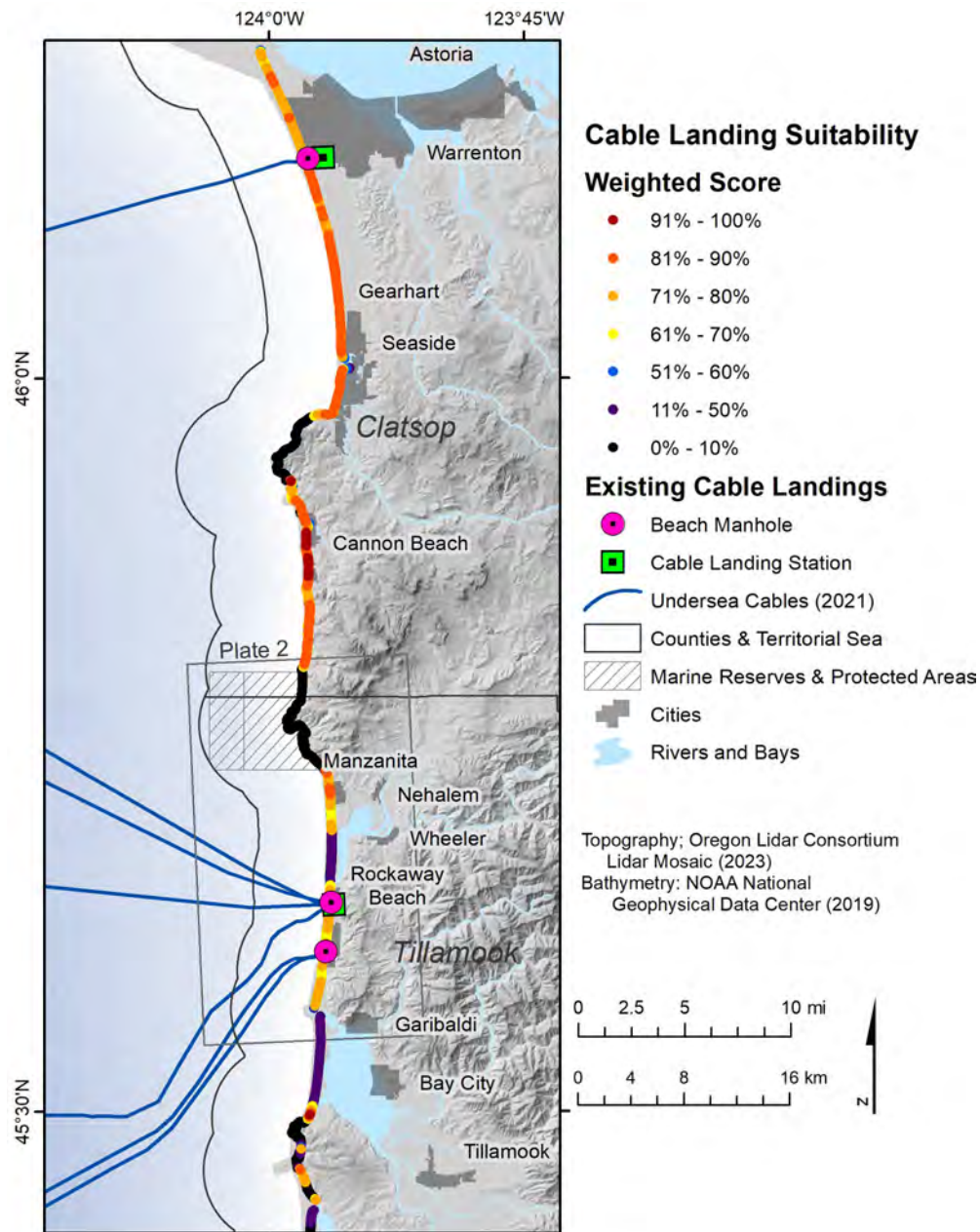
Figure 6-5. Pearson correlation between individual factors and the overall total score for all points with nonzero scores for both weighted and unweighted cases.



6.3.2 Suitability results by Oregon coastal counties

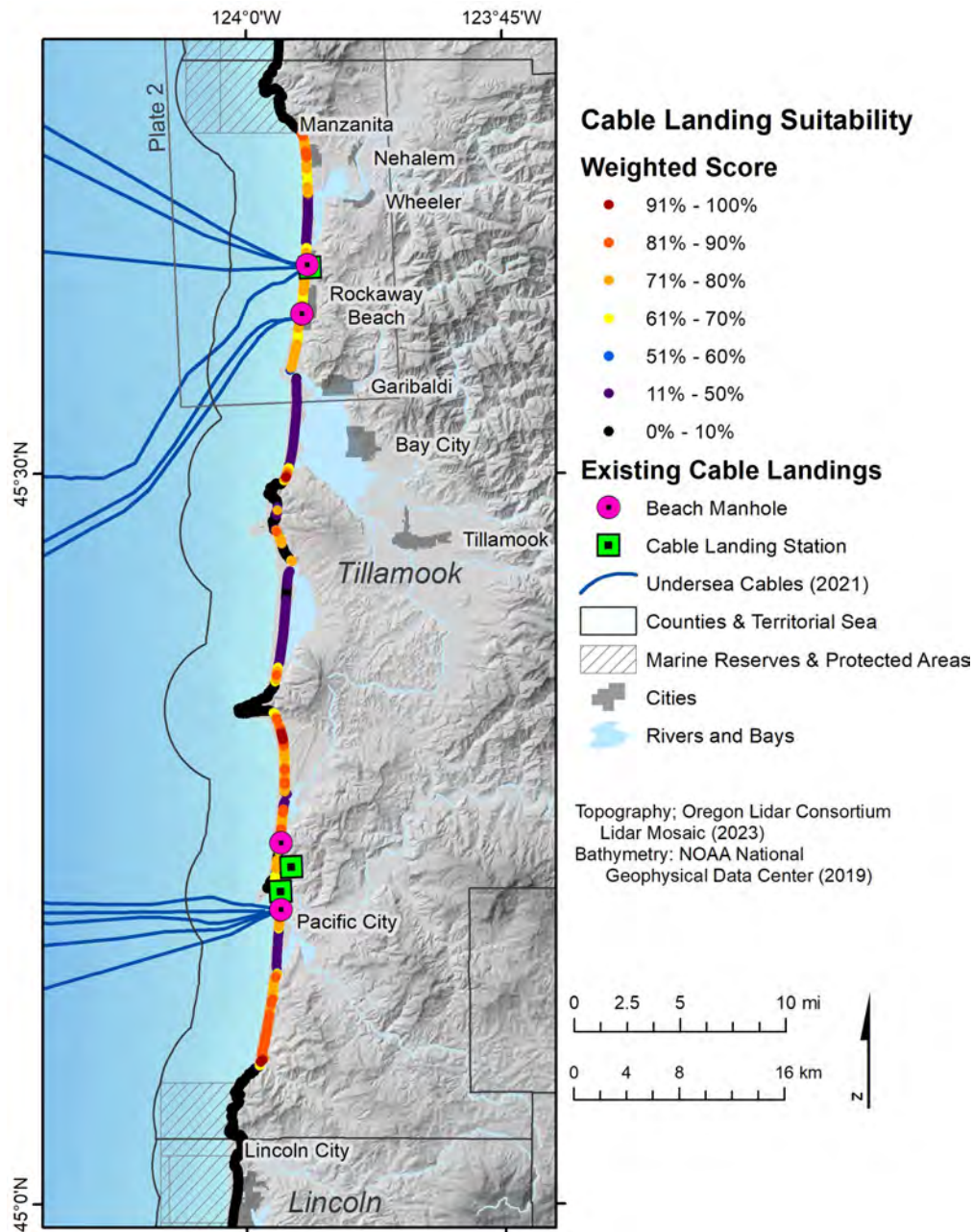
One cable currently lands in Clatsop County (**Figure 6-6**). The northernmost cable landing site at Warrenton is located in a highly favorable location based on our analysis. Adjacent sandy coastal areas appear generally favorable as well. The Cannon Beach area also has suitable physical characteristics.

Figure 6-6. Suitability analysis results for Clatsop and northern Tillamook counties.



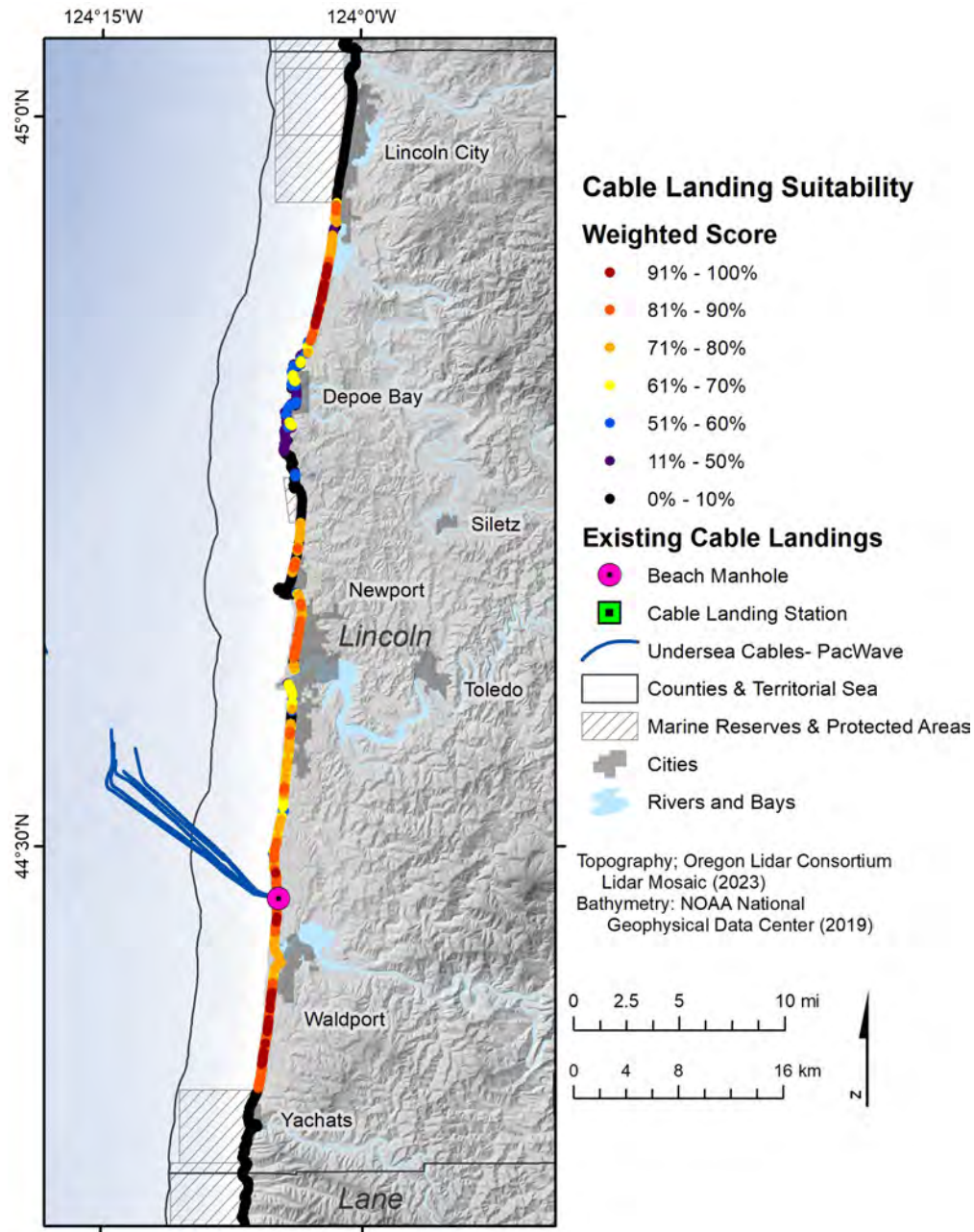
Tillamook County hosts the most current cable landings, and the sectors of the coastline around Pacific City and Rockaway Beach where current cables land are rated as favorable in the suitability analysis (Figure 6-7). Some of the cables in the 2021 compilation shown here have been decommissioned (S. McMullen, personal commun. 2022), and the newly built Jupiter cable lands at the beach manhole in Tierra del Mar, north of Pacific City (Figure 6-7). Plate 2 shows details of individual factors and scoring around Rockaway Beach. Extensive sandy spits with greater mobility are identified as unfavorable. The suitability analysis does not take into account potential crowding issues with a limited number of potential routes through rocky areas west of the Oregon Territorial Sea (e.g., Figure 1-1).

Figure 6-7. Suitability analysis results for Tillamook County.



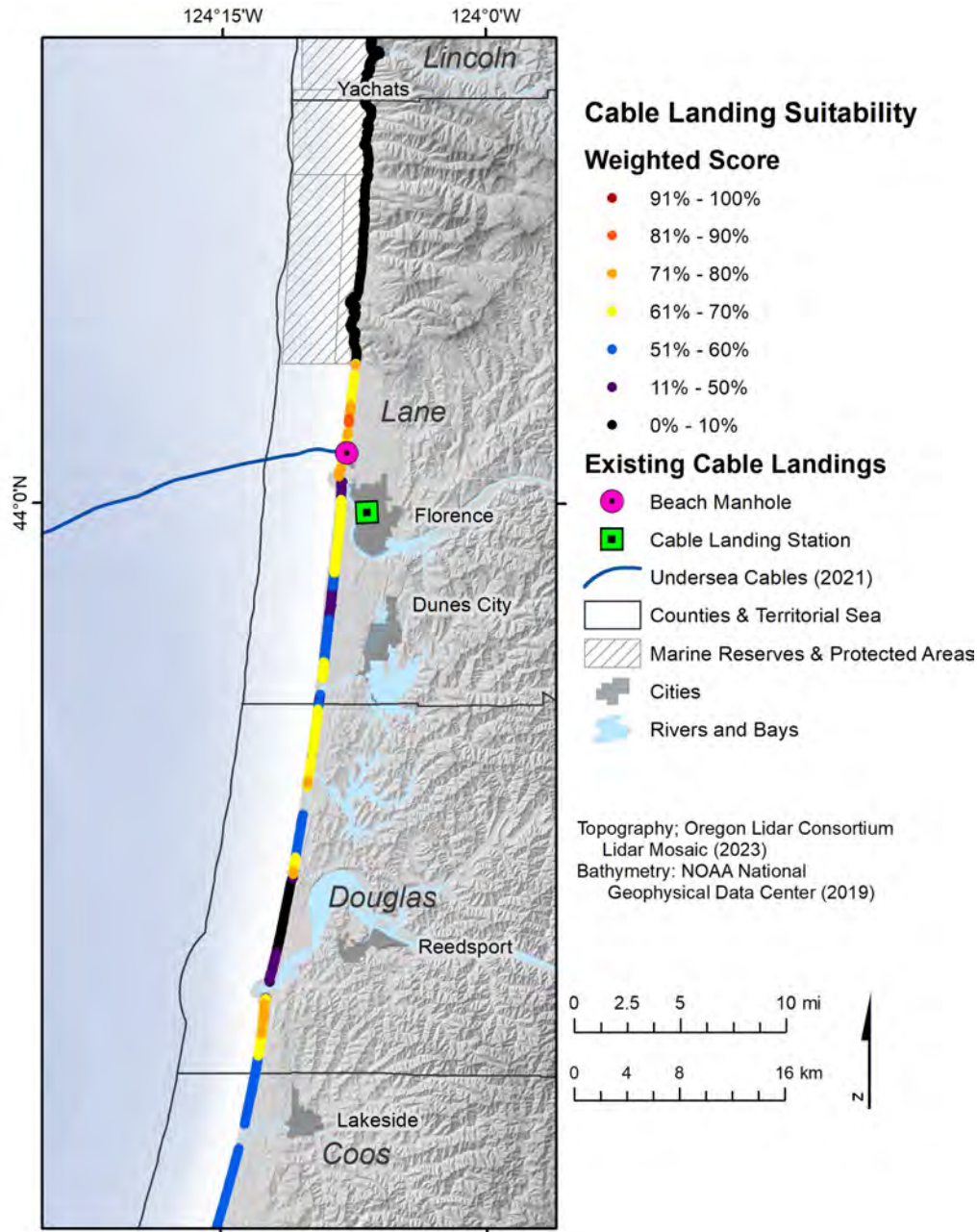
The Lincoln County sector of the coast has numerous rocky headlands and coastal areas composed of hard, basaltic rock that are identified as unfavorable for cable landing construction in our analysis (**Figure 6-8**). We identify three favorable areas: two near Waldport and the other between Depoe Bay and Lincoln City. The recently constructed cable landing site for the PacWave Energy offshore wave energy facility is located in a highly suitable portion of the coastline between Newport and Waldport (**Figure 6-8**).

Figure 6-8. Suitability analysis results for Lincoln County.



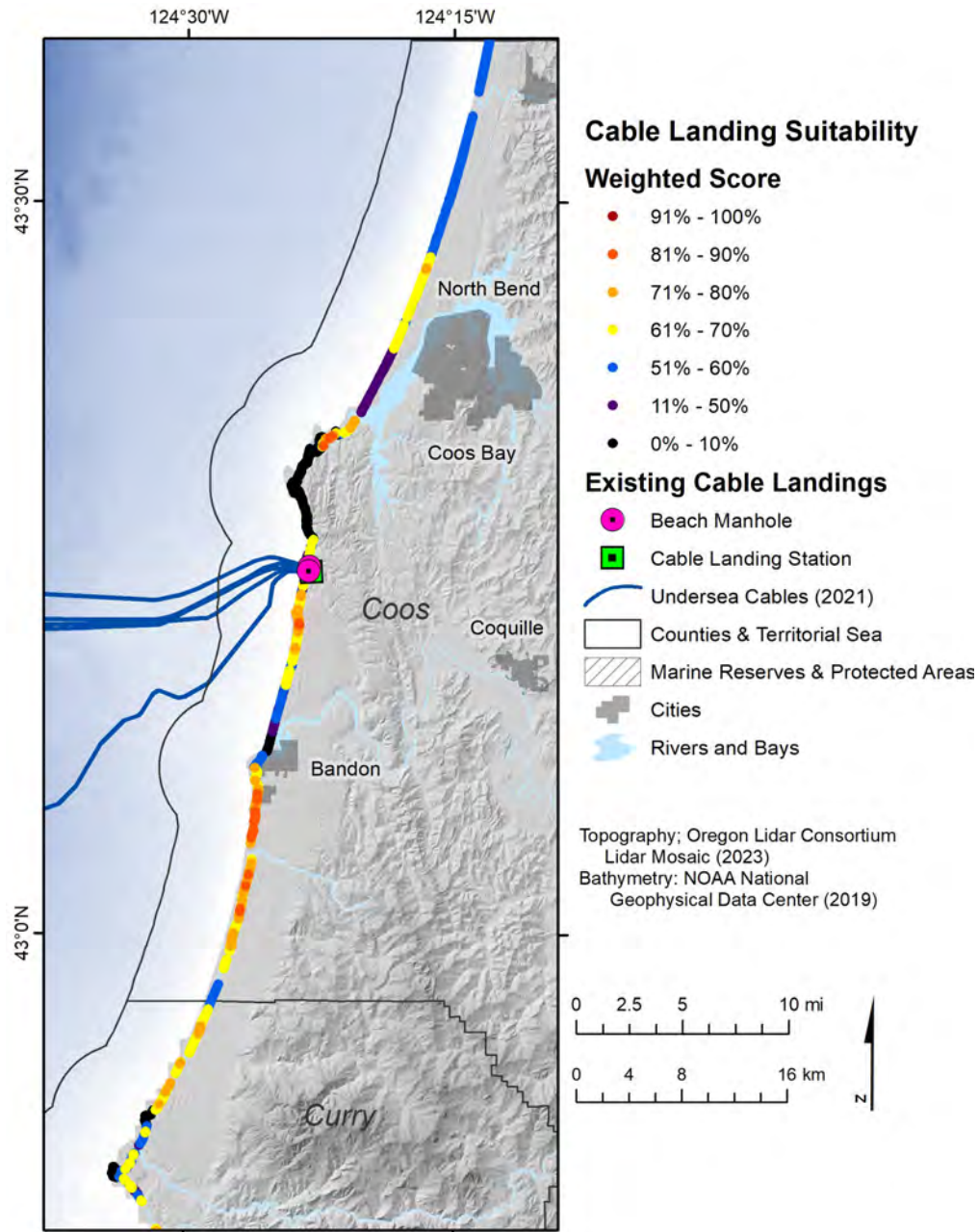
Although the shelf offshore of the Douglas and Lane County sector of the shoreline is relatively amenable to offshore cable burial (**Figure 1-1**), most of this part of the coastline is rated as relatively unfavorable due to the shoreline erosion index in the highest categories, extensive dunes, sand spits, nearshore wetlands, lack of roads at the coast, and the DOD exclusion zone offshore (**Figure 6-9**). The Florence cable landing is in the most suitable part of this coastal sector. This area north of Florence appears favorable for additional cables, and to our knowledge, only one telecommunication cable uses the Florence cable landing station (**Figure 6-9**).

Figure 6-9. Suitability analysis results for Lane and Douglas Counties.



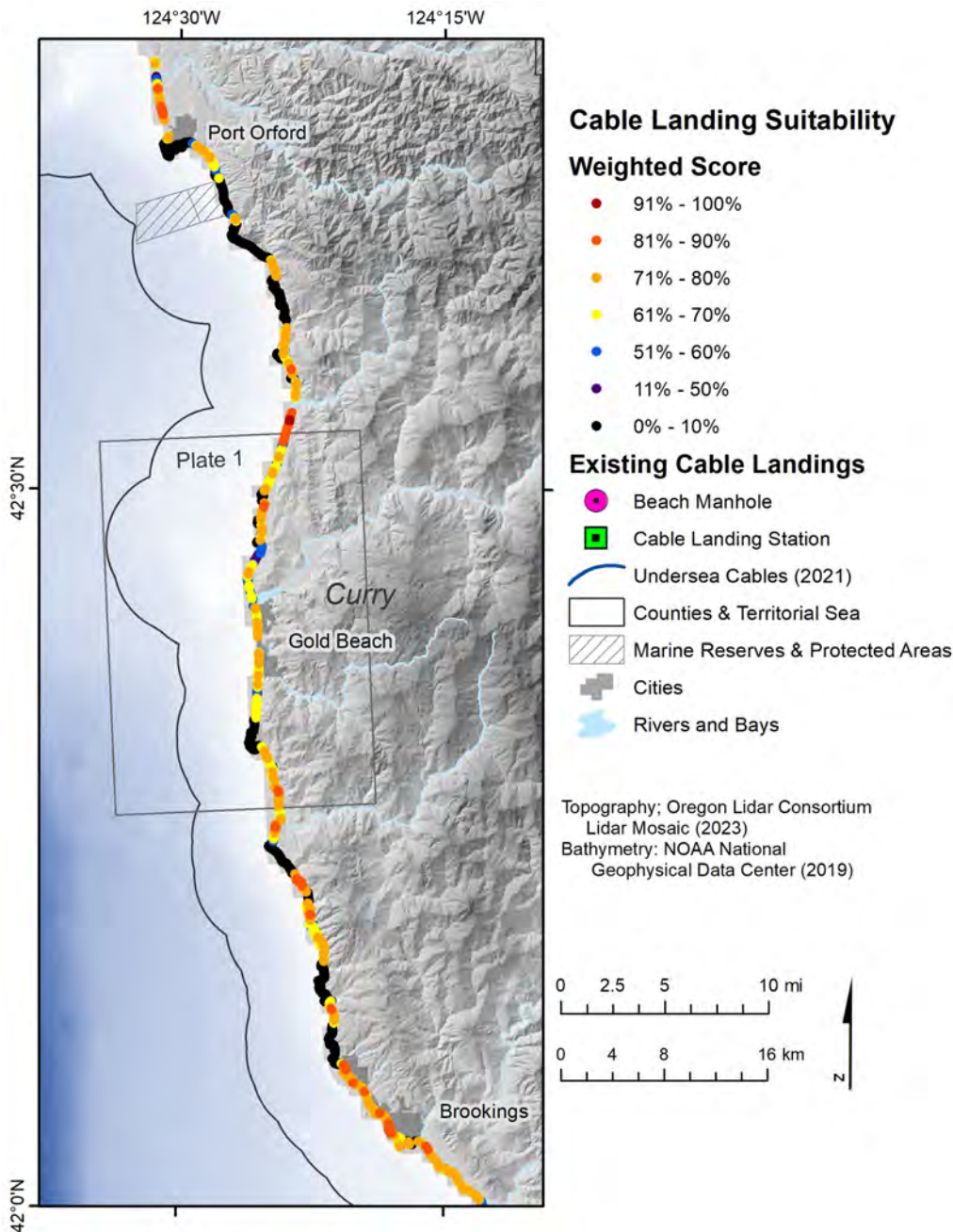
Coos County hosted some of the first transoceanic telecommunications cables to land in Oregon. The vicinity of the two nearby Bandon cable landing sites is rated as relatively unfavorable in our suitability analysis, although nearby areas north of Bandon appear favorable (**Figure 6-10**). The low scores for the Bandon landing site are a product of the rocky seafloor offshore as well as the relatively high, steep, and rocky coastal topography. The scoring likely reflects both changing attitudes toward routing cables over rocks as well as the ability to successfully design cable routes that avoid rock along complex paths. The coastline south of Bandon has favorable characteristics in our analysis (**Figure 6-10**).

Figure 6-10. Suitability analysis results for Coos and northern Curry Counties.



The southern sector of the Oregon coastline has relatively rugged inland topography, and the coastline has mixed suitability scores that show relative variation over kilometer/mile length scales (**Figure 6-11**). More detail for the area around Gold Beach is shown on Plate 1, as an example of the geospatial data that contribute to our analysis and the full resolution of the 100 m spacing of suitability points. Our analysis indicates that favorable areas exist in the vicinity of Brookings, Gold Beach, and Port Orford. Other pockets of more favorable coastline are distributed along the shoreline (**Figure 6-11**) and likely indicate that more detailed planning would allow cable landing siting assuming that the logistical needs related to interconnecting power and/or telecommunications networks could be met.

Figure 6-11. Suitability analysis results for Curry County.



7.0 CONCLUSION

This study provides a regional-scale view of factors that influence locating submarine cables in the Oregon Territorial Sea, and points out where cables cross onto the land to transmit communication data or power to the state. The unique geologic history of the Oregon Coast has produced spatially varying characteristics that have affected how cables may be placed, and how cable landings should be constructed with a minimum of impact on the coastal environment and communities. The new analysis of coastal change over recent decades gives new observations that can help guide placement of cable infrastructure as well as other coastal development in a resilient manner.

Our suitability analysis highlights areas along the coast from the Clatsop Plains in the north to the Gold Beach area in southern Oregon that have characteristics that are generally amenable to construction of new cable landings. Existing cable landings generally occupy relatively favorable settings in our analysis, and suggest that our regional-scale study is compatible with priorities that have guided past placement of specific landing sites. We note that the coarse approach to analysis applied here may miss critical details that would favor or preclude a site being developed for cable landings.

From our review of cable landing site construction and issues experienced on the Oregon Coast in recent years, it appears that cable landings may be developed in a safe way when engineering and design practices are well aligned with the details of local geology. Completion of detailed, site-specific subsurface surveys using geotechnical and geophysical methods prior to construction of HDD boreholes will mitigate many potential problems. We note that HDD construction over the ~1-km-length (0.6 mi) scales required for cable landings brings technical challenges and short spatial-scale heterogeneity in rock or sediment properties may lead to unanticipated damaging effects. These issues motivate locating new cable landings in areas where an engineering issue will not cause unresolvable impacts to the local natural or built environment. Another note is that the publicly available geotechnical reports from the recent PacWave and Jupiter cable projects are helpful for understanding the relevant conditions along the coast. Wider dissemination of geotechnical knowledge from past projects would help in avoiding challenges that might otherwise not be recognized in advance. Design and construction by contractors with state-of-the-art regional expertise is another factor that should improve outcomes for minimally disruptive emplacement of cable landings.

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Undersea Cable Services Best Practices Study

Undersea Cable Placement in the United States and Abroad

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1.0 Executive Summary & Introduction

Wopschall Consulting, LLC (Wopschall) has been contracted by the State of Oregon, acting by and through its Department of Land Conversation and Development (DLCD) to perform a best practices study on the placement of undersea fiber optic and power cables in the United States and abroad. This effort is part of the State of Oregon's House Bill (HB) 2603 which includes an evaluation of the Territorial Sea Plan (TSP) Part Four which governs uses of the seabed.

This report presents undersea cable best practices for the design, placement, installation, and maintenance of undersea fiber optic and power cable systems, as well as high-level permitting or regulatory considerations for these types of infrastructure projects. The sections of this report address the following topics which comprise the scope of this document:

- Siting cable landing sites and coordinating the offshore design with the onshore design requirements of a project
- Offshore cable route selection and engineering
- Onshore landing site construction methods
- Offshore cable installation methods
- The data that goes into the above points
- Stakeholder and other marine user interactions and coordination
- Cable maintenance and repair activities
- Cable decommissioning and removal
- Geomorphology of seabed routing and coastal landing site selection
- Common trends, permitting considerations, and risks to the planning, development and construction of cables

Some of the information presented in this report is based on best practices, guidelines, recommendations and technical brochures that are published by industry bodies, while some of the information is based on Wopschall's experience working in the undersea cable industry on both fiber and power projects. It is noted that there is no governing standards body for the physical placement and construction of undersea cables. Each project, geography, and cable system design are different and unique based on the physical location and jurisdiction where the project is being developed.

The following sections provide background information on undersea fiber optic and power cable systems, best practices for the selection of an undersea cable route, criteria for the selection of an onshore cable landing site and associated infrastructure, best practices for cable installation, protection, maintenance and repair, information on cable decommissioning and recovery, as well as public, stakeholder and marine user coordination. Each section summarizes permitting considerations relevant to each topic addressed in this report.

2.0 Acronyms

The following is a list of acronyms used in this study.

BMH – Beach Manhole

BU – Branching Unit

CHS – Canadian Hydrographic Service
CLS – Cable Landing Station
CPC – Cable Protection Committee
CPT – Cone Penetration Test
DA – Double Armor
DKCPC – Danish Cable Protection Committee
DLCD – Department of Land Conservation and Development
DTS – Desktop Study
DWDM – Dense Wavelength Division Multiplexing
ESCA – European Subsea Cables Association
ft – foot
GEBCO – General Bathymetric Chart of the Oceans
GIS – Geographic Information System
HDD – Horizontal Directional Drilling
HDPE – High Density Polyethylene
HO – Hydrographic Office
HVAC – High Voltage Alternating Current
HVDC – High Voltage Direct Current
ICPC – International Cable Protection Committee
in – inch
ITU – International Telecommunications Union
km – kilometer
kV – Kilovolt
LW – Light Weight
LWA – Lightweight Armor
LWP – Lightweight Protected
m – meter
MBES – Multibeam Echo Sounder
mi – mile

MPA – Marine Protected Area

MRS – Marine Route Survey

MW - Megawatt

NASCA – North American Submarine Cable Association

NEPA – National Environmental Policy Act

Nm – Nautical Mile

NMFS – National Marine Fisheries Service

NMS – Network Management Equipment

NOAA – National Oceanic and Atmospheric Administration

OSCA – Oceania Submarine Cable Association

PFE – Power Feed Equipment

PFS – Permit Feasibility Study

PVC – Polyvinyl Chloride

ROV – Remotely Operated Vehicle

SA – Single Armor

SBP – Sub-bottom Profiler

SLTE – Submarine Line Terminating Equipment

SSS – Side Scan Sonar

TSS – Traffic Separation Scheme

UK – United Kingdom

UKHO – United Kingdom Hydrographic Office

US – United States

USACE – United States Army Corps of Engineers

UNCLOS – United Nations Convention on the Law of the Sea

UQJ – Universal Quick Joint

UXO – Unexploded Ordinance

3.0 Background – Undersea Cable Design and Placement

Regional and international undersea fiber optic cables have been a means of communication between countries and continents since the first telegraph cables were installed in the late

1800's including the first trans-Atlantic cable between England and North America. Since that time, cables have been laid on and buried in the seabed to facilitate the growth of international communications. Communications technology has evolved since the telegraph era, most notably with the era of fiber optics in the 1980's and 1990's, as well as coherent technology in the late 2000's, which are advancements that have kept undersea fiber optic cables as the primary mechanism for global communications and digital data transmission.

The reason undersea cables, specifically fiber optic cables, have been installed on the seabed, is that a physical point-to-point connection is the quickest way to transmit data, whether it be voice, video or other forms of digital data. Routing cables through the world's oceans is the only way to obtain that point-to-point connection with other locations, which have facilitated over 99% of all international communications for decades (Brake, 2019). Compared to satellite technology, which came much later than the first advent of an undersea cable, fiber optic cables have lower latency in transmitting data and can do so at much higher capacities than satellites. These days, undersea fiber optic cables are being developed to transmit data at tens of terabits per second per fiber contained within the cable. New cables are deployed each year and these projects are barely keeping up with the global demand for broadband that has been realized with the use of social media, video streaming, video conferencing, and personal and enterprise cloud services, as well as the growth and use of data centers and data center-to-data center communications/data transfer. The demand for broadband, international connectivity, as well as overall network redundancy is driving the undersea fiber optic cable market and will continue to do so into the future.

As of 2022, there are approximately 530 active and planned undersea fiber optic cable systems (Telegeography, 2022). From this total, approximately 80-85 cables land in the United States on both the east and west coasts. Specific to Oregon, 13 submarine fiber optic cable segments land in the state at approximately 6-7 landing locations. At the time of this report, several new cable systems are also planned to land at existing and new cable landings, including submarine power cables associated with Oregon's PacWave project.

Global communications have relied on hundreds of active undersea cables for decades. As of the last ten years, undersea cables have started to be recovered when decommissioned to remove them from the seabed as part of a permitting or regulatory requirement, as well as for the recycling of raw materials contained in the cable such as copper and steel. In other instances, undersea cables are left in-situ after decommissioning so as to not disturb the seabed by removing buried cables or in the instance of surface laid cables, to not disturb marine life that has colonized the cable (Carter, et al 2009).

The figure below is a schematic representation of the world's major in-service undersea fiber optic cables system.

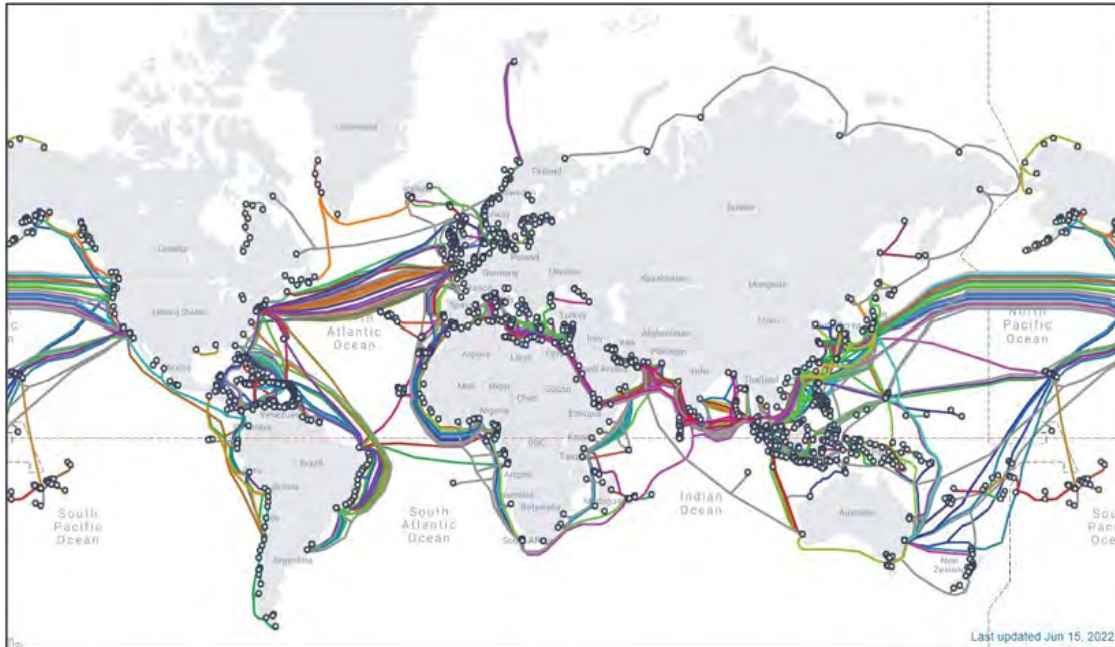


Figure 1: Global Map of In-Service Undersea Fiber Optic Cable Systems, Source: Telegeography, Submarine Cable Map, 2022, <https://www.submarinecablemap.com>

The figure below illustrates the in-service undersea fiber optic cables that land in Oregon at various landing locations. .

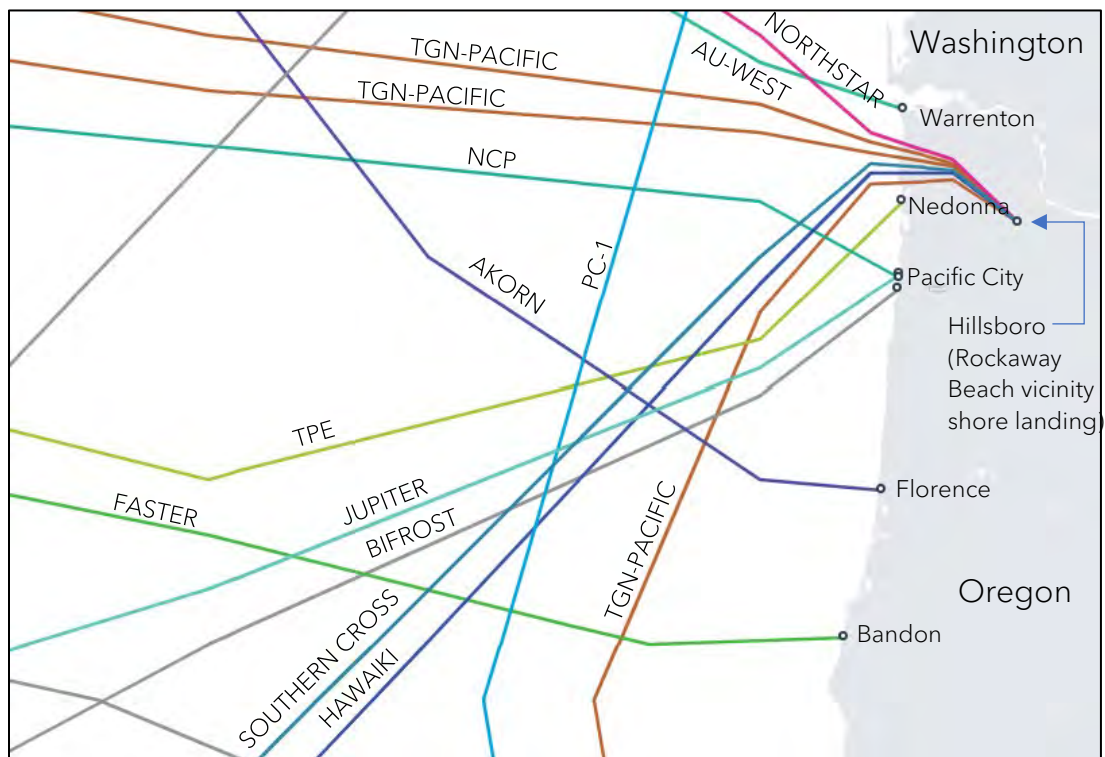


Figure 2: Map of In-Service Undersea Fiber Optic Cable Systems Landing in Oregon, Source: Telegeography, Submarine Cable Map, 2023, <https://www.submarinecablemap.com>

The development of new undersea fiber optic cables is a factor of demand for global broadband connectivity. The figure below illustrates two of the world's major undersea fiber optic cable markets, the Trans-Pacific and Trans-Atlantic markets, which drive fiber optic cable landings on the US east and west coasts. Exponential demand is a factor of increases in video conferencing, video streaming, social media applications, as well as private and commercial broadband connectivity.



Figure 3: Forecasted Broadband Demand for the Trans-Atlantic and Trans-Pacific Markets through 2027, Source: Telegeography, 2022 <https://www.submarinecablemap.com>

Compared to undersea fiber optic cable systems, undersea power cables typically serve regional demands for power transmission including point-to-point transmission and renewable energy applications such as offshore wind. Undersea power cables, both high voltage alternating current (HVAC) and high voltage direct current (HVDC) cables have different physical characteristics than a fiber optic cable, most notably their diameter, but much of the physical siting and installation considerations and best practices are very similar between fiber optic and power cables.

Undersea fiber optic cable systems, and to a lesser degree power cable systems, get damaged each year. The primary cause of damage is bottom contact fishing and vessel anchors with over 70% of fiber optic cable damages resulting from these occurrences globally (Telegeography, 2022). As a result, protecting undersea cables has always been a priority for the cable industry. A consistent theme in industry best practices revolves around the protection of digital and power infrastructure assets both onshore and offshore and drives the placement, installation methods, as well as operations and maintenance of undersea cables.

The following sections provide a more specific overview of industry bodies that promote best practices and the protection of undersea cables, as well as providing a design overview of fiber optic and power cable systems from a physical infrastructure point of view.

3.1 Industry Organizations

The undersea fiber optic cable industry and the power cable industry have trade organizations that look after and promote the protection of undersea cables. This also includes promoting cable infrastructure resilience which covers all aspects of a cable's lifespan including design and siting, installation, operations, maintenance and decommissioning and recovery. From these organizations are publications promoting best practices, guidelines, recommendations, and technical brochures. For the purposes of this report, these various publication forms can be thought of as disseminating best practices for undersea cables.

3.1.1 International Cable Protection Committee (ICPC)

The International Cable Protection Committee (ICPC, www.iscpc.org) was founded in 1958 as a cable protection committee focused on protecting and maintaining undersea communications cables. The organization has since also included undersea power cables. As a membership-based organization headquartered in the United Kingdom, the ICPC comprises about 190 member companies in over 60 countries including cable owners and operators, cable suppliers and installers, vessel operators, marine survey companies, professional services companies, as well as governments. The ICPC is at the forefront of best practices, both technical and regulatory, for the protection of cables.

The ICPC publishes 'Recommendations' that cover a wide variety of technical and other topics to promote awareness of these best practices. These documents can be requested from the ICPC at the following website address: <https://www.iscpc.org/publications/recommendations/>

The list below summarizes the Recommendation titles from the ICPC.

- Recovery of out-of-service cables
- Cable routing and reporting criteria
- Telecommunications Cable and Oil Pipeline / Power Cables Crossing Criteria
- Co-ordination Procedures for Repair Operations Near In Service Cable Systems
- Recommendation for Common Format for Cable Awareness Charts
- Recommended Actions for Effective Cable Protection (Post Installation)
- Offshore Civil Engineering Work in the Vicinity of Active Submarine Cable Systems
- Procedure To Be Followed Whilst Offshore Seismic Survey Work Is Undertaken In The Vicinity Of Active Submarine Cable Systems
- Minimum Technical Requirements for a Desktop Study
- The Minimum Requirements for Load and Lay Reporting and Charting
- Recommended Common Format for Electronic Formatting of Route Position Lists
- Mechanical Testing of Submarine Telecommunications Cables
- The Proximity of Offshore Renewable Wind Energy Installations and Submarine Cable Infrastructure in National Waters
- Basic Power Safety Procedures that are to be followed by Marine Repair Operators and Terminal Station Personnel during Subsea Cable Repair Activities

- Procedure to be Followed Whilst Marine Aggregate Extraction, Dredging or Mining is Undertaken in the Vicinity of Active Submarine Cable Systems
- Considerations for Marking Submarine Cables
- Submarine Cable Operations in Deep Seabed Mining Concessions Designated by the International Seabed Authority
- Minimum Technical Requirements for the Acquisition and Reporting of Submarine Cable Route Surveys
- Preparatory Actions for Civil Claims Development for Cable Damage

The ICPC also publishes 'Best Practices' which are intended to be government facing publications to promote regulatory best practices that can be adopted by governments to help protect undersea cables as critical infrastructure (ICPC, 2022). These best practices are discussed later in this report and are included as Attachment A, for reference.

These best practices present topics including:

- Fishing and anchoring risks [to cables]
- Spatial separation
- Charting
- Domestic cable protection laws; penalties for damage
- Marine spatial planning and inter-industry coordination
- Single point of contact
- Route and landing optimisation; geographic diversity
- Permitting for installation and repair
- Cabotage and crewing restrictions
- Port entry requirements
- Customs duties, taxes, and fees
- Maritime boundary claims and disputes
- Critical infrastructure designation
- Sharing of risk and incident data
- Impact of other high-seas regulatory activities

3.1.2 European Subsea Cables Association (ESCA) & Regional Cable Protection Committees

Where the ICPC primarily focuses on international cable protection issues and best practices from an industry wide or global perspective, much of the ICPC's work is augmented by regional cable protection committees (CPCs). Each CPC has their own focus and initiatives though they maintain close relationship with the ICPC and other CPCs. Some CPCs publish best practice documentation done so in coordination with the broader industry.

Listed below are some of the regional CPCs around the world:

- European Subsea Cables Association (ESCA, www.escaeu.org)
- North American Submarine Cable Association (NASCA, www.n-a-s-c-a.org)
- Danish Cable Protection Committee (DKCPC, <https://dkcpc.dk>)

- Oceania Submarine Cable Association (OSCA, www.oscagroup.com)

There are also regional CPCs in Indonesia and West Africa.

Of these organizations, it is ESCA that also promotes industry best practices by publishing 'Guidelines' which are similar to the ICPC's Recommendations. Some of the guidelines are working level guidance that don't necessarily pertain to the topics of this report.

Guideline topics published by ESCA include the following:

- Principal UK Fishing Organisations
- Principal Operational Regulations
- Fishing Claims forms & Guidance Notes
- Guidance Fishing Reps
- Guidance Notes for Guard Vessels
- Telecom Cable Works Notice
- Fishing Liaison
- UKHO Liaison
- Submarine Cable Navigational Aids
- Offshore Liaison
- Inclusion of ESCA Recommendations
- Proximity of Wind Farms
- Rock Placement
- Typical Decommissioning Summary Report
- Submarine Cable Decommissioning
- Interfaces During Cable Fouling Incidents
- Research Vessel Safe Working Distances
- Reporting Faults Caused by Anchors to the MAIB and MCA
- Fishing Compensation
- Power Cable Installation
- Power and Renewable Energy Cable Repair
- Testing of AC and DC Subsea Power Cables
- Marine Aggregate Extraction Proximity
- Notifications to vessels operating in close proximity to subsea assets

3.1.3 CIGRE

CIGRE [<https://www.cigre.org>] is the International Council on Large Electric Systems and is a global delegation of members who are committed to knowledge development and sharing of power systems expertise, which includes undersea power cable systems. While CIGRE covers a large topic area relating to power systems, the organization recently published for its members a Technical Brochure on the installation of undersea power cables which includes best practices for these activities.

CIGRE's Technical Brochure (TB) 883 – Installation of Submarine Power Cables is a 241-page document that covers the following topics:

- Consents and Permitting
- Submarine cable installation engineering
 - Engineering process
 - Engineering studies
 - Cable routing
 - Cable protection
 - Landfall and offshore asset design
 - Cable and accessory designs and impact on installation
 - Tool and vessel selection
 - Cable installation engineering
- Seabed survey and site investigations
- Installation tools, vessels, and considerations
- Execution of installation including remedial work
- Operation, maintenance, and decommissioning

3.1.4 Cable Awareness – Maps & Data

Essential to cable protection is promoting the awareness that cables exist on the seabed. There is no single consolidated set of existing cable information, as much of this information is held by individual cable owners and is considered confidential. However, cable systems are reported to relevant hydrographic offices (HOs) for charting on nautical charts. Other resources exist to promote the awareness and presence of cables.

One map resource is Telegeography's submarine cable map (<https://www.submarinecablemap.com/>) which depicts schematic routes of existing in-service telecommunications cables. This resource is used as a reference for where cables exist, their ownership, and other information but is not used for accurate route positioning of cables.

Another resource promoted by ESCA is Kis Orca's website which depicts the routing of cables in Europe (<https://kis-orca.org/map/>).

Other organizations such as DKCPC, NASCA, and governmental data sources like NOAA's Marine Cadaster publish cable route information in various forms as well.

Having access, even regionally, to accurate cable information is very helpful not only to the cable industry, but also to other marine and shoreline user groups who are planning other infrastructure in the vicinity of undersea cables.

3.2 Undersea Fiber Optic Cable Systems

Undersea fiber optic cable systems are designed for a twenty-five (25) year design life though some systems are operated longer. Often a cable is decommissioned either because the cost of ownership and maintenance no longer makes sense for the service the cable provides, or because the cable exceeds its ability to be further upgraded with modern transmission equipment, or the cable route or network path is replaced with a new cable, or a combination of these factors.

A cable system that exceeds the distance of approximately 250 - 500 km (155 - 310 miles) is required to have repeaters spaced along the cable at intervals of approximately 70 - 120 km

(43.5 – 74.5 miles) to amplify the signal so that data traffic can continue to be transmitted along the cable for its entire length. As a result of these repeaters, as well as other submerged cable bodies such as branching units (BU), these cable systems are powered with power feed equipment (PFE) housed on land at each end of the cable system.

An overview figure of a repeatered cable system is provided below. This figure illustrates the end-to-end design of a cable system. The undersea portion of a cable system is typically designed from a beach manhole (BMH) or utility vault at a beach. The undersea cable is anchored to the BMH and is installed on the seabed to another location where the cable makes landfall. If a cable system is not a point-to-point system but lands in multiple locations, BU's are installed so the fiber cable can "branch" out to other locations, allowing a cable to serve many different locations from one system.

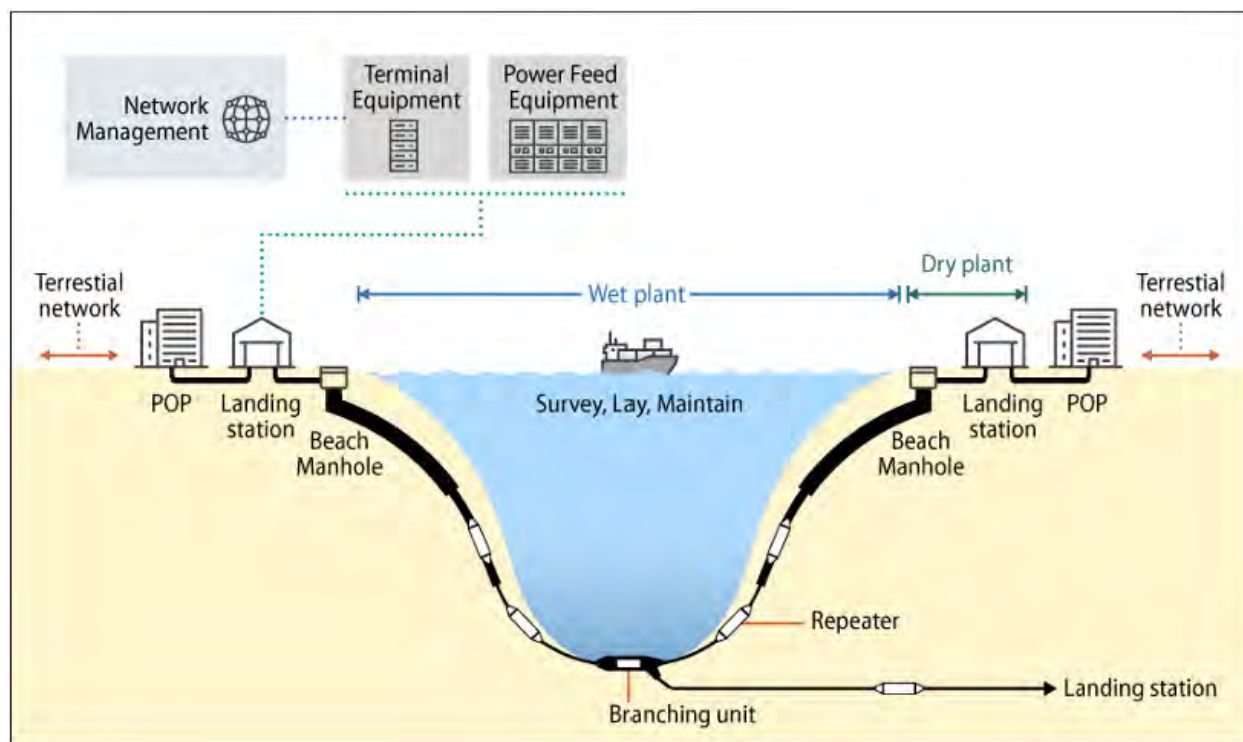


Figure 4: Illustration of an Undersea Fiber Optic Cable System Source: Congressional Research Service (CRS), <https://crsreports.congress.gov/product/pdf/R/R47237>

From the BMH, the undersea cable is typically spliced to a land cable that is installed along a fronthaul path to a cable landing station (CLS) or a PFE hut with fiber running onwards to a data center. The CLS is a telecommunications facility that houses the transmission equipment, or submarine line terminating equipment (SLTE), PFE, network management equipment (NMS), and other ancillary systems required to keep the undersea cable system up and running. From the CLS, the fiber from the undersea cable is connected to terrestrial backhaul fiber that carries traffic further inland to either a Point-of-Presence (PoP) like a carrier hotel, or to a data center. The "on-land" portion of the network is referred to as the dry plant, while the undersea cable portion is referred to as the wet plant. In some cases, and typically only when a PoP or data center is in relatively close proximity to a cable landing, will the undersea cable be spliced

directly to a land cable that terminates in a data center, as an example, which houses all of the system equipment instead of using a CLS. In other cases where a CLS is located usually more than 10 - 15 km from a cable landing, a PFE hut may be constructed as a smaller intermediate facility to house the cable system's power equipment, while the fiber continues further inland to a CLS or a data center. This mitigates the issue of running power along a lengthy fronthaul route. As a result of this, CLS facilities are usually sited as close to a cable landing as possible.

A main driver for where a cable is routed along the seabed is determined by where the cable is required to come to shore for greater onward connectivity within new and existing fiber networks. This may be influenced by where existing CLS facilities are located or new facilities can be constructed, availability of backhaul fiber, locations of PoPs and data centers, and proximity to other network infrastructure including other undersea fiber optic cables. In the last ten (10) years there has been a shift in the types of companies developing cable systems. Content, social media, or internet-based companies are the primary purchasers of new cable systems rather than the traditional carriers or telephone companies who were the main purchasers in the 1990's and early 2000's (and before that). As a result of this shift and based on the growth of the data center market, undersea fiber optic cable systems are being developed to connect data centers, so the selection of offshore route alignments and landing sites is increasingly driven by connecting data centers owned by companies developing undersea cable systems, data centers that house these company's network equipment, or data centers where these company's customers are located.

The figures below illustrate the various types of undersea fiber optic cables which are predominantly characterized by the amount of armor applied to the cable for protection based on the physical environment the cable is placed in.

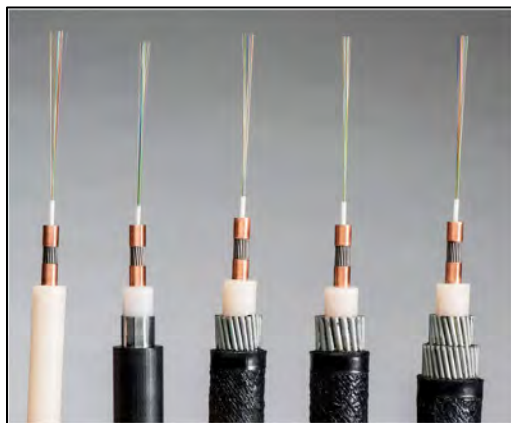


Figure 5: Undersea Fiber Optic Cable Types made by SubCom, Source: Wired.com

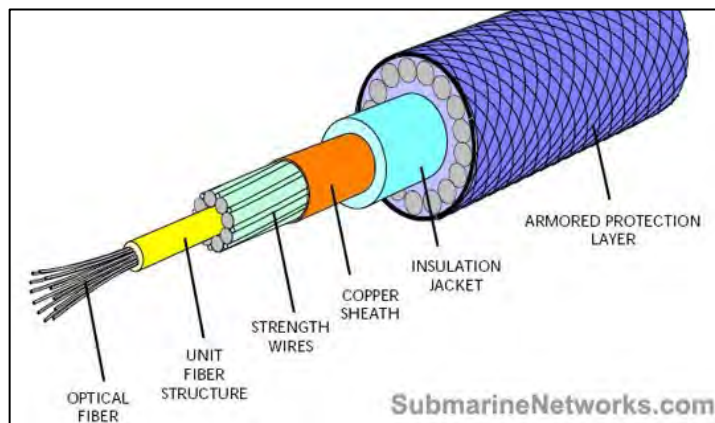


Figure 6: Structure of an Undersea Fiber Optic Cable (Single Armor), Source: submarinenetworks.com

Undersea fiber optic cables are typically comprised of an inner optical fiber unit that houses individual glass fiber strands. For repeatered cable systems, cables will typically have up to 12 - 16 fiber pairs (24 - 32 strands) with each fiber pair providing bi-directional communication across the system. More recently, trans-oceanic systems such as across the Atlantic Ocean are

being built with 24 fiber pairs (48 strands) which is far greater than their predecessor cables built two decades ago which may only have 2 – 4 fiber pairs (4 – 8 strands).

The optical fiber unit is surrounded by steel strength wires, a copper sheath which acts as the power conductor for the cable (for repeatered systems) and insulation jacket, and layers of steel armoring. It is noted that fiber optic cables have a copper sheath to send power to repeaters and BU's and are not utilized for power transmission like undersea power cables.

The figure above illustrates various cable types that are used in undersea fiber optic cable applications, including (from left to right) Lightweight (LW), Lightweight Armor (LWA) (also known as Lightweight Protected (LWP)), Single Armor (SA), Single Armor (SA, with thicker diameter armoring), and Double Armor (DA). Cable types are often selected based on water depth, terrain of the seabed, and the risk of external aggression. It is noted that the names and physical characteristics of each cable type may vary between cable manufacturers.

The table below provides information on the water depths and applications where each cable type is typically used. LW cable is used in deep water applications and is no larger than 17 – 22 mm (0.67 – 0.87 inches) in diameter increasing to 40 – 50 mm (1.57 – 1.97 inches) diameter for a DA cable that is used as the cable approaches shore (Carter et al, 2009).

Table 1: General Cable Types and Their Applications

Cable Type	Installation Depth		Installation environment
	Typical	Max.*	
Double Armor (DA)	0 to 200m	0 to 500m	Generally used in the nearshore portion of cable routes where the risks from high-energy environments and external aggression are highest. Also used on rock outcrops and areas of less than reasonable sediment cover where abrasion is a risk.
Single Armor (SA)	0 to 1,500m	0 to 2,000m	Generally used on the continental shelf and slope where the risks are present and the cable is to be surface laid over marginal bottom conditions. Also used in areas of rock outcrops beyond the deployment depth of DA cable.
Light Weight Protected (LWP)	1,500 to 4,500m	7,000m	Used on continental slope and in deep-sea areas where extra abrasion protection might be necessary, i.e. on rocky bottom, in areas of high relief and/or steep slopes, in areas of strong currents and/or slumping.
Light Weight	1,500 to 6,000m	8,500m	Used in most benign deep ocean environments to full ocean depth.

(LW)			
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The predominant risk of damage to undersea fiber optic cables is from bottom contact fishing and vessel anchoring. Globally there are approximately two hundred (200) undersea fiber optic cable repairs that occur each year. Of these, approximately seventy percent (70%) of the damages are from fishing and anchoring (Telegeography, 2022). Two of the main methods for protecting undersea cables from these forms of external aggression include armoring the cable, as discussed with the various cable types, and burying the cable into the seabed. Both are implemented globally as a matter of standard practice.

Depending on the installation environment, particularly in deeper water or where a cable cannot feasibly be buried, cable armoring also protects the cable from abrasion against rough or rocky surfaces.

From the shore, it is standard to bury cables to a minimum depth of 1 m (3.3 ft) below the surface of the beach and seabed and typically no more than 2 m. There are exceptions to this where certain jurisdictions require deeper burial such as off Singapore and in Indonesian waters; however, these are exceptions rather than best practice. It is also standard that cables be buried to a minimum water depth of 1,000 m (3,280.8 ft), but based on a region's fishing activity, consideration of burial down to between 1,500 and 2,000 m (4,921.3 – 6,561.7 ft) water depth is also practiced. A presentation of the methods used for cable burial is discussed in Section 6.0 of this report.

A few different methods are implemented to achieve burial of the cable through the surf zone and onto shore up to the BMH, which are typically driven by local permitting requirements. The first method is a land-based direct burial method where the beach is trenched using conventional excavation equipment. The cable can either be directly installed in the trench and then buried, or a conduit made out of PVC or HDPE can be installed by which the cable is inserted through the conduit for added protection. Articulated pipe can also be installed over the cable as another method for added protection rather than using a conduit. The direct burial method has traditionally been used throughout the world for shore-end construction.

Another method that is more common in North America, among other locations, is to directionally drill a seaward conduit using horizontal directional drilling (HDD) from the landing or BMH location to a point offshore that is typically beyond the surf zone or in about 10 m (32.8 ft) water depth. The directionally drilled conduit is utilized as added protection to install the undersea fiber optic cable through to the BMH and provides for construction that does not directly disturb the beach or shore. In most cases, whether it be a buried PVC or HDPE conduit, or an HDD conduit, the diameter of the conduit is usually about 4 in (10.2 cm).

For undersea fiber optic cable systems that are equal to or less than 250 to 500 km (155 – 310 miles), modern transmission equipment can transmit data without the need for amplification in the form of repeaters along the cable. As a result, these cable systems can be unrepeaters and, therefore, unpowered. Unrepeaters cable systems are typically implemented as regional

cable systems where the geography of a region allows for shorter cable spans to connect various locations, as opposed to trans-oceanic systems that span the world's major oceans. Aside from being unrepeated, another main difference when compared to repeated systems is the fiber count can often be much greater. It is typical that an unrepeated system can have up to 96 fiber pairs or more, making it akin to a terrestrial fiber optic cable that has been repurposed for an undersea environment.

Unrepeated cables are manufactured with similar cable types as repeated cables and are often armored (DA, SA, LWP cable types) because their application lends themselves to shallower water routes. However, the methods of cable protection (armoring and burial) as well as installation and landing site construction are predominantly the same as what has been described above for repeated cables.

3.3 Undersea Power Cable Systems

Undersea power cables serve the primary purpose of transmitting power through either high voltage direct current (HVDC) or high voltage alternating current (HVAC) cables. Undersea power cables are implemented to serve point-to-point connections for sustainable power transmission between sources. This can include transmitting power from one country to another, from hydroelectric sources, or other renewable energy sources such as wind farms or hydrokinetic sites.

Power cables are designed for a 40-year design life and are often manufactured as Double Armor (DA) or Single Armor (SA) cables, with armoring (and cable burial) being the primary method of cable protection.

HVDC power cables are manufactured for longer distance power transmission which typically serves point-to-point power transfer between sources such as the 525kV, 154 km (387.1 miles) offshore segment of the NordLink cable system between Norway and Germany.

HVAC power cables are manufactured for shorter distances usually less than 80 km (49.7 miles) and are often implemented as export cables from offshore wind farms or shorter point-to-point connections such as connecting hydroelectric plants to city centers.

Undersea power cables can range in diameter from 70 mm to exceeding 210 mm in diameter (ESCA, accessed September 2022). These cables are limited in the water depth they can be installed in. Due to the length limitations of HVAC cables, most are installed in shallow water applications of less than a few hundred meters water depth. HVDC cables can extend for longer distances and as a result transit deeper depths but are generally limited to around 1,000 m (621.4 ft) water depth, though some existing in-service cables have been installed to depths approaching 2,000 m (1,242.7 ft).

The figure below illustrates the cross section of a HVAC and HVDC power cable. The HVAC power cable has a three-core conductor while the HVDC cable is a single core. HVDC cables can only transmit power in one direction so require two cables for bi-directional power transmission. Oftentimes fiber is included in an undersea power cable design. For an HVDC cable the fiber is typically a separate fiber optic cable that is bundled or lashed to the power cable. For HVAC cables, the fiber is integrated in the cable using a tube or fiber optic unit.

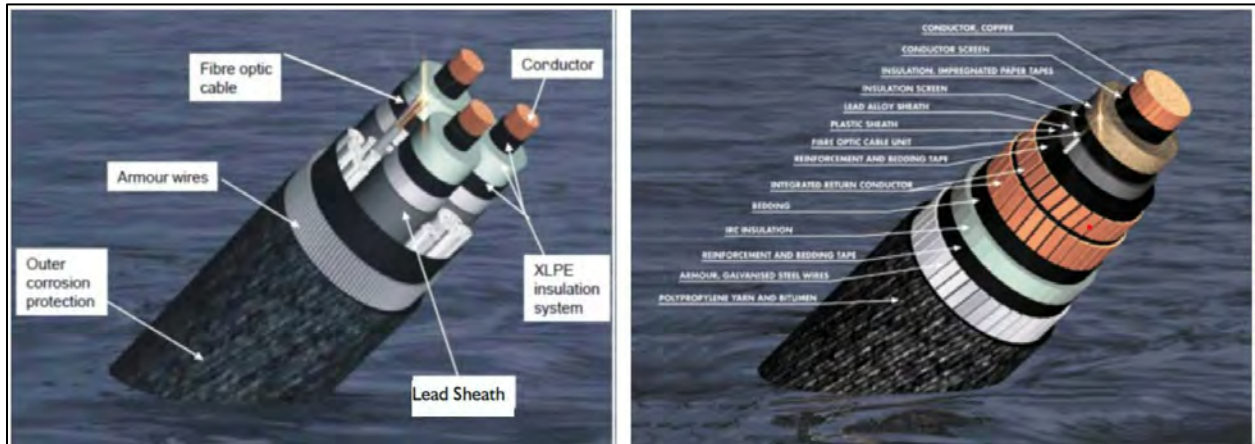


Figure 7: 3 Phase HVAC Power Cable (Left) and Co-Axial HVDC Power Cable (Right) (Source: ESCA)

The physical placement, installation and landing site construction of undersea power cables is very similar to that of undersea fiber optic cables. The armor types protecting the cable are determined by the water depths the cable will be installed in, as well as the seabed environment and risks of external aggression, among other factors. Similar to fiber optic cables, cable armoring also protects against the risk of abrasion from rough or rocky surfaces where the cable is not buried and is instead installed directly on the surface of the seabed. However, burial of these cables is a standard method of cable protection against threats of external aggression, the largest threats being bottom contact fishing and vessel anchoring (same threats as for fiber optic cables). A standard starting point for cable burial is 1 m (3.3 ft) below the surface of the seabed. At the shore-end, direct buried cables, use of conduit, or HDD are all methods used to install and protect an undersea power cable as it comes to shore to a beach or transition vault where the undersea power cable is anchored and jointed to land cable for onward terrestrial transmission.

A main driver for where undersea power cables come to shore is where existing power utility infrastructure is located to support the loads from the power cable and the ability to transfer to loads to other locations or within a local power grid. In the case of offshore renewable energy sites, the routing of the undersea power cable and the location it comes to shore may be more specifically driven by the location of the offshore energy site and new land-based power infrastructure may be required.

3.4 Permitting Overview

Undersea cables span a range of permitting jurisdictions, regulations and legislation. The figure below illustrates the complex permitting environment in which undersea cables cross.

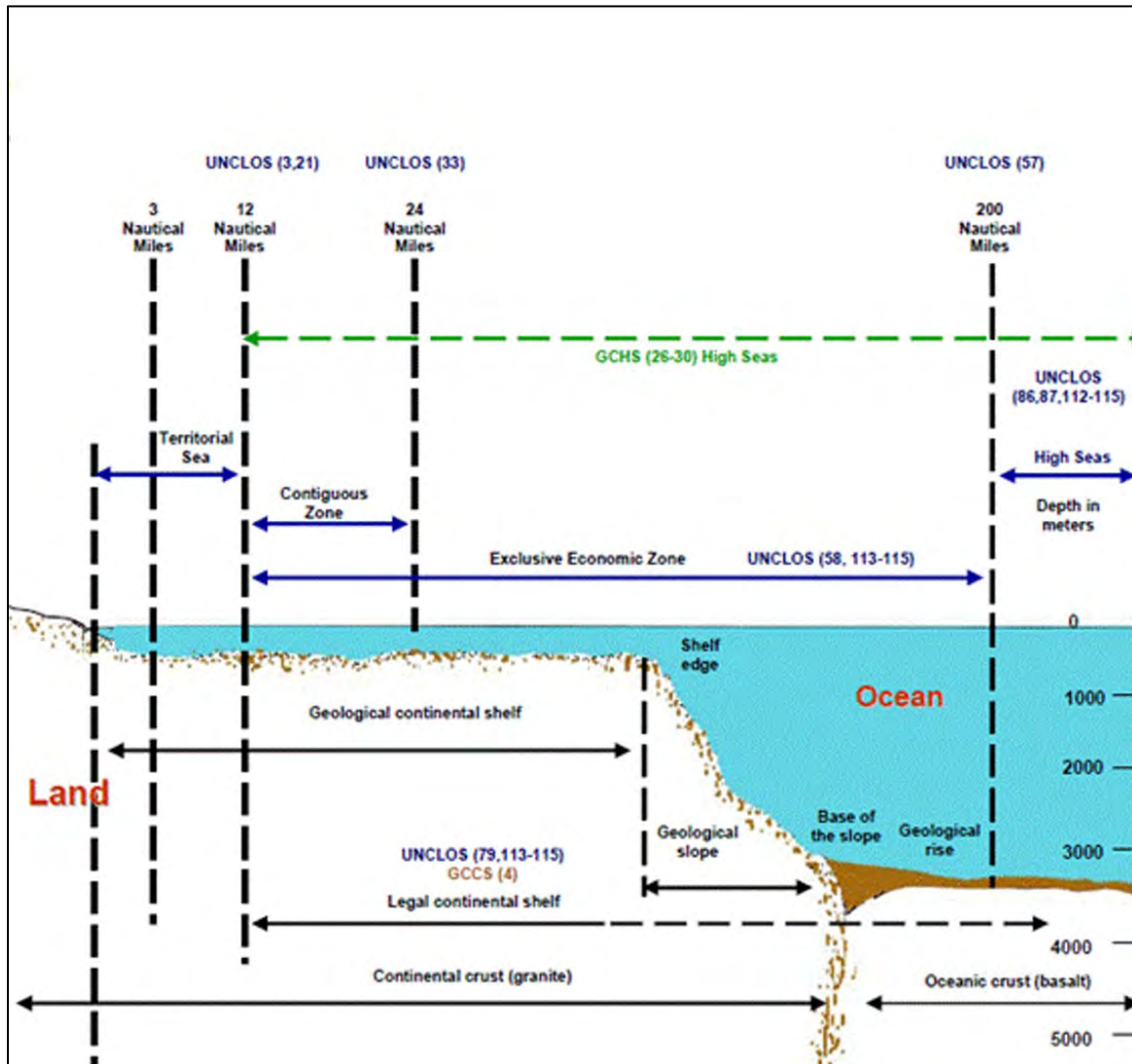


Figure 8: Summary of Relevant Legislation Regarding Use of the Seabed (Source: Squire, Sanders & Dempsey LLC)

From land a cable typically crosses a local city or municipality's jurisdiction as well as any ownership over the first three nautical miles offshore. In the US, the 3 nm limit seaward from shore corresponds to a state's jurisdiction or state waters. Within a state's permitting framework, there is often a permitting component that covers water quality, seabed disturbance, coastal zone management, and environmental assessment, among others. State waters are also part of the larger territorial sea which extends 12 nm from a coastal state's shoreline. Extending from the territorial sea is the contiguous zone (24 nm) and the exclusive economic zone (200 nm) as depicted in the figure above. The federal government, in particular the USACE in the US, governs the territorial sea and has oversight through the extent of the exclusive economic zone which are considered federal waters. Other federal agencies are also stakeholders in the territorial sea including NOAA, NMFS, etc.

The United Nations Convention on the Law and the Sea (UNCLOS) recognizes undersea cables as "common good that [is] the foundation of the increasing globalization and

interconnectedness of the world” (Davenport, 2012). Article 21 of UNCLOS grants a coastal state the freedom to adopt laws and regulations with respect to the protection of cables and other associated activities in its territorial sea, but UNCLOS protects the ability to lay and maintain undersea cables on the high seas without restriction which is also extended to a coastal state’s exclusive economic zone under Article 58. Furthermore, Article 79 extends this freedom to laying cables on the continental shelf. UNCLOS states that in the case of laying or repairing cables, all states should provide due regard to cables already in position and the possibilities of repairing existing cables shall not be prejudiced. It is viewed that unlike any other kind of seabed infrastructure, undersea cables and specifically fiber optic cables, are essentially benign infrastructure that promote the heritage and benefit of mankind by connecting us all together throughout the world (Wopschall, 2017).

In practice, however, not every coastal state is a signatory to UNCLOS (the United States included) and the United Nations does not provide any regulatory or judicial oversight of the provisions of UNCLOS. As a result, some coastal states have not extended the freedoms of laying cables in the exclusive economic zone and instead tried to implement permitting and fee requirements. These are the types of regulatory issues that organizations like the ICPC try to mitigate through direct engagement with government agencies. In addition, sometimes maritime boundary disputes, such as in the South China Sea, can also impact the regulatory and permitting landscape in a region where cables cross disputed zones.

In the application of undersea fiber optic cables, it is typical that large cable systems will cross the high seas, exclusive economic zones, territorial seas, and 3 nm limit, perhaps with multiple coastal states, due to the placement and design of this type of communications infrastructure. As a result, a project will have to apply for permits with federal, state and local level governments. Undersea power cables, which are typically regional systems and of shorter distances, may only exist in the territorial sea of one or more countries, but this will also trigger federal, state, and local government permitting requirements. As a result of these conditions, it is important to assess permitting requirements and feasibility as early as possible in a project’s lifecycle and doing so in coordination with all permitting stakeholders can be very beneficial to both the project team but also the inter-agency coordination that may be required to review and assess and project.

4.0 Offshore Route Selection

One of the early and upfront project planning activities for a new undersea cable, whether it be a fiber optic cable or a power cable, is determining where the cable should be routed along the seabed to points on a coastline. This is usually approached by conducting a desktop study (DTS) which researches all man-made, oceanographic, geologic, environmental, and technical elements of the project’s feasibility and includes the upfront effort to design the cable route(s) and select the landing(s) sites for further investigation. Once the route(s) and landing(s) have been designed and selected, these will form the pre-survey design which will form the basis of conducting visits to each landing sight and a marine route survey (MRS) over the designed route alignments.

In order to accurately define the final cable route for installation and define the adequate cable protection methods including cable types, burial, and external protection, a marine route survey is conducted to map the seabed and sub-surface conditions. This is done by utilizing a variety of acoustic survey equipment from a survey vessel which defines the seabed's bathymetry (topography of the seabed), seabed surface features and sediment types, sub-surface sediment types and structures (to assess cable burial), as well as the presence of other infrastructure or seabed obstructions.

It is best practice to perform a marine route survey over the entirety of a cable route from the landing site (land survey) and throughout the entire marine environment. The ICPC publishes Recommendations for the minimum standards in performing a DTS and MRS.

This section will discuss the factors that drive offshore route selection along the seabed while Section 5.0 will discuss the selection of onshore landing sites. Offshore route selection and landings sites, however, are not mutually exclusive activities. The selection of offshore routing can be driven by onshore landing site selection, and landing site selection can be driven by offshore routing.

4.1 Spatial Planning

When evaluating an undersea cable route, the use of a geographic information system (GIS) software is typically used to collect and assess electronic data pertinent to evaluating and designing a cable route. Software programs such as ArcGIS or QGIS are used, among other platforms. GIS software allows accurate spatial planning for all the factors that influence a cable route. These include offshore hazards and obstructions that are charted on nautical charts, the location of charted areas such as dumping grounds, unexploded ordinance sites (UXO), restricted areas, firing ranges, and vessel anchorages, the location of marine protected areas (MPAs), vessel traffic patterns and the location of traffic separation schemes (TSS) or vessel traffic lanes, the location of fishing activity particularly bottom contact fishing, and the location of existing and planned offshore infrastructure such as other cables, pipelines, offshore renewable energy sites, oil and gas infrastructure, etc.

A standard approach when designing a cable route is to avoid many of the features listed above, where possible. But sometimes it is not possible to avoid everything that exists in the offshore environment.

Due to the complexity of the offshore landscape, undersea cables do cross over existing infrastructure, cross through charted areas or marine protected areas, and through fishing grounds. Usually there are well established mechanisms to handle these types of crossings, which are discussed below.

4.1.1 Charted Hazards and Obstruction

One of the first tasks in designing a cable route is to assess nautical charts for charted hazards and obstructions. These could be outcropping rocks in shallow water, wrecks (sunken vessels or planes), buoys, piers, or any other object on the seabed or at the surface that would impact the feasibility of installing and protecting an undersea cable. Such obstructions would not only put a cable at risk but would adversely impact the vessel operations required to survey, install and maintain an undersea cable. Nautical chart information is typically sourced in the public

domain, or purchased, from relevant hydrographic offices (HO). As an example, in the United States that would be the National Oceanographic and Atmospheric Administration (NOAA), in Canada it would be the Canadian Hydrographic Service (CHS), and in the United Kingdom it would be the United Kingdom Hydrographic Office (UKHO). Sometimes countries do not have a well-established HO, or it is located within the country's navy, making it difficult to obtain charted information which may not exist at all.

Charted information can be imported into a GIS software in various electronic formats, if available. Otherwise, charted information can also be imported by using raster nautical charts or electronic nautical charts. Not every country publishes electronic or raster data or charts for free so sometimes sourcing this information requires the purchase of data and/or charts.

4.1.2 Charted Areas

Similar to charted hazards and obstructions discussed above, nautical chart information also contains charted areas which can include dumping grounds, unexploded ordinance sites, restricted areas, firing ranges or military practice areas, port boundaries, pilot boarding areas, vessel anchoring sites, among others. Typically, it is standard practice to avoid areas that could pose risk to a cable once installed such as dumping grounds (active or inactive), UXO sites and vessel anchoring sites. Other areas can be routed through when designing a cable because they do not impact the protection of an installed cable, but an area may influence vessel operations during a marine route survey or installation, requiring close coordination with the other marine activities that occur in that charted area. These areas can include military practice areas, pilot boarding areas, port and harbor boundaries, etc.

4.1.3 Marine Protected Areas

It is generally best practice for a cable to avoid marine protected areas or other environmental protected areas, where possible. Having said that, some MPAs have a permitting mechanism to allow cables to cross the area. This will be dependent on the jurisdiction and the agency that manages these protected areas. Whether a cable can be permitted through an MPA or not, the purpose of avoiding these areas is generally to avoid the complexity of adding another permitting requirement to a cable project and it is not because the installation of cables necessarily have an adverse environmental impact.

4.1.4 Vessel Traffic

Many existing cables traverse vessel traffic lanes or traffic separation schemes. This is because vessel traffic is often located along coastlines where cables come into shore. When evaluating a new cable route, it is standard practice to look at vessel density maps to understand the flow of vessel traffic, the density or quantity of traffic over the period of a year or more, and to assess what kind of vessels transit an area and whether any vessels are anchoring in a particular area. If there is a lot of vessel traffic around a new landing, or a nearby vessel anchoring area, it is common to assess whether vessels have a historic tendency to anchor over where a cable is being planned. It is prudent to avoid areas where vessels are anchoring.

When crossing a vessel lane or a density of vessel traffic, it is best to cross the traffic perpendicular to avoid increased exposure to vessel related risks such as anchoring. It is generally not recommended to route a cable parallel and within a vessel traffic lane, though

sometimes this is unavoidable for certain distances depending on a cable's routing and other constraints impacting its placement.

4.1.5 Fishing Activity

Assessing fishing activity is more of an exercise in stakeholder engagement when planning a new undersea cable route. At the early planning stages, certain resources can be used to assess fishing activity at a high level such as Global Fishing Watch [globalfishingwatch.org]. The predominant form of fishing that poses a threat to an undersea cable is bottom contact fishing such as trawling. Sometimes pot fishing can also pose a risk due to gear snagging a cable.

When planning a new cable, best practice protection measures are implemented on the basis that fishing will likely occur somewhere along the route in water depths generally less than 1,000 m (3,280.8 ft) and as a result, most all cables are planned to be armored and buried into the seabed sediment as the best and most standard forms of cable protection. Where fishing activity is occurring or is projected to occur in deeper depths over the twenty-five (25) year design life of a cable, burial can extent to depths in the range of 1,500 – 2,000 m (4,921.3 – 6,561.7 ft). Cable burial of 1 m (3.3 ft) below the surface of the seabed is generally deeper than trawling gear can penetrate; however, when determining depth of burial, it is usually assessed based on the specific gear used in that area. In some areas around the world, burial to 1.5 – 2 m (4.9 – 6.6 ft) is common. Achievable burial is also determined based on the burial tool being used. Most modern plows deployed from dedicated cable installation vessels can achieve 2 – 3 m (6.6 – 9.8 ft) burial.

Depth of burial is a direct result of the specific risk of damage to a cable and the consequence of that risk. On this basis, evaluating burial of a cable is different than evaluating burial of a pipeline - pipelines often being buried deeper than cables because the consequence and complexity of repair is greater.

In some areas, such as in parts of Alaska, a moratorium on bottom contact fishing exists and vessel traffic is very limited. As a result, the direct threat of external aggression towards a cable is far less than is typical in most places around the world. Therefore, cables confined to smaller regions in Alaska, or elsewhere where these conditions exist, can be surface laid directly on the seabed. These cables will typically be armored in shallow water depths less than 1,000 m (3,280.8 ft) to provide some form of protection.

Even though cables are buried to protect against fishing activity, it is best practice for cable owners to coordinate directly with fishermen operating in an area where the cable is installed. It is best practice to coordinate in such a way where bottom contact fishing does not occur over a cable even though it is buried. As a result, cables are charted on nautical charts and often cable owners form specific agreements with fishermen so that they avoid cables. If a cable is snagged by fishing gear, it is best practice for a fishing vessel to cut their gear rather than damage a cable. Inadvertent damage to a cable is grounds for a civil claim in most jurisdictions around the world. Obviously, this interaction between cables and fishermen can be impactful for both sides. As a result, in more established jurisdictions familiar with cables, fishermen form organizations that specifically work with cable owners. Within these organizations, there is sometimes a mechanism of payment from cable owners to fishermen to compensate them for

lost fishing ground, any lost or damaged gear, to ensure awareness of the presence of cables, and to incentivize fishermen to avoid installed cables. These types of cable/fishermen organizations are very well established in states like California and Oregon and elsewhere around the world. The level of coordination and any mechanism for financial compensation is very region/jurisdiction dependent though that does not diminish the importance for stakeholder engagement and liaison with fishermen during the planning, installation and operational phases of a cable project.

4.1.6 Offshore Infrastructure and Activities

When planning an undersea cable route offshore, it is prudent to consider existing and planned offshore infrastructure as well as other offshore activities that may or may not be charted on nautical charts. These can include undersea pipelines, other undersea fiber optic or power cables, offshore renewable energy sites, dredging sites, seabed mining sites, fish havens or aquaculture sites, artificial coral reefs, and sewer or wastewater outfall pipes, etc. These can also include seabed infrastructure owned or operated by defense agencies such as the Navy in the US.

In recent years, the most impactful form of offshore infrastructure affecting the design of undersea cables is offshore renewable energy sites, specifically wind farms. Wind farms take up relatively large areas of ocean and seabed and have been located in areas where cables are traditionally routed. For example, areas around the UK and in the North Sea, as well as the Atlantic and Pacific coasts of the US (though these regions are less developed than in Europe), among other locations, have required an increasing amount of coordination between cable owners and wind farm owners. At times there are not clear mechanisms for coordination such as cables being installed through wind farm areas, which can add complexity to the installation and maintenance of each type of infrastructure. During planning stages, it is best practice for cables to avoid wind farm areas, but sometimes this may not be achievable and coordination is required.

When it comes to other existing linear infrastructure such as pipelines and other cables, these are routinely crossed by new cables simply out of necessity. Crossing other linear infrastructure, particularly other in-service fiber optic cables, can be unavoidable.

For fiber optic cable-to-fiber optic cable crossings, it is an industry standard that these crossings are allowed between owners, and the other party is simply notified through a crossing notification process. The ICPC has a standard template for a crossing notification that is used to facilitate this process and the communication surrounding a crossing. In some instances, and still for a fiber optic cable-to-fiber optic cable crossing, parties will want the leeway to provide a no-objection to the crossing. Some parties will take it a step further and want a formal agreement in order to address liability and operations and maintenance concerns, though there is typically no legal framework to prevent crossing another fiber optic cable in a country's waters and definitely not in the high seas (international waters). Some jurisdictions will require evidence of an agreement (evidence that the two parties are working together) in order to obtain a seabed easement for the installation and operations of a cable system. An example of such jurisdiction is the State of Alaska. It is noted that this is not a requirement at the federal level through US waters. Regardless of this, it is the cable industry's stance that a simple notification

process is the best practice as a starting point. Anything beyond that is based on the discretion or requirements of each party or the local jurisdiction.

For fiber optic cable-to-power cable crossing (and vice versa) it can be standard to form an agreement that covers the liability of each party as well as how to maintain each cable and any potential impact to the other cable. The reason for this is that the repair of a power cable can be very costly, often estimated in the range of \$10 - \$100 million compared to the repair of a fiber optic cable which can be in the range of \$500,000 - \$3 million for a repair. In addition, other technical factors need to be considered for these types of crossings such as adding a layer of insulation over the fiber optic cable, mattressing, or other forms of protection at the crossing.

Fiber optic cable-to-pipeline crossings (and vice versa) also occur in areas of oil and gas activity. These can be more complicated to because oil and gas companies usually want a formal agreement to be in place and the potential liabilities associated with a pipeline are different than the other crossings described above. In a lot of cases, crossing an existing pipeline can be unavoidable in certain regions; however, it is generally good practice to avoid such crossings to the extent possible in order to mitigate the complexity of these agreements. If a pipeline is to be crossed, owners typically have very stringent requirements for forming a legally binding agreement.

The ICPC publishes in their Recommendations design criteria for cable crossings such as parallel proximity to cables, as well as recommended crossing angles to ensure that each cable can be maintained in the future without damaging the other cable. The ICPC also publishes an example pipeline crossing agreement for reference.

Crossing undisclosed seabed infrastructure owned or operated by defense agencies such as the Navy in the US can be much more challenging depending on the type, location and use of the infrastructure. In many cases, it is a best practice to consult directly with relevant defense agencies early on in the planning process to see if a planned undersea cable alignment and installation method conflicts with any existing defense infrastructure.

4.2 Bathymetry, Geology and Geomorphology

In addition to the factors discussed in the previous section, the effort to design an offshore cable route also includes the evaluation of seabed bathymetry, geology and geomorphology.

Bathymetry is the contour of the seabed, much like topography on land. Contours are assessed at the desktop study (DTS) stage of project planning based on nautical charts (contours and soundings) and publicly available electronic contour information published by hydrographic offices as well as organizations like GEBCO. This information and data can be imported into GIS for the purposes of designing an undersea cable route. The purpose in evaluating bathymetry is to avoid areas of steep slopes, undersea canyons, slumps and slides, and to target appropriate water depths for various aspects of the cable's design. As an example, a cable burial plow has a maximum slope angle that it can install a cable along. In addition, it is best practice to route cables perpendicular to a slope (parallel to the slope angle) because if that slope suffers a slump or slide the debris will flow parallel to the cable and not across it. Additionally, it is best

practice to avoid undersea canyons and other such features. Cable types are also preliminarily assessed based on the rugosity of the seabed as well as water depth.

Geology is also assessed first at the DTS stage of project planning. Sediment information is compiled, where available, from publicly available sources which characterize the seabed surface sediment types. If geotechnical core data is available for an area, sediment stratigraphy is also assessed at depth for areas where a cable may be buried. Characterizing the sediment in areas of planned burial is important in order to anticipate the feasibility of cable burial. Often this consists of evaluating areas of exposed bedrock, sub-cropping rock (shallow rock covered by thin sediment layers), sand, clay, mud, as well as areas of boulders which can pose risk to a cable and its installation operations. Assessment of the geology can reveal historic undersea landslide debris or other slump/slide events. In general, soft sandy sediments are preferred for cable burial. Firm sediments such as clay are less ideal as they can act as a hard layer that is not penetrable by a cable plow, therefore not allowing for adequate burial of a cable for its protection. Once in deep water beyond the depth of planned cable burial, seabed surface geology is typically not assessed, only bathymetry, as the cable will be surface laid and not buried.

Geology at a landing site is also assessed based on geologic maps, other data, and during site visits. Favorable geology depends on the construction methods that are to be used at a landing site, but generally avoiding bedrock environments (though HDD can drill through hard rock), surface and subsurface boulders, or very loose saturated soils is best.

Geomorphology refers to the physical features of the seabed and their related geologic structures. Geomorphology can be assessed from bathymetry and geologic data and information. An example of physical features that are to be avoided when designing a cable route include seamounts, undersea canyons, ridges, pockmarks, sand waves, or features indicating an environment of mobile sediment, among others.

Sometimes, unfavorable bathymetry, geology and geomorphology is hard or impossible to avoid. As an example, a trans-Pacific cable route can be 10,000 km or greater (6,213.7 miles) and passes through many various subsea conditions. The likelihood that the cable will transit unfavorable terrain is likely. As a result, cable armor is a standard way of protecting from unfavorable terrain.

Many of the route design criteria that are based on the evaluation of bathymetry, geology and geomorphology are published in ICPC's Recommendations.

4.2.1 Marine Route Survey

Once a cable route has been designed in the early project planning phases, that cable route (either power or fiber) is then surveyed during a marine route survey.

The purpose of a marine route survey is to map the seabed and characterize the subsurface of the seabed. These activities provide detailed information on the bathymetry, geology and geomorphology of the seabed in order to determine a final route for the cable that will ensure the feasibility of its protection, operations, and any future maintenance. Determining the final route also includes final engineering of cable types, cable lengths, cable bodies and other

technical parameters of the overall design. The marine route survey and final cable information will be handed over to the contracted cable supplier for manufacturing and the installer for installation planning and execution.

A marine route survey uses acoustic equipment to collect information from the seabed. This includes multibeam echo sounder (MBES) equipment which collects bathymetric data, side scan sonar (SSS) which collects seabed imagery which is interpreted by geologist and/or geophysicists for geology and sediment types and surface features or obstructions, as well as sub-bottom profiler (SBP) data which collects subsurface information to help assess burial feasibility. A magnetometer is also used to identify ferrous (metallic) objects on the seabed that can be obstructions for cable installation or pose risk to the cable, as well as to help identify crossing points of other metallic infrastructure. The portion of a marine route survey that utilizes acoustic equipment is also referred to as the geophysical survey.

A geotechnical survey is also carried out, usually from the same geophysical survey vessel. The geotechnical investigation includes collecting core samples and/or cone penetration tests (CPTs) which help geologists characterize the seabed surface and subsurface sediment, which aides in determining the feasibility of cable burial. The geotechnical data also helps “ground-truth” the geophysical interpretation of the side scan sonar data.

Marine route survey activities are usually conducted from a main vessel starting from 15 m (49.2 ft) water depth (safe operating limit of larger vessels) and extending to the full depth of a cable route. Beyond the limit of cable burial, only MBES is collected. Smaller vessels are utilized for surveying water depths shallower than 15 m (49.2 ft) and divers are utilized for survey operations through the surf zone. Land surveys are also carried out on land at each landing site using traditional land survey techniques.

The ICPC publishes a Recommendation on the minimum standards for a marine route survey to help provide guidance to the industry.

4.3 Trends in Siting Cables

The offshore cable route is largely driven by where the cable will land onshore. In many cases, the offshore route is a factor of the specific landing sites selected for a project. While the offshore route has to be feasible, the landings are often evaluated first based on a cable owner/developer’s larger network requirements. For undersea power cables, this may be strictly driven by where on land a cable can be integrated into the power grid or such new land-based infrastructure can be built. For undersea fiber optic cables, there has been a trend in the recent years for these cables to connect data centers in the various locations where cables come to shore in a country. One cable owner may have data centers in one location, which will drive where they want to land undersea cables, while another cable owner may want to route data traffic to another location where that particular company has data centers. This determination may be driven by the location company-owned data centers, third party data centers, or the location of customers. As a result, new undersea cables often have relatively strict requirements for where the cable should land in order to meet the larger objectives of that cable system.

One additional trend that has introduced variability in where cables land, particularly for fiber optic cables, is that companies are seeking route diversity, and therefore landing site diversity.

Large network operators develop what are called “mesh networks” which is a web of fiber routes both on land and offshore to ensure that if one fiber route is damaged, data traffic can be offloaded on other routes. This is a fundamental strategy in building and operating a resilient network. But as more cables are routed or come to shore in close proximity to one another, as is often the case when landing site infrastructure has been built out in a particular location, there develops a need to start to diversify digital infrastructure to support cable resilience. Major builders of undersea fiber optic cable systems have started over the last few years to plan for future, diverse landing sites. As an example, on the east coast of the US this can include landing cables in states where cables have not traditionally come to shore before. This diversity will then drive new offshore route alignments. In the case of the west coast of the US, as an example, this will include coastal cities where cables have never landed simply as a means to avoid congestion at other existing landing sites.

Perhaps not applicable in North America, but geopolitical factors also influence where companies build undersea cables. Staying out of certain country’s waters, as well as the need for network diversity in general, are trends driving undersea fiber optic cable routes in locations such as Asia and Southeast Asia, as well as the South Pacific, among other places.

A more detailed review of onshore landing site selection is presented in Section 5.0 of this report.

4.4 Risks

There are many risks to the offshore placement of undersea cables, both power and fiber. Many of these risks are similar between the two types of cables and are based on the physical and technical parameters of offshore routing. Some of these risks include the following:

- Too long of a cable route equating to increased cost
- Steep slopes where burial installation is not feasible or there is a risk of suspensions in the installed cable
- Hard bottom (rock) which poses a risk for cable abrasion and prevents cable burial where burial is required
- Inadequate route options to avoid charted areas, protected areas, or other features that will add project or permitting complexity
- Congestion of existing seabed infrastructure
- Fishing and vessel anchoring
- Lack of coordination or cooperation from other seabed users to deconflict spatial separation or crossing issues
- Multiple offshore jurisdictions (country’s waters) adding to increased project complexity
- Geopolitical issues

In the US, state and federal agencies get involved through the permitting process for new undersea cable projects, but they do not have scrutinizing oversight over the offshore route selection unless a cable route crosses an MPA or other similar area. Though factors that may impact project complexity are the presence or migration of marine mammals, impacts to protected species, or other such issues that may have associated operational requirements for vessel related operations. These are largely evaluated by NOAA and NMFS in the US.

4.5 Permitting Considerations

It is standard that undersea cable projects in the US are principally permitted activities and are categorically excluded under the National Environmental Policy Act (NEPA) and will receive a Nationwide Permit 57 (used to be 12) for the construction of an undersea cable. Due to the application of a Nationwide Permit 57, the USACE is typically the lead federal agency though other agencies like NOAA and NMFS will have jurisdiction over elements of the project concerning impacts to marine habitat and protected species in federal waters.

US states have jurisdiction over state waters where a seabed easement is usually the mechanism for granting space on the seabed for the installation of an undersea cable within the 3 nm limit. Each state has their own process to verify and grant a seabed easement, but generally states do not get involved in the precise placement of an offshore route unless there is a conflict with other seabed users/land owners or other existing easements or it is determined there is some environmental impact with the specific routing. Easements are usually first granted through an early entry authorization which allows the construction of the cable and then the final easement is determined based on the as-laid positions of the cable post-installation. Each state has their own fee structure for a seabed easement which may consist only of a one-time payment or can consist of a recurring annual payment. It is common that easements are granted for the operational life of the cable, but once the cable is decommissioned, removal of the cable is required. There is a growing trend towards the removal of cables at decommissioning, which is a requirement that already exists in many states like California, Oregon, Alaska, Rhode Island, etc.

4.5.1 Hard Bottom Habit

When siting an undersea cable along the seabed, it is best practice to identify and select as favorable of conditions as possible. But sometimes the constraints of routing a cable (i.e. the landing site location, the start and end point of a cable, etc.) result in that cable not being able to avoid all of the factors that have been discussed in this section. Additionally, the more congested an area is with other cables or offshore infrastructure, it can be more difficult to adhere to the best practices for cable siting.

As discussed in this section, it is a best practice to avoid areas of hard rock where seabed habitat can exist, and the marine route survey specifically characterizes the sediment (including rock) on the seabed so that appropriate routing decisions can be made. Hard bottom is not only a potential risk to a cable, but generally most jurisdictions want cables to avoid areas of sensitive habitat (which can exist on hard rock) to the greatest extent possible. However, as mentioned, sometimes it can be difficult to impossible to avoid all hard bottom areas.

Depending on how developed a jurisdiction's oversight is on cable routing, the crossing of hard bottom habitat is handled in a variety of ways. Some jurisdictions do not have requirements to avoid hard bottom areas, some jurisdictions manage these areas only if there is demonstrated habitat on the outcropping rock, some jurisdictions will not allow the crossing of hard bottom areas unless it is proven there is no alternative and the cable cannot be relocated elsewhere, and some jurisdictions will allow the crossing of these areas but require a monetary compensation as a result.

On the west coast of the US, there is a variety of ways each state handles this, but most notable is probably California where a cable developer pays the state (California Coastal Commission) a monetary compensation for the crossing of hard bottom where it cannot be avoided. Based on past projects this compensation funds the U.C. Davis Wildlife Health Center's California Lost Fishing Gear Recovery Project or other conservation programs. As of 2019, the amount of the hard bottom mitigation fee is calculated by applying a 3:1 mitigation ratio to the total square footage of impacted hard bottom and multiplying that square footage by a compensation rate of \$14.30 per square foot (RTI Infrastructure, Inc., 2019).

Where mitigation fees are collected for the use of a project or conservation program, it is important that a state incorporates a mechanism for accountability to that program to ensure the funds are used for a productive purpose that can be demonstrated to cable owners.

4.5.2 Cable Protection Corridors

Some countries such as Australia (off Sydney) have implemented cable protection corridors that are meant to protect undersea cables by prohibiting activities in the corridor that pose risk to a cable such as fishing, anchoring, and dredging. Discretionary cable protection zones offer protection should a developer choose to install a cable in the zone. Mandatory cable protection zones require that new undersea cables be installed in the zone. In the case of Australia, the protection zone is discretionary, but in the case of landings in New Zealand, the zone is mandatory.

States with cable protection zones enforce them with air and sea patrols and infringement penalties and where zones exist, cable owners tend to favor discretionary zones rather than mandatory zones. While cable protection corridors offer protection for cables, they also promote clustering and congestion of cables which adds to the difficulty of maintaining and repairing this infrastructure as well as adding to the risk that a single human or natural event could damage multiple cables.

At a global level, cable protection corridors are the exception rather than the norm and the cable industry prefers to maintain freedom in the selection of an offshore cable route.

If a state or country is to consider implementing cable protection corridors, it would be important for a regulator to understand from the cable industry what the main drivers are in their jurisdiction for cable placement and landing site selection, including the requirements for current and future diversity. Undersea cables are economic enablers that extend beyond just the cable itself. They also enhance terrestrial fiber/power routes and networks and data center development. Coordination and balance of offshore use and placement of cables relative to other regulatory initiatives, requirements and objectives is important.

5.0 Onshore Landing Site Selection

This report has discussed the interdependencies between the offshore route design of undersea cables, the selection of the landing site, and the terrestrial factors that drive the selection of a landing site. As mentioned in the previous section, it is often the terrestrial factors that first drive the selection of a landing site such as substation locations or grid connections for power cables or backhaul fiber availability and data center locations for fiber optic cables. The

landing site then dictates the required offshore route alignment for an undersea cable, which must be vetted against the topics listed in Section 4.0 of this report.

This section explores the factors that go into landing site selection. While this section is written mostly from the perspective of undersea fiber optic cables, much of the factors also pertain to undersea power cables and where differences exist, they are pointed out under each topic.

5.1 Landing Site

A landing site generally refers to the location where an undersea cable comes to shore where it then transitions to terrestrial cable infrastructure. Whether it be an undersea power cable or an undersea fiber optic cable, the cable must be installed across a beach to a point onshore where the cable is anchored within a buried utility vault that is accessible at-grade. This vault, commonly referred to as a beach manhole (BMH), beach vault or transition vault, is the location where a cable is usually spliced/jointed to a land cable that extends further inland to either a substation or power facility or a cable landing station (CLS), as is the case for fiber optic cables. While there can be exceptions to this, the BMH is the transition from wet plant to dry plant.

Landing sites are selected based on a cable systems overall design. In the case of a fiber optic cable, a landing site may be selected based on where data traffic would ultimately terminate, like at a data center. A landing site may be selected because a cable owner already has existing landing site infrastructure at a particular location or is leasing existing infrastructure from another owner. Or a landing site could be selected because it offers diversity away from a cable owner's other undersea infrastructure adding to the resilience of their overall network. Regardless of a company's specific requirements, the selection of a landing site goes beyond simply the design of the undersea cable and includes factors like available space and power at existing CLS sites, feasibility to construct a new CLS including availability of land and suitable commercial power from the grid, availability of backhaul fiber, locations of data centers or PoPs, as well as the overall permitting feasibility for construction in a city, county and state jurisdiction.

Today, the trend is to develop a landing site to accept multiple cables. There is tremendous demand for undersea fiber optic cables globally (broadband demand) so developing sites suitable for several cables is an approach being taken in California, Oregon, Alaska, and in states on the east coast, among other locations around the world. Additionally, landing sites for undersea power cables such as export cables from offshore renewable energy sites, are being contemplated and developed for multiple cables. There are synergies in developing one landing site that can serve multiple needs, so a natural aggregation of export power cables from multiple offshore sites is a trend that developers lean towards. As a result, it should not be surprising for any state agency to see plans to build out a landing for multiple cables planned to be constructed over time.

The following sections go into each of these factors that govern landing site selection, as they would be evaluated during an actual site selection process. The evaluation starts at a desktop study (DTS) phase of project planning, or perhaps earlier than that. Once a landing site has been identified, as well as alternative options, a project team will visit the site(s) to vet the technical feasibility in-person. At this time, it is also common to meet with local agencies to discuss permitting processes and overall acceptance of the project at a local level. This effort may

coincide with a broader permit feasibility study (PFS) in which the project team also engages state and federal agencies about the feasibility of the project.

5.2 Beach Manhole Placement

A BMH is one of the first physical pieces of infrastructure that is sited when evaluating an undersea cable landing location. In a way, it is the “anchor” for a landing site, and everything else is based around this location. The BMH needs to be close to shore to make the seaward construction feasible and positioned where a fronthaul route can extend inland. The BMH also needs to be outside of areas of coastal erosion and ideally sea level rise, though the BMH itself, as well as the cable(s) within it can stand to get wet.

Dimensions for BMH’s vary, but generally a rectangular concrete vault that is approximately 10 ft x 6.5 ft (3 m x 2m) is a standard starting point. The vault may have a rectangular or circular vault lid as an entry point. All BMH’s are buried with the surface at or just below grade. Once a BMH is installed, there is very rarely ever a need to go into the vault for maintenance. Most BMH’s utilized for undersea cables go completely unnoticed by most people and the general public would have no idea that an undersea cable comes to shore.

The figure below shows examples of a BMH lid at grade at the seaward terminus of a beach access road, as well as vault placement at the time of construction.

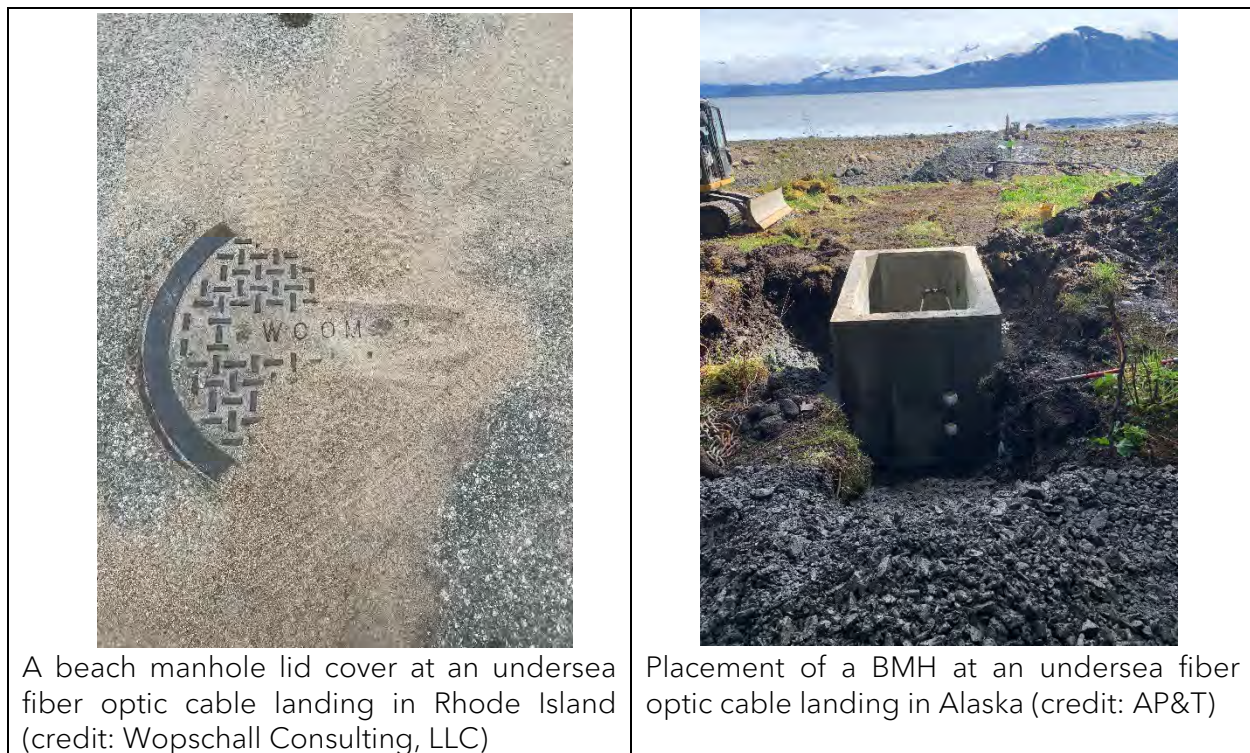


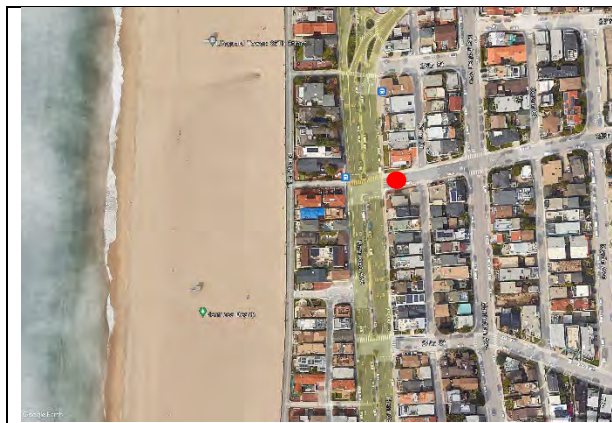
Figure 9: Undersea fiber optic cable beach manholes

Standard locations for BMH placement can be at the landward terminus of a beach, at the seaward terminus of a road, in a parking lot located on the coast such as a beach access parking lot or at a park, or sometimes BMH’s are placed in parks or on private property. An important factor in siting a BMH is assessing land ownership and the feasibility to obtain permits,

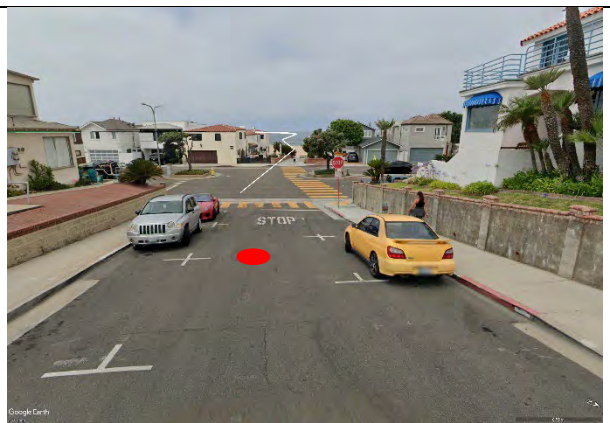
approvals, and easements for the project's construction. Because of the importance of siting a BMH location, it is best practice to engage landowners as early as possible in the planning processes of an undersea cable project.

Risks to BMH placement typically involve lack of engagement with local stakeholders, landowners and the public. Constructing a landing site and BMH is a temporary activity with infrastructure that will be completely buried and is very rarely needed to be maintained. Most landing site infrastructure including a BMH go "untouched" for years after installation. But failure to engage the public about the project, particularly where a BMH is to be placed in areas of public recreation, businesses or residential areas, can lead to complication and ill-will towards the project developer. Most local cities will want to see some form of public engagement before and during construction with project information posted including contact information.

The figure below shows some existing BMH locations in California and Oregon and illustrates the types of locations BMH's are typically placed.



Existing Hermosa Beach, CA BMH location (BMH in red)



Corresponding street level view of the BMH vault lid in Hermosa Beach, CA (BMH in red)



Existing Morro Bay, CA BMH locations at beach access parking lot



Corresponding street level view of two BMHs at Morro Bay, CA



Figure 10: Examples of Existing BMH Locations in California and Oregon

The above BMH locations are illustrated approximately based on publicly available information and highlight the variability of suitable sites that are standard for undersea cable construction. While these sites are for undersea fiber optic cables, much of the same evaluation criteria and types of locations are suitable and commonly selected for undersea power cables as well.

5.3 Fronthaul

For an undersea fiber optic cable, fronthaul is a term used to refer to the route from the BMH to a CLS. Oftentimes the route is merely dictated by the location of a BMH and a CLS, though it is important to assess how a fronthaul may be feasibly routed on land to connect these two locations.

A fronthaul route typically involves constructing buried conduit or ducts, each being approximately 4 - 6 inches in diameter (10.2 - 15.2 cm) depending on the application. Each conduit can then be sub-ducted for various purposes such as installing multiple cables within one duct. Ducts are usually made out of PVC. A buried fronthaul route is preferable compared to an aerial route on poles because it is better protected and less susceptible to damage from

natural or man-made events. Constructing a fronthaul is no different than most buried utility work common to see on city streets, and can include plowing, trenching, or directional drilling to install conduit. The exact method of construction is determined by the type of sediment and/or rock the route encounters, whether the route is within a paved area of a street or off on a shoulder or in green space, and whether any sensitive areas are encountered such as streams or rivers. Directionally boring for the installation of conduit under streams, wetlands, or rivers is the preferred method to mitigate impacts to these areas.

In most standard cable system designs for long-haul repeatered systems, a fronthaul route will run fiber, power, and a ground cable from the BMH to the CLS. As discussed in this report, there are variations to this design, but this is most common.

Fronthaul conduits are usually installed 36 - 48 inches (91.4 - 121.9 cm) deep and may be concrete capped to protect the conduits and their cables from external aggression such as land-based construction activities (i.e. a backhoe inadvertently digging into the fronthaul route).

In vetting a possible fronthaul route, it is best to meet with the local city or municipality to understand their permitting and easement requirements for accessing existing utility easements, constructing along new easements, as well as obtaining as-built information for existing utilities to deconflict planned routes and construction.

The same "fronthaul" terminology does not necessarily apply to undersea power cables; however, once an undersea power cable reaches a BMH, it can be a standard design to anchor the power cable in the vault and joint it to a land cable in order to run power transmission inland to a substation or other facility that will connect to the greater power grid. It is preferred that such a route be buried and constructed in a similar manner as described for an undersea fiber optic cable; however, the conduit sizes may be larger. Inland, terrestrial power can also be routed aurally from a BMH.

In some regions, and based on standard construction methods for existing utilities, it may be feasible to attach fronthaul cable(s) (power or fiber) to existing poles and run these cables aurally back to a CLS or substation. In this case, a fronthaul route may be buried from the BMH to the nearest existing or new riser pole and then will be attached along a pole line before reaching a final destination. However, in most cases it is not preferred to run cable aurally because it is more exposed and prone to damage from human activity and natural/environmental events.

5.4 Cable Landing Station

If an existing CLS is to be utilized for a new undersea fiber optic cable, or if an existing substation or power facility is to be used for an undersea power cable, this will drive the general location where a BMH should be located. In instances where a new facility will be constructed, cable owners may have an idea of what city or area they want to develop a new CLS or power facility based on broader factors like the availability of terrestrial fiber or connectivity to the power grid. But from a process perspective, many times a BMH will be selected first to ensure a feasible location to bring a cable to shore, and then a project team will evaluate where they can build a new facility. This section primarily discusses the case of an undersea fiber optic cable and the siting of a CLS.

A CLS is a telecommunications facility that is typically located no more than 10 km (6.2 miles) from a BMH. A CLS building can accommodate one or more undersea cable depending on its purpose and design. The CLS houses the equipment to operate and monitor the undersea fiber optic cable system including PFE (if powered), NMS, SLTE, among other equipment types. Transmission equipment such as DWDM equipment is also placed in the CLS for connection to backhaul fiber to bring data traffic further inland to data center or PoP destinations.

These facilities will also have ancillary equipment that helps support the facility including backup batteries, generators, fire detection and suppression equipment, temperature and humidity sensors, and security equipment. There may also be office space, conference rooms, and restrooms for staff working at the facility. A CLS property is often fenced with controlled entrance(s) and access. The building or its façade may have to adhere to local building requirements, among other local building requirements to account for seismicity or other natural factors.

A CLS property can be half to one acre in size, minimum, for older systems. For older systems, the building itself may be around 3,000 to 5,000 square feet (278.7 – 464.5 square meters). Generally, these would be minimum parameters for existing older systems though there is a lot of variability to this depending on how many cable systems go to a particular CLS, among other factors. Recent undersea fiber optic cable systems, as well as future systems, are now being developed with more fiber strands in the cable. There is also a trend to future-proof landings by ensuring it is feasible to bring multiple cables to one landing, built out over time. More cables and more fiber require larger facilities to house the equipment necessary for modern systems. With more equipment, the power draw at a CLS is more than it has been historically. For reference, a new CLS that is intended to serve two or three trans-oceanic undersea fiber optic cables may be on the order of 15,000 to 25,000 square feet (1,393.5 – 2,322.6 square meters) or more with a 2 – 4 MW power requirement. Older CLS' may only require less than 1 MW. These are only general figures to be used for reference.

CLS' are usually sited in light industrial zoned areas, but these facilities have been built in all types of zoning locations including also commercial and residential areas.

In some cases, depending on overall cable system design and distances to data centers, an undersea fiber optic cable may be spliced to a land cable in the BMH which extends all the way to a data center which will then serve the purpose of a CLS. In Oregon, this is done by some cables in the Pacific City vicinity with fiber running directly to data centers in Hillsboro. Another location in the world where this is typically occurring is in Singapore where the distance from a BMH to a data center is relatively short. This is also driven by demand for data center-to-data center connectivity. In these cases, and for powered/repeated undersea fiber optic cables, the PFE may be housed in a separate "PFE hut" close to the landing, which removes the need to run power the entire distance from the BMH to the data center. Overall, the design of running fiber to a data center is not a standard method and is project/location dependent, also based on the preferences and requirements of the cable owner.

5.4.1 Environmental Factors

When siting a CLS, many environmental factors are evaluated to determine a feasible location for these types of facilities. Undersea fiber optic cable systems and their cable landing stations are viewed as critical infrastructure. Fiber optic networks are measured by their up-time and any downtime due to damages to cables or failure of equipment can be impactful to a cable owner's business, the services they provide, and even to a region's connectivity including broadband service to homes and businesses. Many small or developing nations rely on undersea fiber optic cables to obtain international IP transit to bring internet service to its residents. As a result, ensuring protection of cables and protection of CLS facilities is critical.

To mitigate environmental risks that could pose a threat to a CLS and the equipment inside, CLS sites are assessed for flood zones, tsunami inundation zones, wetlands impacts, sea level rise, and landslides, among other factors. It is best practice to site a CLS outside of these risks. As a result, sites at a higher elevation above sea level are most suitable. The elevation doesn't need to be extreme and a CLS doesn't need to be on a hillside. Sometimes only a 5 - 10 m (16.4 - 32.8 ft) elevation above sea level is adequate to remain outside of these environmental risks.

5.5 Backhaul

Backhaul is a consideration mainly for undersea fiber optic cable systems and refers to fiber that connects from a CLS to a PoP or data center. This can also apply to any end point or interconnect point in a network where traffic carried on an undersea cable is routed to. Backhaul is important because it is the terrestrial fiber that carries undersea data traffic to its ultimate destination and beyond. If traffic simply terminated in a CLS, there is virtually nothing anyone can do with it. It has to extend further through a terrestrial network.

As a result, landing points and their corresponding CLS locations are selected in part by where terrestrial backhaul fiber is located or where it can be constructed. Often, however, backhaul routes are very long, easily exceeding 100 km (62 miles). Construction of new backhaul routes that terminate at an existing interconnect point for onward connectivity to a PoP or data center can be challenging and costly. As a result, preference is always to utilize existing fiber routes, where available.

In Oregon, as an example, undersea fiber optic cable traffic would typically be routed to a data center in Hillsboro or further east in Oregon, northward to a PoP like the Westin Building in Seattle, WA, southward to a data center in the Bay Area, or to a data center or PoP in Los Angeles. The desired destination is dependent on a cable owners' network, the type of traffic their system carries, and where their existing traffic and transmission equipment congregates, among other factors.

An additional consideration is the large amounts of capacity that undersea fiber optic cable systems are capable of. In order to carry traffic terrestrially, owners prefer to have access to backhaul fibers (dark fiber) that they can use in their entirety to handle the amounts of traffic being transmitted across a network. Sometimes backhaul routes have aging fiber or limited or no available dark fiber which can impact the design for an overall network. Further to this, cable system owners have varying degrees of backhaul requirements. For example, some backhaul routes are more susceptible to damage than others from natural or human events like landslides

or construction activities. As a result, having redundant backhaul routes may be desired for undersea cable systems to connect to. Having two separate backhaul routes can be difficult, especially through remote coastal areas.

There is not a single consolidated resource that maps out where terrestrial fiber routes are located. There are some public websites and paid services to get after this information, but often times backhaul routes are assessed through direct relationships with the companies that own and/or operate the terrestrial fiber. Sometimes fiber providers will provide maps or diagrams of their network, but there is generally a trend towards keeping this information, particularly for strategic infrastructure, confidential and not accessible in the public domain.

5.6 PoPs and Data Centers

Undersea fiber optic cable systems will transmit data traffic along a backhaul route that typically terminates at a PoP or data center. In the last ten years, there has been a trend to connect data centers globally and steer away from routing traffic to traditional PoPs or carrier hotels, though there is some variability to this depending on the requirements of an undersea cable developer, their network and the region where a cable system is to be constructed.

Just as other factors are interdependent and not mutually exclusive for the siting of cables and landings, the location of data centers or PoPs drive the requirements for the backhaul route, i.e. to connect the CLS to these locations. Furthermore, the requirements to go to a particular end location is driven by a company's network, their customers, where they house their network equipment, and other factors like maintaining network diversity as well as redundancy. Generally, however, a cable developer will know exactly where they want their undersea cable traffic to end terrestrially which will drive a lot of the other elements outlined in this report.

Additionally, data centers may be owned by the same company developing an undersea cable system, or that developer may lease space with one or more third party data center operators. As mentioned before, common locations for undersea cables to connect to along the west coast of the US include the Westin Building (carrier hotel) in Seattle, WA, data centers in Hillsboro or further east in Oregon, data centers in the San Francisco Bay area, and Los Angeles at the carrier hotel and data center(s) location at 1 Wilshire Blvd. As an example, it is estimated that one third of all internet traffic from the US to Asia passes through the building at 1 Wilshire Blvd in Los Angeles, representing a major interconnect point for IP transit and the reason so many trans-Pacific undersea fiber optic cables land in the Los Angeles area and elsewhere in California - they generally all go to 1 Wilshire (Fortune.com, accessed Sept. 2022)

5.7 Landing Site Construction Methods

Constructing a landing site first and foremost includes placing the BMH and installing an undersea cable across a beach to the BMH. While landing site construction also includes the fronthaul build, this section of the report is primarily focused on beach and BMH construction.

BMH's are typically precast concrete vaults that are placed on site using an excavator/backhoe to dig out, lift, place, and backfill the vault site so that the vault lid is at or slightly below grade.

There are two primary methods for installing an undersea cable across a beach or landing site to a BMH. One method is direct trenching where excavation equipment is used to dig a trench

across the beach to the BMH. The trench may be shored up in sandy conditions and is typically a minimum of 1 m (3.28 ft) deep below the surface of the beach but usually no more than 2 m (6.56 ft). The other method is utilizing horizontal directional drilling (HDD) to drill seaward from the BMH to install a seaward conduit to a point offshore in the ocean. Where the HDD conduit “daylights” or punches out in the ocean, an undersea cable is installed in this conduit and is pulled back to the BMH.

Conventional land-based trenching is generally the traditional method of landing site / beach construction and is still used around the world including in some US states like Alaska. This method is used for both undersea fiber optic cables and undersea power cables. While an undersea cable can be installed directly in the trench, it is also common that the cable is further protected using articulated pipe, or the cable is installed in a conduit that is placed in the trench. These methods add further protection to the cable beyond just burial of the cable. Excavation will typically occur during a low tide in order to extend the buried section of cable to the lowest point accessible by land-based equipment.

HDD construction directionally drills a borehole along a designed profile out to a point in the ocean. Typically, an HDD conduit is installed from the BMH seaward for a distance of 1 km (0.62 miles). This distance is dictated by the water depths offshore from a landing. It is advantageous to have the HDD conduit punchout from the seabed in a water depth around 10 m (32.8 ft). This water depth is accessible by divers to assist with installation of a cable into the HDD conduit and is close to the shallow water operating limit of a cable installation vessel. Depending on a target water depth for HDD punchout, the length of the HDD can change, but usually these bores are no longer than about 1.5 km which is near the distance limit of this construction method. HDD construction is the standard method of landing site construction in most US states and elsewhere in the world, though at a global level trench excavation is more common.

In order to adequately assess subsurface conditions and plan a profile for HDD construction, geotechnical/geophysical investigations are often required at or along the beach in order to characterize the sediment layers that are to be anticipated during drilling. Geotechnical investigations can include hollow stem auger boring at a BMH location and at points along the beach. Geophysical/remote sensing techniques can also be used from the BMH and along the beach. The goal of characterizing the subsurface conditions is to de-risk the construction/HDD boring.

There are benefits and challenges for each landing site construction method. The table below presents the benefits and challenges of each method, direct trenching and HDD.

Table 2: Landing Site Construction Methods – Benefits and Challenges

Landing Site Construction Method	Benefits	Challenges
Direct Trenching	• Cost-effective construction method • Construction equipment is common and easily accessible	• Limitation on achievable burial depth • Can impact environmentally sensitive areas (or add design

	• Low risk construction method from an environmental impact perspective	challenges to avoid such areas) • Diver burial is required through intertidal zone
HDD	• Drilling can reach deeper depths, offering better cable protection from external aggression, beach and shallow water erosion, etc. • Drilling reaches further offshore through the intertidal zone, providing better cable protection • Mitigates the risk of impacting environmentally sensitive areas on the beach and offshore • Can accommodate more challenging landing site conditions/terrain such as cliffs, variable geology, etc. • Avoids having to trench a beach	• Higher cost method of construction • Equipment/personnel may not be available in certain regions/countries • Risk of frac-out exists (release of drilling fluid due to excessive down-hole pressure or presence of a seepage pathway) • Temporary noise impacts to neighboring residents/businesses • Sites to be assessed for sediment/land stability during construction

Based on the above table, it is noted that frac-outs from HDD are relatively common and do not prevent drilling a successful directional bore. Having said that, characterization of the subsurface conditions that an HDD are anticipated to drill through is important in order to mitigate the risk of a frac-out. In the event of a frac-out, or in the event the HDD drill encounters conditions that it cannot pass through, the drill is typically backed out of those conditions and redrilled in a different alignment.

Different diameter HDD bores can be drilled for the installation of both undersea fiber optic cables and undersea power cables. An HDD conduit for an undersea fiber optic cable is usually about 4 inches (10.16 cm) in diameter. Conduits for power cables can be a minimum of 8 inches (20.3 cm) or more in diameter and is determined by the diameter of the power cable, which varies based on the transmission capacity of the cable.

5.8 Risks

Many of the risks or evaluation factors associated with landing site selection have been outlined in this section but generally include finding a site where land can be acquired or land use is permitted, sites are outside of environmental risk factors, sites are permittable, backhaul connectivity exists, and the public is in general acceptance of the project. These factors are evaluated as early as possible in the planning stages of a project in order to de-risk the project from a developer's perspective.

Permitting agencies are typically also concerned over the same risk factors with interest that undersea cable landing infrastructure is sited appropriately. For both cable developers and

permitting agencies, early discussion and coordination over a project ensures that these risks are looked out for, addressed, and mitigated to the greatest extent possible.

As mentioned in this section, there is a trend that new cable landings be assessed for multiple future cables. There is also a trend to re-use existing landing site infrastructure and cable landing station facilities where older cables are being decommissioned. As a result, where cables have landed before, there will always generally be a trend to try and land cables at the same locations except for where diversity is a larger governing factor in cable design.

5.9 Permitting Considerations

Based on experience, it has been found that inter-agency coordination regarding the overall permitting of an undersea cable from the offshore placement to the landing site can be very beneficial for a cable developer and permitting agencies. Joint agency pre-application meetings are a useful mechanism for this, though often the consultation approach with various local, county, state and federal agencies is siloed with lack of coordination. This can work in jurisdictions that have well established mechanisms to permit undersea cables, but generally the more coordination among all stakeholders the better.

In the process of evaluating permitting feasibility of a landing site, it is also useful to a cable developer to have local engagement with agencies regarding a public engagement approach for the project. There is a trend for the public to want to know about and understand everything going on in a local community and more often than not a local city or city council will have the best understanding of how local residents will accept a project.

From a permitting perspective, it is usually not permissible for a cable developer to construct multiple seaward bores whether by direct trenching or HDD to future-proof a cable landing. Constructing a seaward bore needs to have a purpose for a named project. However, considering the trend to develop landing sites for multiple cables, to reduce any risks or impacts (technical, environmental, social) of multiple iterations of landing site construction, it is worth considering how much landing site infrastructure can be permissible given an overall master buildout plan for a site. There is a trend in California to buildout multiple seaward bores at a landing location by naming generic cable projects that are to serve the trans-Pacific axis that will be built out over a several year period of time. It is generally accepted that if a seaward bore is built out for an undersea fiber optic cable system, it will be utilized. The risk that it sits vacant is very low given the demand for fiber optic cable systems globally.

Given the trend that new cables will also target existing landings based on the presence of existing landing site infrastructure and cable landing stations that could be available for use or re-use, it is worth noting that the permitting regime that may have existed 20 + years ago could be different than the permitting regime that exists today and concerns over the environment, coastal erosion, water quality and other factors tend to change over time. While this may be the case, a state or country should have interest in the sustainable re-use of existing infrastructure rather than abandoning these assets, where there is an acceptable and permissible way forward for new cables to come into existing landings.

6.0 Cable Installation

Undersea cables are installed by purpose-built or modified vessels that are capable of storing, handling, laying and burying undersea fiber optic cables and power cables. There are many dedicated cable vessels operating around the world. A list of most of the major cable installation vessels worldwide is provided on ICPC's website, for reference [<https://www.iscpc.org/information/cableships-of-the-world>].

Some of the world's largest cable vessels are purpose-built for fiber optic cables and can store approximately ten thousand (10,000) kilometers (6,213.7 miles) of cable and are used for the installation of the longest trans-oceanic fiber optic cable systems around the world.

For both undersea fiber optic cables and power cables, dedicated cable vessels are also supported by smaller vessels and barges for shallow water cable installations, among other marine resources that support installation activities.

Most dedicated cable vessels have burial tools which typically include a cable plow. For fiber optic cables, burial plows are built to bury cables to around 1 - 3 m (3.3 - 9.8 ft) depth below the surface of the seabed. Cables buried with a plow are simultaneously laid and buried at the same time with the plow being towed behind a vessel. Some vessels are also equipped with remotely operated vehicles (ROV) that can bury cables. An ROV is used as a post-lay burial tool which buries cables after a cable is laid on the surface of the seabed. Post-lay burial can occur in areas where a cable plow cannot safely operate such as for short sections of burial or near crossings of other infrastructure.

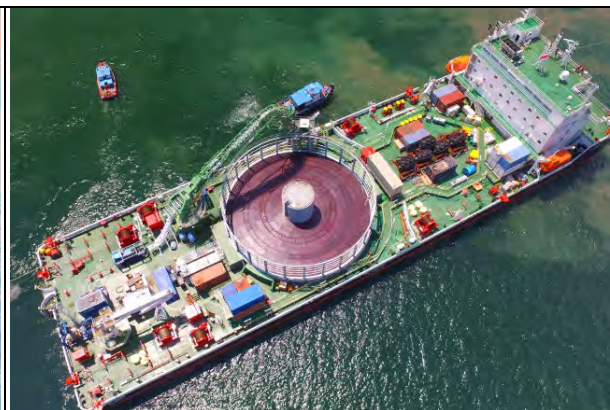
In shallower water applications, and depending on seabed sediment types, other plow burial tools are used such as jet- or vibra- plows that use water or vibration, respectively, to assist the plow through the sediment to bury the cable.

6.1 Vessels

The figures below show some indicative undersea cable installation vessels.



Dedicated fiber optic cable installation vessel
(source: submarinenetworks.com)



Modified power cable installation barge
(source: offshorewind.biz)



Dedicated fiber optic cable installation vessel
(source: iscpc.org/information/cables-hips-of-the-world)



Dedicated power cable installation vessel
(source: thenavalarch.com)

Figure 11: Examples of Undersea Cable Installation Vessels

Cable vessels can be purpose-built or modified vessels and/or barges.

6.2 Burial and Burial Tools

The figures below show some indicative undersea cable burial tools



Fiber optic cable plow (source: submarinenetworks.com)



Power cable plow (source: subsea-rov.com)

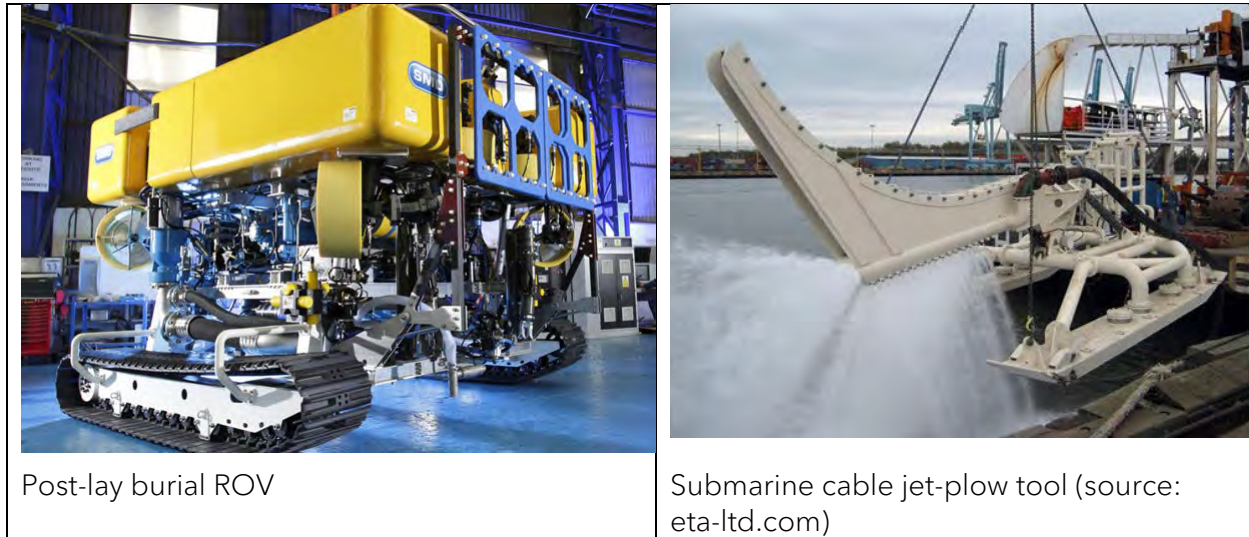


Figure 12: Examples of Undersea Cable Burial Tools

The methods and tools used for burying fiber optic cables and power cables are much the same, but are specifically constructed based on the diameter of the cable.

6.3 Permitting Considerations

Vessel-based installations and burial of cables are the most common and necessary means to install an undersea cable. From a permitting perspective, these activities are typically viewed as benign to the environment with only a temporary impact to the seabed over a relatively small footprint. It is also common that permitting agencies prefer cable infrastructure to be buried in order to mitigate the risks of other seabed infrastructure or activities impacting cables and vice versa.

For undersea cables, it is noted that the depth of cable burial and extent of cable burial is evaluated and dictated by the actual threats towards that cable. Consensus on the best practices for cable installation, burial and protection have been developed globally through decades of installing and maintaining cables. However, there is a general trend towards sector creep, primarily initiated by the offshore renewable energy industry which has adopted, in part, installation practices derived from the oil and gas industry. As a result, even in the US there is a trend that some permitting agencies or regulators are requiring cable installations to adhere to requirements that are more stringent or excessive than those necessary for undersea fiber optic cables and power cables. This could include requirements for deeper burial, as an example.

Sector creep is not just occurring in the US but is a very pertinent trend in Europe and in other parts of the world. As a result, cable developers and the industry at large do make attempts to educate regulators on these best practices and the reasons for them, as well as the concept that not all offshore infrastructure is the same. Educational outreach towards regulators can be a recurring activity due to turnover of agency staff.

7.0 Cable Protection, Maintenance & Repair

It's been presented in this report that undersea cables are critical infrastructure and, as a result, their protection is critical. Standard protection measures include cable burial beyond the threat of human and natural events, cable armoring, as well as stakeholder engagement and cable awareness. Cable protection drives the methods of installation.

It has also been presented in this report that cables, predominantly undersea fiber optic cables, are inadvertently damaged each year and this has occurred ever since cables were first installed on the seabed. As a result, the maintenance and repair of cables is very important to the overall operations of undersea cables.

For undersea fiber optic cables, owners organize under maintenance "zones" that divide up the world with dedicated maintenance vessels that are on call to repair fiber optic cables.

The figure below illustrates the various maintenance zones that provide maintenance coverage across the world for undersea fiber optic cables. This figure does not show private agreement for cable maintenance.

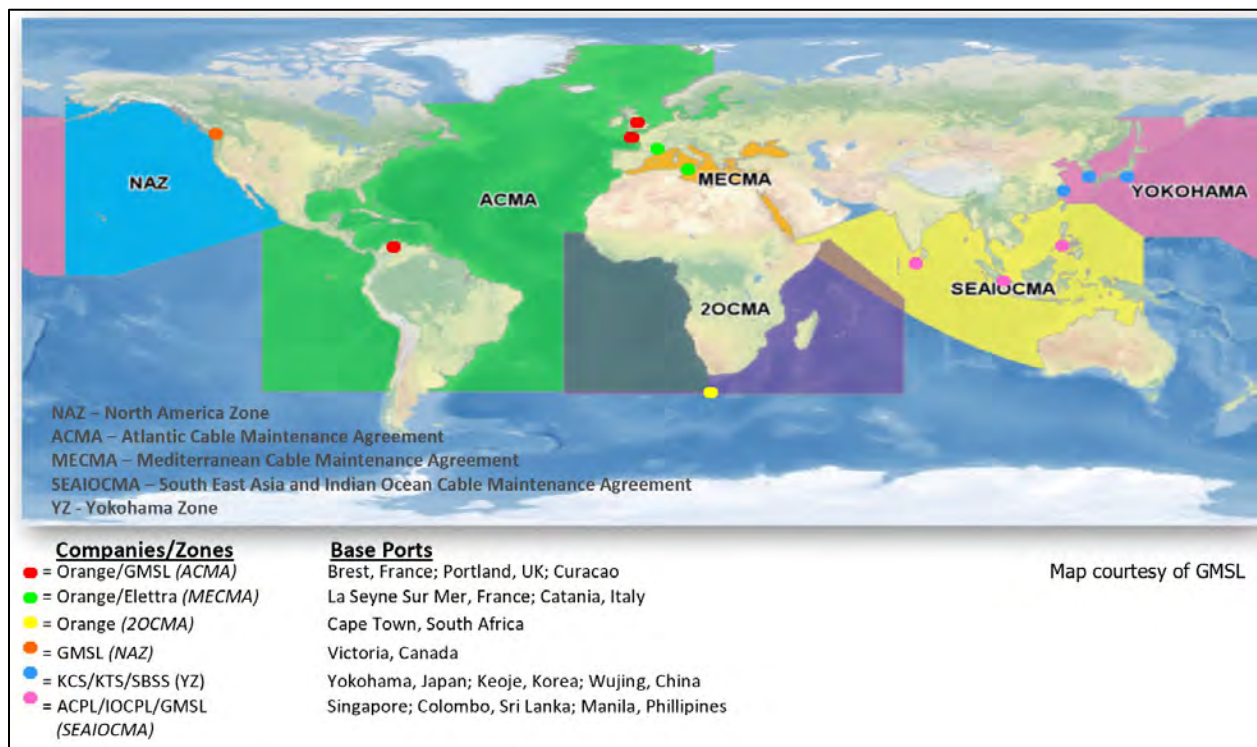


Figure 13: Undersea Fiber Optic Cable Maintenance Zones (source: ICPC)

When an undersea fiber optic cable is damaged, a standard method of maintenance involves a maintenance vessel sailing to the location of damage and using a grapnel hook to retrieve the cable and its damaged section. The damaged section of cable is cut out and a spare section of cable is spliced and jointed into the cable system before it is laid back down on the seabed. If the cable was originally buried, the repaired cable section can be post-lay buried with an ROV, if required. Once retrieved, an undersea fiber optic cable usually takes a few

days to repair. Due to the use of spare cable for this activity, undersea fiber optic cable owners store spare cable at strategic depot locations specifically for the repair of their system(s), if damaged.

The figure below shows an undersea fiber optic cable “universal quick joint” (UQJ) which is used to splice/joint an undersea fiber optic cable.

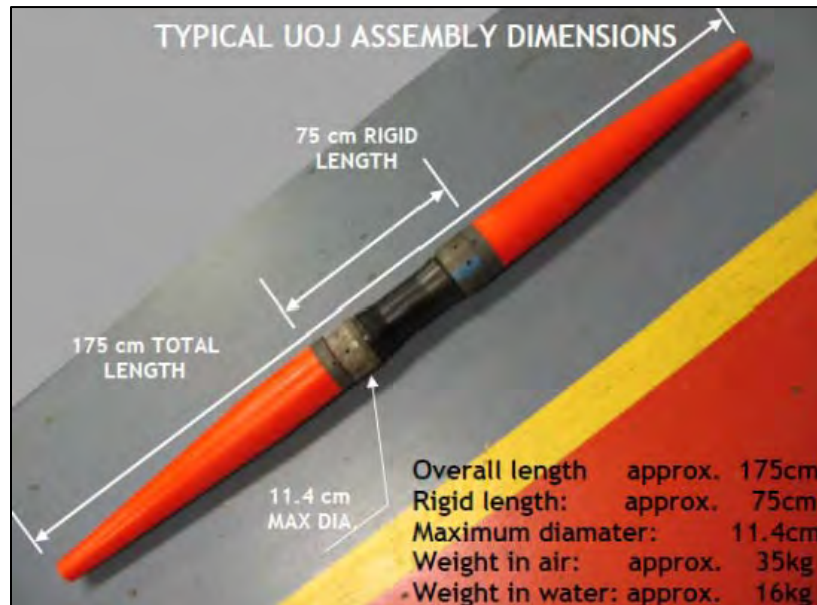


Figure 14: Undersea Fiber Optic Cable Universal Quick Joint (UQJ) (source: ujconsortium.com)

Maintenance of undersea power cables is different from undersea fiber optic cables for a variety of reasons. First, undersea power cables are typically regional systems due to their purpose and distance limitations for power transmission. As a result, there are not pre-arranged maintenance regimes serving the industry. Maintenance strategies are usually company dependent and based on spot-market resources at the time of cable damage. In some instances, power cable owners may have arranged agreements with third party companies in the event a cable has to be repaired.

Similar to undersea fiber optic cables, it is standard for an owner to store spare cable for use in a repair, but unlike fiber optic cables, repair joints are very large in dimension due to the size of power cables themselves and can take much longer to install over a damaged cable. Power cable joints can take one- to two- weeks to install over a damaged cable or longer and requires very specialized personnel that are not necessarily available in all parts of the world.

The cost to repair an undersea power cable can vary widely depending on the complexity of the repair and the time required. Generally, it is estimated that a repair can cost between \$10 - 100 million US dollars. Given this cost, a repair may not actually be as cost effective as it would be to replace the cable in its entirety, which is a strategy that has been implement in different part of the world including places on the west coast of the US like in Alaska. The cost for the repair of an undersea power cable is significantly higher than average estimates for the cost of repair for

a fiber optic cable system which can be between \$500,000 and \$3 million US dollars per repair. These are just estimates for indicative reference to the cost of each type or repair.

The figure below shows a typical power cable joint and its dimensions.



Figure 15: Undersea Power Cable Repair Joint (source: NKT)

Unlike undersea fiber optic cables which have a relatively global footprint and therefore maintenance resources have a global footprint as well, undersea power cables congregate where there are power transmission applications, which tend to be regional. Currently, these activities exist in areas such as in Europe, Asia, and to a growing extend in North America.

7.1 Permitting Considerations

Cable damage typically occurs in shallower water and as a result, these locations exist in a country's waters. Due to this, a maintenance vessel is required to obtain operational permits to go and repair a cable. Permitting lead times for vessels to repair cables in a coastal states waters can vary significantly from a few weeks to several months. Meanwhile, the cable can be out of service for that entire time which can have a tremendous impact on power or broadband deliver in a state or country.

Organizations like the ICPC have always advocated for shorter permitting timeframes for cable repair and, in fact, it should be viewed as being in a country's interest to have these infrastructure repaired as quickly as possible though rarely is cable maintenance a principally permitted activity, which would significantly lower the time-to-repair for vessels.

In the US, the west coast and east coast are relatively low fault (cable damage) zones, but due to the limited distance of state waters, most repairs occur either in the territorial sea or exclusive economic zone, making repair activities an activity under federal and not state jurisdiction.

8.0 Cable Decommissioning & Recovery

Undersea cables are usually decommissioned at the end of their useful or operational/design life. For example, undersea fiber optic cables are built for a twenty-five (25) year design life but may be operated for a shorter or longer duration. Undersea power cables are similar but with a

forty (40) year design life. Once decommissioned, undersea cables have typically remained in-situ. As a result, there are out-of-service cables, both fiber and power, on the seabed all over the world. In some cases, marine habitat has grown on undersea cables where those cables are laid directly on the seabed in only a matter of a few years after installation (Carter et al, 2009). In other cases where cables are buried, it has been viewed that the cable is best left buried rather than pull it up from the sediment.

Some jurisdictions require the removal of a decommissioned cable whether or not it is surface laid or buried and there is a current growing trend towards sustainability efforts where removal of decommissioned infrastructure is a sustainable activity in terms of the use of a country's waters (or the world's oceans for that matter). Oftentimes, however, removal of undersea cable infrastructure may only be required in a coastal state's waters (i.e. state and/or federal waters in the US). Once in the high seas or international waters, there is no governing body that dictates or requires cable removal.

In the last ten (10) years, commercial companies have been able to develop business plans that make it commercially viable to recover and recycle undersea cables due to the quantity of steel and copper contained in these cables. These efforts can be irrespective of any jurisdiction's requirements to recover a decommissioned cable and is more often than not conducted in international waters due to the ease of marine operations from a permitting perspective (no permits required) as opposed to recovery operations in a country's waters where permits would then be required. This type of recovery operation is conducted by companies who have purchased the rights to out-of-service cables. Typically, an entire cable won't be recovered in its entirety, but rather recovered in sections so as to avoid areas where the recovery operations could potentially damage nearby or overlapping (crossing) cable infrastructure.

In both scenarios, jurisdictional requirement or commercial activity, cables are retrieved from the seabed and usually removed by pulling the cable from a vessel. In shallow water areas, this activity may need to be assisted to some extent with divers or other support vessels.

In the US, the jurisdictional requirement to recover a decommissioned cable is a state-by-state decision/requirement. Recovery is required in California, Oregon and Alaska by virtue of the seabed easement granted to a cable owner. Cable recovery is also required by a handful of east coast states. Recovery is usually conducted not just in state waters but throughout federal waters as well. On the east coast, some state's that do not currently have undersea cable infrastructure coming to their shores may not have a recovery requirement simply for lack of precedent in dealing with such cases, but other state's have requirements to recover decommissioned cables. With the growth of offshore renewable energy, and the continued growth of the trans-Atlantic fiber optic cable market, state requirements are evolving through experience, again with a trend towards cable recovery.

8.1 Permitting Considerations

Cable recovery requires vessel operational permits in state and federal waters. While most recovery operations are benign to the environment, it is noted that there may be cases where a cable should not be recovered due to its potential impact on the environment in which it was installed. For example, cables installed over rocky or reef areas (as is the case around the world)

may get snagged during recovery operations and risk damage to the surrounding habitat when a cable is attempted to be pulled up to a vessel. As a result, it may be in the best interest of all stakeholders that cables be evaluated to remain in-situ in certain conditions.

Additionally, where cables have been recovered, it is pertinent both for cable developers and permitting agencies to assess if new cables can and should be encouraged to occupy the same seabed alignment or approach to a landing site. Where feasible, this helps with sustainable infrastructure construction and presents an opportunity for future cables to utilize seabed and existing infrastructure without creating further congestion issues offshore and on land.

9.0 Permitting Agency, Stakeholder, and Public Coordination

Unlike the technical, design, or construction and installation related methodologies for undersea cables which have established best or common practices, engagement with other marine users, permitting and other stakeholders, as well as the public is based on a softer set of skills and methods that can often vary between undersea cable projects and the companies involved in implementing them. While the process to obtain permits and approvals to install an undersea cable can be very well defined, the manner in which a team engages people and agencies through the planning, design and implementation phases of a project is typically not based on a set methodology or best practice. Depending on the management of this process, gaps in engagement can often surface which can lead to difficulties later on.

If there were a best practice related to engagement and coordination, it would be “engage early and engage often”. While this is typically used in reference to agency engagement for permitting purposes, this should also apply to other stakeholder and public engagement. We live in an era where everyone wants to know everything all the time and transparency is an expectation. If a person or group, whether it be a permitting agency, another marine user, a landowner, or a member of the public, learns of a new undersea cable project too late due to poor engagement, there can often be a negative affect due to the perception of being excluded or left out of the engagement process, whether the engagement was actually required to construct the project or not.

Despite the above, it is common for an undersea cable project to first vet the feasibility of a project at the permitting level. This is often done at the feasibility level stage without the full commitment that a company is going to build the cable system. During this stage, all permitting stakeholders are identified and approached to discuss the project and the permits or approvals involved. There can be a tendency to focus on state and federal agencies and permits, but it is equally important to engage local city and county agencies regarding the feasibility of a landing site design, as well as any other landowners whose land is crossed by the project.

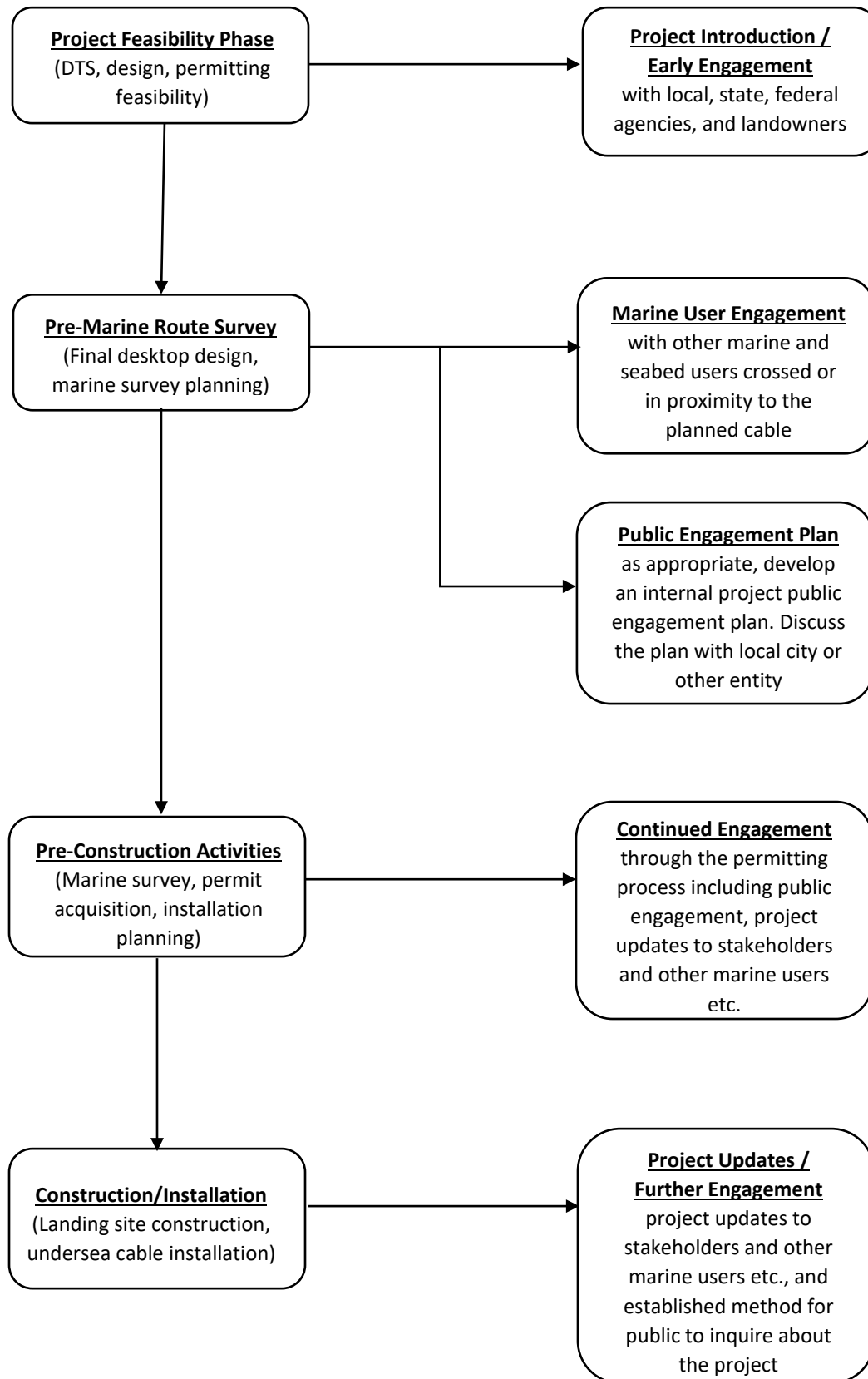
Word of a project can travel fast, and dialogue with one agency can spread by word of mouth to other agencies and landowners, making it difficult to manage the project narrative which can also impact how people receive information about a project. As a result, at an agency level it is always very useful to have joint agency meetings with local, state, and federal agencies where possible so that dialogue about the project can be coordinated with as many people present rather than having “siloeed” conversations separately with each agency or project stakeholder.

Once a company has decided to develop an undersea cable project, and typically after all feasibility level investigations and early engagements have been conducted, it is appropriate to approach other stakeholders. Other marine or seabed users, for example, should be approached in advance of the marine route survey phase of the project to notify others of any crossings, discuss proximity issues, and to promote awareness of the new undersea cable project. It is at this stage that a project developer should also consider if and how the public should be engaged regarding the project. Early dialogue with the local city where the planned cable landing site is located is important not just to assess what local permits may be required to construct terrestrially (i.e. BMH, fronthaul and CLS), but also what reaction the public may have to the project. Local agencies, officials and city councils are often very attuned to their community and how a project will be received and can often advise on how and when the public should be engaged to learn more about the project. These days, if the public is being engaged for the first time at a public hearing related to a permit application, that may be too late of an engagement depending on the particular location and community where the project is located.

An additional and nuanced layer related to public or community engagement is that undersea cables, particularly fiber optic cables, are no longer being developed by the nation's phone companies. When older cables were being brought to shore in the 90's and early 2000's, they were being developed by carriers, so it made sense that a telecommunications company would be building a fiber optic cable. Today, undersea fiber optic cables are being developed by content, cloud or internet companies. The connotation or perception from the general public will be different, and this is something that should be anticipated by a project team.

The flow chart presented below is a general concept for guiding the coordination discussed in this section. It is not meant to be prescriptive nor represent every activity or phase of an undersea cable project.

Figure 16: General Guidelines for Stakeholder Coordination and Communication



The above figure is not a one-size-fits-all concept or guideline. Every project is different including the level of interaction with other stakeholders, marine users, and the public. Some projects are in very remote settings and do not trigger an overlap with other groups or people. Some projects are constructed in developed coastal areas or neighborhoods. Any engagement or communications plan needs to be developed appropriately for the context of the project.

Additionally, it should be noted that at the time of construction when crews are on site placing a BMH or directionally drilling a seaward conduit, or when a large cable installation vessel is positioned offshore from a landing, these activities will draw interest and curiosity from people. These events don't occur every day. As a result, some jurisdictions require the project to post a method for the public or others to reach out and inquire about the project, whether it be a website, phone number or email address. Generally in developed areas where neighborhoods, businesses and coastal recreation exists, it is good practice that the public already is well aware of the project before they witness any on-site construction or presence of a cable installation vessel.

10.0 Critical Infrastructure

It is common practice for the undersea cable industry, both power and telecoms, to promote this infrastructure as critical infrastructure. Not unlike the importance of a bridge to a state's or country's citizens, digital and power infrastructure is a cornerstone of our society that helps facilitate our way of life and our economy. Damage to this infrastructure can have a serious impact, and as a result, the protection of this infrastructure is critical.

Whether or not a country designates undersea cables as critical national infrastructure or not, it is important to acknowledge that the global demand for bandwidth and sustainable power is increasing and will result in the development of more cables.

Best practices relating to undersea cables do not pertain solely to the technical, design and permitting elements of a project. Best practices also pertain to steps governments can take to manage and protect undersea cables. The ICPC has recently published a publicly available document titled "Government Best Practices for Protecting and Promoting Resilience of Submarine Telecommunications Cables" (ICPC, 2022). Though focused on undersea fiber optic cables, many of the same principles apply to undersea power cables.

The best practices document discusses the following topics listed below. This document should be reviewed by any government agency evaluating the management and protection of undersea cables in their jurisdiction as it provides a lot of guidance across multiple topic areas. This document has been provided as an attachment to this report.

- General Principles for Best Practices
- Fishing and Anchoring Risks
- Spatial Separation
- Charting
- Domestic Cable Protection Laws; Penalties for Damage
- Marine Spatial Planning and Inter-Industry Coordination
- Single Point of Contact

Undersea Cable Placement in the US and Abroad
A Best Practices Study

- Route and Landing Optimization; Geographic Diversity
- Permitting for Installation and Repair
- Cabotage and Crewing Restrictions
- Port Entry Requirements
- Customs Duties, Taxes, and Fees
- Maritime Boundary Claims and Disputes
- Critical Infrastructure Designation
- Sharing of Risk and Incident Data
- Impact of Other High-Seas Regulatory Activities

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12.0 Attachment A – ICPC Best Practices for Governments



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**GOVERNMENT BEST PRACTICES FOR PROTECTING AND PROMOTING
RESILIENCE OF SUBMARINE TELECOMMUNICATIONS CABLES**

With these Best Practices, the International Cable Protection Committee (“ICPC”) identifies recommended actions for governments to foster the development and protection of submarine telecommunications cables and to maintain continuity of communications even in the event of damage to a submarine cable. In implementing these Best Practices, a state should adapt them to address national and regional circumstances, including but not limited to: localized risks to submarine cables; localized activities of other marine industries; national laws, regulations, and governmental structures; and jurisdictional disputes with littoral states.

1. General principles

In adopting and implementing a submarine cable resilience plan, the state should be guided by the following principles:

- Focus on statistically-significant risks where government action could have the greatest impact on risk reduction;
- Promote commercial and regulatory environments that encourage multiple and diverse (both with domestic and foreign landings) submarine cable landings within the state’s territory;
- Observe and implement treaty obligations (particularly under the United Nations Convention on the Law of the Sea (“UNCLOS”)) and customary international law defining state jurisdiction over, and protection of, submarine cables;
- Promote transparent regulatory regimes that expedite cable deployment and repair according to well-established timeframes;
- Consult closely with industry to understand industry technology and operating parameters and to share data regarding risks;
- Complement existing industry best practices;
- Recognize that laws and government policies themselves can sometimes exacerbate risks of damage and reduce resilience; and
- Engage with other states on a global and regional basis, as other states’ actions can greatly affect an individual state’s own connectivity.

2. Fishing and anchoring risks

ICPC statistics indicate that each year, fishing and anchoring account for approximately 70 percent of global damage to submarine cables—far more than other human or natural causes. Commercial fishing-related damage is most often caused by bottom-tending fishing gear such as trawl nets and dredges, but it is also caused by long lines and fish aggregation devices anchored to the seabed and pot and trap fisheries using grapnels for gear retrieval. Anchor-related damage



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is most often caused by: improperly-stowed anchors, which release or fall overboard and can be dragged for great lengths along the sea floor, damaging cables along the anchor's path; anchoring outside of approved anchorages and near installed submarine cables; anchors dragged by properly-anchored vessels, depending on sea conditions; and dropping of anchors in marine emergencies. Mooring lines of fish aggregating devices ("FADs"), especially in deep-water can cause abrasion to submarine cables during installation, and FAD anchors have caused damage to deployed cables.

The submarine cable industry uses a variety of mitigation measures to limit damage from fishing and anchoring, including: route selection and design to avoid areas of particular risk (for example, routing around designated anchorages); cable armoring; cable burial (from 0.5 meters to 3 meters) for cable installed at water depths less than 1500 meters, where seabed conditions permit; cable awareness and liaison programs designed to educate fishing fleets regarding the location of submarine cables, and actions to take if gear is snagged; and programs to compensate fishermen for snagged gear (so that they abandon snagged gear rather than damage cables in trying to free it). Coordination with FAD owners and with governments to obtain FAD positions so cables can be routed around them, and/or measures to relocate or recover FADs in coordination with the owners have proven beneficial. These industry self-help measures can be effective, but they are insufficient absent additional actions to be taken by governments.

ICPC statistics confirm that state adoption and implementation of effective cable protection measures directed at fishing and anchoring risks can greatly reduce the risk of damage to submarine cables. As best practices, ICPC recommends that states therefore adopt and implement the following measures:

- Prohibit fishing in close proximity to submarine cables—including deployment of drift nets, gill nets, fish aggregation devices, and vessel anchors—consistent with default and minimum separation distances discussed in part 3 below;
- Require use of designated anchorages and establish and prosecute legal offenses for anchoring outside of designated anchorages;
- Promote the distribution and use of cable awareness charts (prepared by submarine cable operators) to fishermen;
- Promote direct engagement between submarine cable operators, including establishment of fishing-cable committees that can compensate fishermen for snagged and lost gear in exchange for not risking cable damage through gear retrieval efforts;
- Require use of automated identification systems ("AIS") and vessel monitoring systems ("VMS") on vessels at all times and establish and prosecute legal offenses where vessel operators turn off or disable AIS or VMS;
- Require that vessel operators carry appropriate insurance;
- Require use of AIS or VMS by even the smallest of vessels; and
- Direct the coast guard to issue local notices to mariners regarding submarine cable protection and to communicate with vessels operating or drifting near submarine cables.
- Limit deployment of FADs proximate to installed and planned submarine cables.



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- Establish a FAD registry, requiring FAD owners to identify and update FAD locations, and make such registry available to submarine cable operators during the route planning process for new cables.
- Require removal of ropes and ghost gear in the water column and consider removal requirements for end-of-life disposition of FADs.

3. Spatial separation

Spatial separation of submarine cables from other marine activities is one of the effective means of cable protection. It minimizes the risk of damage from other marine activities and ensures that submarine cable operators have ready and unfettered access to their cables for installation and maintenance needs and to minimize outage time in connection with a repair. The oceans, however, are increasingly crowded spaces where ideal spatial separation might not be possible, and where marine industries make compromises regarding proximity while seeking to reduce risk through closer coordination and communication.

A default separation distance establishes a minimum separation distance between an existing submarine cable and another marine or coastal activity in the absence of any mutual agreement to allow the activity in closer proximity to the submarine cable. By contrast, a minimum separation distance establishes an absolute minimum separation distance between the submarine cable and the other marine or coastal activity. Consistent with ICPC recommendations, many countries—as diverse as China, Denmark, Russia, Singapore, and the United Kingdom—have established default or minimum separation distances to protect submarine cables.

Some states have established cable protection zones and corridors that prohibit specified activities posing risks to submarine cables—including fishing, anchoring, and dredging—within fixed geographic areas. Discretionary cable protection zones grant protections to submarine cables that choose to locate in them or that may be declared around them, as in the case of Australia. Mandatory cable protection zones (or cable corridors) require submarine cable operators to route their infrastructure in defined geographic areas (as in the case of New Zealand). States with cable protection zones enforce them with air and sea patrols and infringement penalties. Submarine cable operators generally disfavor mandatory cable protection zones and corridors because they (1) provide insufficient spatial separation from other submarine cables for installation and maintenance and (2) encourage geographic clustering of submarine cable routes and landings, which magnifies the risk that a single natural or man-made event could damage multiple cables.

As best practices to promote spatial separation, ICPC recommends that states:

- Adopt and enforce the following recommended separation distances between cable ships and other vessels in the exclusive economic zone (“EEZ,” extending 200 nautical miles seaward from the shore) and the territorial sea (extending 12 nautical miles seaward from the shore):



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- In shallow water with a depth of 75 meters or less: 500 meters; and
 - In greater depths of water: the greater of 500 meters or two times the depth of water;
- Implement on nautical charts the text box specified in International Hydrographic Organization (“IHO”) Resolution 4/1967 (amended April 2017), as discussed in part 4 below;
- Ensure that any cable protection zones are adopted with consultation and support of cable operators;
- Demarcate cable protection zones using nautical charts rather than buoys, as nautical charts are more effective than buoys for navigation and do not create obstructions on the seafloor, in the water column, and on the ocean surface that can interfere with cable operations, fishing, and navigation; and
- Maintain flexibility with the number and size of cable protection zones.

4. Charting

Nautical charts (such as Admiralty charts) issued by government hydrographic offices consistent with IHO recommendations are graphical representations of ocean and adjacent coastal areas showing, among other things, water depths, seabed and coastline details, tidal information, and human-made features such as harbors, munitions dumps, offshore wind farms, and submarine cables. Nautical charts aid in navigation and alert users to the presence of other ocean activities. Nautical charts were previously issued periodically in paper form, but they are now generally maintained in electronic form and available on a computer screen or using a print-on-demand function.

Submarine cables are charted using data provided by operators and their contractors to hydrographic offices (such as the U.K. Hydrographic Office, the Indian Naval Hydrographic Office, the South African Navy Hydrographic Office, and the Hydrographic Department of the Maritime and Port Authority of Singapore). Historically, the IHO recommended charting only to a depth of 2,000 meters, in light of a focus on safety at sea. Some submarine cable operators still charted their cables at all depths. In 2018, however, the IHO revised its approach, due in part to a recognition that charting of submarine cables in areas proximate to deep seabed mining could reduce the risk of cable damage. The IHO and ICPC have established a pilot program to chart cables in areas proximate to contract areas of the International Seabed Authority.

As best practices for charting, ICPC recommends that states adopt and implement the following measures:

- Update nautical charts regularly and in near-real-time;
- Show all submarine cables on nautical charts, distinguishing between in-service and out-of-service cables;
- Show on nautical charts all other human activities that could pose risks to submarine cables, including but not limited to mining areas (including sand and gravel borrow



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- areas), renewable energy facilities, traffic separation schemes, munitions dumps, and military test areas;
- Ensure that national and regional charting authorities implement amended IHO Resolution 4/1967, which requires that charting authorities include a text box in publications such as mariners' handbooks and notices to mariners:
 - Directing vessels to avoid anchoring, fishing, mining, dredging, or engaging in underwater operations near cables at a minimum distance of 0.25-nautical mile on either side of a cable, and
 - Recognizing submarine cables as critical infrastructure, noting that damage to a submarine cable can constitute a national disaster.

5. Domestic cable protection laws; penalties for damage

The 1884 Convention on the Protection of Submarine Telegraph Cables requires state parties to establish offenses for cable damage. Article 113 of the UNCLOS provides that every state shall adopt the laws and regulations establishing a punishable offense under national law for the breaking or injury by a ship flying its flag or by a person subject to its jurisdiction of a submarine cable beneath the high seas done wilfully or through culpable negligence.

Countries such as Australia and New Zealand have implemented these treaty obligations by establishing substantial penalties—particularly with respect to their cable protection zones—that are more likely to deter those who might damage submarine cables. Other countries such as Sweden impose strict liability, requiring that if the owner of a cable or pipeline causes damage to another cable or pipeline, the owner shall pay the cost of repairing the damage. By contrast, countries such as the United States adopted penalties to implement their 1884 Convention obligations but have not updated the penalty amounts for more than 130 years. Finally, many other states have failed to adopt any measures to punish cable damage, even when their treaty obligations require them to do so.

To implement their treaty obligations, to compensate cable owners for damage, and to deter future damage, particularly by commercial fishermen and vessel anchors, ICPC recommends that states:

- Adopt and enforce effective cable protection laws, consistent with the 1884 Convention and UNCLOS;
- Adopt and update penalties to ensure they are substantial enough to deter damage; and
- Ensure that coast guards and law enforcement agencies are sufficiently familiar with cable protection laws to enforce them, and that they cooperate with and assist cable operators in investigating cable damage claims (including preservation and sharing of evidentiary material).



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6. Marine spatial planning and inter-industry coordination

Governmental bodies and other marine industries are often unfamiliar with the presence of, operational requirements for, vulnerabilities of, status as critical telecommunications infrastructure of, and statutory and treaty protections that apply to, submarine cables. In some cases, marine spatial planning activities omit submarine cables entirely. This lack of familiarity with, or neglect of, submarine cables can greatly impair their protection and resilience.

As best practices, ICPC recommends that states undertake the following to protect cables and de-conflict cable routes:

- Include and consult with submarine cable operators as stakeholders in such processes;
- Identify submarine cables in their mapping resources and tools (not just on nautical charts);
- Identify and include submarine cable operators as critical stakeholders in marine spatial planning and policymaking;
- Adopt regulatory frameworks for other marine activities, such as oil and gas development and renewable energy installations, to require coordination with submarine cables at the earliest stage of planning and development of those other projects; and
- Ensure that planning and leasing documents for oil, gas, and renewables specifically reference submarine cable protection and coordination.

7. Single point of contact

Submarine cable development, installation, operation, and repair implicates the regulatory and policy responsibilities of numerous government agencies, including those ministries, departments, and agencies responsible for telecommunications, maritime and shipping, environment, customs, and national security, to name a few. The dispersion of responsibilities for submarine cables can impair government action with respect to submarine cables and also make it difficult for other industries to coordinate with submarine cables. Singapore has addressed this issue by designating its telecoms regulator, the IMDA, as the point of contact for submarine cables, even if other government bodies have ultimate responsibility for a particular issue.

As a best practice, ICPC recommends that states:

- Establish a single point of contact for submarine cables—and not just for permitting purposes, but also for any issues arising with respect to installation, repair, and protection.

8. Route and landing optimization; geographic diversity

Submarine cable operators consider a variety of factors when choosing routes and landings, including:



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- Economic need (for connections between data centers and points of presence, and on highly-trafficked routes);
- Economic opportunity (in the case of wholesale capacity sales);
- Seafloor topography (seeking flat and uninteresting seabed that avoids geographic features with steep gradients, seamounts, vents, or fracture zones);
- Geographic diversity (to minimize the impact of a single event causing damage to multiple cables);
- Proximity to other marine activities and infrastructure (which pose risks of damage);
- Access to terrestrial networks (to ensure secure, diverse, and low-cost connectivity between submarine and terrestrial networks);
- Environmental restrictions (such as marine protected areas); and
- Regulatory considerations (including length and expense of permitting).

They design routes to follow the shortest viable route between landing points exhibiting the lowest risk to the installed cable. They start with a great circle route (the shortest distance between two points on a globe), which provides the lowest latency for communications transmissions (the time taken for data to pass from point A to point B) and then adjust for technical, economic, and regulatory factors.

Submarine cable operators and their capacity customers increasingly seek to maximize geographic diversity of submarine cable routes and landings in order to enhance network resilience and reduce the risk of damage from a single event, whether an earthquake, a tsunami, a vessel anchor, fishing gear, or a terrorist attack. Their options may be limited by other factors, such as slow and expensive permitting, coastal landowners, and marine protected areas. Moreover, they operate in dynamic coastal and marine environments that are increasingly crowded and that lack a single landowner or a single regulator. Other activities and infrastructure are frequently authorized without regard to the potential to foreclose particular areas to future submarine cable development, increasing the potential for clustering of cables and landings, and the risks inherent in non-diverse infrastructure.

As best practices, ICPC recommends that states undertake the following to promote resilience of submarine cable networks:

- Adopt and implement regulatory frameworks to optimize routes and landings, including geographic diversity of routes and landings;
- Recognize that diversity can be impaired by government shore-end permitting, marine protected areas, and marine spatial planning (or lack thereof) that results in clustering of cables, magnifying risk that a single incident will damage multiple cables and impair connectivity; and
- Recognize that submarine cables cannot be hidden or armored and buried to guard against all malicious and non-malicious sources of cable damage.



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9. Permitting for installation and repair

As noted in part 8 above, permitting can greatly affect route and landing location decisions for submarine cable operators. In many cases, coastal states apply a “one-size-fits-all” permitting regime that applies equally to polluting activities (such as oil and gas development) and environmentally-benign activities (like submarine cables), which can burden and delay the environmentally-benign activities.

Moreover, the permitting actions of one state can greatly affect the connectivity of other states. UNCLOS articles 2, 58, 79, and 87 authorizes a coastal state to impose conditions and consent requirements for submarine cables entering its territorial sea, but not beyond it in the EEZ or on the continental shelf. UNCLOS articles 2 and 51 also allow archipelagic states to impose conditions for new submarine cables entering archipelagic waters.

As best practices, ICPC recommends that states ensure that permit requirements for installation and repair:

- Are consistent with UNCLOS in the EEZ and archipelagic waters and on the continental shelf—excessive jurisdictional assertions by one’s neighbors can impair installation of new cables and repairs of existing ones;
- Reflect the best available science showing that submarine cables are neutral-to-benign in the marine environment;
- Are transparent;
- Establish clear timeframes that are as short as possible; and
- Promote diversity of routes and landings.

10. Cabotage and crewing restrictions

Cabotage is the transport of goods and passengers between domestic ports. For a variety of reasons, including protection of domestic industry and national security, a number of states have restricted cabotage to domestic vessels, with varying criteria including domestically-built, domestically-owned, domestically-flagged, and/or domestically-crewed vessels. Some states have expanded their cabotage restrictions to a broader range of economic activities in their territorial seas and EEZs, including submarine cable installation and repair. Application of cabotage laws to submarine cable installation and repair is inappropriate and undermines the resilience of submarine cable networks.

Cable ships are built specifically for cable-related operations and are crewed by highly trained and experienced merchant mariners, engineers, and cable operations staff. Most of the world’s countries with submarine cable landings and transits lack locally-flagged and locally-crewed cable ships. Instead, most of the world’s installation and repair services are provided by a few global and regional providers with the necessary expertise and economies of scale. Submarine cable operators often pool risks and resources to contract for cable ships in regional zone



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agreements. These zone arrangements cover vast multinational geographic areas, meaning that there are no discrete national maintenance markets.

Cabotage and crewing restrictions render installations and repairs more expensive and can result in performance and safety problems arising from the use of inappropriate vessels and inexperienced crew. They generally impair the operation and economies of scale of maintenance consortia. Cabotage and crewing restrictions can also greatly delay critical repairs, as a submarine cable operator must wait to qualify a foreign-flagged/crewed vessel through an exemption or waiver process. Cabotage and crewing restrictions can harm the connectivity of other neighboring countries.

Within the EEZ and on the continental shelf, cabotage and crewing restrictions are inconsistent with UNCLOS articles 79 and 87, which provide for the freedom to install, maintain, and repair submarine cables in those maritime zones. Within archipelagic waters, cabotage restrictions on repair of existing cables that merely transit the state are inconsistent with UNCLOS article 51. Although permissible within the territorial sea, cabotage and crewing restrictions are inadvisable.

As best practices, ICPC recommends that states:

- Refrain from defining submarine cable installation and repair as cabotage, as they do not involve the transport of goods or passengers between domestic ports;
- Refrain from applying cabotage or crewing restrictions on vessels engaged in installation or repair, whether in the territorial sea, archipelagic waters, or EEZ/continental shelf.

11. Port entry requirements

Based on installation or repair work within the territorial sea, archipelagic waters, or EEZ, some states require that a cable ship enter a domestic port for regulatory clearance purposes, even when crew members would not otherwise embark or disembark. Such requirements disrupt operations and delay installation and repair.

As best practices, ICPC recommends that states:

- Refrain from requiring port entry for cable ships conducting installations and repairs beyond the territorial sea; and
- For work within the territorial sea and archipelagic waters, establish annual pre-clearance procedures for cable ships and crews.

12. Customs duties, taxes, and fees

Some states view the entry of new submarine cables into their jurisdictions as an opportunity to extract revenue from the operator in the form of customs duties, taxes, and fees. Such charges increase the cost of capacity to users and in some cases can deter landings, thereby undermining



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government policies designed to foster new cable landings. Such charges can also serve as a source of disputes that delay installation and repair.

As noted in part 9 above, UNCLOS articles 2, 58, 79, and 87 authorizes a coastal state to impose conditions for submarine cables entering its territorial sea, but not beyond it. UNCLOS articles 2 and 51 also allow archipelagic states to impose conditions for new submarine cables entering archipelagic waters. Some states, however, have sought to impose customs duties, taxes, and fees for activities and infrastructure in the EEZ and on the continental shelf, in contravention of UNCLOS.

As best practices, ICPC recommends that states:

- Refrain from imposing customs duties, taxes, and fees on installation activities beyond the limits of the territorial sea, and on cable ships merely transiting an EEZ;
- Reduce or eliminate customs duties on submarine cable equipment imported into a state's territory, in order to foster submarine cable deployment and facilitate quick access to spare plant for repair; and
- Refrain from imposing importation requirements and customs duties on cable ships conducting installation or repair.

13. Maritime boundary claims and disputes

Competing maritime boundary claims and boundary disputes can impede installation and even foreclose certain routes. Such disputes can also greatly delay repairs due to duplicative and time-consuming permit requirements. In some cases, boundary disputes pose a danger to the cable ship and its crew due to the threat of military action.

As best practices, ICPC recommends that states:

- Facilitate installation and repair without prejudice to any maritime boundary claim; and
- Recognize that submarine cable operators seek to remain neutral in boundary disputes and seek to conduct their activities without prejudice to such disputes.

14. Critical infrastructure designation

Critical infrastructure is generally understood to include assets that are essential for the functioning of society and the economy, and damage or destruction of which would harm national and economic security, public health, and public safety. Governments use critical infrastructure designations to highlight asset criticality and to identify and mitigate vulnerabilities and threats through specific laws and policies.

As best practices, ICPC recommends that states:

- Designate submarine cables as critical infrastructure;
- Gather and assess data regarding vulnerabilities of, and threats to, submarine cables; and



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- Develop and implement policies to reduce those vulnerabilities and threats.

15. Sharing of risk and incident data

Sharing of risk and incident data between operators and governments and among operators is useful for identifying patterns of activity, gaps in existing cable protection efforts, areas for improving resilience, and identification of malicious acts by state and non-state actors.

As a best practice, ICPC recommends that states:

- Consistent with competition laws, establish mechanisms for exchanging incident data and threat information.

16. Impact of other high-seas regulatory activities

Regulatory activities of other states, bodies, and institutions far beyond a state's maritime boundaries can impair submarine cable installation, repair, and resilience. Such activities include uncoordinated deep seabed mining and environmental regulation on the high seas under the proposed treaty to conserve and promote sustainable use of biodiversity beyond national jurisdiction ("BBNJ").

Deep seabed mining poses risks of: damage to existing submarine cables, increasing the risk of a communications blackout for certain countries, and route foreclosure for new submarine cables, rendering them less resilient. Some mining contractors have argued either that cable owners proceed at their own risk or that mining contractors have a right to exclude submarine cables from their contract areas, which cover vast areas of the seabed. UNCLOS does not establish any specific coordination mechanisms, including instead only mutual "due regard" and "reasonable regard" obligations. The Exploration Regulations adopted by International Seabed Authority ("ISA") do not address submarine cables at all. Based on a joint proposal by the ICPC and France, with support from numerous other developing and developed states, the Draft Exploitation Regulations now contain provisions to ensure early coordination between mining and submarine cables, to protect existing submarine cables, and to permit future submarine cables. Although the ISA's jurisdiction, and the potential for mining, extends globally throughout the Area (the seabed and subsoil of the high seas), the greatest number of mining contract areas current exist in the Indian and Pacific Oceans.

The proposed BBNJ treaty to promote conservation and sustainable use of BBNJ could impair submarine cable protection and resilience. Specifically, the treaty could require environmental impact assessments ("EIAs") for cables in high seas areas, restrict cable transits and repairs in new marine protected areas on the high seas, and create a new international regulatory body to oversee such activities. Many of the proposals under consideration by the treaty conference would impose significant costs and delays on new builds and repairs and result in cable routes that are less efficient and resilient.



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As best practices, ICPC recommends that states:

- Seek to ensure that the ISA Exploitation Regulations protect existing submarine cables and avoid foreclosing routes for future cables;
- Support amendment of the ISA Exploration Regulations to protect existing submarine cables and avoid foreclosing routes for future cables; and
- Seek to ensure that the BBNJ treaty accounts for the socio economic importance of submarine cables, recognize the benign environmental impact of submarine cables and their co-existence in existing MPAs in areas of jurisdiction, and recognizes submarine cables as a sustainable use of the oceans.



Oregon

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October 16, 2023

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LCDC Chair Hallová and Members of the Commission:

On behalf of the Ocean Policy Advisory Council (OPAC), we transmit the Territorial Sea Plan (TSP) recommendations made during the September 8, 2023, meeting of the Council. Our recommendations are related to OPAC's work in completion of the amendments to TSP Part Four – Uses of the Seafloor.

Background: TSP Part Four – Uses of the Seafloor

Oregon's coast is a prime landing zone for fiber-optic telecommunication cables that cross the ocean floor from sites around the Pacific Rim. Other types of utilities such as ocean outfall pipes also make use of the seafloor. In the future, utilities such as pipelines and power transmission cables from renewable energy facilities, may eventually be routed across the seafloor of the state territorial sea. Proper placement of easements and installation of infrastructure is required to avoid damage to or conflict with other ocean uses and to avoid, minimize, and mitigate adverse effects on natural resources, marine habitats, and coastal communities.

LCDC originally adopted Part Four of the Territorial Sea Plan on December 1, 2000, based on a January 28, 2000, recommendation from OPAC. In May 2022, OPAC convened the TSP Part Four Workgroup, as mandated by 2021 House Bill 2603, to review and draft amendments to this chapter of the Plan. Over the course of 10 meetings, Workgroup members discussed the current regulatory framework, considered the needs of industries that might make use of the seafloor, and identified processes for addressing impacts to state resources and other ocean users. The Workgroup strove for and reached consensus on the draft amendments it forwarded on to OPAC.

OPAC Recommendations:

The Council deliberated and acted to recommend amendments to TSP Part Four based on recommendations from the Workgroup at their September 2023 meeting. The proposed amendments provide a strategic framework for the decision-making, partnerships, and collaborative process for permitting undersea infrastructure on, affixed to, or buried under the seafloor in the state territorial sea. The framework aims to maintain the long-term protection of marine ecosystems, preservation of their ecological functions, economic and social services, and, at the same time, protection of infrastructure on, affixed to, or buried under the seafloor in the state territorial sea from potential threats to preserve the services such infrastructure provides Oregonians.

To ensure better coordination and communication among state agencies early in project planning, OPAC recommends implementing a Joint Agency Review Team that would work with applicants and interested and affected communities to review proposed projects and provide input on applications for uses of the seafloor.

Conclusion

Planning and coordination are vital to ensure uses of the seafloor are properly sited and designed to avoid impacts to our ocean and coastal resources and ocean users. We applaud the hard work and commitment of the Workgroup members and state agencies that developed the proposed amendments and urge your adoption of OPAC's recommendations.

Thank you,



Chair Susan Chambers

The Ocean Policy Advisory Council



Vice-Chair Tara Brock

Chair, TSP Part 4 Workgroup