Puget Sound Shoreline Mapping Project

Baseline Shoreline Mapping Report 2023–2024

Visualizing the Changing Interface of Land and Water for Resilience and Restoration

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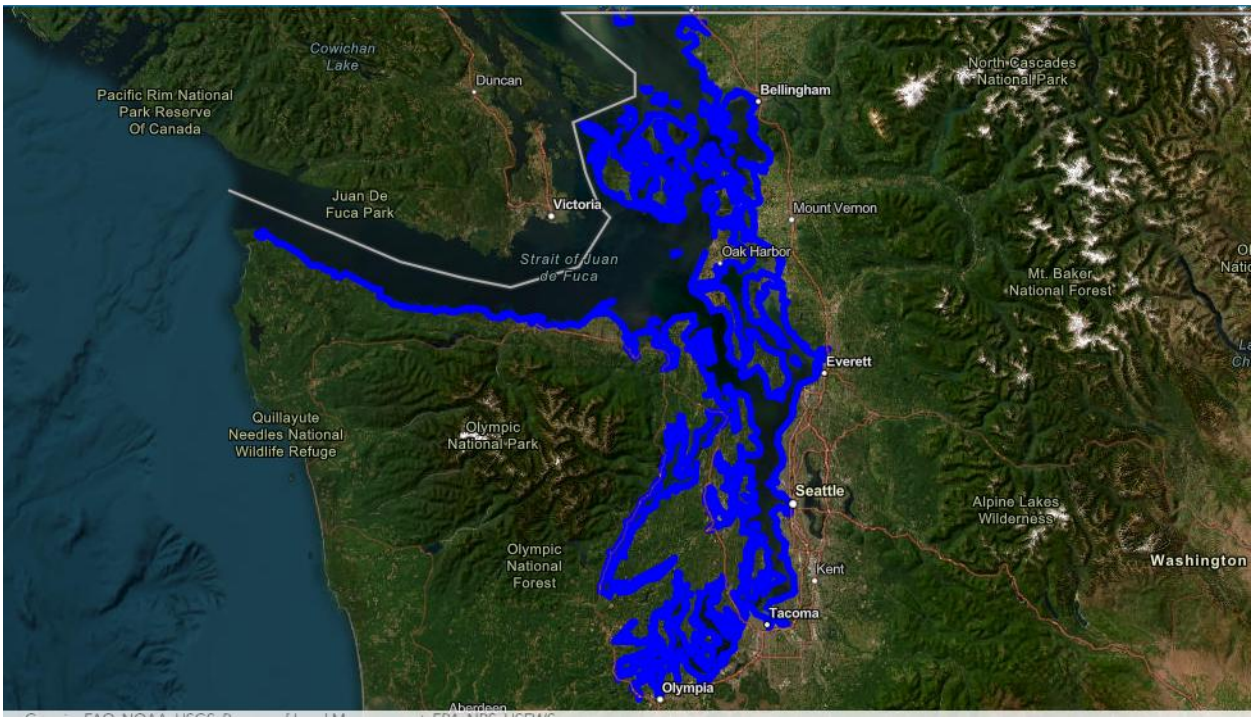

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Acknowledgements

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The Puget Sound 360-degree On-the-Water Shoreline Photo Mapping Project is a groundbreaking initiative by EarthViews Conservation Society (EVC) and funded by the Washington State Department of Ecology, which processes, maps, and publishes digital imagery.

The goal was to create a publicly accessible, high-resolution visual record of Puget Sound's marine shoreline. The project successfully documented 2,571.05 linear miles of shoreline across 14 counties, making it one of the most extensive water-level shoreline image surveys in Washington State history.

Using kayak- and vessel-based surveys equipped with 360-degree panoramic imaging systems and geospatial tracking, EVC collected 433,317 geotagged image scenes. These data are published through *the* EarthViews platform, an interactive online map that allows agencies, researchers, and the public to explore current shoreline conditions in a spatially organized and user-friendly format.

The project fulfills part of a state mandate passed in March of 2023 (Senate Bill 5104) to provide improved documentation of shoreline condition and offers a scalable, replicable model for science-based conservation. The resulting dataset provides a robust visual and spatial baseline that can support future restoration planning, regulatory review, climate resilience strategies, and long-term monitoring.

This effort reflects an unprecedented achievement in coastal documentation, offering a new standard for transparent, accessible shoreline data and delivering tools that will help protect the ecological and cultural integrity of Puget Sound for years to come.

Introduction

Puget Sound is one of the most ecologically and economically important estuarine systems in the United States. Stretching over 2,500 miles of intricate shoreline, it is home to rich biodiversity, including endangered salmon populations, marine mammals, and vital shoreline habitats. The region also supports millions of residents and underpins a complex network of industries ranging from fishing and shipping to tourism and recreation. Yet, Puget Sound's shoreline is increasingly threatened by the combined pressures of urban development, sea-level rise, and habitat degradation.

The shoreline, the critical boundary where land meets water, plays a vital role in the ecological health of Puget Sound. It supports essential functions such as sediment transport, nutrient cycling, and the buffering of inland areas from storm surge and sea-level rise. This transitional zone is also where human development and natural systems most directly intersect, making it both highly dynamic and increasingly vulnerable. The condition of the shoreline influences habitat quality for salmon, forage fish, birds, and other species, while also affecting water quality, public access, and climate resilience for surrounding communities.

Despite the ecological significance of the shoreline, existing monitoring methods have been limited in scope and temporal resolution. The most recent comprehensive visual dataset, oblique aerial photographs captured by the Washington Department of Ecology, previously was updated only every five to seven years. With the passage of Senate Bill 5104 in March of 2023, the state has reinitiated this aerial documentation effort with updates every two years as a critical tool for tracking shoreline change. The Puget Sound Shoreline Mapping Project serves as a companion to this work, offering a water-level perspective that complements the aerial imagery. While aerial obliques provide valuable landscape overviews, the EarthViews Conservation Society approach delivers immersive, high-resolution imagery at the waterline—capturing details often missed from above and enabling a more granular, intuitive understanding of shoreline conditions.

This growing need for shoreline-specific information has created an opportunity for high-resolution, water-level data to play a more central role in regional recovery efforts. The shoreline mapping conducted by EarthViews Conservation Society directly supports the work of state agencies, local governments, and restoration practitioners by filling a critical data gap. Fine-scale, water-level imagery enhances the ability to identify and prioritize shoreline restoration opportunities, especially in areas with armoring, infrastructure encroachment, or degraded riparian conditions. Restoration teams can distinguish between different shoreline types and assess the condition, continuity, and material of existing armoring—critical information for determining restoration feasibility and design.

The mapping also establishes essential baseline documentation, enabling project managers to capture “before” conditions for restoration projects and track ecological changes over time. In doing so, the data provides a foundation for long-term monitoring, adaptive management, and performance reporting, key elements in Puget Sound’s regional recovery strategies.

For Tribal governments, whose connection to the lands and waters of Puget Sound Basin dates to time immemorial, the shoreline is not only an ecological boundary—it is a cultural and sovereign one. Working directly with State, Federal, County and Municipal entities Treaty Tribes in the region serve as co-managers of fisheries and natural resources, and their treaty-reserved rights depend on the protection of shoreline habitats that support salmon, shellfish, and other species central to cultural survival, economic opportunity and food security. The detailed geotagged imagery produced by this project support Tribal monitoring and management efforts by improving visibility of shoreline conditions across large geographic areas. This tool can help document habitat pressures within usual and accustomed fishing grounds and inform government-to-government consultations related to shoreline development, permitting, and climate adaptation planning. In doing so, it aligns with the broader goal of supporting Tribal sovereignty and stewardship throughout the Salish Sea.

Beyond conservation, cultural and restoration applications, the shoreline data set also serves as a powerful public education and outreach tool. By making shoreline conditions visible and accessible through interactive web maps, the project invites community members, educators, and students to explore Puget Sound in a new way, fostering greater environmental literacy and place-based learning. The imagery supports interpretive programming, curriculum development, and citizen science efforts that connect people to their local shorelines and highlight both challenges and opportunities for stewardship.

Additionally, the visual documentation can inform recreational planning by identifying public access points, water-trails, and water routes, as well as helping land managers assess conditions at popular use areas. By bringing people closer to the shoreline, virtually and physically, the project helps cultivate a broader constituency for conservation and builds public support for long-term protection of Puget Sound.

Methods

The shoreline mapping workflow was organized into three sequential phases: data collection, data processing, and data publication. This structure reflects the practical

steps required to capture, manage, and deliver high-resolution shoreline imagery across a large and varied geographic area. Each phase involved field-tested protocols developed to ensure consistency, adaptability to diverse shoreline conditions, and high-quality outputs suitable for long-term reference and monitoring.

Operational Planning

To manage the logistical complexity of surveying more than 2,500 miles of Puget Sound shoreline, data collection was preceded by a detailed operational planning phase. Shoreline segments were prioritized based on geographic continuity, launch access, environmental sensitivity, and weather exposure. Planning involved the identification of feasible watercraft routes, factoring in tidal fluctuations, wind conditions, and known navigational hazards. Public launch points, haul-out locations, and staging areas were mapped in advance using nautical charts, state shoreline databases, and firsthand knowledge of local conditions. Seasonal timing was also considered to align surveys with optimal weather windows and daylight hours. This phase ensured that field teams could efficiently cover diverse shoreline types, from exposed headlands to sheltered inlets, while minimizing safety risks and maximizing spatial coverage.

Where necessary, access permissions were coordinated with public and private shoreline stakeholders, including port authorities, municipalities, Tribal governments, military facilities, correctional institutions, and waterfront landowners.

Survey Platforms

A range of small, shallow-draft watercraft were used to accommodate the diverse shoreline conditions encountered across Puget Sound. The primary survey platforms were two 12-foot-long, 3-foot-wide fishing kayaks, selected for their stability, low profile, and ability to navigate in tight, shallow areas such as estuaries, marsh edges, and under docks. These kayaks enabled precise shoreline tracking and minimal environmental disturbance during data collection (Figure 1).

Figure 1. Kayak surveying platform. Tripod camera mount on stern.

For longer-distance routes and areas with stronger tidal currents—such as the San Juan Islands and Deception Pass—an 18-foot inflatable skiff with 20 hp outboard motor was deployed (Figure 2). Its increased range, load capacity, and performance in dynamic water conditions made it well suited for open-water and high-flow environments. In southern Puget Sound, where many shoreline segments required shorter, more intermittent surveys, a 12-foot inflatable craft with a 9.8 hp motor provided a lightweight and efficient option. This flexible platform mix allowed survey teams to match vessel type to environmental conditions, ensuring consistent data collection across a wide range of coastal settings.

Figure 2. Eighteen-foot inflatable with guest. Yellow mast for camera mount.

Mounting Systems

All survey imagery was captured from a fixed height of approximately eight feet above the waterline to ensure consistent horizon framing and minimize obstruction from the vessel or paddlers. On the fishing kayaks, 360-degree cameras were mounted to standard tripods securely strapped to the stern deck (Figure 1). This configuration offered both stability and an unobstructed rearward view of the shoreline, while allowing the paddler to maintain full control of the vessel. For the inflatable platforms, custom vertical masts were fabricated and installed at the center of the vessel to support the camera mount (Figure 2). These centerline masts provided a balanced, elevated point of view and reduced camera movement from vessel sway or operator activity. All mounting systems were tested for stability in various sea states and designed to be modular, allowing for quick setup, takedown, and adjustments in the field.

Onboard Equipment

Survey teams used a suite of compact, off-the-shelf equipment designed for durability, ease of use, and field reliability. The primary data collection tool was a consumer-grade 360-degree camera mounted to the vessel's mast or tripod system. These cameras captured continuous high-resolution imagery while in motion, with each image geotagged

using internal GPS. For navigation and safety, crews used handheld VHF radios for real-time communication between vessels and with support personnel onshore. Additional documentation of the shoreline, infrastructure, flora and fauna and points of interest was conducted using 35mm digital cameras and handheld video cameras. These supplemental images and footage supported storytelling, public engagement, and visual records beyond the core survey imagery. Power was supplied by rechargeable lithium battery packs, which were rotated and charged between survey days to support full-day field operations. All equipment was stored in waterproof cases and dry bags to ensure functionality in wet and variable marine conditions.

Field Surveys

Daily survey operations were governed by two primary environmental criteria: precipitation and tidal conditions. Survey days were selected only when a six-hour window of dry weather was forecast, ensuring both equipment safety and consistent image quality. In addition, tidal heights were assessed in advance to maintain an optimal survey distance from the shoreline—generally no less than 10 feet and, in most cases, no more than 50 feet from shoreline infrastructure and natural features. This range allowed for accurate spatial framing while minimizing interference from wave action, shallow hazards, or grounded obstructions. Vessels traveled at speeds ranging from 2 to 5 miles per hour, depending on platform type and prevailing sea conditions. 360-degree images were captured at timed intervals of every 5 to 10 seconds, with image frequency calibrated to vessel speed. This approach resulted in an average spacing of 20 to 30 feet between geotagged images, providing continuous visual coverage of the shoreline at a fine spatial resolution.

Data Storage and Management

Image and spatial data collected in the field were initially stored on microSD cards within each 360-degree camera system. At the end of each survey day, data were transferred to portable external hard drives and backed up to cloud-based storage via Microsoft OneDrive. Project coordination and data access were managed using Microsoft Teams, which allowed survey technicians to upload, share, and organize files from multiple remote locations. This decentralized approach was essential, as the project did not operate from a single centralized office or lab. In some cases, such as the 32-day continuous survey of the San Juan Islands, data were collected and managed entirely in the field. Final image files and associated metadata were archived and structured within a dedicated SharePoint site. This allowed the Washington Department of Ecology to access raw data in near real time throughout the project's duration.

Data Processing and Database Management

Once field data were uploaded and verified, the 360-degree imagery and associated metadata were transferred via Cloud to be processed by EarthViews Conservation Society's partners at EarthViews.com. Through a proprietary workflow, the EarthViews team parsed the geospatial data including time, location, and orientation to further process with Esri ArcGIS Pro, spatially referencing each image along the survey route and creating a feature layer compatible with multiple GIS-based software. These feature layers, data-rich survey tracklines, were then added via ArcGIS Online to an overall digital map. Each 360-degree image was parsed into multiple tiles and optimized to enable efficient loading, panning, and zooming in the web-based environment to enhance user experience. The ArcGIS Online maps and processed imagery were then integrated through the EarthViews platform into the user interface. All data were structured in a PostgreSQL database and hosted on Amazon Web Service (AWS) to support both storage and retrieval at speed and scale.

Data Publication

Final imagery and spatial data were published through EarthViews custom-built, web-based platform specifically designed for open access and ease of navigation. Users access the data via arcgis.earthviews.com, an HTML-based website featuring an embedded Esri map interface and custom-built navigation and visualization tools, developed using JavaScript and Esri's SDK. The map displays survey routes as clickable blue polylines, each corresponding to a mapped shoreline segment and linking directly to the associated 360-degree image scenes. Highlighted areas of interest are marked for quick exploration, allowing users to navigate the shoreline visually and interact with the data. Explorers are able to learn from others and share their own knowledge and insights. This web interface, known as an EarthView of the Puget Sound is publicly accessible as part of the Puget Sound Atlas.

The Puget Sound Atlas can be accessed via direct links shared through partner websites, digital media, and outreach campaigns. It is also embeddable in organizational websites, allowing agencies, educators, and advocates to integrate the visual shoreline dataset into their own platforms. This flexible distribution model ensures that the mapping product reaches a wide range of users, from resource managers and policy makers to educators, researchers, and members of the public.

Results

The primary product of this project is the **Puget Sound interactive shoreline map**, now available to the public via the Puget Sound Atlas on the EarthViews platform. This online tool allows users to explore over 2,500 miles of Puget Sound shoreline through 360-degree imagery, organized spatially and accessible through an interactive interface.

Explore the map: https://arcgis.earthviews.com/puget-sound-home.html

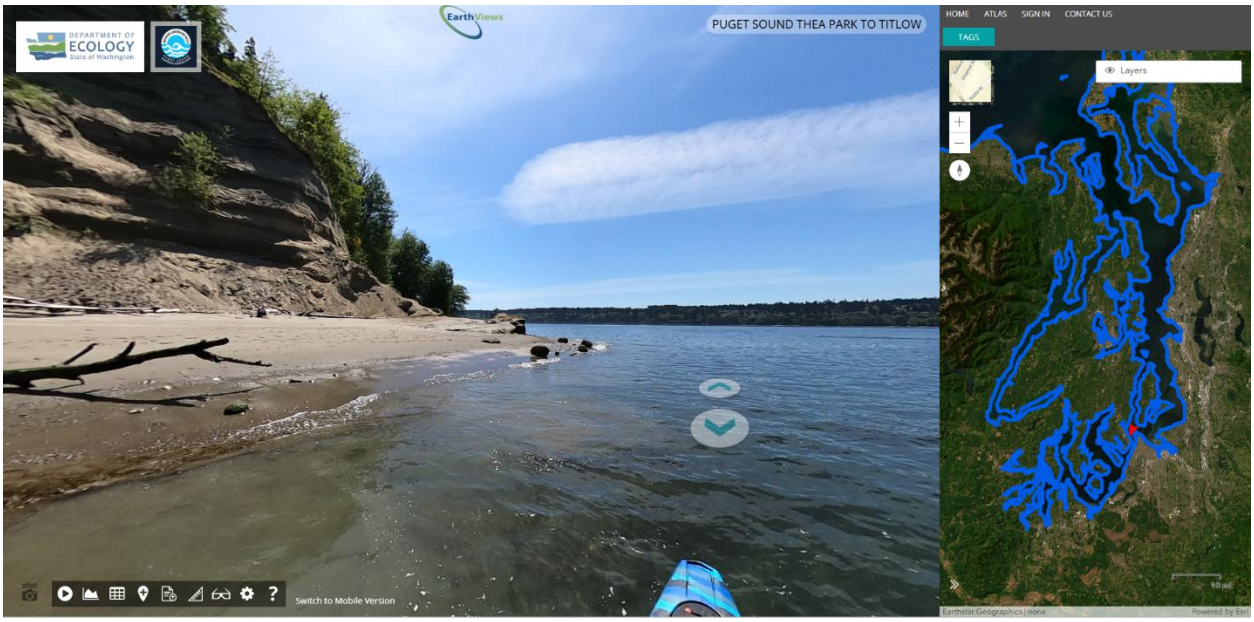

Figure 3. Screen capture of an EarthView of Puget Sound. Click figure to access map.

Geographic Extent and Data Coverage

The Puget Sound Shoreline Mapping Project achieved comprehensive geographic coverage of the marine shoreline throughout Puget Sound. Surveys were conducted across 14 counties and encompassed a wide range of shoreline environments including urban-industrial waterfronts, forested bluffs, estuarine deltas, residential developments, and island shorelines. The data collection was designed to maximize spatial continuity, with

routes planned to follow the full length of the shoreline whenever access and conditions permitted.

For the purposes of organizing survey planning and reporting, Puget Sound was conceptually divided into six broad geographic regions commonly used in shoreline science and management:

- **South Puget Sound**, including the inlets and estuaries from Olympia north to the Tacoma Narrows.
- **Central Puget Sound**, covering the heavily urbanized shorelines of Pierce, King, and Snohomish Counties.
- **North Puget Sound**, extending from Everett to the southern edge of Bellingham Bay.
- **Hood Canal**, encompassing the fjord-like waterway west of the Kitsap and Olympic Peninsulas.
- **San Juan Islands**, comprising the island archipelago and associated exposed shoreline systems.
- **Strait of Juan de Fuca**, including the outer coastal reaches of Clallam and Jefferson Counties where Puget Sound meets the Pacific Ocean.

This regional framework provides context for understanding the distribution of shoreline imagery and enables alignment with restoration planning, regulatory frameworks, and scientific studies that use similar geographic divisions.

Survey Output Summary

Between October 2023 and December 2024 (excluding December 2023 and January 2024), the Puget Sound Shoreline Mapping Project documented a total of 2,571.05 linear miles of shoreline using three distinct survey platforms. These surveys resulted in the collection of 433,317 geotagged 360-degree image scenes, each paired with spatial metadata for use in visualization, planning, and long-term monitoring. The project comprised a total of 260 recorded surveys, conducted across 14 counties and representing a significant cumulative field effort. While shoreline survey mileage reflects only actively mapped segments, the full scope of the project required more than 3,292.33 miles of on-water travel, including vessel repositioning, transit between launch sites, and shoreline access.

A detailed breakdown of survey effort by platform is presented in Table 2. Notably, 1,239.1 miles, or 48.2 percent of the total shoreline surveyed, were completed using kayaks, underscoring the critical role of human-powered platforms in accessing and documenting complex or sensitive nearshore environments across Puget Sound (Table 1).

Table 1. Survey Statistics by Platform (n = 290*, Total Distance = 2,571.05 miles)

Platform Type	Number of Surveys	Miles Surveyed	% of Total Miles	Median Distance (mi)
Kayak	170	1,239.1	48.2%	7.08
12-foot Inflatable	61	610.3	23.7%	9.84
18-foot Inflatable	29 (59)**	721.6	28.1%	13.38
Total	260 (290)**	2,571.05	100%	8.23

* Reflects total number of individual survey efforts.
** An additional 30 surveys conducted using the 18-foot inflatable in the San Juan Islands were operationally combined into 29 recorded survey entries for the purpose of mapping display, resulting in one continuous polyline per island to simplify visual presentation.

Discussion

The Puget Sound Shoreline Mapping Project has established a new foundation for visualizing and understanding the marine shoreline of Puget Sound. As of publication, the EarthView of the Puget Sound is directly supporting a shoreline condition survey conducted by the Washington Department of Ecology. It is also proving to be a valuable resource for other state agencies, nonprofit organizations, and research partners. The ability to visually reference real-world shoreline conditions at scale has enhanced transparency, improved decision-making, and expanded access to coastal data for a range of stakeholders.

Overall, the field methods developed and applied throughout the project functioned effectively, producing consistent and high-resolution results across a complex and dynamic coastal environment. The combination of kayak- and vessel-based survey platforms allowed the team to navigate and document nearly every shoreline type within the estuarine system. While post-processing and data management proved to be resource-intensive, the team identified clear opportunities to improve efficiency by refining field techniques to support more consistent image quality and metadata capture at the source.

The scope, scale, and accessibility of this project are unprecedented. To our knowledge, it represents one of the largest continuous ground-level shoreline imagery collection efforts

in the world, delivering a publicly available, geolocated visual dataset that will support restoration, planning, education, and policy for years to come.

Conclusion

The Puget Sound Shoreline Mapping Project reflects what is possible when technology, coordination, and mission-driven fieldwork come together to address complex environmental challenges. By creating a publicly accessible, high-resolution visual archive of more than 2,500 miles of shoreline, this effort lays the groundwork for more informed and equitable conservation, restoration, and shoreline planning. As the project continues into its next phase, it offers a model not only for Puget Sound, but for other coastal regions seeking scalable, data-driven approaches to protecting their shorelines.