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Monitoring Protocol for Marine Riparian Forested Cover in Puget Sound

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Monitoring Protocol for Marine Riparian Forested Cover in Puget Sound

Oleksandr Stefankiv and Timothy J. Beechie

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Fish Ecology Division
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

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Introduction

The condition of marine riparian habitat has been recognized as a principal metric by regional habitat status and trends monitoring programs as an important indicator for threatened salmonid species that rely on nearshore habitats. These include the Salmon Habitat Status and Trends Monitoring Program (SHSTMP) that we began in 2014 (Beechie et al. 2017) and the Puget Sound Partnership's (PSP) Common Indicators and Vital Signs (CI/VS). In 2018, we developed our initial protocol to measure marine riparian forested cover. We carried out a pilot study within the Strait of Juan de Fuca basin and presented our approach to the Puget Sound Ecosystem Monitoring Program Nearshore Salmonid Work Group (PSEMP NSWG, 2019). A Marine Riparian Technical Advisory Group (TAG) was developed in 2021 and met in 2022, with the goal of refining protocols for marine riparian mapping. Based on the recommendations of the PSEMP NSWG and inputs from the TAG, we refined our protocol as described in this report, including shoreline delineation, forest cover delineation, and data structure. Products developed using this protocol will also aid in application of NOAA's Nearshore Conservation Calculator.

Shoreline Delineation

Currently, two geospatial datasets are available that describe shoreline in the Puget Sound: The National Oceanic and Atmospheric Administration Continuously Updated Shoreline Product (NOAA CUSP) and the Washington Department of Natural Resources (WDNR) ShoreZone (WDNR, 2001; NOAA 2021). While many regional data products rely on these shoreline layers, both are unsuitable for measurement of marine riparian forested cover due to age, known alignment errors, or inappropriate tidal datum reference. As a result, the first step of our approach was the development of an updated shoreline layer. To do so, we followed the methods described in Anderson et al. (2016), digitizing a line describing the Ordinary High Water Mark (OHWM). The OHWM is defined as a biological vegetation mark by Washington's Shoreline Management Act (DOE, 2017). The OHWM location is commonly similar to the mean higher high water (MHHW) line, although it can be lower where vegetation is established below the MHHW line (Anderson et al. 2016). While delineation of OHWM is most accurate through field measurements, field delineation across all of Puget Sound was not possible due to funding and time constraints. Consequently, our method aims to approximate OHWM identification through the use of remotely sensed indicators.

We used available lidar datasets in conjunction with aerial and oblique imagery to digitize the OHWM line. The primary geospatial data sources are listed in Table 1. Using a 1-meter lidar Digital Terrain Model (DTM) hillshade, we identified elevation inflection points to estimate the location of the shoreline. We then used the National Agriculture Imagery Program (NAIP) aerial color-infrared (CIR) imagery to differentiate vegetation from non-vegetation and refine delineation of the shoreline based on topography. Oblique imagery form the Coastal Atlas (DOE 2018) and EarthViews were also used as a reference and employed in areas with obscured visibility due to aerial imagery parallax or overhanging vegetation. Two years (2009 and 2017) were selected for analysis to ascertain trend in the contiguous forested cover within Puget Sound. We selected 2009 because it is the earliest

Table 1. Geospatial data layers used in this study.

Input data layer	Description
Beach Strategies Nearshore Geospatial Framework (NGF)	Nearshore geospatial framework, developed by Coastal Geologic Services for Washington Department of Fish and Wildlife Estuary and Salmon Restoration Program in 2017, based on WDNR ShoreZone shoreline. Contains polyline and polygon layers that include geomorphic shoreform classifications. (https://geodataservices.wdfw.wa.gov)
Coastal Atlas oblique shoreline imagery	Oblique imagery produced by Washington State Department of Ecology (https://apps.ecology.wa.gov/shorephotoviewer)
EarthViews oblique shoreline imagery	Oblique imagery produced by EarthViews (https://arcgis.earthviews.com/home.html)
Lidar	Lidar derived Digital Terrain (DTM) and Digital Surface Models with spatial resolution of up to 3-feet, maintained by Washington Department of Natural Resources (WDNR). (https://lidarportal.dnr.wa.gov)
National Agriculture Imagery Program (NAIP)	High spatial (1 meter), temporal (every two years), and spectral resolution (Red (619–651 nm), Green (525–585 nm), Blue (435–495nm), NIR (808–882 nm)) aerial imagery. (http://www.earthexplorer.usgs.gov)

year of NAIP imagery with 4-bands, including near-infrared that allows configuration of aerial imagery into a CIR composite. We selected the 2017 aerial imagery to match the imagery year of a parallel effort to map the percent of forested cover using methods developed by Hall et al. (2019), which used the Washington Department of Fish and Wildlife Puget Sound High Resolution Land Cover data set (HRLC) (Pierce, 2015). The layer for 2017 aerial imagery was developed first, as coverage of higher quality lidar was more extensive for that time period, ranging from 2013 to 2020. Subsequently, we used the 2009 imagery to identify locations of change to the 2017 data, with causes of shoreline change between years identified in the attribute table. For the Coastal Atlas oblique shoreline imagery within Puget Sound, the closest available years to the vintage of aerial imagery were 2006–2007 and 2016–2017 (DOE 2018), while EarthViews oblique shoreline imagery was based on surveys carried out in 2021–2022.

The placement of the OHWM line varies among geomorphic shoreforms, such as beaches, bluffs, or rocky shores. As a result, the shoreline layer should include stratification by shoreforms. The ESRP Beach Strategies NGF layers contain major shoreform classifications in Puget Sound that were used to stratify the shoreline (Table 2). During the digitizing process, we segmented the output layers to match NGF polygon boundaries in order to retain shoreform designations. In addition, we aggregated the NGF shoreform classification into shoreform groups to support the Puget Sound Partnership’s Common Indicators and Vital Signs metrics.

Table 2. Shoreforms used in the calculation of marine riparian Common Indicator metrics and the respective shoreform classification system used in the ESRP Beach Strategies Nearshore Geospatial Framework (NGF) (CGS 2017).

Marine Riparian Common Indicator Shoreform Group	ESRP Beach Strategies NGF Shoreform
FB	FBE (Feeder Bluff Exceptional) FB (Feeder Bluff)
FB-T	FB-T (Feeder Bluff – Talus)
Coastal Landform	TZ (Transport Zone) AS (Accretion Shoreform) Modified NAD-B (No Appreciable Drift – Bedrock) NAD-AR (No Appreciable Drift – Artificial) PB (Pocket Beach) PB-AR (Pocket Beach – Artificial) NAD-LE (No Appreciable Drift – Low Energy) (large features)
Excluded from analysis	NAD-D (No Appreciable Drift – Delta) NAD-LE (No Appreciable Drift – Low Energy) (small features)

Within most shoreforms, the most common observed indicators that helped to identify OHWM in aerial imagery were drift logs and a line of persistent vegetation. Color infrared imagery was particularly useful in this task, as vegetation was distinguished by hues of red and drift logs could be observed as bright white objects. However, these features were often obscured by shadow or vegetation cover, especially along bluff topography, including Feeder Bluff, Feeder Bluff Exceptional, and Feeder Bluff – Talus (Table 2). These shoreforms were characterized as landforms with steep bluffs or banks, toe erosion, landslides, and minimal vegetation on the bluff face indicative of disturbance (MacLennan et al., 2013). Within bluff shoreforms, the digitized shoreline was placed at the toe of the bluff due to lack of vegetation from regular inundation (Anderson et al., 2016). The lidar DTM hillshade was used to identify the inflection point that represents the bluff toe, while oblique imagery helped to confirm the location of drift logs or persistent vegetation (Figure 1). In locations where armoring was present along the bluff toe, the shoreline was delineated along the toe of the armored structure (Figure 2). A similar approach was used in other shoreforms with armoring and/or artificial structures, such as Accretion shoreform or No Appreciable Drift – Artificial shoreform (Figures 3 and 4). Lidar DTMs were also employed to identify shorelines along rocky shores, including No Appreciable Drift – Bedrock and Pocket Beach, where vegetation occurs at varying heights and distances from the edge of the bedrock. For consistency, we decided to place the shoreline at the toe of the bedrock wall (Figures 5 and 6). Transport Zones were defined by the presence of gently sloping bluffs with forested vegetation (McLennan et al., 2013). In those sections, the shoreline was placed at the toe of the bluff, mainly relying on lidar DTM hillshades due to poor visibility from overhanging tree canopy (Figure 7). Accretion shoreforms were characterized as barrier beach and marsh landforms with the presence of backshore and accompanying vegetation, often with old or rotten drift logs (McLennan et al., 2013). According to Anderson et al. (2016), in these shoreforms, the OHWM is generally located at the face or top of the second berm, where drift logs meet persistent vegetation (Figure 8). In sections where vegetation is absent, the OHWM is most often located at the landward edge of a drift log pile. If persistent vegetation was dispersed among the drift log pile or the drift log pile extends landward, the shoreline was identified by observing color differences (Anderson et al., 2016). In Accretion shoreforms with bulkheads present, the shoreline was placed at the face of the bulkhead, unless the beach in front of the bulkhead was accreting and persistent vegetation was located shoreward of the bulkhead. We elected to exclude smaller No Appreciable Drift - Delta and No Appreciable Drift – Low Energy shoreforms, which included small embayments and pocket estuaries, as they were beyond the scope of this metric and the forested cover within them will be measured in other efforts. For those shoreforms, the shoreline was connected at the presumed outlet using the ESRP Beach Strategies NGF shoreform boundaries (Figure 9).

Figure 1. Example of digitized shoreline along Feeder Bluff Exceptional shoreform with armoring present in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

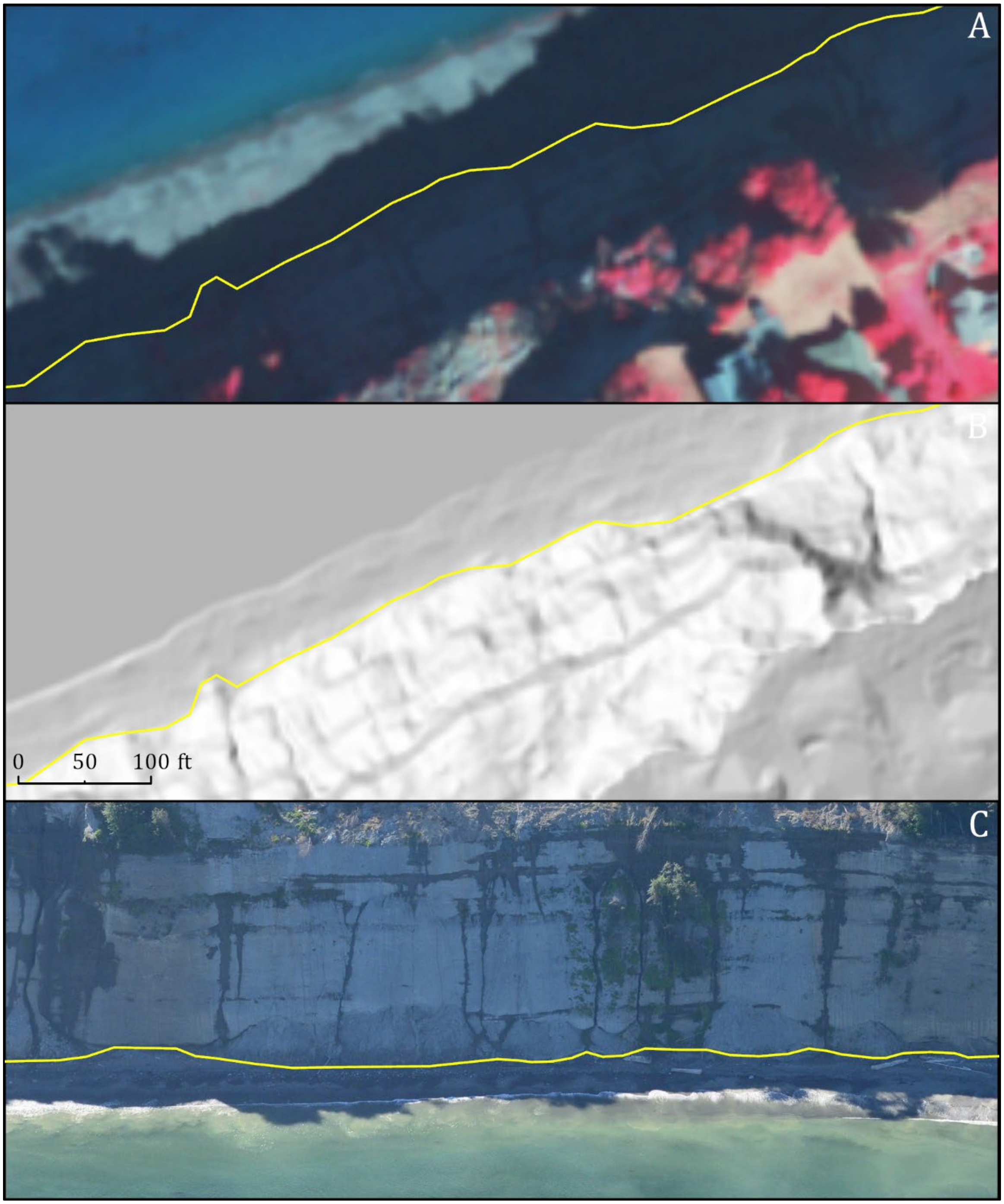


Figure 2. Example of digitized shoreline along Feeder Bluff shoreform with armoring present in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

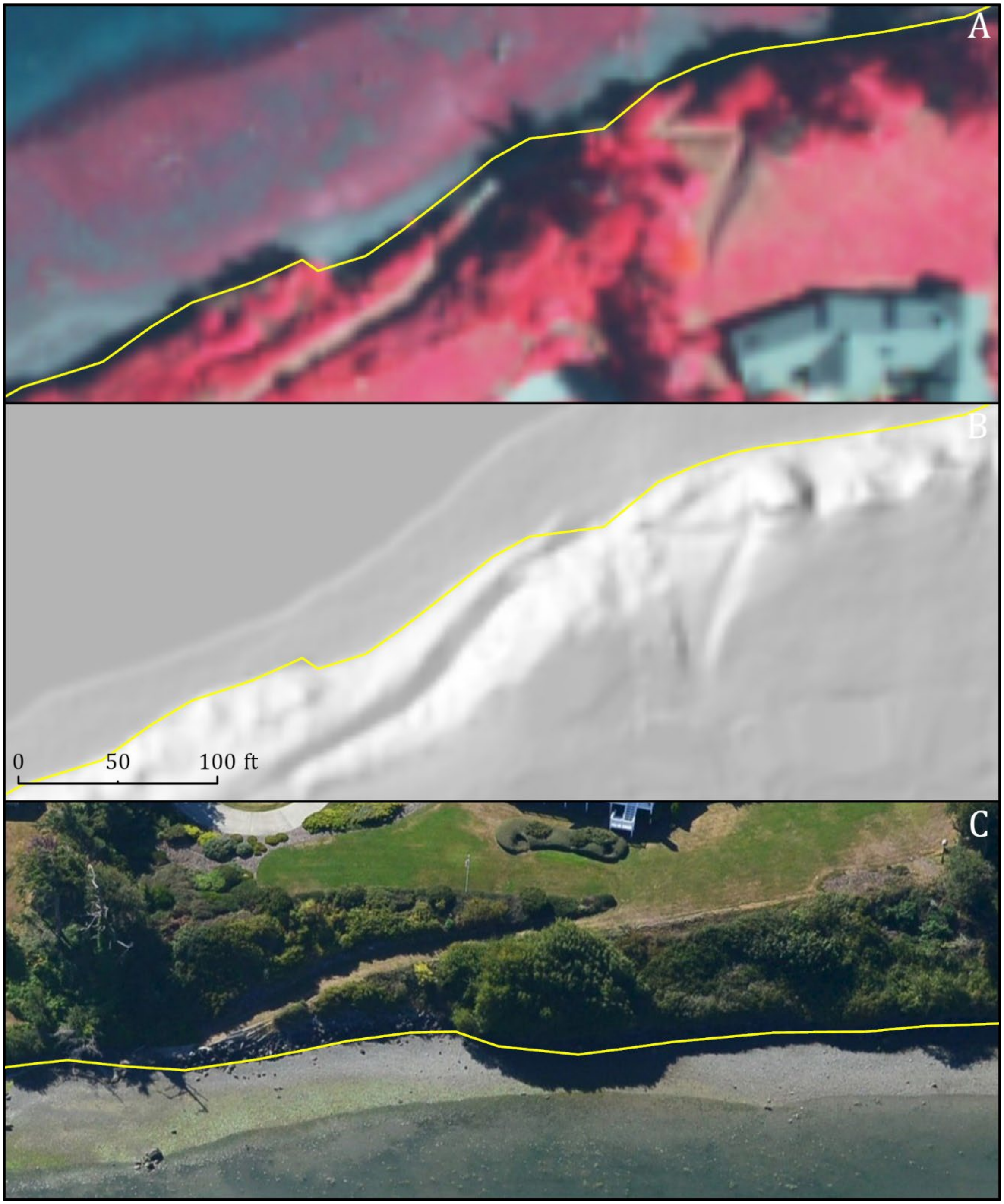


Figure 3. Example of digitized shoreline along Accretion Shoreform with armoring present in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

Figure 4. Example of digitized shoreline along No Appreciable Drift - Artificial shoreform in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

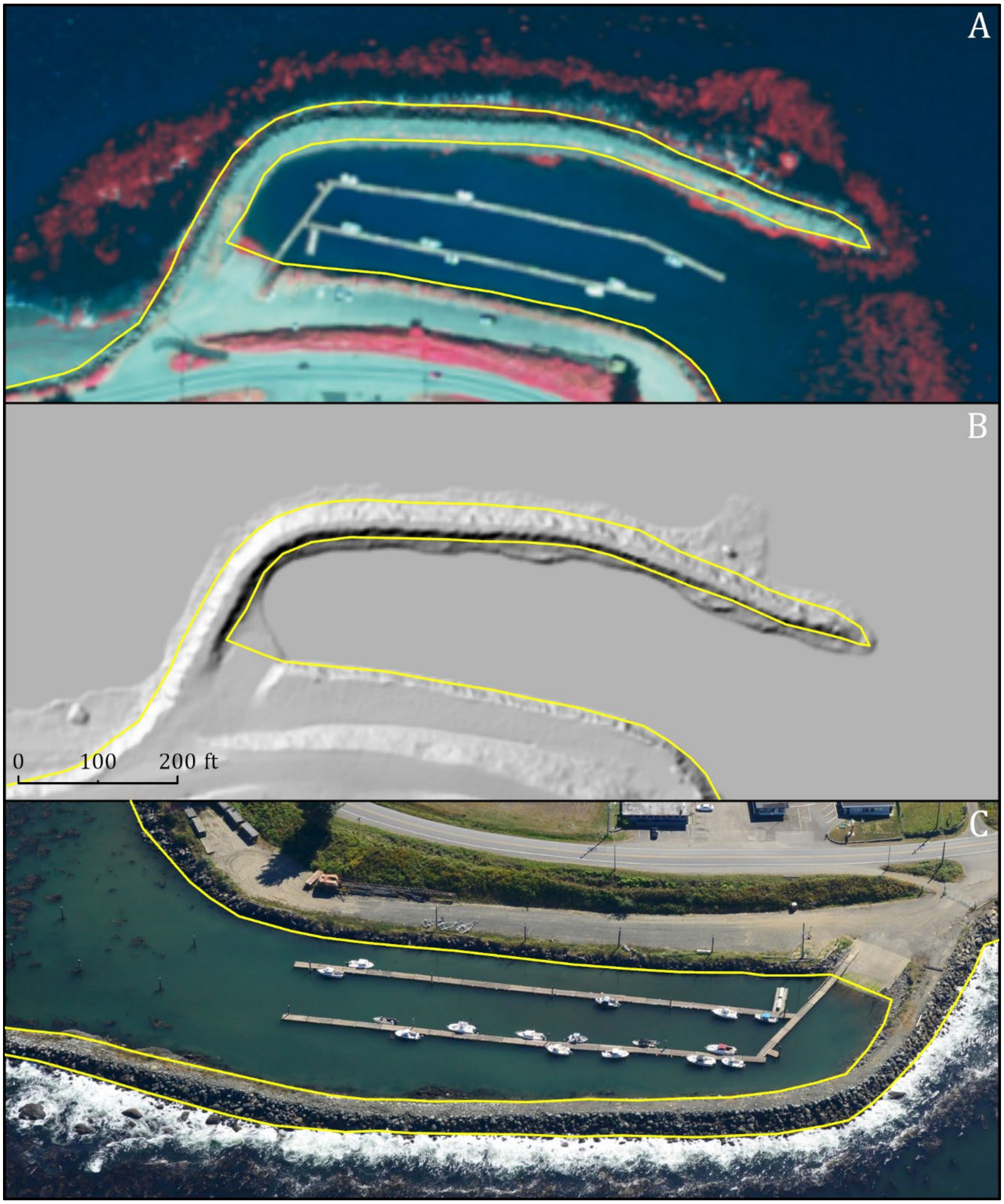


Figure 5. Example of digitized shoreline along No Appreciable Drift - Bedrock shoreform in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

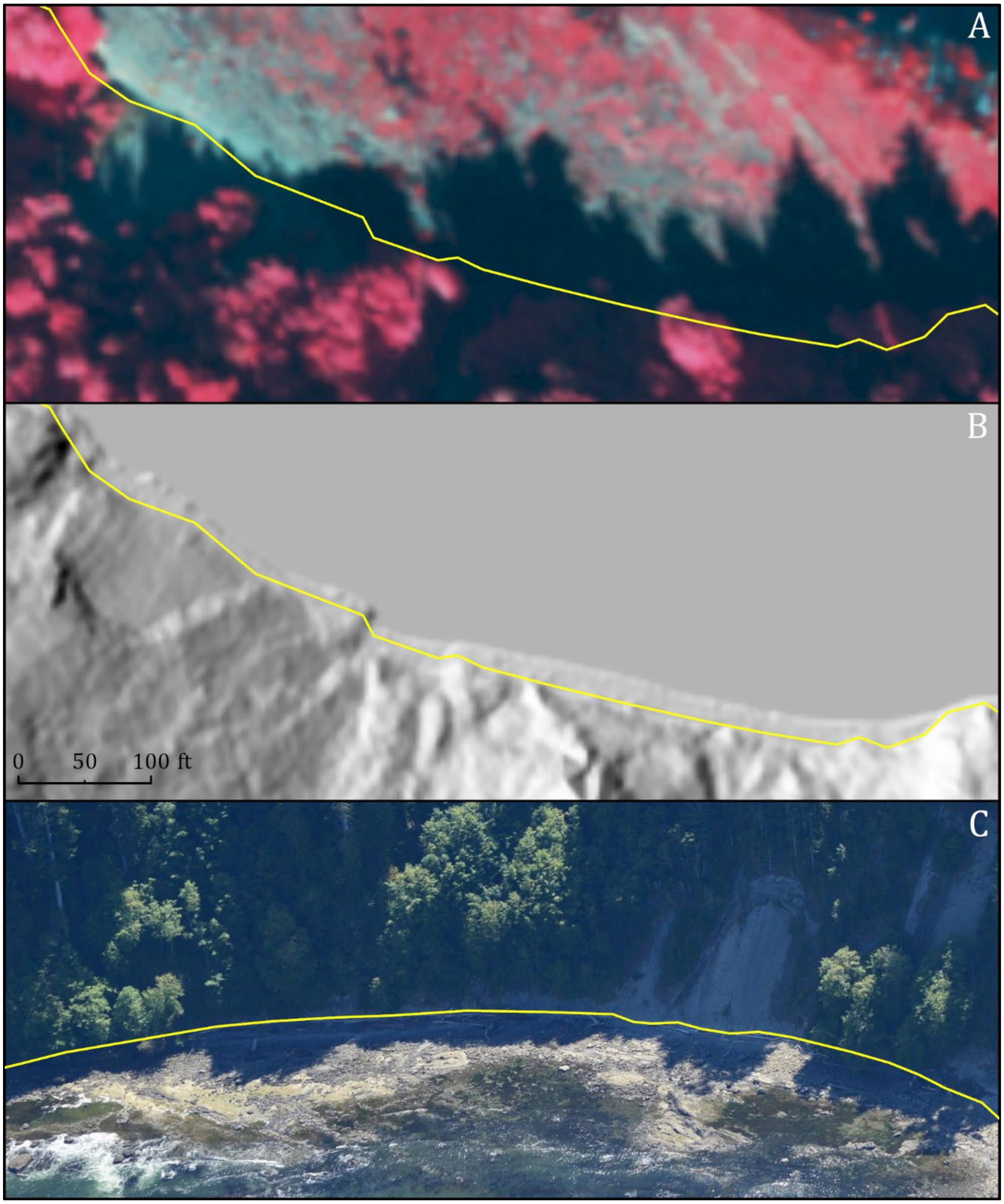


Figure 6. Example of digitized shoreline along Pocket Beach shoreform in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

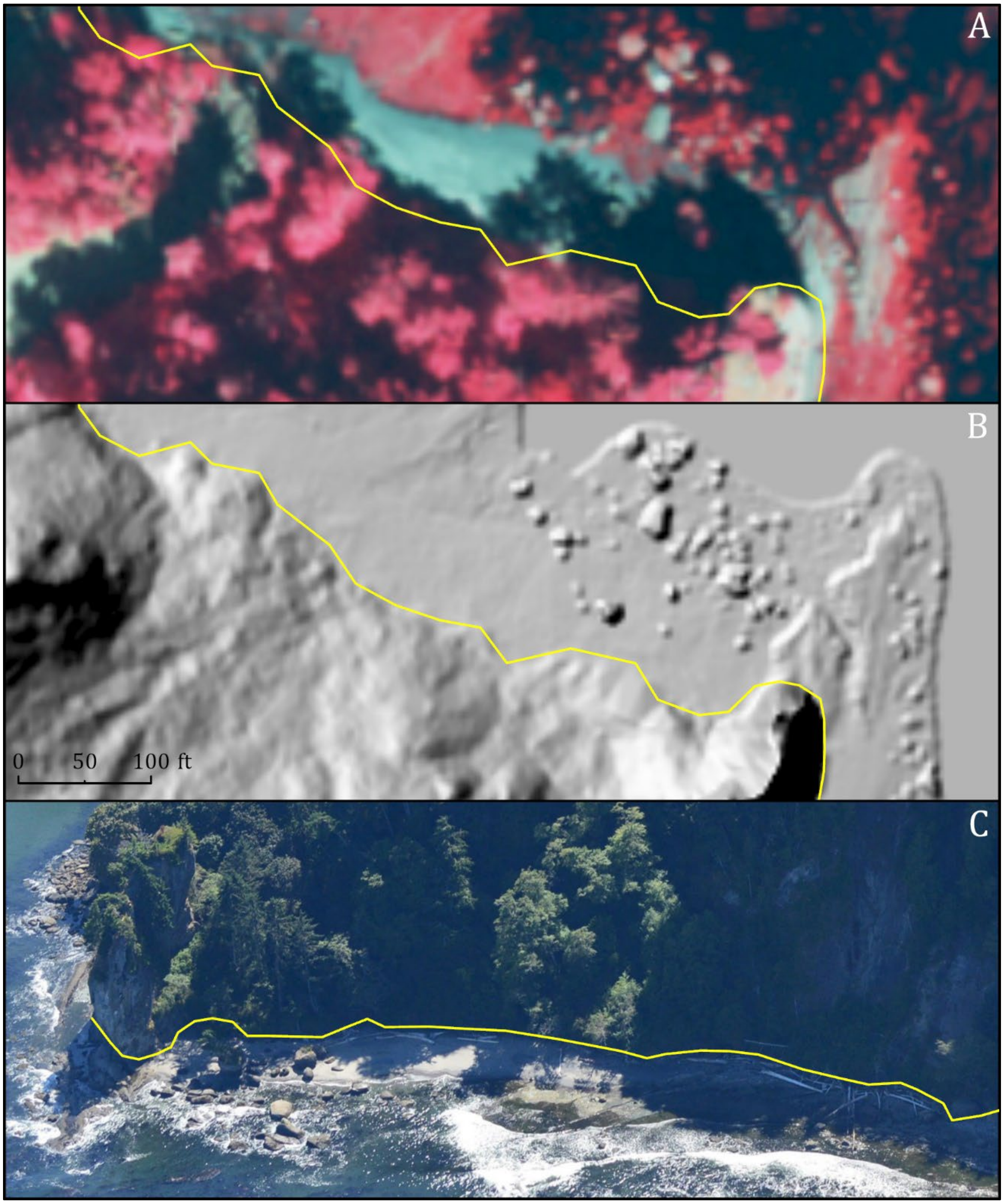


Figure 7. Example of digitized shoreline along Transport Zone shoreform in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

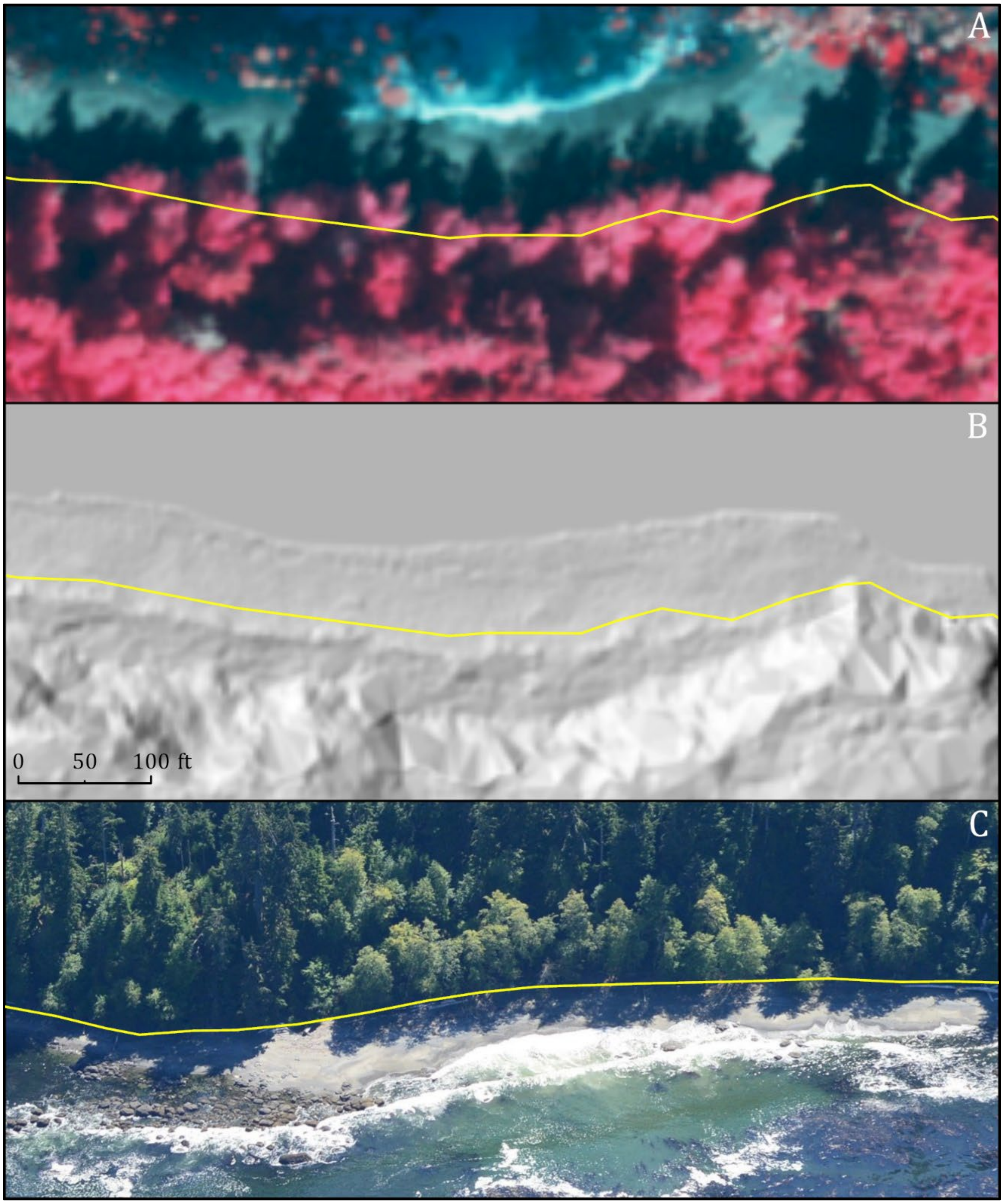


Figure 8. Example of digitized shoreline along Accretion shoreform in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).

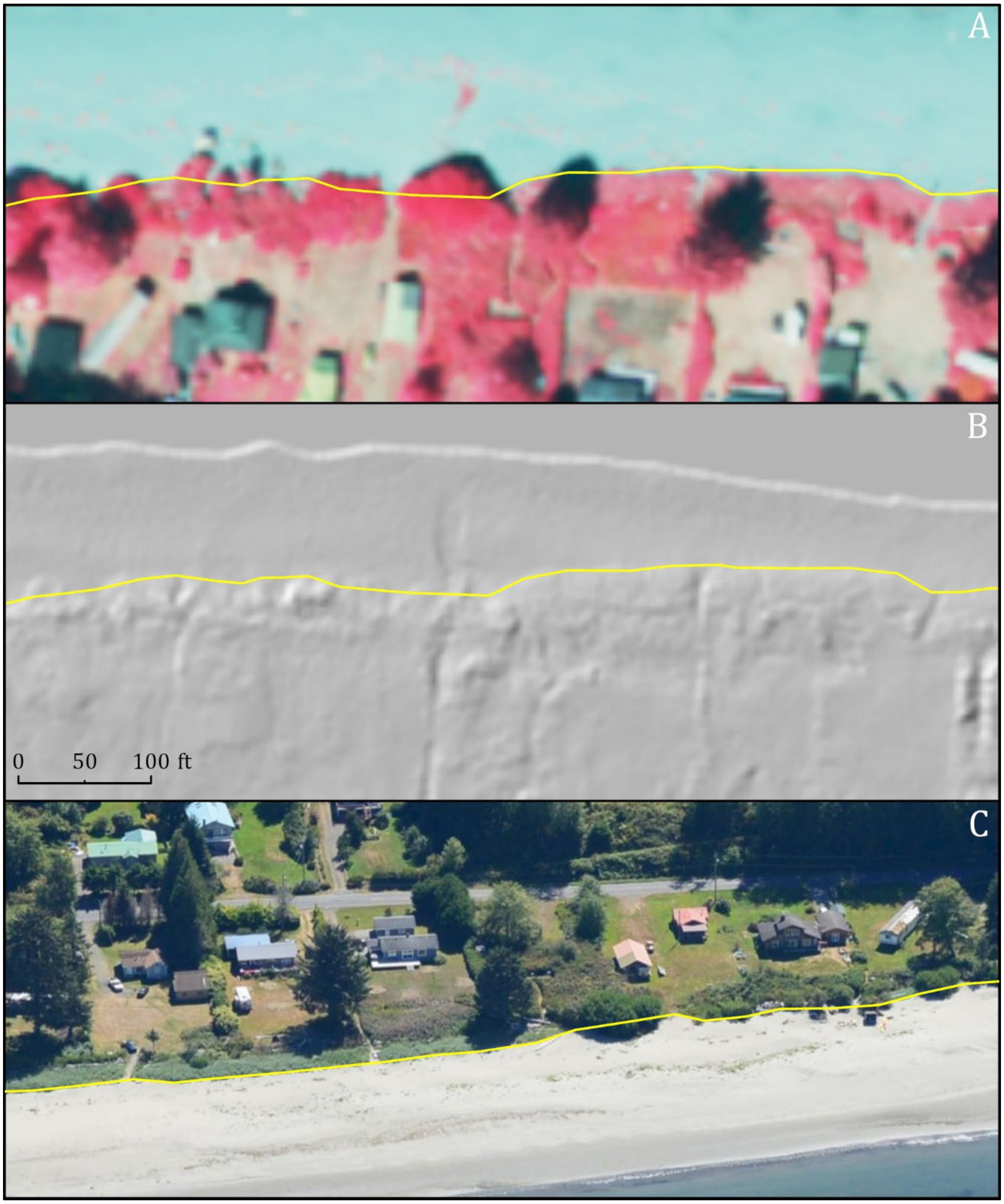
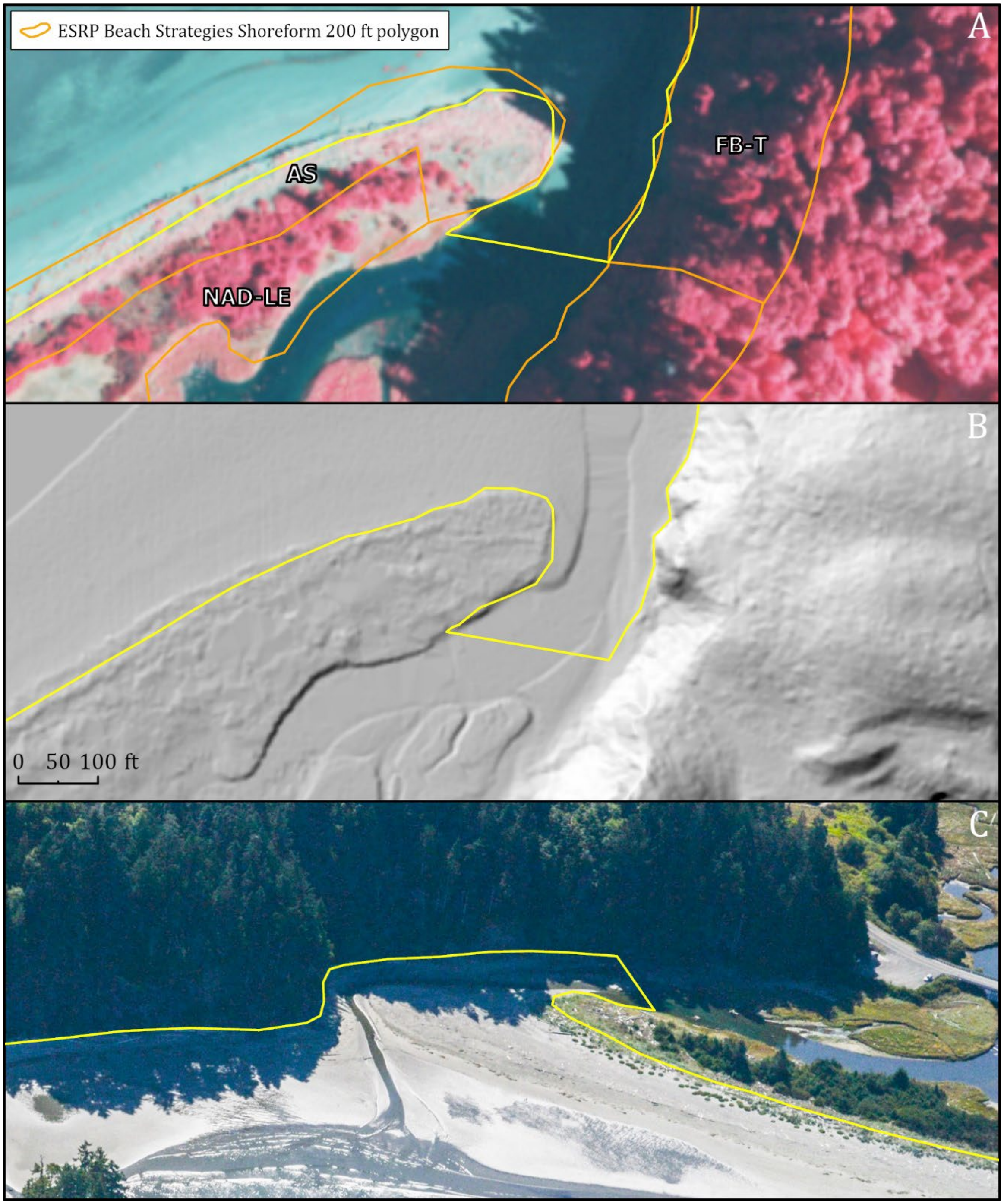


Figure 9. Example of digitized shoreline (yellow line) along No Appreciable Drift – Low Energy shoreform outlet in NAIP color infrared aerial imagery (A), lidar DTM hillshade (B), and oblique imagery (DOE 2018) (C).



Contiguous Forest Cover Measurement

The updated shoreline was segmented based on seven contiguous forested cover width classes, which were assigned to shoreline segments using the interpretation of aerial and oblique shoreline imagery. The contiguous forested cover width classes were based on the Shoreline Master Programs Handbook recommendations, including widths of 30 to 60 feet in developed areas, 150 feet in rural areas, and 150-200 feet in undeveloped shorelines (DOE, 2017). A width break of 100 feet was also included, as it is often a recommended metric in freshwater riparian studies (Table 3). Per recommendations from the Puget Sound Ecosystem Monitoring Program Nearshore and Salmon Working Group (PSEMP NSWG, 2019), contiguous width classes will also be aggregated into three simpler riparian zones of influence (0 feet, 0-100 feet, and 100-200 feet). Forested cover width measurements were based on the interpretation of aerial and oblique imagery, mapping continuous cover of trees with a comparable range of heights. Forested cover had minimum vegetation height of 10 feet, which was determined by differencing the lidar canopy elevation from the lidar bare earth elevation, as well as visual estimation from NAIP imagery and oblique imagery. This height was selected based on a threshold utilized in the HRLC dataset by Pierce (2015) as an approximation of medium and large tree cover. In addition, this height was close to the lowest height at which riparian ecological functions (such as large woody debris recruitment, litter fall, shade, etc.) have a minimum cumulative effectiveness (Brennan et al., 2009). Our preliminary accuracy assessment, which compared aerial and oblique imagery interpretation to the addition of lidar canopy height measurements using 30 random points within each shoreform, revealed that the overall accuracy in classifying shoreline into forest cover (vegetation greater than 10 feet) and no forest (below 10 feet or no vegetation) was 94% (Kappa coefficient = 0.89) (Table 4).

Table 3. Riparian zones of influence represented by width classes used to measure contiguous forested cover landward from the shoreline.

Riparian Zone of Influence	Width Class	Description
0 feet	No forest	No forested riparian shoreline
0-100 feet	0 – 30 feet	Less than recommended
0-100 feet	30 – 60 feet	Recommended width of forested riparian buffer for developed areas (DOE, 2017)
0-100 feet	60 – 100 feet	Commonly recommended riparian buffer width from freshwater studies (e.g., FEMAT 1993)
100-200 feet	100 – 150 feet	Recommended width of forested riparian buffer for rural areas (DOE, 2017)
100-200 feet	150 – 200 feet	Recommended width of forested riparian buffer for undeveloped areas (DOE, 2017)
200 + feet	200 + feet	Wider than recommended

Along Accretion shoreforms, forested cover width was measured landward from the shoreward edge of vegetation (Figure 10). Within this shoreform, persistent vegetation at the OHWM was often characterized as perennial emergent grasses and rushes as well as scrub-shrub sedges, with forest cover occurring further landward (Anderson et al., 2016). To account for forest cover in those locations, we measured its width if the canopy was located within 10 feet of the OHWM (Figure 10). In contrast, within shoreforms with the presence of a bluff or bedrock wall, forested cover width was determined by measuring vegetation width from the bluff or bedrock wall toe to the end of vegetation on the bluff or bedrock wall slope (Figure 11). We considered sections of these shoreforms for measurement if forested cover began near or at the base; otherwise, width was classified as no forest (Figure 12). In armored or artificial shoreforms, we measured forest cover width landward from the toe of the armoring structure, considering forested cover that overhangs it. Within all shoreforms, the width measurements stopped at canopy clearings or topographic breaks, such as roads (Figures 12 and 13).

Table 4. Error matrix for the aerial and oblique imagery interpretation of shoreline into forest cover (vegetation greater than 10 feet) and no forest cover (vegetation below 10 feet or no vegetation) as compared to addition of lidar canopy height measurement as reference.

		Reference data			
	Class	**Forest cover**	**No forest cover**	**Total**	**User's Accuracy**
Classified data	Forest cover	152	13	165	0.92
	No forest cover	2	103	105	0.98
	Total	154	116	270	
	Producer's Accuracy	0.99	0.89		0.94
	Kappa				0.89

Figure 10. Example of forest width class measurement along Accretion Shoreform in oblique imagery (DOE 2018). Shoreline sections marked in red are classified as no forest due to the distance of greater than 10 feet from OHWM to where forested cover begins. Shoreline sections marked in yellow and green are classified as 60-100 and 150-200 feet width classes, respectively, as a natural break in forested cover is present. The orange shoreline section represents a measurement of forested cover width greater than 200 feet.

Figure 11. Example of forest width class measurement along Accretion Shoreform in NAIP color infrared aerial imagery (A) and lidar DTM hillshade (B).

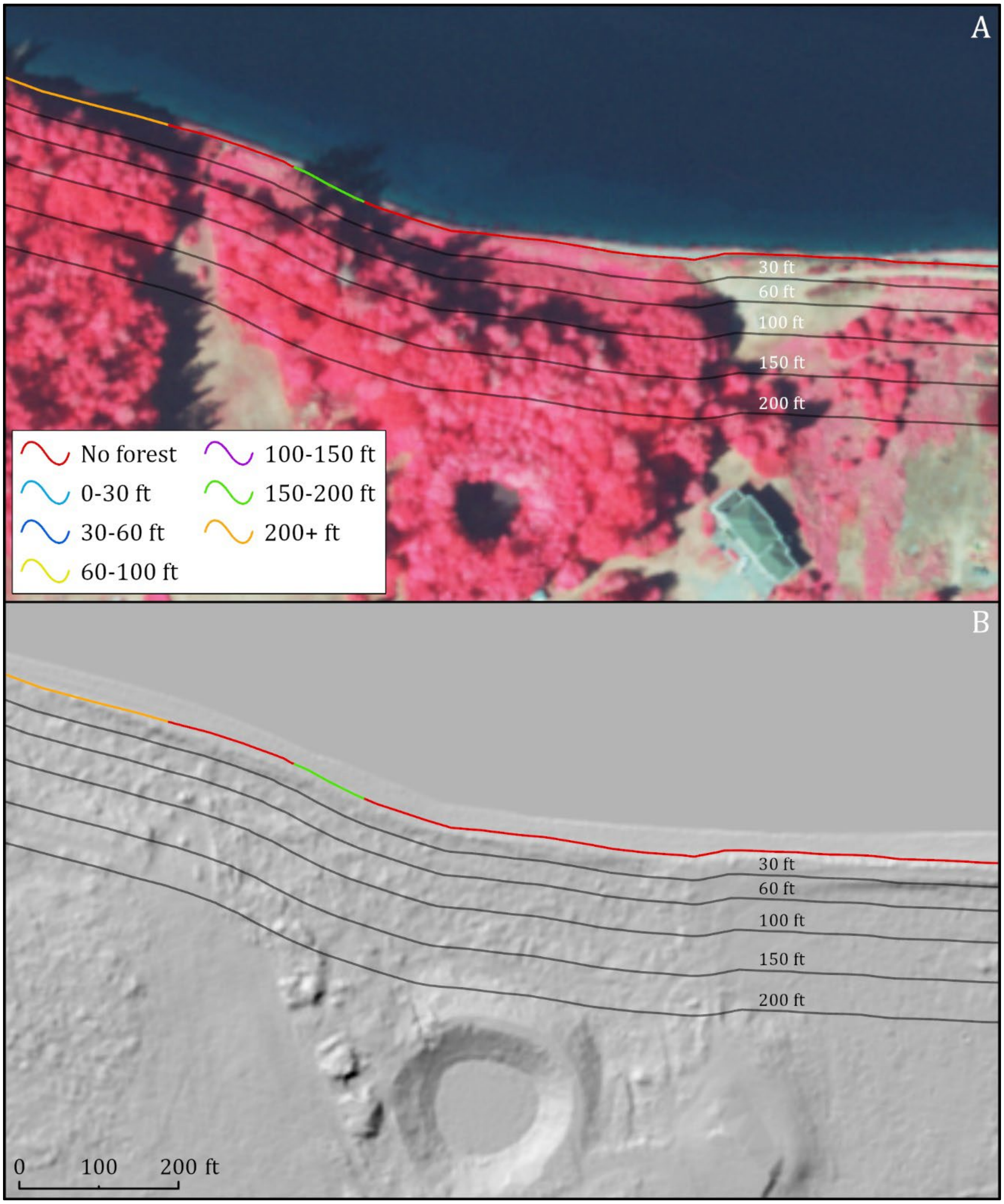
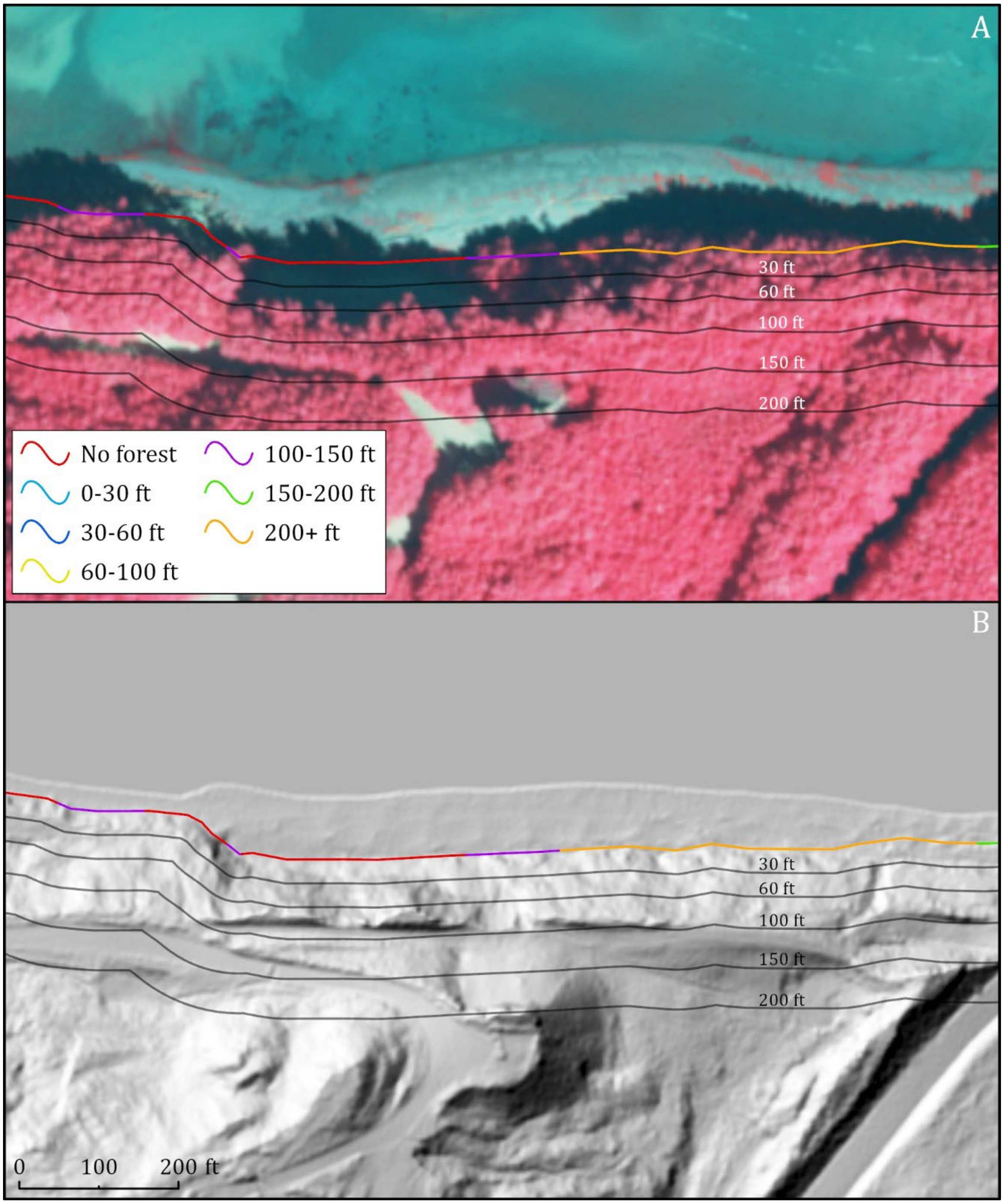


Figure 12. Example of forest width class measurement along No Appreciable Drift - Bedrock shoreform in oblique imagery (DOE 2018). Shoreline sections marked in red are classified as no forest due to the height at which forested cover begins. Shoreline sections marked in blue and purple are classified as 30-60 and 100-150 feet width classes, respectively, as a natural break in forested cover is present. The orange shoreline sections represent measurements of forested cover widths greater than 200 feet.

Figure 13. Example of forest width class measurement along Feeder Bluff shoreform in NAIP color infrared aerial imagery (A) and lidar DTM hillshade (B).



Data Structure

The output polyline layers were digitized at 1:1,000 scale and projected to a common WA State Plane South NAD 83 HARN Coordinate Reference System (EPSG 2927) to ensure conformance and consistency with Washington State standards. We added and populated attribute table fields with the ESRP Beach Strategies NGF shoreforms, Chinook Recovery Watershed name, Lead Entity Area name, and Water Resource Inventory Area number and name so that proportion of forested cover width can be reported by these strata (Table 5). We also added a field to identify the reason for the end of the contiguous forested cover width measurement or the reason no forested cover is present at the shoreline. A “modified” classification was used to identify sources of forested cover absence due to clearing, development, roads, or other anthropogenic shoreline alterations. The “modified-overhanging” designation was used to identify forested cover that overhangs an armored shoreline. A “natural” classification identified natural sources of forested cover absence, such as feeder bluff landslides or bedrock walls where there is no potential for tree growth. The "natural-proximity" designation was used to identify shoreline that was classified as "no forest" due to exceeding horizontal or vertical distance to forest thresholds. In addition, the “natural-proximity-modified” designation was used for sections where forested cover has ended due to anthropogenic sources. A certainty field was added to identify sections that require further validation. In addition to these fields, for the 2017 layer, the source of shoreline and forested cover change fields was added to document the causes of shoreline and forested cover changes between 2009 and 2017, respectively.

Table 5. Data structure proposed for the width of contiguous forested cover. Addition of shoreline and forest cover change fields only apply to the 2017 layer and future years.

Field	Type	Description	Values
NGF_PolyID	Double	Unique ID linking width of contiguous forested cover line to NGF polygons	Values linked to Beach Strategies NGF
Shoreform	Text String	Shoreform designation	Values from Beach Strategies NGF
CRW_Name	Text String	Name of the Chinook Recovery Watershed	CRW Name
WRIA_NR	Integer	WRIA number the line segment falls within	WRIA NR (Numbers 1-19, not WRIA ID numbers)
WRIA_NM	Text String	WRIA name the line segment falls within	WRIA Name
LE_Name	Text String	Name of the Lead Entity management area that line segment falls within	Lead Entity Area Name
Width	Text String	Width class of riparian forest	No forest, 0-30 ft, 30-60 ft, 60-100 ft, 100-150 ft, 150-200 ft, 200+ ft
Certainty	Text String	Identifies if the forested width is flagged for review	High, Low
MeasBrk	Text String	Identifies the reason for the end of the forested cover width measurement	Modified, Modified – overhanging, Natural, Natural – proximity, Natural – proximity - modified
Image_Yr	Integer	Identifies year of aerial imagery used	Year
ShoreChg	Text String	Source of shoreline change among years	Modified, Natural
CovChg	Text String	Source of riparian forested cover change among years	Modified, Natural
Shape_Length	Double	Length of line segment (feet). Calculated under EPSG 2927.	Calculated length

Literature Cited

Anderson, P.S., S. Meyer, P. Olson, and E. Stockdale. 2016. Determining the Ordinary High Water Mark for Shoreline Management Act Compliance in Washington State. Publication Number 16-06-029. Washington State Department of Ecology, Olympia, WA.

Beechie, T. J., O. Stefankiv, B. Timpane-Padgham, J. Hall, G. R. Pess, M. Rowse, M. Liermann, K. Fresh, and M. Ford. 2017. Monitoring salmon habitat status and trends in Puget Sound: development of sample designs, monitoring metrics, and sampling protocols for large river, floodplain, delta, and nearshore environments. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-137, Seattle, Washington.

Brennan, J., H. Culverwell, R. Gregg, and P. Granger. 2009. Protection of marine riparian functions in Puget Sound, Washington. Prepared by Washington Sea Grant for Washington Department of Fish and Wildlife, Olympia, Washington.

CGS (Coastal Geological Services). 2017. Beach Strategies Phase 1 Summary Report. Prepared for the Estuary and Salmon Restoration Program (ESRP) by Coastal Geologic Services, Inc., Bellingham, Washington. Available at: https://salishsearestoration.org/wiki/File:CGS_ESRP_BeachStrategies_SummaryReport_20171025.pdf

DOE (Washington State Department of Ecology). 2017. Shoreline Master Programs Handbook. Publication Number 11-06-010. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1106010.html

DOE (Washington State Department of Ecology). 2018. Washington State Coastal Atlas. Available at: https://fortress.wa.gov/ecy/shorephotoviewer/

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Departments of Agriculture, Commerce, and Interior. Portland, Oregon.

Hall, J., S. Burgess, and K. Ross. 2019. Chinook Salmon Progress Report: A summary of Chinook salmon habitat Common Indicators. Memorandum to the Washington State Recreation and Conservation Office and Estuary and Salmon Restoration Program, Olympia, Washington.

MacLennan, A. J., J. W. Johannessen, S. A. Williams, W. Gerstel, J. F. Waggoner, and A. Bailey. 2013. Feeder bluff mapping of Puget Sound. Prepared for the Washington

Department of Ecology and the Washington Department of Fish and Wildlife by Coastal Geologic Services, Inc., Bellingham, WA. 118 p.

National Oceanic and Atmospheric Administration (NOAA). 2021. NOAA continually updated shoreline product (CUSP). Available at: https://shoreline.noaa.gov/data/datasheets/cusp.html

Pierce, K. 2015. Accuracy optimization for high resolution object-based change detection: an example mapping regional urbanization with 1-m aerial imagery. Remote Sensing 7(10):12654-12679.

Puget Sound Ecosystem Monitoring Program Nearshore and Salmonid Work Group (PSEMP NSWG). 2019. Salmon and nearshore work groups meeting notes. University of Washington, Seattle, WA. March 29, 2019. Available at: https://pspwa.box.com/s/akuboegs4ik0fvz9f8jqa1tq4qikicq8

Washington State Department of Natural Resources (WDNR). 2001. Shorezone Inventory-Shoreline type. Available at: https://datawadnr.opendata.arcgis.com/datasets/36fc7f33340c4d9ca5497d2ab8e2984a_51/about

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2725 Montlake Boulevard East
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