# Department of Ecology Shoreline Monitoring Profiles

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# Contents

# 1 Overview

## 1.1 Project description

This analysis aims to characterize approximately 25 years of shoreline profile transect data, provided by NANOOS (Northwest Association of Networked Ocean Observing Systems). Using this data combined with area expertise, the relevant coastal areas have been delineated into reaches.

The raw data consists of approximately 4500 individual profiles across 54 coastal sites in Washington and Oregon. The profiles are in x y z format (Easting Northing elevation).The naming convention is prof_X_ssYY.out where prof is short for profile, X is the profile number, ss is a season code (e.g. f = fall) and YY is the year, in the format of the last two digits (e.g. “98” is 1998”, “00” is 2000, “08” is 2008, etc).

## 1.2 Data discrepancies

Quite a few profiles are null (empty) and have been removed and noted. See the “Explore Profiles” section for more information.

A small portion of the profiles had non-conforming filenames: “BigE06”, “beachface”, etc. These files do not represent a large percentage of the files and have not been included in the analysis.

Profiles 42 - 47 are in Oregon and have been excluded from most of the analysis.

*Geographically, profiles do not proceed sequentially.*

## 1.3 Metadata

The vertical datum is NAVD88. The horizontal is WA State Plane South. All of the units are in meters.

## 1.4 List of profiles and their geographic locations

Table 1: Profiles with Corresponding Geographic Location

| profile | location | notes |
|---|---|---|
| 1 | Haynisisoos Park, North Beach | |
| 2 | Santiago, North Beach | |
| 3 | L443, North Beach | |
| 4 | B1, North Beach | |
| 5 | A1.5, North Beach | |
| 6 | Moclips, North Beach | |
| 7 | Pacific Beach, North Beach | |
| 8 | Roosevelt Beach Rd OBA, North Beach | |

Table 1: Profiles with Corresponding Geographic Location *(continued)*

| profile | location | notes |
|---|---|---|
| 9 | Griffiths-Priday State Park, North Beach | |
| 10 | Ocean City OBA, North Beach | |
| 11 | Ocean Shores SR 115 OBA, North Beach | |
| 12 | Ocean Shores Pacific Blvd OBA, North Beach | |
| 13 | Ocean Shores Butter Clam St OBA, North Beach | |
| 14 | Ocean Shores North Jetty North, North Beach | |
| 15 | Ocean Shores North Jetty South, North Beach | |
| 16 | Westport Light North, Grayland Plains | |
| 17 | Westport Light South, Grayland Plains | |
| 18 | Westport Ocean Ave OBA, Grayland Plains | |
| 19 | Bonge Ave OBA, Grayland Plains | |
| 20 | Marine Drive OBA, Grayland Plains | |
| 21 | Cranberry Beach Road OBA, Grayland Plains | |
| 22 | Midway Beach Rd OBA, Grayland Plains | |
| 23 | Warrenton Cannery Rd OBA, Grayland Plains | |
| 24 | North Cove, Grayland Plains | |
| 25 | Leadbetter Point North, Long Beach | |
| 26 | Leadbetter Point South, Long Beach | |
| 27 | Leadbetter Point Bearberry Trail, Long Beach | |
| 28 | Leadbetter Point Hines, Long Beach | |
| 29 | Leadbetter Point 357th Pl, Long Beach | |
| 30 | Oysterville Rd OBA, Long Beach | |
| 31 | Oysterville Beach 311th St, Long Beach | |
| 32 | Oysterville Beach 295th St, Long Beach | |
| 33 | Pacific Pines, Long Beach | |
| 34 | Klipsan Beach, Long Beach | |
| 35 | Loomis Lake State Park, Long Beach | |
| 36 | Oceanside 156th Pl, Long Beach | |
| 37 | Oceanside 115th Ln, Long Beach | |
| 38 | Long Beach 11th St, Long Beach | |
| 39 | Holman, Long Beach | |
| 40 | Oceanview South, Long Beach | |
| 41 | Cape Disappointment CANBY, Long Beach | |
| 42 | Clatsop Spit | OREGON |

Table 1: Profiles with Corresponding Geographic Location *(continued)*

| profile | location | notes |
|---|---|---|
| 43 | Peter Iredale Rd OBA | OREGON |
| 44 | Delaura Beach Rd OBA | OREGON |
| 45 | Slusher Lake Rd OBA | OREGON |
| 46 | Del Rey Beach Rd OBA | OREGON |
| 47 | Seaside Beach | OREGON |
| 48 | Quinault Beach, North Beach | Located between 10 and 11 |
| 49 | Chautauqua Resort, Long Beach | Located between 37 and 38 |
| 50 | Seaview, Long Beach | Located between 38 and 39 |
| 51 | Beard's Hollow Cape Disappointment, Long Beach | Located between 40 and 52 |
| 52 | A Loop Cape Disappointment, Long Beach | |
| 53 | Benson Beach North Cape Disappointment, Long Beach | |
| 54 | Benson Beach South Cape Disappointment, Long Beach | |

## 2 Individual profiles, single year visualization

Below is a rendering of a single profile for a single year (in this case, profile 17, located near Westport Light State Park).

This is a direct plot of the x y z coordinates to understand the general idea of the data format. It is *not* a geographic representation of the data.

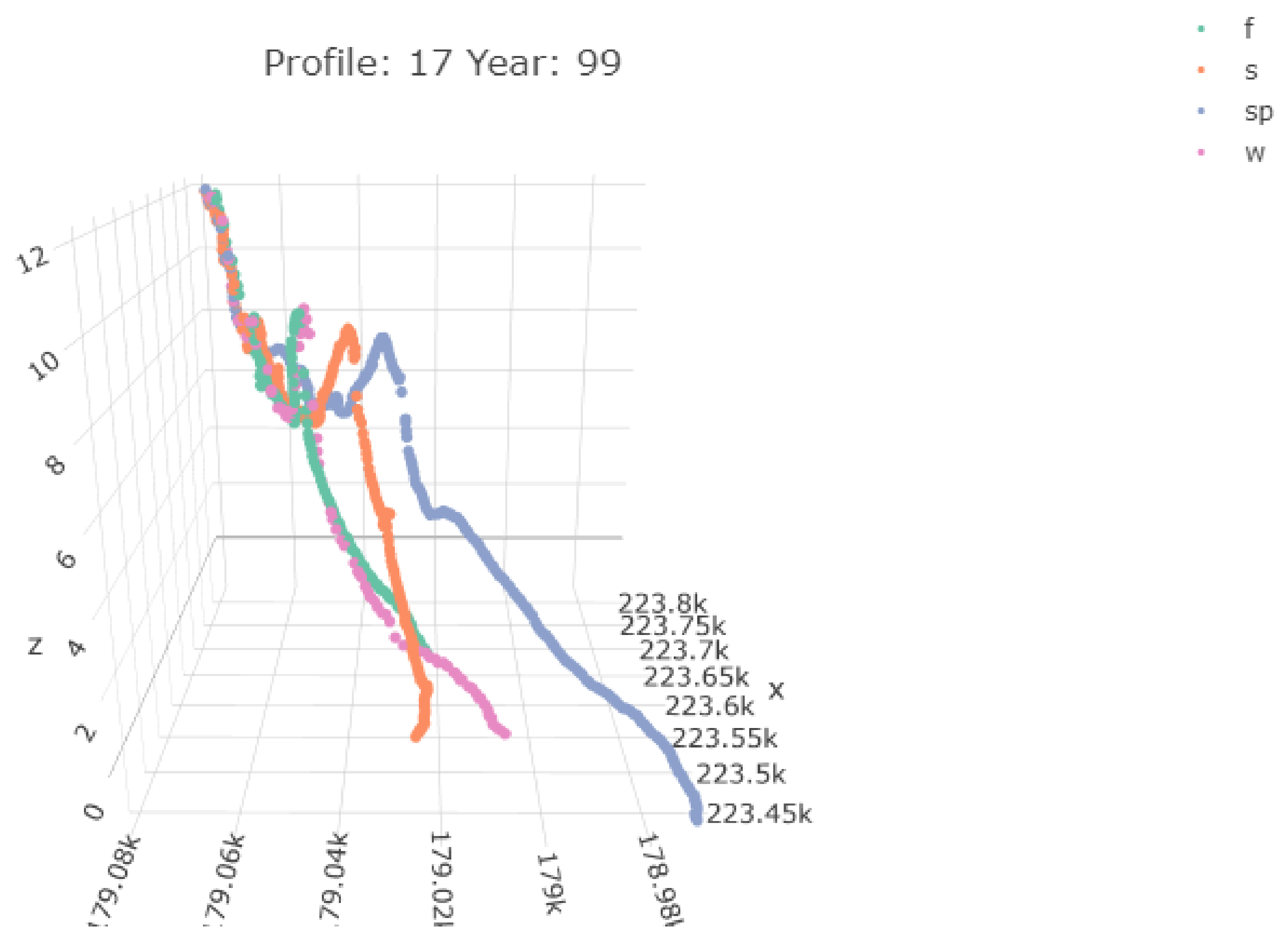


Figure 1: Profile 17 near Westport Light State Park, from the year 1999.

# 3 Individual profiles, all available years visualization

Below is a rendering of a single profile (again, profile 17 from Westport State Light) over all the available years. The orange horizontal plane represents the approximate mean high high water (MHHW) mark, as a proxy for understanding how the transect data is shifting over time.

## 3.1 Times series representation

It can also be helpful to see the above plot spread over time, to provide a clearer picture of profile migration.

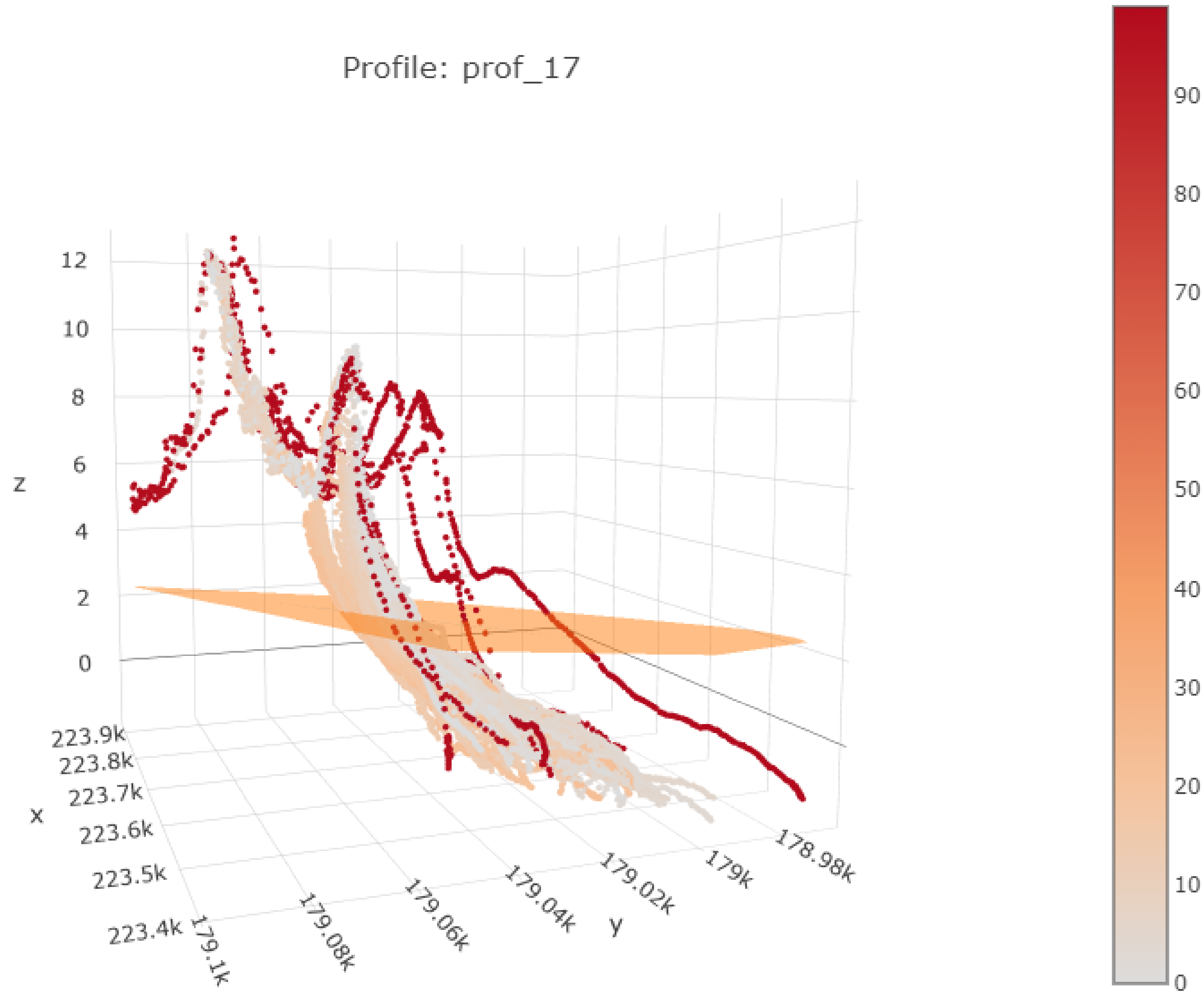


Figure 2: Profile 17 near Westport Light State Park, including all available years of data and a horizontal plane of the Mean High High Water mark.

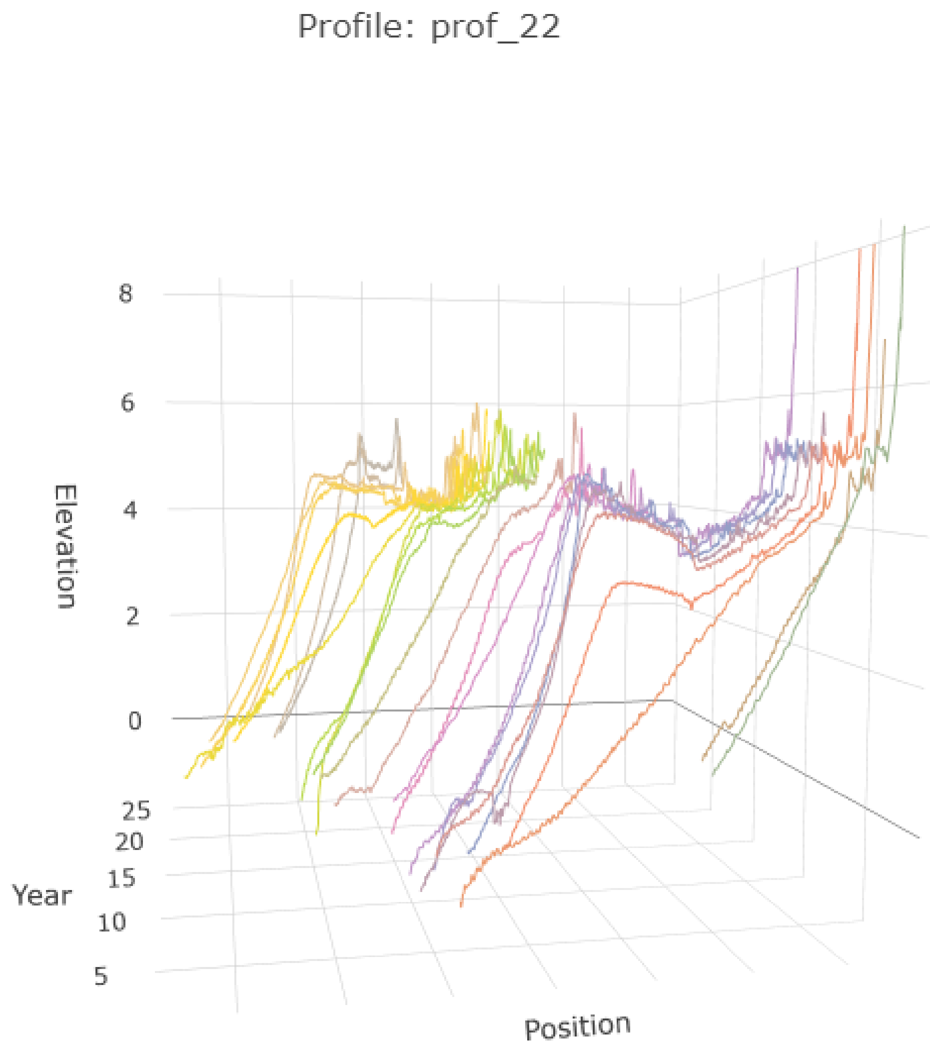


Figure 3: Profile 17 near Westport Light State Park, including all available years of data.

## 4 The "BasePoint" reference line and Euclidean distance as an accretion/erosion proxy

In order to quantify shoreline change, an arbitrary "BasePoint" reference line, approximately parallel to the shoreline, was drawn at a reasonable distance from the profiles so as to be unaffected by temporal change.

The NANOOS profiles are perpendicular to this BasePoint, allowing for a reference against which to calculate spatial change.

In order to visualize this concept, the images below display 1) a simplified selection of profiles (plotted in black) compared to the BasePoint (plotted in red) and 2) an individual profile (plotted in black) and its BasePoint (plotted in red).

Using Euclidean distance, migrations of the transects over time as compared to the BasePoint act as proxies for accretion and erosion.

The midpoint of each transect is calculated to determine a single comparative point using the midpoint formula pictured below.

$$\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$$

The Euclidean distance between the midpoint and the fixed BasePoint is calculated for each transect and each year, resulting in an increasing or decreasing Euclidean distance. This distances correlates to an accreting or eroding transect.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

| | |
|---|---|
| Increasing Euclidean distance | Accretion |
| Decreasing Euclidean distance | Erosion |

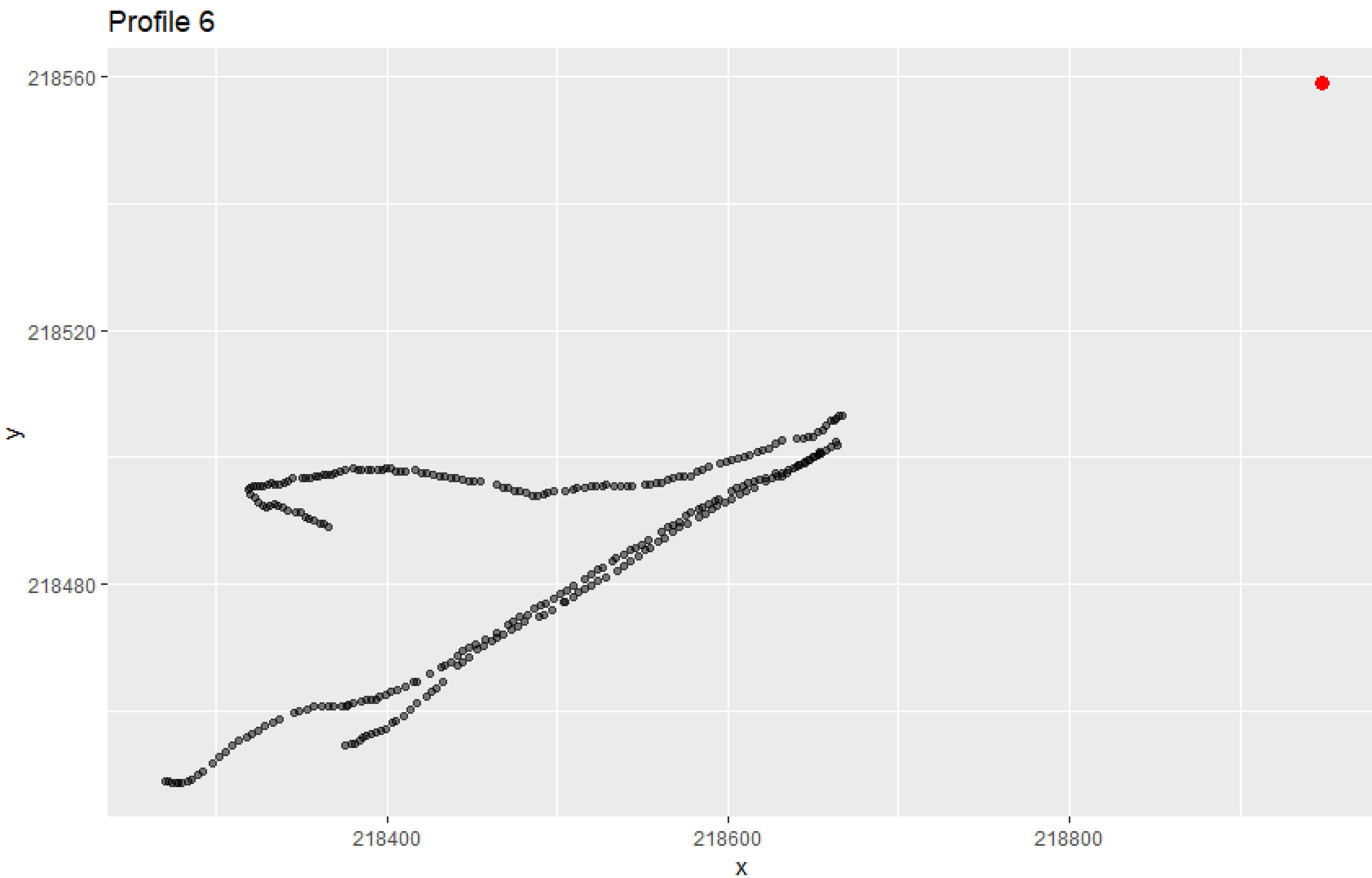


Figure 4: Profile 6 plotted in x y format, compared to a fixed inland basepoint (plotted in red in the upper right hand corner).


Figure 5: Profiles 6 - 9 plotted in x y format, compared to a fixed inland basepoint (plotted in red).

## 5 Determining significance in accretion and erosion classifications for profiles.

Apply the midpoint formula and distance formula to each transect/BasePoint pair, and plot the movement of the midpoint over time. This produces an x:y, distance:time relationship to which a linear model can be fitted. Once the linear model has been produced, the slope and p values can be extracted and used as respective indicators of transect characterization and significance.

If the slope of a given distance:time relationship is positive, this indicates the distance between the transect midpoint and the BasePoint is increasing and the shoreline is accreting. If the slope is negative, the distance is decreasing and the shoreline is eroding. Linear models with a pvalue $< 0.05$ are considered significant.

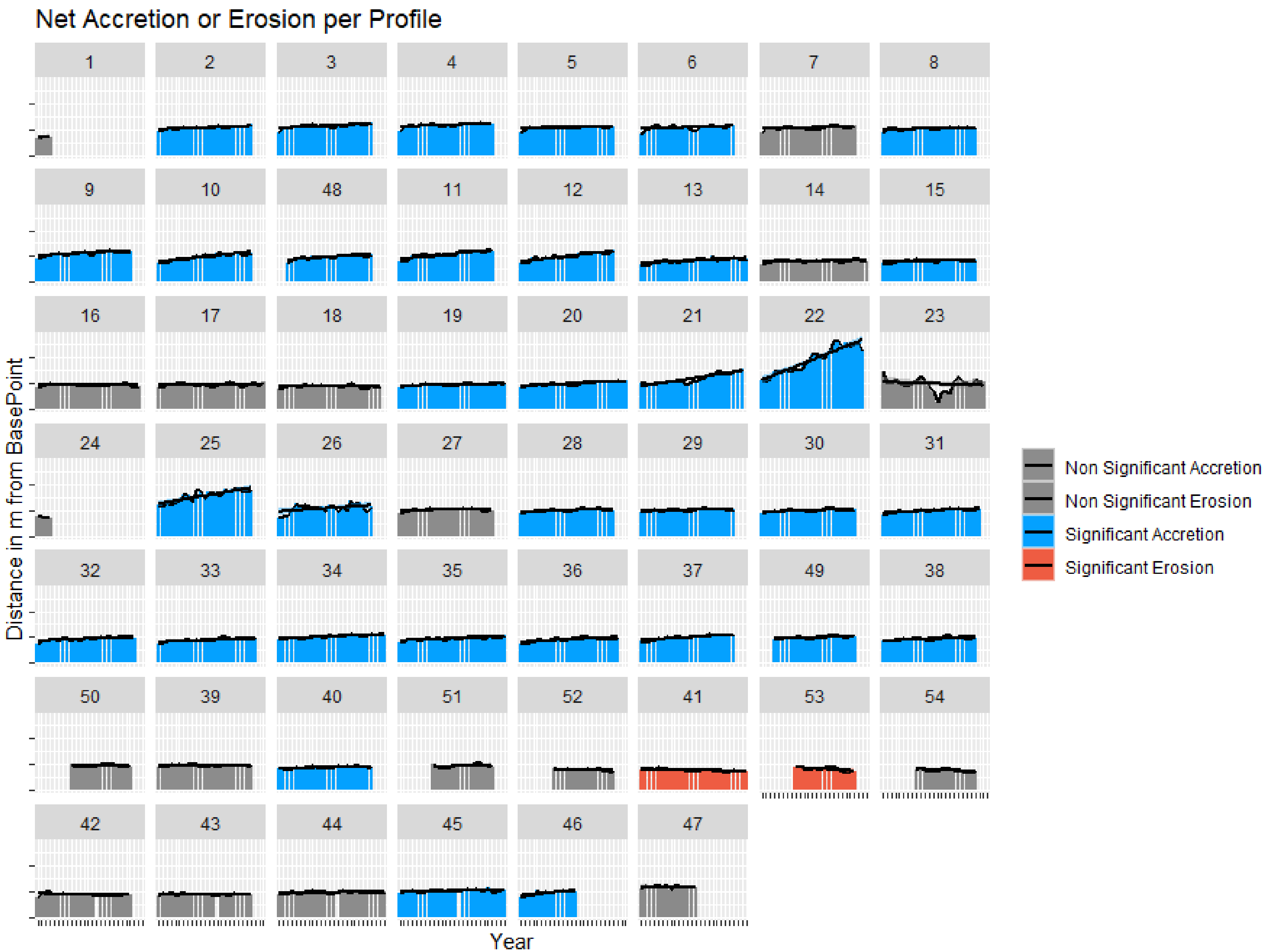


Figure 6: Euclidean distance of transect midpoints over time.

# 6 Assign status to each profile according to linear regression equation details.

Below is a table with the relevant results of each profile's linear regression over time, including pvalues (less than 0.05 indicates a significant relationship), rsquared values (indicitive of how good the fit of the regression is) and the Pearson correlation (how closely are time and euclidean distance, or x and y, related).

Table 3: Linear equation parameters

| profile | Park | shoreline_profile | slope | rsq | se | pvalue | pearson_correlation |
|---|---|---|---|---|---|---|---|
| 1 | Haynisisoos Park, North Beach | Non Significant Accretion | 3.29 | 0.11 | 15.07 | 0.67 | 0.33 |
| 2 | Santiago, North Beach | Significant Accretion | 3.03 | 0.47 | 22.18 | 0.00 | 0.69 |
| 3 | L443, North Beach | Significant Accretion | 3.98 | 0.43 | 32.17 | 0.00 | 0.65 |
| 4 | B1, North Beach | Significant Accretion | 2.84 | 0.40 | 24.11 | 0.00 | 0.63 |
| 5 | A1.5, North Beach | Significant Accretion | 2.24 | 0.28 | 24.68 | 0.01 | 0.53 |
| 6 | Moclips, North Beach | Significant Accretion | 2.66 | 0.19 | 38.56 | 0.04 | 0.43 |
| 7 | Pacific Beach, North Beach | Non Significant Accretion | 2.07 | 0.17 | 31.74 | 0.05 | 0.41 |
| 8 | Roosevelt Beach Rd OBA, North Beach | Significant Accretion | 1.93 | 0.24 | 23.89 | 0.02 | 0.49 |
| 9 | Griffiths-Priday State Park, North Beach | Significant Accretion | 4.56 | 0.61 | 25.12 | 0.00 | 0.78 |
| 10 | Ocean City OBA, North Beach | Significant Accretion | 9.00 | 0.80 | 31.53 | 0.00 | 0.89 |
| 11 | Ocean Shores SR 115 OBA, North Beach | Significant Accretion | 8.20 | 0.73 | 34.40 | 0.00 | 0.86 |
| 12 | Ocean Shores Pacific Blvd OBA, North Beach | Significant Accretion | 9.11 | 0.78 | 33.42 | 0.00 | 0.88 |
| 13 | Ocean Shores Butter Clam St OBA, North Beach | Significant Accretion | 4.22 | 0.55 | 29.80 | 0.00 | 0.74 |
| 14 | Ocean Shores North Jetty North, North Beach | Non Significant Accretion | 0.90 | 0.05 | 29.33 | 0.25 | 0.23 |
| 15 | Ocean Shores North Jetty South, North Beach | Significant Accretion | 2.36 | 0.32 | 24.05 | 0.01 | 0.56 |
| 16 | Westport Light North, Grayland Plains | Non Significant Accretion | 0.26 | 0.01 | 21.26 | 0.66 | 0.09 |
| 17 | Westport Light South, Grayland Plains | Non Significant Accretion | 0.89 | 0.04 | 32.97 | 0.31 | 0.21 |
| 18 | Westport Ocean Ave OBA, Grayland Plains | Non Significant Accretion | 0.46 | 0.01 | 30.24 | 0.59 | 0.11 |
| 19 | Bonge Ave OBA, Grayland Plains | Significant Accretion | 1.68 | 0.37 | 17.07 | 0.00 | 0.61 |
| 20 | Marine Drive OBA, Grayland Plains | Significant Accretion | 3.96 | 0.74 | 18.22 | 0.00 | 0.86 |
| 21 | Cranberry Beach Road OBA, Grayland Plains | Significant Accretion | 12.22 | 0.84 | 40.61 | 0.00 | 0.91 |
| 22 | Midway Beach Rd OBA, Grayland Plains | Significant Accretion | 32.59 | 0.88 | 91.95 | 0.00 | 0.94 |
| 23 | Warrenton Cannery Rd OBA, Grayland Plains | Non Significant Erosion | -2.81 | 0.03 | 127.40 | 0.43 | -0.16 |
| 24 | North Cove, Grayland Plains | Non Significant Erosion | -8.61 | 0.53 | 12.86 | 0.27 | -0.73 |
| 25 | Leadbetter Point North, Long Beach | Significant Accretion | 13.85 | 0.68 | 65.92 | 0.00 | 0.82 |
| 26 | Leadbetter Point South, Long Beach | Significant Accretion | 5.55 | 0.19 | 79.72 | 0.04 | 0.43 |
| 27 | Leadbetter Point Bearberry Trail, Long Beach | Non Significant Accretion | 1.22 | 0.08 | 29.19 | 0.20 | 0.28 |
| 28 | Leadbetter Point Hines, Long Beach | Significant Accretion | 2.74 | 0.32 | 27.96 | 0.01 | 0.56 |
| 29 | Leadbetter Point 357th Pl, Long Beach | Significant Accretion | 2.23 | 0.29 | 24.39 | 0.01 | 0.54 |

Table 3: Linear equation parameters *(continued)*

| profile | Park | shoreline_profile | slope | rsq | se | pvalue | pearson_correlation |
|---|---|---|---|---|---|---|---|
| 30 | Oysterville Rd OBA, Long Beach | Significant Accretion | 2.55 | 0.32 | 25.68 | 0.00 | 0.57 |
| 31 | Oysterville Beach 311th St, Long Beach | Significant Accretion | 3.90 | 0.60 | 22.98 | 0.00 | 0.78 |
| 32 | Oysterville Beach 295th St, Long Beach | Significant Accretion | 3.40 | 0.49 | 25.20 | 0.00 | 0.70 |
| 33 | Pacific Pines, Long Beach | Significant Accretion | 3.34 | 0.56 | 21.51 | 0.00 | 0.75 |
| 34 | Klipsan Beach, Long Beach | Significant Accretion | 3.53 | 0.68 | 18.80 | 0.00 | 0.83 |
| 35 | Loomis Lake State Park, Long Beach | Significant Accretion | 3.17 | 0.47 | 25.99 | 0.00 | 0.69 |
| 36 | Oceanside 156th Pl, Long Beach | Significant Accretion | 4.27 | 0.52 | 29.89 | 0.00 | 0.72 |
| 37 | Oceanside 115th Ln, Long Beach | Significant Accretion | 5.11 | 0.71 | 22.67 | 0.00 | 0.84 |
| 38 | Long Beach 11th St, Long Beach | Significant Accretion | 3.53 | 0.44 | 27.86 | 0.00 | 0.66 |
| 39 | Holman, Long Beach | Non Significant Accretion | 0.29 | 0.01 | 18.96 | 0.63 | 0.10 |
| 40 | Oceanview South, Long Beach | Significant Accretion | 2.06 | 0.35 | 19.42 | 0.00 | 0.59 |
| 41 | Cape Disappointment CANBY, Long Beach | Significant Erosion | -2.01 | 0.43 | 18.25 | 0.00 | -0.65 |
| 42 | Clatsop Spit | Non Significant Erosion | -1.36 | 0.14 | 22.15 | 0.08 | -0.38 |
| 43 | Peter Iredale Rd OBA | Non Significant Erosion | -0.75 | 0.06 | 20.28 | 0.29 | -0.24 |
| 44 | Delaura Beach Rd OBA | Non Significant Accretion | 1.09 | 0.08 | 27.48 | 0.17 | 0.28 |
| 45 | Slusher Lake Rd OBA | Significant Accretion | 1.55 | 0.19 | 24.04 | 0.03 | 0.44 |
| 46 | Del Rey Beach Rd OBA | Significant Accretion | 7.64 | 0.60 | 27.27 | 0.00 | 0.77 |
| 47 | Seaside Beach | Non Significant Erosion | -0.98 | 0.01 | 36.02 | 0.69 | -0.12 |
| 48 | Quinault Beach, North Beach | Significant Accretion | 5.52 | 0.63 | 26.85 | 0.00 | 0.79 |
| 49 | Chautauqua Resort, Long Beach | Significant Accretion | 2.71 | 0.34 | 23.19 | 0.01 | 0.58 |
| 50 | Seaview, Long Beach | Non Significant Accretion | 0.55 | 0.01 | 22.80 | 0.69 | 0.11 |
| 51 | Beard’s Hollow Cape Disappointment, Long Beach | Non Significant Accretion | 2.88 | 0.15 | 31.27 | 0.15 | 0.39 |
| 52 | A Loop Cape Disappointment, Long Beach | Non Significant Erosion | -1.97 | 0.16 | 20.58 | 0.13 | -0.41 |
| 53 | Benson Beach North Cape Disappointment, Long Beach | Significant Erosion | -5.12 | 0.30 | 36.44 | 0.04 | -0.55 |
| 54 | Benson Beach South Cape Disappointment, Long Beach | Non Significant Erosion | -4.00 | 0.25 | 32.21 | 0.06 | -0.50 |

## 7 Comparison of results to Washington Coastal Erosion Hazard Assessment (WCEHA)

The WCEHA (https://waecy.maps.arcgis.com/apps/View/index.html?appid=389d0a3ce642485db912d4a416a56e25) is a second database that can be used as a comparison to the results from the NANOOS profiles.

Table 4: Comparison with WCEHA data

| profile | Park | shoreline_profile | WCEHA | conflict |
|---|---|---|---|---|
| 1 | Haynisisoos Park, North Beach | Accreted | Accreted | |
| 2 | Santiago, North Beach | Accreted | Accreted | |
| 3 | L443, North Beach | Accreted | Accreted | |
| 4 | B1, North Beach | Accreted | Accreted | |
| 5 | A1.5, North Beach | Accreted | Accreted | |
| 6 | Moclips, North Beach | Accreted | Accreted | |
| 7 | Pacific Beach, North Beach | Accreted | Accreted | |
| 8 | Roosevelt Beach Rd OBA, North Beach | Accreted | Accreted | |
| 9 | Griffiths-Priday State Park, North Beach | Accreted | Accreted | |
| 10 | Ocean City OBA, North Beach | Accreted | Accreted | |
| 11 | Ocean Shores SR 115 OBA, North Beach | Accreted | Accreted | |
| 12 | Ocean Shores Pacific Blvd OBA, North Beach | Accreted | Accreted | |
| 13 | Ocean Shores Butter Clam St OBA, North Beach | Accreted | Accreted | |
| **14** | **Ocean Shores North Jetty North, North Beach** | **Accreted** | **Erosion** | **flag** |
| **15** | **Ocean Shores North Jetty South, North Beach** | **Accreted** | **Erosion** | **flag** |
| **16** | **Westport Light North, Grayland Plains** | **Accreted** | **Erosion** | **flag** |
| **17** | **Westport Light South, Grayland Plains** | **Accreted** | **Erosion** | **flag** |
| 18 | Westport Ocean Ave OBA, Grayland Plains | Accreted | Accreted | |
| 19 | Bonge Ave OBA, Grayland Plains | Accreted | Accreted | |
| 20 | Marine Drive OBA, Grayland Plains | Accreted | Accreted | |
| 21 | Cranberry Beach Road OBA, Grayland Plains | Accreted | Accreted | |
| 22 | Midway Beach Rd OBA, Grayland Plains | Accreted | Accreted | |
| **23** | **Warrenton Cannery Rd OBA, Grayland Plains** | **Erosion** | **Accreted** | **flag** |
| 24 | North Cove, Grayland Plains | Erosion | Erosion | |
| 25 | Leadbetter Point North, Long Beach | Accreted | Accreted | |
| **26** | **Leadbetter Point South, Long Beach** | **Accreted** | **Erosion** | **flag** |
| 27 | Leadbetter Point Bearberry Trail, Long Beach | Accreted | Accreted | |
| 28 | Leadbetter Point Hines, Long Beach | Accreted | Accreted | |
| 29 | Leadbetter Point 357th Pl, Long Beach | Accreted | Accreted | |
| 30 | Oysterville Rd OBA, Long Beach | Accreted | Accreted | |

Table 4: Comparison with WCEHA data *(continued)*

| profile | Park | shoreline_profile | WCEHA | conflict |
|---|---|---|---|---|
| 31 | Oysterville Beach 311th St, Long Beach | Accreted | Accreted | |
| 32 | Oysterville Beach 295th St, Long Beach | Accreted | Accreted | |
| 33 | Pacific Pines, Long Beach | Accreted | Accreted | |
| 34 | Klipsan Beach, Long Beach | Accreted | Accreted | |
| 35 | Loomis Lake State Park, Long Beach | Accreted | Accreted | |
| 36 | Oceanside 156th Pl, Long Beach | Accreted | Accreted | |
| 37 | Oceanside 115th Ln, Long Beach | Accreted | Accreted | |
| 38 | Long Beach 11th St, Long Beach | Accreted | Accreted | |
| 39 | Holman, Long Beach | Accreted | Accreted | |
| 40 | Oceanview South, Long Beach | Accreted | Accreted | |
| 41 | Cape Disappointment CANBY, Long Beach | Erosion | Erosion | |
| 42 | Clatsop Spit | Erosion | | |
| 43 | Peter Iredale Rd OBA | Erosion | | |
| 44 | Delaura Beach Rd OBA | Accreted | | |
| 45 | Slusher Lake Rd OBA | Accreted | | |
| 46 | Del Rey Beach Rd OBA | Accreted | | |
| 47 | Seaside Beach | Erosion | | |
| 48 | Quinault Beach, North Beach | Accreted | Accreted | |
| 49 | Chautauqua Resort, Long Beach | Accreted | Accreted | |
| 50 | Seaview, Long Beach | Accreted | Accreted | |
| **51** | **Beard's Hollow Cape Disappointment, Long Beach** | **Accreted** | **Erosion** | **flag** |
| 52 | A Loop Cape Disappointment, Long Beach | Erosion | Erosion | |
| 53 | Benson Beach North Cape Disappointment, Long Beach | Erosion | Erosion | |
| 54 | Benson Beach South Cape Disappointment, Long Beach | Erosion | Erosion | |

## 7.1 Some notes on comparisons between the NANOOS analysis and the WCEHA data

The profiles that don't match up with WCEHA data are:

- Profiles 14 and 15 at the North Jetty
  - These two profiles fall into a small "erosion" classification according to the WCEHA data, and are located at a highly dynamic shoreline zone.
- Profiles 16 and 17 (Westport Light North and South)
  - Both profiles' NANOOS classification of "accretion" conflicts with the WCEHA classifcation of "erosion". It's true that Westport North is

eroding overall, but WCEHA contains data from 2006 - 2019, and NANOOS contains data from 1997 - 2022. NANOOS incorporates the geomorphologically impactful Army Corp nourishment more holistically. Both of the Westport profiles were “non significant” accretion, and speaks to the volatility of shorelines on the peninsula.

- Profile 23, located at Warrenton Cannery road, is delineated as non-significant erosion within the NANOOS profiles. This results from a dramatic shoreline change around 2008 where a large chunk of the coast was eroded very quickly before returning to accretion. Profile 23 falls within a section of coastline that has been subject to extreme erosion and accretion over the past several decades, and is currently accreting.
- Profile 26, one of the Leadbetter Point profiles, falls into a very small ‘erosion’ window on the WCEHA dataset on an otherwise accreting peninsula. This slice of land is also the site of vegetation clearance for snowy plover habitat, potentially complicating the aerial-imagery-based WCEHA designation.
- Profile 51, slightly north of the North Head lighthouse. NANOOS indicates accretion and WCEHA indicates erosion, however, this is also a non-significant data point from the NANOOS profile. Additionally, this point is influenced by the presence of the North Head outcropping.

# 8 Quartile Points and Change Rates

Using the midpoint of each transect selects a single point as a proxy for erosion through time. This can obscure the inherent variation in the collection of profiles.

The profiles have roughly linear relationships due to the geographic layout: in general, a change in x (moving along the Easting plane) will result in a *roughly* equal change in y (the Northing plane). Therefore, a linear regression can be applied to the x and y variables of each profile to obtain a line proxy rather than a single point.

Below are images of a single profile and year to see the applied linear regression. In the first image, a linear regression is overlaid onto a single profile, and in the second, the linear quartiles of the regression are added. Note that in the second image, the red "BasePoint" has been included to visualize distance.

These quartiles are labeled "minimum", "quartile1", "median", "quartile3", and "maximum" in accordance with standard boxplot parameters, although they are calculated using *only distance* and not boxplot delineations.

Characterizing the profiles with more points allows for a more detailed look at erosion and accretion rates.

Each quartile's Euclidean movement is tracked over time, using the same calculations as the midpoint proxy used above. The rate of change is then calculated for each quartile of each profile, using a standard rate of change calculation between each year:

$$\frac{EucDist_2 - EucDist_1}{EucDist_1} \times 100\%$$

EucDist2 is the more recent year, and EucDist1 is the older year. This is calculated for each set of years from 1997 - 2022. For each profile, the average rate of change (ROC) between all quartiles is taken.

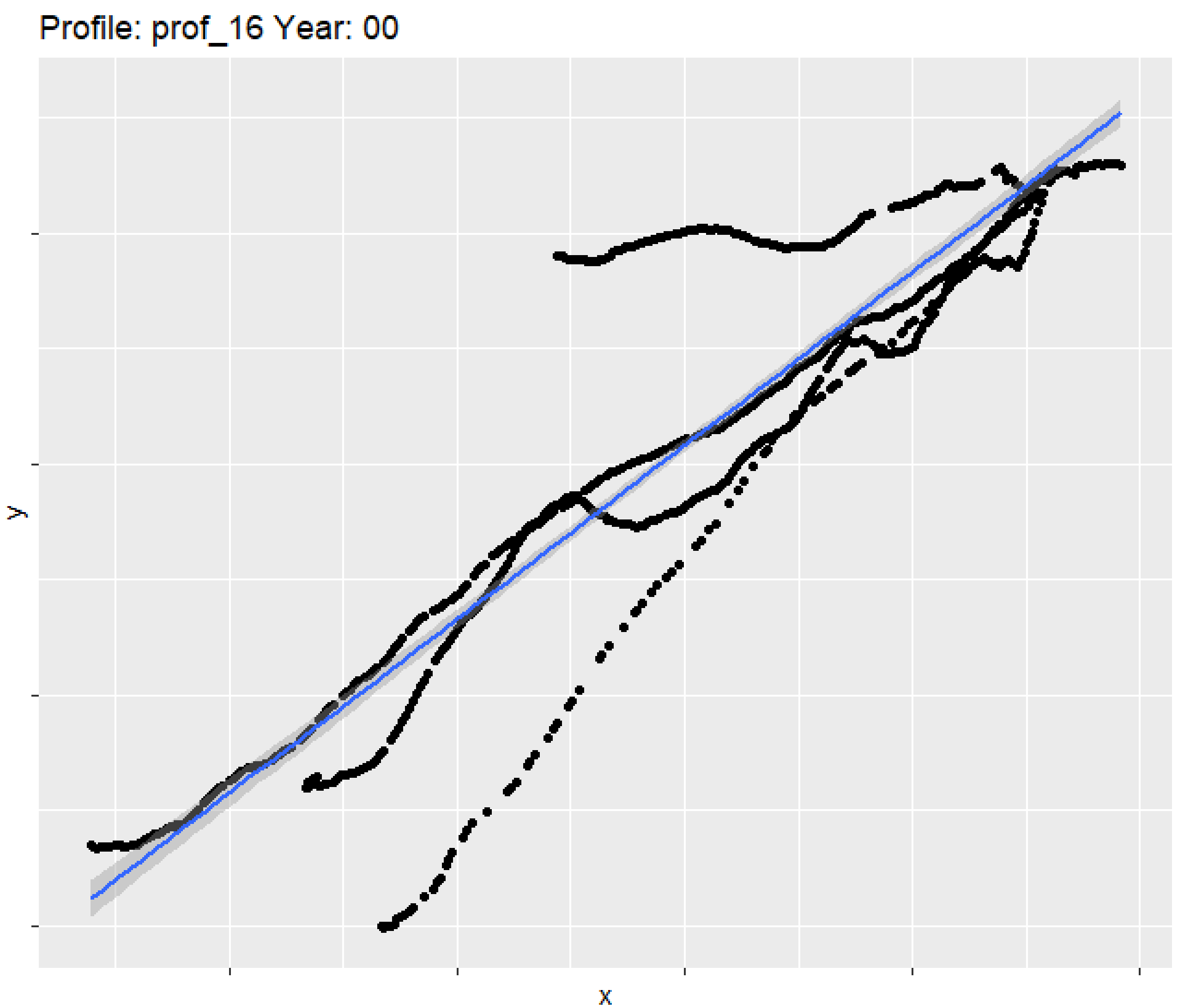


Figure 7: Linear regression (plotted in blue) overlaid on the profile 16 transect data points (plotted in black) from 2000.

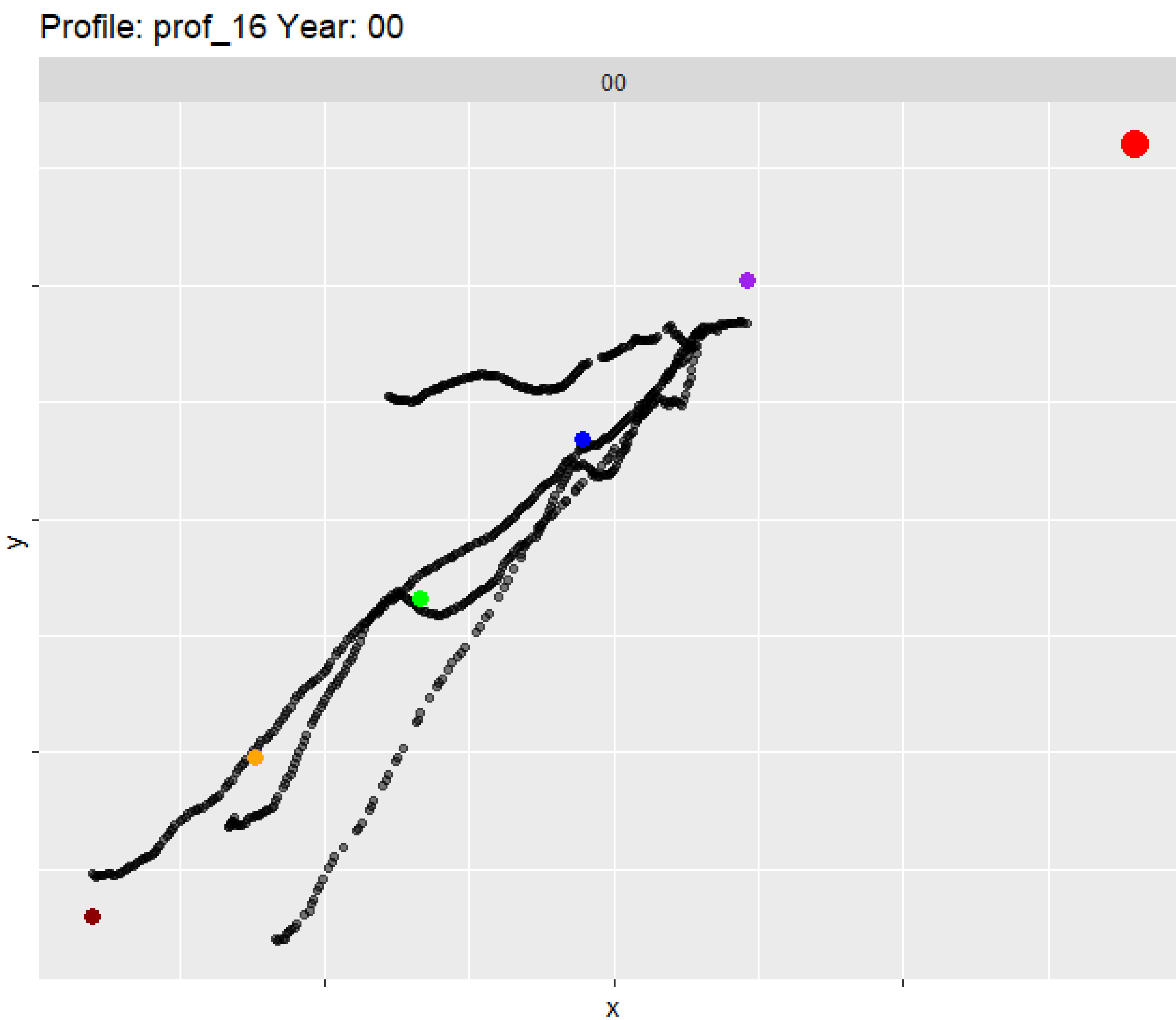


Figure 8: Distance-calculated quartiles (plotted in colorful points over the black data points) of profile 16 in the year 2000, including the fixed BasePoint (plotted in red, upper right corner).

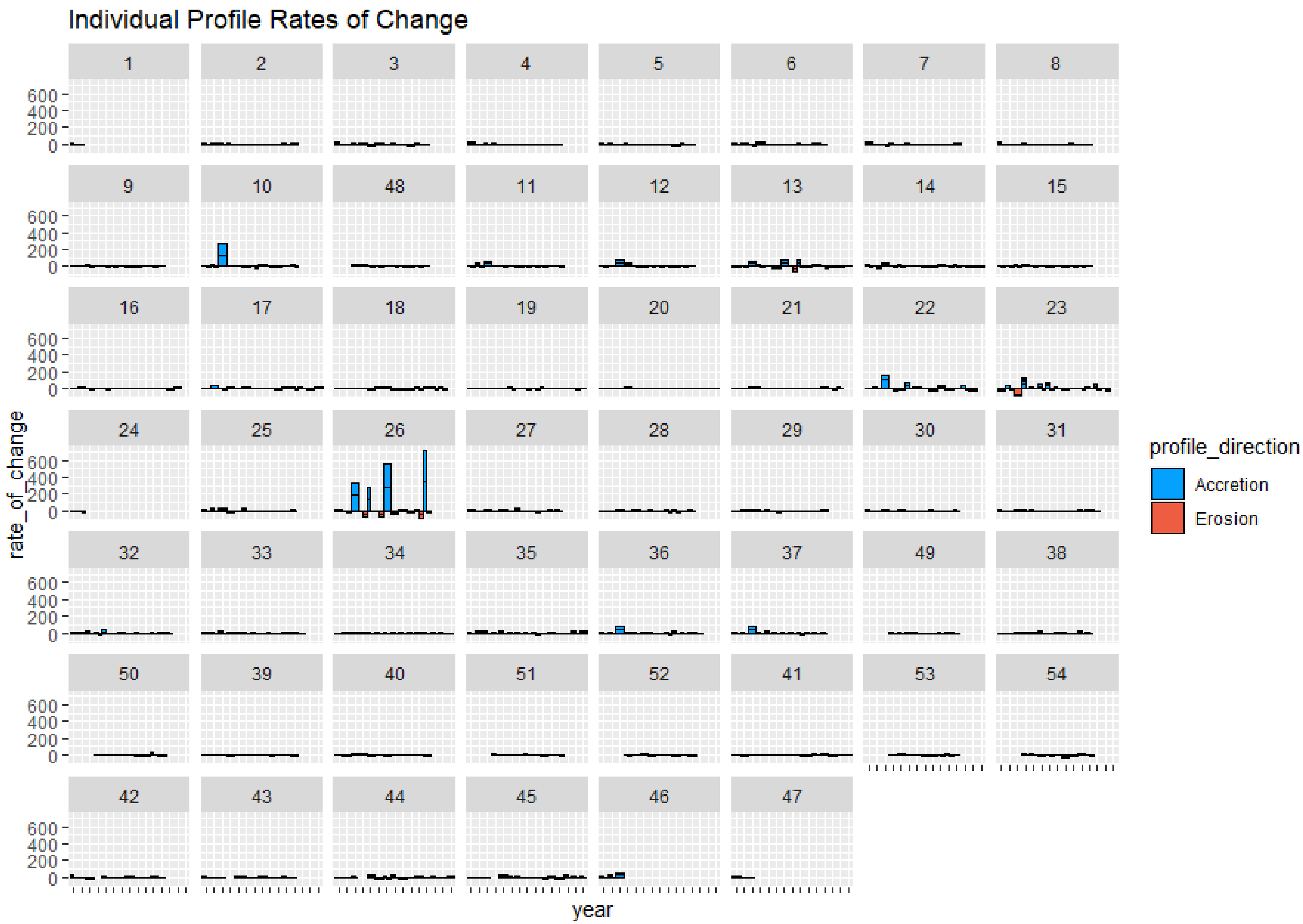


Figure 9: Annual rates of change for each profile.

# 9 Clustering profiles into geographic reaches.

Using the Euclidean distance between the quartile mean and the BasePoint, there is now data available for clustering. By clustering the Euclidean movement of the profiles over time, geographic reaches of profiles with similar movements can be determined.

This analysis applies unsupervised clustering, as the input is unlabeled, untrained data.No prior information will be given to complete the analysis, such as the number of groups into which the data could be sorted. The unsupervised clustering applied in this analysis is hierarchical agglomerative clustering, a type of clustering algorithm used to group together similar data points based on pairwise similarity.

The algorithm starts with each data point in its own cluster, and then iteratively merges clusters that are most similar to each other, based on a chosen distance or similarity metric. This merging process continues until all the data points belong to a single cluster, forming a dendrogram, or hierarchical tree of clusters.

This is an appropriate technique for this analysis because the reaches will be determined first by the clustering, and then geographic expertise will be applied to ensure the numerical clustering is properly delineated by geographic features.

## 9.1 Preparing the data

Clustering is very sensitive to outliers, so those profiles that display high variability compared to the full dataset will be removed and grouped into their own reach. Profiles 21 - 26 will be considered their own subreach, according to the boxplot below.

Once the outliers have been removed, all missing values must also be removed. Clustering can only be performed on complete data, and so any profiles are years that are incomplete must be dropped.

Next, data must be scaled. Clustering algorithms are distance-based and can be sensitive to the different scales of input variables. For example, if one variable has a range of values between 0 and 1, and another variable has a range of values between 0 and 1000, the latter variable may dominate the distance measure and make the clusters more sensitive to changes in that variable.

Create a distance matrix that computes and returns the distance between rows, using the default “euclidean” method.

## 9.2 Clustering and dendograms

Next, the clustering algorithm will be applied to this distance matrix using a variance-minimizing method known as “ward.D2”. This is a hierarchical clustering algorithm that seeks to minimize the variance within each cluster, rather than using simple “closest neighbor” clustering.

Merge the two points that are closest to each other based on this variance minimization. This removes one cluster and also corresponds to the first height of the cluster dendogram. Reapply the algorithm with the new number of clusters and continue to combine. This continues until all clusters have been merged.

Create a dendogram using the history of the point combination, which shows the sequence of combinations of the clusters. The distances of merge between clusters, called heights, are illustrated on the y-axis.

The above dendogram shows the clustering process, and highlights the decision to “cut” the tree into four clusters based on dendogram height.

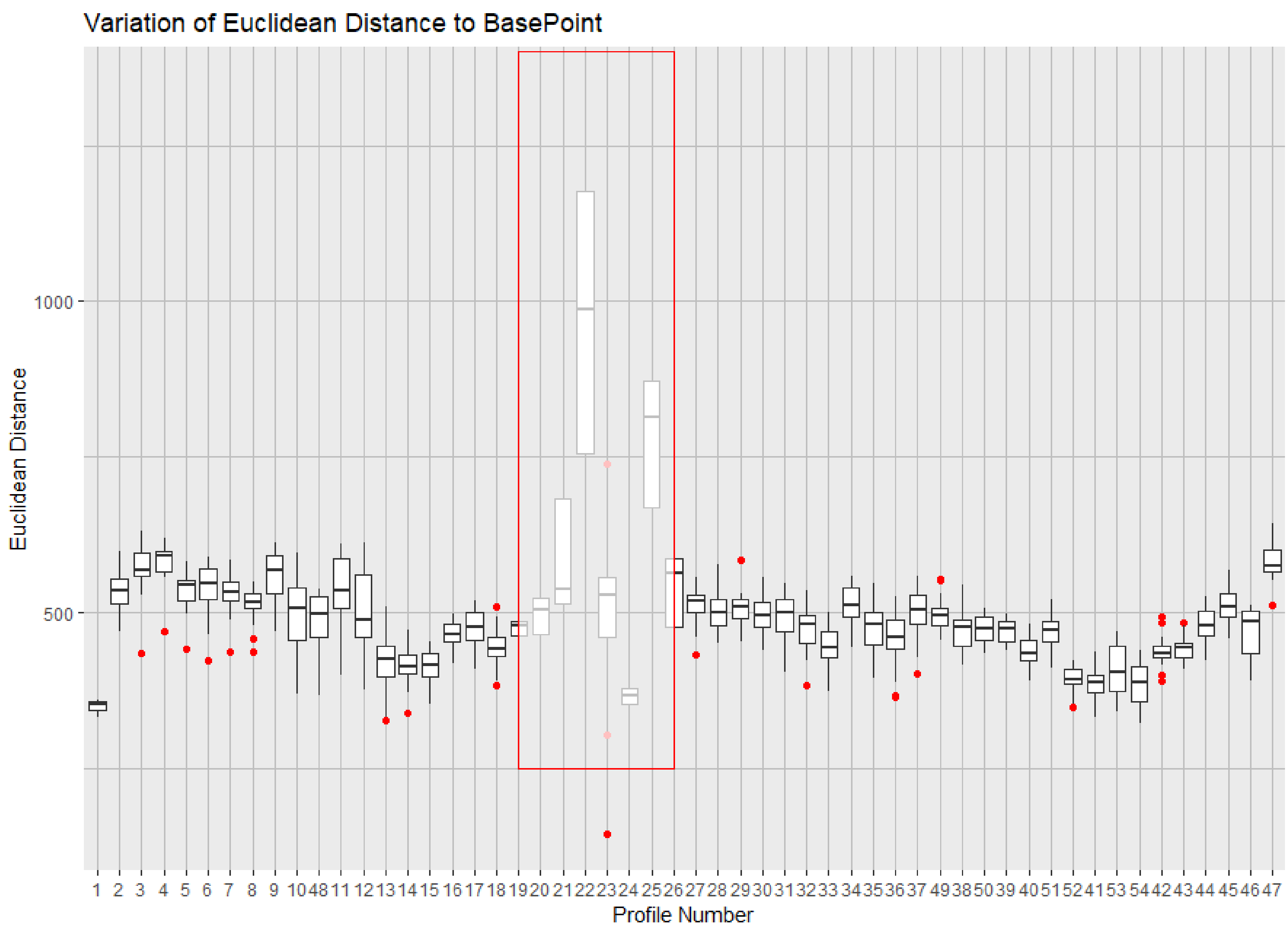


Figure 10: Boxplot of Euclidean distances, highlighting those profiles that will be removed before clustering analysis.

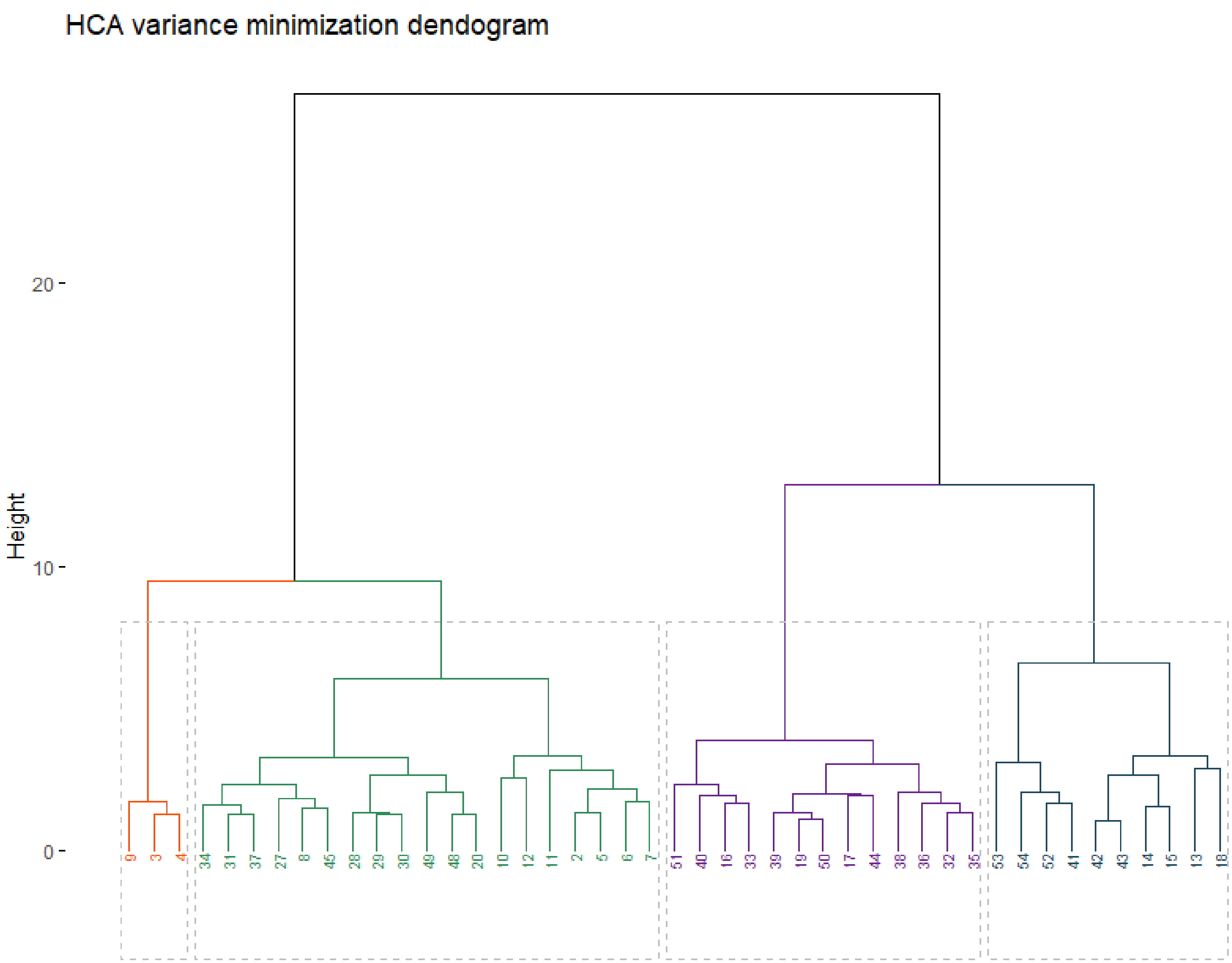


Figure 11: Dendogram of clustered profiles.

## 9.3 Final table with clustering and change rates

With each profile assigned a cluster, the final table of reaches is made combining geographic knowledge informed by the numerical clustering.

Table 5: Final table

| Reach | Change_Rate | Zone | Description |
|---|---|---|---|
| A | 1.74 | North Beach Accretion Zone | Relatively stable and steady accretion |
| B1 | 1.56 | North Beach Transition Zone | Marks a transition between steady accretion decreased rates of accertion |
| B2 | 0.95 | North Jetty Dynamic Zone | An area of shifting erosion and accretion, influenced by the shoreline armor at the entrance to North Bay, and defies broad characterization due to many environmental and manmade factors |
| B3 | 0.52 | Westport North Dynamic Zone | Highly built environment, frequently nourished by the Army Corps of Engineers and influenced by sediment input and the Westport Jetty |
| B4 | 0.91 | Westport South Dynamic Zone | Another dynamic environment, marked by shoreline development influencing wave action and sediment transport |
| C | 1.09 | South Beach Transition Zone | Breakpoint between Westport and the highly dynamic zone at the entrance to Willapa Bay |
| D1 | 2.70 | Washaway Beach Dynamic Zone | Highly dynamic, highly volatile and uncertain area of rapid erosion at the south end of the entrance to Willapa Bay accompanied by rapid accretion to the north |
| D2 | 2.92 | Leadbetter Accretion Zone | Strong rates of accretion and buildout of beaches |
| E | 0.77 | Long Beach North Accretion Zone | Characterized by moderate, stable accretion |
| F | 1.25 | Long Beach Mid Accretion Zone | Small zone of increased accretion |
| G | 0.74 | Long Beach OBA Influence Zone | Another small subreach of decreased rates of accretion, potentially influenced by the presence of a heavily used OBA near a suburb of Klipsan beach |
| H | 1.40 | Long Beach South Accretion Zone | Steady, relatively high levels of accertion present through this area |
| I | 0.88 | Long Beach South Mid Zone | Small subreach of decreased accertion rates as erosion begins |
| J | 0.06 | Long Beach South Transition Zone | Area of fluctuation but overall erosion, potentially stabilized by the North Head Lighthouse outcropping |
| M | -0.78 | Long Beach South Erosion Zone | Highly unstable area of strong erosion |