The ShoreZone Coastal Vulnerability Indices

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Background

The Alaska ShoreZone program is a coastal habitat mapping system that has been widely applied in Alaska and presently covers about 80% of the Alaska shoreline. A protocol is used so that the mapping follows explicit procedures and is consistent from region to region. In 2011, the ShoreZone program began mapping in arctic regions where permafrost significantly affects the coastal morphology and processes. The initial arctic mapping was funded by the Bureau of Ocean and Energy Management (BOEM) and the Arctic Landscape Conservation Cooperative (ALCC) for the North Slope of Alaska through a contract to Nuka Planning and Research and Coastal & Ocean Resources. As part of that contract, the existing ShoreZone Mapping Protocol (Harney et al 2008) was revised to include permafrost shorelines (Harper and Morris 2013)[1].

The Western Alaska Landscape Conservation Cooperative (WALCC) was interested in assessing potential sensitivity of coastlines to climate change and as part of their contribution to funding for the Kotzebue Sound ShoreZone mapping, requested that some type of sensitivity indices be developed to delineate coasts sensitive to coastal change. Coastal Vulnerability Indices (CVI) were developed to address this concern and these are incorporated into the most recent version of the ShoreZone Coastal Habitat Mapping Protocol (Harper and Morris 2013; Appendix D). While the CVI and associated attributes are included in that appendix, there is no background on rationale used to develop the indices. This short document summarizes the rationale used to develop the indices.

Rationale

The CVI is meant to provide users with a spatial picture of where and how shorelines are likely to be sensitive to climate change, specifically sea level rise. The ShoreZone system does not make any “measurements” so is not meant to replace detailed elevation measurements like coastal LIDAR. But ShoreZone does include very detailed coastal imagery, and systematic observations of morphology can provide an index of potential sensitivity to sea level rise. The CVI is built around the premise that coastal features can be classified into categories that provide a relative measure of sensitivity to coastal change. For example, a shoreline with a storm-log-debris line that is more than 100 m inland from the present high water line is going to be more sensitive (i.e., experience more inundation in storm surges or sea level rise) than shorelines with a storm-log-line 15 m landward of the present high-water line. So this approach uses categorical data (e.g., categories of inundation based on the observed log-line position) to rank the relative sensitivity to flooding.

Coastal Vulnerability Indices

Coastal Vulnerability Indices provide a measure of coastal sensitivity to climate change in terms of three separate indices that are based on observed coastal geomorphology of the shoreline. The three indices are:

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[1] http://alaskafisheries.noaa.gov/shorezone/chmprotocol0114.pdf

Coastal Stability Index - provides a measure of stability (retreating or prograding) for both clastic/sediment shorelines or for wetland shorelines.

Flooding Sensitivity Index - provides an estimate of the degree of observed flooding of immediate backshore areas.

Thaw Sensitivity Index - an estimate of thaw lake or water coverage in the backshore that is an indirect indicator of thaw settlement potential.

These indices are complemented by an inventory of descriptive coastal features of mass-wasting/ wetland morphology that are potentially of interest to coastal planners and managers.

Coastal Stability Index

This index (Table 1) was developed for estimating the erosional/accretional characteristics of a coastal segment. In developing this, we recognized that there are four fundamentally different types of substrate – bedrock, man-made substrate, clastic sediment and wetland (organic sediment) – and that only two are sensitive to erosion – clastic and wetland shorelines. The index is meant to provide some type of relative measure of the present stability of the shoreline. That is, is it erosional or stable or accretional? Using other features that can be observed (e.g., % cover of vegetation on a cliff) a relative measure of stability can be estimated. The categories are ranked from highest erosion to highest accretion using a coding system. Each ShoreZone alongshore unit is categorized into one of these 15 classes. Examples of three of the categories are illustrated in Figure 1.

At the present time, the Coastal Stability Index is included in the database but has not been utilized to its full potential in terms of modelling. Figure 2 shows an example of a map that highlights the location of highest category of clastic erosion (Classes CE4).

Table 1 Coastal Stability Index

		Stability Class	Description
CLASTIC	**CE4**	Erosional	Actively eroding, bare-faced cliff (<10% vegetation cover)
	CE3		Actively eroding, partially vegetated cliff (10 - 90% vegetation cover) cliff
	CE2		Actively eroding, complete vegetated cliff (>90% cover) but veg “disturbed”
	CE1		Retreating barrier island, spit; possibly with outcropping peat
	CS	Stable	Stable slope with tundra vegetation
	CA1	Accretional	Prograding beach with a single storm berm or dune
	CA2		Prograding beach with multiple storm berms or dunes
	CA3		Prograding beach with wide beach ridge plain in backshore
WETLAND	**WE2**	Erosional	Peat layers in sub-tidal, often with polygon form still evident
	WE1		Eroding peat scarp
	WS	Stable	Stable – no obvious features indicating erosion or accretion
	WA1	Accretional	Prograding wetland – immature wetland Prograding across flats (most common in deltaic wetland complexes)
Bedrock	**R**	Not applicable	Assumed stable, Coastal Vulnerability Module not applicable
Anthropogenic	**A**	Seawall	Assumed stable, Coastal Vulnerability Module not applicable
Other	**X**	Provisional	use for initial testing phase, if unit cannot be assigned to any of above

Figure 1a. Stability Class ***CE4***, an actively eroding, bare-faced cliff with <10% vegetation cover.

Figure 1 b. Stability Class ***CE3***, an actively eroding, partially vegetated cliff (10-90% vegetation cover)

Figure 1c. Stability Class **CE2**, an actively eroding, completely vegetated cliff (>90% vegetation cover) but with "disturbed vegetation (indicting down-slope movement)

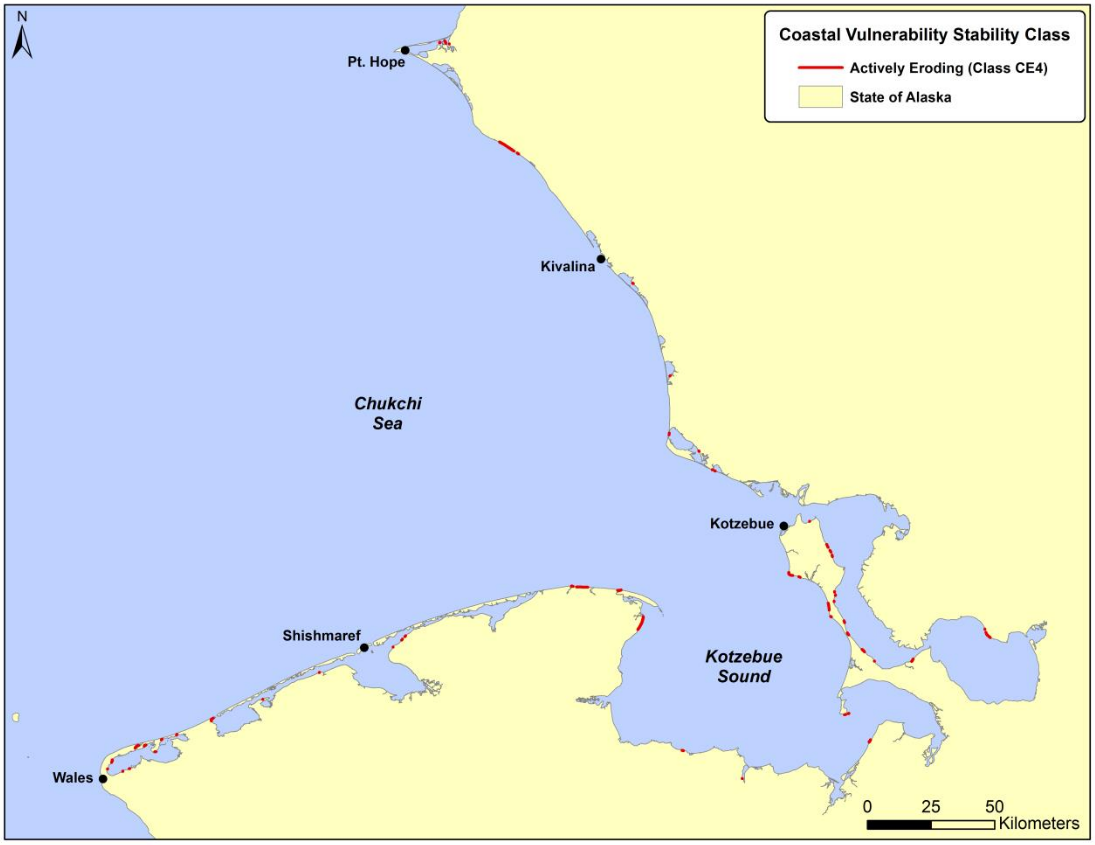

Figure 2. Example of erosion sensitivity map showing locations of ***CE4*** (actively eroding, bare-faced cliffs).

Flooding Sensitivity Index

The Flooding Sensitivity Index (Table 2) is based mainly on observations of the storm-log-debris-line position that is in the backshore of most shorelines (Fig. 3). This is an indirect measure of the backshore gradient, where on low gradient backshores, the storm-log-line can be hundreds of meters landward of the normal high-water line. On high-gradient backshores, the storm-log-line may only be a few meters landward of the normal high-water line. Along most shorelines, the position of the storm-log-line is easily seen and the distance categories are easy to estimate (Fig. 3).

Table 2 Flooding Sensitivity Index

	Flooding Class	Description
F4	Major	Flooding >100 m inland from HWL as indicated by the highest logline
F3	↑	Flooding 50-100m inland from HWL as indicated by the highest logline
F2	↑	Flooding 10-50 m inland from HWL as indicated by the highest logline
F1	Minor	Flooding <10 m inland from HWL as indicated by the highest logline
X		Coastal Hazards not applicable (rock, anthropogenic)

Figure 3. An oblique aerial photo of a section of shoreline showing (a) log lines associated with normal astronomical and meteorological tides on the beach (right) and (b) the highest storm-log line in the tundra (center frame). Two mappers estimated that the landward-most storm-log line is more than 50m landward of the normal high-water lines but less than 100 m (F3 Flooding Category).

Thaw Sensitivity Index

The Thaw Sensitivity Index (Table 3) gives a measure of how coastal areas might respond to more frequent storm surges or sea level rise that could cause thaw and melting of pore ice within the permafrost. Much of the near-surface permafrost has elevated concentrations of pore ice – typically 70% ice by volume. Once this pore ice thaws, the elevation of the tundra surface may settle (*thaw subsidence*) making the area more sensitive to inundation. Another mechanism that results in thaw of permafrost is *thaw-lake coalesence*, where small thaw lakes become larger and larger, coalescing from numerous small lakes to a few large thaw lakes. The premise of the Thaw Sensitivity Index is that areas with more standing water are likely to be more sensitive to thaw settlement (Fig. 4).

Table 3 Thaw Sensitivity Index

	Thaw Sensitivity Class	Description
T4	High ↑ Low	Extensive thaw lakes, standing water, >50% standing water in flooding zone
T3		Moderate thaw lake density, 25-50% standing water in flooding zone
T2		Minor thaw lake density or standing water, 10-25% standing water in flooding zone
T1		Negligible standing water, <10% standing water in flooding zone
X		Coastal Hazards not applicable (rock, anthropogenic)

Figure 4a. A shoreline section with a moderate percentage of thaw lakes (estimated at 25-50% or Thaw Sensitivity Class T3).

Figure 4b. A shoreline section with a comparatively small percentage of thaw lakes in the backshore (estimated at 10-25% or a Thaw Sensitivity Class of T2)

Other Indicators Potentially Useful for Estimating Sensitivity to Change

There are other geomorphic features that provide potential indicators of climate change sensitivity (Table 4). There a number of mass-wasting processes that are all associated with periglacial shorelines. These include: ground ice slumps, block slumps, debris flows/solifluction or ice wedges (that can indicate sensitivity to slumping).

We also noted that there are often “inherited patterns” in the morphology of wetlands. For example, often the thaw-lake patterns in wetlands include a lineation that may be related to former shoreline positions or to former stream positions. While these patterns are not necessarily indicators of future change, they do indicate the type of changes that have occurred in the past. We included attributes for each of the classes that might support future analysis.

Table 4 Other Morphologic Indicators

Category	Feature
Mass Wasting	Ground ice slumps
	Block slumps
	Debris flows/solifluction
	Ice Wedges
Wetlands	Lagoonal complex
	Deltaic complex
	Marsh clones
	Associated mudflats
	Submerged morphology
	Relict river morphology
	Relict shoreline morphology
Other	Add description of relevant feature
None	Unit assessed, no relevant features (none of the above)
Not Applicable	Unit assessed, Coastal Hazards not applicable (rock, etc.)

Discussion

The Coastal Vulnerability Indices were developed as a cost effective add-on to the ShoreZone Mapping program. Mappers could add these attributes with only a small incremental increase in mapping effort. The attributes are all based on observations that can be systematically catalogued. In the case of the three indices, they rationale for ranking is based on classifiable metric (e.g., estimated existing inundation extent).

This dataset has not been fully exploited and there is scope to do more with the dataset. The only analysis to date is to plot regional occurrences of selected classes (Figure 2). There is scope to combine the three indices together to predict an aggregate sensitivity. Or the indices might be used with other data (e.g., tundra swan nesting habitat) to estimate sensitivity to change.

Acknowledgements

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References

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