Shoreline Management Plan Update 2018

Review of Recession Rate Analyses

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Shoreline Management Plan Update 2018

Review of Recession Rate Analyses

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Rev 0	8 June 2018	Draft	To ABCA for Review	SKL	FJLD	FJLD
Rev 1	18 June 2018		Incorporate comments	SKL	FJLD	FJLD
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1. Introduction

1.1 Scope of Work

The Ausable Bayfield Conservation Authority (ABCA) retained W.F. Baird & Associates Coastal Engineers Ltd. (Baird) to complete a technical review of the various datasets and methodologies used to determine shoreline recession rates along the ABCA Lake Huron shoreline. Recession rates are used to determine the erosion hazard limit and development setbacks.

The scope of work of the technical review included:

1. Review of the recession data and methodologies used by the ABCA to determine recession rates
2. Provide recommendations regarding the combination of datasets and methodologies the ABCA should be using for its planning and regulation programs
3. Make recommendations for a defensible methodology that may be used by a property owner who wishes to undertake a site-specific assessment of recession rates

Point 1 is addressed in Section 2 of this report; points 2 and 3 are presented in Section 3.

1.2 Documents and Data Reviewed

The following documents were reviewed:

- *Shoreline Management Plan, Second Edition 2000*, prepared by ABCA
- *ABCA Lake Huron Shoreline Monitoring Program, Assessment of Data Available for the Calculation of Long-Term Erosion Rates, ABCA*, dated July 2015
- *ABCA Historic Photo Pilot, Assessment of Techniques Using Historic Imagery to Locate the Toe and Top of the Slope in a Section Along Lake Huron*, prepared by Tracey McPherson, ABCA, dated June 2016
- *Estimating and Mapping Shoreline Recession Rates – Draft for Review,* prepared by Tracey McPherson, ABCA, dated February 26, 2018

In addition to the documents identified above, the following three-geospatial databases were received:

- Aerial Imagery from 3 different time periods: 1973 individual frames (21) georeferenced individually by ABCA staff, named according to the original contact print frame number; 2007 Orthophoto mosaic, 3 band colour, 10 cm ground resolution, and an accompanying hillshade raster at 25 cm ground resolution; and 2015 Orthophoto mosaic, 4 band colour/Infrared, 20 cm ground resolution
- Shoreline 2007 Vectors Geodatabase, derived from the 2007 stereo pairs
  - Elevation as contour lines and DEM points
  - Feature breaklines that provide supplemental elevation information for bluffs, valleys and drainage features
  - Feature vectors (37,047 total) such as bridges, accessways, road edges, parking lots, creeks and streams, ponds, marshes, ditches centrelines, culvert headwalls, river shoreline, retaining walls and other visible features. It also includes features for virtual connectivity, such as virtual stream networks
- Shoreline Erosion Geodatabase:
  - Ground Survey transects with cross-section data from 1994, 2006 and 2012, as measured by Farncomb, Kirkpatrick & Stirling Surveying Ltd (FKS)

- Historic 1935 survey “Plan of the Shore Line in Front of the Township of Stanley County of Huron” that recorded water’s edge and High Water Mark features as point features captured at a spacing of 4 chains (80.47 metres). Linework included all the intermediate lines, traverses and transects and the derived “Toe1935” feature
- Photogrammetric cross-section lines representing the stations from the Environment Canada Ontario Ministry of Natural Resources Ontario Great Lakes Shore Damage Survey, Technical Report, 1975, edge of bank, with additional values from the Reinders Shoreline Processes Study, 1989
- A feature dataset called “Shore1988files” with features including Bluffs 100 yr Erosion line, Building 1988 polygons, L100 year Lake Flood lines, Lakeshore contours, N of Bayfield polygons, STOB 1988 lines, T100yr Lake Flood lines, T100yr Retwalls lines, TOB1988 lines and Toe1988 lines
- Shoreline 2010 TOB lines
- Shoreline 2015 data including Stable Slope 3to1 for 2015, TOB 2015, and TOB 2015 No Gully
- Shoreline 2007 Derived Data including shore 3 to 1 slope line, Toe 2007 line, Toe 2007 Gullies removed, and Top of Bank
- Top Of Bank (TOB) Changes with 2 point datasets including TOB 1988 to 2010 with erosion rate values for points with a 10 metre horizontal spacing
- A feature dataset called “Toe_Top1973” with 2-line feature class datasets separating the toe and top of bank
- A feature dataset called “ToeChanges” with a point feature class dataset “Toe1935to1988” with 3,345 points each with recession rate values
- A feature class dataset “Transects_All_Rates” with transects, 50 metres apart, extending from Hwy 21 or the nearest road running parallel to Lake Huron to the toe of the slope in 1973. The transect layer was originally created by Bonneycastle/Davidson-Arnott, but ABCA altered the original layer by adding/deleting transects, extending the layer to the ABCA digitized 1973 toe, and adding additional fields of information
- Various other features without metadata but identified as: Building2007, Subcells, TileIndex2000_11x17, TileIndex5000

It is our understanding that the data sets listed represent the data used by the ABCA to evaluate recession rates for delineation of the erosion hazard limit.

2. Review of Methodologies

This section provides a review of the methodologies used to estimate shoreline recession rates and the spatial data upon which the estimates are based. The methodology has evolved since recession rates were initially estimated for the ABCA shoreline Management Plan 2000; Section 2.1 provides an overview of key updates. Each of the approaches is then reviewed in the following sections.

2.1 Overview of History and Development of ABCA Methodology

Shoreline recession rates were initially estimated by comparing the 1935 shoreline traverse survey to the 1988 shoreline mapping as reported in the ABCA Shoreline Management Plan 2000. This method provided recession rates for the entire approximately 60 km of ABCA shoreline. In 2016, ABCA retained Mr. Adam Bonnycastle and Dr. Robin Davidson-Arnott to update the recession rate estimates. Scanned maps from the 1973 Canada-Ontario Great Lakes Shore Damage Survey and Atlas (Environment Canada and Ontario Ministry of Natural Resources, 1976), (henceforth referred to as the 1973 Atlas) and 2007 ortho-imagery (leaf-off, terrain-corrected imagery at 10 cm ground resolution) were used in the comparison. The shoreline recession rates estimated by Bonnycastle and Davidson-Arnott were reviewed by ABCA and it was concluded that improved results could be obtained using the original historic imagery from 1973 instead of the scanned map sheets. ABCA completed these updates and was able to make additional improvements by taking measurements from top of bluff.

The ABCA database also includes historic recession rates calculated from ground surveyed monitoring locations and recession rates from photogrammetric cross-sections (Environment Canada and Ontario Ministry of Natural Resources, 1975). These data provide recession rates at specific locations along the ABCA shoreline but they do not provide the comprehensive rates required to define the hazard limits.

2.2 Best Practice

In establishing shoreline recession rates, the general best practice is to select the most suitable datasets in terms of quality, accurate feature definition, spatial resolution and scale that provide the longest possible temporal period for comparison. A longer temporal period provides a more representative measurement of the long-term bluff recession (Zuzek et al., 2003; MNR, 2001). Compared to the toe of bluff, the top of bluff feature is preferred for measuring recession rates because it is less susceptible to short-term fluctuations in the lake water level and is generally more distinctive in historic black and white air photos. Data must be for an unprotected shoreline, as recession rate values are required to represent the erosion potential without any structures (MNR, 2001).

2.3 Comparison 1935 Shoreline Traverse Survey to 1988 Shoreline Mapping

This approach was used to estimate the average annual recession rates (AARR), as presented in the ABCA Shoreline Management Plan 2000. The approach involved the comparison of the surveyed toe of bluff from the 1935 Shoreline Traverse Survey to the 1988 Shoreline Mapping of toe of bluff.

The 1935 survey recorded Water's Edge and High Water Mark features as point features captured at a spacing of 4 chains (80.47 metres). While the surveyors provided a cartographic representation of these features, the actual measurements are spot measurements and not continuous line features. An example 1935 Shoreline Traverse Survey showing the 1935 "Plan of the Shore Line in Front of the Township of Stanley County of Huron" is provided in Appendix A.

The 1988 mapping was identified as 1:2,000-scale and was derived from stereo pairs. A detailed review of the 1988 data was not completed by Baird for this report.

2.3.1 Interpolation of Surveyed High Water Mark

With the natural sinuosity/variability of the shoreline, it is misleading to connect the 80 metre-spaced surveyed point locations with a straight line. It implies that the shoreline is straight between these locations, when it is not. In Figure 2.1, the larger hollow black circles identify the 1935 surveyed High Water Mark spaced at 80 metre intervals, and the smaller yellow circles represent the toe of bluff from the 1988 mapping spaced at 10 metre intervals, following the methodology presented in the ABCA Shoreline Management Plan 2000. The 1988 toe of bluff line highlights the sinuosity/variability of the shoreline that is captured in the higher resolution sampling.

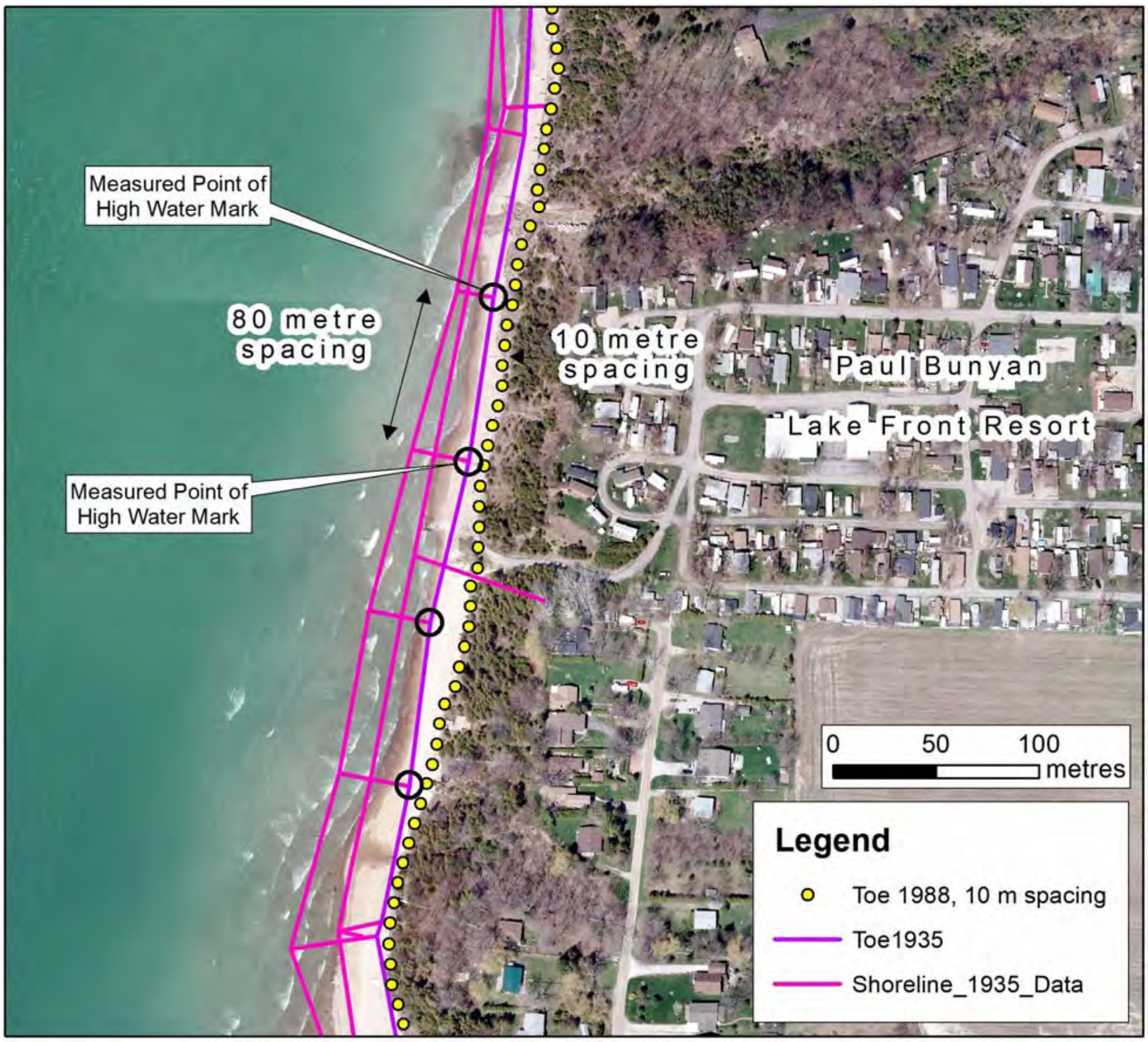

Figure 2.1: Comparison of High Water Mark from 1935 Survey and Toe of Bluff points from 1988 Mapping, with 2007 orthophoto as the background (all data provided by ABCA).

2.3.2 Interpretation of Features

The ABCA Shoreline Management Plan 2000 (p.27) refers to the use of the High Water Mark shown on the 1935 Survey to define the toe of bluff:

> *"Comparison of the location of the toe of the bluff was generally based on the high water mark from the 1935 survey (this feature is representative of the toe of bluff along most of this shoreline)."*

A review of the survey "Plan of the Shore Line in Front of the Township of Stanley County of Huron", representing 13 km of shoreline, reveals lengths of shoreline where the High Water Mark does not coincide with the toe of bluff. Based on the nine inset maps, it is estimated that the toe of slope differs from the High Water Mark along one quarter of the shoreline on this plan, or approximately 3 km.

Figure 2.2 shows mapped features at a location north of Pavillion Road; on the left is the 1935 Survey (rotated so North is up); and on the right is the corresponding 1935 transect data overlaid on the 2007 orthophoto to provide context. Starting just south of traverse line 296.00 a Toe of Slope line is shown. The Toe of Slope line diverges from the High Water Mark line, and is further inland at each traverse moving south. The offsets which represent the resulting error are listed in Table 2.1.

Table 2.1: Error in Toe of Bluff Delineation on 1935 Survey resulting from use of High Water Mark

Traverse Line	HWM to Toe of Slope (Chains)	HWM to Toe of Slope (metres)
300.00	0.25	5.0
304.00	0.50	10.1
308.00	0.25	5.0
312.00	0.26	5.2

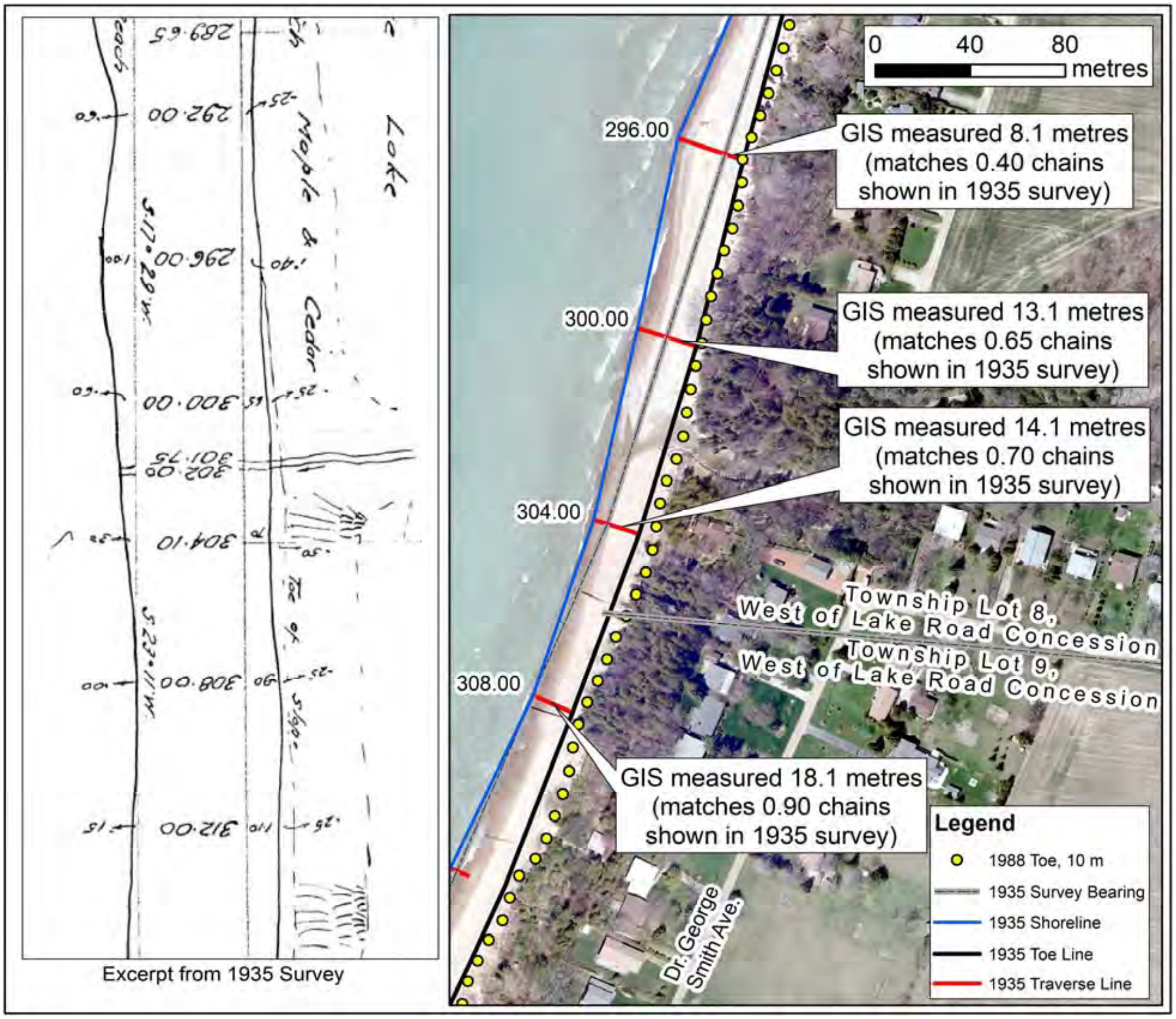

Figure 2.2: Location where the High Water Mark is divergent from the Toe of Slope. Map on the right labels the dimensions of features used in the 1935 vector data set, and confirms they match the High Water Mark feature dimensioned in the 1935 survey.

2.3.3 Summary

The difference between the toe of bluff on the 1935 Shoreline Traverse Survey and the 1988 Shoreline Mapping was used to estimate recession rates for the ABCA Shoreline Management Plan 2000, representing change over a 55 year time. This review focused on the 1935 Shoreline Traverse Survey and the methodology used to delineate the shoreline. While these data provided the most accurate data for estimating shoreline recession for the ABCA Shoreline Management Plan 2000, there are limitations with the 1935 data as summarized below:

1. The estimate is based on a comparison of toe of bluff location in 1935 and 1988. As discussed in Section 2.2, there are challenges with delineating the toe of bluff and greater success may be obtained if the top of bluff is used.

2. The use of High Water Mark to delineate toe of bluff introduces errors, which may be more significant at locations where the toe of bluff does not coincide with the High Water Mark.
3. The use of 10 m spacing for transects, when comparing the toe of bluff location in 1935 and 1988 is not appropriate. Instead, a transect spacing of 80 m, matching the limitation of the spacing of the 1935 survey points (surveyed point every 4 chains) should be used.
4. This review focused on the methodologies associated with data base developed from the 1935 Shoreline Traverse Survey; methodologies associated with the 1988 toe of bluff delineation were not provided for review.

2.4 Comparison 1973 Shoreline Atlas to 2007 Imagery by Adam Bonnycastle and Dr. Robin- Davidson Arnott (2016)

In 2016, ABCA retained Adam Bonnycastle and Dr. Robin Davidson-Arnott to update the recession rate estimates. Briefly, their approach involved the comparison of distances along transects between the toe of bluff and major north-south inland roads on 1973 air photo images taken from the 1973 Atlas, and on the digital 2007 aerial imagery provided by ABCA. The 2007 orthoimagery is a product of a 3D-processed OMNR SWOOP program based on aerial photographs, collected in the spring during a leaf-off period. The air photos were terrain corrected, and are at 10 cm ground resolution. These images still represent the best-available most recent base imagery for mapping because the more recent 2015 imagery has trees with leaf-on, is a coarser resolution of 20 cm, and has a lot of high-contrast and shadows that obscure ground features such as bank features.

2.4.1 Approach and Limitations

Bonnycastle and Davidson-Arnott (2016) selected 1973 air photo images from the printed (hardcopy) 1973 Atlas for determining the initial shoreline position. We are not aware of the scope limitations of Bonnycastle and Davidson-Arnott, and the decision to use 1973 Erosion Atlas images may have been one of convenience or budget constraints, and not based on best practice using best-available data. While copies of the printed 1973 Atlas are readily available, the use of the copies is not a preferred choice, considering other, better quality data is reasonably available. The reproduction of the printed air photos from the Erosion Atlas further degraded the quality of the image which is already poor compared to the original photo negative or a photo contact print of the original. The air photos printed in the 1973 Atlas have been distorted using limited 1973 technology and methodologies. Portions of the photos have also been obscured with contour lines and labels.

The Bonnycastle and Davidson-Arnott (2016) procedure to georeference the 1973 Erosion Atlas imagery included: scanning the pages at 600 DPI; cropping the image in Adobe Photoshop©; and applying ArcMap© Georeferencing functionality (temporarily scale image to match original 1:20,000 scale, georeferenced cropped images (1st order polynomial), permanently rectify georeferenced images at resolution that best matches scaling of imagery). Bonnycastle and Davidson-Arnott (2016) note that "*this process does NOT produced* [sic] *a true orthorectified product*". Orthorectification is the process of removing all the distortions from an aerial photo to create a planimetrically correct image. These distortions include radial lens distortion (image perspective or tilt from a single viewpoint) and (more importantly) terrain distortions (relief effects). The output orthorectified image has a constant scale so that it appears that each pixel was acquired from directly above. When working with aerial imagery, it is possible to correct for radial lens distortion using a polynomial adjustment, but the control alignment points should be at the same vertical/elevation plane as the feature of interest in the imagery because the adjustment does not compensate for terrain distortions. This is a consideration when using control points located high on a bluff and the features of interest are at a lower elevation down at the water's edge.

The Bonnycastle and Davidson-Arnott (2016) methodology identified the use of the 1st order polynomial method for rectification of the 1973 air photo scanned image. This suggests that only the minimum two or three reference control points were used to georegister the image. This is the simplest transformation method and is usually reserved for a quick georeferencing of data when insufficient matching ground control points can be established. Using higher resolution photos, aids in identifying ground control points. The use of additional control points allows for more accurate georeferencing using more sophisticated methods, such as 2nd or 3rd order polynomials, spline and others, and could be considered commonly accepted practice in situations such as this analysis.

The position of the toe of the shoreline bluff and the position of major north-south inland roads were selected by Bonnycastle and Davidson-Arnott (2016) as the features for comparison between the 1973 Atlas images and the 2015 aerial ortho-imagery. But due to the limitations of the 1973 imagery, the road feature is not a discrete feature, instead it is a wide blurry feature, so there can be significant discrepancies when drawing transect lines from a such feature. Further, the transects were not coincident for both time periods, so their methodology resulted in toe of bluff measurements at different locations.

2.4.2 Summary

This approach measured the difference between the toe of bluff on the 1973 Atlas and the 2007 aerial imagery and provides change over a 34 year time period. There were multiple compounding errors with the methodology and datasets including:

- Accuracy of distance from inland road to toe of slope on 1973 image
- Using lowest contour line to represent the location of toe of slope was inappropriate because there is visible misalignment between the contours and the underlying air photo at many locations; it is visually apparent that the lowest contour is not likely the toe of bluff at some locations;
- Possible error of 4 m when digitizing lowest contour based on thickness of printed line and scanning image because at the Erosion Atlas source map scale of 1:20,000 scanning at 600 DPI produces at image with a 1 metre ground resolution and the thinnest contour lines are drawn as a 0.2 mm thickness which equates to 4 metres at scale;
- Misaligned contours and features in underlying 1973 photo in Erosion Atlas;
- Poor georegistration results in misalignment of inland road features;
- Comparison of (non-coincident) transect from 1973 to nearest adjacent transect in 2015, i.e., not using the same transects for both years means measuring at different locations; and
- The comparison is between toe of bluff positions, which is more difficult to accurately delineate than top of bluff.

ABCA recognized many of these issues and the effect of multiple compounding errors, and concurrently undertook additional analyses to assess the recession rate estimates as described in Section 2.5.

2.5 Comparison of 1973 Georeferencing Options and Derived Rates

This approach improves on the methodology developed by Bonnycastle and Davidson-Arnott, and compares the toe and top of bluff delineated from the 1973 georeferenced National Air Photo Library print image scans with the 2007 orthophotos.

2.5.1 Georegistration of Historic Imagery

ABCA undertook a review of methodologies used to estimate recession rates as described in "*ABCA Historic Photo Pilot, Assessment of Techniques Using Historic Imagery to Locate the Toe and Top of the Slope in a Section Along Lake Huron*" prepared by ABCA dated June 2016. Three methods for georeferencing historic imagery in support of obtaining the top and toe of the slope along the Lake Huron shoreline from 1973 imagery and map sheets were reviewed:

A. Georeference National Air Photo Library print image scans
B. Georeference map sheet 80 from Great Lakes Shore Damage Survey and Atlas
C. Send out data for capture in 3D softcopy photogrammetry system

Method A was the focus for ABCA's efforts, and their results compared favourably with Method C as completed by St. Clair Region Conservation Authority (SCRCA). Method B was quickly discounted due to the low level of accuracy. Method A is a common method used by GIS analysts because it is a capability included in the ESRI ArcGIS ™ software used on a regular basis, whereas Method C requires more specialized software such as PCI Geomatica OrthoEngine ™ that is specific to the science of photogrammetry.

Using a georegistration method such as ESRI ArcGIS ArcMap's Georeferencing, the software is not aware that the photo has radial distortions (the distortion increases the further away from the photo centre), or is able to compensate for elevation differences in the underlying image. Regardless, with the correct horizontal distribution of similar elevation reference Ground Control Points (GCP) as the target reference feature it is possible for the software to correct this distortion sufficiently: select GCP at the same elevation as the top of bluff feature.

In general, more points that are well distributed across an airphoto will actually have a higher RMS value than would points that were clustered within a more specific region of the photo, such as a linear strip. Method A used good base data for GCP selection, and in reviewing the points as presented for photos #60 and #64 (Figures 2.3 and 2.4 respectively), the GCP appear well distributed with a focus of points near the coast. For example, Figure 2.3, Photo #60 shows 9 of 10 points near the coast, with a point further inland to help anchor the image in an East-West direction. Figure 2.4, Photo #64 shows an ideal distribution of GCPs, with most points along the coast and then additional points scattered inland.

Figure 2.3: Photo #60 Showing ABCA Ground Control Point Selection.

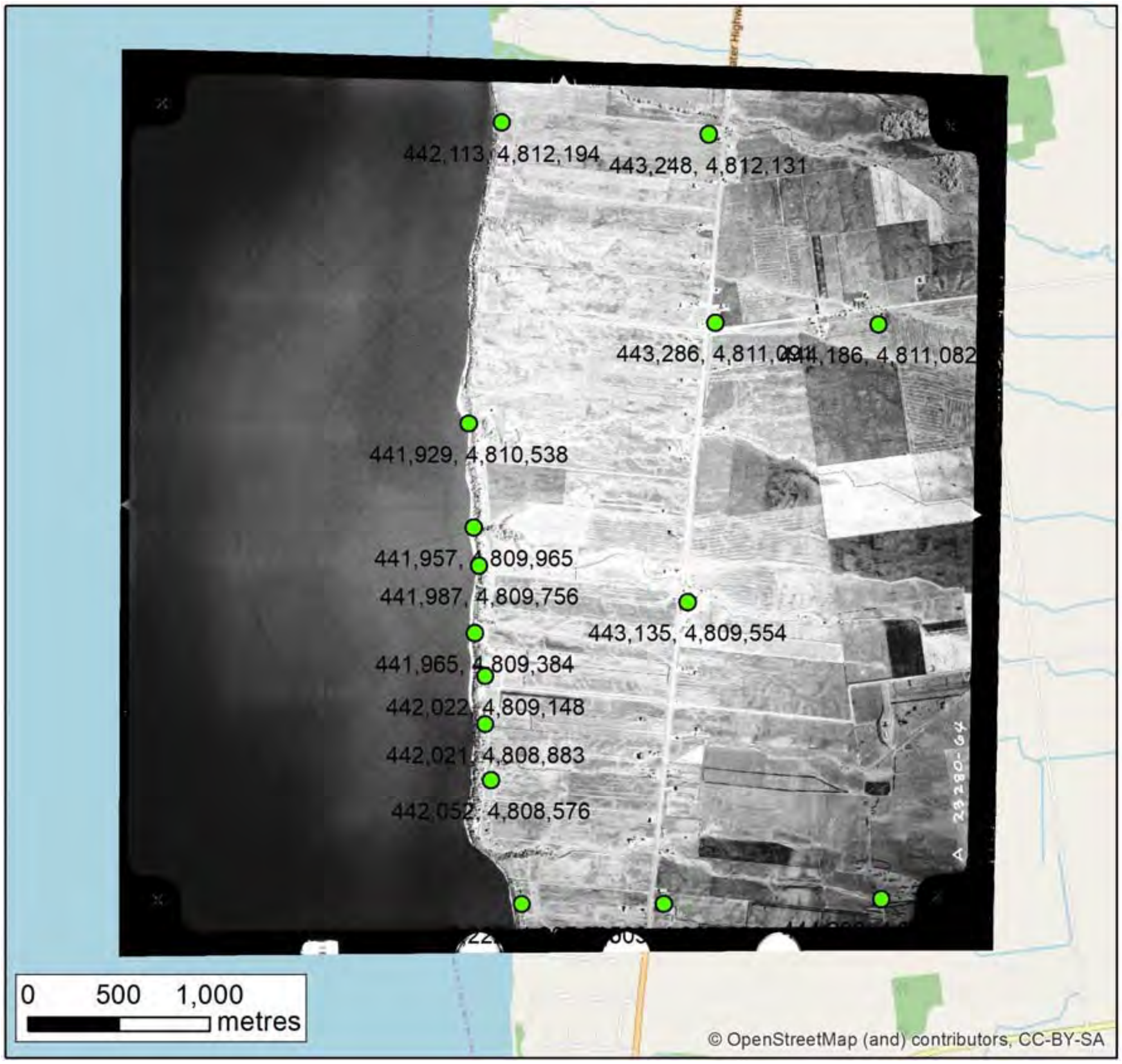

Figure 2.4: Photo #64 Showing ABCA Ground Control Point Selection.

2.5.2 Extraction of Features

While Figure 2.3 has a lower Total RMS Error value than Figure 2.4, the overall alignment of Figure 2.4 is likely better. Yet this is not something that will benefit the goal of shoreline change analysis, because the focus is only on comparing features within the narrow coastal strip of the bluff area. A review of the alignment of the photos in Figures 2.3 and 2.4, and comparison with the 2015 orthophoto demonstrates that there is good alignment with both.

It is important to reiterate that a higher Total RMS Error value does not indicate that the particular photo has a worse georegistration than that of a photo with a lower Total RMS Error. Because the photos have an overlap of 60%, there is an opportunity to choose from more than one photo as the source for the feature extraction. But in their described methodology, ABCA chose the images with the lower RMS to digitize the toe of bluff feature, sometimes excluding the adjacent image.

Figure 2.5 illustrates this point; it can be seen that Image 66 was not used for any of the transects. This is not the preferred method because the photos become more distorted towards the edge of the photo, so the ideal situation is to select only the centre portions of the photos, and with the extensive overlap only a small portion of each photo is actually used. Each photo provides coverage of 4.8 km of shoreline, but only using the centre of each photo equates to about 2 km of photo for feature extraction. The central portion of each photo is where the vertical distortions are most limited, and the edges have the greatest vertical displacement, so with all the GCP selected from the top of bluff elevations there is greater distortion of features like the toe of bluff.

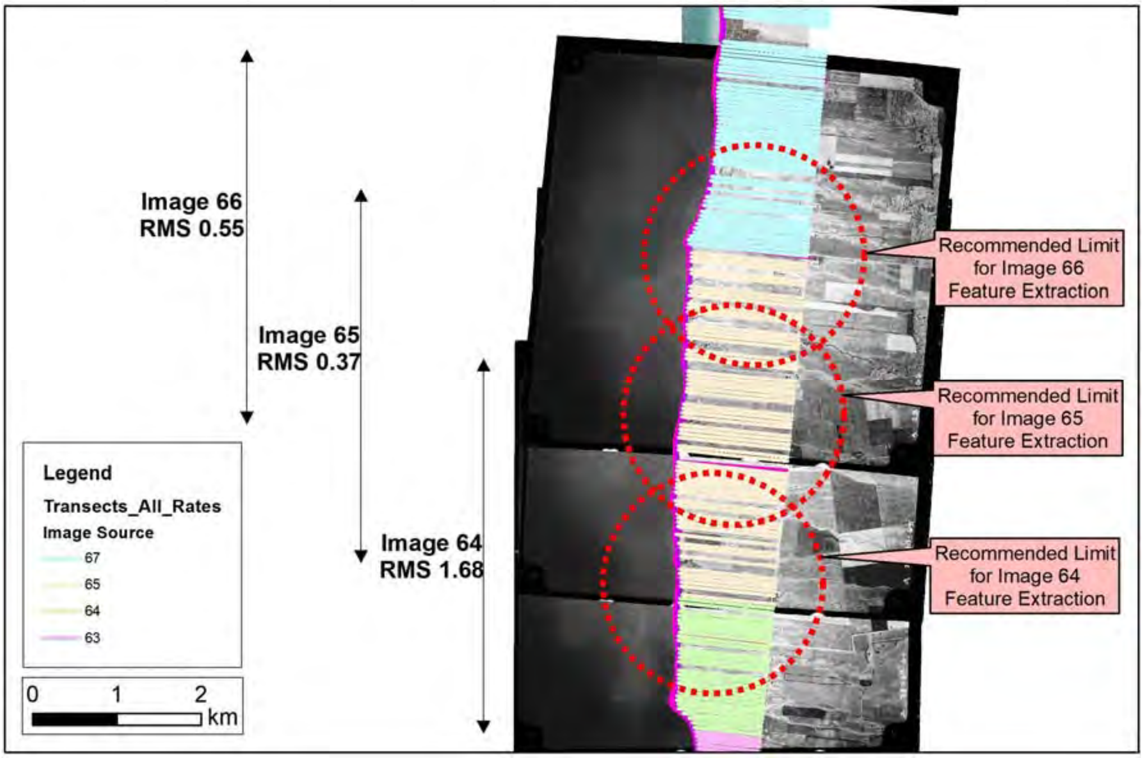

Figure 2.5: Comparison of Adjacent Overlapping Georegistered Photos and Transects Corresponding to Source Photo as Identified by ABCA.

It is further noted that the inaccurate methodology uses the method developed by Bonnycastle and Davidson-Arnott, to estimate erosion based on the toe of bluff location, as defined by a measurement from a distant road feature which introduces unnecessarily long measurements to distant features that are not clearly defined. For example, a road feature is quite wide and variable depending upon variables such as road width, shoulder conditions, clarity of the painted centrelines, etc. The more accurate and preferred approach (which is assumed to be used here as the 2018 report in Section 3.3 describes "the '**absolute**' digitized locations of the tops and toes of the bluffs that were created allowed for the measurement of movement to calculate the AARR") is to take measurements directly between features of different time periods: particularly measure the direct distance between the top of bluff from different time periods.

2.5.3 Summary

This approach measures the difference between the toe of bluff and top of bluff location on the 1973 georeferenced National Air Photo Library print image scans and with the 2007 orthophotos and provides change over a 34-year time period. The following issues that may affect the accuracy of the recession rate estimate were identified:

1. The preference for selecting a photo with the lowest RMS value instead of choosing the centre of photos to reduce the terrain displacement;
2. Use of top of bluff feature is preferred over the toe of bluff feature as discussed previously; it is easier to delineate and it matches better with the elevation of the chosen Ground Control Points;
3. The short temporal period (34 years) could be mitigated by choosing different time periods, for example the use of 1955 aerial photographs would add 18 years to the temporal range.
4. Of the 558 transects, 70 do not have a top of bank recession rate, and these are acceptable as they are at locations where measurements were inappropriate (north of Bayfield fillet beach) or the bank has been altered or obscured. In these latter areas, additional transects could be added to compensate for the data gaps.

2.6 Rates Calculated from Ground Surveyed Monitoring Locations

The ABCA has continued the Lake Huron Shoreline Erosion Monitoring Program (LHSEM) started by Environment Canada (EC) and the Ontario Ministry of Natural Resources (OMNR) in the 1970s. In 1994, 2006 and 2012 land surveyors completed ground surveys at eight long term monitoring stations along the ABCA shoreline. Five of the stations were located on bluff shorelines; top and toe of bluff were surveyed, along with bathymetry profiles in 1994 and 2006.

These surveys provide precise measurements at repeatable locations and extend over a 39 year period (1973 to 2012). While it is noted that the profiles provide site specific data for five locations only, it provides a valuable dataset for use in verifying long-term erosion rates estimated using geospatial data. It is recommended that the monitoring program be continued. Surveys were completed in 2006 and 2012; if funding permits, they could be repeated in 2018.

This dataset should also be checked for errors. While reviewing the Melina Heights H-9-25 profile, it was observed that the 1994 profile appears vertically shifted (including the top of bank elevation) relative to the 2006 & 2012 profiles.

2.7 Photogrammetric Cross-Sections Used in Atlas (1973) and in Reinders Lake Huron Shoreline Processes Study (1989)

Measurements from aerial imagery were gathered as photogrammetric cross-sections in two documents: The Canada – Ontario Great Lakes Shore Damage Survey and Atlas of 1973 provides top of bluff measurements from 1955 to 1973, and supplemented with other land survey data, and the 1989 F.J. Reinders and Associates report Lake Huron Shoreline Processes Study of 1989 added the period of 1955 to 1988 from air photo analysis. While this data set (25 cross-sections) is spatially sparse relative to the Bonneycastle and Davidson-Arnott transects currently used by ABCA in the methodology to estimate recession rates (558 transects), these photogrammetric cross-sections represent longer temporal periods of analysis in support of establishing long-term erosion rates.

Many of the photogrammetric cross-sections are at locations where there is not any shore protection (for example, a municipal road right-of-way, presumably so that the locations could be consistently identified on airphotos), so these locations are ideal for establishing erosion rates for unprotected shoreline as required by the Technical Guide.

3. Recommendations

This section provides recommendations for estimating recession rates, based on the review of ABCA's data base and our understanding of best practices. Section 3.1 summarizes our recommendations regarding use of the existing recession rate database for ABCA's planning and regulation programs. In Section 3.2, recommendations are made for improvements to the recession rate estimates, based on best practice. It is recognized that these improvements may be implemented over time, as funding becomes available. In Section 3.3 recommendations are provided for a defensible methodology that may be used by a property owner who wishes to undertake a site-specific assessment of recession rates.

3.1 Recommended Data for Planning and Regulation Programs

This section provides recommendations for the combination of ABCA's datasets that will provide the best estimate of long term shoreline recession rates for the purpose of calculating hazard limits and regulation limits along the ABCA shoreline:

1. The ABCA has developed a top of bank data set from the geo-referenced 1973 imagery and the 2007 imagery as described in Section 2.5 ('TopRate' field in the 'Transects_all_Rates' line dataset). Top of bank recession was measured at the transect locations used by Bonnycastle and Davidson Arnott (2016). This top of bank shoreline comparison is the preferred data set for calculating recession rates. Where the shoreline is protected, the rate may be estimated from the adjacent unprotected shoreline with similar characteristics. If this is not possible due to extended areas of protection, the 1935-1988 rates may be used, if there was no protection during that period of comparison.
2. The 1935 Shoreline Traverse Survey and the 1988 Shoreline Mapping provided the most accurate data for estimating shoreline recession for the ABCA Shoreline Management Plan 2000. However, there are limitations with that data set, as discussed in Section 2.3. In particular, the use of the High Water Mark to delineate toe of bluff introduces errors at some locations. In addition, recession measurements should only be extracted at the 1935 survey transect locations, which are spaced at 80 m intervals. Interpolating between the transects introduces errors and a false sense of accuracy. For these reasons, it is recommended that the ABCA consider this recession data to be superseded by the 1973-2007 data discussed above.
3. The LHSEM ground survey monitoring stations provide precise measurements at five repeatable locations, two stations include data from 1973 to 2012; three stations include data from 1994 to 2012. Though the data set is limited, it is useful for verifying long-term erosion rates estimated using 1973 to 2007 imagery; the time periods for two stations coincide well with the ground measurements considering surveys were conducted in 1973 and 2006. It is recommended that the monitoring surveys continue and that the data is used as a validation check on the recession rates calculated for nearby transects using the 1973 and 2007 imagery.

3.2 Recommended Data Updates/Refinements

Recommended updates and refinements to improve shoreline recession estimates are summarised for future consideration and as funding becomes available.

1. In general, it is best practice to use the earliest available historic air photos, considering scale and quality, to provide longest possible temporal period of comparison. Photos from 1955, 1964 and 1966 are available and could extend the period of comparison by up to 18 additional years (1973 photos are currently used as the basis for historic top of bank comparison). While the 1955 aerial photography within

the ABCA jurisdiction was flown with east-west direction flight lines and would not have the same overlap at the shoreline, as the 1966 or 1973 photography, the 1955 aerial imagery has the important temporal advantage. To compensate for the decreased overlap on adjacent flight lines, it is recommended that the 1955 aerial imagery be photogrammetrically processed to create georeferenced orthoimagery. This should be done using 3D ground control points in a stereo processing environment such as PCI Geomatica's OrthoEngine, which is able to adjust the imagery by compensating for lens and terrain distortions. The 1955 aerial imagery is available from Archives of Ontario, of the Ministry of Government and Consumer Services (http://www.archives.gov.on.ca/en/index.aspx). The scale of the 1955 aerial imagery is approximately 1:15,840, which is slightly better than the 1:20,000-scale of the 1973 aerial imagery. The 2007 imagery still currently represents the best-available base imagery for mapping because the more recent 2015 imagery has trees with leaf-on, is a coarser resolution of 20 cm, and has a lot of high-contrast and shadows that obscure ground features such as bank features. When new imagery becomes available in the future, the imagery should be reviewed to determine if the quality suggests it would be worthwhile to extend the period of comparison, potentially provided an additional 11+ years.

2. Review the 1973 georeferenced photos as described in Section 2.5, reduce the image distortion by reducing the photo overlap by cropping the photos to just the centre ~2 km radius, a further option is to generate a single (continuous) mosaic, minimizing the selection of portions of images with lower alignment, and applying a similar selection process to base the transect measurements on the centre of these photos.
3. A smoothing function has been used in developing the recession values for each transect, based on recommendations in the Consultant Recommendation Report (Aqua Solutions 5 et al, 2016). The smoothing function is intended to address random errors arising from errors in the methodology and spatial and temporal variability in recession rates. The smoothing function considers data 100 m either side of a given transect. Different approaches to smoothing have been used by other Conservation Authorities and while the current smoothing routine seems to provide a sufficient correction, ABCA may wish to review the approach and the statistical implications of applying different weighting factors and considering erosion rates greater than 100 m from the transect. Application of the smoothing function should consider the shoreline characteristics, for example, where a gully is present or the shoreline changes from bluff to beach.

3.3 Investigation to Calculate Site Specific Recession Rates

The ABCA has spent considerable effort estimating recession rates and the accuracy of these estimates has improved with ongoing technical advances in geomatics. The 588 transects used to calculate the 1973-2007 bluff recession rates provide good regional-scale coverage. For a particular site, the nearest bluff recession rate transects provide a representative value that takes into account the temporal and spatial variability of shoreline erosion. When delineating the Erosion Hazard Limit, the ABCA uses a smoothing function that recognizes temporal and spatial variations in shoreline recession along the shoreline. For example, along a stretch of eroding bluff with similar characteristics, a failure may occur at one property in a given year, and at another several years later. In general, the shoreline will retreat at a consistent rate. The smoothing function allows this variability to be taken into consideration.

The following provides a checklist of requirements for site-specific recession rate estimates by property owners:

1. The analysis must provide additional data that extends the temporal range of analysis. The analysis must also meet or exceed the level of accuracy of the ABCA analysis.
2. Data must be for an unprotected shoreline, as recession rate values are required to represent the erosion potential without any structures (MNR, 2001).

3. Imagery or data must be georegistered and analysis undertaken by a geomatics professional; and surveys must be completed by an Ontario Land Surveyor (OLS). A report outlining QA/QC procedures is to be provided.
4. The scale of aerial photography used should 1:20,000 or better; the scale of a survey should be 1:1,000 or better.
5. While this site-specific set of measurements may be more accurate in a localized sense, it must still be considered within the regional context of adjacent properties to provide context of trends of shoreline erosion.

4. References

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Appendix A

1935 Traverse Survey Example


DETAILS AT BAYFIELD RIVER
LAKE HURON
LAKE ROAD WEST CONCESSION
TOWN PLOT OF BAYFIELD
OF THE SHORE LINE
IN FRONT OF THE Tp OF STANLEY
Co OF HURON