U.S. Army Corps of Engineers - Detroit District

A REVISED GEOMORPHIC, SHORE PROTECTION AND NEARSHORE CLASSIFICATION OF THE LAKE MICHIGAN SHORELINE

LAKE MICHIGAN POTENTIAL DAMAGES STUDY




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1.0 Introduction and Background

In March of 1993, the International Joint Commission completed the 1986-1993 Reference Study of Water Level Fluctuations in the Great Lakes - St. Lawrence River basin. As part of this work, the Erosion Processes Task Group (Stewart and Pope, 1993) had developed a three-tiered shoreline classification scheme for the Great Lakes that took into account factors related to the overall erodibility of the shoreline. These included the geomorphic shore type present, the level of shoreline protection present, and the geological composition of the nearshore zone. This original classification was applied to all of the Great Lakes shoreline, including Lake Michigan, and associated statistics on the various shoreline types were generated.

2.0 Limitations of Original Scheme

While the shore classification scheme and the resulting database of classification information provided a comprehensive attempt to recognize and quantify the complex nature of the Great Lakes shoreline, there were some limitations that arose, primarily due to time and budget constraints associated with the Reference Study:

1) The United States shoreline was classified using various published and unpublished data sources, photographs, and personal knowledge. The mappers proceeded by reviewing their materials and writing the shore type, protection level, and offshore type on U.S Geological Survey topographic quadrangles. The quadrangles were then sent to USACE Detroit District, where the classifications were entered into a Geographical Information System (GIS) database. Note that the quadrangles were used merely as a convenient base upon which the mappers could write their classifications and notes. The shorelines in the GIS database are not based on the quadrangles but rather on recent aerial photographs. Many portions of the shore, especially along barrier spits and sandy coasts, have changed significantly since the maps were printed. In addition, man-made structures have caused major changes in some areas. This resulted in inaccuracies in shore type boundaries or misclassification of shore types.

2) Although the classification of several shore sections were re-evaluated to cross-check the initial classification, there was insufficient time to conduct a broad ranging quality control check. Therefore there are undoubtedly some sections of the shoreline which were mis-classified and cases where similar shores may have been interpreted into different classes.

3) The limited time and budget allocated to the study did not allow for additional data collection or for field verification of the classification. In addition, several different coastal geological experts were used to apply the classification scheme across the basin. This resulted in some variability in interpretation, particularly between the U.S. and Canada, and between different lakes on the U.S. side.

4) The variability in descriptive data throughout the literature, between states and across Canada, the limited availability of recent good-quality aerial photography and/or oblique video tapes, the lack of information on nearshore geology and bathymetry, and the generality of the classification scheme, made it impossible to assure an equal level of quality and detail in the classification across the basin.

5) The protection classification scheme developed for the Reference Study did not recognize the quality of the protection, only the percentage of shoreline covered. To be true to the purposes of the classification scheme, verification is needed that a "heavily protected shore" is engineered to provide a predictable design life and level of protection.

6) Additional data is needed on nearshore geology and bathymetry (including nearshore slope). The six classes utilized were fairly basic. Further refinements based on a better knowledge of offshore stratigraphy and lithology, as well as the degree of sand cover are required.

A number of other issues and limitations were identified in the Erosion Processes Task Group Report (Stewart and Pope, 1993).

3.0 Opportunities For Improvement / Revision

With renewed interest in the classification scheme through the Lake Michigan Potential Damages Study, there was an opportunity to revise and improve the classification scheme so that the above limitations could be removed, or at least significantly reduced.

In undertaking the revision of the classification scheme, a number of activities were undertaken. First, detailed discussions were held with LMPDS Study Team members (primarily staff of USACE Detroit District and CHL, and other consultants) who

provided a number of alternatives and possibilities relative to the existing limitations and relative to how the scheme was to mesh with the potential damages "model" that was to be developed in the LMPDS. This resulted in the development of a "Strawman" Classification that was then distributed to the Study Team as well as to other interested parties.

Comments on the Strawman Classification were compiled and used as a focus of discussion at a Shoreline Classification Revision Meeting that was held in Chicago in June of 1997. This meeting included staff of various USACE offices, other consultants involved in the Study, as well as interests from other state agencies (e.g., State of Ohio, State of Illinois). A thorough discussion of all issues was held and an attempt at consensus was made in order to reach decisions on any classification issues.

A Draft Revised Shoreline Classification Scheme was prepared following the above meeting and was circulated to Study Team Members as well as to members of the LMPDS Advisory Committee that was established in January of 1997. This revised scheme was then presented to the Advisory Committee at a Study Update meeting in September of 1997. Comments received at this meeting were incorporated and a final revised classification scheme was prepared (see Stewart, 1997).

4.0 The Revised Classification Scheme

The final revised classification scheme for use in the Lake Michigan Potential Damage Study is presented below:

4.1 Geomorphic Classification

Key changes here were to expand the bluff and bank categories of the original scheme to incorporate aspects of the bluffs physical character (i.e., homogeneous or composite), as well as it's sand content. As a result, a number of new sub-classes of bluff type are identified.

1. Sand or Cohesive Bluffs (define heights and other information as separate attributes)
    - 1a. Homogeneous Bluffs (sand content 0-20%)
    - 1b. Homogeneous Bluffs (sand content 20-50%)
    - 1c. Homogeneous Bluffs (sand content >50%)
    - 1d. Composite Bluffs (sand content 0-20%)
    - 1e. Composite Bluffs (sand content 20-50%)
    - 1f. Composite Bluffs (sand content >50%)

2. Sand or Cohesive Bluffs With Beach (define heights and other information as separate attributes)
    2a. Homogeneous Bluffs (sand content 0-20%)
    2b. Homogeneous Bluffs (sand content 20-50%)
    2c. Homogeneous Bluffs (sand content >50%)
    2d. Composite Bluffs (sand content 0-20%)
    2e. Composite Bluffs (sand content 20-50%)
    2f. Composite Bluffs (sand content >50%)
3. Low Bank
    3a. (Sand content 0-20%)
    3b. (Sand content 20-50%)
    3c. (Sand content >50%)
4. Baymouth Barrier
5. Sandy Beach / Dune
6. Coarse Beaches
7. Bedrock (Resistant)
8. Bedrock (Non-Resistant)
9. Open Shoreline Wetlands
10. Artificial
11. Unclassified

4.2 Shore Protection Classification

In this tier of the classification, more detail has been provided to gain insight into the "purpose" of the protection (e.g., armouring or erosion control), the "type" of structure (e.g., revetment or seawall), and the "quality" of the structure (the "Quality Qualifier"). This has resulted in a much expanded scheme than the original.

1. Coastal Armoring
    1a. Revetments
    1b. Seawalls / Bulkheads
2. Beach Erosion Control Devices
    2a. Groins
    2b. Jetties (littoral barriers?)
    2c. Offshore Breakwaters
    2d. Perched Beaches
3. Non-Structural
    3a. Beach Nourishment
    3b. Vegetation Planting / Bioengineering
    3c. Slope Grading / Bluff Stabilization
4. Protected Wetlands

5. Ad-Hoc
    5a. Concrete Rubble
    5b. Other Materials
6. Unclassified
7. No Shore Protection

Quality Qualifier

1 - Full Effect - >45 year predicted lifespan
2 - Some Effect - 5 - 45 year predicted lifespan
3 - No Effect - 0-5 year predicted lifespan
4 - Unprotected - 0 years

All would be +/- 5 years

As an example, a shore protection type of 1A1, would be a revetment with a predicted lifespan of greater than 45 years.

4.3 Nearshore Subaqueous Classification

Similar to the geomorphic classification, the goal here was to provide more detail as to the amount of sand covering the nearshore zone. Thus, key categories have been split to indicate three separate sand cover classifications.

1. Cohesive (Till)
    1a. Thick Sand Cover (>200 m3/m)
    1b. Moderate Sand Cover (50-200 m3/m)
    1c. Thin Sand Cover (<50 m3/m)
2. Cohesive (Laccustrine Clay)
    2a. Thick Sand Cover (>200 m3/m)
    2b. Moderate Sand Cover (50-200 m3/m)
    2c. Thin Sand Cover (<50 m3/m)
3. Cobble / Boulder Lag Over Cohesive
    3a. Thick Sand Cover (>200 m3/m)
    3b. Moderate Sand Cover (50-200 m3/m)
    3c. Thin Sand Cover (<50 m3/m)
4. Sandy
5. Bedrock (Resistant)
6. Bedrock (Non-Resistant)
7. Unclassified

5.0 Reclassification Activities

A number of activities took place in late 1997 and early 1998 to facilitate the re-classification of the Lake Michigan shoreline using the new shoreline classification scheme. First, in November 1997, staff of USACE Detroit District conducted a helicopter survey of the shoreline and obtained new video-tape coverage the majority of the shoreline.

Second, all associated background data was collected and reviewed for key classification information. This included lithology data, bore hole data, profiles, SHOALS data and GPR data where available.

Third, a one week "shirtsleeve" classification session was held in March of 1998 with key members of the Study Team (Chris Stewart - VGI, Rob Nairn-Baird & Associates, Joan Pope - USACE, CERC, Charles Thompson - USACE, Detroit, and Rob Ferguson - USACE, Detroit). At the workshop, all available materials including the video tapes, recent color aerial photography, topographic maps, land use maps, reports and other data were made available. Proceeding kilometer-by-kilometer along the shoreline, the reclassification team examined all the data and recorded new classification information on hardcopy maps with reach boundaries noted on them.

Following the workshop, the hardcopy information was converted into a kilometer-by-kilometer spreadsheet and associated statistics on shore type, shore protection level and nearshore type were generated. This new shoreline classification data was incorporated into the Recession Rate Analysis System (see Stewart 1998) developed for USACE Detroit.

Summary statistics for each of the shoreline classification categories are presented in the following section.

6.0 Shore Classification Summary Statistics

Shoreline classification data generated during the reclassification activities were entered into an MS Excel spreadsheet for analysis purposes. Summary statistics generated include the number of kilometers of shoreline falling into the classification category as well as the associated percentage of Lake Michigan shoreline falling in the same category. Summary table, histograms and pie charts were also generated to provide visual interpretations of the data.

6.1 Geomorphic Shore Type

Table 1 presents summary statistics of the number of kilometers of each of the geomorphic shore type categories found for the Lake Michigan shoreline. These are further illustrated by the histogram in Figure 1 and the pie chart illustrating the percentages in each category in Figure 2.

Table 1 - Geomorphic Shore Type Classification

Shore Type	Km's of Coast
1. Sand or Cohesive Homogeneous Bluffs	
1A - Homogeneous Bluffs Sand Content 0-20%	79
1B - Homogeneous Bluffs Sand Content 20-50%	41
1C - Homogeneous Bluffs Sand Content >50%	16
1D - Composite Bluffs Sand Content 0-20%	4
1E - Composite Bluffs Sand Content 20-50%	131
1F - Composite Bluffs Sand Content >50%	5
2. Sand or Cohesive Bluffs With Beach	
2A - Homogeneous Bluffs Sand Content 0-20%	11
2B -Homogeneous Bluffs Sand Content 20-50%	30
2C - Homogeneous Bluffs Sand Content >50%	77
2D - Composite Bluffs Sand Content 0-20%	0
2E - Composite Bluffs Sand Content 20-50%	4
2F - Composite Bluffs Sand Content >50%	0
3. Low Bank	
3A - Sand Content 0-20%	102
3B - Sand Content 20-50%	152
3C - Sand Content >50%	111
4 - Baymouth Barrier	90
5 - Sandy Beach / Dune	606
6 - Coarse Beaches	297
7 - Bedrock (Resistant)	0
8 - Bedrock (Non-Resistant)	376
9 - Open Shoreline Wetlands	105
10 - Artificial	199
11 - Unclassified	0
Total	2436

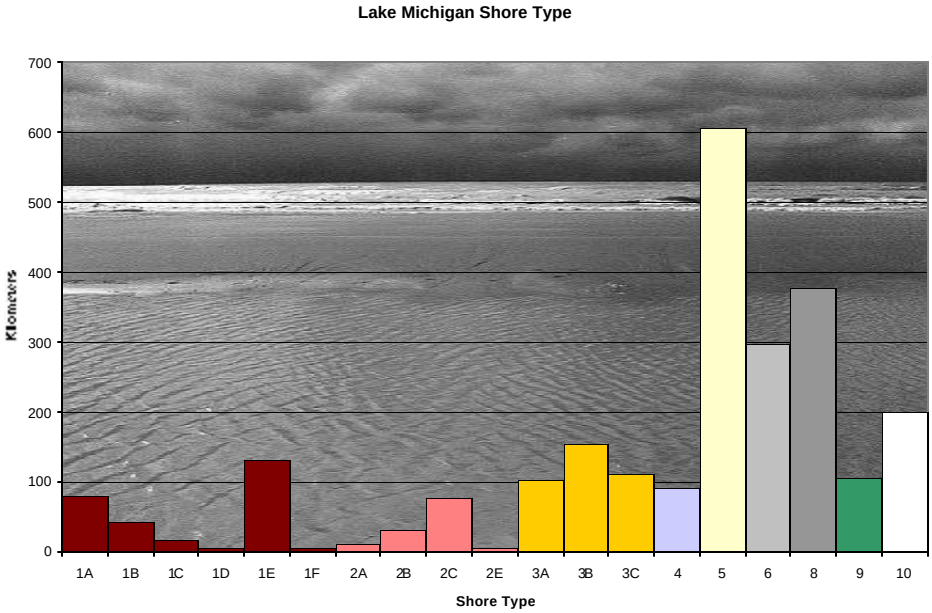

Figure 1 - Lake Michigan Shore Type - By Kilometer

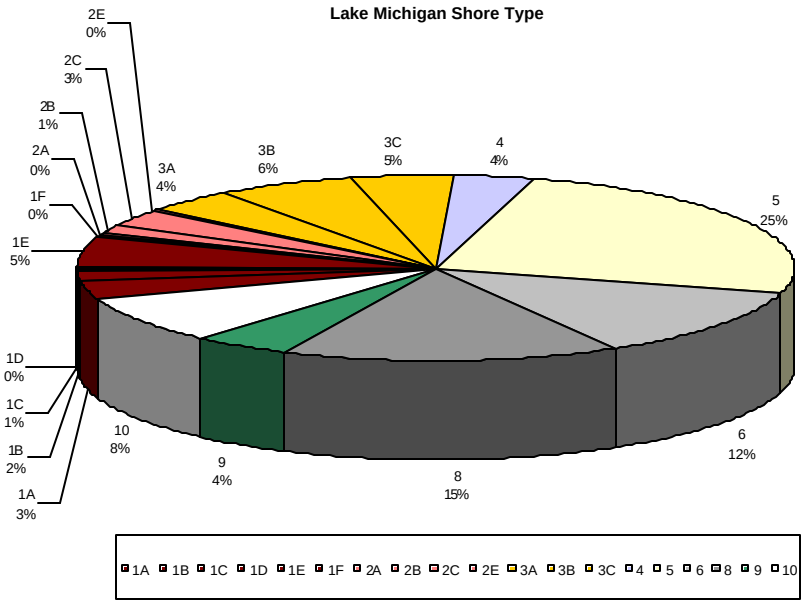

Figure 2 - Lake Michigan Shore Type - By Percentage

The most predominant shore type along Lake Michigan is Type 5 - Sandy Beach/Dune - with 606 kilometers or 25% of the entire shoreline. If combined with Type 6 - Coarse Beaches (297km or 12%) - "beach" type shorelines account for almost 37% of the Lake Michigan shoreline. The next most frequent shoreline types are Non-Resistant Bedrock (Type 8) with 376km or 15% of the shoreline, followed by Low Bank (Type 3) shorelines, with 365km or 15% of the shoreline (these are divided fairly equally between the three sub-categories for this category). It is interesting to note that there were no "Resistant" Bedrock shorelines (Type 7) classified for the lake. Sand or Cohesive Homogeneous Bluffs (Type 1) account for 11% of the total shoreline length, with the majority of these (131km or 5%) falling into the 1E category (Composite Bluffs, Sand Content 20-50%).

6.2 Shoreline Protection Classification

Table 2 presents summary statistics of the number of kilometers of each of the shoreline protection type categories found for the Lake Michigan shoreline. These are further illustrated by the histogram in Figure 3 and the pie chart illustrating the percentages in each category in Figure 4.

Table 2 - Shoreline Protection Classification

Shore Protection Type	KMs of Coast
1. Coastal Armoring	
1A - Revetments - Unknown Quality	1
1A1 - Revetments >45 year lifespan	208
1A2 - Revetments 5-45 year lifespan	192
1A3 - Revetments 0-5 year lifespan	88
1A4 - Revetments 0 year lifespan (disrepair)	0
1B1 - Seawalls/Bulkheads >45 year lifespan	84
1B2 - Seawalls/Bulkheads 5-45 year lifespan	18
1B3 - Seawalls/Bulkheads 0-5 year lifespan	67
1B4 - Seawalls/Bulkheads 0 year lifespan (disrepair)	2
2. Beach Erosion Control Devices	
2A1 - Groins >45 year lifespan	6
2A2 - Groins 5-45 year lifespan	17
2A3 - Groins 0-5 year lifespan	71
2A4 - Groins 0 year lifespan (disrepair)	7
2B - Jetties - Unknown Quality	1
2B1 - Jetties >45 year lifespan	57

2B2 - Jetties 5-45 year lifespan	13
2B3 - Jetties 0-5 year lifespan	30
2B4 - Jetties 0 year lifespan (disrepair)	1
2C - Offshore Breakwaters - Unknown Quality	3
2C1 - Offshore Breakwaters >45 year lifespan	16
2C2 - Offshore Breakwaters 5-45 year lifespan	0
2C3 - Offshore Breakwaters 0-5 year lifespan	0
2C4 - Offshore Breakwaters 0 year lifespan (disrepair)	0
3. Non-Structural	
3A1 - Beach Nourishment >45 year lifespan	7
3A2 - Beach Nourishment 5-45 year lifespan	4
3A3 - Beach Nourishment 0-5 year lifespan	0
3A4 - Beach Nourishment 0 year lifespan (disrepair)	0
3B1 - Vegetation Planting >45 year lifespan	1
3B2 - Vegetation Planting 5-45 year lifespan	0
3B3 - Vegetation Planting 0-5 year lifespan	0
3B4 - Vegetation Planting 0 year lifespan (disrepair)	1
3C1 - Slope/Bluff Stabilization >45 year lifespan	0
3C2 - Slope/Bluff Stabilization 5-45 year lifespan	0
3C3 - Slope/Bluff Stabilization 0-5 year lifespan	1
3C4 - Slope/Bluff Stabilization 0 year lifespan (disrepair)	0
4. Protected Wetlands	0
5. Ad-Hoc Structures	
5A1 - Concrete Rubble >45 year lifespan	0
5A2 - Concrete Rubble 5-45 year lifespan	2
5A3 - Concrete Rubble 0-5 year lifespan	14
5A4 - Concrete Rubble 0 year lifespan (disrepair)	0
5B1 - Other Materials >45 year lifespan	0
5B2 - Other Materials 5-45 year lifespan	0
5B3 - Other Materials 0-5 year lifespan	1
5B4 - Other Materials 0 year lifespan (disrepair)	
6 - Unclassified	4
7 - No Protection	1566
Grand Total*	2483

*Note: More than one shore type was recorded for each kilometer reach in some cases along the shoreline. As a result the total kilometers for shore protection add up to more than the total length of the Lake Michigan shoreline.

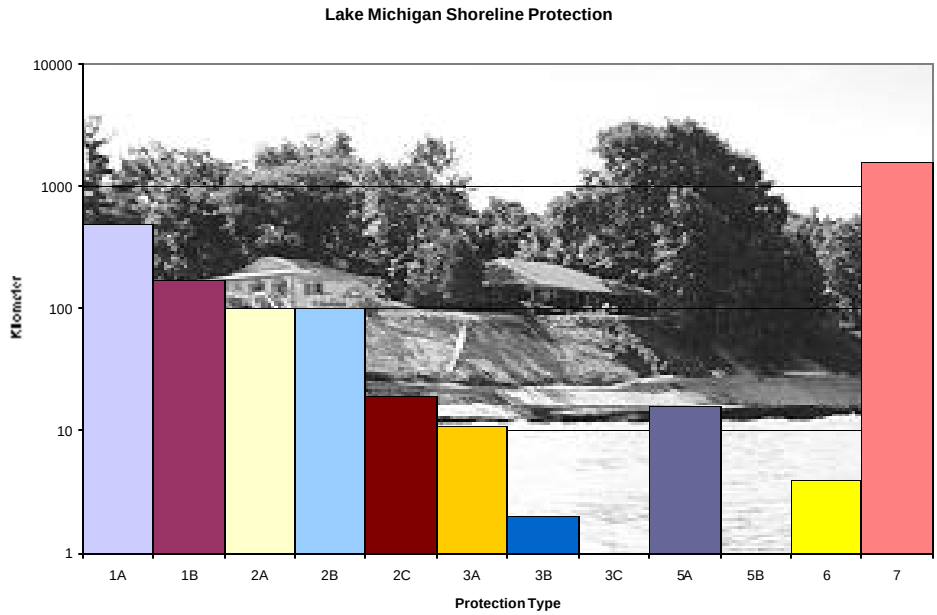

Figure 3 - Lake Michigan Shore Protection Classification - By Kilometer

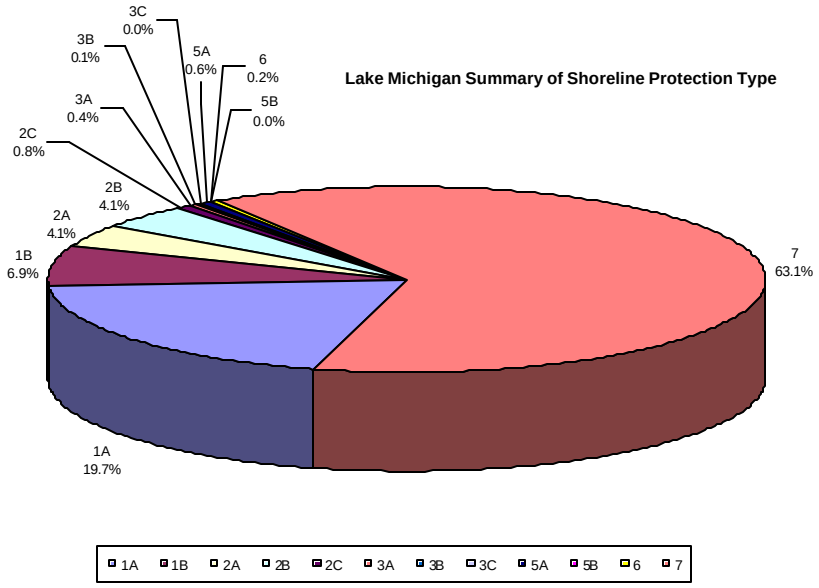

Figure 4 - Lake Michigan Shore Protection Classification - By Percentage

Just over 63% (1566 km) of the Lake Michigan shoreline is classified as unprotected. Of the remaining shoreline, the majority is protected with Revetments (Type 1A - 20%), that are in relatively good condition (208km with predicted lifespan of >45years (1A1) and 192km with predicted lifespan of 5-45 years (1A2)). Seawalls (Type 1B) are the next most predominant protection type (171km - 7%), however many of these (69km) are in poor condition (1B3 or 1B4). Next most predominant types of shore protection found on Lake Michigan are jetties (102 km) and groins (101km). Additional breakdown of shore protection class statistics are provided by each major sub-group in Figures 5-8 found below.

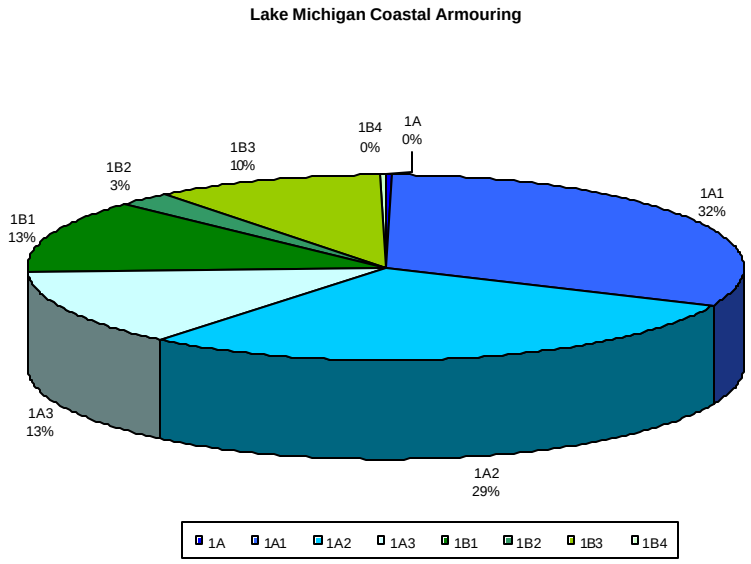

Figure 5 - Lake Michigan Shore Protection Classification - Coastal Armoring Classification

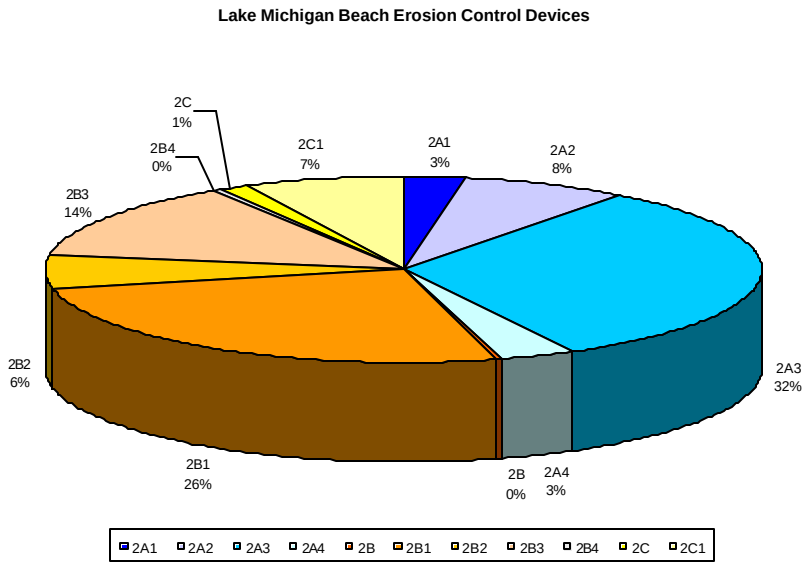

Figure 6 - Lake Michigan Shore Protection Classification - Beach Erosion Control Classification

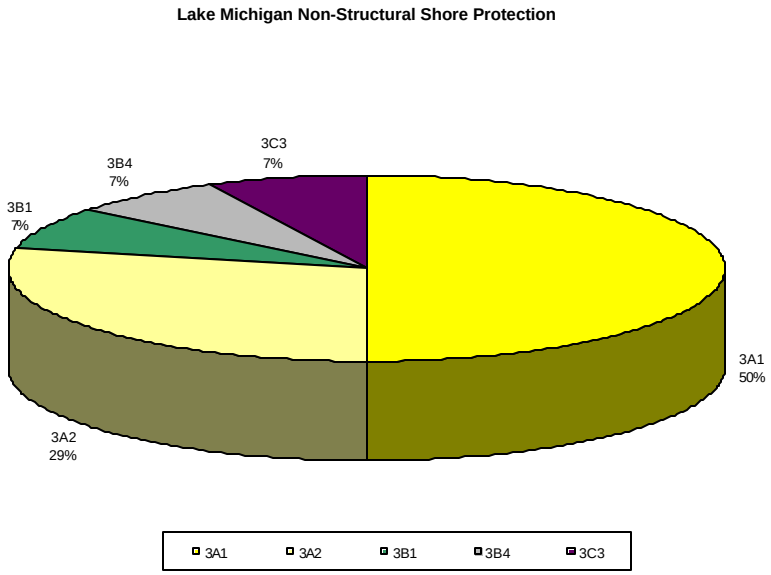

Figure 7 - Lake Michigan Shore Protection Classification - Non-Structural Classification

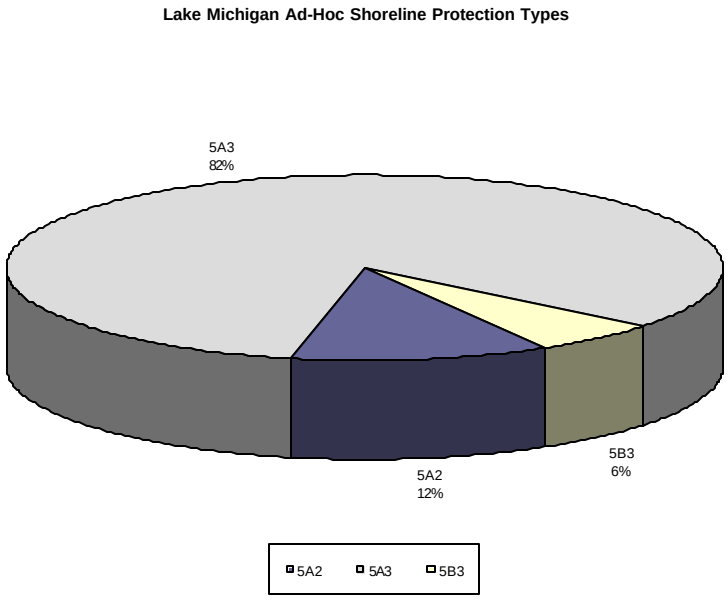

Figure 8 - Lake Michigan Shore Protection Classification - Ad-Hoc Classification

6.3 Nearshore Sub-Aqueous Classification

Table 3 presents summary statistics of the number of kilometers of each of the nearshore subaqueous type categories found for the Lake Michigan shoreline. These are further illustrated by the histogram in Figure 9 and the pie chart illustrating the percentages in each category in Figure 10.

Table 3 - Nearshore Subaqueous Classification

Nearshore Class	Kms of Coast
1. Cohesive (Till)	
1A - Thick Sand Cover (>200m3/m)	125
1B - Moderate Sand Cover (50-200 m3/m)	224
1C - Thin Sand Cover (<50 m3/m)	7
2. Cohesive (Lacustrine Clay)	
2A - Thick Sand Cover (>200m3/m)	21
2B - Moderate Sand Cover (50-200 m3/m)	46
2C - Thin Sand Cover (<50 m3/m)	3

3. Cobble/Boulder Lag Over Cohesive	
3A - Thick Sand Cover (>200m3/m)	188
3B - Moderate Sand Cover (50-200 m3/m)	233
3C - Thin Sand Cover (<50 m3/m)	202
4 - Sandy	518
5 - Bedrock (Resistant)	0
6 - Bedrock (Non-Resistant)	861
7 - Unclassified	8
Total	2436

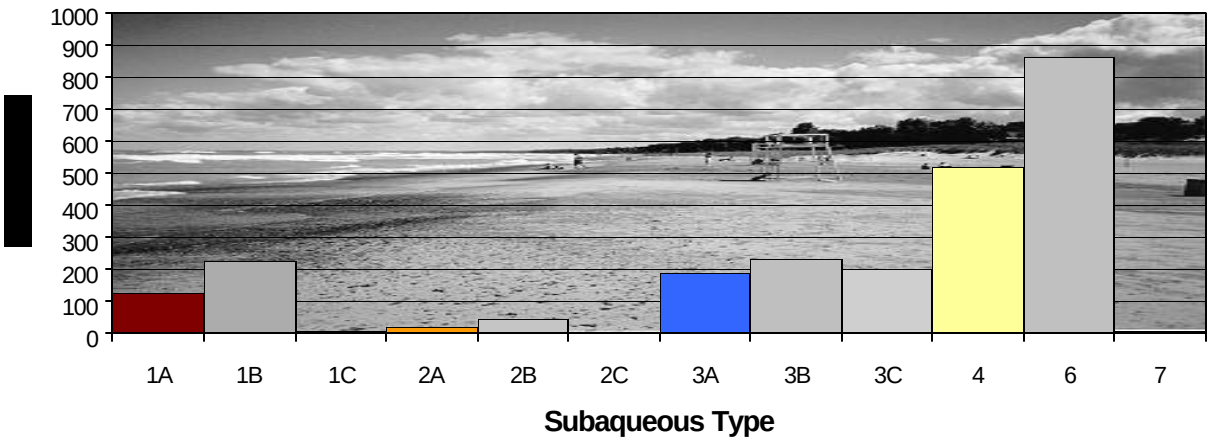

Figure 9 - Lake Michigan Nearshore Subaqueous Classification - By Kilometer

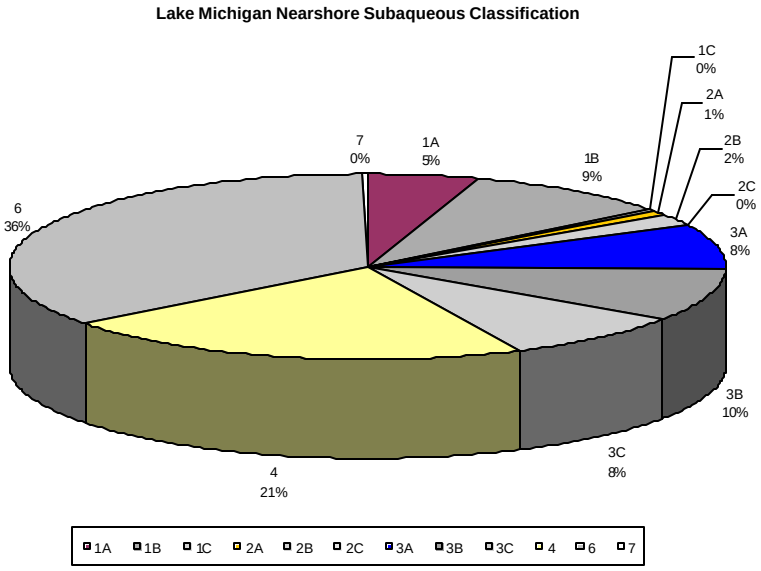

Figure 10 - Lake Michigan Nearshore Subaqueous Classification - By Percentage

Non-Resistant Bedrock (Type 6) and Cobble-Boulder Lag (Type 3) make up the majority of the nearshore classification for Lake Michigan with 861km (36%) and 723km (26%) respectfully of each class recorded. In the Cobble Boulder Lag category, the split is relatively even between Types 3A (188km), 3B (233 km) and 3C (202km). Type 4 (Sandy) are the next most predominant, occupying 21% of the shoreline (518km), followed by the Cohesive (Till) category (Type 1), occupying 14% (or 356km) of the shoreline. The majority of the Type 1 category are Type 1B - Moderate Sand Cover (50-200m3/m), with 224 kilometers of this category recorded.

7.0 Future Refinements to the Shoreline Classification System

While the Shoreline Classification system and it's associated application to the Lake Michigan shoreline has undergone substantial refinement and improvement from the original scheme developed for the IJC Reference Study, it is likely that a number of additional improvements may be required as a result of ongoing activities within the Lake Michigan Potential Damages Study, as well as other activities being carried out on other lakes for both the Detroit and Buffalo Districts of the USACE. This includes the following issues:

- Additional quality control / assurance review of the lakewide data base will likely be required as part of the lakewide application of the Flood and Erosion Prediction System being developed as part of the LMPDS. While steps were taken to re-classify the shoreline as accurately as possible, there are certain to be areas which have been incorrectly classified (particularly in areas where new video was not available, and where geologic information was scarce) and these will be highlighted in both statistical and deterministic approaches to assessing lakewide predictive capabilities of the Flood and Erosion Prediction System;
- Depending on the outcome of LMPDS work by Baird & Associates and the University of Wisconsin on bluff failure types and the implication for an uncertainty band around projected shoreline positions, modifications of the system may be required to allow for lakewide classification of bluff failure modes;
- Discussions are currently underway with Detroit and Buffalo USACE Districts to conduct similar reclassifications for the remaining lakes in the Great Lakes basin including Lake St. Clair AND major islands in each of these lakes. It may be possible that the shore classes in the present scheme do not account for all shore types present on these other lakes. As such, minor revisions may be required to address this. Similarly, if islands are added to the database, the Lake Michigan database will need to be adjusted to reflect such changes.
- Data on nearshore subaqueous shore types, while largely improved for this classification effort, are still relatively scarce around the entire Lake Michigan shoreline. As new nearshore information is recorded in the literature, it could also be added to the classification database to improve our knowledge of this tier of the classification.

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