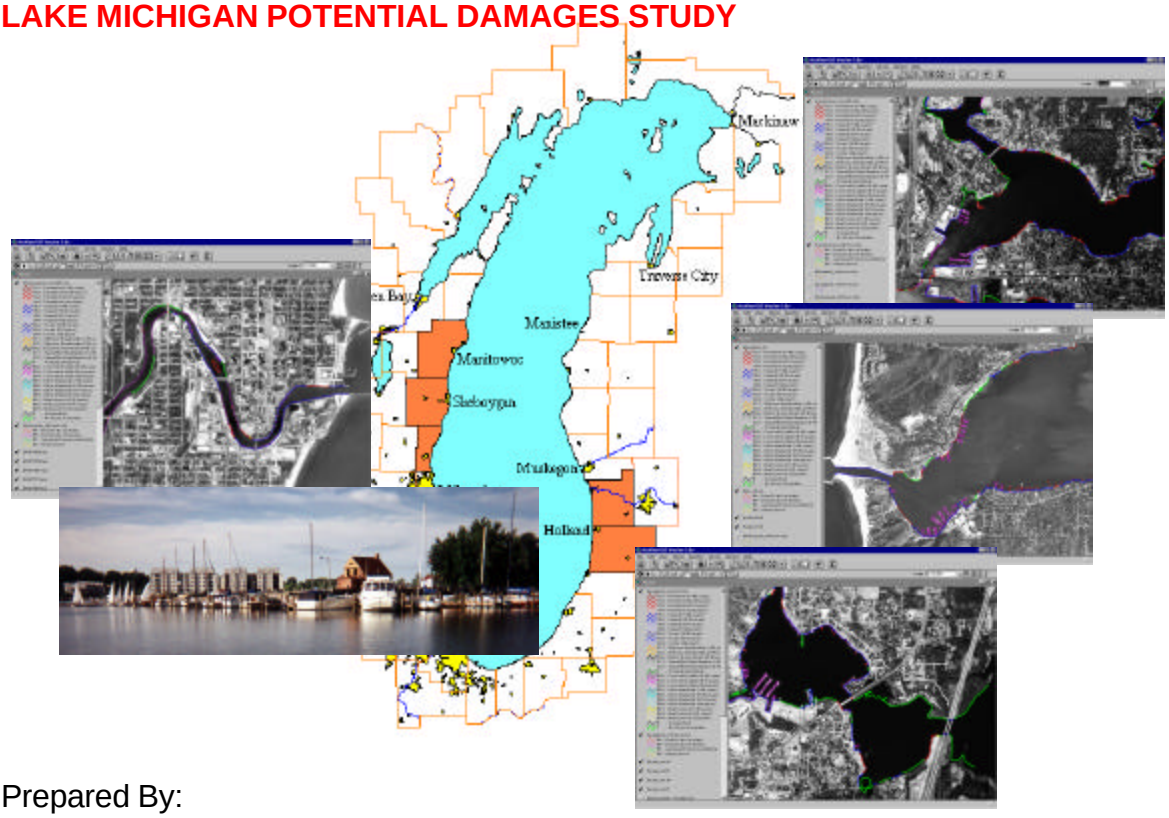
U.S. Army Corps of Engineers - Detroit District

INVENTORY AND MAPPING OF SHORELINE PROTECTION AND BOATING STRUCTURES IN DROWNED RIVERMOUTH AREAS OF LAKE MICHIGAN

GRAND RIVER, GRAND HAVEN, MI
LAKE MACATAWA, HOLLAND, MI
KALAMAZOO LAKE AND RIVER, SAUGATUCK/DOUGLAS, MI
SHEBOYGAN RIVER, SHEBOYGAN, WI

LAKE MICHIGAN POTENTIAL DAMAGES STUDY



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1.0 Introduction

1.1 Background

The U.S. Army Corps of Engineers - Detroit District has initiated an extensive and long-term assessment of potential shoreline damages over the next 50 years due to fluctuating lake levels along the Lake Michigan shoreline. This "Lake Michigan Potential Damages Study" (LMPDS) will ultimately lead to the development of a series of state-of-the-art engineering, mapping and coastal zone management tools that can be used for the accurate prediction of flood and erosion damages that might arise due to fluctuating lake levels.

A key task in this assessment is to determine the interdependence between coastal processes and the extent, type and quality of structural shore protection put in place along the Lake Michigan shoreline. Many coastal processes influence the effectiveness of shore protection structures over their design life. Alternatively, structural shore protection has a direct and measurable effect upon alongshore sediment transport interfering with natural processes of beach accretion and erosion.

In 1999, an inventory and historical trend analysis of shore protection structures in five prototype counties along the Lake Michigan shoreline was conducted (Stewart, 1999). This information is being used to assist in determining the level of shore protection that may reasonably exist along these shorelines over the next 50 years, as well as the level of potential damage that these structures may prevent (or alternatively cause).

1.2 Purpose of This Report

In 2000, USACE Detroit District requested the extension of this inventory to four drowned rivermouth systems on Lake Michigan, within these five prototype counties (Figure 1). These were:

1) the Grand River at Grand Haven, MI;
2) Lake Macatawa at Holland, MI;
3) Kalamazoo Lake and River at Saugatuck/Douglas, MI; and
4) the Sheboygan River in Sheboygan, WI.

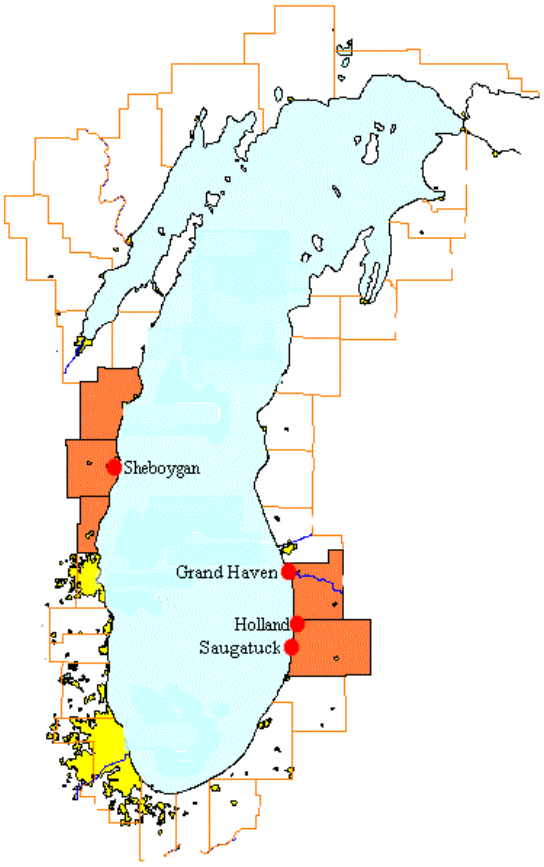


Figure 1 - Lake Michigan Prototype Counties and Location of Rivermouth Areas

The information collected will be used within the LMPDS to calculate the potential damages due to the backwater effects of high and low water scenarios in these rivermouth areas. The inventory of structures in these areas included all of the shore protection structures as per the shoreline protection classification scheme that was developed for the LMPDS (see Stewart 1997 and 1998) and sought to also identify key structures in the water such as boat slips, marinas, launch ramps, etc. that could reasonably be expected to

be affected by high or low water levels. No trend analysis was required for this task, only an inventory and mapping of present day structures.

All information was mapped in an ArcView GIS environment and statistical summaries of structure type have been prepared for each rivermouth area.

1.3 Format of This Report

The approach and methodology used in inventorying and mapping these structures is presented in Section 2.0. Resulting statistical data and related mapping products are presented in Section 3.0. Recommendations and conclusions are presented in Section 4.0 and hardcopy printouts of the mapping for all four rivermouth areas is presented in an Appendix.

2.0 Methodology

2.1 Data Sources and Limitations

Detailed field mapping of the structures was not required for this task. As such, various data sources were relied upon to inventory and map the structures. A brief description of each source and their limitations is provided below.

2.1.1 Backwater Mapping

In 1999, Wade Trim conducted a series of backwater and storm water rise determinations for these four rivermouth areas. A product of this analysis was a series of "high water maps" that showed the upstream limit of high water events on Lake Michigan in these rivermouth areas. An example is presented in Figure 2. For mapping purposes in this task, shore protection and boating structures were only required to be identified within these backwater limits.

Figure 2 – Example of High Water Mapping, Grand River, Grand Haven, Michigan

While the backwater mapping is likely adequate to capture structures that might be impacted by high water events on Lake Michigan, it may not be adequate to capture the upstream limit of structures that may be impacted by extreme low water levels. As an example, discussions with local officials in Saugatuck revealed that a number of docks, marinas and other facilities well upstream of the backwater mapping limits, were rendered unusable by the low water levels experienced on the Lake and in the river in the early spring and summer of 2000 (Joe Milauckas, personal communication). These structures have not been captured in this inventory and would need to be included in any low water potential damage estimates that are prepared for these areas.

2.1.2 Aerial Photography

Shore protection and boating structure mapping was primarily conducted using 1:6000 scale 1999 aerial photography for the Grand River, Lake Macatawa, and Kalamazoo River/Lake, in Michigan and 1992 air photography for a portion of the Sheboygan River in Wisconsin.

The Sheboygan River photography only covered the vicinity of the river near the outlet to Lake Michigan and did not extend far enough inland to capture the backwater limit of mapping that was required. To rectify this, recent 2000 aerial photography was obtained from the Bay Lake Regional Planning Commission. Unfortunately, while this photography covered the full extent of the river, the scale was such that it was impossible to accurately discern protection structures along the riverbank. Thus, for areas not covered by the original photography, we relied upon the digital orthophotography to complete the mapping. We also met briefly with city officials during an on-site workshop in Milwaukee to verify the type of protection in place along this shoreline.

Other minor limitations were also encountered with the photography. These included:

- in some instances, the sun angle at the time of photography created tree and structure shadows along the riverbank, totally obscuring any structures present. Where these areas could not be examined using the video or other sources, some errors in classification may occur;

- in some instances, glare off highly reflective surfaces (e.g., concrete, rip rap, sand) made it difficult to "see" and discern whether a structure was a concrete wall, or a rip rap structure. In most cases where this occurred, the video was able to be used to make the differentiation, however there may be some cases where video coverage does not exist and where errors in classification may occur;

2.1.3 Digital Orthophotography

Digital orthophotography that has been prepared for the Lake Michigan shoreline was used as a second or third level of data where air photography and video did not exist. In most cases it served as a backdrop for the mapping activities that were undertaken. Where video and air photography were not available, classification was done directly from the available DOP or DOQQ image. In most cases this was adequate, but some structures may not have been recorded as they may not have been visible at the scale and resolution of the digital orthophoto.

2.1.4 Mr. Sid Images

Mr. Sid images were provided for a number of sections of the rivermouth areas being mapped. In most cases, these served as an excellent data source for verifying structures observed on the video or on the standard air photo, as the resolution and clarity of the images, particularly when zoomed in, were extremely good, and allowed for on-screen determination of features that could not be seen with the stereoscopes on the air photos.

2.1.5 Video Tape

Video tape of the drowned rivermouth areas along the Michigan shoreline was obtained by USACE staff in May of 2000. This video tape proved to be extremely valuable in classifying the shoreline structures present, as, in addition to the images being captured, USACE staff provided narration and descriptions of the structures being observed. There were a number of limitations to this data source however:

- video was not obtained for the Sheboygan River in Wisconsin;
- due to extremely low water levels in May of 2000, there were a number of backwater areas and small embayments that could not be accessed by the boat and thus that could not be videotaped at close range. Where possible, USACE staff tried to zoom into these areas with the camera and describe the structures present, or in some cases videotaped from land based locations in an attempt to film all the areas in question. Despite this, there were still areas that could not be taped and where other data sources had to be utilized.
- during the filming of a portion of the Grand Haven rivermouth area, a malfunction in the video camera resulted in a significant portion of this area not being captured and

in extremely poor video quality. In this case, classification had to be done primarily from the aerial photography.

2.1.6 Field Verification

Given some of the limitations in the data sources noted above, attempts were made to field verify some of the areas in question, particularly those areas where air photography did not exist.

Field visits took place in late July of 2000 and focused on Lake Macatawa in Holland, MI and Kalamazoo Lake and River at Saugatuck, MI. Due to time and logistical constraints, field visits were not conducted at the Grand Haven or Sheboygan sites.

In addition to these site visits, discussions with municipal officials from the Saugatuck and Sheboygan sites, assisted in the verification of the types and extents of structures present.

2.2 Shoreline Delineation

In developing various coastal zone databases for the LMPDS, the majority of data (e.g., shoreline classification, recession rates, land use, etc.) have been ascribed to the open coast shoreline using a series of 1 kilometer reach segments that were defined during the IJC Water Level Reference Study in the early 1990s, using what, at that time, were the best available mapping products to "define" the shoreline. With the advance in digital mapping and digital photographic techniques over the past ten years, a new digital shoreline, with a much higher resolution, has been produced by USACE Detroit that is much more accurate than the shoreline used in 1993 and that has corrected a numbers of errors that were present in the 1993 shoreline. Similarly, as the original (IJC) shoreline did not include the rivermouth areas being examined, USACE Detroit developed a new digital shoreline for these areas which was used as the "baseline" shoreline for the mapping activity.

Utilizing this newly created digital shoreline for each rivermouth area, the rivermouth and upstream river shorelines were sub-divided into 1/10th of a kilometer sub reaches for mapping and classification purposes and to be consistent with new reach numbering that was being developed for the open coast of the lake in a separate activity. Unlike the open coast shore protection mapping that was conducted in 1999 (Stewart, 1999), these reach extents were not utilized to determine the extent of shore protection structures present,

but instead only served as a mapping reference (available as a separate layer of information in the ArcView GIS database). Extent of the structures in this activity was determined directly within ArcView by using the start and end points of the structures, which were mapped (plotted) along the new digital shoreline (see Section 2.3 below).

Despite the increased accuracy of the new digital shoreline in these rivermouth areas, some minor errors were observed during the classification process. First, in some cases, USACE staff mistakenly digitized floating barges, other vessels, or non-permanent dock structures as part of the fixed shoreline. Second, in a few cases, the mapped shoreline had been physically altered (as observed on the May 2000 video) since the date of the photography used to delineate the new shoreline. A notable example of this is the location of the entrance to a semi-circular marina on the north side of the entrance channel from Lake Michigan to the Grand River and Spring Lake study area. Where these errors and changes were observed, corrections were made to the digital shoreline prior to mapping the shore protection structures.

2.3 Protection Structure Delineation and Measurement

Delineation of shore protection and boating structures for the rivermouth areas was completed directly in ArcView GIS. The new digital shoreline was plotted for the area in question and the associated digital orthophoto was brought in to serve as a backdrop for reference purposes. Proceeding linearly along the shoreline, start and end points of each discernable shore protection structure were obtained through the examination of the various data sources (video, air photos, digital orthophotography, Mr. Sid images). These were then plotted on the digital shoreline by bi-secting the shoreline line string in the appropriate spot. This created a distinct line segment which was then classified using the shoreline protection classification scheme developed for Lake Michigan in the first phases of the LMPDS study (Table 1). This classification includes a breakdown by structure purpose (e.g., Coastal Armoring), Structure Type (e.g., Revetment) and Structure Quality (e.g., 5-45 Year Lifespan).

An additional goal of this mapping exercise was to capture key "shore-perpendicular" structures in the water such as boat slips, marinas, launch ramps, etc. that could reasonably be expected to be affected by high or low water levels. In this regard, a new, secondary level of classification was developed for boating related structures as follows:

Class 6A - Private Boat Docks - Applies primarily to private property owner docks constructed for recreational boating purposes.

Table 1: Shore Protection Type Classification Legend

1. Coastal Armoring

1A1 - Revetments >45 year lifespan
1A2 - Revetments 5-45 year lifespan
1A3 - Revetments 0-5 year lifespan
1A4 - Revetments 0 year lifespan (disrepair)

1B1 - Seawalls/Bulkheads >45 year lifespan
1B2 - Seawalls/Bulkheads 5-45 year lifespan
1B3 - Seawalls/Bulkheads 0-5 year lifespan
1B4 - Seawalls/Bulkheads 0 year lifespan (disrepair)

2. Beach Erosion Control Devices

2A1 - Groins >45 year lifespan
2A2 - Groins 5-45 year lifespan
2A3 - Groins 0-5 year lifespan
2A4 - Groins 0 year lifespan (disrepair)

2B1 - Jetties >45 year lifespan
2B2 - Jetties 5-45 year lifespan
2B3 - Jetties 0-5 year lifespan
2B4 - Jetties 0 year lifespan (disrepair)

2C1 - Offshore Breakwaters >45 year lifespan
2C2 - Offshore Breakwaters 5-45 year lifespan
2C3 - Offshore Breakwaters 0-5 year lifespan
2C4 - Offshore Breakwaters 0 year lifespan (disrepair)

3. Non-Structural

3A1 - Beach Nourishment >45 year lifespan
3A2 - Beach Nourishment 5-45 year lifespan
3A3 - Beach Nourishment 0-5 year lifespan
3A4 - Beach Nourishment 0 year lifespan (disrepair)

3B1 - Vegetation Planting >45 year lifespan
3B2 - Vegetation Planting 5-45 year lifespan
3B3 - Vegetation Planting 0-5 year lifespan
3B4 - Vegetation Planting 0 year lifespan (disrepair)

3C1 - Slope/Bluff Stabilization >45 year lifespan
3C2 - Slope/Bluff Stabilization 5-45 year lifespan
3C3 - Slope/Bluff Stabilization 0-5 year lifespan
3C4 - Slope/Bluff Stabilization 0 year lifespan (disrepair)

4. Protected Wetlands

5. Ad-Hoc Structures

5A1 - Concrete Rubble >45 year lifespan
5A2 - Concrete Rubble 5-45 year lifespan
5A3 - Concrete Rubble 0-5 year lifespan
5A4 - Concrete Rubble 0 year lifespan (disrepair)

5B1 - Other Materials >45 year lifespan
5B2 - Other Materials 5-45 year lifespan
5B3 - Other Materials 0-5 year lifespan
5B4 - Other Materials 0 year lifespan (disrepair)

6 - Unclassified

7 - No Protection

Class 6B - Marina Structures - Applies to recreational boat docks and slips associated with commercial, private and municipal marina operations.

Class 6C - Commercial and Industrial Docks - Applies to docks and wharves associated with commercial and industrial operations.

Class 6D - Boat Ramps / Launch Areas - Applies to launch ramps and docks associated with commercial, private and municipal boat launch ramps.

Within the overall shoreline protection classification scheme, Class 6 previously applied to "unclassified" situations. As there were previously no occurrences of this Class, it was converted for use in application to boating structures. A quality quantifier was not assigned to these classifications.

All structures pertaining to these classes, where observed, were digitized and captured in the ArcView database. Where possible, attribute information for these structures, particularly marina docks, included an estimate of the number of boat slips associated with each structure.

2.4 Classification Limitations

While every effort was made to map and classify structures in each rivermouth area as accurately as possible, in addition to the data limitations noted earlier (Section 2.1), a number of additional limitations were present that need to be highlighted:

1. The aerial photography used for mapping these areas was dated April of 1999. Thus, at this time of year, many marinas and shore property owners may not have yet installed seasonal docks or piers. As such not all of these perpendicular dock features may have been captured when using this photography to digitize these features.

2. For the Boat Ramp / Launch category, it can apply to both the alongshore (linear) shoreline classification, as well as the shore perpendicular classification where docks are associated with the launch area.

3. Portions of the shoreline underneath highway or road overpasses were not visible on air photos, and where video of these areas was not available, it was assumed shore protection consisted of a sloping rip rap or concrete revetment.

4. In some backwater areas, shoreline and marsh vegetation significantly obscured the water-land interface making it difficult to see any shore protection present.

This was particularly true in the backwater areas of Lake Macatawa in Holland, along the shoreline of Windmill Island and along the southern shoreline of this area.

3.0 Data Presentation and Analysis

3.1 Data Structure

All classification data was entered directly into attribute tables within ArcView GIS. These tables contained the following key information:

For shore parallel structures:

Length - This provided the length of the particular shoreline segment (and shore protection type) in meters based on the start and end points that were mapped;

Shore_prot - The shore protection classification as assigned, including the quality quantifier;

Notes - any relevant additional information about the nature of the structure.

For shore perpendicular structures:

Length - This provided the length of the particular structure (and dock type) in meters based on the start and end points that were mapped;

Dock_type - The shore perpendicular classification as assigned (6A - 6D);

Berths - where determinable, a count of the number of estimated berths, or boat slips;

Comments - any relevant additional information about the nature of the structure.

3.2 Data Presentation

The shore protection, dock structure, and reach classification data were all mapped in ArcView GIS and provided as separate data coverages (Arc shape files) which were delivered electronically to USACE Detroit. Examples of the mapping for each rivermouth area can be found in Figures 3-6. Hardcopy map printouts showing the entire area of each rivermouth are presented in Appendix 1.

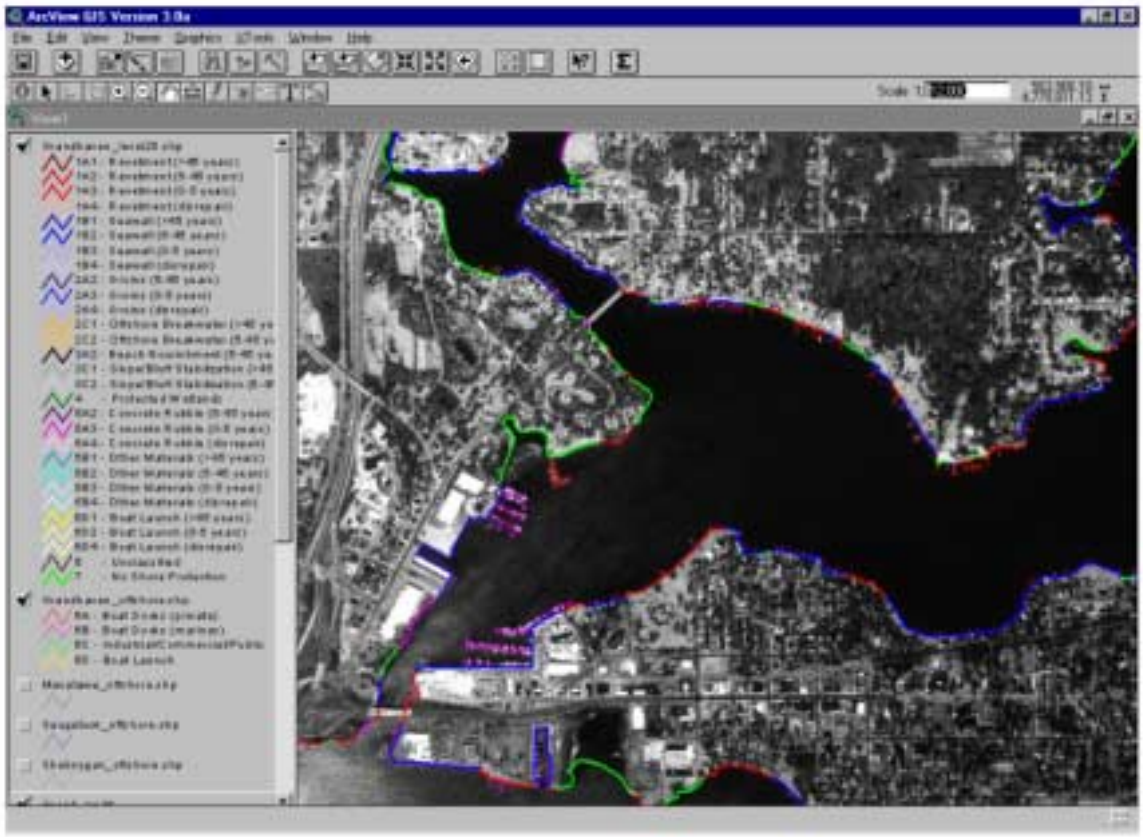


Figure 3 - Example of Shoreline Protection and Boating Related Structures GIS Mapping, Portion of Grand River and Spring Lake, Grand Haven, Michigan

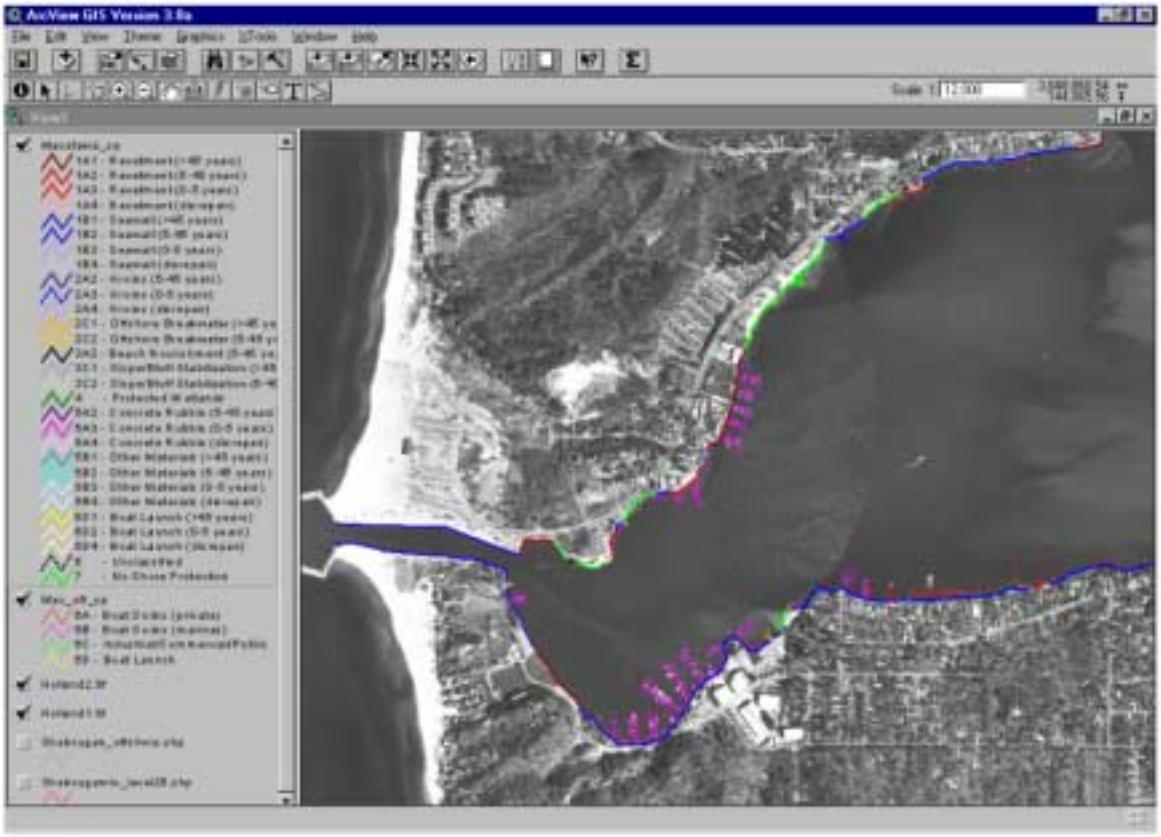


Figure 4 - Example of Shoreline Protection and Boating Related Structures GIS Mapping, Portion of Lake Macatawa, Holland, Michigan

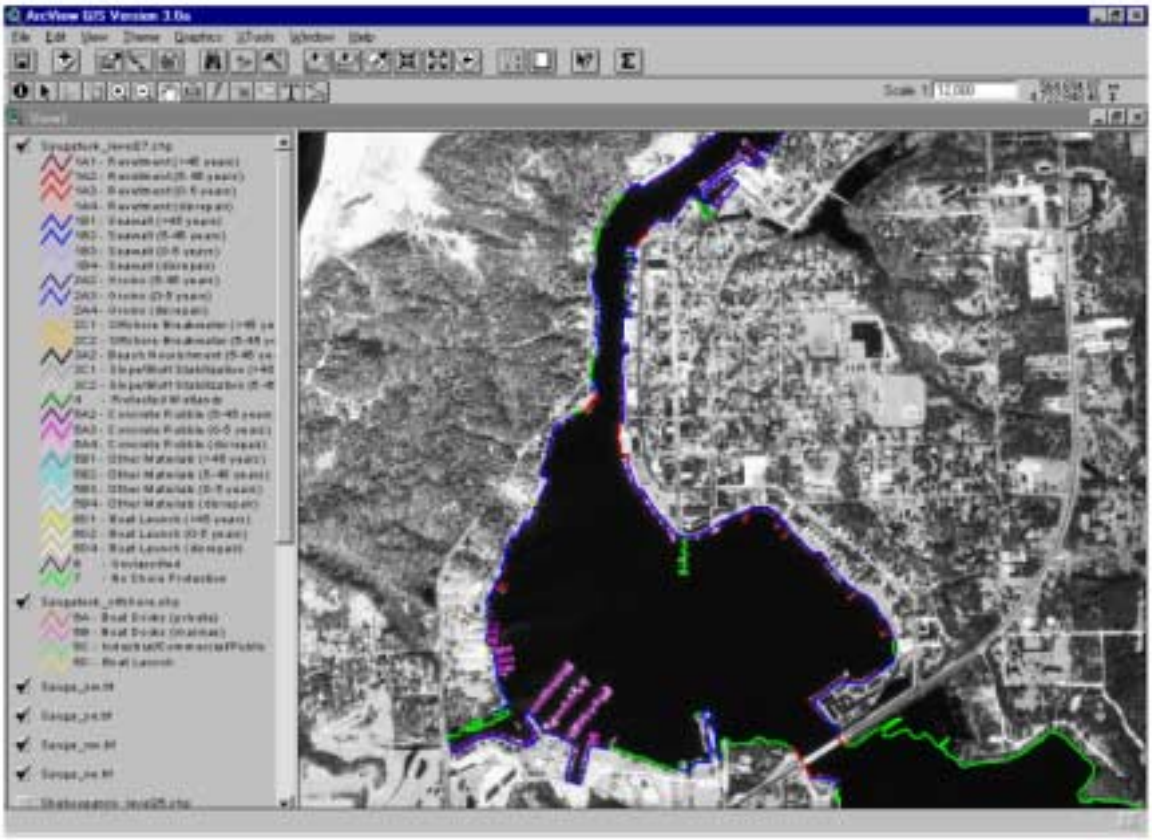


Figure 5 - Example of Shoreline Protection and Boating Related Structures GIS Mapping, Portion of Kalamazoo Lake and River, Saugatuck, Michigan

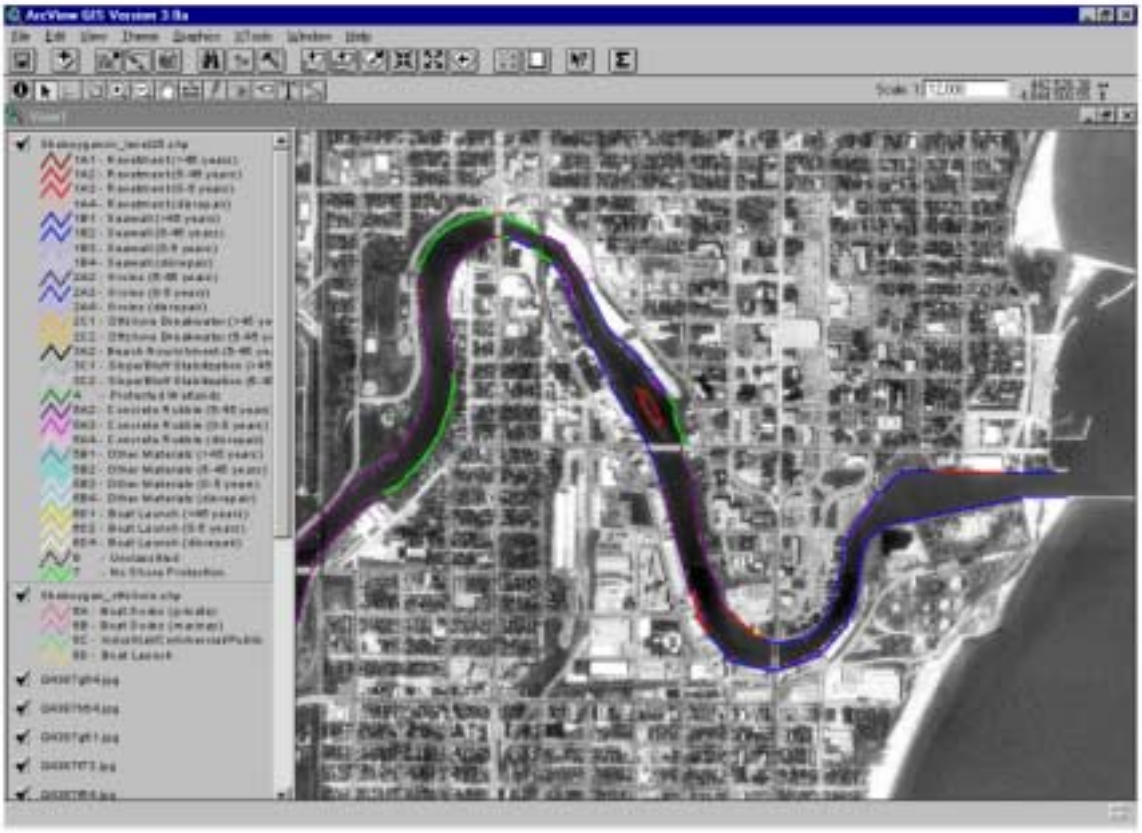


Figure 6 - Example of Shoreline Protection and Boating Related Structures GIS Mapping, Portion of Sheboygan River, Sheboygan, Wisconsin.

3.3 Data Analysis

For analysis purposes, data was exported from the ArcView GIS program into MS-Excel in order to compute overall statistics on the total lengths of the different types of structures for each rivermouth area, as well as the types and numbers of shore perpendicular boating structures. Analysis of the data for each of the 4 rivermouth areas is presented below.

3.3.1 Grand River, Grand Haven, Michigan

Summary statistics on the type and extent of shore protection structures for the Grand River and Spring Lake site are provided in Table 2.

For this area, seawalls and revetments comprise the bulk of any linear shore protection that is in place (over 30km and 16km respectively), with most of these falling into the class 2 quality category (5-45 year lifespan). Generally, as compared to the open coast of Lake Michigan, such structures appear to be better maintained and of higher quality. The next most frequent type of linear shore protection was concrete rubble, usually dumped to simulate a low quality revetment. One example of beach nourishment was noted in an area where a group of property owners had created a sandy beach in front of their properties. One small breakwater structure was recorded and was protecting the entrance to the North Shore Marina. Over 28km of this rivermouth area was unprotected, the majority of which is focused around the marshy shorelines of Martinique and Dermo Islands in the Grand River, as well as in the upper reaches and bayous of Spring Lake.

Table 3 presents a count of the types of boating structures at this site. Over 1000 private and marina dock structures (6A and 6B) were counted for this area, with only 7 commercial or industrial dock spaces noted. Boat launch areas occupied just over 100 meters of the shoreline in total and had 11 boat docks associated with them.

Table 2 - Shore Protection Type Summary Statistics (Grand River / Spring Lake at Grand Haven, Michigan)

Type	Description	Length (m)
1. Coastal Armoring		
1A1	Revetments >45 year lifespan	45
1A2	Revetments 5-45 year lifespan	9,469
1A3	Revetments 0-5 year lifespan	7,092

1A4	Revetments 0 year lifespan (disrepair)	0
1B1	Seawalls >45 year lifespan	9,274
1B2	Seawalls 5-45 year lifespan	21,324
1B3	Seawalls 0-5 year lifespan	485
1B4	Seawalls 0 year lifespan (disrepair)	130
2. Beach Erosion Control Devices		
2A1	Groins >45 year lifespan	0
2A2	Groins 5-45 year lifespan	0
2A3	Groins 0-5 year lifespan	0
2A4	Groins 0 year lifespan (disrepair)	0
2B1	Jetties >45 year lifespan	0
2B2	Jetties 5-45 year lifespan	0
2B3	Jetties 0-5 year lifespan	0
2B4	Jetties 0 year lifespan (disrepair)	0
2C1	Offshore Breakwaters >45 year lifespan	0
2C2	Offshore Breakwaters 5-45 year lifespan	26
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	0
3A2	Beach Nourishment 5-45 year lifespan	86
3A3	Beach Nourishment 0-5 year lifespan	0
3A4	Beach Nourishment 0 year lifespan (disrepair)	0
3B1	Vegetation Planting >45 year lifespan	0
3B2	Vegetation Planting 5-45 year lifespan	0
3B3	Vegetation Planting 0-5 year lifespan	0
3B4	Vegetation Planting 0 year lifespan (disrepair)	0
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	0
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	737
5A3	Concrete Rubble 0-5 year lifespan	812
5A4	Concrete Rubble 0 year lifespan (disrepair)	45
5B1	Other Materials >45 year lifespan	0
5B2	Other Materials 5-45 year lifespan	56
5B3	Other Materials 0-5 year lifespan	0
5B4	Other Materials 0 year lifespan (disrepair)	0

6. Boating Structures (Alongshore Lengths)		
6D1	Boat Launch >45 year lifespan	34
6D2	Boat Launch 5-45 year lifespan	74
6D3	Boat Launch 0-5 year lifespan	0
6D4	Boat Launch 0 year lifespan (disrepair)	0
7	No Shore Protection	28,917

Table 3
Shore Perpendicular Boating Structure Counts
(Grand River / Spring Lake at Grand Haven, Michigan)

Type	Description	Number
6A	Private Docks	587
6B	Marina Docks	486
6C	Commercial & Industrial Docks	7
6D	Boat Launch Docks	11

3.3.2 Shore Protection Mapping, Lake Macatawa, Holland, MI

Summary statistics on the type and extent of shore protection structures for the Lake Macatawa site are provided in Table 4.

For this area, seawalls and revetments once again comprise the bulk of any linear shore protection that is in place (over 18km and 5km respectively), with most of these falling into the class 2 quality category (5-45 year lifespan). The next most frequent type of linear shore protection was concrete rubble, usually dumped to simulate a low quality revetment (over 2 km). One example of slope stabilization was noted in an area where a group of property owners had graded a low bank area in front of their properties. One small breakwater structure was recorded and was protecting a small marina just to the south of the entrance channel from Lake Michigan. Over 11km of this rivermouth area was unprotected, the majority of which is located in the eastern portion of Lake Macatawa. In addition, over 1.6 km of the shoreline was classed as protected wetlands. This consisted of the entire Windmill Island shoreline, as well as a portion of the causeway leading to Windmill Island.

Table 4 - Shore Protection Type Summary Statistics (Lake Macatawa at Holland, Michigan)

Type	Description	Length (m)
1. Coastal Armoring		
1A1	Revetments >45 year lifespan	874
1A2	Revetments 5-45 year lifespan	2,905
1A3	Revetments 0-5 year lifespan	1,468
1A4	Revetments 0 year lifespan (disrepair)	0
1B1	Seawalls >45 year lifespan	5,747
1B2	Seawalls 5-45 year lifespan	12,231
1B3	Seawalls 0-5 year lifespan	270
1B4	Seawalls 0 year lifespan (disrepair)	108
2. Beach Erosion Control Devices		
2A1	Groins >45 year lifespan	0
2A2	Groins 5-45 year lifespan	0
2A3	Groins 0-5 year lifespan	0
2A4	Groins 0 year lifespan (disrepair)	0
2B1	Jetties >45 year lifespan	0
2B2	Jetties 5-45 year lifespan	0
2B3	Jetties 0-5 year lifespan	0
2B4	Jetties 0 year lifespan (disrepair)	0
2C1	Offshore Breakwaters >45 year lifespan	22
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	0
3A2	Beach Nourishment 5-45 year lifespan	0
3A3	Beach Nourishment 0-5 year lifespan	0
3A4	Beach Nourishment 0 year lifespan (disrepair)	0
3B1	Vegetation Planting >45 year lifespan	0
3B2	Vegetation Planting 5-45 year lifespan	0
3B3	Vegetation Planting 0-5 year lifespan	0
3B4	Vegetation Planting 0 year lifespan (disrepair)	0
3C1	Slope/Bluff Stabilization >45 year lifespan	0
3C2	Slope/Bluff Stabilization 5-45 year lifespan	84
3C3	Slope/Bluff Stabilization 0-5 year lifespan	0
3C4	Slope/Bluff Stabilization 0 year lifespan (disrepair)	0
4	Protected Wetlands	1,629

5. Ad-Hoc Structures		
5A1	Concrete Rubble >45 year lifespan	0
5A2	Concrete Rubble 5-45 year lifespan	1,310
5A3	Concrete Rubble 0-5 year lifespan	1,052
5A4	Concrete Rubble 0 year lifespan (disrepair)	69
5B1	Other Materials >45 year lifespan	100
5B2	Other Materials 5-45 year lifespan	0
5B3	Other Materials 0-5 year lifespan	253
5B4	Other Materials 0 year lifespan (disrepair)	0
6. Boating Structures (Alongshore Lengths)		
6D1	Boat Launch >45 year lifespan	127
6D2	Boat Launch 5-45 year lifespan	156
6D3	Boat Launch 0-5 year lifespan	0
6D4	Boat Launch 0 year lifespan (disrepair)	0
7	No Shore Protection	11,311

Table 5
Shore Perpendicular Boating Structure Counts
(Lake Macatawa at Holland, Michigan)

Type	Description	Number
6A	Private Docks	347
6B	Marina Docks	159
6C	Commercial & Industrial Docks	15
6D	Boat Launch Docks	12

Table 5 presents a count of the types of boating structures at this site. Over 500 private and marina dock structures (347 - 6A and 159 - 6B) were counted for this area, with 15 commercial or industrial dock spaces noted. Boat launch areas occupied just over 280 meters of the shoreline in total and had 12 boat docks associated with them.

3.3.3 Kalamazoo Lake and River, Saugatuck / Douglas, Michigan

Summary statistics on the type and extent of structures for the Kalamazoo Lake and River site are provided in Table 6.

Where shore protection exists (largely in the built up areas of Saugatuck and Douglas), seawalls predominate and occupy over 9 km of shoreline. Revetments are less popular in this location and were recorded for only 885 meters of shoreline. Almost 8 km of this area's shoreline is unprotected, particularly large sections of the river in the Saugatuck Dunes area, as well as upstream areas near Highway 31 and the Blue Star Memorial Highway.

Table 7 presents a count of shore perpendicular boating structures and shows a near equal amount of private and marina dock structures (144 and 141 respectively), with 24 commercial and industrial docks noted. Boat launch areas occupy over 100 meters of shoreline and have 6 dock structures associated with them.

Table 6 - Shore Protection Type Summary Statistics (Kalamazoo Lake & River at Saugatuck, Michigan)

Type	Description	Length (m)
1. Coastal Armoring		
1A1	Revetments >45 year lifespan	0
1A2	Revetments 5-45 year lifespan	342
1A3	Revetments 0-5 year lifespan	543
1A4	Revetments 0 year lifespan (disrepair)	0
1B1	Seawalls >45 year lifespan	6,770
1B2	Seawalls 5-45 year lifespan	3,155
1B3	Seawalls 0-5 year lifespan	92
1B4	Seawalls 0 year lifespan (disrepair)	76
2. Beach Erosion Control Devices		
2A1	Groins >45 year lifespan	0
2A2	Groins 5-45 year lifespan	0
2A3	Groins 0-5 year lifespan	0
2A4	Groins 0 year lifespan (disrepair)	0
2B1	Jetties >45 year lifespan	0
2B2	Jetties 5-45 year lifespan	0
2B3	Jetties 0-5 year lifespan	0
2B4	Jetties 0 year lifespan (disrepair)	0

2C1	Offshore Breakwaters >45 year lifespan	0
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	0
3A2	Beach Nourishment 5-45 year lifespan	0
3A3	Beach Nourishment 0-5 year lifespan	0
3A4	Beach Nourishment 0 year lifespan (disrepair)	0
3B1	Vegetation Planting >45 year lifespan	0
3B2	Vegetation Planting 5-45 year lifespan	0
3B3	Vegetation Planting 0-5 year lifespan	0
3B4	Vegetation Planting 0 year lifespan (disrepair)	0
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	0
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	0
5A3	Concrete Rubble 0-5 year lifespan	0
5A4	Concrete Rubble 0 year lifespan (disrepair)	23
5B1	Other Materials >45 year lifespan	0
5B2	Other Materials 5-45 year lifespan	0
5B3	Other Materials 0-5 year lifespan	0
5B4	Other Materials 0 year lifespan (disrepair)	0
6. Boating Structures (Alongshore Lengths)		
6D1	Boat Launch >45 year lifespan	88
6D2	Boat Launch 5-45 year lifespan	17
6D3	Boat Launch 0-5 year lifespan	0
6D4	Boat Launch 0 year lifespan (disrepair)	33
7	No Shore Protection	7,838

Table 7
Shore Perpendicular Boating Structure Counts
(Kalamazoo Lake & River at Saugatuck, Michigan)

Type	Description	Number
6A	Private Docks	144
6B	Marina Docks	141
6C	Commercial & Industrial Docks	24
6D	Boat Launch Docks	6

3.3.4 Sheboygan River, Sheboygan, Wisconsin

Summary statistics on the type and extent of structures for the Sheboygan River site are provided in Table 8.

The Sheboygan River site was the least diversified of the four sites examined and shore protection consisted of either seawalls (3.4 km) or concrete rubble (3.3 km). Small pockets of revetment were present (880 meters) and a large portion of this shoreline was unprotected (3.5 km).

Over 100 private and marina boat docks (Table 9) were counted, the majority of which (86) were associated with commercial marinas lining the river in the downtown Sheboygan area of the river. Twelve (12) commercial and industrial docks were counted and two small boat launch areas were noted occupying approximately 40 meters in total of the entire shoreline.

Table 8 - Shore Protection Type Summary Statistics (Sheboygan River at Sheboygan, Wisconsin)

Type	Description	Length (m)
1. Coastal Armoring		
1A1	Revetments >45 year lifespan	0
1A2	Revetments 5-45 year lifespan	742
1A3	Revetments 0-5 year lifespan	139
1A4	Revetments 0 year lifespan (disrepair)	0
1B1	Seawalls >45 year lifespan	3,472

1B2	Seawalls 5-45 year lifespan	0
1B3	Seawalls 0-5 year lifespan	0
1B4	Seawalls 0 year lifespan (disrepair)	0
2. Beach Erosion Control Devices		
2A1	Groins >45 year lifespan	0
2A2	Groins 5-45 year lifespan	0
2A3	Groins 0-5 year lifespan	0
2A4	Groins 0 year lifespan (disrepair)	0
2B1	Jetties >45 year lifespan	0
2B2	Jetties 5-45 year lifespan	0
2B3	Jetties 0-5 year lifespan	0
2B4	Jetties 0 year lifespan (disrepair)	0
2C1	Offshore Breakwaters >45 year lifespan	0
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	0
3A2	Beach Nourishment 5-45 year lifespan	0
3A3	Beach Nourishment 0-5 year lifespan	0
3A4	Beach Nourishment 0 year lifespan (disrepair)	0
3B1	Vegetation Planting >45 year lifespan	0
3B2	Vegetation Planting 5-45 year lifespan	0
3B3	Vegetation Planting 0-5 year lifespan	0
3B4	Vegetation Planting 0 year lifespan (disrepair)	0
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	0
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	3,379
5A3	Concrete Rubble 0-5 year lifespan	0
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	0
5B4	Other Materials 0 year lifespan (disrepair)	0

6. Boating Structures (Alongshore Lengths)

6D1	Boat Launch >45 year lifespan	38
6D2	Boat Launch 5-45 year lifespan	0
6D3	Boat Launch 0-5 year lifespan	0
6D4	Boat Launch 0 year lifespan (disrepair)	0
7	No Shore Protection	3,538

Table 9
Shore Perpendicular Boating Structure Counts
(Sheboygan River at Sheboygan, Wisconsin)

Type	Description	Number
6A	Private Docks	21
6B	Marina Docks	86
6C	Commercial & Industrial Docks	12
6D	Boat Launch Docks	2

4.0 Summary and Conclusions

The shore protection mapping and classification exercise carried out in this task provides detailed information on the types, extent and quality of shore protection and shore perpendicular boating structures present in four drowned rivermouth areas of Lake Michigan. As a result of this exercise, there are a number of conclusions and recommendations that should be considered during future exercises of this nature:

1) If using aerial photography to assist in the classification of rivermouth areas, efforts should be made to collect this photography with a minimum of shadow or glare along the shoreline. There were some areas where tree shadows greatly obscured the shoreline and where determination of protection structures was difficult. In addition, the photography should be conducted as soon as possible after ice break up and prior to vegetation growth so that summer vegetation growth, particularly in wetland / marsh areas does not obscure the shoreline.

2) When classifying shore perpendicular boating structures, it would be useful to have aerial photography taken in late July or early August, the peak recreational boating season, so that there is a higher likelihood of capturing all seasonal boating structures that are in place.

3) The narrated video tape of the shoreline was extremely useful in conducting "desktop" classification of the shoreline. For future efforts, video should be taken later in the summer when water levels are usually seasonally higher than May levels, or shallower draft vessels should be utilized to forge backwater areas and small embayments that were not accessible due to low water.

4) Given some of the limitations noted above, perhaps a more accurate mapping of shore protection structures in other rivermouth areas would be realized through an on-site field mapping exercise. This would result in a more accurate determination of the start and end points of the shore protection structures, as well as a better assessment of structure quality. Physical changes in the shoreline, or structures put in place subsequent to the date of photography proposed to be used could also be noted. Such a field mapping exercise could likely be done in tandem with the video taping of the shoreline in these areas. Information could be mapped on air photo copies in the field and then transferred into ArcView once back in the office, using the video and other associated data sources (air photos, Mr. Sid images, etc.) for additional guidance where required.

5) Detailed shore protection information for other drowned rivermouths around Lake Michigan will ultimately be required at this level in order to conduct the level of

potential damages modeling and FEPS modeling envisioned for the whole lake. As such, USACE should proceed, as budget permits, with an extension of this shore protection mapping for the remaining drowned rivermouth areas along the Lake Michigan shoreline.

REFERENCES

Stewart, C.J., 1997. Development of a Revised Great Lakes Shoreline Classification System and Recommendations for Application to the Lake Michigan Shoreline – Lake Michigan Potential Damages Study. Consulting Report prepared for the U.S. Army Corps of Engineers – Detroit District and Coastal and Hydraulics Lab, 18pp.

Stewart, C.J., 1998. A Revised Geomorphic, Shore Protection and Nearshore Classification of the Lake Michigan Shoreline - Lake Michigan Potential Damages Study. Consulting Report Submitted to U.S. Army Corps of Engineers - Detroit District, 19pp.

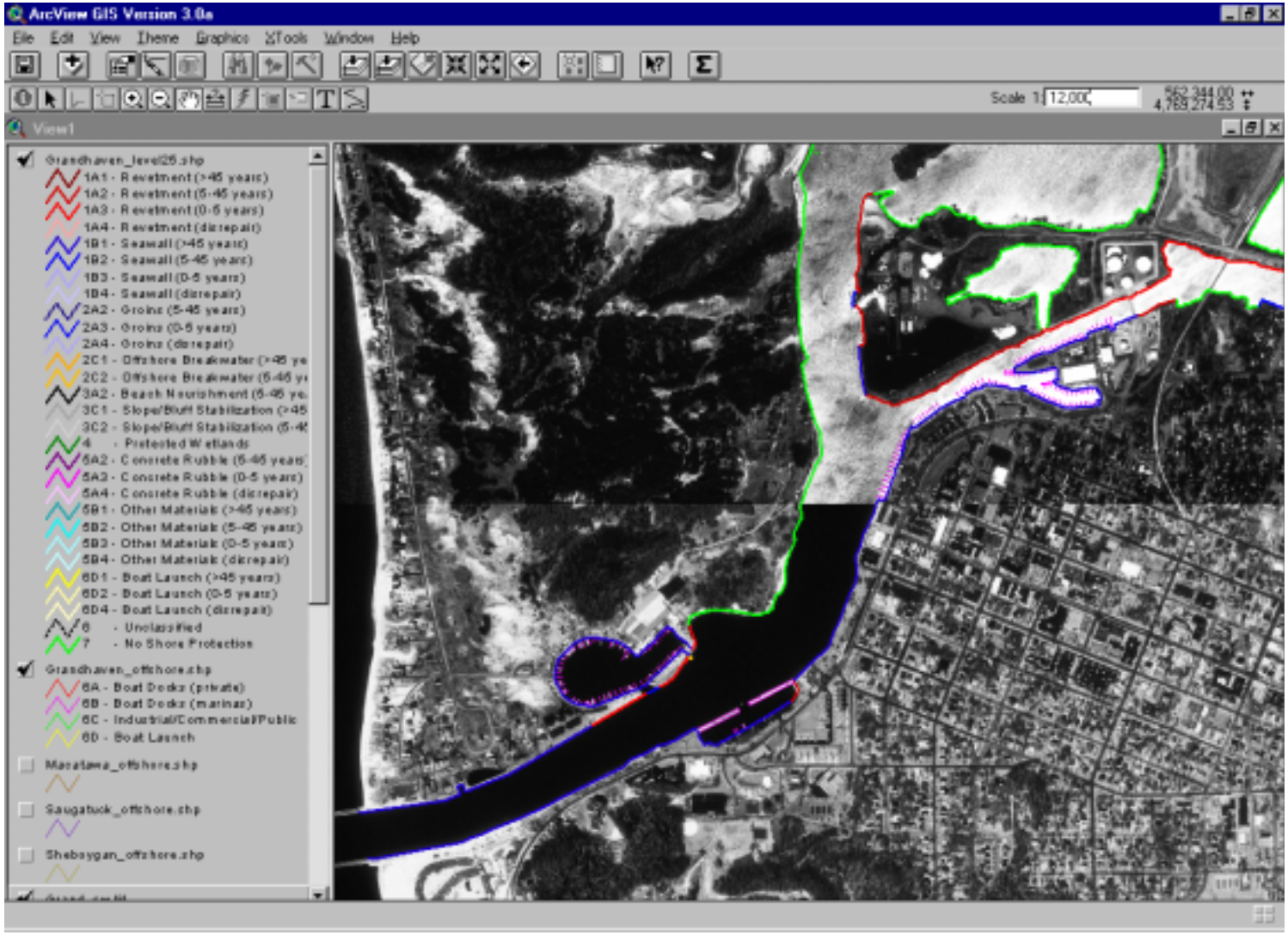
Stewart, C.J., 1999. Detailed Mapping and Classification of Shoreline Protection Structures, Lake Michigan Potential Damages Study. Consulting Report prepared for the U.S. Army Corps of Engineers, Detroit District, 33pp., plus Appendices.

APPENDIX 1

SHORE PROTECTION MAPPING PRINTOUTS

DROWNED RIVERMOUTH AREAS

GRAND RIVER and SPRING LAKE
GRAND HAVEN, MICHIGAN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1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
2C1 - Offshore Breakwater (>45 ye
2C2 - Offshore Breakwater (5-45 y
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-4
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
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6A - Boat Docks (private)
6B - Boat Docks (marinas)
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6D - Boat Launch
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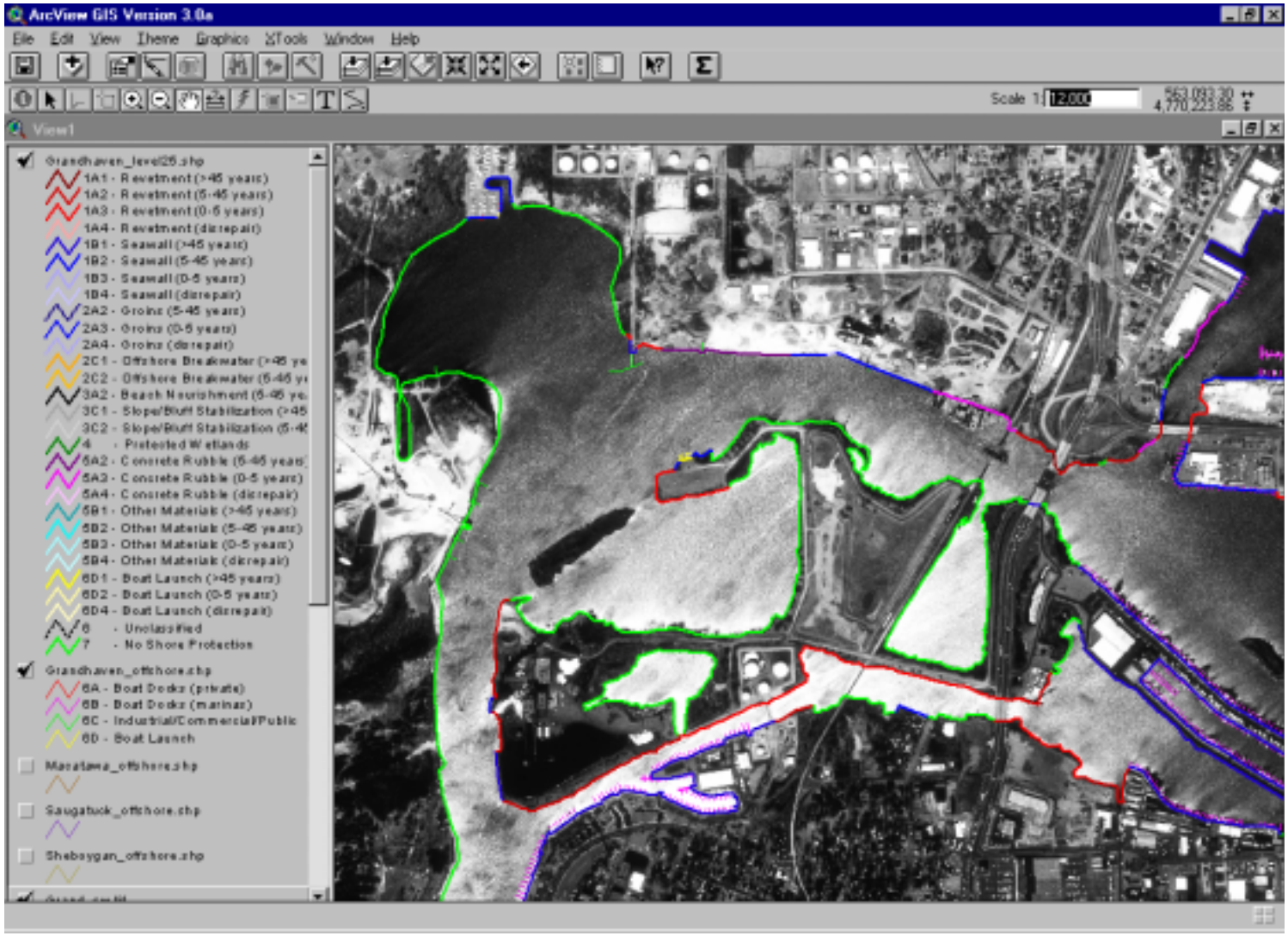
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1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
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5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
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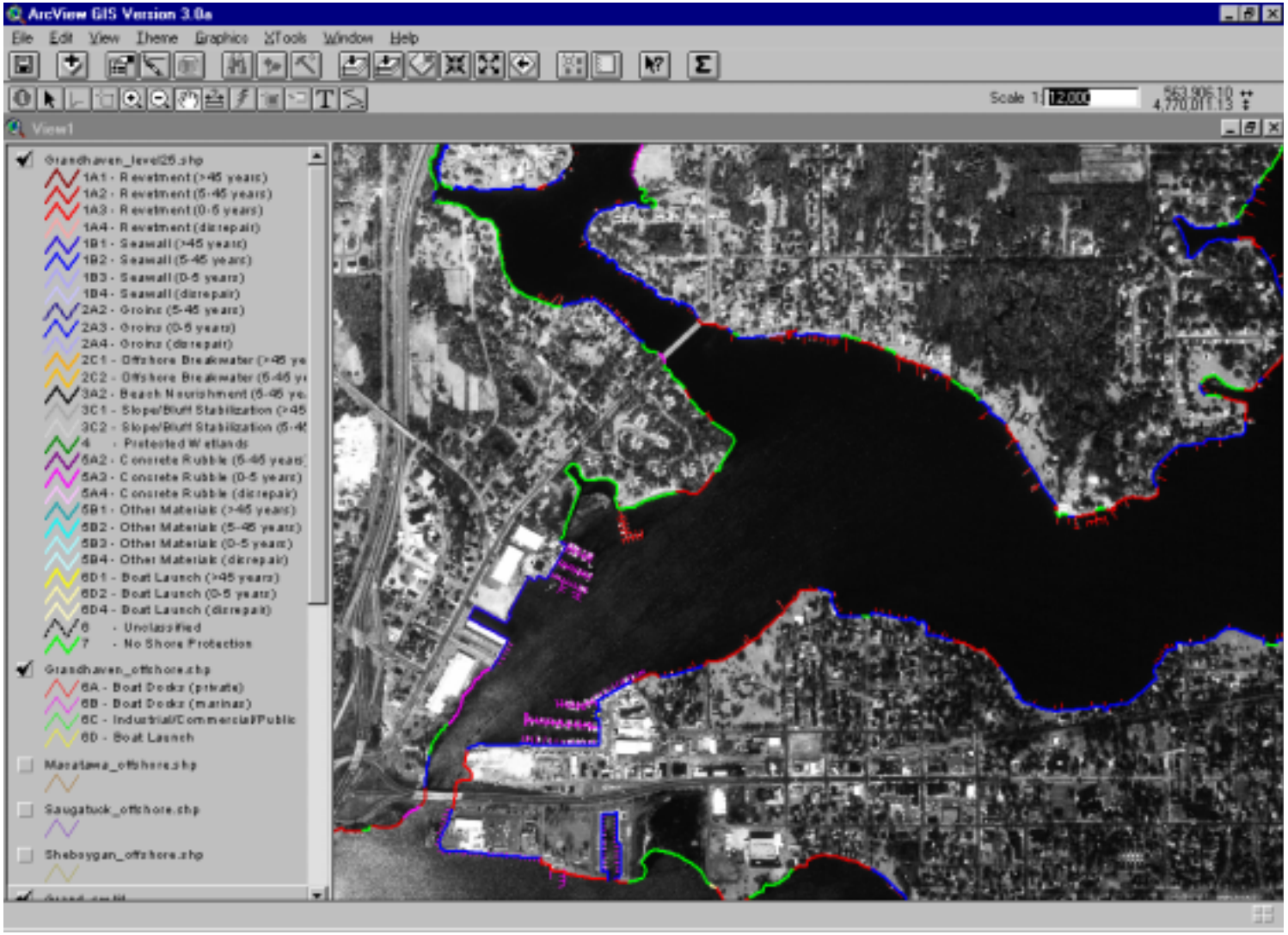
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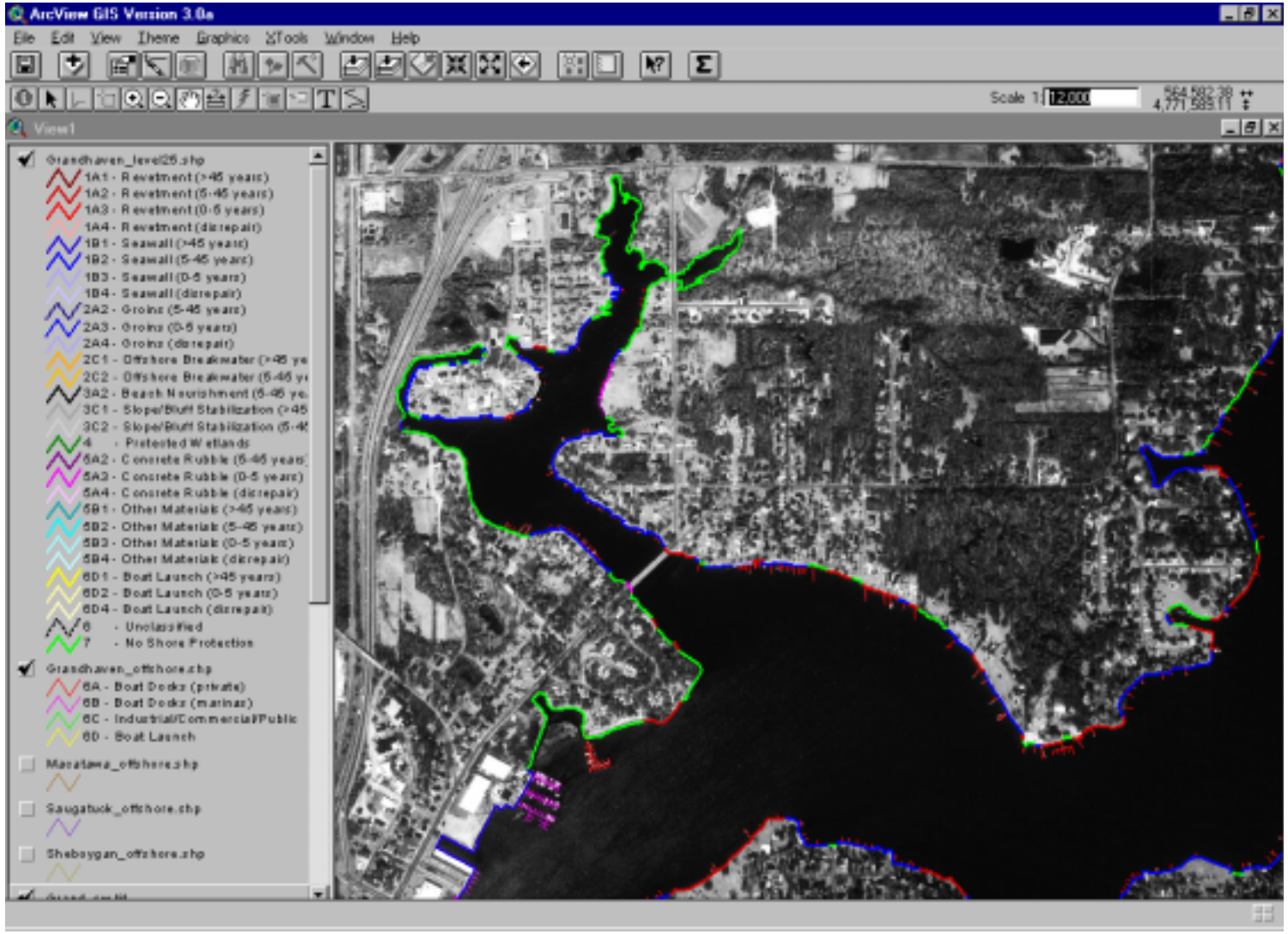
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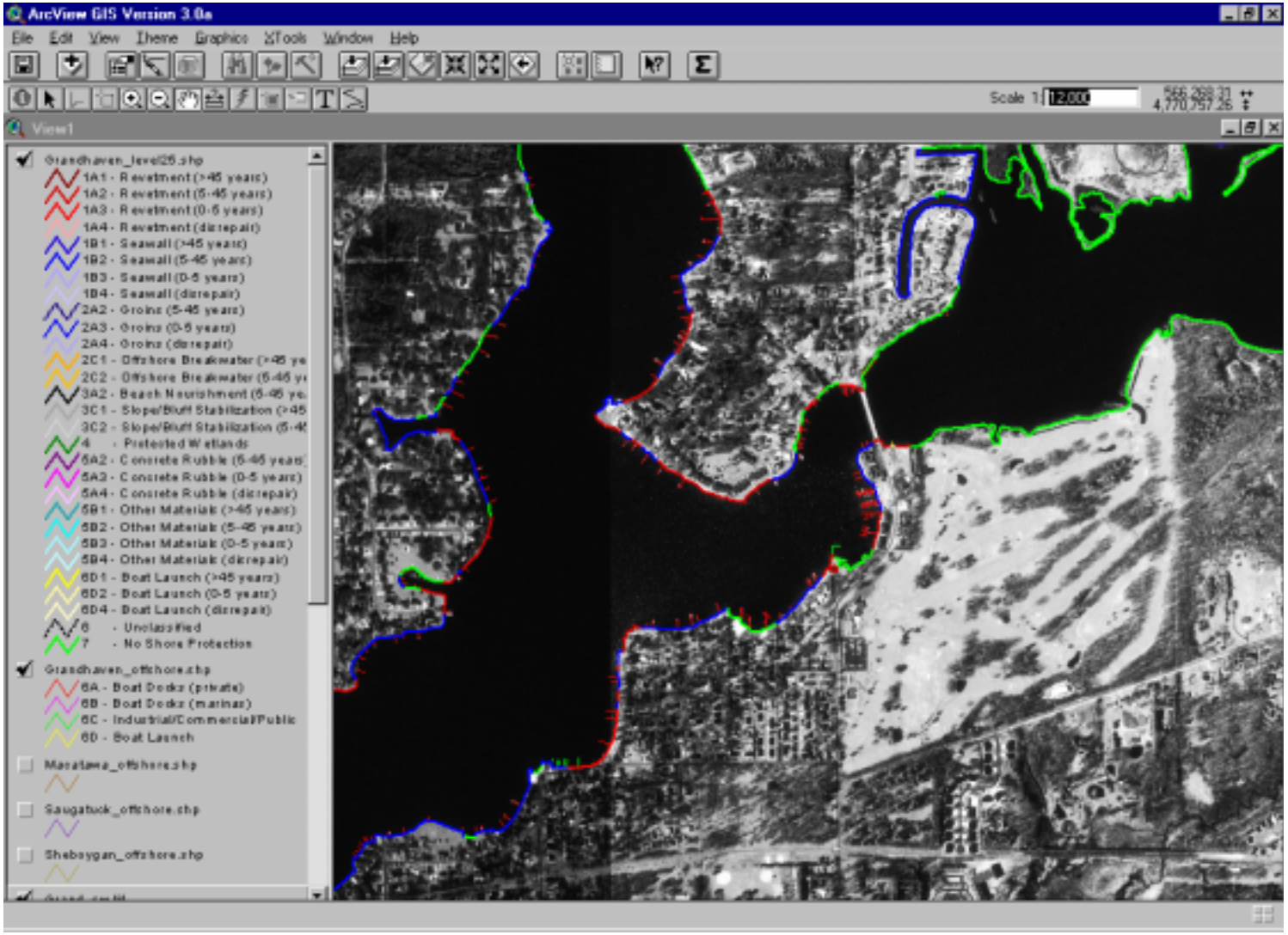
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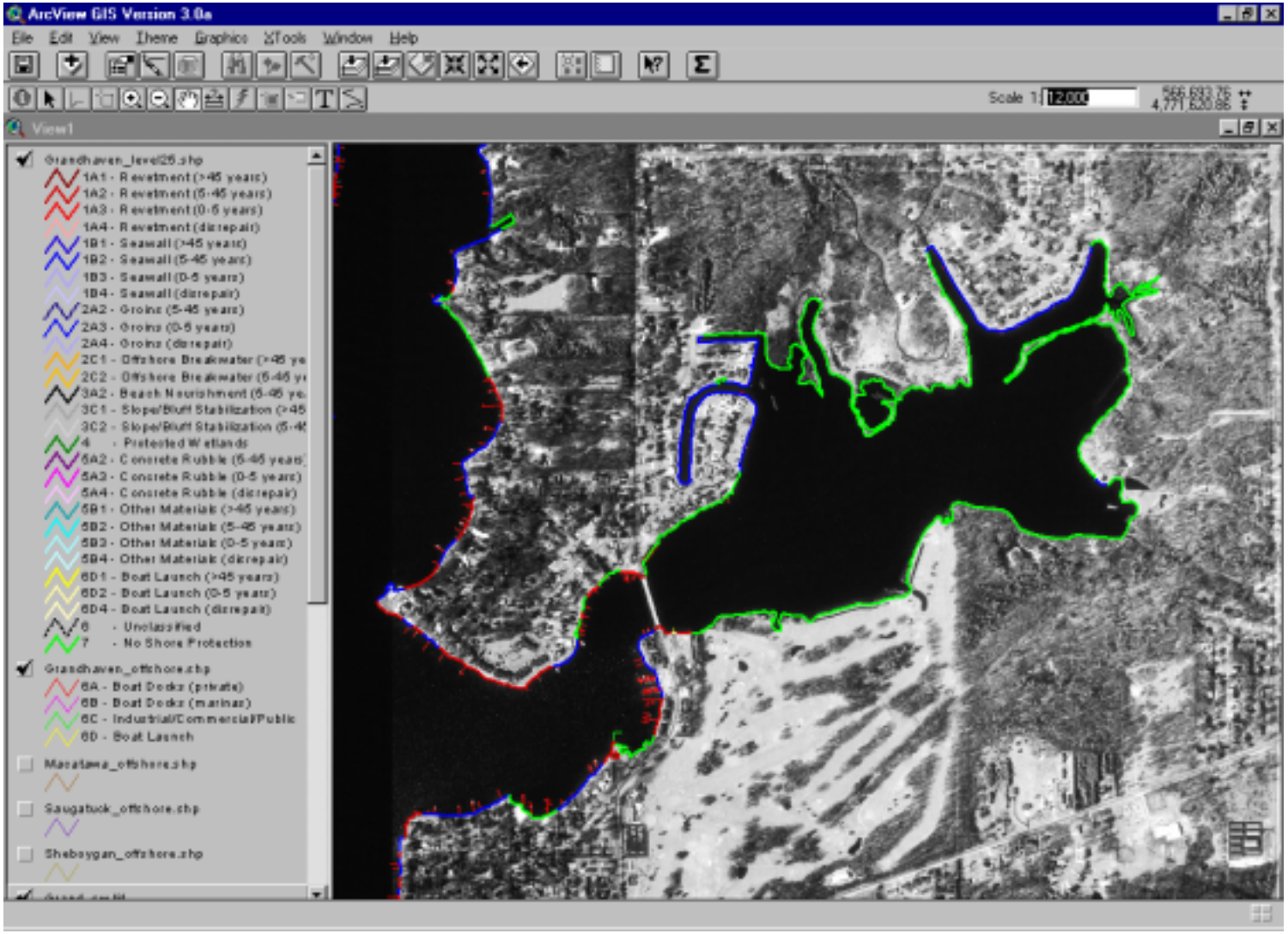
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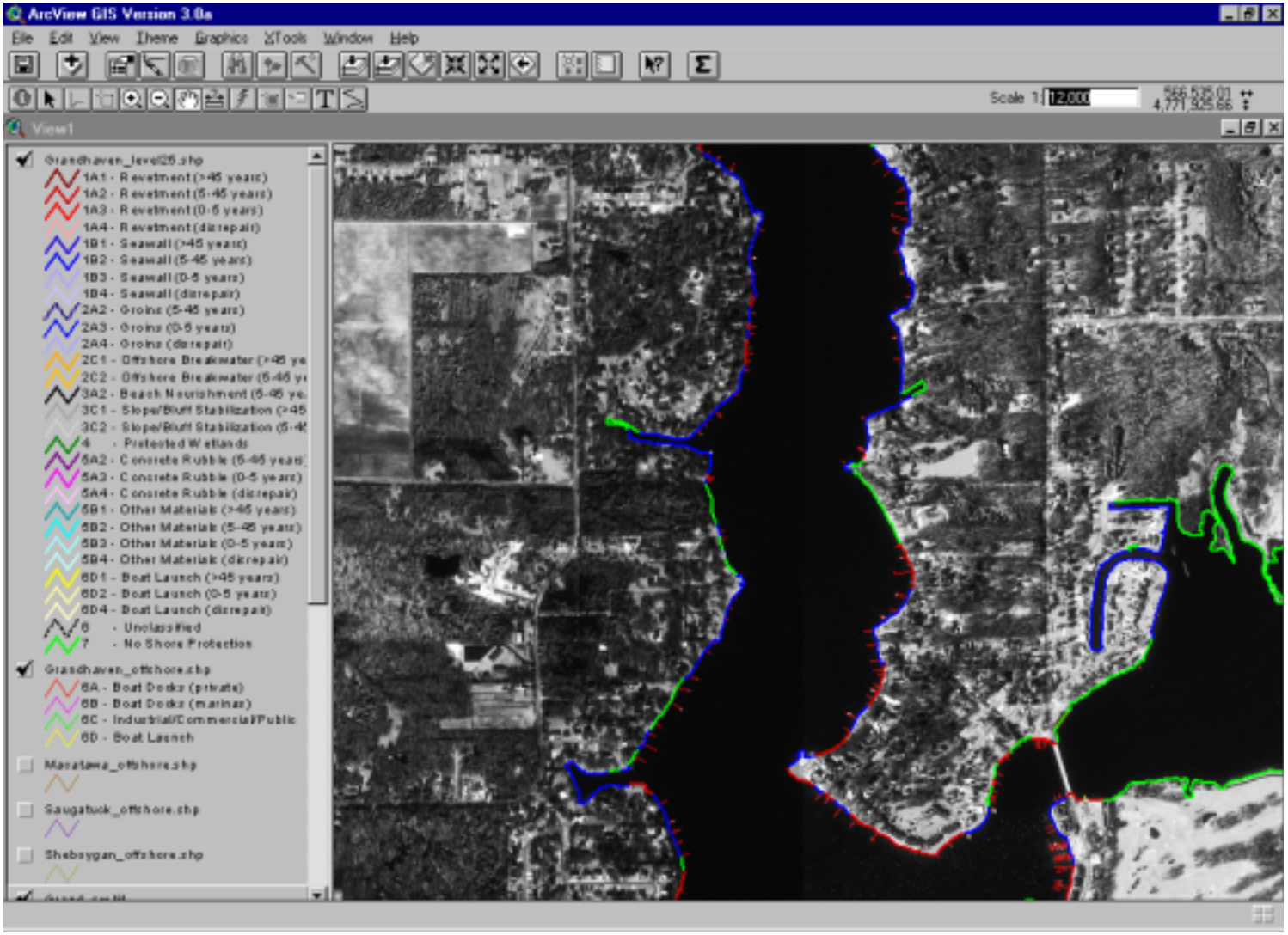
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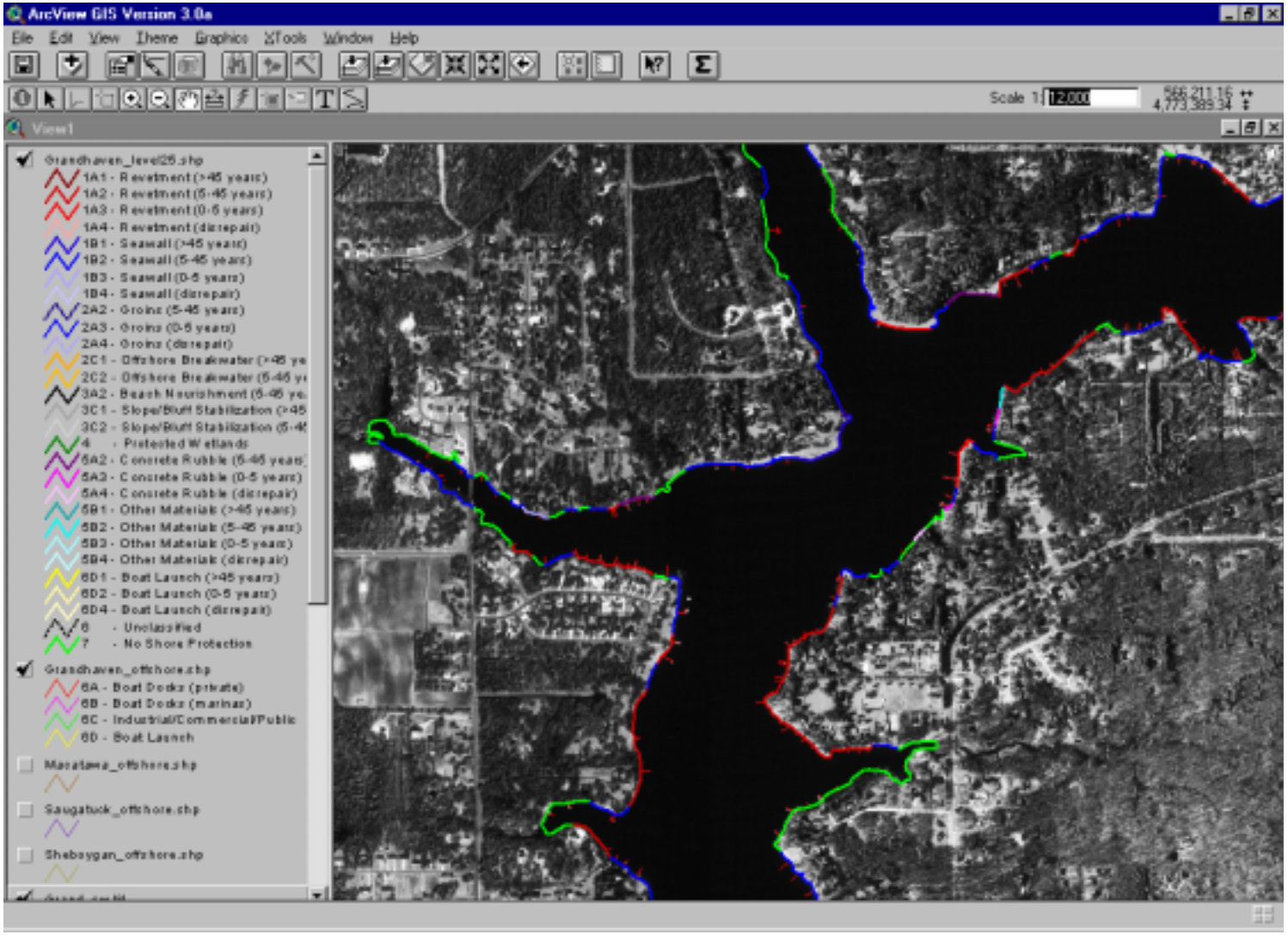
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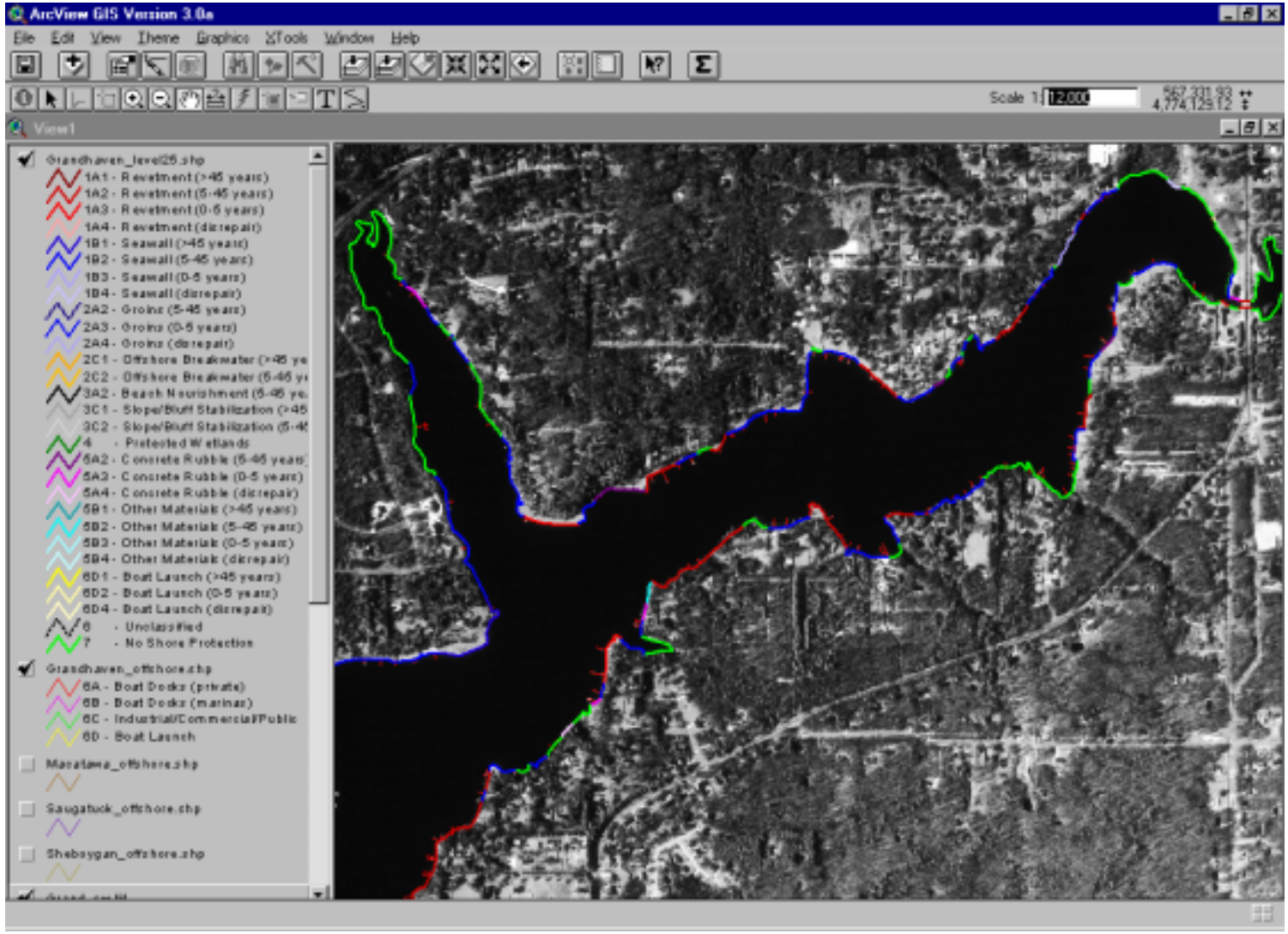
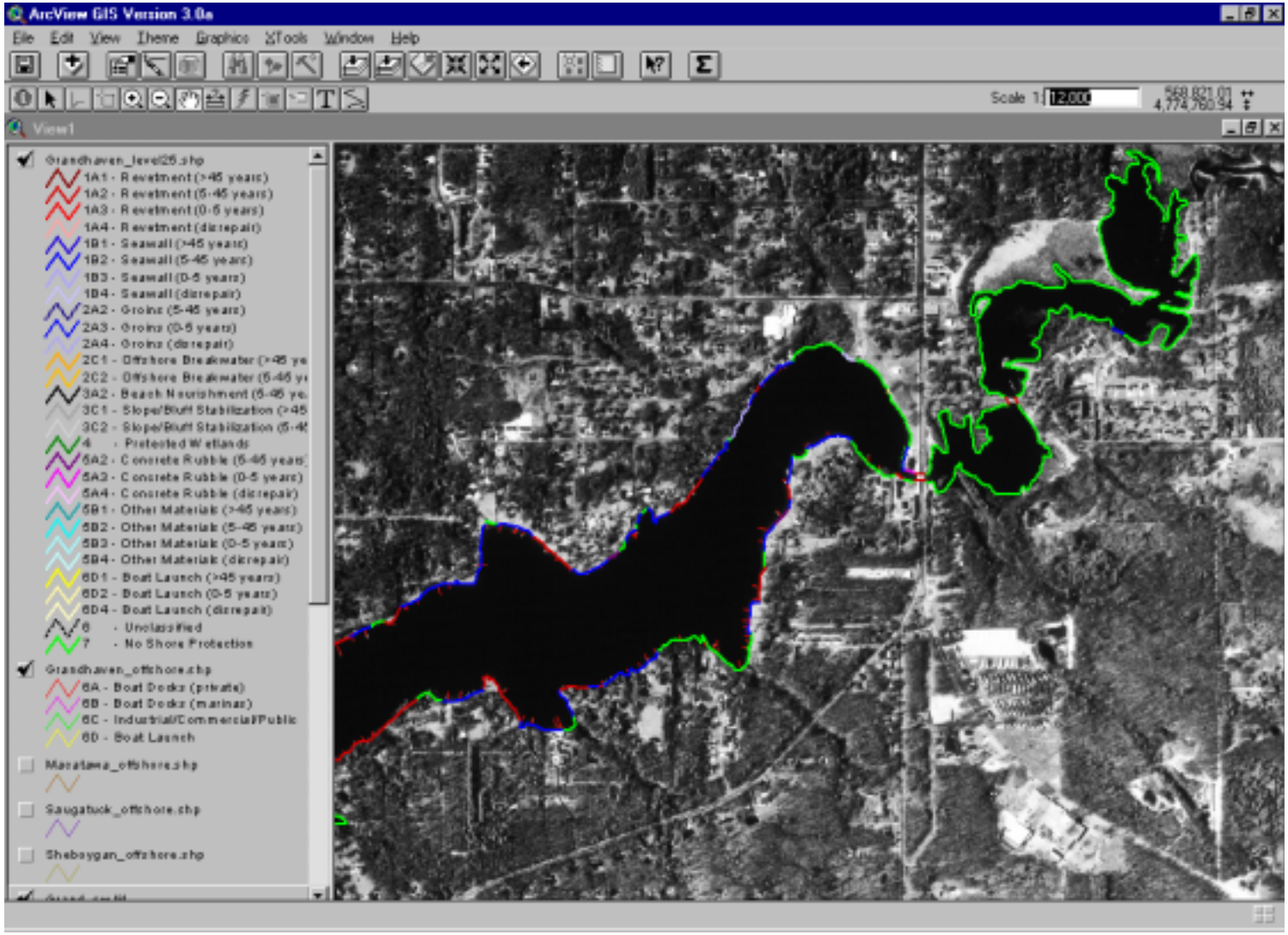
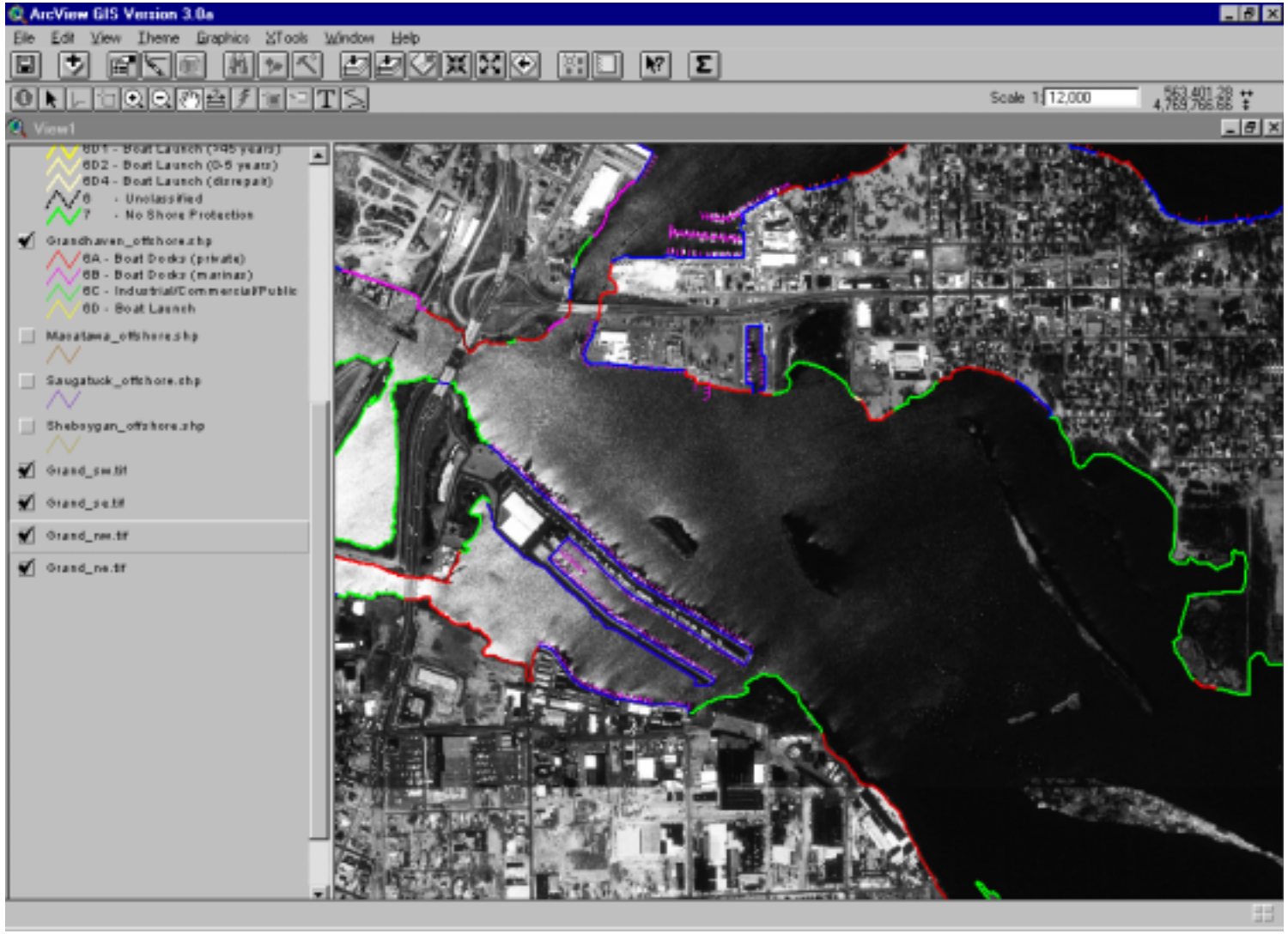
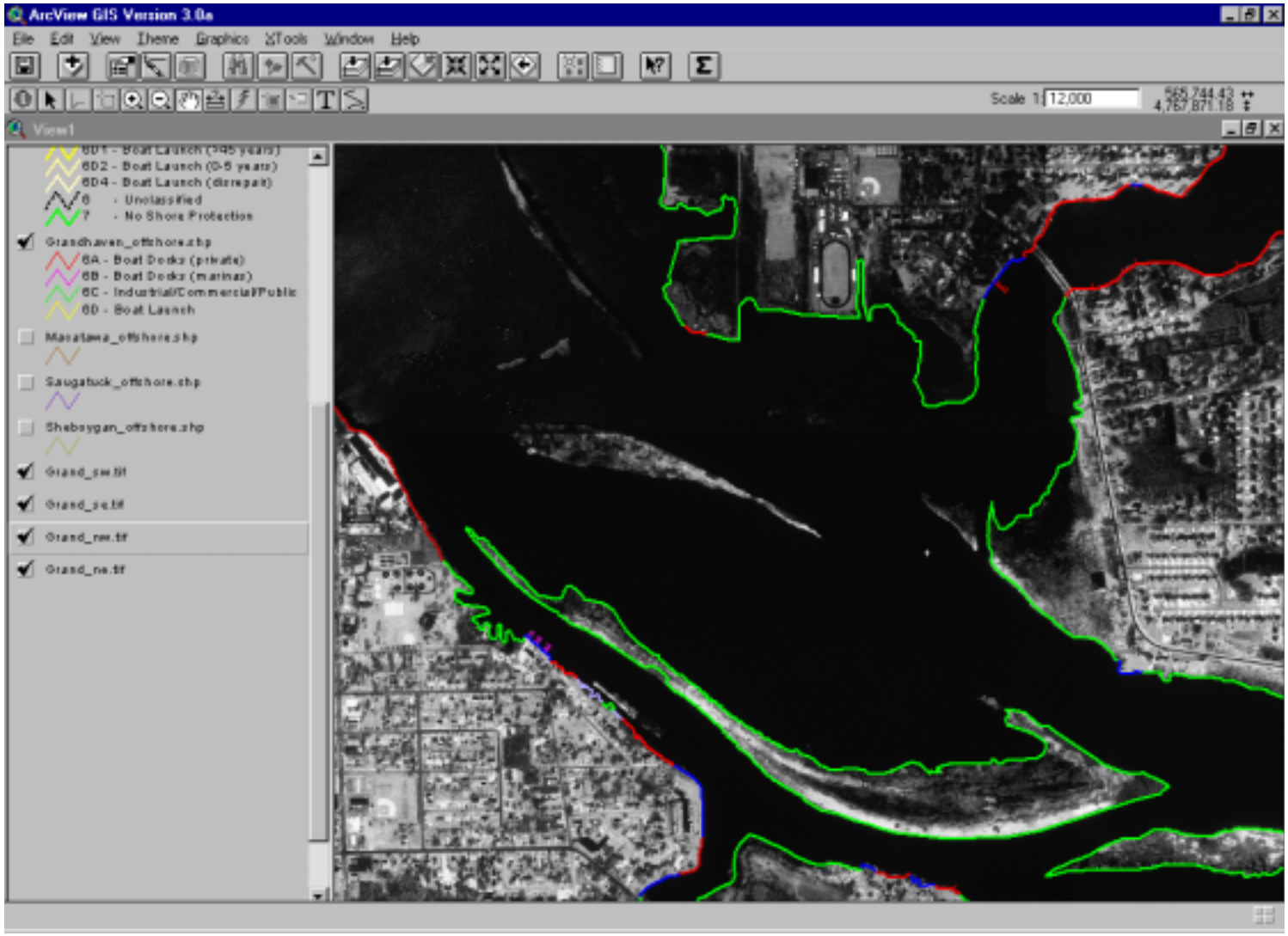
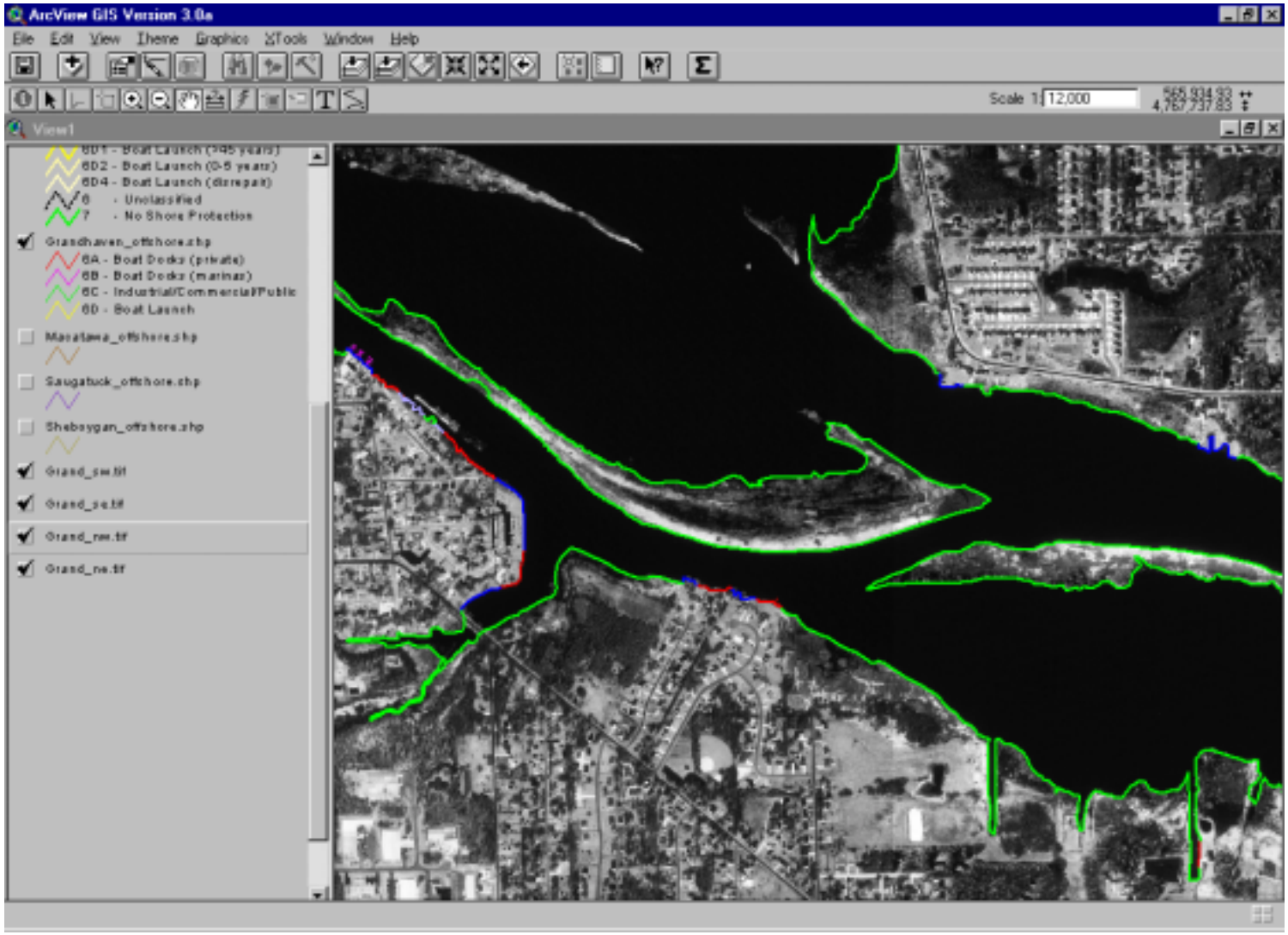
Saugatuck_offshore.shp
Sheboygan_offshore.shp

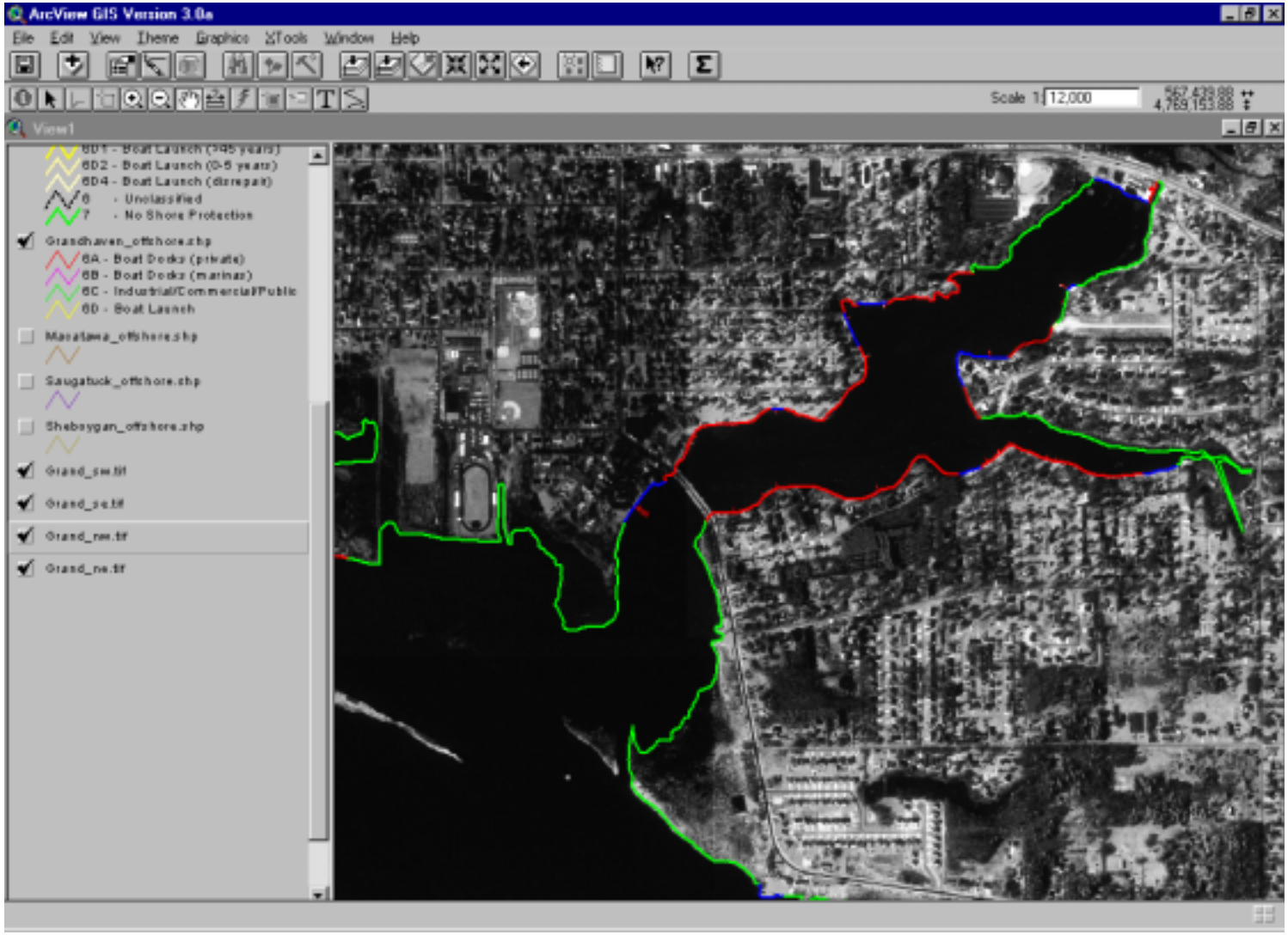

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:
View1
Grandhaven_level25.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistee_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp

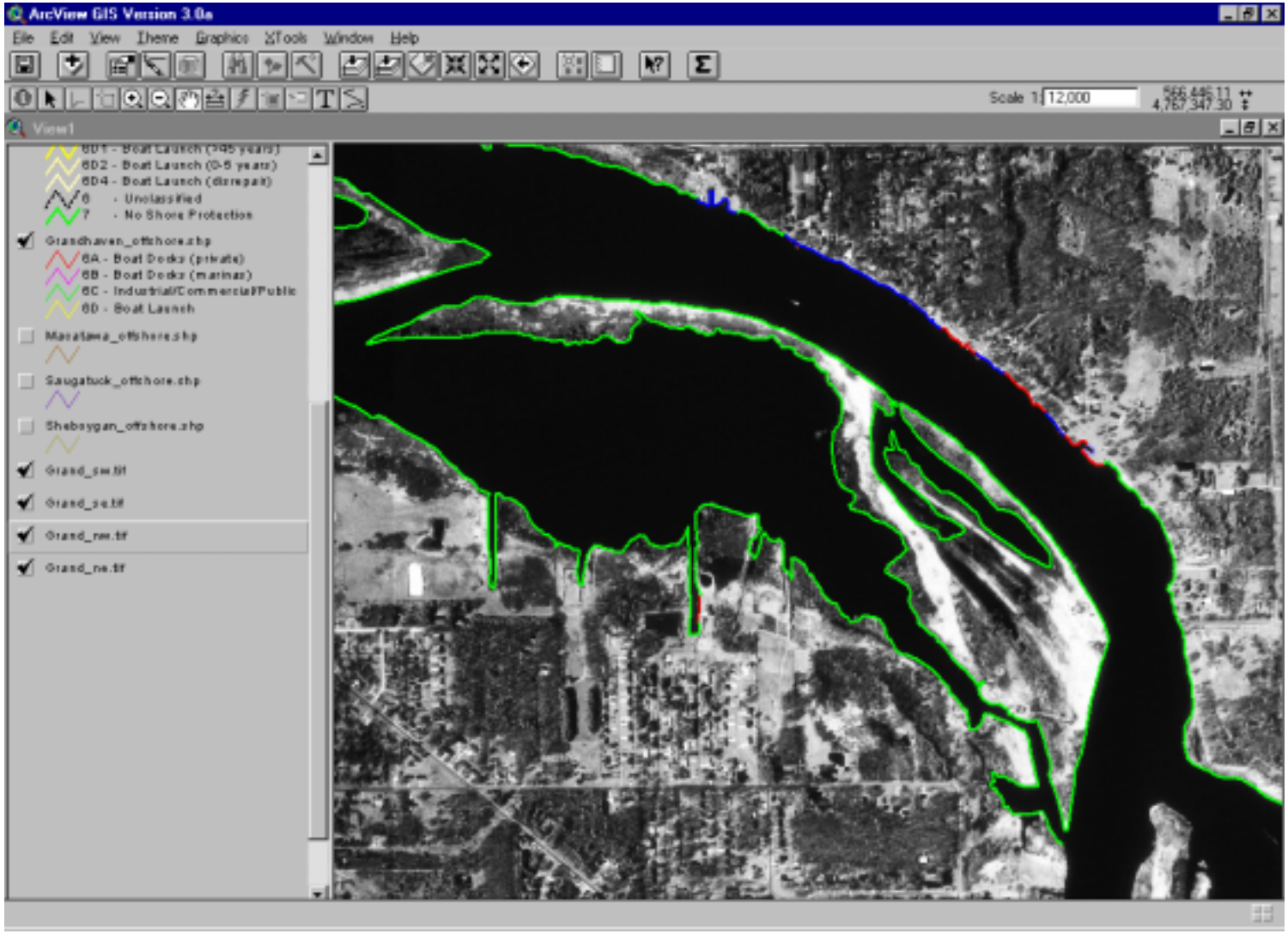

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Grandhaven_level2B.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-4
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistee_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp

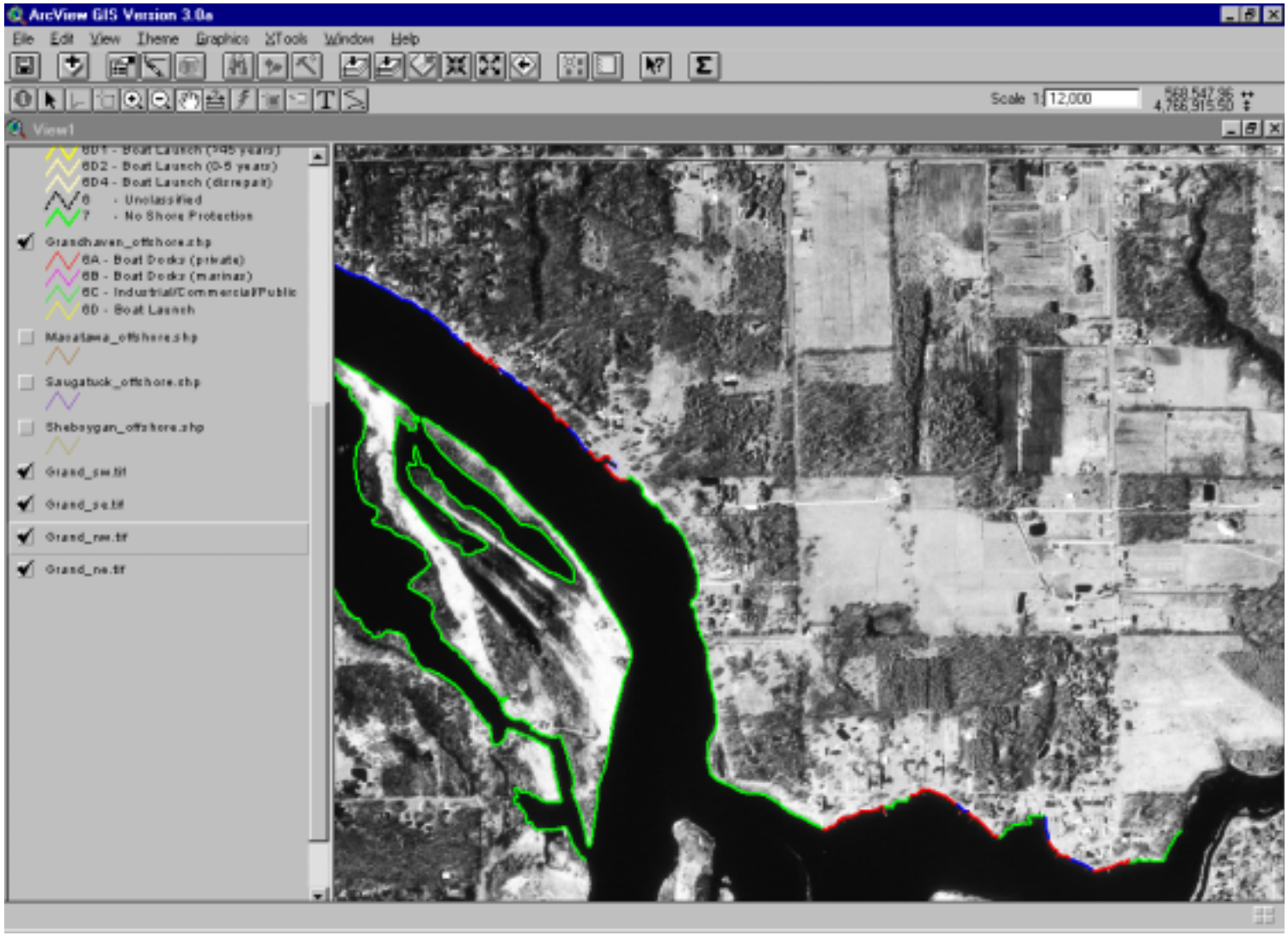

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manatawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_nw.tif
Grand_ne.tif


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
602 - Boat Launch (0-5 years)
604 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_ne.tif

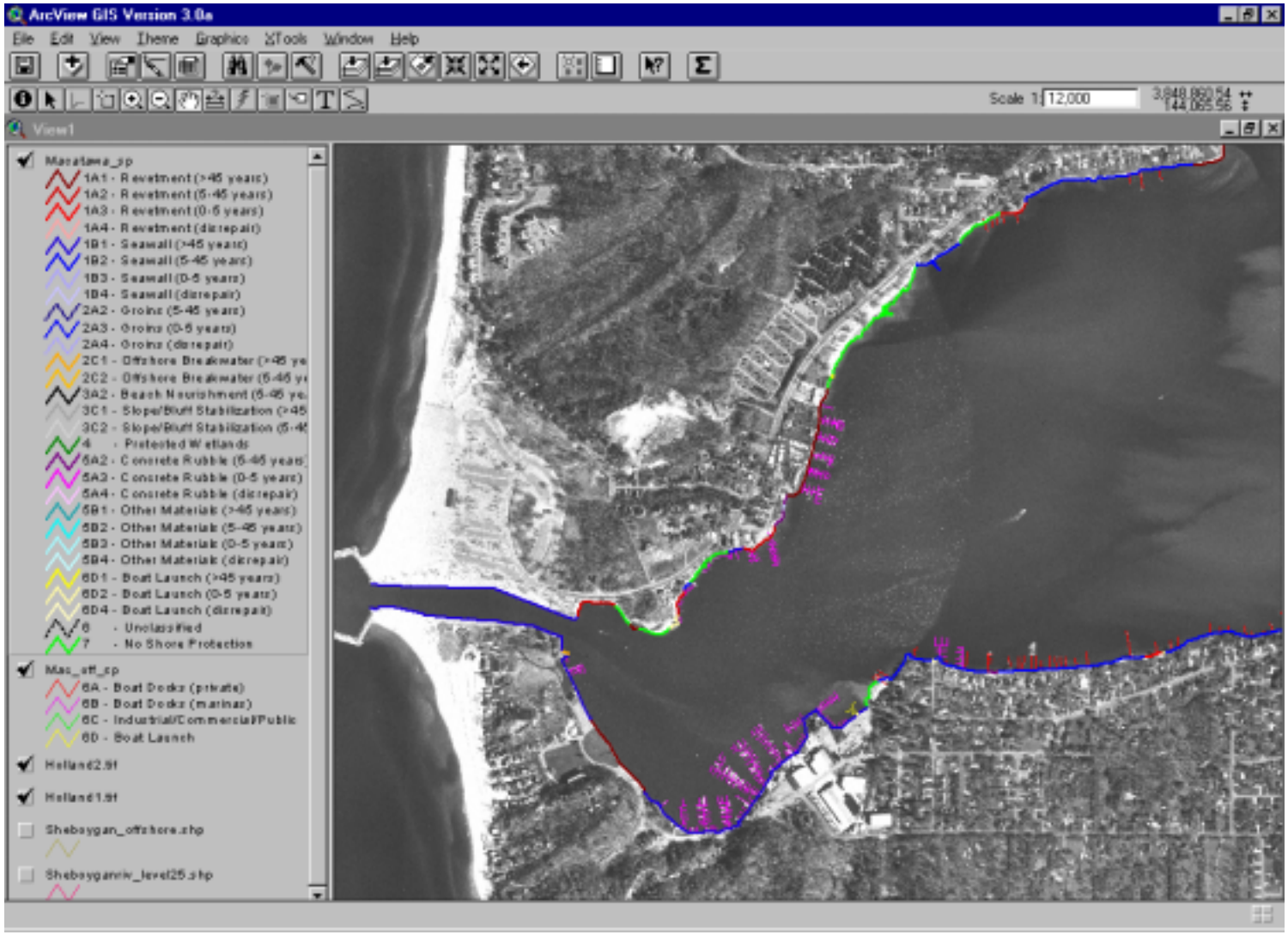

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
602 - Boat Launch (0-5 years)
604 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_nw.tif
Grand_ne.tif

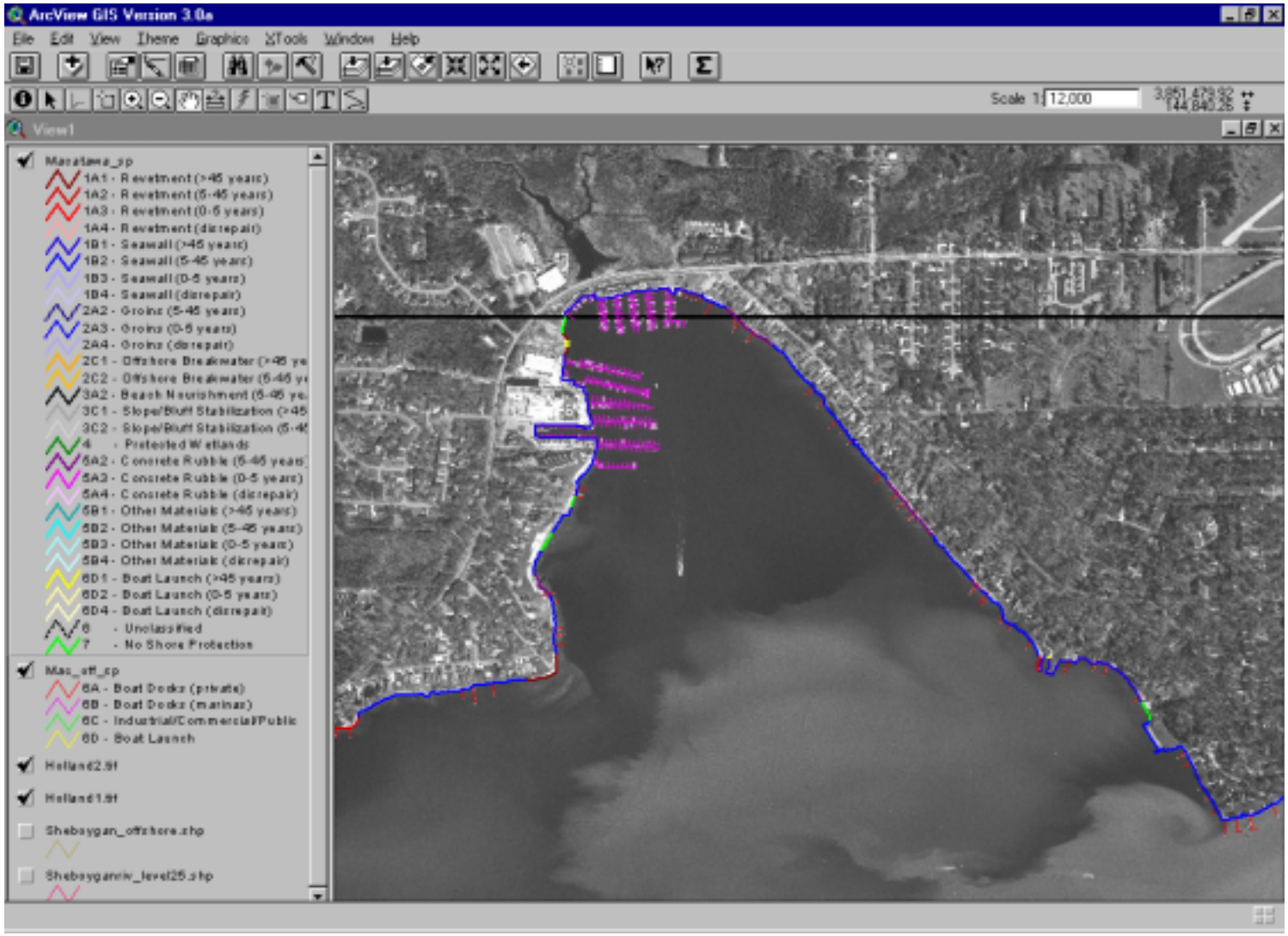

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manatawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_nw.tif
Grand_ne.tif

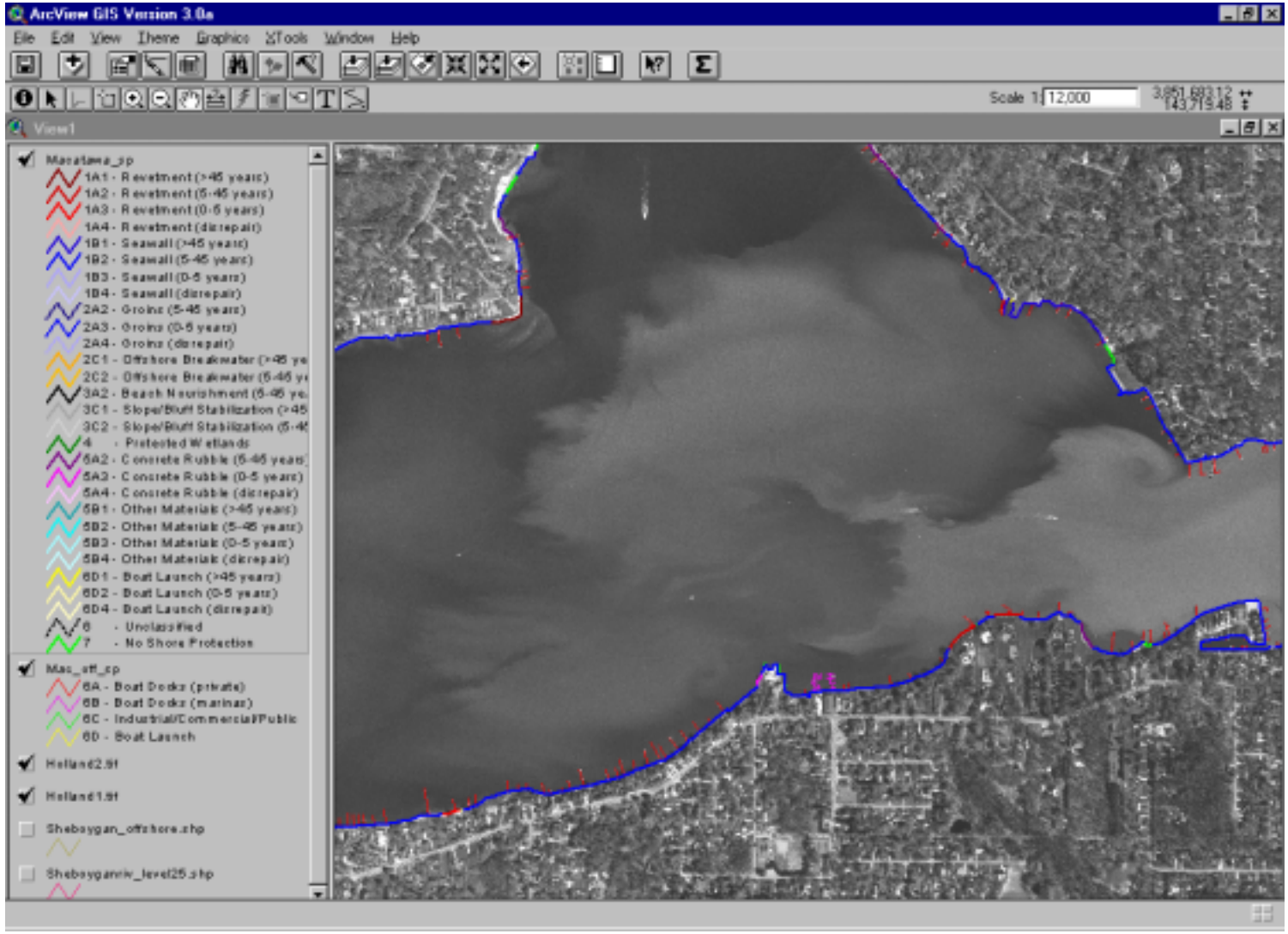

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_nw.tif
Grand_ne.tif

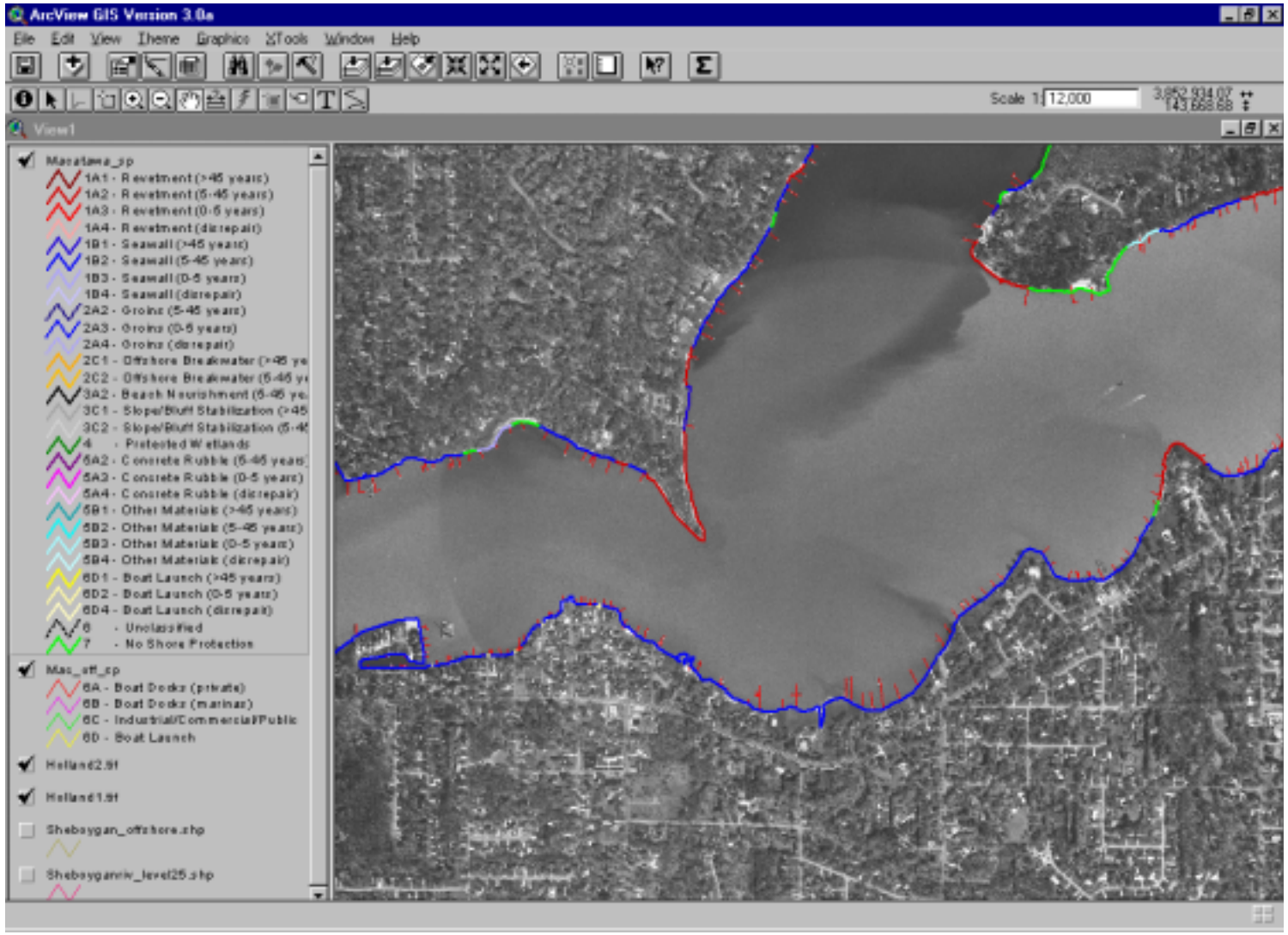

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Grandhaven_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Manistawa_offshore.shp
Saugatuck_offshore.shp
Sheboygan_offshore.shp
Grand_sw.tif
Grand_se.tif
Grand_nw.tif
Grand_ne.tif

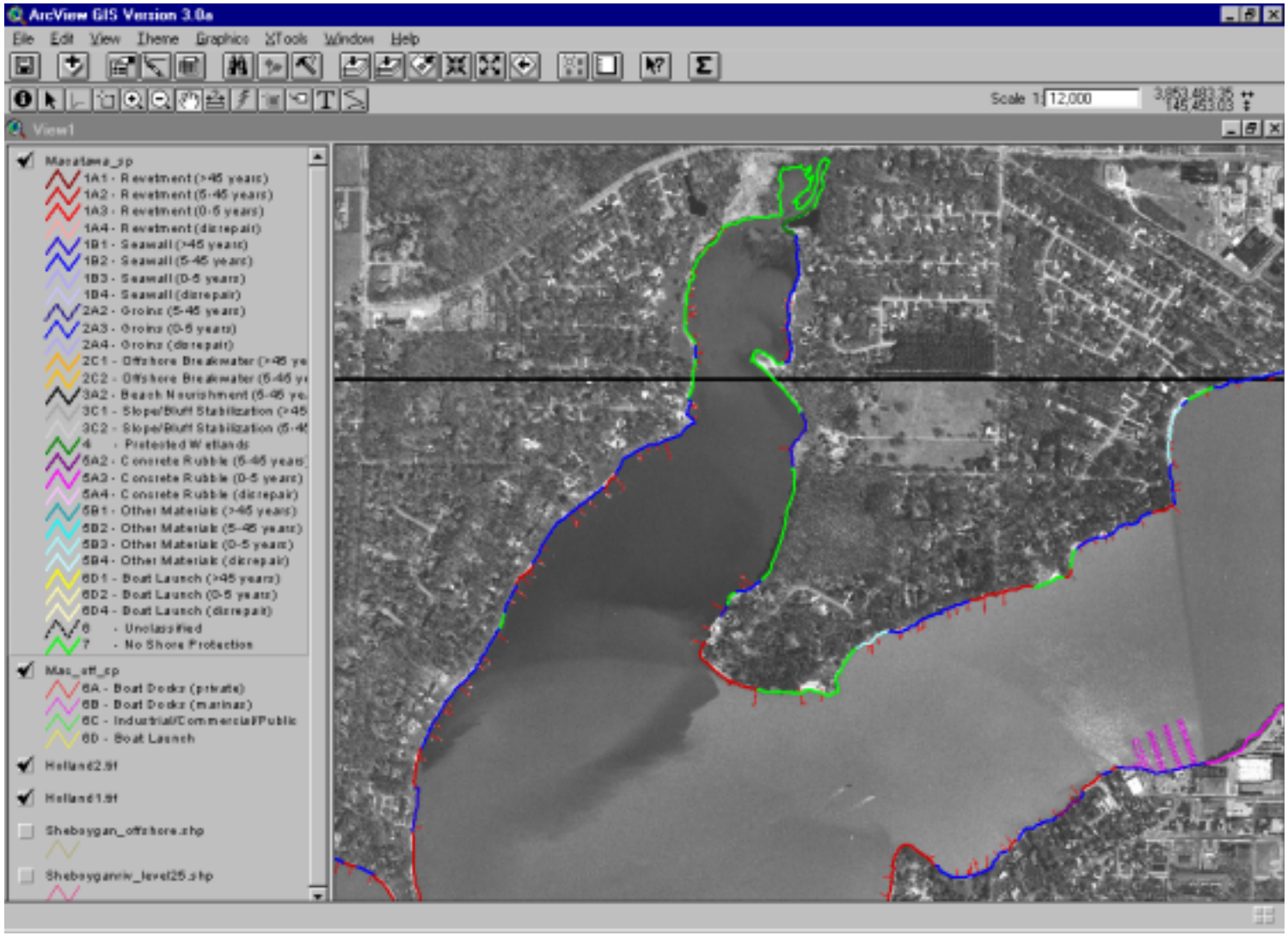
LAKE MACATAWA
HOLLAND, MICHIGAN

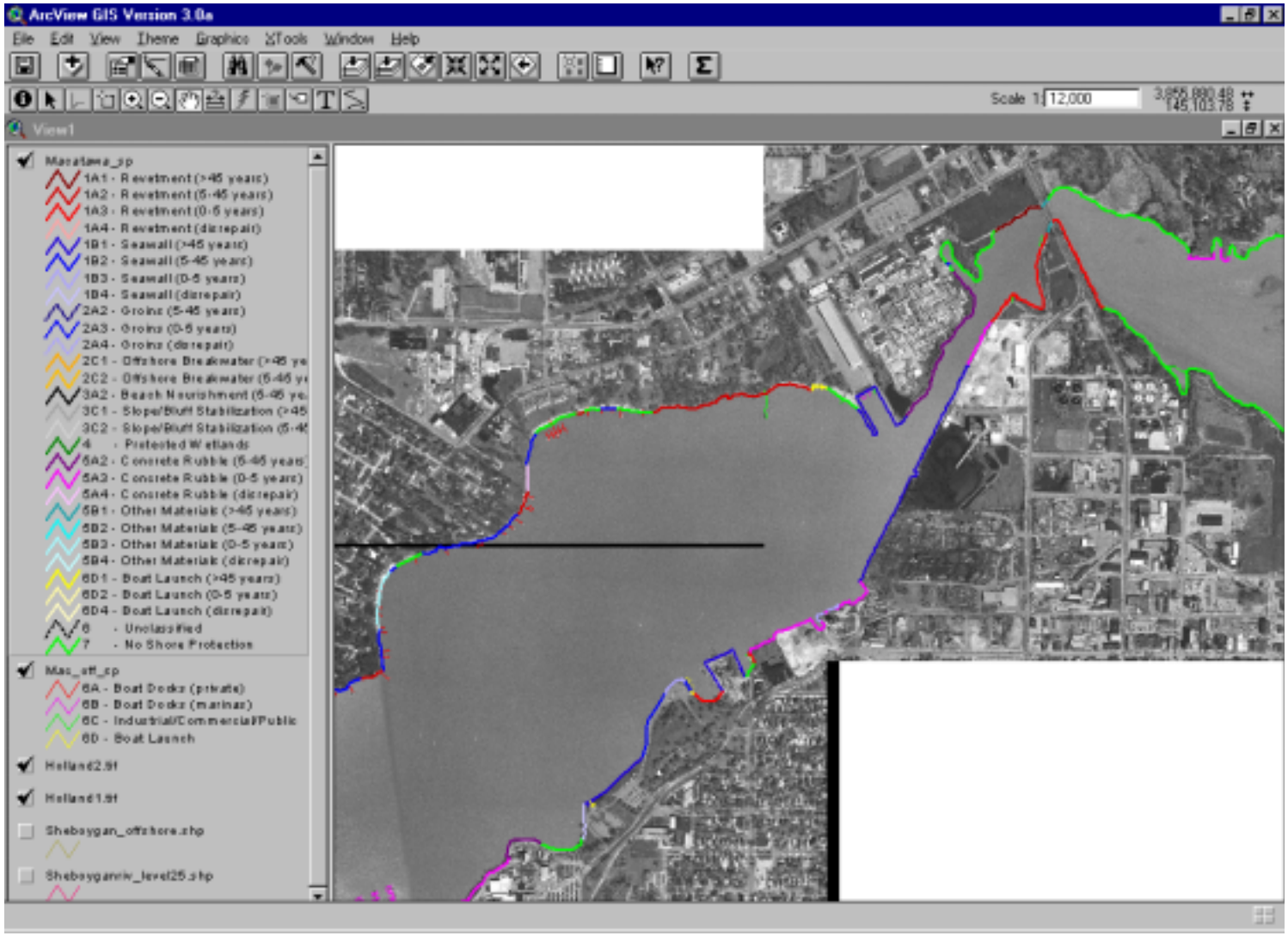

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Manitowoc_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
2C1 - Offshore Breakwater (>45 ye
2C2 - Offshore Breakwater (5-45 y
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mac_aff_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp

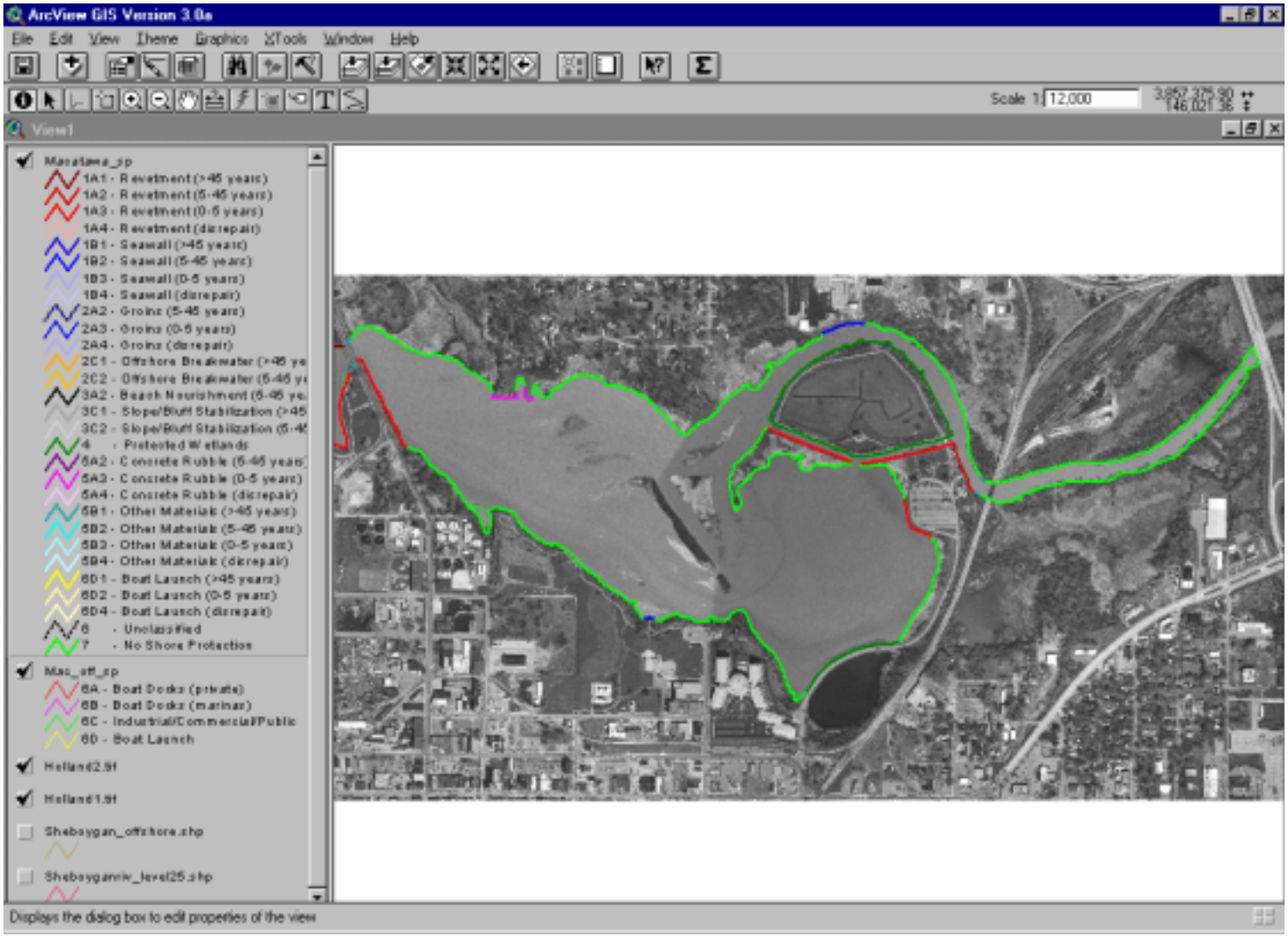

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Manitowoc_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
2C1 - Offshore Breakwater (>45 ye
2C2 - Offshore Breakwater (5-45 y
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mac_aff_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Manatawa_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
2C1 - Offshore Breakwater (>45 ye
2C2 - Offshore Breakwater (5-45 ye
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-4
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mac_aff_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp

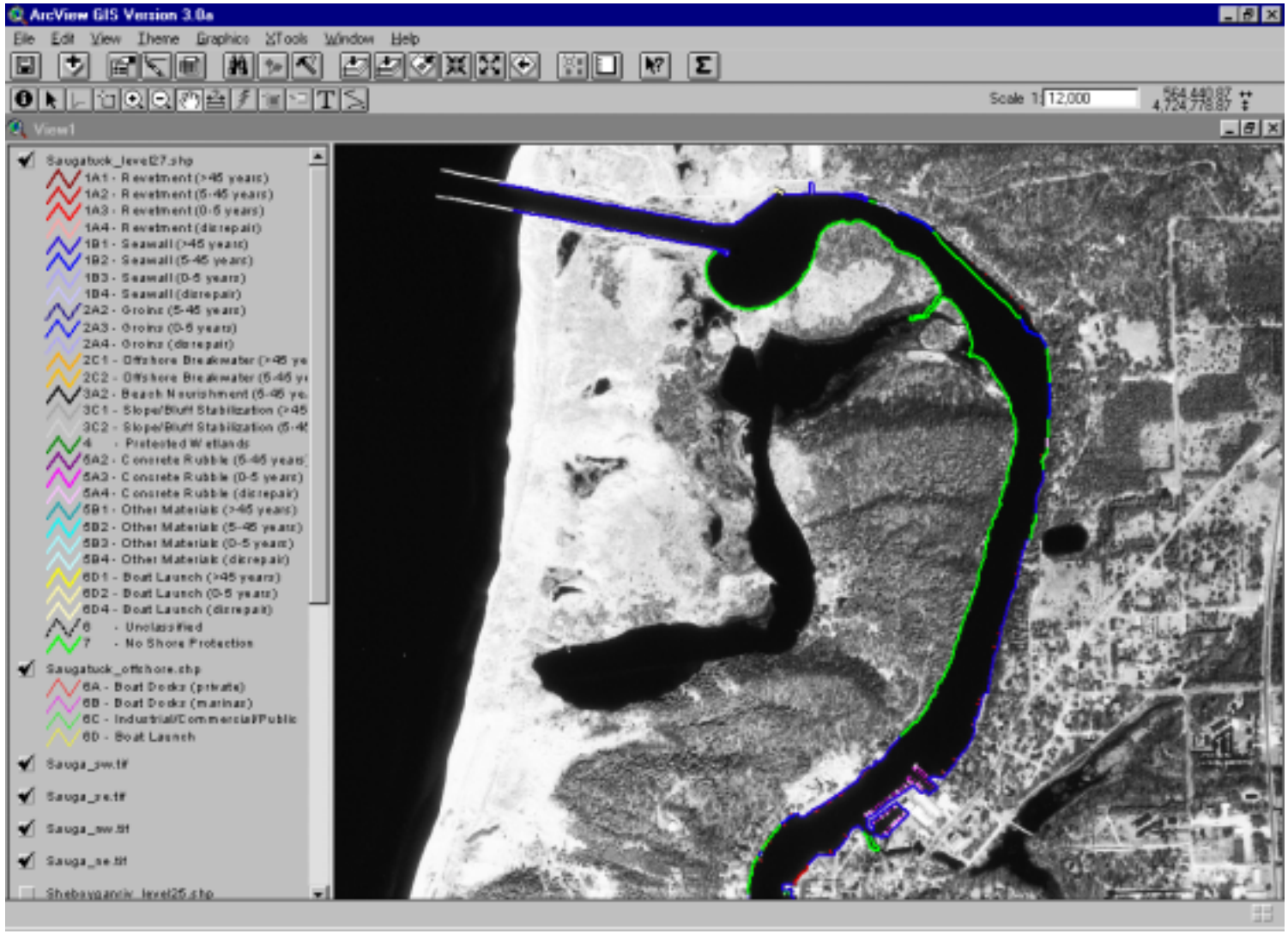

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Manitowoc_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-4
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mas_str_cp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp

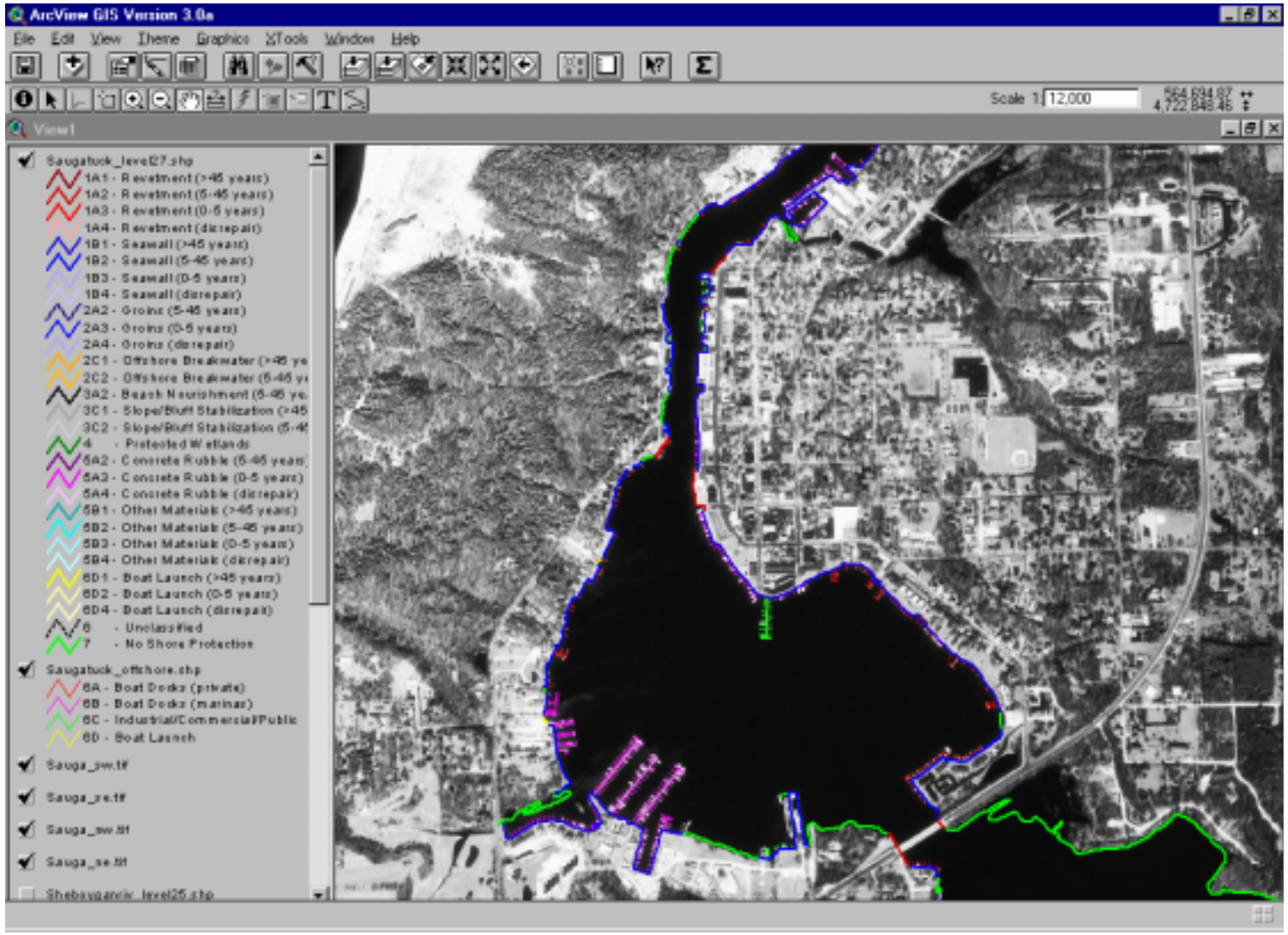

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Macatawa_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
2C1 - Offshore Breakwater (>45 ye
2C2 - Offshore Breakwater (5-45 y
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mac_aff_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp

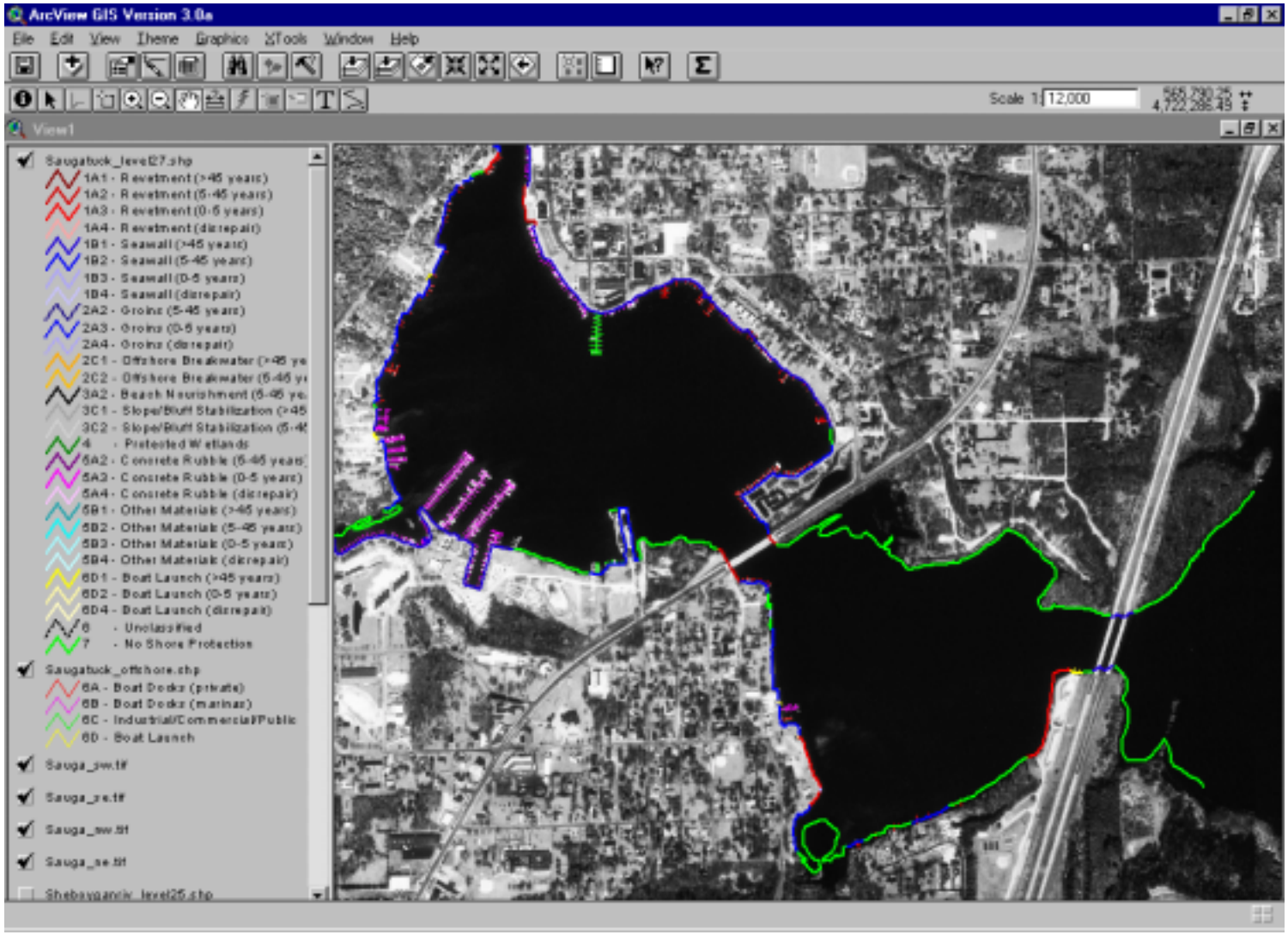

ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Manitowoc_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Mac_aff_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Manatawa_sp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (dis repair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (dis repair)
2A2 - Groinz (5-45 years)
2A3 - Groinz (0-5 years)
2A4 - Groinz (dis repair)
3A2 - Beach Nourishment (5-45 ye
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (dis repair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (dis repair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (dis repair)
6 - Unclassified
7 - No Shore Protection
Mas_utl_sp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Holland2.shp
Holland1.shp
Sheboygan_offshore.shp
Sheboyganriv_level25.shp
Displays the dialog box to edit properties of the view

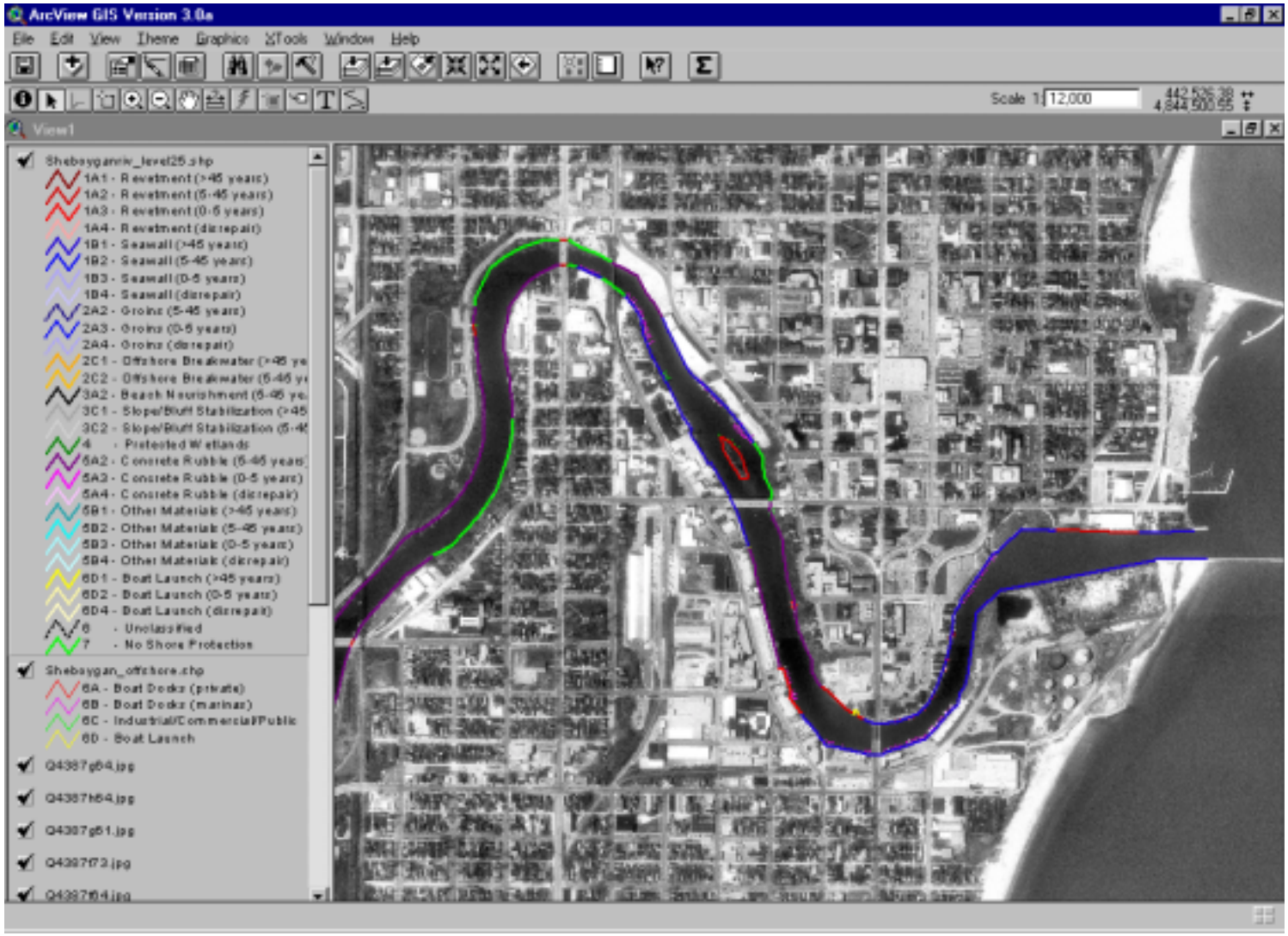
KALAMAZOO LAKE AND RIVER
SAUGATUCK AND DOUGLAS, MICHIGAN


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Saugatuck_level27.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Saugatuck_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Sauga_sw.tif
Sauga_se.tif
Sauga_sw.tif
Sauga_se.tif


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Saugatuck_level27.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Saugatuck_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Sauga_sw.tif
Sauga_se.tif
Sauga_sw.tif
Sauga_se.tif


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Saugatuck_level27.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
6 - Unclassified
7 - No Shore Protection
Saugatuck_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Sauga_sw.tif
Sauga_se.tif
Sauga_sw.tif
Sauga_se.tif
Sheboygan riv_level25.shp

SHEBOYGAN RIVER
SHEBOYGAN, WISCONSIN


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1:12,000
View1
Sheboyganriv_level25.shp
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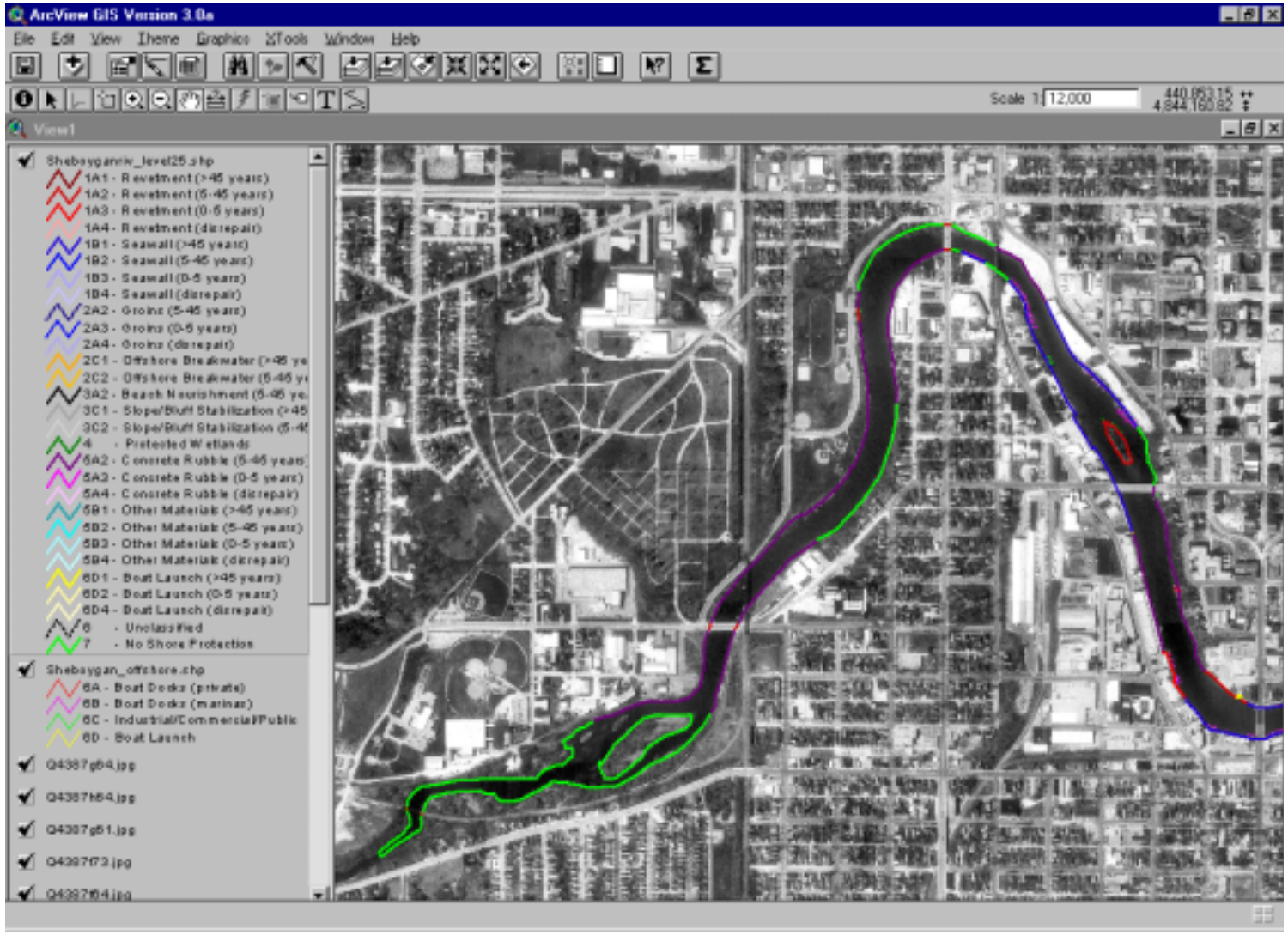
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (disrepair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (disrepair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (disrepair)
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
3C2 - Slope/Bluff Stabilization (5-45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
5A4 - Concrete Rubble (disrepair)
5B1 - Other Materials (>45 years)
5B2 - Other Materials (5-45 years)
5B3 - Other Materials (0-5 years)
5B4 - Other Materials (disrepair)
6D1 - Boat Launch (>45 years)
6D2 - Boat Launch (0-5 years)
6D4 - Boat Launch (disrepair)
8 - Unclassified
7 - No Shore Protection
Sheboygan_offshore.shp
6A - Boat Docks (private)
6B - Boat Docks (marinas)
6C - Industrial/Commercial/Public
6D - Boat Launch
Q4387g64.jpg
Q4387h64.jpg
Q4387g61.jpg
Q4387f73.jpg
Q4387f64.jpg


ArcView GIS Version 3.0a
File Edit View Theme Graphics XTools Window Help
Scale 1: 12,000
View1
Sheboyganriv_level25.shp
1A1 - Revetment (>45 years)
1A2 - Revetment (5-45 years)
1A3 - Revetment (0-5 years)
1A4 - Revetment (dis repair)
1B1 - Seawall (>45 years)
1B2 - Seawall (5-45 years)
1B3 - Seawall (0-5 years)
1B4 - Seawall (dis repair)
2A2 - Groins (5-45 years)
2A3 - Groins (0-5 years)
2A4 - Groins (dis repair)
3A2 - Beach Nourishment (5-45 ye
3C1 - Slope/Bluff Stabilization (>45
4 - Protected Wetlands
5A2 - Concrete Rubble (5-45 years)
5A3 - Concrete Rubble (0-5 years)
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Q4387g64.jpg
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Q4387g61.jpg
Q4387f73.jpg