PEORIA RIVERFRONT DEVELOPMENT
(ECOSYSTEM RESTORATION) STUDY, ILLINOIS
FEASIBILITY REPORT WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX E-1
SEDIMENTATION RATE ANALYSIS

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APPENDIX E-1 SEDIMENTATION RATE ANALYSIS

INTRODUCTION

Peoria Lake has experienced significant sedimentation during the last century as a result of a combination of geomorphic and anthropomorphic factors. What was once a lake with diverse bathymetry, numerous islands and a variety of habitat types, is now a large, shallow lake. The only deepwater is found in and immediately adjacent to the navigation channel. This loss of bathymetric diversity has been accompanied by an equally impressive loss of biological diversity. Aquatic vascular plants are no longer present anywhere in the lake, and the lack of off-channel, deepwater habitat for overwintering may be limiting for some fish species. Efforts to restore some portions of the lake, which have been degraded by excessive sedimentation, can benefit from a more thorough understanding of the sedimentation processes that have occurred over the past 100 years. This study expands upon work done by previous researchers by incorporating data from timeframes not previously identified and by converting the data to an electronic form that is compatible with commonly used software.

PURPOSE

The purpose of this study was to utilize existing bathymetric information in order to determine historic sedimentation rates within Peoria Lake. While previous researchers have performed similar analyses (Demissie and Bhowmik 1986, Lee and Stall 1976 & 1977, Bellrose et al. 1983), this study expands upon their work in several ways. In researching the existing records for this study, a series of bathymetric surveys from the 1930's was discovered. This is an important period in the recent history of Peoria Lake because it approximates the time when significant increases in Lake Michigan diversion occurred. It also immediately precedes the construction of Peoria Lock and Dam. Both of these events resulted in changes in lake hydrologic conditions (lake area and depth). By incorporating these data into the analysis, it was possible to measure the rate of sedimentation during a time when events were occurring which raised the minimum water level in the lake.

The current study also incorporated a very complete survey performed in 1988 as well as the most recent bathymetric surveys completed in 1996 and 1999. Previously mentioned studies warned of further lake sedimentation and the eventual emergence of land forms; however, these predictions were based on extrapolations of observed trends. This study helps to establish recent trends in sedimentation.

Finally, while historic data were digitized as part of previous studies, the storage media utilized are no longer compatible with current computer technology. In this study, all data were digitized, stored on the most advanced media available, and analyzed using advanced Geographic Information Systems (GIS) software. The use of these analytical tools permitted interpreting the data in ways not previously possible. These efforts also will make the data available to other users for further analysis.

BACKGROUND

Peoria Lake is located between River Miles (RM) 162 and 181 on the Illinois Waterway. It was formed as a result of an alluvial fan that developed near the mouth of Farm Creek, a small tributary to the Illinois River (Demissie and Bhowmik 1986). Several other tributary streams also drain directly to Peoria Lake. These streams are generally very steep relative to the Illinois River, and deltas have formed near the mouths of each tributary. The Tenmile Creek delta, which is located at RM 165.5, has formed a constriction in the river which divides the lake into Upper Peoria Lake and Lower Peoria Lake.

The earliest detailed survey of Peoria Lake was completed in 1903 by J. W. Woermann. The maps created from this survey depict the lake at low-water conditions. Under these conditions, the lake exhibited diverse bathymetry and several islands in both the Upper and Lower Lakes. Lake area was significantly less than currently exists and, as will be shown later, lake volume was also less than more recent time periods. As a result of flow diversion from Lake Michigan, minimum water levels throughout the Illinois Waterway were significantly raised from natural levels. Changes in diversion caused the water levels to vary from time to time. In 1939, the Peoria Lock and Dam was constructed, which further affected low-water levels and established a minimum pool elevation of 440 feet NGVD, 1929.

SEDIMENT SOURCES

Sediment sources to Peoria Lake include the Illinois River, which drains an area of about 13,765 square miles upstream of Peoria Lake, and 10 tributaries flowing directly to the lake, which have a combined drainage area of about 400 square miles (Figure E-1-1). It was estimated by Bhowmik et al. (1994) that nearly 100% of the sediment load to the lake comes from these sources. Previous work by Demissie and Bhowmik (1986 and 1993) indicated that as much as 40% of the total sediment deposition in the lake originated from the small tributary streams; however, both of these studies were based on short periods of record. While the large drainage area of the Illinois River compared to the tributaries belies this conclusion, one must consider the nature of the sediment load coming from these two sources. The Illinois River transports primarily suspended sediment, much of which may flow through the lake. The tributaries, on the other hand, transport substantial amounts of very coarse sand and even larger-sized materials that likely remain in the lake.

HYDROLOGIC CONDITIONS

The history of flow conditions on the Illinois Waterway is well documented by others (Bellrose et al. 1983, Larson 1979, Lee and Stall 1976, Havera et al. 1980). Beginning as early as the mid-1800's and continuing to the present, the Illinois Waterway has been modified for the purposes of improving commercial navigation and carrying waste materials away from the Chicago metropolitan area. These modifications included the construction of canals, locks and dams, channel training structures and levee systems, as well as extensive dredging and diversion of water from Lake Michigan. Major structural modifications culminated with the construction the 9-foot navigation system (consisting of 8 locks and dams) in the late 1930's. Dredging and flow diversion continue as part of the system maintenance activities.

All of these modifications have resulted in unnatural hydrologic conditions throughout the Illinois Waterway. Figure E-1-2 shows how low water levels near Henry, IL (immediately upstream of Peoria Lake) reacted to these modifications during the 1900's. Initially, water levels increased, then briefly fell, then have remained near elevation 440 NGVD. Figure E-1-3 depicts the frequency with which water levels have occurred at locations immediately upstream and downstream of Peoria Lake for the period beginning around 1870 through the present. Figure E-1-4 shows the depth contours of how Peoria Lake appeared in 1903 at different stage levels. Because most of the landforms within the lake had relatively low elevations, the character of the lake changed dramatically with small changes in water surface elevation. For instance, going from water surface elevation 434 to 438 caused the lake surface area to increase significantly and islands to all but disappear.

METHODS

Data sources for this study included bathymetric survey maps from 1903, 1932-1938, 1965, 1976, and 1988. Similar data in electronic form were available for 1996 and 1999. Each of these data sources had unique qualities which dictated how they were treated. While a detailed discussion of each data set is beyond the scope of this report, the following web site provides this type of information: http://www.mvr02.usace.army.peroialake.mil. Included on this web site is information about the form of the original maps and the various formats in which these maps may be obtained (paper copy, electronic images, rectified images, and GIS coverages). It also discusses characteristics of the various products generated from these data (Metadata). This report includes a general discussion of each data set and how they were analyzed.

INTERPRETING BATHYMETRIC SURVEY DATA AND CONVERTING TO DIGITAL FORM

Before the various survey data sets were digitized, inconsistencies pertaining to coordinate systems, vertical datum systems, and data densities were addressed. Unique characteristics of each data set are discussed in the following sections.

1903 Data

Between 1902 and 1904, J. W. Woermann of the U.S. Army Corps of Engineers, Chicago District (CE-NCC) directed a bathymetric and topographic survey of the Illinois Waterway from RM 287.5 to the confluence with the Mississippi River, including Peoria Lake. Survey range data were spaced approximately 500 feet apart. Data were plotted on maps showing water depths and some surrounding 1-foot topographic data. These maps were scanned using a 400 dpi gray scale color scheme. The coordinate system used for the Woermann maps was different from any system used today. Attempts to convert the coordinates to a current projection system were unsuccessful. The maps did have section/township markings that were used wherever possible to rectify the maps. Street intersections and building locations were also used if there were not enough section/township markings available. Because of the large area covered by the Woermann maps, six to eight reference points (tic marks) were used per map. The scanned images were rectified to real world coordinates using the Illinois State Plane West NAD 83 projection. After the maps were rectified, it was noticed that some adjacent maps had gaps of 100 feet or more. It was decided that attempts to adjust these gaps would only compound the problem.

The elevations noted on the map were not in the current NGVD 1929 datum. Notes on the original maps document the vertical datum as follows:

> "The precise (bathymetric) levels are based upon elevations of U.S.P.B. Ms. 2, 3, and 4, at Grafton, Illinois, established by the Mississippi River Commission in 1880. The elevations are therefore in feet above the Memphis Datum plane, which is approximately 8.13 feet below mean Gulf Level at Biloxi, Mississippi. The soundings are expressed in feet and tenths below the low water of 1901, which is the lowest stage of water on record since the opening of the Chicago Drainage Canal. The Shore line is represented for this same low water stage."

The Memphis Datum is 7.44 feet higher than NGVD 1929 datum, so all elevations were adjusted accordingly when the data were digitally recorded.

Because the maps were created prior to the construction of the Peoria Dam, there was no established flat pool value. The "low water surface" elevation noted on the Woermann maps was determined for several locations throughout the lake. When the digitized depths were converted to elevations, the nearest downstream "flat pool" elevation value was used.

1932-1938 Data

The 1930's maps were the most important and most difficult set of maps with which to work. They were the most important because previous studies had not utilized data from this time period. Changes in the amount of water Lake Michigan diverted took place between 1903 and 1965. It was felt that this time period was essential in understanding trends in sedimentation. Working with the data was difficult because there was not one complete set of maps that contained data for the entire lake.

Between 1932 and 1938, bathymetric surveys of Peoria Lake were completed by the CE-NCC on several occasions. It appears from the data that a complete lake survey was performed in 1934-1935. However, the only existing copy of the maps had been overwritten, in places, with more recent data. In order to get a complete picture of lake bathymetry, additional data were obtained from surveys performed between 1932-1938. By using maps from several different years, a very complete data set was assembled for the entire lake. Because of the variety of maps used, care was taken to ensure that data were clearly identified and documented in the metadata.

Most of the data for Upper Peoria Lake came from large "hard shell" maps. In general, the survey ranges were spaced approximately 200 feet apart and included some 1-foot topography. The hard shell maps were very deteriorated and their large size (20-30 feet in length by over 40 inches wide) and fragile condition made it impossible to work with them directly. The maps were first photographed in several sections. To permit later rectification, steps were taken to ensure that each photographed section included several coordinate markings and that adjacent photographs overlapped. Other survey data gathered in 1935 were available as a set of Mylar maps dated 1938. These maps covered the entire Lower Lake. A set of paper maps dated 1965, but containing data clearly labeled 1932-1938, was used as an additional data source.

All maps, including the photographic negatives of the hard shell maps, were scanned using a 400 dpi gray scale color scheme. All maps were rectified using at least 4 points. For the hard shell maps, at least 4 points were used for every photographed section. State plane coordinate points were used when possible. The images were converted to the Illinois State Plane West NAD 83 projection system using the CORPSCON projection conversion program.

1965 Data

In 1965 and again in 1976, the Corps of Engineers Chicago District performed complete bathymetric surveys of Peoria Lake. The survey range data were available as photocopies of maps dated 1965. The transect data were spaced approximately 1,000 feet apart. This resulted in a less dense data set compared to previous surveys, and small areas of the lake were not included. Data for these areas were taken from the 1934-1935 hard shell maps which had been overwritten with data clearly labeled 1965. All maps were scanned using a 400 dpi gray scale color scheme. The images were rectified to real world coordinates in the Illinois State Plane West NAD 1983 projection.

1976 Data

The 1976 data were available on a series of photocopied maps. The data were complete but transects were only spaced 500 feet apart. All maps were scanned at 400 dpi using a gray scale color scheme. The images were rectified to real world coordinates using the Illinois State Plane West NAD 1983 projection.

1988 Data

When Demissie and Bhowmik (1986) evaluated sedimentation rates in Peoria Lake, they constructed 18 transects spaced approximately 1 mile apart. They used these data to represent bathymetric conditions immediately preceding their analysis. This density of data is not compatible with GIS analysis tools and thus was not used in this study. In 1988, CENCC performed a survey of the entire lake. The survey range data were spaced approximately 1,500 feet apart, resulting in a very dense data set. The survey data were available on paper maps that included 1988 aerial photography. The maps were scanned at a resolution of 400 dpi using a gray scale color scheme. The images were rectified to real world coordinates using the Illinois State Plane West NAD 1983 projection.

1996 and 1999 Data

In 1996 and 1999, complete surveys were performed by the Rock Island District (CEMVR). Both surveys resulted in data sets that were very dense compared to other time periods used in this study. The field data from the 1996 and 1999 surveys were available in an electronic x,y,z format in the Illinois State Plane West NAD 1983 projection. The tabular data were imported into ArcView™ as an Event Theme and converted to shapefiles.

FILE MANAGEMENT AND ANALYSIS TECHNIQUES

File Management

All maps were saved in the .tif file format. Once the maps were scanned, the images were digitally rectified. Four to six coordinates were selected to rectify each map, except as noted above. Points were chosen near the 4 corners of the map, and the center if deemed necessary, in an attempt to keep the root mean square (RMS) error below 1. When maps did not have enough usable coordinates, section/township crossings and street intersections were used. Coordinates for these points were taken from maps that were already rectified. Rectifying images associated a Tif World File (.twf) to each corresponding .tif image.

Rectified maps were digitized using ArcView™. This process was facilitated by creating a script using ESRI's Avenue™ language, which allowed the user to easily enter each bathymetric point value. The decimal point of the depth value recorded on the maps was used for the location of the bathymetry point. Once the depths were entered into the ArcView™ table, they were converted to elevations using the flat pool elevation documented on the map. Where available, some topography information was also digitized. This was done to create a better coverage near the land-water interface.

Analysis Techniques

Point data for each time period were converted to a surface model (Tin) using ArcInfo™ . These coverages were "clipped" to eliminate data above elevation 440 NGVD from being included in later area and volume computations. This was done by first converting the tins to 20-foot grids, creating a point coverage from the grid, and converting the point coverage to finalized tins. This process minimized distortions in the initial tins due to irregular spacing of the raw data. Where data gaps existed, such as shallow areas in the Upper Lake, fill polygons were added to the coverage. These finalized tins were used for all area, volume, and sedimentation rate computations.

Utilizing these tins, it was possible to calculate various statistics pertaining to different areas of the lake for each timeframe analyzed. It was even possible to further identify how different depth classes have changed over time. Four depth classes were used in this analysis: <3 feet, 3-6 feet, 6-9 feet, and >9 feet. These depth classes were chosen as being representative of habitat types which benefit various species of aquatic organisms. Because much of the deepwater found in the lake under low-flow conditions is associated with the navigation channel (and may be of limited habitat value), off-channel and channel areas are identified separately. For this analysis, the navigation channel is defined as an area running the length of the lake, which is 150 feet on either side of the deepest part the lake. This technique was used for all timeframes.

Finalized grids were created from the finalized tins, for appearance purposes. In certain instances, these grids were filtered in ArcInfo™ to permit creation of smooth contours for display purposes. All figures of surface models are labeled as being created from filtered or unfiltered grids.

DATA AVAILABILITY

As mentioned previously, one objective of this study was to make available in current form, data from all timeframes utilized for analysis. This will permit others to use these data for additional analyses. Paper copies of all maps except the 1934-1935 hard shell maps are available from the U.S. Army Corps of Engineers, Rock Island District (CEMVR). The photographic images of the 1934-1935 maps are available on CD from CEMVR. The photographic negatives of these maps are held by Boyd Fitzgerald Photography, Davenport, Iowa.

All maps were scanned as previously described. These are available on CD as .tif image files and as rectified files with associated .twf files. The rectified files are in the Illinois State Plane West NAD 83 projection. The scanned images and related world files are available from CEMVR. Data from the 1996 and 1999 bathymetric surveys are available as x,y,z ASCII files from CEMVR. Shapefiles and GIS coverages created during this study are available at the web site: http://www.mvr02.usace.army.peroialake.mil.

RESULTS

SEDIMENTATION RATE DATA

For the purpose of this study, 1903 is used to represent the baseline condition for Peoria Lake (since this was when the first detailed bathymetric data were collected). In order to compare data for the 1903 and 1932-1938 timeframes to data collected following dam construction, one must utilize some surface water level which represents conditions which existed during those earlier timeframes. Demissie and Bhowmik (1986) determined a rate of sedimentation for the 1903-1965 time period as though the low lake level were 440 feet NGVD. For the purpose of comparing techniques used in the different studies, lake capacity in 1903 at elevation 440 was determined. The results are plotted in Figures E-1-5 and E-1-6, along with the results from Demissie and Bhowmik (1986). Considering the different techniques utilized in the two studies, the results compare very well. The absolute volumes and rate of volume loss are very similar, especially during the earlier time periods. Differences appear around the mid-1980's because the 1986 study utilized only a few cross sections to calculate volume. Also, the authors of that study were only able to estimate lake volume for the year 2000.

A more detailed analysis of results is summarized in Tables E-1-1 through E-1-4. In these tables, and elsewhere in the report, results for the 1903 and 1930's time periods are based on the low-water surface elevation of 434 NGVD 1929. The decision to use this level was based upon information presented on the Woermann maps and data presented in Figures E-1-2 and E-1-3. Tables E-1-1 and E-1-2 list the lake volume and water surface area of the lake, respectively, by different depth classes for the eight timeframes analyzed. Also included are the lake volume and area computations after construction of the preferred project alternative (proposal 2 plus proposal 3). Table E-1-3 shows the amount of sediment that has deposited or scoured between surveys, and Table E-1-4 expresses this as an annual sedimentation rate. As noted in the tables, all values listed were computed independently from grids. In some cases, the total values may not equal the sum of the individual components due to rounding errors. In cases where the rate of change was determined, area measurements utilized in the computations were based on the first time period.

The data presented thus far attempt to describe where and to what extent scour and deposition have occurred throughout the lake. However, two specific areas located in the Lower Lake, close to the project site, were analyzed in even greater detail. These areas are shown in Figure E-1-7A. Both areas were originally greater than 9 feet and have experienced rapid sedimentation. These areas may be more representative of the worse-case rate of sedimentation which could occur at the project site, compared to the average rates of sedimentation observed in the lake. Table E-1-5 shows the sedimentation rate results of from Site A, located closest to the proposed project site, and Site B located on the opposite side of the river.

BATHYMETRIC CONTOUR DATA

Graphical representations of these data are presented in Figures E-1-8 through E-1-10. Figure E-1-8 summarizes how water depths have changed throughout the lake between 1903 and 1999, bathymetric diversity has simplified, and deposition has dominated throughout the lake. Figure E-

1-9 shows the progressive loss of water depth diversity. Figure E-1-10 shows how these depositional and erosive processes have occurred by timeframe.

CROSS SECTION DATA

Figure E-1-11 shows the locations of cross sections that were constructed from the tins. Cross sections were positioned at or near the whole river miles and at intermediate locations which were of particular interest. Figures E-1-12 through E-1-19 show these cross section results. Each plot shows all eight timeframes analyzed.

DISCUSSION

SEDIMENTATION RATE

It can be seen from the sedimentation rate results that between 1903 and 1976 the rate of sedimentation determined by this study agrees quite well with that determined by Demissie and Bhowmik (1986). After that, the rate of sedimentation seems to have lessened, with some overall scour being observed most recently. This is most pronounced in the Upper Lake, while the Lower Lake continued to fill until just recently. It is not surprising that this should occur as the trap efficiency of the Upper Lake probably decreased sooner than the Lower Lake because it experienced more rapid sedimentation during the early 1900's.

What is interesting are the results of the most recent surveys which show both the Upper and Lower Lakes gaining volume. This could be an artifact resulting from the short elapsed time between surveys. This change is also rather small and could be due to local dredging and scour which are not occurring on a wide-spread basis. However, from Figure E-1-9 it is apparent that the navigation channel is scouring throughout its length. It also appears that some scour is occurring immediately upstream of the Tenmile Creek and Farm Creek deltas where water velocities would be expected to be slightly higher compared to wider areas of the lake. Whether this trend will continue is unclear.

BATHYMETRY

It is also evident that the deeper areas of the lake, away from the navigation channel, have experienced more rapid sedimentation than shallow areas. This has resulted in little bathymetric diversity and loss of off-channel, deepwater habitat. The proposed project alternative will significantly increase both the volume and area of deepwater habitat in the Lower Lake. While these deep areas have been shown to be subject to rapid sedimentation, design features will attempt to minimize this by orienting the islands and channels to make them self-maintaining.

CROSS SECTION

From the cross-section data, it is obvious that the navigation channel has narrowed and deepened throughout the lake over time. In most locations, the navigation channel has not moved laterally over time. This appears to be the case in the project area, especially in recent years.

LITERATURE

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