ILLINOIS RIVER BASIN RESTORATION
COMPREHENSIVE PLAN
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX C

SUMMARY OF HYDROLOGY AND HYDRAULICS INVESTIGATIONS

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INTRODUCTION

This appendix summarizes the hydrologic and hydraulic investigations undertaken as a part of this Comprehensive Plan. Some of the reports and efforts summarized in this appendix were prepared by contract and are indicated as such. The reports are available at the Corps of Engineers, Rock Island District office in Rock Island, Illinois.

1. GENERAL

The Illinois River Basin enjoys a continental-type climate characterized by frequent penetrations throughout the year of different types of air masses and their associated weather disturbances (USACE 1996). The basin lies in the path of low- and high-pressure areas that pass from west to east at more or less frequent intervals of about three to five days. Great variations in temperature occur from day-to-day, month-to-month, and year-to year, and in annual precipitation from year-to-year. The seasons are conspicuously distinct. Summers are commonly warm to hot and often humid. Winters are moderately cold. July is the warmest month, with mean monthly temperatures of 72 to 78 degrees F (north to south), and January the coldest, with mean monthly temperatures of 16 to 28 degrees F (north to south). Lake Michigan moderates temperatures locally in the Chicago area and causes relatively heavy snowfall in a narrow band adjacent to the lake. The growing season varies from about 200 days near the mouth of the Illinois River to about 160 days in the Fox River Watershed west of Chicago.

Storms in the Illinois River Basin are commonly of two types: the widespread frontal type and the local thermal convection (thunderstorm) type. There are no orographic storms because of the low relief. Total annual precipitation is fairly uniform throughout the basin, averaging from 34 to 36 inches. Flood-producing storms can occur at any time, but their frequency is greatest from late winter to early fall. During the cold season, large-area storms of from two to five days' duration predominate. In the warm season, storms are shorter but more intense. The average number of thunderstorms per year varies from about 40 in the northeast to about 55 in the downstream end of the basin. June is the month of maximum thunderstorm activity. Thunderstorms account for about 40 to 45 percent of the annual precipitation.

Because of its flat gradient and copious channel and flood plain storage, floods on the Lower Illinois River rise slowly, persist for long periods and recede slowly. A simple direct relationship between stage and discharge does not pertain because of these conditions and the effects of changing discharge and variable flows from tributaries. Quite often, flood-peak discharges actually diminish as a flood proceeds down the river. Since records have been kept, the average flood year has resulted in water being out of banks about 90 days.

The two hydrologic conditions that have the greatest effect on the ecosystem integrity of the main stem Illinois River are rapid water level fluctuations and lack of pool drawdown (Section 2, Illinois River Ecosystem Restoration Study Water Level Management Analysis). High peak flows and low base flows are the primary ecosystem stressors in the tributaries to the Illinois River. A suite of models was used to analyze the current hydrologic conditions and the effects of proposed restoration alternatives on the main stem Illinois River and its tributaries.

A hydrologic model of the Illinois River Basin was developed by the Illinois State Water Survey using the USEPA’s Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) model (Section 3, Hydrologic Model Development for the Illinois River Basin Using Basins 3.0). This hydrologic model was utilized by the USACE to evaluate restoration alternatives proposed for the tributary watersheds to the Illinois River. The two types of restoration alternatives studied were: increasing floodplain storage volume and increasing floodplain infiltration area. Increasing floodplain storage volume was analyzed by modeling storage areas adjacent to the main channels of the tributaries. This added storage volume was to be utilized at a water elevation in the channel that is achieved three or four times per year during high runoff events. Increasing floodplain infiltration area was analyzed by converting a portion of existing agricultural land areas in each tributary basin to land areas with higher infiltration characteristics within the model. The simulations implementing each alternative independently resulted in decreased peak flows and a general attenuation of the storm volume occurring at the respective tributaries confluences with the Illinois River. The effects of the basin restoration efforts on the water level conditions in the Illinois River main stem were evaluated by using the tributary model results as input to the hydraulic model of the Illinois River and comparing the fluctuation characteristics of the various scenario combinations.

A hydraulic model of the Illinois River main stem was developed using the One-Dimensional Unsteady Flow Through a Full Network of Open Channels (UNET) model. The UNET model of the Illinois River is routinely used for management of the Illinois River and can simulate the interaction between channel and floodplain flows; channel and storage areas; levee failures; and flow-through navigation dams, gated spillways, weir overflow structures, bridges and culverts, and pumped diversions. The Hydrologic Engineering Center Data Storage System (HEC-DSS) database was used for managing input and output hydrographs with various time intervals, such as weekly, daily, hourly, 2-hour, 30-minute, etc. The hydrographs resulting from the BASINS model described above were input to the UNET model using HEC-DSS. The UNET model was used during the course of this study to evaluate the benefits from various restoration alternatives on water level conditions along the Illinois River. The output hydrographs at specified locations along the main stem were developed for each restoration alternative by the UNET model.

A FORTRAN program was developed by the Rock Island District to calculate the number of water level fluctuations at specified locations along the main stem for the observed data and the alternative restoration scenarios studied. Using HEC-DSS, the output hydrographs from the UNET analysis described above, were input to FORTRAN program. The three time windows that were analyzed with the FORTRAN program are 6 hours; 24 hours; and 120 hours (5 days). Each fluctuation was categorized by the magnitude of water level change: 0.5 to 1.0 feet, 1.0 to 2.0 feet, and greater than 2.0 feet. The fluctuation regime at each location of interest was defined by the number of water level fluctuations that occurred over the specified time windows. Nine different classes of fluctuation were determined for each location; and the characteristics are as follows:

- Time window = 6 hours
    - Water level fluctuations greater than or equal to 0.5-foot and less than or equal to 1.0-foot
    - Water level fluctuations greater than 1.0-foot and less than or equal to 2.0-feet
    - Water level fluctuations greater than 2.0-feet

- Time window = 24 hours
    - Water level fluctuations greater than or equal to 0.5-foot and less than or equal to 1.0-foot
    - Water level fluctuations greater than 1.0-foot and less than or equal to 2.0-feet
    - Water level fluctuations greater than 2.0-feet

- Time window = 120 hours (5 days)
    - Water level fluctuations greater than or equal to 0.5-foot and less than or equal to 1.0-foot
    - Water level fluctuations greater than 1.0-foot and less than or equal to 2.0-feet
    - Water level fluctuations greater than 2.0-feet

The benefit for each of the proposed restoration alternatives was quantified as the reduced incidence of fluctuation.

2. ILLINOIS RIVER ECOSYSTEM RESTORATION STUDY WATER LEVEL MANAGEMENT ANALYSIS. (U.S. Army Corps of Engineers 2004a). This analysis was conducted by the Rock Island District to investigate the potential for ecosystem benefits arising from possible changes in water level management activities on the Illinois Waterway, primarily in terms of reduced incidence of rapid water level fluctuations. Since 1900, alterations in the Illinois River Basin have resulted in an increased incidence of water level fluctuations at many points along the Illinois Waterway. Water level management was determined to contribute to some of these fluctuations due in part to the hydraulic nature of the flat pools, the methods of operation, and the highly variable inflows from the watershed. Hydraulic modeling results indicate that certain management changes have the potential to reduce water level fluctuations in the system.

Twenty water level records were analyzed to evaluate the current and historic fluctuation regimes in the Illinois River system. Data from recent records were compared with available historic records to investigate various influences on fluctuation patterns, including season and climate. Water level fluctuation regimes differ by location on the river and location relative to dams; gages a short distance downstream of dams exhibit many more fluctuations than do gages immediately upstream of dams, but the differences tend to be less pronounced at the dams farther downstream. Some of the downstream differentiation arises because from Lockport to Starved Rock the dams control the navigation pools throughout the year whereas the Peoria and La Grange Dams maintain water levels only during lower flow periods. Comparable records indicate that the river experiences more fluctuations now than it did pre-1900, but in most locations the period 1989 through 2000 contained fewer fluctuations per year than did the period 1979 through 1988.

Although a number of water level management activities are conducted in the canal system of the upper Illinois Waterway, most of the fluctuations in the upper portion of the waterway arise due to storm water flows. At times, gate changes at the run-of-river dams contribute to water level fluctuation in dam tailwaters and areas immediately downstream. Downstream, wicket dam operation also causes some water level fluctuations, but these are largely due to the hydraulic nature of changing between impounded and unimpounded conditions and are not controllable by changes in operations. In general, the run-of-river water level management increases the magnitudes of water level fluctuations immediately downstream of dams as a response to the changing flows from the basin.

Hydraulic modeling suggests that a number of management changes could reduce the fluctuations occurring along the Illinois Waterway. A management scenario simulating smaller but more frequent gate changes at the dams in response to a more complete knowledge of inflows is likely to significantly reduce total fluctuations. These benefits would occur almost solely during times of low water. Storm water detention has the potential to reduce the fluctuations due to storm events in the reaches immediately downstream of the detention facilities. In order to be fully successful, storm water control would have to be implemented throughout the basin, as improvements at one point can be masked by fluctuating inflows downstream. Improved coordination in anticipation of storm operations would likely reduce water level fluctuations associated with release of flows from Lockport. Finally, use of the limited storage in the system to reduce fluctuations by centralizing control and optimizing management might also provide benefits, but at this time the technology required for system optimization has not yet been sufficiently developed.

This report also investigated the potential to lower the water level in the Peoria and La Grange Pools in order to stabilize sediments and allow plant establishment. Without additional action, including overdredging, drawing pool water levels down would have significant effects on navigation, recreation and infrastructure, the extent of which and mitigation costs would increase with drawdown depth. Flow conditions that allow maintenance of 30-consecutive-day drawdowns are most likely to occur during the months of September or October, or if attempted over an extended period of time in the late summer, but navigational and recreational users would be greatly affected during those times. Drawdowns in December are less likely to succeed but may be desirable due to the reduced conflicts during that month. From a biological perspective, optimal drawdowns would start in late June or early July and extend for at least 60 days, but flow conditions during that period would allow a drawdown in fewer than 1 in 5 years. The area exposed by a given drawdown is directly related to the depth below flat pool that is maintained at the downstream dam.

3. HYDROLOGIC MODEL DEVELOPMENT FOR THE ILLINOIS RIVER BASIN USING BASINS 3.0 (Demissie et al. 2003)

The objective of this study was to initiate the development of a continuous hydrologic model of the entire Illinois River Basin. This model was developed by the Illinois State Water Survey (ISWS). This model may be used to assist in the development of critical restoration projects conducted as part of the Illinois River Basin Restoration Program. The model will also be useful in assessing the flow characteristics throughout the basin, the effects of changes in land use and climate, changes due to project alternatives, and potential problem areas and restoration alternatives.

The BASINS modeling system, developed by the U.S. Environmental Protection Agency, was selected for this study because it:

- is designed for multiple purposes in environmental and hydrological practices,
- is based on state-of-the-art ARCVIEW technology for easy data processing,
- incorporates the widely-accepted HSPF and SWAT models to simulate watershed hydrology and the transport of nutrients, pesticides and sediments,

- utilizes a user-friendly interface to generate hydrological parameters,
- has an existing database of DEMs, land use, streams, and soils for the Illinois River Basin.

The Hydrologic Simulation Program – FORTRAN (HSPF, version 12) was used in this study to simulate daily watershed stream flow. It was accessed through WinHSPF, a graphical user interface, which interacts with the BASINS 3.0 utilities and data sets to aid in the development of an HSPF project. The HSPF requires spatial information about watershed topography, river/stream reaches, land use, and meteorology to accurately simulate the stream flow. It uses hourly precipitation, potential evapotranspiration, temperature, wind speed, and solar radiation time series data for performing hydrologic simulations when snow is also simulated. HSPF is a comprehensive and dynamic watershed scale model that simulates nonpoint source hydrology and water quality, combines it with point source contributions, and performs flow and water quality routing in the watershed reaches. It has been widely used for watershed scale hydrologic simulations and for assessing the effects of land-use changes on watershed scale hydrology and water quality.

The study plan to develop a calibrated and verified HSPF model for the entire Illinois River Basin involved tasks that were performed in different phases. The initial phase involved preparation of data that would be used for model development throughout the study. In the second phase, the HSPF model was developed and parameters were calibrated for the Kankakee River and Spoon River watersheds. In that process, the Kankakee River watershed was subdivided into two portions, the upper-Kankakee and Iroquois River watersheds, with parameters calibrated for each. Thus, calibration was performed for three areas: the upper-Kankakee, Iroquois, and Spoon River watersheds. In the third phase of study, a model for the entire Illinois River Basin was developed, parameters from the three calibrated watersheds were tested in other tributary watersheds, appropriate parameter values were adopted, and the HSPF model was run to simulate flows for the entire Illinois River watershed. This report discusses the work performed in all three phases.

A. Preparation of Input Data. Of the USEPA-WDM stations for which meteorological data are given in the BASINS database, only 17 stations are located in the general vicinity of the Illinois River Basin. More precipitation data stations were needed in order to reduce the effect of spatial variability of rainfall over the large area of the watersheds studied. Numerous additional weather stations in the Illinois River Basin with daily precipitation data available for the period of the study were identified and daily data was extracted from the Midwestern Climate Center database for those stations. Hourly precipitation data for sixteen more stations located in the watershed was also extracted from the NOAA-NCDC database. All hourly stations were used as reference stations for disaggregating daily precipitation data available at local stations into hourly precipitation.

B. Model Calibration and Verification for Two Watersheds. In the second phase of this study, hydrologic component of HSPF was calibrated and validated separately for Kankakee and Spoon River watersheds. The entire Kankakee River watershed was modeled in three sections: the upper Kankakee River watershed upstream of Momence, Illinois; the Iroquois River watershed upstream of Chebanse, Illinois; and the remainder of the watershed. During calibration of the Kankakee and Spoon watersheds, values of several sensitive model parameters were varied within a reasonable range to obtain an optimal agreement between the observed and simulated stream flow data. Calibration and verification were based on data from the 25-year period—1970 to 1995—for which complete stream flow and meteorological data records were available. Data from the 11-year period (1985 through 1995) was used to calibrate HSPF, and the calibrated model was verified separately for the 16-year period of 1971 to1986. Agreement between observed and simulated stream flow data, on an annual, seasonal (monthly), and continuous (daily) basis was determined objectively (by plotting the time series) as well as quantitatively. This was done to determine any trends due to seasonality and to have an idea of any discrepancies in long-term data values. Quantitative comparison was based on calculation of objective functions such as Nash-Sutcliffe efficiency (NSE), and coefficient of determination (R^2), intercept and slope of linear regression fit between observed and simulated data. For monthly and annual time scales, relative percent difference between observed and simulated flows was also calculated and reported.

C. Development of a Model for the Entire Illinois River Basin. In the third phase of this study, hydrologic simulations were performed using HSPF for the entire Illinois River Basin using two different approaches: an HSPF model using a single UCI data file; and an HSPF model using modular approach. In the first approach, the entire Illinois River Basin was delineated into 60 sub-watersheds using meteorological data from 56 gaging stations. The 60 sub-watersheds represent the practical limit that can be developed and still be able to model the entire Illinois River Basin in a single HSPF project. In the second approach, individual HSPF projects were created for the watersheds of seven additional major tributaries (Des Plaines, Fox, Vermilion, Mackinaw, Sangamon, La Moine and Macoupin) and the main stem Illinois River. In the modular approach, the entire Illinois River Basin was divided into approximately 250 sub-watersheds, and data from all 95 available precipitation gages were used in the simulation.

Model calibration was not performed for the entire Illinois River Basin for either of the two approaches. Instead, calibrated parameters from the three previously calibrated watersheds—the upper-Kankakee, Iroquois, and Spoon River watersheds—were tested over the entire Illinois River Basin to determine which set of parameters worked best for various portions of the basin. Out of the three parameter sets, the best results were consistently obtained by using calibrated parameters of Spoon River watershed for all remaining portions of the Illinois River Basin.

For both approaches, much of the Des Plaines watershed was removed from the HSPF model and replaced by an inlet location, by which flows from the Des Plaines River and Chicago Sanitary and Ship Canal are represented by observed flows instead of model simulation. This was done for two reasons: (1) the Chicago area is highly urbanized and the watershed characteristics are totally different from the three calibrated watersheds; thus, it would not be appropriate to use any one of the three calibrated sets of the parameters directly for the Chicago area; and (2) the Lake Michigan flow diversion provides an additional source of flow to the Chicago Sanitary and Ship Canal. In the future, a detailed HSPF model that includes the Des Plaines River watershed and Chicago-Calumet drainage could potentially be linked with the model for the remainder of the Illinois River Basin.

The modular approach for modeling the entire Illinois River Basin is preferred for this project because it provides a broader framework for future modeling work, leading to more detailed applications in the major tributaries and sub-watersheds, such as may be needed for the evaluation of watershed management practices and other applications.

4. FLOODPLAIN ANALYSIS

One of the major restoration concepts is the reconnection of the Illinois River with its floodplain, since much of the floodplain has been disconnected from the river using levees. Reconnection involves managing available areas for purposes such as flood storage, water level management, and ecosystem restoration. Hydraulic modeling is used to better understand the influence of restoration efforts on river hydraulics. The UNET model was used to evaluate the impacts of different floodplain management alternatives on water level conditions in the Peoria and La Grange Pools along the Illinois River.

The Hennepin Drainage & Levee District (HDLD) at river mile (RM) 206 is the only significant contiguous area of disconnected floodplain within the Peoria Pool. That area is 2,900 acres protected from the river by an agricultural levee system. UNET modeling indicated that making use of the leveed area to attenuate high flows could reduce maximum water levels at Henry, approximately 7 miles downstream, by as much as 0.5 feet, although benefits depend on the design of the structure that would be used to divert flows into the district. Hydraulic modeling indicates that the area would be most effective at reducing fluctuations if its inlet weir is set just above level pool elevation (440 feet NGVD). With this design, the HDLD would reduce 5-day fluctuations downstream to the Peoria Lock and Dam (RM 158) by approximately 5 percent. Upstream reductions would be less (2 percent at Starved Rock Tail, RM 231), and downstream of the Peoria Lock and Dam, the river would display 1 percent reduction or less. These benefits would be roughly additive when combined with work to restore tributary hydrologic regimes; if storage is added in the basin at levels of 10 acre-feet per square mile or greater, additional fluctuation benefits can be expected, but combinations with infiltration alternatives or low levels of storage are unlikely to display additional benefits beyond those attributable to the HDLD alone.

Modeling of floodplain storage in the La Grange Pool indicates somewhat smaller reductions in water level fluctuations from added storage area than the modeling of the HDLD. For this report, the Illinois State Water Survey used the UNET model to simulate a number of scenarios wherein different combinations of floodplain areas in the La Grange Pool were made available to attenuate low-level fluctuations, in the same way that the HDLD was modeled in Peoria Pool. Changes in the water level fluctuation regime were quantified at Kingston Mines, Copperas Creek, Havana, and Beardstown. The results of this effort suggest that although location-specific effects are significant, the fluctuation reductions due to the storage areas are roughly additive. The effects also depend on area at each site, diminish quickly with distance, and are much greater downstream of the added storage than upstream.

5. INVESTIGATION OF FLOW HYDRAULICS AND SEDIMENT TRANSPORT PROCESSES AT THE CONFLUENCE OF THE KANKAKEE AND IROQUOIS RIVERS WITH THE EnSed2D MODEL (Duan, 2003)

This report summarizes the results of computational modeling for the confluence of the Kankakee and the Iroquois rivers. It consists of three parts: (1) post-processing of the survey data and generation of the computational mesh; (2) technical descriptions of the hydrodynamic, mass dispersion, and sediment transport model, which are included in Appendices A and B; and (3) modeling results of flow hydrodynamics and sediment transport at the confluence of the Kankakee and the Iroquois Rivers. This project aims to study the effectiveness of engineering alternatives on reducing sedimentation at the confluence. The hydraulics and sediment transport patterns of three management scenarios, which are maintain in a natural state without engineering structures, construction of three short dikes on the left banks of the Kankakee River, and construction of three longer dikes on the left banks, are studied by applying the EnSed2D model.

The sediment transported in the Kankakee and Iroquois Rivers is primarily suspended sediment. The channel bed has a thin layer of bed material, and occasionally be rocks are exposed. Therefore, this study focused on the simulation of suspended sediment transport in the system. Two methods were applied to simulating suspended sediment deposition and erosion processes. One method assumes that the bed material layer is not thick enough for entrainment so that only deposition occurs; the other method assumes there is a sufficient amount of sediment that can be entrained from the channel bed so that the change of bed elevation is the difference between the rate of deposition and entrainment.

The simulated results showed that if the bed material layer is very thin, there is no scour in front of the dikes, while if there is an entrainment, the scouring in front of the dikes is very apparent. In case of no construction, the deposition at the confluence will spread at the confluence as well as immediately downstream. The construction of three short dikes will reduce the deposition of suspended sediment at the confluence and facilitate the passage of suspended sediment from the Iroquois River to the Kankakee River. However, increasing the dike lengths will potentially block flow from the Iroquois River to the Kankakee River, and worsen deposition at the confluence. Therefore, the results of this study recommended that dikes with a reasonable length could be the most cost-effective alternative to reduce sedimentation at the confluence. However, the locations, alignments, and dimensions of these dikes should be determined through another detailed computational modeling study. To ensure the mechanical stability and minimize the negative environmental effect of these dikes, flow hydrodynamics and sediment transport at the near-dike region should be investigated by applying an advanced computational model or conducting physical laboratory experiments.