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Pool 13 Drawdown: Predicting Success Rates and Affected Areas

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Pool 13 Drawdown: Predicting Success Rates and Affected Areas

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Upper Midwest Environmental Sciences Center (formerly the Environmental Management Technical Center), a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

This report was prepared under Strategy 1.2.3, *Determine Effects of Water Levels and Discharges on the Upper Mississippi River Ecosystem*, and Goal 3, *Develop Alternatives to Better Manage the Upper Mississippi River System*, as specified in the Operating Plan of the LTRMP for the UMRS (USFWS 1993). The purpose of this report is to estimate areas affected by a drawdown on Pool 13. This report was developed with partial funding provided by the LTRMP and part from the Rock Island District, U.S. Army Corps of Engineers.

Pool 13 Drawdown: Predicting Success Rates and Affected Areas

by

James T. Rogala, Joseph H. Wlosinski, and Kevin J. Landwehr

Abstract

The likelihood of 1- or 2-foot drawdowns, and the area affected by such alternative drawdowns, was estimated for Pool 13 on the Upper Mississippi River. Minimum water surface (elevation) requirements were compared to computed water surface profiles to determine a critical low flow that would allow a navigation channel 400 feet wide and 10.5 feet deep. An upper limit on flow was established based on the flow at which open river conditions would exist for a given drawdown. The range in flows that would allow for a drawdown was used to estimate success rates using historical daily discharge data. Success rates were determined for a variety of drawdown durations between two time periods, May 1–August 15 and June 15–August 15. The greatest effect of the drawdown would be near Lock and Dam 13. Higher discharges, as well as distance from the dam, lessen the drawdown amount. Areas that would be affected by these two drawdown scenarios were predicted by overlaying maps of water surfaces with depths using a geographic information system. Although the drawdown effects on most physical and biotic components of Pool 13 are unknown, some general drawdown effects likely to occur because of the changes in water surface elevation are presented.

Introduction

The Upper Midwest Environmental Sciences Center (UMESC; formerly the Environmental Management Technical Center) and the Rock Island District of the U.S. Army Corps of Engineers collaborated to estimate the likelihood of a successful drawdown in Pool 13 (Figure 1) based solely on historical discharge estimates. We also quantified areas that would be affected by a drawdown. Pool 13 is controlled by Lock and Dam 13 at river mile 522.5 and extends 34.2 miles upriver to mile 556.7. The Fish and Wildlife Interagency Committee requested the drawdown (Appendix) as an experiment to evaluate alternative regulation effects on moist soil plant production, sediment oxidation and compaction, and the photic zone for submersed vegetation. Estimates of areas, both dewatered and with changed water depths, were used to describe benefits anticipated as a result of the requested deviation from the current operating plan for Lock and Dam 13.

Constraints used for this study include the following: (1) channel dimensions of 400 feet wide and 10.5 feet deep must be available for the entire pool at all times, (2) the drawdown should not significantly affect commercial navigation or recreational craft, and (3) no additional dredging should be required. These constraints limit the chance of success of a drawdown as well as the effective zone of influence. The purpose of this report is to estimate these factors. Other constraints related to ecological benefits also exist, but are not evaluated in this report.

This report is a continuation of work performed at the UMESC to determine the effects of water levels and discharges on the Upper Mississippi River and to develop water-level management alternatives. Eight previous papers and reports are included in this series (Lubinski et al. 1991; U.S. Army Corps of Engineers 1991; Wilcox and Willis 1993; Wlosinski and Hill 1995; Wlosinski and Rogala 1995, 1996; Wlosinski 1996; and Wlosinski and Koljord 1996).

Some of the terminology used in this report may not be common but is used routinely for water-level management or analysis using geographic information systems (GIS). Definitions for these terms are included in Table 1. All elevations in this report are referenced to sea level, using the 1912 National Geodetic Vertical Datum.

Methods

Success Rates

Locations in Pool 13 where the navigation channel might first be threatened because of a drawdown were identified using bathymetric data obtained by the UMESC from 1989 through 1993. The minimum water surface (elevation) for each critical location was determined assuming minimum, post-drawdown, channel dimensions of 400 feet wide and 10.5 feet deep. These minimum water surface requirements were then compared to computed water surface profiles to determine the critical flow for each location. The most restrictive flow was then selected as the lowest discharge that would allow a 10.5-foot navigation channel. An upper limit representing the flow at which open river conditions would exist for a given drawdown was also used to estimate success rates.

Computed water surface profiles and water velocities were estimated from the one-dimensional flow model UNET under steady flow conditions. Water surface profiles were predicted for three water-level scenarios representing the current water-level management plan and drawdowns of 1 and 2 feet for discharges ranging from 25,000 to 110,000 cfs. The current plan calls for holding water levels at Lock and Dam 13 at 583 feet above sea level when discharges are less than 125,000 cfs. Data for bathymetric transects for the model were obtained from 1989–1992 hydrographic surveys. Elevation transects for the model were at approximately 1-mile intervals. The model internally interpolates cross sections at approximately half-mile intervals. The UNET model used in this analysis is the same model presently used for real-time forecasting of water levels on the Upper Mississippi River. The model has been calibrated and verified against historical flood events as well as daily observations of the river stage and flow.

The U.S. Geological Survey stream gage near Clinton, Iowa, was used to estimate success rates. Discharges have been estimated daily at that gage since 1873. The Clinton gage is 10.6 miles below Lock and Dam 13 and no major tributaries enter the Mississippi River between the gage and the dam. Computed success rates were determined for two time periods, May 1–August 15 (107 days) and June 15–August 15 (62 days). We calculated, for the same time periods, the percentage of the time discharges are exceeded.

We computed two independent measures of drawdown success. The first quantifies how often (expressed as a percentage of years) a drawdown of a given duration could have been conducted during the 123 years of flow record. This analysis was based on the largest number of consecutive days that the average daily flow remained within the specified flow range in any given year. In predicting drawdown opportunities, this represents the chance that a drawdown of a given duration could be accomplished in a random year. The second measure of drawdown success reflects how often the drawdown process produces a successful result once initiated.

The success curves were computed based on the following five assumptions:

1. The flow must remain within the defined flow limits for 5 consecutive days, else the process (drawdown) is not initiated and no failure occurs.

2. The number of days required for success is firm (e.g., 27 consecutive days is a failure for a 28-day requirement).

3. The flow boundaries are semiflexible in that if the flow deviates above or below the prescribed range no more than 5,000 cfs for 1 or, at most, 2 days the string of consecutive days is considered unbroken.

4. The remaining days in the time window must be sufficient for the drawdown requirement, else the process is not initiated and no failure occurs.

5. More than one drawdown attempt can be made in a given year, but no additional attempts were made within a year after a successful result was obtained.

Affected Areas

Water surfaces predicted by the UNET model were transformed into four GIS coverages representing two water levels (current conditions and the 1-foot drawdown) at 50,000 cfs and two (current conditions and the 2-foot drawdown) at 70,000 cfs. The discharge condition was selected on the basis of the lowest discharge at which a drawdown could occur successfully, which equates to the maximum water-level change and affected acreage. The coverages were created using templates containing cells approximately 1 mile long arranged longitudinally along the river and perpendicular to the direction of flow. However, if off-channel areas are only contiguous with the main channel at a downstream location, the template cell would have an irregular pattern. For example, because Spring Lake (Figure 1) is protected by a levee and only connected to the river at mile 532, the model assumed that the water levels in the lake would be controlled by water levels at river mile 532. We assigned a river mile to each cell and assumed no lateral changes in water surface elevation within the cells. Each cell was attributed with the water elevation for each river mile as predicted by the UNET model. The use of a template to generate a water surface coverage is described in Wlosinski and Rogala (1996).

The water surface coverages representing the four water-level management conditions were used in the GIS to adjust a bathymetry coverage representing conditions with a water surface elevation of 583 feet. The original bathymetry coverage was generated by interpolation between depth soundings collected between 1989 and 1993. Using the GIS, areas dewatered and changes in water depths as a result of the 1-foot drawdown were determined by comparing bathymetry representing current management to bathymetry representing the drawdown conditions at 50,000 cfs. A similar comparison of current and drawdown conditions at 70,000 cfs estimated changes for the 2-foot drawdown. Bathymetry data did not cover areas that had persistent nonaquatic vegetation types present in 1989, as interpreted using aerial photographs. Therefore, water-depth changes in the areas that would be inundated at 50,000 and 70,000 cfs could not be predicted with the available data. These data gaps, however, cover only a small area in the impounded portion of the pool. Also, these areas are not covered by submergent vegetation types that would have benefitted by changes in water depth.

Results and Discussion

Success Rates

The permissible flow range at the Clinton gage required for a 1-foot drawdown is 50,000–110,000 cfs and for a 2-foot drawdown is 70,000–100,000 cfs. The lower flow values represent the minimum flow required to maintain a reliable navigation channel. The four possible problem areas that could limit a drawdown were near river miles 527.2, 528.5, 531.1, and 533.4. The higher flow values of the permissible range correspond to open river conditions for the two drawdown conditions.

For May 1 through August 15, discharges are between 50,000 and 110,000 cfs approximately 48% of the time and between 70,000 and 100,000 cfs approximately 22% of the time (Figure 2). The percentage of time when flow is within the ranges is somewhat smaller (40% and 18%, respectively) for the shorter time period, June 15 through August 15. This suggests that conditions suitable for a drawdown will occur infrequently, especially for the 2-foot drawdown and the shorter time period. However, the percentage of time within the required discharge ranges alone does not tell how often a drawdown of a given duration can occur.

A more informative measure of success is the chance, expressed as a success rate, of performing a drawdown of a given duration each year (Figure 3). On average, discharges will be in the required range for a 1-foot drawdown for 30 consecutive days between May 1 and August 15, 2 years out of 3. For the shorter time period, June 15 through August 15, the success rate is 1 year out of 3. With 30 consecutive days of required discharges occurring 1 year out of 7 for the longer time period, chances of a 2-foot drawdown are far less.

To conduct a drawdown of a given duration, several attempts may be necessary. The percentage of attempts successful was low, especially for a 2-foot drawdown (Figure 4). The percentage of attempts successful is important information when assessing the effects of drawdown regulations because it measures negative effects related to attempted drawdowns. One such negative effect would be greater than normal water-level fluctuations, especially at the dam. For example, 1-foot drops in water levels at the dam would occur an average more than 2 times per year to achieve a single 1-foot drawdown for 30 days. The percentage of attempts successful are much lower for a 2-foot drawdown, with an average of 10 2-foot fluctuations needed to achieve a single 2-foot drawdown for 30 days. The high percentage of failure while attempting a 2-foot drawdown, in combination with the infrequent potential for a 2-foot drawdown, suggests the 2-foot drawdown management alternative is less suitable than a 1-foot drawdown given the constraints in this study.

Predicted water surface elevations from the UNET model are included in Table 2 for the existing regulation, 1-foot drawdown, and 2-foot drawdown scenarios. The drawdown amount is presented in Table 3 and is shown for selected discharges in Figure 5. This drawdown amount is the difference between the water surface elevation at the existing regulation and each of the two drawdown schemes. Although the model predicted surface elevations for the entire pool, (river miles 522.5–556.7), we are only including predictions to river mile 535 because the drawdown amounts upriver of this area were considered insignificant (<0.25 foot change in water levels). The small drawdown amount is most likely because of the constriction of the river near Spring Lake that results in greater water surface elevation slope in this region. Table 2 shows that the effects of the drawdown decreases upriver and are negatively correlated to flow. This is significant when attempting to estimate the acreage of dewatered land because affected areas change as a function of discharge.

At higher flows, increases in computed (average) channel velocities are greatest immediately upriver of the dam. At lower flows (less than 50,000 cfs), the maximum velocity increase occurs at river mile 533.0, at the head of Big Cook Island. Although these average velocities generated from a one-dimensional hydrodynamic model provide some general information, velocities predicted from a two-dimensional model are needed to better assess the velocity effects of a drawdown.

Affected Areas

Discharges of 50,000 cfs for a 1-foot drawdown and 70,000 cfs for a 2-foot drawdown would result in the maximum amount of dewatering and loss of water depth. If the discharges are less than these amounts, the navigation channel could be maintained only if water levels at the dam were raised. Discharges greater than these amounts would cause higher water surface elevations at all points within the pool. Therefore, the total dewatered acreages predicted during the drawdown are estimates of maximum amounts. Fewer areas would be exposed during the drawdown periods because discharges above the 50,000 and 70,000 cfs conditions will certainly occur. Interpretation of the dewatered amounts should also consider that although a 2-foot drawdown will provide larger amounts of dewatering and loss of water depth, a 2-foot drawdown would be far less likely to occur under the constraints of this study. In contrast, the 1-foot drawdown could be achieved more frequently, but the magnitude of vertical exposure of sediments would be less.

In Table 4, the predicted amount of dewatered area and distribution of water depth (1-foot increments) for the four water-level conditions are presented by river mile. No areas upriver of river mile 533 were predicted to be dewatered, therefore predicted acreages are only presented to river mile 533. A maximum of about 440 acres would be dewatered with the 1-foot drawdown and about 530 acres with a 2-foot drawdown. Respectively for the 1- and 2-foot drawdowns, the dewatered acreage represents about 1.6% and 1.9% of the total surface area of normally aquatic areas of Pool 13 and about 3.1% and 4.5% of the total area of the impounded area below river mile 530. In general, dewatered acreage is greater near Dam 13 (Figure 6) because of the greater drawdown effect illustrated in Figure 5. Dewatered area near the dam was greater for the 2-foot drawdown, but the effect of the 2-foot drawdown does not extend upriver as far as does the effect of the 1-foot drawdown.

The effect of the drawdown is not solely a function of discharge and distance upriver of the dam. The amount of land dewatered at each river mile is also affected by shoreline slope and shoreline length. This is evident in lateral variability of dewatering across the river (Figure 7). For example, the large amount of dewatered area at river mile 532 for a 1-foot drawdown (Figure 6) is the result of exposure of shallow aquatic areas in Spring Lake. The presence of Spring Lake increases the shoreline length, and the lake has less slope than channel shorelines in adjacent areas, resulting in the increase in dewatered acreage at river mile 532.

Both the 1- and 2-foot drawdowns produced increased acreage of each 1-foot depth range less than 3 feet deep and a decrease in acreage of the deeper depth ranges (Figure 8). This is because of a peak at 3.6 feet in the distribution of water depths at low water conditions. Nonetheless, there is still a substantial increase in the cumulative acreage of areas less than 4 feet deep as a result of the drawdown (Figure 8). Change in acreage, both increase and decrease, of each depth range was greater for the 2-foot drawdown. The spatial changes in water depth are depicted as maps in Figures 9 and 10.

A somewhat different longitudinal pattern was predicted for increases of shallow water depths as compared to predictions of previously described dewatered areas near Dam 13. Predicted areas with water depths less than 1 foot increased only slightly for a 1-foot drawdown with a greater increase farther from the dam (Figure 11). A 2-foot drawdown produced a similar pattern, but with greater magnitude and a greater increase in area with depths less than 1 foot near the dam. The longitudinal slope of the water surface at this discharge is much less than the longitudinal slope of the bed elevation of shallow impounded areas and, therefore, changes in water surface elevation have more effect on water depth. This relation has a more pronounced effect on the 1- to 2-foot depth range. For this depth range, both drawdown conditions result in a large increase in acreage within the impounded area at river miles 526 and 527.

In contrast to the increases in acreage of shallow areas, the drawdown decreased acreage of areas deeper than 2 feet in the impounded area nearest the dam. Up to river mile 526, acreage of areas 2–4 feet deep increased as a result of drawdown, but acreage either decreased or was unchanged upriver in the impounded area (Figures 11 and 12). The drawdown also decreased the acreage of areas with 3–4 foot depths in most of the impounded area (Figure 12). We predicted less acreage of areas 4–5 feet deep for all river miles within the impounded portion of Pool 13.

As was found for dewatered areas, changes in water depth resulting from drawdown were different at river mile 532, which includes Spring Lake. Large increases in the area with depths less than 1 foot were predicted for both the 1- and 2-foot drawdown (Figure 11). Also, increased acreage was predicted for water depths up to 3 feet, as well as largely decreased acreage for depths greater than 3 feet.

Earlier, we described the success of the drawdown in terms of dewatered areas and reduced water depth (and the frequency at which these could be obtained), as well as having no effect on navigation. However, the ecological success, although not entirely predictable, can be estimated by conditions present in the affected areas. The sediment characteristics play a large role in the success of moist soil plant production, sediment oxidation and compaction, and submersed vegetation response to photic zone changes. In addition to sediment suitability, sediment types also provide an indication of hydraulic conditions and disturbance over a long time period (>10 years), which also affects ecological response.

Although detailed sediment data were not collected in the affected areas, we did limited sediment mapping in Pool 13 in 1996. According to the data collected, backwater lake sediments had higher moisture content than sediments in channels and the impounded area. Within the impounded areas, some areas sheltered from wind-generated waves had higher moisture sediments relative to the open areas of the impounded area and, conversely, shallow alluvial deposits near islands had very low (<30%) moisture sediments. Overall for the pool, we found most sediments to have low moisture content (<50%) and very few areas to have sediments with moisture content greater than 60%. Similar patterns were found in a study of Pools 4 and 8 (Rogala 1996).

The sediment distribution patterns described earlier suggest what type of sediments would be exposed. Three predicted dewatered areas that would likely contain high moisture sediments (>50% moisture) are Thomson Slough, Gomer's Lake, and Spring Lake (Figure 1). These areas of high moisture sediments total about 120 acres for the 1-foot drawdown and 170 acres for the 2-foot drawdown. Several areas predicted to be dewatered would result in exposure of low moisture sediments (<30% moisture); most of which were shallow areas adjacent to remnant islands around river miles 527 to 529. Areas of exposed low moisture sediments total about 65 acres for both the 1- and 2-foot drawdowns. Although moist soil plant response to exposure of low versus high moisture sediments is varied, the sediment oxidation and compaction would certainly be less on the low moisture sediments. Therefore, dewatered acreage that would provide for sediment oxidation and compaction would be only a fraction of the predicted dewatered acreage.

Those areas only slightly dewatered will likely retain water through capillary action and remain moist, thereby reducing impacts on the sediment characteristics. This is important when assessing the advantages of a 1-foot drawdown compared to 2-foot drawdown. The 2-foot drawdown, although occurring less frequently, would provide for greater drying of sediments in the areas nearest the dam, which includes Thomson Slough and Gomer's Lake. Most of the sediment exposed during a 1-foot drawdown would remain moist for the duration of the drawdown.

The effects of reduced water depth on the photic zone for submersed plants should be positive and the acreage of reduced water depths appears substantial (Figure 8). However, the reduced water depths may have additional impacts in the form of disturbances in the water column. For example, the impounded area where most of the reduction in water depth is predicted has measurable velocity at current conditions. These velocities may increase as a result of reduced cross sectional area and increased water surface slope during drawdown. Also, the impounded area is a large expanse of water subject to wind wave action. The narrow band of dewatered area would not reduce fetch values greatly, but the areas susceptible to the wave disturbances would increase because of reduced water depths. Resuspension of sediments may be greater if the shallow depths do not reduce wave energy and impede wave propagation.

Biotic response to the predicted physical changes is far less predictable. The short-term effects of dewatering on highly mobile aquatic biota such as fish (e.g. stranding) is expected to be less than for biota incapable of retreating with the dewatering. However, areas that do not dewater from the shoreline outward may more likely strand fish. The drawdown conditions we investigated show little area that may strand fish by formation of pockets of water. In addition, the rather narrow band that is dewatered (generally <250 feet) would not require movement over long distances to avoid stranding. With a larger drawdown, areas such as Thompson Slough may likely dewater in a manner that would strand fish. Fish eggs laid just prior to attempted drawdowns would probably become non-viable in the dewatered zone, but that likelihood would be reduced during the shorter period of June 15–August 15.

Positive effects from a drawdown have been suggested by data collected in Pools 24 and 25 and Melvin Price Pool. In these pools, the number and diversity of young-of-the-year fish were similar between 1986 and 1993, when no drawdown occurred, as compared to 1994 through 1996, when water levels were held lower than in earlier years (Butch Atwood, Illinois Department of Natural Resources, personal communication).

Opinions differ concerning drawdown effects on invertebrates. In a literature search by Wlosinski and Koljord (1996), factors found to affect invertebrate populations during a drawdown included season, duration, vertical drop in water levels, species, vegetation, and sediment type. Becker et al. (1981) mentioned that invertebrate losses in shoreline zones because of drawdowns may be of little importance to overall ecosystem dynamics. Fredrickson and Reid (1988) suggest that management for specific plant communities may be the most practical way of increasing invertebrate production. Although information concerning invertebrate populations in the predicted drawdown areas are not available, we compared average invertebrate numbers in Pool 13 samples taken at depths greater than 1 foot to samples taken at depths less than 1 foot (Table 5). Based on a small sample size in the near shore regions, average density in shallower areas were less for mayflies and fingernail clams, but greater for midges.

The effects of a drawdown on native mussels in Pool 13 will also depend on many variables. As the water is lowered, some mussels will move to deeper water whereas some will burrow into the substrate. The mussels that bury themselves will be subjected to low moisture, elevated temperatures, and predation. The mussels in dewatered areas that survive will be stressed. Mussels in shallow, but not exposed areas, will be more vulnerable to predation. High mussel mortality has been observed in the Tennessee River System during periodic drawdowns (Steve Ahlstedt, U.S. Geological Survey, personal communication). Some mussel species appear to be more susceptible than others.

The effects of a drawdown on aquatic and emergent vegetation have been documented on many aquatic systems. The U.S. Fish and Wildlife Service routinely manipulates water levels to enhance moist-soil plant production (Fredrickson 1991). The St. Louis District of the U.S. Army Corps of Engineers has held water levels 1–2 feet lower than historical levels in Pools 24 and 25 and the Melvin Price Pool for at least 30 days. Between 255 and 881 acres of preferred plants were found near the shoreline during the drawdown years as compared to little acreage of the preferred plants in Pool 22, which was not drawn down. The preferred species responding to the drawdown include *Polygonum* spp. (Smartweed), *Cyperus* spp. (Chufa), *Echinochloa* spp. (Wild Millet), *Amaranthus* spp. (Pigweed), *Setaria* spp. (Yellow Foxtail), *Panicum*, and *Leersia* (Rice Cutgrass). However, these pools are about 300 miles south of Pool 13 and water levels in those pools have been managed differently than in Pool 13. At Small Bay West in Pool 5, a drawdown with similar duration and magnitude to that proposed for Pool 13 was conducted. Minnesota Department of Natural Resources personnel found that the number of plant taxa increased from 22 to 42 species and the acreage of vegetation increased following this drawdown.

In a system as complex as a large impounded floodplain river, ecological effects of a drawdown are unpredictable. However, the information provided here suggests some effects from a drawdown in Pool 13. The monitoring of components of the ecosystem before and after a drawdown may provide valuable information on the effects of the drawdown. That information, with the use of models, could be used to better predict drawdown effects. Nevertheless, spatial and temporal variability in the river system would prohibit highly accurate predictions of ecological effects of a drawdown.

The physical effects we estimated are within the constraints currently established for potential drawdown management. The effects could be much greater if some constraints were less strict. For example, nearly twice the dewatered area (1,071 compared to 530 acres) could be attained with a 2-foot drawdown at 50,000 cfs. This drawdown would require lowering the minimum channel depth to less than 10.5 feet in a limited number of areas. Failure to obtain ecological benefits, as measured during drawdowns occurring under current drawdown options, should lead to investigating the potential for altering constraints in the future.

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Table 1. Definitions of terms used in this report.

Term	Definition
Attributed	The process of defining information about specific parts of a geographic information system (GIS) map or coverage
Bathymetric data	The water depth at a particular location in the river for a specific water-level elevation
Control point	A specific location in a pool where the U.S. Army Corps of Engineers maintains a target water level over a range of discharges
Coverage	A geographical data set containing attributes for discrete point, line, and/or polygon features in a vector data set or cell values for raster data sets
Drawdown	Water levels that are managed below the project pool elevation
GIS	An organized collection of computer hardware, software, geographic data, and personnel adapted to efficiently capture, store, update, analyze, and display all forms of geographic information
Hydrologic model	As used in this report, a mathematical model that predicts water-level elevations from upriver to downriver using bottom geometry, gate elevation settings at the downstream dam, and discharge data
Impounded area	The area of the pool immediately upriver of the dam with little change in water surface elevations; in Pool 13 this area is between the dam and river mile 530
Maximum drawdown	The maximum drop in water levels at the headwater, below the project pool elevation, which would still allow a 9-foot navigation channel
Open river	The condition when all of the movable gates at a dam are raised out of the water and the headwater and tailwater elevations are nearly equal
Overlay	A GIS process which operates on two or more data sets based on their geographic location, types of operations include combining attributes of different coverages and performing mathematical functions based on attributes of multiple coverages
Pool	The body of water created upriver of a dam
Project pool elevation	The water-level elevation needed to maintain a 9-foot channel at zero discharge and for which each dam was designed
Vector	A GIS data structure that represents map features as a list of ordered *x,y* coordinates

Table 2. Predicted water surface elevations (feet above sea level) from the UNET model.

Drawdown	Discharge (cfs)	River mile							
		522.5	523	525	527	529	531	533	535
Existing regulation	50,000	583.00	583.04	583.23	583.37	583.52	583.68	584.33	585.36
	60,000	583.00	583.06	583.32	583.50	583.71	583.91	584.70	585.90
	70,000	583.00	583.08	583.43	583.66	583.92	584.17	585.06	586.42
	80,000	583.00	583.10	583.54	583.82	584.13	584.42	585.43	586.90
	90,000	583.00	583.13	583.66	583.99	584.35	584.68	585.78	587.36
	100,000	583.00	583.16	583.79	584.17	584.56	584.93	586.13	587.79
	110,000	583.00	583.19	583.93	584.35	584.77	585.19	586.45	588.20
1-foot	50,000	582.00	582.07	582.38	582.61	582.86	583.06	583.89	585.13
	60,000	582.00	582.10	582.53	582.82	583.12	583.37	584.34	585.72
	70,000	582.00	582.13	582.68	583.03	583.38	583.69	584.77	586.27
	80,000	582.00	582.17	582.84	583.25	583.65	584.01	585.18	586.79
	90,000	582.00	582.21	583.01	583.47	583.92	584.32	585.56	587.25
	100,000	582.00	582.26	583.19	583.69	584.18	584.61	585.94	587.71
	110,000	582.00	582.31	583.36	583.91	584.44	584.90	586.29	588.12
2-foot	70,000	581.00	581.20	582.06	582.58	583.03	583.38	584.60	586.19
	80,000	581.00	581.26	582.29	582.85	583.34	583.74	585.03	586.72
	90,000	581.00	581.33	582.51	583.11	583.64	584.09	585.43	587.20
	100,000	581.00	581.39	582.71	583.34	583.92	584.40	585.81	587.65

Table 3. Drawdown amounts (feet) predicted by the UNET model at various river miles when water levels at Dam 13 are held at 582 feet (1-foot drawdown) and 581 feet (2-foot drawdown).

Drawdown	Discharge (cfs)	River mile							
		522.5	523	525	527	529	531	533	535
1-foot	50,000	1.00	0.97	0.85	0.75	0.67	0.62	0.43	0.23
	60,000	1.00	0.96	0.80	0.69	0.60	0.54	0.35	0.18
	70,000	1.00	0.95	0.75	0.63	0.54	0.48	0.30	0.15
	80,000	1.00	0.93	0.70	0.57	0.48	0.42	0.25	0.12
	90,000	1.00	0.91	0.65	0.53	0.43	0.36	0.22	0.11
	100,000	1.00	0.90	0.61	0.48	0.38	0.32	0.19	0.08
	110,000	1.00	0.88	0.57	0.44	0.34	0.28	0.17	0.07
2-foot	70,000	2.00	1.88	1.37	1.08	0.89	0.79	0.46	0.23
	80,000	2.00	1.84	1.25	0.97	0.79	0.68	0.40	0.18
	90,000	2.00	1.80	1.15	0.88	0.71	0.59	0.35	0.16
	100,000	2.00	1.77	1.08	0.83	0.64	0.53	0.32	0.14

Table 4. Area (acres) dewatered and within 1-foot depth increments at various river miles when water levels are held at the four conditions at Lock and Dam 13.

River mile	Depth (feet)	Acreage at each management condition			
		583 feet @50,000 cfs	583 feet @70,000 cfs	582 feet @50,000 cfs	581 feet @70,000 cfs
523	Dewatered	11	12	62	133
	0	51	52	84	239
	1	84	86	257	197
	2	257	263	182	231
	3	182	177	243	225
	4	243	237	209	93
	5	541	541	332	250
524	Dewatered	0	0	93	146
	0	102	96	91	95
	1	88	92	143	137
	2	149	144	389	547
	3	433	421	403	367
	4	390	381	303	227
	5	677	705	417	319
525	Dewatered	0	0	45	70
	0	57	50	87	84
	1	82	84	68	85
	2	76	70	260	616
	3	412	308	733	558
	4	683	718	337	159
	5	465	545	245	203
526	Dewatered	0	0	47	60
	0	62	45	75	79
	1	77	75	457	499
	2	514	422	477	513
	3	498	493	395	335
	4	342	397	128	105
	5	373	434	289	275
527	Dewatered	0	0	61	77
	0	101	69	140	148
	1	199	138	693	747
	2	803	714	543	500
	3	413	525	265	256
	4	257	265	163	145
	5	407	469	315	306

Table 4. Continued.

River mile	Depth (feet)	Acreage at each management condition 583 feet @50,000 cfs	583 feet @70,000 cfs	582 feet @50,000 cfs	581 feet @70,000 cfs
528	Dewatered	0	0	30	30
	0	67	32	120	120
	1	172	117	265	265
	2	252	265	228	228
	3	228	228	211	211
	4	167	211	68	68
	5	241	273	205	205
529	Dewatered	0	0	18	12
	0	34	18	74	58
	1	80	72	164	151
	2	216	158	271	270
	3	256	272	157	182
	4	134	165	85	88
	5	370	405	320	329
530	Dewatered	0	0	7	2
	0	20	7	42	31
	1	48	33	71	56
	2	88	60	108	113
	3	105	114	95	94
	4	95	98	72	87
	5	291	335	252	264
531	Dewatered	0	0	16	0
	0	53	12	128	105
	1	156	121	116	132
	2	119	121	144	127
	3	136	142	120	136
	4	92	123	67	74
	5	314	352	279	295
532	Dewatered	0	0	64	0
	0	217	0	385	229
	1	441	358	558	430
	2	673	517	950	701
	3	956	817	571	928
	4	306	773	124	310
	5	433	562	376	428
533	1	20	14	24	24
	2	18	20	17	17
	3	14	15	14	14
	4	19	14	20	20
	5	322	330	318	318

Table 5. Average invertebrate numbers (per m^2) in Pool 13 between 1992 and 1997.[a]

Invertebrate species	Samples less than 1 foot deep		Samples greater than 1 foot deep	
	Mean	**Sample size**	**Mean**	**Sample size**
Mayflies	48	8	177	750
Fingernail clams	17	8	707	750
Midges	234	6	141	627

[a]Data collected by the Long Term Resource Monitoring Program.

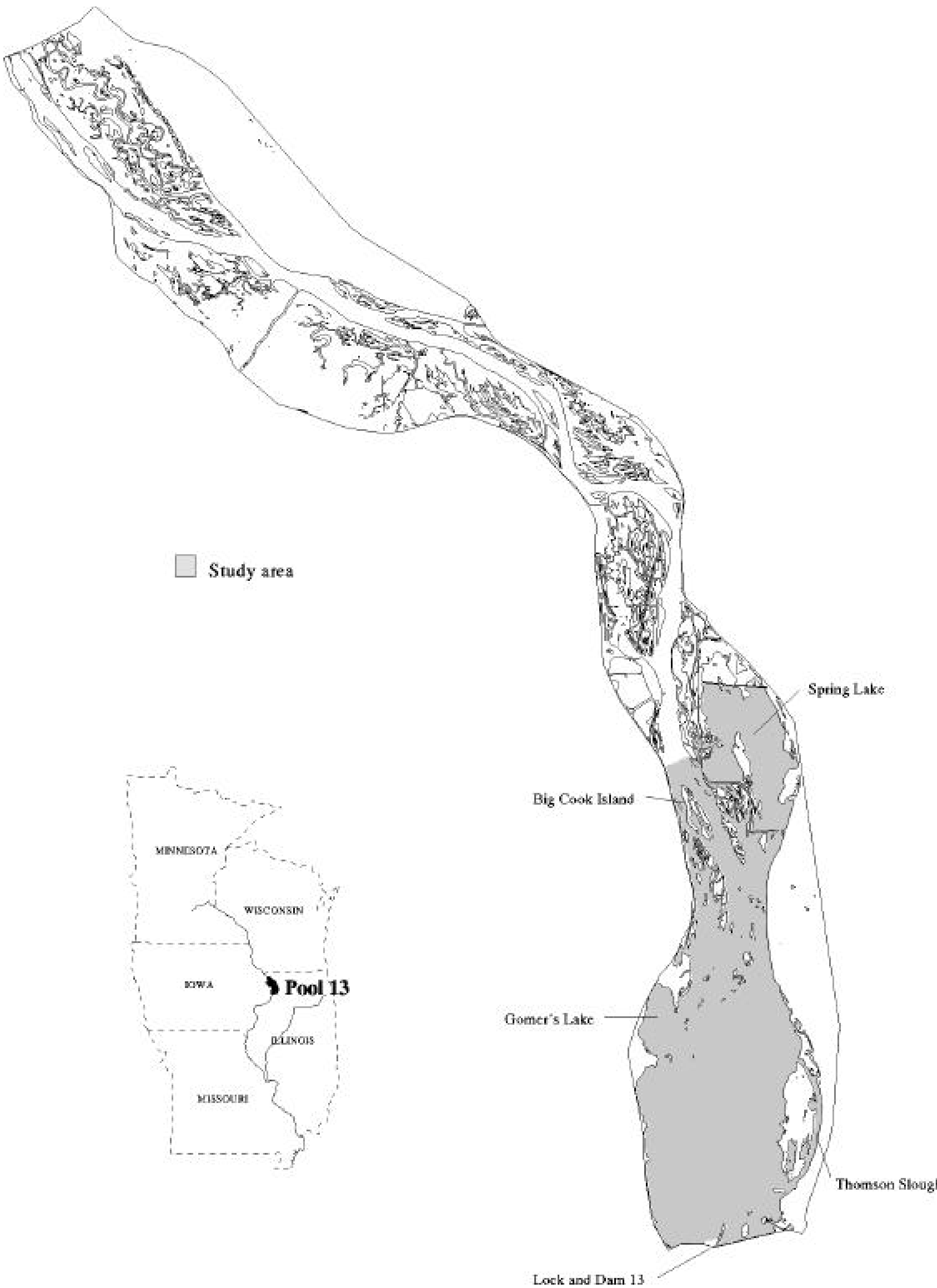


Figure 1. Detail map of Pool 13. Inset: Map of the Upper Mississippi River System and the relative position of Pool 13.

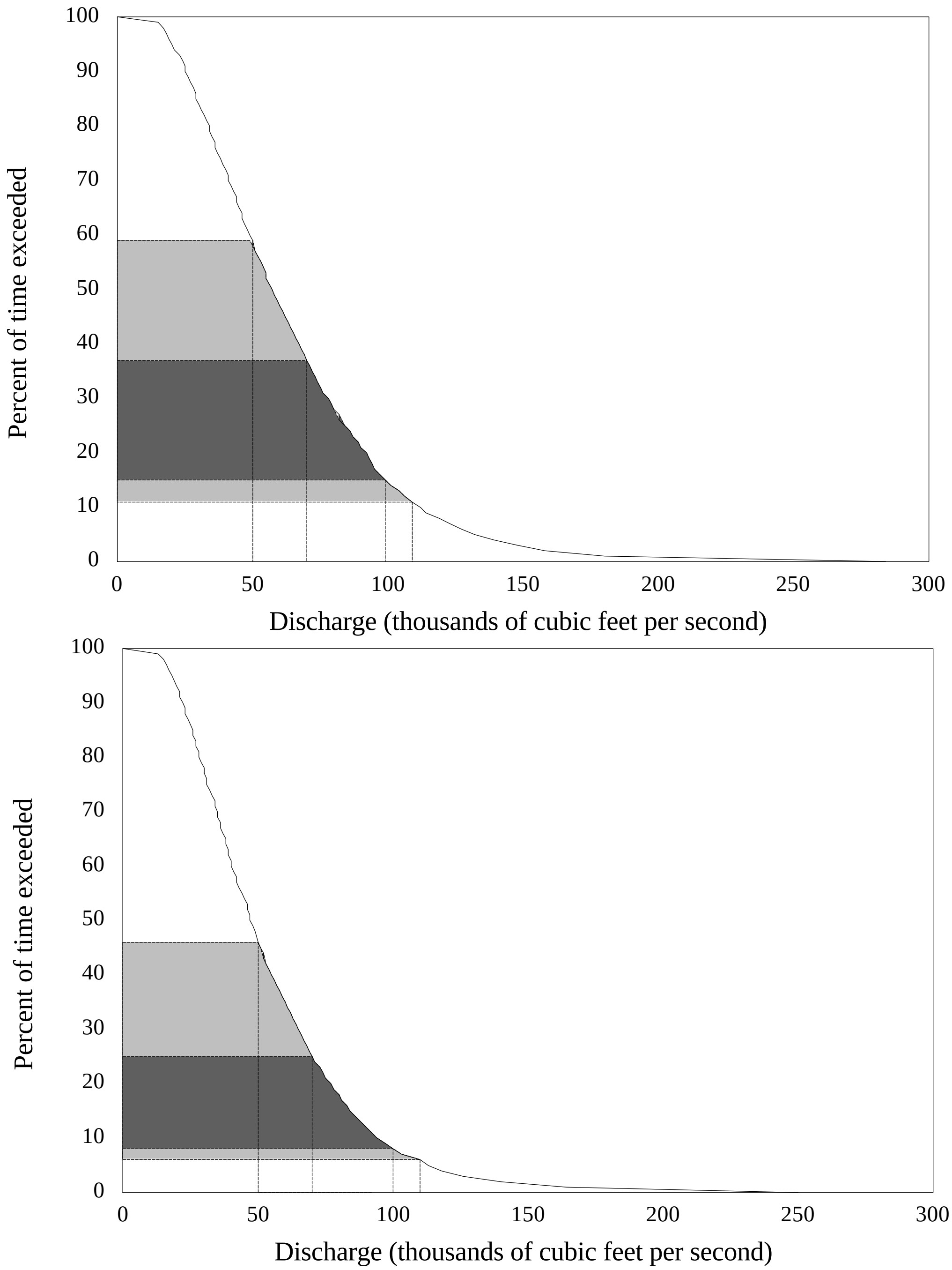


Figure 2. Percentage of time discharge was exceeded for Clinton, Iowa, between May 1 and August 15 (upper) and June 15 and August 15 (lower), based on daily values collected from 1873 to 1996. The hatched area represents frequency of discharge needed for a 2-foot drawdown and the shaded plus the hatched area represents frequency of discharge needed for a 1-foot drawdown.

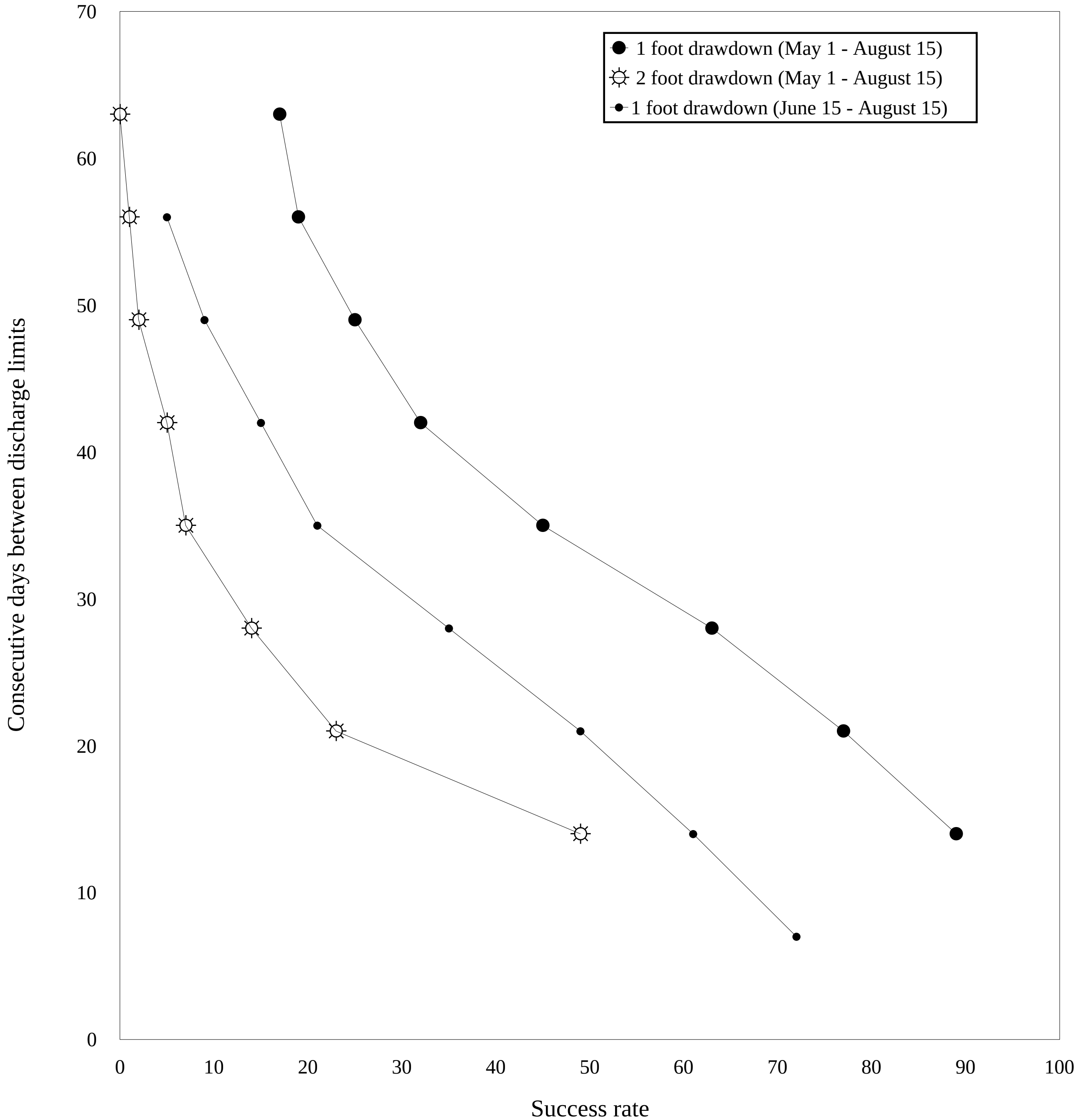


Figure 3. Estimated success rates for a 1- or 2-foot drawdown between May 1 and August 15 or a 1-foot drawdown between June 15 and August 15 for Pool 13 based on the annual occurrence of discharge for the required number of consecutive days.

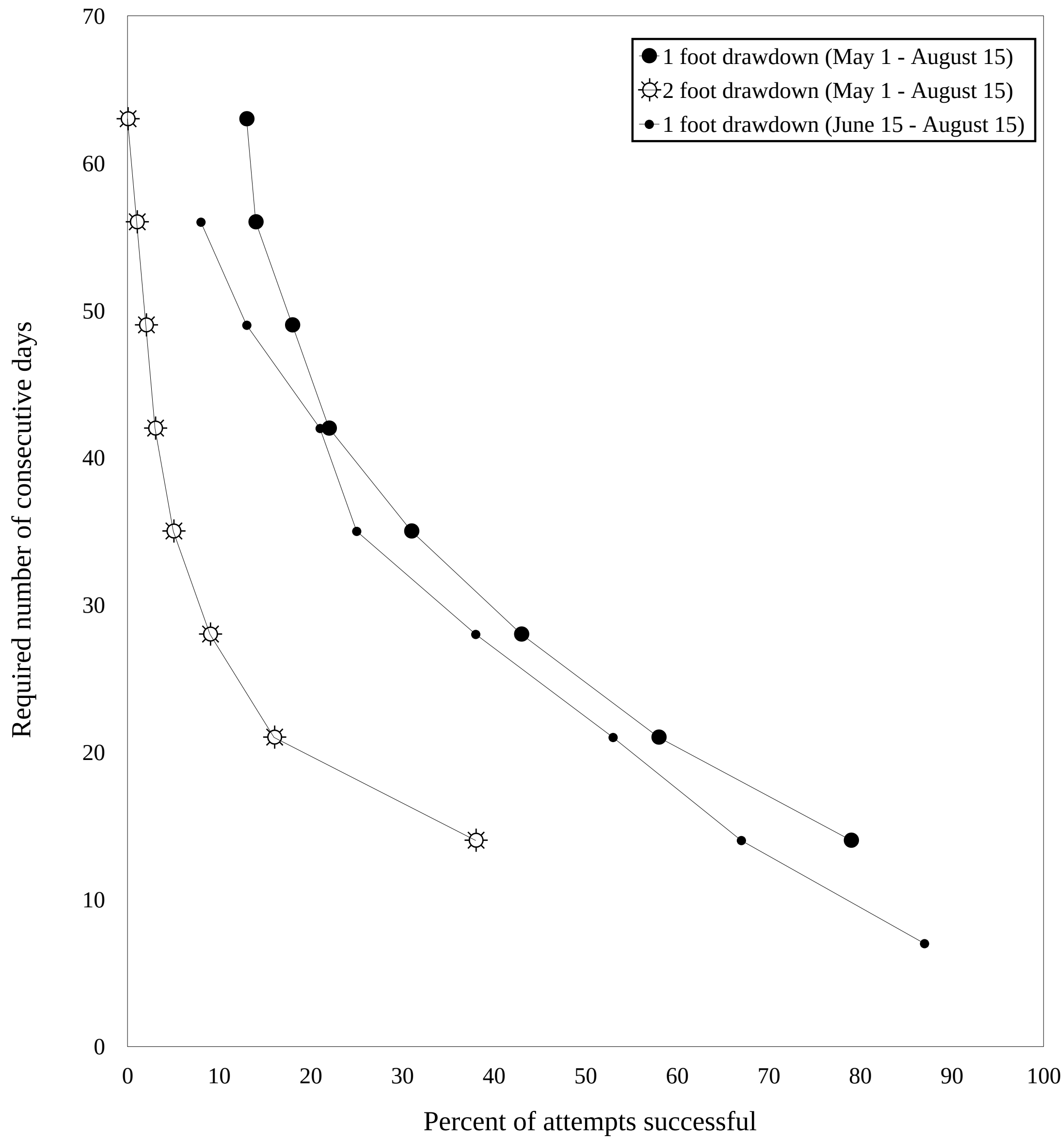


Figure 4. Percentage of drawdown attempts successful for Pool 13 based on the required number of consecutive days for the periods between May 1 and August 15 for a 1- or 2-foot drawdown or between June 15 and August 15 for a 1-foot drawdown.

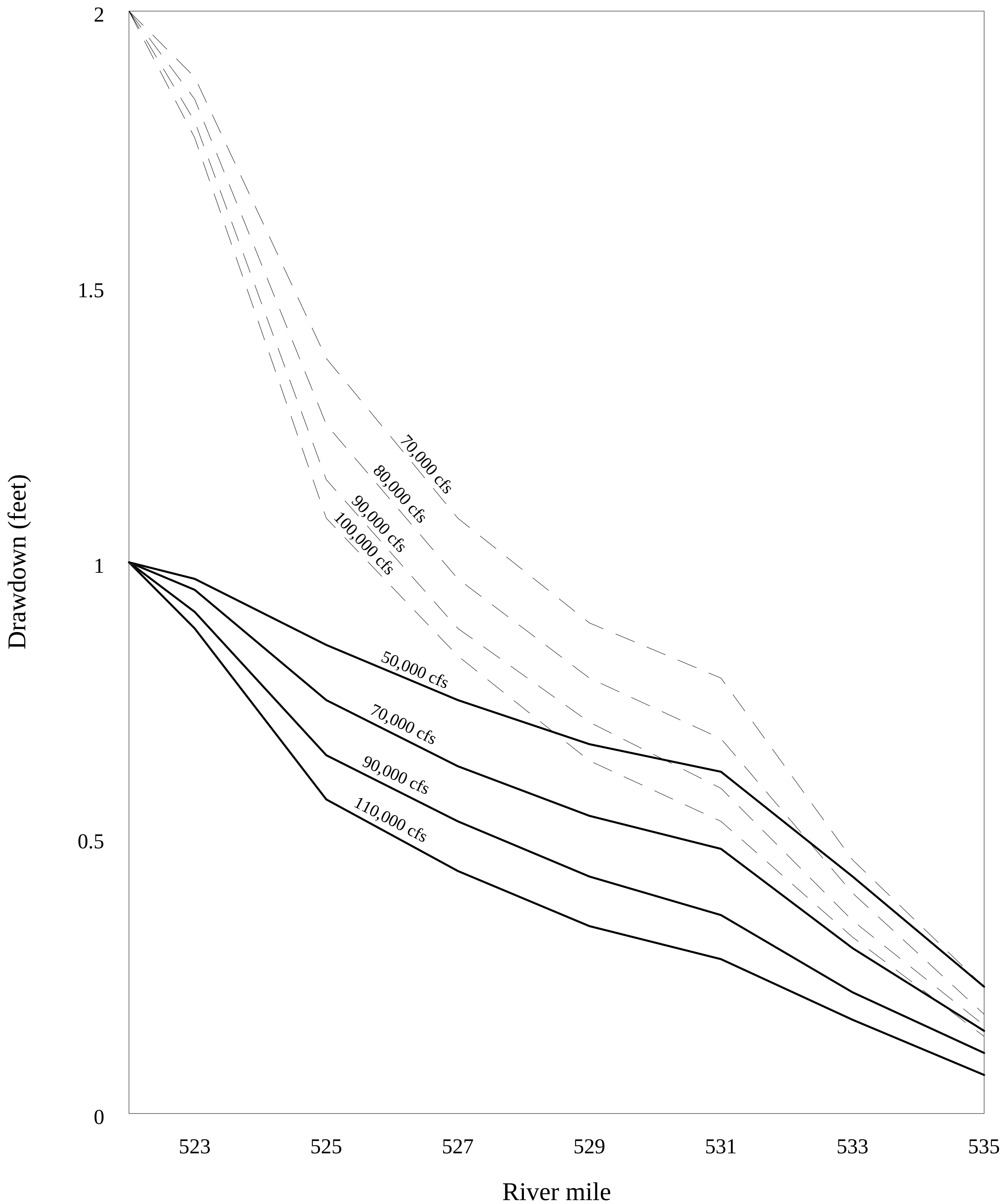


Figure 5. Drawdown amounts (feet) by river mile when water surface elevations are held at 1 foot (solid line) and 2 feet (dashed line) lower at Dam 13 for the discharge range required for the drawdown.

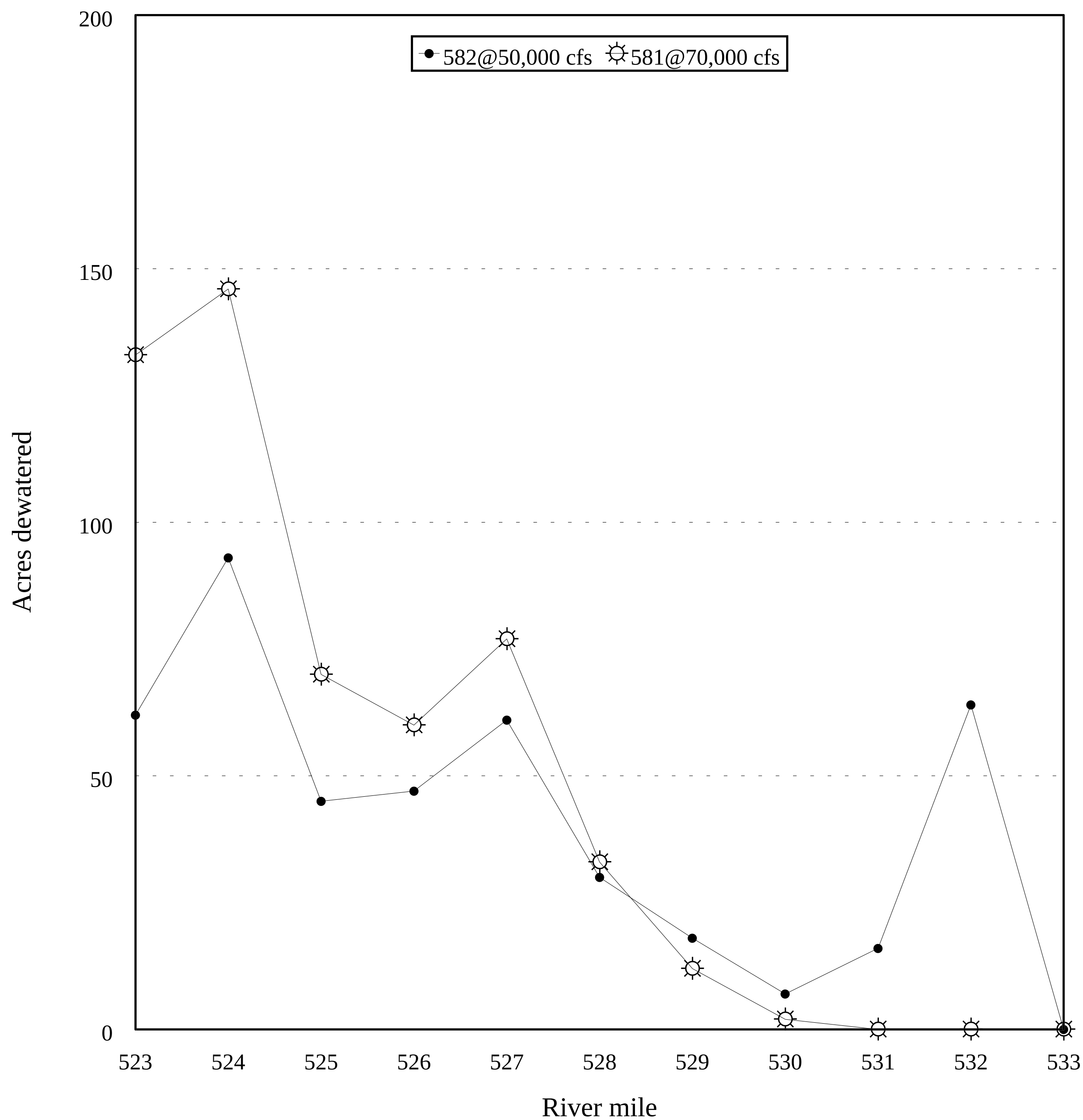


Figure 6. Acreage dewatered at 50,000 cfs for a 1-foot drawdown (582 feet above sea level at the dam) and at 70,000 cfs for a 2-foot drawdown (581 feet above sea level at the dam) in Pool 13.

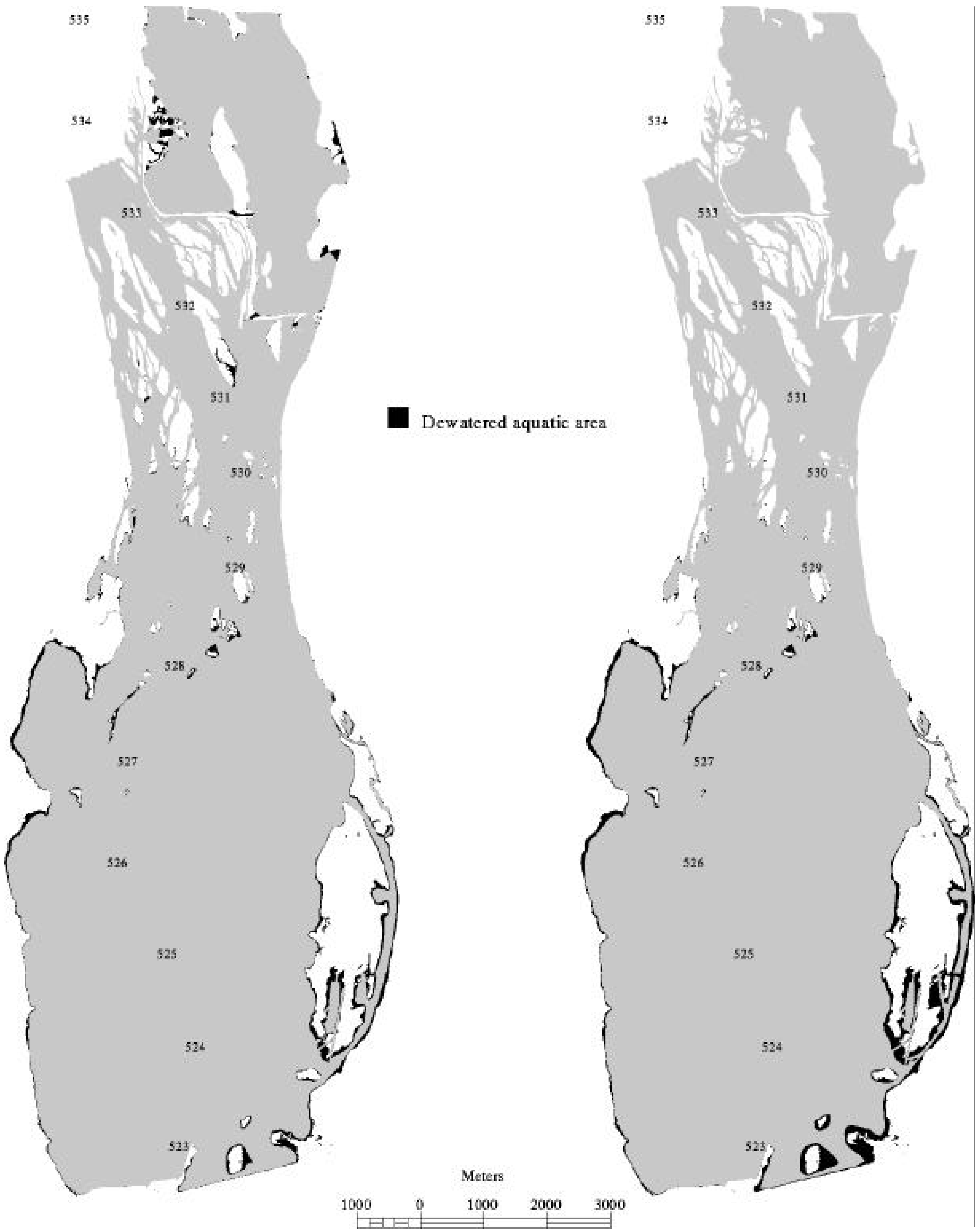
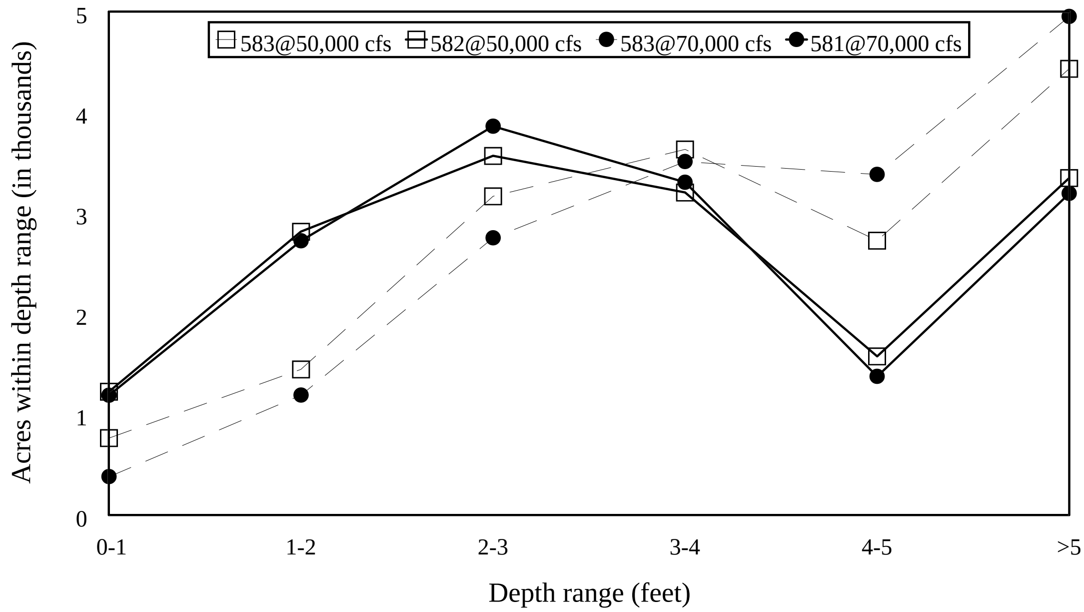


Figure 7. Maps of Pool 13 depicting areas dewatered from a 1-foot drawdown at 50,000 cfs (left) and 2-foot drawdown at 70,000 cfs (right).



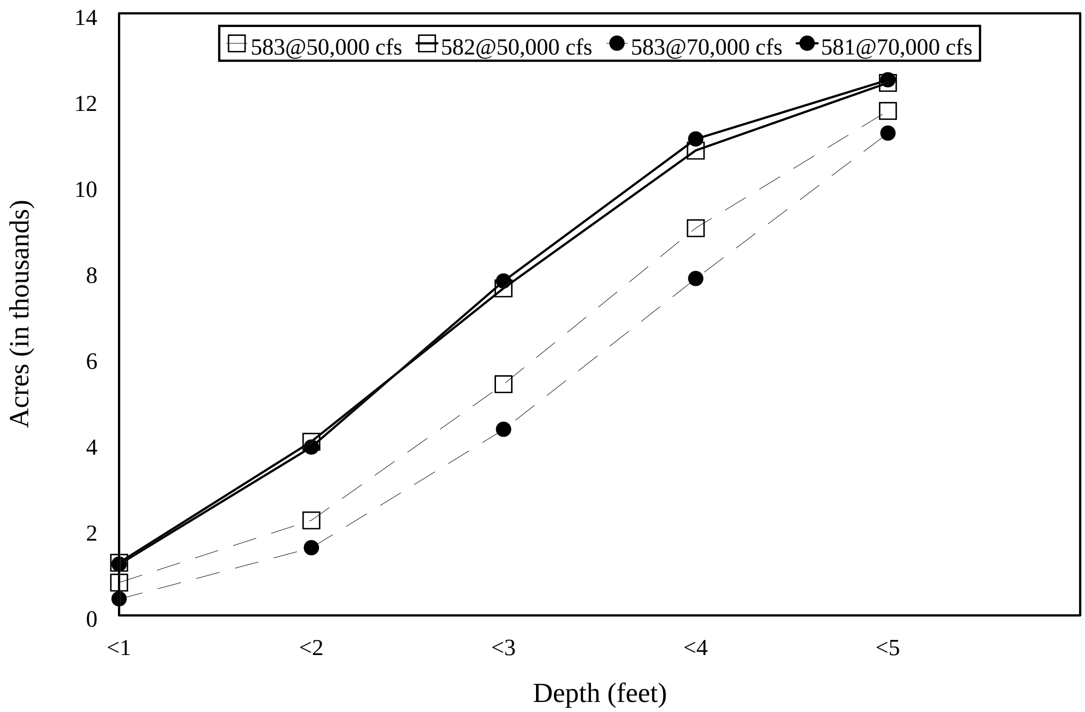


Figure 8. Acreage (upper) and cumulative acreage (lower) within each 1-foot water-depth range for 583-foot elevation at 50,000 and 70,000 cfs, 582-foot elevation at 50,000 cfs, and 581-foot elevation at 70,000 cfs.

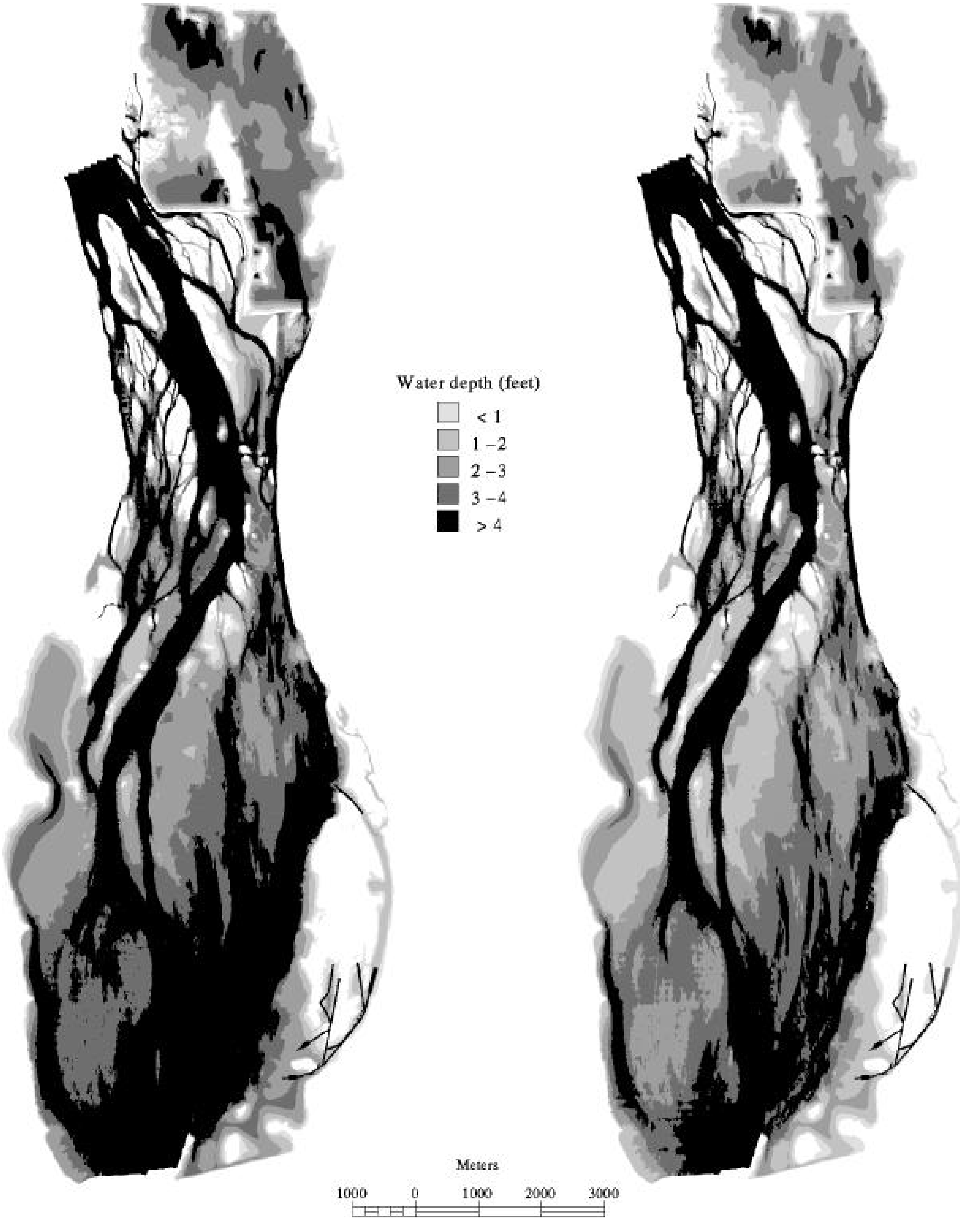


Figure 9. Maps of water depth, at 50,000 cfs, for the study area of Pool 13 when water levels at the dam are held at 583 feet (left) and 582 feet (right) above sea level.

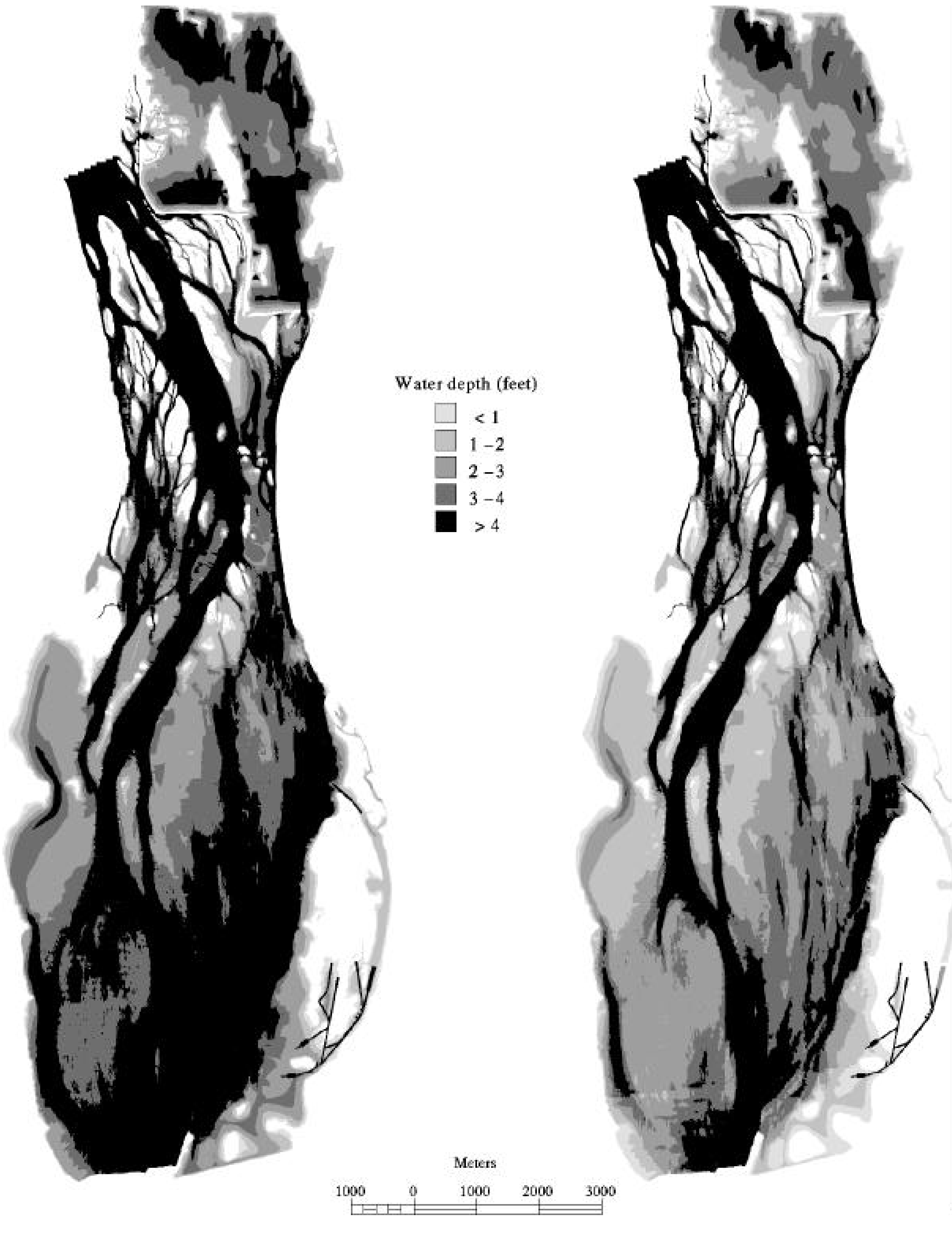


Figure 10. Maps of water depth, at 70,000 cfs, for the study area of Pool 13 when water levels at the dam are held at 583 feet (left) and 581 feet (right) above sea level.

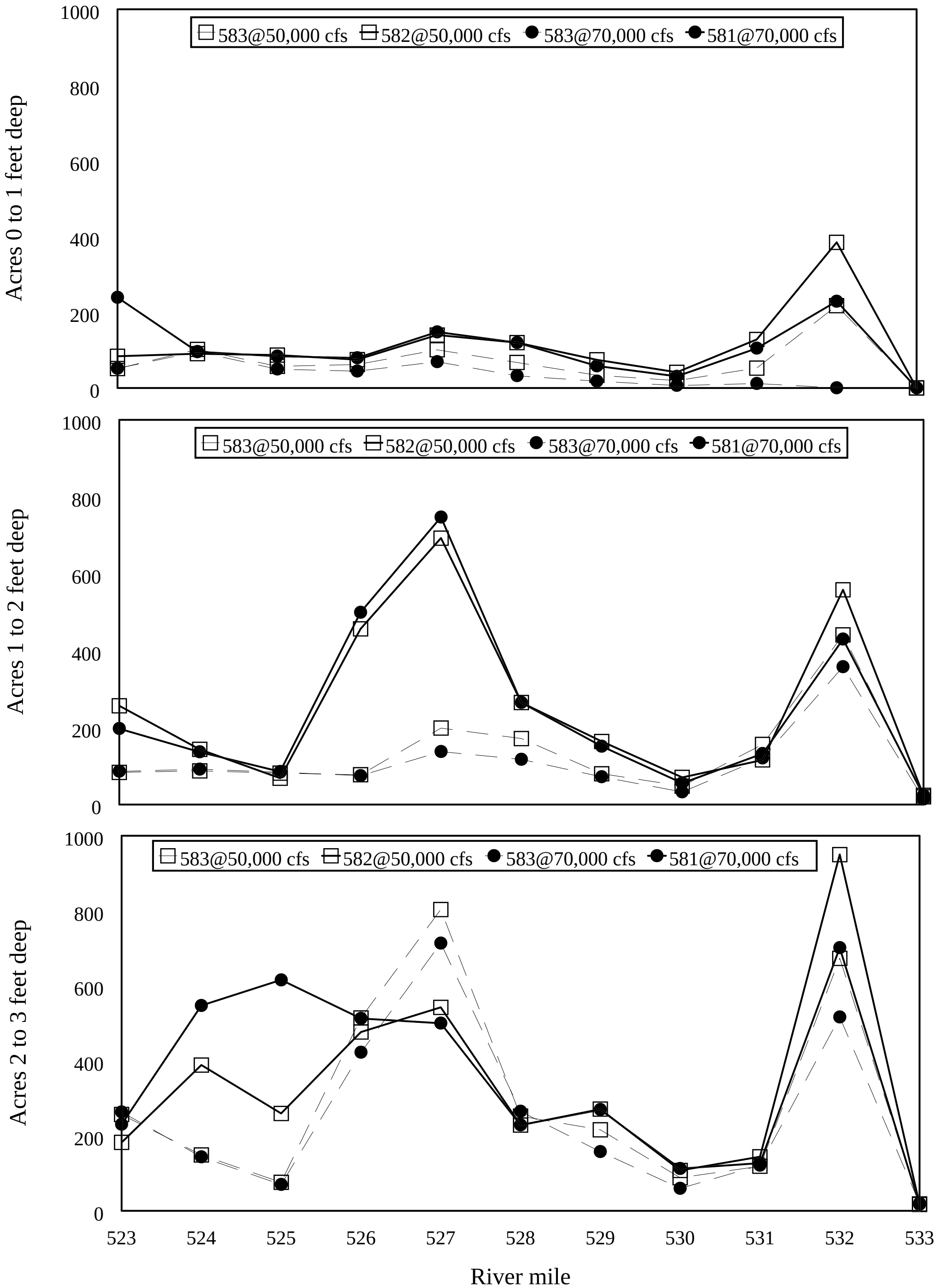


Figure 11. Acreage, by river mile, of areas with water depths between 0–1 feet (top), 1–2 feet (middle), and 2–3 feet (bottom) for each of the four conditions.

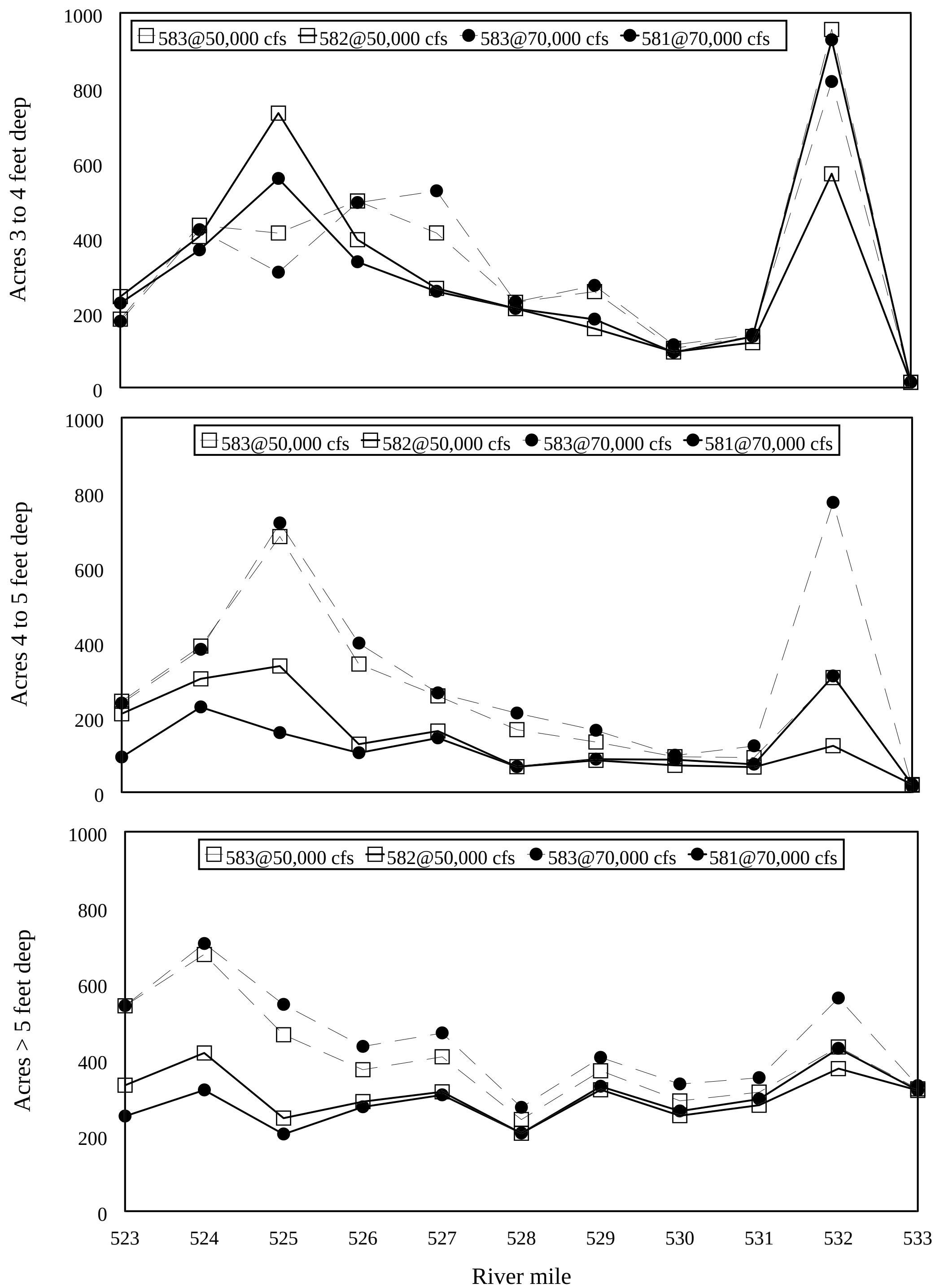


Figure 12. Acreage, by river mile, of areas with water depths between 3–4 feet (top), 4–5 feet (middle), and greater than 5 feet (bottom) for each of the four conditions.

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13. ABSTRACT (Maximum 200 words) The likelihood of 1- or 2-foot drawdowns, and the area affected by such alternative drawdowns, was estimated for Pool 13 on the Upper Mississippi River. Minimum water surface (elevation) requirements were compared to computed water surface profiles to determine a critical low flow that would allow a navigation channel 400 feet wide and 10.5 feet deep. An upper limit on flow was established based on the flow at which open river conditions would exist for a given drawdown. The range in flows that would allow for a drawdown was used to estimate success rates using historical daily discharge data. Success rates were determined for a variety of drawdown durations between two time periods, May 1–August 15 and June 15–August 15. The greatest effect of the drawdown would be near Lock and Dam 13. Higher discharges, as well as distance from the dam, lessen the drawdown amount. Areas that would be affected by these two drawdown scenarios were predicted by overlaying maps of water surfaces with depths using a geographic information system. Although the drawdown effects on most physical and biotic components of Pool 13 are unknown, some general drawdown effects likely to occur because of the changes in water surface elevation are presented.			
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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.