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Kaskaskia Regional Water Supply Planning: Projected Water Needs from Lake Shelbyville and Carlyle Lake During Extreme Drought Conditions

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ABSTRACT

Within the Kaskaskia River watershed are two large federally owned reservoirs, Lake Shelbyville and Carlyle Lake, which are two of the three largest reservoirs in Illinois. By way of contracts with the federal government, in 1983 the State of Illinois was allocated roughly 14 percent of the joint-use storages in Lake Shelbyville and Carlyle Lake for water supply. The combined designated water supply storage (57,406 acre-feet) is estimated to produce an annual average yield of 42 million gallons per day (mgd) during a calculated 50-year drought condition (excluding 5 mgd used to support minimum water quality releases from the reservoirs). The Illinois Department of Natural Resources (IDNR), which administers the rights to the water supply storage, has sub-allocated that yield to a total of nine entities, with five (three electricity-generating plants and two regional water supply systems) accounting for roughly 99 percent of the total allocation. Four of the five major entities do not directly withdraw water from the reservoirs but instead have intakes in the Kaskaskia River downstream of the reservoirs and when needed must request supplemental reservoir releases from upstream to augment the river's flow at their intakes. The allocation contracts between IDNR and the five major water users were executed in 2000–2004. Each allocation has a 40-year contract period, after which it must be reviewed and renegotiated. As of 2017, the region's droughts have not yet had sufficient severity to result in the use of reservoir releases.

This study simulates the use of the state's designated water supply storage under observed historical drought condition sequences rather than the hypothetical 50-year drought which is statistically based. Water budget modeling of the two reservoirs (and the downstream flow conditions at each intake), using measured hydrologic and climatic records from historical droughts as input, provides a more thorough understanding of how often the major water supply allocation holders would need to request reservoir releases during such droughts. This in turn leads to a better analysis of the performance of the reservoirs' water supply during droughts. Particular emphasis in this study is given to the water supply adequacy during conditions represented by the 1953–1955 drought, the worst drought on record and estimated to have a recurrence interval of approximately 100 years or greater.

The water budget simulations assume that each major allocation holder will operate at its full capacity, thus maximizing the release and withdrawal from the reservoirs' water supply storage. However, there are two external factors that also can influence reservoir releases: 1) water needs at the Kaskaskia Lock, which controls commercial navigation between the Kaskaskia and Mississippi Rivers, and 2) the amount of the summer water quality release from each reservoir needed to maintain acceptable water quality in the river downstream. These factors particularly influence the water needs of two power plants, the Dynegy-Baldwin Power Station and the Prairie State Energy Campus, located downstream of Carlyle Lake that have direct withdrawals from the Kaskaskia Navigation Channel.

The results indicate that the State of Illinois' combined water supply storage in Lake Shelbyville and Carlyle Lake is not only likely to be sufficient to meet the needs of all allocation holders during an extreme (1953–1955) drought condition, but there is also a greater likelihood that a sizeable portion of the water supply storage will remain unused during such an extreme event. Even if unused, however, it is not clear that additional allocations could be made given the

current manner in which water is allocated by IDNR (and accounted by the U.S. Army Corps of Engineers) based on each user's maximum annual use. But the finding generally bodes well regarding the future availability of water leading up to the 2040s when the existing allocation contracts come up for review.

The only future scenario in which the state's water supply storage would not be sufficient during an extreme drought involves an unlikely combination of several factors, the greatest of which is a substantial increase in commercial navigation through the Kaskaskia Lock (to nearly 10 million tons per year); this in turn would likely require a ten-fold increase or greater in the exportation of locally mined coal to outside markets. In contrast, the exportation of coal has generally been declining since the late 1980s.

ACKNOWLEDGMENTS

This study was initiated as part of the State of Illinois' regional water supply planning process for the Kaskaskia River region, conducted from 2009 to 2013. The study was originally funded by the Illinois Department of Natural Resources (IDNR), Office of Water Resources, with results submitted to IDNR in a 2013 Final Report to the Sponsor. Additional support was also provided by the Illinois State Water Survey (ISWS), a division of the Prairie Research Institute at the University of Illinois, including the later expansion of the original study to analyze and present information relative to 1) expected water levels in the federal reservoirs during extreme drought periods, and 2) the potential effects of navigation releases on the availability of water supply. Lisa Sheppard of the ISWS edited the report, and Gary R. Clark (IDNR, retired) and Jason Zhang (ISWS) provided technical review. Any opinions, findings, conclusions, or recommendations expressed in this report are those of the author and do not necessarily reflect those of the sponsor, the Illinois State Water Survey, or the Prairie Research Institute.

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1. INTRODUCTION

In 2009, the Illinois Department of Natural Resources' (IDNR) Office of Water Resources designated the Kaskaskia River region for a regional water supply planning effort and provided funding for a group of stakeholders, the Kaskaskia Basin Water Supply Planning Committee (KBWSPC), to develop a comprehensive water supply plan for the region. The IDNR and the Illinois Department of Commerce and Economic Opportunity (DCEO) also funded a series of technical studies to identify potential water demand and availability in the region through 2050. Kaskaskia was the third region in Illinois selected for water supply planning as technical studies and comprehensive plans for the northeastern and east-central Illinois regions have already been completed (Figure 1.1). Technical studies for the Middle Illinois region and the Kankakee River subregion of northeastern Illinois are ongoing.

IDNR defined the Kaskaskia region to include the entire Illinois counties of Bond, Christian, Clay, Clinton, Coles, Cumberland, Douglas, Effingham, Fayette, Jasper, Marion, Montgomery, Moultrie, Randolph, Richland, Shelby, Washington, and Wayne, and portions of Macoupin, Madison, Monroe, and St. Clair in the Kaskaskia River watershed. Five of these counties (Clay, Cumberland, Jasper, Richland, and Wayne) are located entirely outside of the Kaskaskia watershed (Figure 1.2); however, water from the Kaskaskia watershed is purveyed to portions of Clay and Wayne Counties, and it was considered that the potential exists for Cumberland, Jasper, and Richland Counties to receive Kaskaskia water in the future. Thus the region's boundary is determined by the use of water that originates from sources within the Kaskaskia watershed.

Groundwater resources within the Kaskaskia watershed are limited. As a result, the study primarily highlights the surface water resources of the region, with particular interest in the two federal reservoirs, Lake Shelbyville and Carlyle Lake, and water supply allocations from these two reservoirs. Both reservoirs are operated and maintained by the U.S. Army Corps of Engineers (USACE), but a portion of their reservoir storage has been provided to the State of Illinois specifically for water supply, with allocation rights administered by IDNR.

The first two technical studies conducted to support the Kaskaskia region's water supply planning effort (Dziegielewski and Thomas, 2011; Knapp et al., 2012) were prepared with cooperative funding from the DCEO through the Illinois Clean Coal Institute. The current report, the third technical report in the planning effort supported primarily with cooperative funding from IDNR, focuses almost entirely on the role of water supply storage in the federal reservoirs (Lake Shelbyville and Carlyle Lake) in meeting projected water demands in the region through 2050. The KBWSPC also published a comprehensive evaluation and plan for the region (KBWSPC, 2012). The Kaskaskia Watershed Association now stewards that plan.

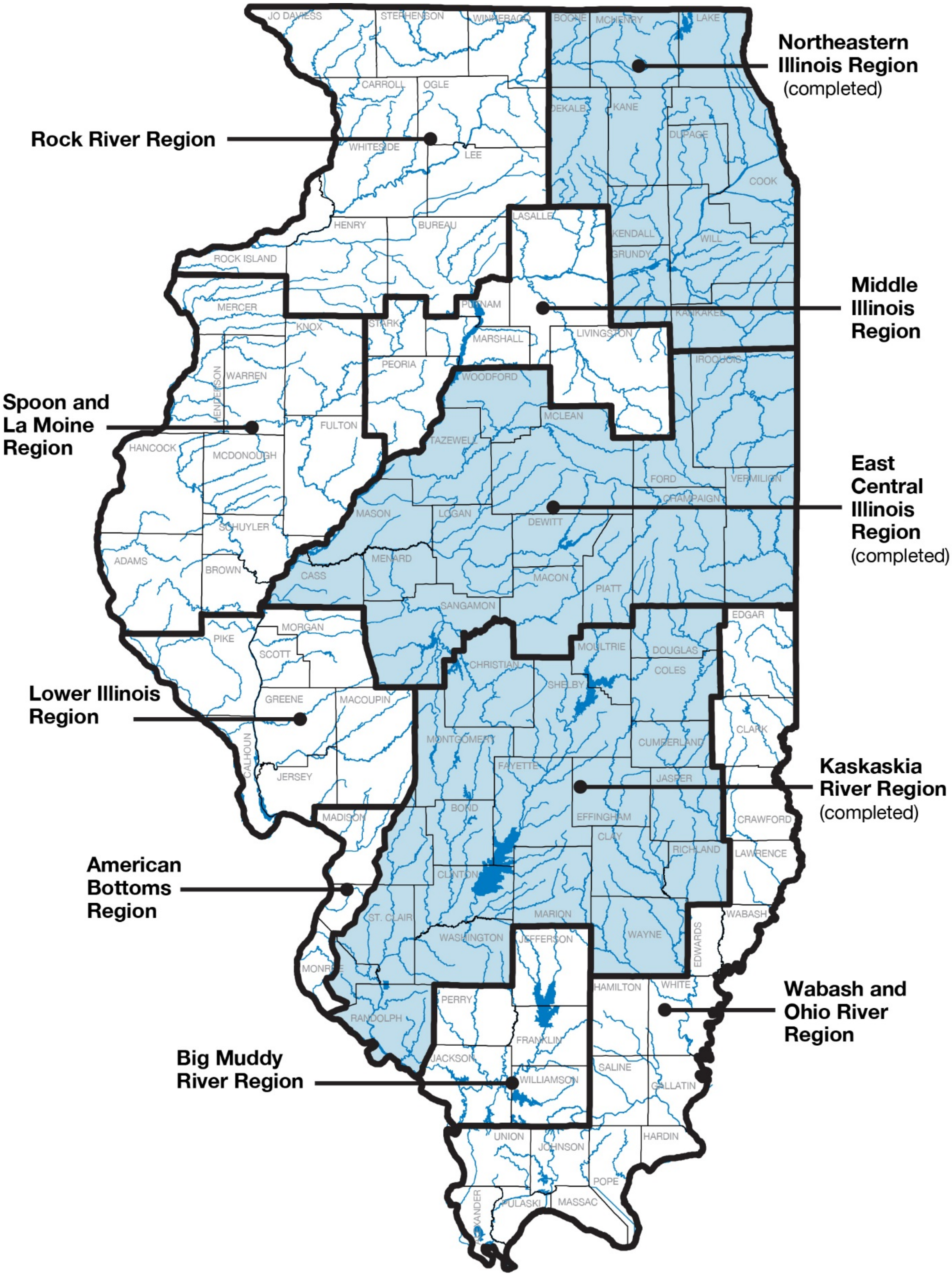

Figure 1.1. Water supply planning regions in Illinois as designated by IDNR

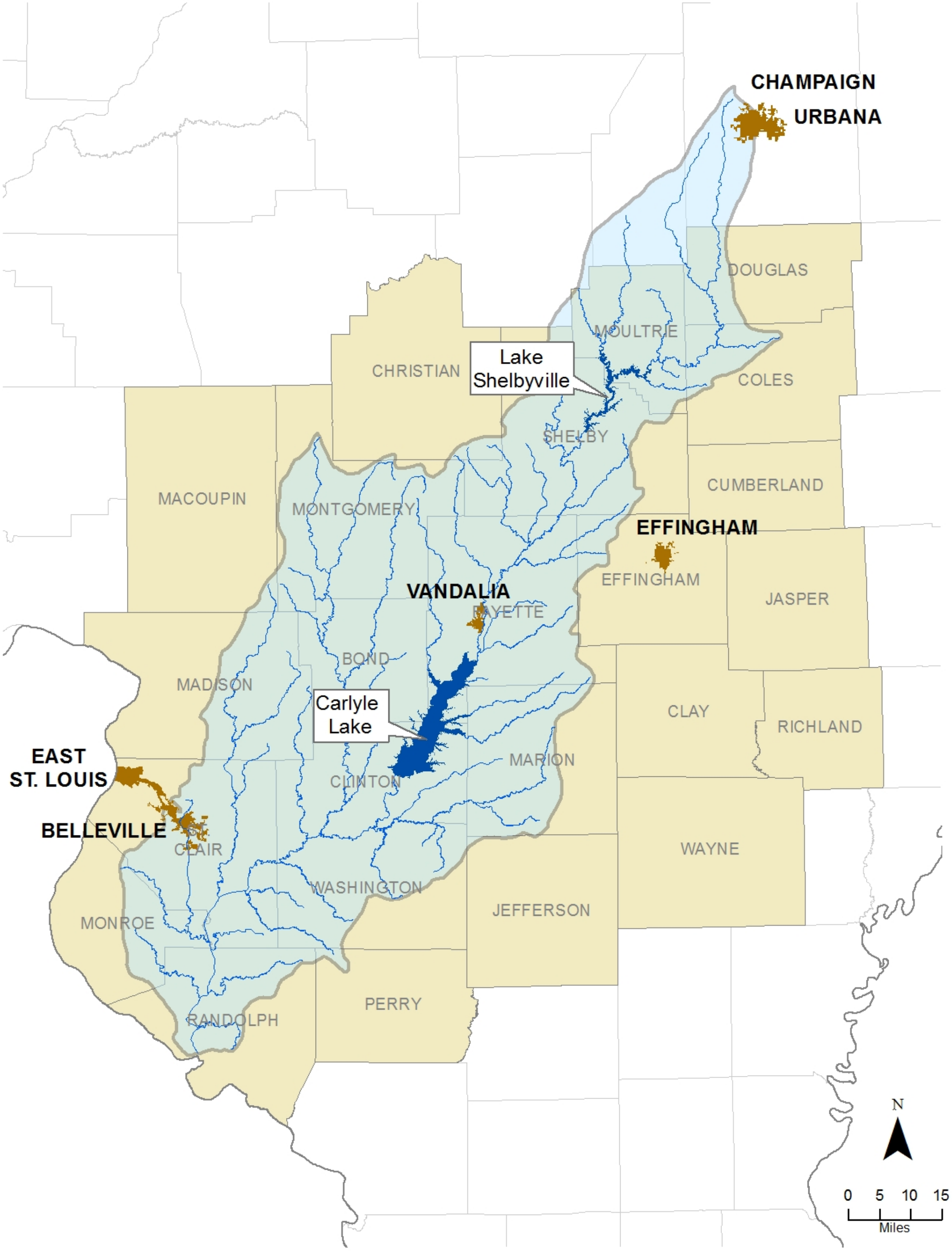

Figure 1.2. Locations of the Kaskaskia River watershed and counties included in the Kaskaskia planning region

UNDERSTANDING DROUGHTS AS THEY AFFECT WATER SUPPLY STORAGE

The State of Illinois' water supply rights to Lake Shelbyville and Carlyle Lake were allocated to nine users from 2001 to 2004. Four of the five largest of these allocations do not involve direct water withdrawals from these federal reservoirs. Instead, water is released from the reservoirs into the Kaskaskia River, where that water is subsequently withdrawn downstream. During moderately severe drought conditions, there can be sufficient available water in the river to satisfy the needs of these users without the need for a reservoir release. To date, no designated releases from either reservoir for such downstream uses have occurred, although in hindsight, a release from Lake Shelbyville during the 2012 drought would have been appropriate.

For this study, it is considered useful to describe or categorize drought events by their severity relative to the degree in which the use of water supply storage in the federal reservoirs might be required. A drought event is generally considered *severe* if conditions become necessary for major users to request a water supply release from either Lake Shelbyville or Carlyle Lake. Within the broader category of severe droughts, a drought event is considered *extreme* if the total volume of water expected to be released in a year constitutes a substantial portion of the maximum allowed annual withdrawal rate for any user as specified in each user's allocation agreement. Drought episodes that do not require use of water supply storage are herein generally termed as *moderate* events.

Extreme hydrologic droughts, which have the intensity and duration needed to threaten the availability of water stored in large reservoirs, are rare events, and for the Kaskaskia region and many other locations in Illinois, the last such extreme event occurred in the 1950s. Although future droughts and climate conditions may potentially be somewhat different than they have been in the past, the extent of such potential changes is uncertain. Extreme droughts of the past continue to provide the best available examples for analyzing the potential water supply impacts of future droughts.

SIMULATING WATER AVAILABILITY FOR FUTURE SEVERE AND EXTREME DROUGHTS

By analyzing severe droughts in recorded history, we are better able to understand how similar future droughts may impact water scarcity and availability. At the same time, analyses must consider that major water resource changes in the past half century affect future water supply availability. For example, within the Kaskaskia watershed, federal reservoirs did not even exist during many of our most extreme drought episodes, such as those of the 1930s and 1950s. Other changes include population growth and the associated increases in both water usage and treated wastewater returned to our streams. To predict what could happen if a drought similar to that of the 1950s were to recur today, it is essential that we examine, and in many cases modify, historical hydrologic records as needed to reflect current-day watershed conditions. In all cases in this report, when a reference is made, for example, to the 1953–1955 drought or other severe drought periods of the past, it is important to understand that the analysis has juxtaposed these droughts with the water resource landscape in the Kaskaskia region as it currently exists or is projected to occur over the 2050 horizon of the regional water supply planning effort.

Storage in Lake Shelbyville and Carlyle Lake designated for water supply use provides the single largest source of available water supply in the Kaskaskia region. Yield calculations for water supply storage in Lake Shelbyville and Carlyle Lake, and the allocations of that storage by the IDNR, have been based on an underlying assumption that its users will withdraw water from storage uniformly and consistently throughout the duration of a drought–in most cases similar to the actual daily consumptive needs of each user. In contrast, the three largest allocations from the state storage are for power plants located downstream of the two federal reservoirs. Although the water needs of these power plants may generally be uniform, the need to request water supply releases from the reservoirs might occur only during specified low flow drought conditions. In these situations, the maximum rate of water released is expected to be similar or identical to that specified in the allocation agreement. But since these releases may not be constant over time, the total volume of water released over the course of a drought could be noticeably different (less) from the volume expressed in the allocation agreement.

To better understand how storage volumes would be used during future drought episodes, it is necessary to examine historical drought sequences and identify specific periods when water supply releases would likely be needed. With specific regard to releases from Carlyle Lake and the associated downstream withdrawal of water from the Kaskaskia Navigation Channel, it is also necessary to understand other water demands in the navigation channel. The potentially largest single demand is from the Kaskaskia Lock and Dam for lockages of commercial and recreational vessels.

Lake Shelbyville and Carlyle Lake are large multipurpose reservoirs, and the water supply storage provided to Illinois represents a comparatively small portion (roughly 14 percent) of the joint-use storage in these reservoirs. The remaining storage in the joint-use pools of the two reservoirs is designated for federal uses, with the greater portion for river navigation needs. Specifically, the USACE may release water from federal storage in the two reservoirs to 1) provide water needs to operate the Kaskaskia Lock, or 2) be passed downstream to augment flow in the Mississippi River during infrequent circumstances when critically low river stages threaten to close or curtail the use of the river for navigation. Figure 1.3 shows the locations of the Kaskaskia federal reservoirs and the Kaskaskia Lock and Dam with respect to the USACE's Middle Mississippi Navigation System.

This report focuses only on the uses and water budgets of the State of Illinois' water supply storage in the reservoirs, which the USACE accounts separately from the remaining federal storage in the joint-use pool. Although federal and state storages in the joint-use pools are generally considered to be independent entities, this report recognizes that federal navigation releases during extreme drought conditions, particularly those releases designated for the Kaskaskia Lock, can influence the need for water supply releases from Carlyle Lake. At times when reservoir releases are needed for both navigation and water supply purposes, the simulation analyses presented herein assume a shared expenditure of storage proportional to the downstream state and federal water needs. However, as there have yet been no such navigation or water supply releases, there is no precedence for such operational decisions.

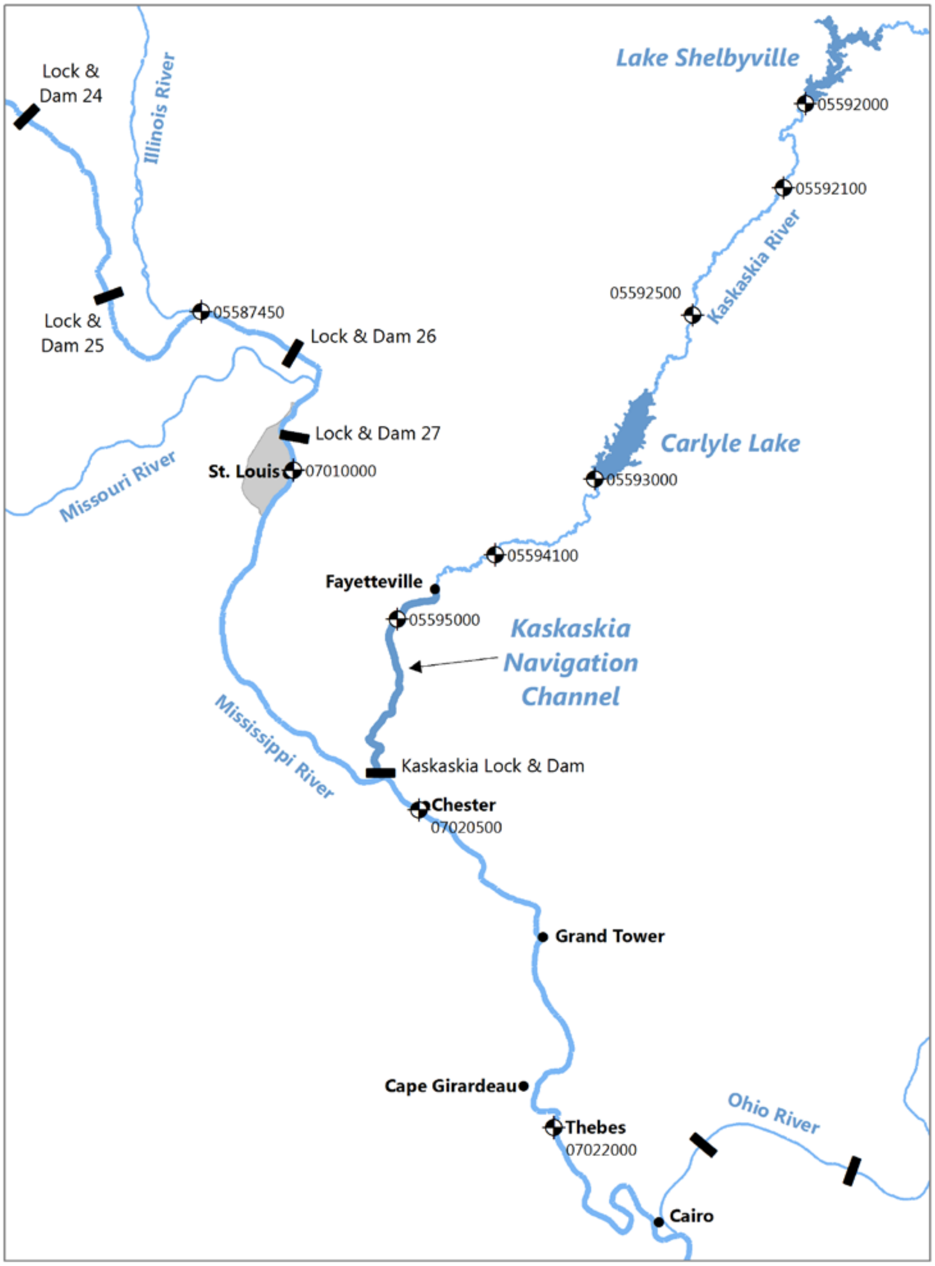

Figure 1.3. The Kaskaskia and Middle Mississippi River navigation systems, showing the locations of locks and dams, the Kaskaskia Navigation Channel, and U.S. Geological Survey streamflow monitoring gages

2. YIELD ASSESSMENT OF THE WATER SUPPLY STORAGE IN LAKE SHELBYVILLE AND CARLYLE LAKE

The State of Illinois has received water storage rights in Lake Shelbyville and Carlyle Lake specifically for water supply, as defined in the July 6, 1983 Contract Numbers DACW43-83-C-0008 and DACW43-83-C-0009 between the United States and the State of Illinois. The state's water supply storage represents approximately 14 percent of water in the joint-use pool of each lake (13.9 percent for Lake Shelbyville and 14.2 percent for Carlyle Lake), which is the primary segment of water stored beneath the target summer pool elevation in each lake. Estimates of water supply yields and allocations discussed in this report pertain only to the state's share of the joint-use storage in each reservoir, and therefore does not include the total amount of water stored in the reservoirs, a value which often includes flood control storage at water levels above the target summer pool.

TERMINOLOGY AND METHODS IN CALCULATING RESERVOIR YIELD

The reservoir yield is defined as the maximum amount of water that can be withdrawn from that reservoir during a specified measure of drought severity without incurring a supply shortage or deficit. Drought severity and its duration are typically represented by either 1) an observed historical drought sequence, or 2) an artificial set of drought conditions calculated to have an associated frequency of occurrence, such as a drought with a recurrence interval of 50 or 100 years. Oftentimes, the "drought of record," the worst drought during the period when applicable hydrologic conditions have been recorded, is the historical drought sequence used to calculate yield. For most water supply systems in the Kaskaskia River region, the 1953–1955 drought has been calculated to be the drought of record.

For each historical or artificial drought sequence and set of water withdrawal conditions, there is a duration of critical drawdown in the reservoir, often called the *critical duration*, which is a period within the drought between the time when the reservoir first starts to be drawn down below its full pool and the time when storage in the reservoir reaches its minimum level, i.e., immediately before the reservoir storage begins to recover. With the 1953–1955 drought of record, for example, the critical duration for Lake Shelbyville and Carlyle Lake is estimated to be 547 days. If the two reservoirs had been constructed prior to that drought, it is estimated that the drawdown in the lakes would have begun to occur on or about August 22, 1953, and the minimum storage in the two reservoirs would have been reached on or about February 19, 1955 (a total period of 547 days).

The calculation of yield attempts to identify the amount of water that enters and exits the reservoir during the critical duration period. Water typically enters the reservoir, increasing the available storage through stream inflows and precipitation falling over the surface of the reservoir. Water typically exits the reservoir, decreasing the available storage, through 1) evaporation from the reservoir surface, 2) water withdrawals, and 3) releases or diversions from the reservoir. The resulting calculation of the water budget and available lake storage is quite similar to computing a bank account balance with its various debits and deposits. Water can also enter and exit reservoirs through groundwater sources, and, in other regions of the United States, groundwater outfluxes can be a significant portion of a reservoir's water budget. In contrast, in the few cases in which groundwater fluxes in Illinois reservoirs are suggested by available data, the amount of movement is small and suggests a net inflow into the reservoir (Knapp and Hecht, 2009). Since assessing groundwater fluxes is difficult, this factor is generally neglected when analyzing Illinois reservoir water budgets.

The reservoir yield is often expressed as a daily rate of withdrawal, such as in million gallons per day (mgd). The calculation of yield typically assumes that the withdrawal of water from the reservoir (at the yield rate) throughout the critical duration of the drought is uniform and constant, such that the usable storage in the reservoir is exhausted at the end of the critical duration. In most real-world situations, however, the withdrawal of water from a reservoir is not uniform; for example, withdrawal amounts often vary by season. In dealing with non-uniform withdrawal circumstances, it is important to remember that an associated volume of available water during the drought exists, which is equal to the yield rate times the critical duration. For example, if a reservoir yield is calculated to be 10 mgd and the critical duration is 547 days, then its effective maximum volume available for water supply is 5470 million gallons (equivalent to 16,787 acre-feet of storage).

YIELD ESTIMATES FOR LAKE SHELBYVILLE AND CARLYLE LAKE

Tables 2.1 and 2.2 present the estimated water balance of Lake Shelbyville assuming that drought conditions similar to the 1953–1955 and 1930–1931 droughts, respectively, were to recur under present-day conditions of water use. The 1930–1931 drought is calculated to be the second worst drought on record in the Kaskaskia River watershed and is the historical drought most comparable to a 50-year drought event.

Historical climatic and hydrologic records from each drought were used to estimate inflows, precipitation, and evaporation during the lake's calculated critical drawdown period. The primary hydrologic records used to estimate inflows during these droughts include the historical flow records on the Kaskaskia River at the Shelbyville, Vandalia, and Carlyle gages operated by the U.S. Geological Survey (USGS). Of the total amount of inflow, precipitation, and evaporation, only 13.9 percent is credited to (or debited from) the state-owned water supply storage in Lake Shelbyville, whereas the remaining 86.1 percent is credited to the federal share of the entire joint-use pool of the lake. When these inflows and outflows are added to the starting (full) amount of water supply storage of 24,714 acre-feet, the resulting calculated amount of 29,939 acre-feet for the 1953–1955 drought represents the effective maximum volume of water that can be withdrawn from the lake during its 547-day critical period without causing a deficit in the water supply storage. When divided by the number of days in the critical duration (547 days), the yield rate is estimated to be 17.8 mgd.

The estimated inflow amount to Lake Shelbyville includes not only the natural streamflows as primarily identified using historical streamflow records, but also 1) effluents added to the upper Kaskaskia River from the Urbana-Champaign Sanitary District's Southwest Treatment Plant, and

Table 2.1. Estimated Yield and Effective Volume of Available Water from Lake Shelbyville during a Drought Similar to the 1953–1955 Drought of Record

Critical Duration: August 22, 1953 to February 19, 1955 (547 days)

Water Supply Storage	24714 acre-feet
Inflows	7900 (13.9% of 56,834)
Precipitation	3451 (13.9% of 24,829)
Evaporation	-6126 (13.9% of 44,074)
	29939 acre-feet = 17.8 mgd over 547 days

Table 2.2. Estimated Yield and Effective Volume of Available Water from Lake Shelbyville during a Drought Similar to the 1930–1931 Drought

Critical Duration: May 12, 1930 to October 12, 1931 (519 days)

Water Supply Storage	24714 acre-feet
Inflows	9973 (13.9% of 71,747)
Precipitation	4901 (13.9% of 35,259)
Evaporation	-7291 (13.9% of 52,450)
	32297 acre-feet = 20.3 mgd over 519 days

2) groundwater from the Mahomet Aquifer that is pumped into the Kaskaskia River for use by a chemical company near Tuscola, IL. Collectively, these two sources add roughly 11.5 mgd of water to the Kaskaskia River. As only 13.9 percent of this added water is credited to the state-owned water supply storage in that lake, the net increase in Lake Shelbyville created by these two sources of added water is 1.6 mgd. As this report was being prepared, there was the potential sale of some of the effluent water from the Sanitary District to a proposed fertilizer plant in Tuscola, which would reduce the amount of effluent water flowing to Lake Shelbyville, calculated to reduce the lake's overall yield by 0.8 mgd.

Tables 2.3 and 2.4 present the estimated water balance of Carlyle Lake assuming that the 1953–1955 and 1930–1931 droughts, respectively, were to recur under present-day conditions. Of the total estimated amount of inflow, precipitation, and evaporation, 14.2 percent is credited to (or debited from) the state-owned water supply storage in Carlyle Lake, whereas the remaining 85.8 percent is credited to the federal share of the entire joint-use pool of the lake. Estimates of inflow consider expected changes to the river's flow as caused by the upstream operation of Lake Shelbyville. When these inflows and outflows are added to the starting (full) amount of water supply storage of 32,692 acre-feet, the resulting calculated amount of 39,197 acre-feet represents the effective maximum volume of water that can be withdrawn from the lake during that critical period without causing a deficit in the water supply storage. When divided by the number of days in the critical duration (547 days), the yield rate is an estimated 23.3 mgd.

Table 2.3. Estimated Yield and Effective Volume of Available Water from Carlyle Lake during a Drought Similar to the 1953–1955 Drought of Record

Critical Duration: August 22, 1953 to February 19, 1955 (547 days)

Water Supply Storage	32692 acre-feet
Inflows	11602 (14.2% of 81,714)
Precipitation	9162 (14.2% of 64,524)
Evaporation	-14347 (14.2% of 101,036)
	39109 acre-feet = 23.3 mgd over 547 days

Table 2.4. Estimated Yield and Effective Volume of Available Water from Carlyle Lake during a Drought Similar to the 1930–1931 Drought of Record

Critical Duration: May 12, 1930 to October 12, 1931 (519 days)

Water Supply Storage	32692 acre-feet
Inflows	20026 (14.2% of 141,031)
Precipitation	11680 (14.2% of 82,257)
Evaporation	-17254 (14.2% of 121,508)
	47144 acre-feet = 29.6 mgd over 519 days

Future (2050) Reservoir Yields

If conditions similar to the 1953–1955 drought were to recur in future years such as 2050, the yield calculation for such a situation needs to be adjusted to account for expected changes in water availability. Whereas climatic and natural hydrologic factors associated with the drought would not be expected to change, there would likely be changes in 1) the water supply storage volumes as affected by the accumulation of sediments deposited in the reservoirs, and 2) inflow amounts as affected by the amounts of effluents and other human influences.

Since the reservoirs were built roughly 50 years ago, storage volumes of Lake Shelbyville and Carlyle Lake have been reduced because of sedimentation. Although much of the volume loss has occurred at the lake's lower elevation in the inactive storage pool, some sedimentation has also occurred in the joint-use pool which potentially affects the state's water supply storage. The most recent survey of the Carlyle Lake capacity conducted in 1999 indicated that storage in the joint-use pool had been reduced by 3.5 percent and had an average annual sedimentation rate of 252 acre-feet per year (Resource Technology, Inc., 2000). Because this change in the overall storage was judged by the USACE to not yet affect any project operations, the USACE decided at that time not to modify the amount of storage designated for the state's water supply use.

Lake Shelbyville was last surveyed in 1984 and at that time, over its first 15 years alone, it had lost roughly 5 percent of its total capacity. The average annual sedimentation rate in the joint use pool was estimated to be 602 acre-feet per year. The calculated sedimentation rate, based on the first 15 years of sediment, may not accurately characterize the long-term rate for that reservoir.

For example, the 1999 sedimentation study for Carlyle Lake produced a sedimentation rate that was less than half of what had previously been estimated in 1984 (Resource Technology, Inc., 2000). Thus a new survey is needed to better project how Lake Shelbyville's capacity will change by the year 2050 and beyond.

For water supply planning, at some point in the future it is expected that the USACE will need to adjust the water supply storage to more closely match percentage shares (13.9 percent for Lake Shelbyville and 14.2 percent for Carlyle Lake) as identified in the state–federal water supply contract. Using the sedimentation rates identified in the most recent surveys of each lake, the Illinois State Water Survey (ISWS) has projected that by 2050 the storage in the joint-use pools of Lake Shelbyville and Carlyle Lake will be reduced to 131,838 acre-feet and 192,736 acre-feet, respectively. The state's water supply share of the 2050 storages is projected to be 18,325 acre-feet for Lake Shelbyville and 29,703 acre-feet for Carlyle Lake. If the sedimentation rate of Lake Shelbyville were shown to be only half of that estimated from the 1984 survey, for example, the projected 2050 water supply storage might instead be higher than 21,000 acre-feet (adding nearly 2 mgd to the projected yield).

Water demand projections for the Champaign-Urbana area (Wittman Hydro Planning Associates, 2008) identify a range of potential growth rates from 20 to 45 percent greater than current demands. As a result, it is expected that by 2050 there will be a proportional increase in the volume of effluents being released to the upper Kaskaskia River, increasing flow in the river by an additional 2 to 4 mgd. For yield estimates, the 2050 projected average effluent loading to the upper Kaskaskia River is projected to be 11.5 mgd. However, a proposed fertilizer manufacturing facility near Tuscola will reportedly purchase 6.3 mgd from the Southwest Champaign wastewater treatment plant, reducing the overall wastewater loading to the river. Other potential water supply uses or developments along the river could affect these projections. The potential collective changes by 2050 would be expected to only modestly affect the Lake Shelbyville yields, in part because only 13.9 percent of the potential increases or decreases in flow amounts would be credited/debited to the state's water supply storage in the lake.

Table 2.5 presents projected yields for the two federal reservoirs, taking into account both the projected reduced storage amounts and potential increases in upstream effluent flows. Whereas the 2050 horizon has been adopted for regional planning purposes, the 2040 projection is also provided since the existing IDNR allocation agreements expire between 2040 and 2044.

Table 2.5. Projected Reservoir Yields (mgd) for the Years 2040 and 2050

	Lake Shelbyville	Carlyle Lake
2040 Yield		
1953–1955 Drought	15.0	22.4
1930–1931 Drought	19.2	26.9
2050 Yield		
1953–1955 Drought	14.8	22.2
1930–1931 Drought	18.9	26.6

Potential Effect of Winter Drawdown on Yield Amounts

Water levels in Lake Shelbyville and Carlyle Lake are dropped from their summer pool to winter pool levels in December each year. Even with the lower water levels that occur during a severe drought, the lakes may still need to be lowered further and water released in December to reach an acceptable winter pool level as defined by USACE operation guidelines. In such circumstances, storage reduction in joint-use pools will be designated to come only from the federal share of storage and will not affect the water supply storage in the reservoirs. Furthermore, it is expected that the state's water supply storage would not be debited for any withdrawals or water uses that occur during the transitional period when water levels in the reservoirs are being lowered to reach the winter pool. If debits in the water supply storage were not to be registered for such a period in the middle of a drought, this inaction would effectively increase the total yield during that drought. Such circumstances during the 1953–1955 drought conditions, for example, would effectively increase the collective yields of the two reservoirs by nearly 2 mgd during that drought.

However, the USACE could alternatively decide to designate such releases in December for navigation purposes, especially if flow levels in the Mississippi River were very low, threatening the ability of barges to navigate the river. Providing water for navigation needs is a primary purpose of the two federal reservoirs, and the USACE reserves the right to use all of the federal share of the joint-use pool for such a purpose, although to date there has never been a navigation release from either Lake Shelbyville or Carlyle Lake. During the 2012 drought, however, the USACE was reportedly considering such a designated navigation release in late December. In this circumstance, the water supply storage in the reservoirs would be debited for withdrawals as well as any additional reservoir releases needed to ensure that downstream water use would not interfere with the volume and conveyance of water designated for navigation. The estimated yields of the two reservoirs presented herein have assumed that a navigation release will occur during an extreme drought in place of the winter drawdown and water supply debits will be incurred during the time of that release, thereby producing a conservative estimate of the water supply yield of the two reservoirs.

PREVIOUS YIELD ESTIMATES

A previous yield analysis for Lake Shelbyville and Carlyle Lake was conducted by the ISWS in 2001, resulting in the yield estimates (Knapp et al., 2012) shown in Table 2.6. From this table, yield estimates for the 100-year drought are most comparable to the 1953–1955 drought-of-record yields given in Tables 2.1 and 2.3, whereas estimates for the 50-year drought are most comparable to the 1930–1931 yield estimates from Tables 2.2 and 2.4. The ISWS also provided a projection of the 50-year yield for the year 2041 based on expected sedimentation losses in both reservoirs, resulting in 2041 yield estimates for Lake Shelbyville and Carlyle Lake of 18 and 29 mgd, respectively, resulting in a total yield of 47 mgd.

Table 2.6. Yield Estimates for Lake Shelbyville and Carlyle Lake, Analyzed by the ISWS in 2001

Drought Recurrence	*Lake Shelbyville*	*Carlyle Lake*
	2001 Yield Estimate (mgd)	
10-year	40	100
20-year	31	62
25-year	28	53
40-year	23	37
50-year	21	31
100-year	15	21
	2041 Yield Estimate (mgd)	
50-year	18	29

The IDNR referenced the 2001 ISWS yield estimates when determining an appropriate limit to the amount of water that would be allocated from the water supply storage. In setting allocation limits, the IDNR attempted to fully allocate the state's water in the lake with the expectation that allocated water would be available in all but perhaps the most extraordinary drought situations, to which the 50-year drought was considered an appropriate measure.

The 1930–1931 drought was considered in the 2001 ISWS analysis to have a recurrence interval of roughly 50 years and was used as the primary datum for establishing the 50-year yield. In the latest analysis, this is still considered to be the case, as the 1930–1931 drought is the second worst drought identified in the 100 years of the region's hydrologic records, with the USGS Vandalia gage record on the Kaskaskia River dating back to 1908. The latest yield estimates for the 1930–1931 drought (Tables 2.2 and 2.4) are similar to the 50-year drought estimates shown in Table 2.6 but show roughly a 5 percent decrease in the yield estimate. Differences between the latest yield estimates and those from 2001 are caused by three primary changes in the computation methodology:

- The 2001 analysis used monthly climatic and streamflow records, whereas the recent estimates use daily records. When using monthly records, for example, the 1953–1955 drought estimate had an associated 19-month critical duration from August 1, 1953 to February 28, 1955. The 1930–1931 drought estimate had an associated 18-month critical duration from May 1, 1930 to October 31, 1931. The estimated drought yields tend to be slightly reduced when computed using daily records as compared to monthly records.
- The latest analysis includes an estimate of the effect of surcharge storage on the initial date of the drought's critical duration. Surcharge storage is the volume of water above normal pool that remains temporarily in a lake following a high flow event. For Lake Shelbyville and Carlyle Lake, it can take months for the lake to return to normal pool following a high flow event, even amid the onset of drought. The effect of surcharge storage noticeably increases yield estimates for the 1953–1955 drought but has no effect on the 1930–1931 drought yields.
- Effluents and other added flow amounts were not considered in the 2001 estimate.

UNCERTAINTY IN THE YIELD ESTIMATES

Reservoir yield values provided in Tables 2.1 through 2.6 represent the traditional *best* estimates of yield given the available climatic and hydrologic data. The best yield estimate is also sometimes called the “firm yield” or “safe yield,” but these terms are considered herein to be misnomers. To the contrary, estimating the best yield contains a number of uncertainties. Not only do the various climatic and hydrologic data contain certain measurement errors, but also in many cases the data must be translocated; i.e., adjustments are made in cases in which the data were measured at a different location from the point of interest. For example, if the only available streamflow record on the Kaskaskia River during a particular drought is from the Vandalia gage, then that data must be adjusted using appropriate hydrologic transfer methods to properly represent flow conditions that might be expected to occur at Shelbyville, Carlyle, or other locations on the river. In analyzing various types of climatic and hydrologic records, the ISWS has identified a generic set of expected uncertainties in various data types and data transfer methods (Knapp, 2007).

The traditional best methods essentially identify the “mid-point” in estimating a system’s yield; i.e., there is roughly a 50 percent chance that the estimate may overestimate the unknown “true” value of yield and roughly a 50 percent chance that the estimate may underestimate the true yield. In some cases the mid-point or “50 percent confidence” yield estimate is appropriate for planning purposes, but in many other risk-averse situations, a more conservative yield estimate is appropriate. For this reason, in recent years the ISWS has developed quantifiable estimates of data uncertainties that can calculate a “90 percent confidence limit for the yield,” otherwise designated herein as the “90 percent yield,” meaning that there is 90 percent confidence that the true yield is greater than the computed 90 percent yield. The need for greater confidence is considered appropriate for water supply systems that have limited alternative water supply sources.

Tables 2.7 and 2.8 present the 90 percent yield estimates for Lake Shelbyville and Carlyle Lake for a drought of record condition similar to the 1953–1955 drought. When compared with Tables 2.1 and 2.3, it can be seen that adjustments have been made to the climatic and hydrologic data, resulting in reduced inflows to the lake, reduced precipitation, and increased evaporation amounts. Specifically, inflows have been reduced by 12.8 percent, precipitation has been reduced by 5 percent, and evaporation has been increased by 17.9 percent. Inflows into Carlyle Lake are also influenced by changes in expected outflows from Lake Shelbyville. It may also be noted that the critical duration of drawdown for the 90 percent estimate is a few days longer than the 50 percent estimate, primarily because of associated reductions in lake inflow.

Under most circumstances in estimating the 90 percent yield, the available storage would also be reduced to represent measurement errors from bathymetric surveys. For very large reservoirs, such as Lake Shelbyville and Carlyle Lake, the standard error of measurement for detailed bathymetric surveys is expected to be roughly 5 percent. However, the amount of storage allocated to water supplies in these lakes is not strictly based on measurement, but instead is an operational value established by the USACE. For this reason the storage values were not modified.

An examination of Tables 2.7 and 2.8 shows that the 90 percent confidence yields for the 1953–1955 drought are roughly 10 percent less than the 50 percent (best) yield estimates (Tables 2.1 and 2.3), with a combined 90 percent confidence yield of 36.9 mgd for the two lakes. The combined volume of water available for water supply with the 90 percent confidence estimate is 62,365 acre-feet, compared to 69,135 acre-feet using the 50 percent yield calculation.

Table 2.7. Estimated 90 Percent Confidence Yield for Lake Shelbyville during a Drought Similar to the 1953–1955 Drought of Record

Critical Duration: August 17, 1953 to February 19, 1955 (552 days)

Water Supply Storage	24714 acre-feet
Inflows	6926 (13.9% of 49,828)
Precipitation	3279 (13.9% of 23,588)
Evaporation	-7374 (13.9% of 53,051)
	27545 acre-feet = 16.3 mgd over 552 days

Table 2.8. Estimated 90 Percent Confidence Yield for Carlyle Lake During a Drought Similar to the 1953–1955 Drought of Record

Critical Duration: August 17, 1953 to February 19, 1955 (552 days)

Water Supply Storage	32692 acre-feet
Inflows	10673 (14.2% of 75,160)
Precipitation	8631 (14.2% of 60,784)
Evaporation	-17144 (14.2% of 120,734)
	34852 acre-feet = 20.6 mgd over 552 days

3. GENERAL INFORMATION ON ALLOCATIONS AND WATER SUPPLY RELEASES

IDNR ALLOCATION AGREEMENTS

A detailed presentation of the State of Illinois' allocation of water supply storage from Lake Shelbyville and Carlyle Lake is given in the Phase I Technical Report (Knapp et al., 2012) of the Kaskaskia Water Supply Planning effort, with material prepared by IDNR's Frank Pisani. Some material presented in this chapter has been extracted from that earlier report.

Water supply storage from Lake Shelbyville and Carlyle Lake has to date been allocated by IDNR to nine entities. The four smallest allocations from the water supply storage are provided to golf courses located on the shores of Lake Shelbyville or Carlyle Lake and withdrawn directly from their respective reservoir. The collective annual allocation for these four golf courses is 770 acre-feet of water, roughly equivalent to 1.3 percent of the state's water supply storage in the two lakes.

The five largest allocations from the two lakes have been given to three electricity-generating plants (Dynegy Baldwin Power Station, Prairie State Energy Campus, and Holland Energy) and two regional water supply systems (Holland Regional Water System and Gateway Water Company). IDNR agreements for each of the five allocations have a 40-year term, with all scheduled to expire or be renewed in the years between 2040 and 2044. Each allocation allows for either 1) a direct withdrawal of water from the lakes, or 2) the release of water from the lakes to the Kaskaskia River for downstream use. Only the Gateway Water Company directly withdrawals water from the lakes. If any of the other four largest allocations desire water from either Lake Shelbyville or Carlyle Lake, they must request a water supply release. None of these facilities has to date requested such a release of water.

The USACE has also provided two separate water supply allocations to the cities of Centralia and Salem, which allow for average annual withdrawals from Carlyle Lake of up to 7.56 and 3.5 mgd, respectively. These two allocations are based on water withdrawal rights that existed prior to the construction of Carlyle Lake along that portion of the Kaskaskia River that is now inundated by the lake. Centralia and Salem withdrawals from Carlyle Lake are debited to the federal share of the joint-use pool and thus do not affect the water supply allocations administered by IDNR, nor are the Centralia and Salem withdrawals otherwise addressed in this report.

IDNR allocation agreements have specified limits on maximum and average annual withdrawal/release amounts. The average annual amount is determined over each federal fiscal year (October 1 through September 30 of the following year), which also coincides with the water years typically associated with hydrologic data. The maximum and average annual allocation limits are presented for each of the five major water use entities in Table 3.1.

Table 3.1. The Five Largest Allocations of Water from the State of Illinois' Water Supply Storage in Lake Shelbyville and Carlyle Lake

	Maximum rate (mgd)	Average annual rate (mgd)
Dynegy Baldwin Power Station	58	14.35
Prairie State Energy Campus	18	13.35/9.50[a]
Holland Energy	8.0	(b)
Holland Regional Water System	7.5	5.00
Gateway Water Company	6.4	4.00

Note: (a) Prairie State's allocation agreement will be reviewed by IDNR every 10 years. Although the allocated annual rate is currently 13.35 mgd, during its review IDNR has the option to reduce that amount to no less than 9.5 mgd.
(b) Not specified in the allocation agreement. However, Holland Energy has informed IDNR that they expect their annual usage to be 5.3 mgd.

If, as indicated by Holland Energy, its power station uses an average annual amount of 5.3 mgd, then the five allocation agreements allow for a collective annual use rate of up to 42 mgd. IDNR has reserved an additional 5.5 mgd for use in satisfying the state share of the minimum water quality releases from the two reservoirs, resulting in a total operative allocation from the two reservoirs of 47.5 mgd (annual rate). The total operative allocation is thus slightly greater than the 2041 yield of the two reservoirs during a 50-year drought condition (47 mgd) as estimated in 2001 (Table 2.6). Contracts for all five allocations shown in Table 3.1 were executed in 2000–2004; and, for all but the first utility (Holland Energy), IDNR's evaluation of water availability was based on the available 2001 yield estimate. The five allocation agreements were considered by IDNR to fully obligate the water supply storage from the two federal reservoirs.

The total amount allocated by IDNR, however, exceeds the combined reservoir yields during the 1953–1955 drought of record, both under current conditions (Table 2.1 and 2.3) and future conditions (Table 2.5). At face value, it thus appears that there would be insufficient water to satisfy all allocation agreements during any future droughts that are more extreme than a 50-year drought. The expected conditions during a future drought similar to the 1953–1955 drought of record are examined in more detail in Chapters 4 and 5 of this report, with emphasis not solely on drought yield, but also on the total amount of water supply released from each reservoir during such an extreme drought.

Water Supply Billing

As stipulated in the IDNR allocation agreements, each water user will be billed a proportionate amount of the annual water supply costs as incurred by the State of Illinois as specified in its federal contracts. As of the time of this report, there have been no water supply releases from Carlyle Lake and Lake Shelbyville and thus no costs have yet been incurred. Once water supply releases have occurred, each user will be charged an annual water supply cost proportional to their maximum water usage from any previous or current water year. The water year and federal fiscal year are both calculated from the previous October 1 through September 30. The full costs associated with using all or most of the state's water supply storage will not be incurred until such storage has been depleted during an extreme drought similar to the 1953–1955 drought of record; thus potentially many years may pass before this situation occurs.

CONDITIONS REQUIRING A WATER SUPPLY RELEASE

Water supply releases from the federal reservoirs may be requested by any of four different holders of water supply allocations: 1) Prairie State Generating Company (Marissa power plant), 2) Dynegy Midwest Generation (Baldwin power plant), 3) Holland Energy (Beecher City power plant), and 4) the Holland Regional Water System (HRWS). Water supply releases for Holland Energy and HRWS would be requested from Lake Shelbyville, and releases for the Dynegy-Baldwin facility would be requested from Carlyle Lake. Although IDNR's allocation agreement with Prairie State indicates that water may be released for their usage from either Carlyle Lake or Lake Shelbyville, all such releases are expected to come from Carlyle Lake. However, if the storage amounts in the two reservoirs become unbalanced, the USACE has the operational prerogative to transfer (release) storage from Lake Shelbyville into Carlyle Lake as deemed necessary.

All conditions requiring a water supply release from Lake Shelbyville or Carlyle Lake are specified in the contract language between the United States and the State of Illinois or the allocation agreements between the state and the holders of each allocation. For descriptive purposes and clarity, we have subdivided these conditions into three types of circumstances as described below.

Deficit-Driven Releases

A deficit is considered to occur when the available flow from a federal reservoir's water quality release and additional tributary inflows downstream of the reservoir are insufficient to meet the collective water demands from the river downstream of either lake. As discussed in upcoming chapters, this condition most commonly applies when available flows are unable to meet the collective water supply and navigation needs in the Kaskaskia River navigation channel downstream of Carlyle Lake. At such times the amount of water stored (or pooled) in the navigation channel is considered to have a "water supply deficit," and the reservoir releases needed to overcome this deficit are described in this report as "deficit-driven water supply releases." Typically in these cases, water users would release only the amount of water needed to avoid a water deficit. In the case of Prairie State and Dynegy-Baldwin facilities, in particular, the need for deficit-driven releases would typically be coordinated with the USACE in consideration of the downstream needs for lockage water at the Kaskaskia Lock and Dam.

Contract-Driven Releases

Water supply releases would also be required if users want to withdraw when the flow level in the Kaskaskia River falls below the designated protected minimum flow (most commonly taken as the 7-day, 10-year low flow or Q7,10). As required in their water supply contract with IDNR, allocation holders would need to request that water be released from the reservoir immediately upstream even if sufficient water is available in the river for all users, i.e., regardless of whether there is a “water supply deficit” in the navigation channel. Because releases are required by a restriction imposed by the allocation agreements or the federal contract, they are described herein as “contract-driven water supply releases.” As described in the contract language, all withdrawers would need to release an amount equal to or greater than their gross withdrawal rate.

Conditions during a Navigation Release

Water supply releases will also be required when there is a navigation release from one of the federal reservoirs *and* the natural tributary inflow downstream of that reservoir is insufficient to meet water supply withdrawal needs. The stipulation regarding water supply releases during times of navigation releases is taken from Article 1C (3) of the 1983 contract between the United States and the State of Illinois regarding protection of navigation releases, previously cited in the Phase I Report (Knapp et al., 2012).

> “At the time of such navigation release, downstream consumptive use of Kaskaskia River water in excess of natural inflows is prohibited to the State and others unless such usage is replenished to the navigation system by pumping or other means or unless water is released for that purpose.”

Although the primary intent of that contract language is to protect flows released from the federal reservoirs for expressed purposes such as navigation, it also implies that the natural inflow into the river is available for water supply uses by the state and others whenever a conflict occurs between water supply and navigation needs.

The term “natural inflow” appears in the federal water storage contracts with the state with regards to protection of navigation releases. Although the term does not appear to be strictly defined in that document, in the context of its use it refers to all flows that enter the Kaskaskia River by means other than the regulated releases from the federal reservoirs, thus including flows from tributary streams and baseflow entering the river from the floodplain and other groundwater sources. For this study, and in the apparent context of the federal–state contracts, effluent discharges to streams are also considered to be part of the overall “natural” inflow from the watershed, although these and certain other sources of flow are clearly of human origin.

Although the navigation release condition is clearly contract-driven, it could also be considered deficit-driven as it addresses cases in which there is insufficient flow in the river to meet both designated navigation and water supply needs. Unlike other contract-driven releases, it does not necessarily require that the users release a water amount equivalent to their rate of withdrawal, only that sufficient water is released so that such withdrawals do not interfere with the amount of water designated for navigation needs. Thus, in this respect, this situation is considered herein to be deficit-driven.

4. THE POTENTIAL FOR WATER SUPPLY RELEASES FROM LAKE SHELBYVILLE DURING SEVERE DROUGHT

The only withdrawals from the Kaskaskia River considered in this analysis (and that for Carlyle Lake presented in Chapter 5) are those associated with permanent intake structures permitted by IDNR. Intermittent withdrawals such as those for irrigation may occur at various locations along the river during a severe drought; however, no data are available on such withdrawals. Lacking such data, it is assumed that such withdrawals are not of sufficient quantity and duration to interfere with water released from the federal reservoirs for targeted purposes such as water quality, navigation, or water supply. Furthermore, such potential withdrawals taken from Illinois Public Waters are believed to fall within the jurisdiction of IDNR, and all non-allocated withdrawals within that jurisdiction must be limited to that amount which may be provided by natural inflows into the river.

WATER NEEDS FOR HOLLAND ENERGY AND THE HOLLAND REGIONAL WATER SUPPLY

Holland Energy

The state's agreement with Holland Energy provides for an 8-mgd water allocation for either a release or direct withdrawal from Lake Shelbyville. The agreement does not include any specific restrictions on withdrawal amounts assuming Holland Energy withdraws from the Kaskaskia River downstream of the lake, as is its current practice. But Holland Energy informed the IDNR's Office of Water Resources (OWR) that based on operational requirements, their weighted average annual usage would be about 5.3 mgd (Knapp et al., 2012). There are no minimum low flow restrictions on the withdrawal; however, a special condition in Holland Energy's National Pollutant Discharge Elimination System (NPDES) permit states that there may be no wastewater discharge from the plant when the flow rate in the Kaskaskia River upstream of the outfall (downstream of the withdrawal intake) falls below 10 cubic feet per second (cfs), a restriction that is expected to limit plant operations during such low flow conditions.

The 8-mgd allocation to Holland Energy potentially obligates up to 13,400 acre-feet of water supply storage from Lake Shelbyville equivalent to or the effective maximum volume associated with using 8 mgd over the 547-day period during the 1953–1954 drought of record. However, this estimated volume assumes that the plant is operating and requires flow releases during the entire 18-month critical duration of the drought. The Holland Energy plant is an intermediate-load natural gas facility that may not be operating all times throughout the drought. Even if it were operating full time, there would be brief periods during the drought, as discussed in this chapter, when flow conditions on the Kaskaskia River at the plant's intake would be sufficiently high so as not to require a concurrent water supply release from Lake Shelbyville.

Holland Regional Water Supply

The Holland Regional Water Supply (HRWS) obtains its water from Holland Energy. Although the water is withdrawn from the same intake on the Kaskaskia River, the State's agreement for HRWS's water withdrawal is more restrictive than the agreement with Holland Energy. By the contract agreement, HRWS must request a designated release of water from Lake Shelbyville whenever the river's flow as measured at the Cowden gage is equal to or less than 29 cfs.

The 5 mgd allocation to HRWS (with a 7.5 maximum withdrawal rate) is currently split between three entities: Effingham (3 mgd), the EJ Water Company (1.5 mgd), and the Lake Sara Water Co-op (0.5 mgd). As of 2012, the EJ Water Company was the only entity providing water constantly; their average water usage in 2012 was 0.8 mgd. Water designated for Effingham and the Lake Sara Water Co-op is essentially reserved for projected growth in these supply systems over the 40-year term of the allocation agreement; but even with projected growth, water from the Kaskaskia River may only be a supplemental source of supply that is accessed during severe drought conditions. The demand of the Effingham supply system, which also provides water to the Lake Sara Water Co-op, currently averages about 2.1 mgd. The ISWS has estimated that Effingham's primary sources of supply (the Little Wabash and Lake Sara) are capable of providing a yield in excess of 5 mgd with 90 percent confidence during a record drought similar to the 1953–1955 drought. Even though these primary sources appear to be capable of providing considerable growth in Effingham's water use through the 2050 planning horizon of this study, Effingham could possibly prefer to use water from the HRWS during a severe drought instead of depleting the storage in Lake Sara.

The 5-mgd HRWS allocation potentially obligates about 8400 acre-feet of water supply storage from Lake Shelbyville, equivalent to or the effective maximum volume associated with using 5 mgd over the 547-day critical drought period during the 1953–1954 drought of record.

AVAILABLE INFLOW TO THE HOLLAND INTAKE DURING DROUGHT CONDITIONS

Three sources of flow define the amount of flow available for pumping at the Holland Energy intake: 1) water quality releases from Lake Shelbyville, 2) natural inflows entering the Kaskaskia River between Shelbyville and the Holland intake either from tributary streams or baseflow originating from groundwater sources, and 3) special releases from Lake Shelbyville to meet downstream water supply or navigational needs. There have yet been no special releases from Lake Shelbyville, although, as discussed in this chapter, given the allocation stipulations, water supply releases should expect to be required during many drought conditions, including that experienced in 2012.

Water Quality Releases from Lake Shelbyville during Drought Periods

The official minimum flow release at Lake Shelbyville is 10 cfs. However, USACE sometimes has difficulty maintaining that minimum release rate with the current outflow structure and the occasional obstructions typically caused by debris. As a result, since 1992 the USACE has more commonly released a slightly higher flow amount during low flow conditions when the lake is below full pool. Selected annual 7-day low flows since 1986, listed in Table 4.1, demonstrate the change in the minimum flows released from Lake Shelbyville that occurred in 1992. Also noted is that the frequency of low flows has diminished somewhat since the mid-1980s; however, the frequency of low flows does not directly affect the magnitude of the releases (which are directly tied to gate operation). The minimum outflow from Lake Shelbyville during the 2012 drought was the lowest in the past 20 years, with an observed 7-day low flow of 12 cfs occurring in late September and early October. But over a three-month period (July–September 2012), the daily low flow releases from the dam most commonly ranged from 15 to 25 cfs. To simulate downstream flow conditions during future severe drought episodes, a constant low flow release value of 15 cfs has been assumed, except where noted.

Natural Inflows between Shelbyville and the Holland Intake

Along the 22 river miles between Lake Shelbyville and the Holland Energy intake near Thompson Mill Bridge, roughly 183 square miles of watershed drain to the Kaskaskia River. The greatest contributing drainage area in this reach is the Robinson Creek watershed. The difference in flow between Shelbyville and the Holland Energy intake is for this study termed the natural inflow, although it includes a small amount of treated wastewater (usually less than 0.5 cfs) discharged to Robinson Creek from the city of Shelbyville.

The USGS streamgage on the Kaskaskia River near Cowden, IL is located less than 4 miles downstream of Holland Energy's intake and outfall. Although there is an additional 89 square miles of contributing drainage area at the Cowden gage, for this analysis, the flows measured at the Cowden gage are assumed to be essentially equivalent to flows immediately upstream of the Holland intake, with the exception of recent years when water has been withdrawn from the river by Holland Energy and the HRWS. Thus the Cowden flow observations provide a measure of natural inflow into the Kaskaskia River between Shelbyville and the Holland intake to determine compliance with the allocation agreements and NPDES restrictions.

Table 4.1. Annual 7-day Low Flows Released from Lake Shelbyville Over the Past 25 Years (observed flows at the USGS streamgage downstream of the lake)

Year	*7-day low flow (cfs)*	*Year*	*7-day low flow (cfs)*
1986	6.0	1992	17
1987	7.8	1999	19
1988	11	2001	21
1989	7.1	2003	16
1990	6.2	2009	15
1991	7.5	2012	12

Observed Conditions during the 1976–1977, 1988, and 1999–2000 Droughts

The Kaskaskia River flow records at Cowden and Shelbyville were analyzed to identify the natural inflow that occurred during three historical drought periods, namely the 1976–1977, 1988, and 1999–2000 droughts. These are the three primary drought periods for which flow records are available at the Cowden gage prior to the construction of the Holland Energy withdrawal. As discussed individually below, data from these periods collectively suggest that the magnitude of natural inflows between Shelbyville and Cowden can be as low as 2 to 5 cfs during drought conditions.

1976 – The 1976–1977 drought represents the most persistent drought episode that occurred since the construction of Lake Shelbyville. Figure 4.1 shows the flow amounts estimated by the USGS during that drought at the Shelbyville and Cowden gages. As seen in this figure, releases from Lake Shelbyville generally ranged from 5 to 15 cfs throughout the summer and fall of 1976. But from mid-November 1976 through January 1977, flow releases at Shelbyville were most often below 4 cfs. Flows at the Cowden gage show greater variability and include several events lasting two to three days each when local rainfall caused a swell in the natural inflow to the Kaskaskia River. But for most days between late August and January, observed flows at the Cowden gage were generally 3–4 cfs greater than the flows at Shelbyville. This 3–4 cfs difference between the two USGS gages appears to provide a fairly consistent measure of the expected natural inflows over this reach of the Kaskaskia River during a drought condition.

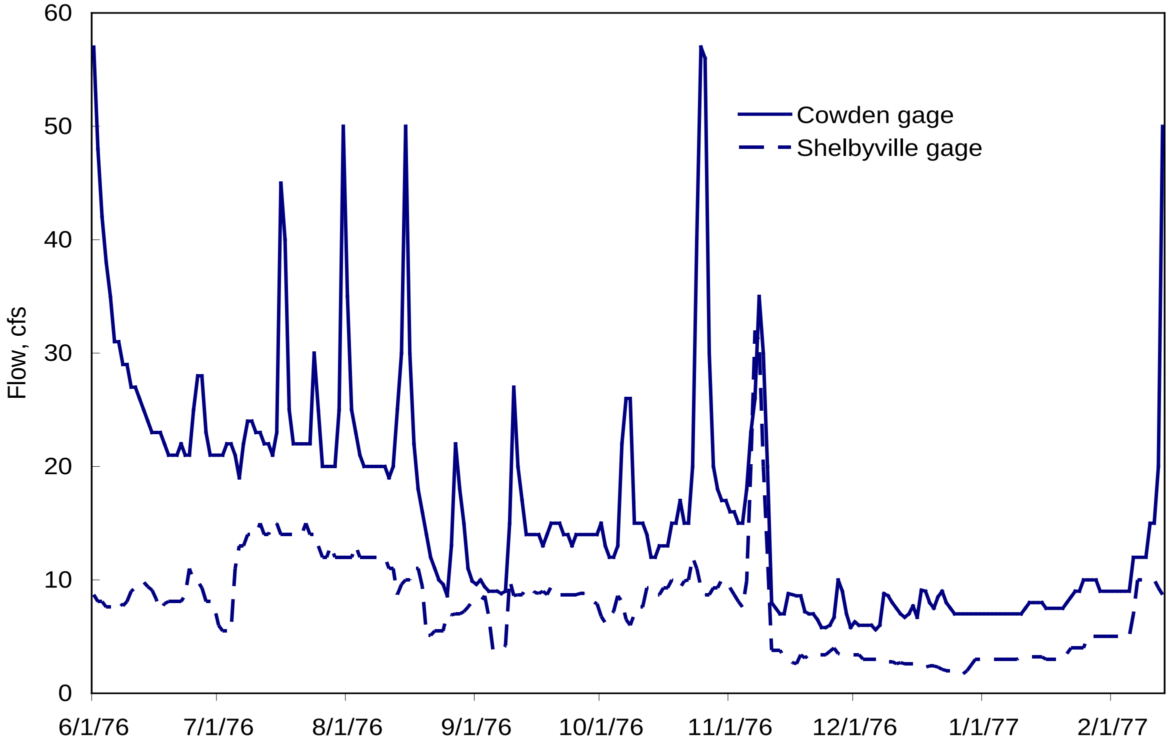

Figure 4.1. Observed daily flows in 1976 from the USGS gages at Shelbyville and Cowden

1988 – Although the 1988 drought is generally considered to be the most severe drought in central Illinois over the past 50 years, the effects were relatively short-lived at many locations. The release of water from Lake Shelbyville was generally about 15 cfs throughout the summer, and was increased to 30 cfs in late September (Figure 4.2). During portions of the 1988 summer, the observed flows at the Cowden gage fell to within 2–5 cfs higher than the Shelbyville flows, but was interrupted by a period of two weeks beginning in late July when local rainfall caused a considerable increase in low flows downstream of the dam. For a two-week period in late September and early October, the flows at Cowden were near 30 cfs, generally 0–2 cfs greater than the flows at Shelbyville. However, the inconsistency in this difference and potential estimation error makes it difficult to derive any definitive conclusions related to natural inflows during this period. In mid-September, the flows at Shelbyville were higher than at Cowden for roughly two days, which illustrates the time lag for low flow releases from Shelbyville to reach the downstream location at Cowden.

1999–2000 – This drought had a very late start in 1999, such that sustained low flow releases from Lake Shelbyville did not occur until September. Figure 4.3 shows the flows at the Shelbyville and Cowden gages for a seven-week period when the water quality release was at its lowest level. During this time period, the flows at Cowden were most often 2–5 cfs above the flows at Shelbyville, with periodic rainfalls causing only moderate increases in the natural inflow amount.

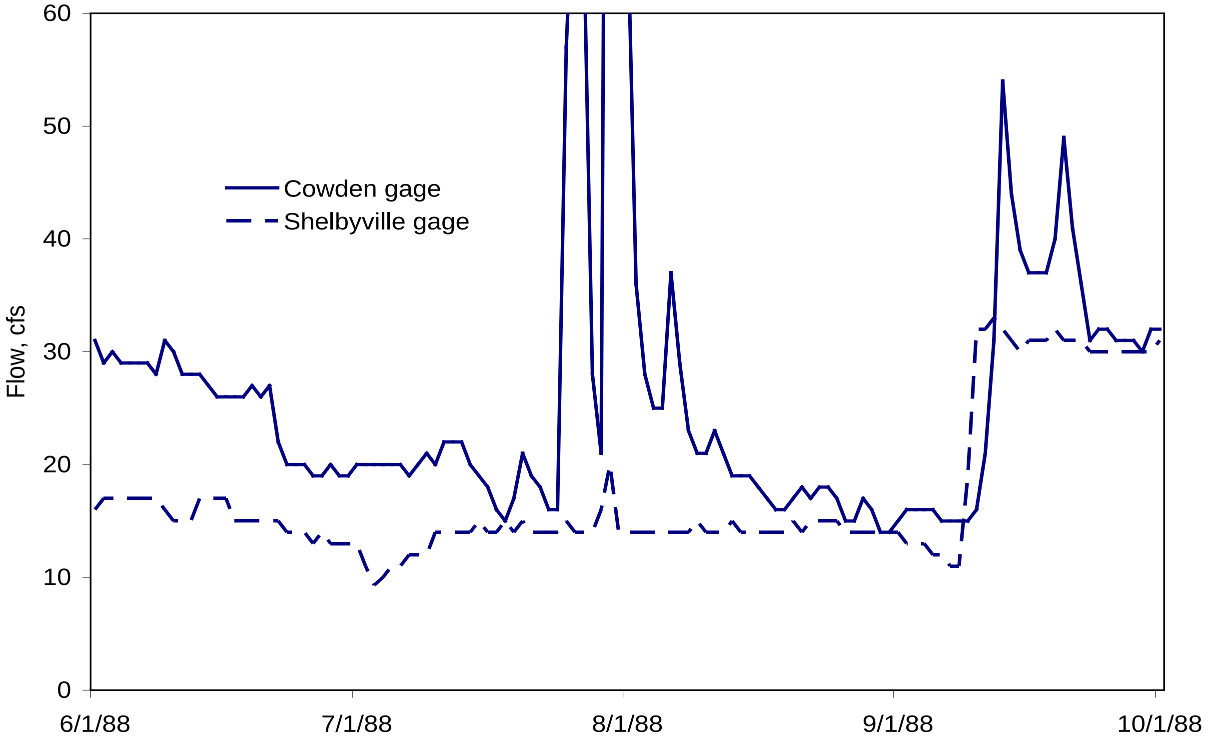

Figure 4.2. Observed daily flows in 1988 from the USGS gages at Shelbyville and Cowden

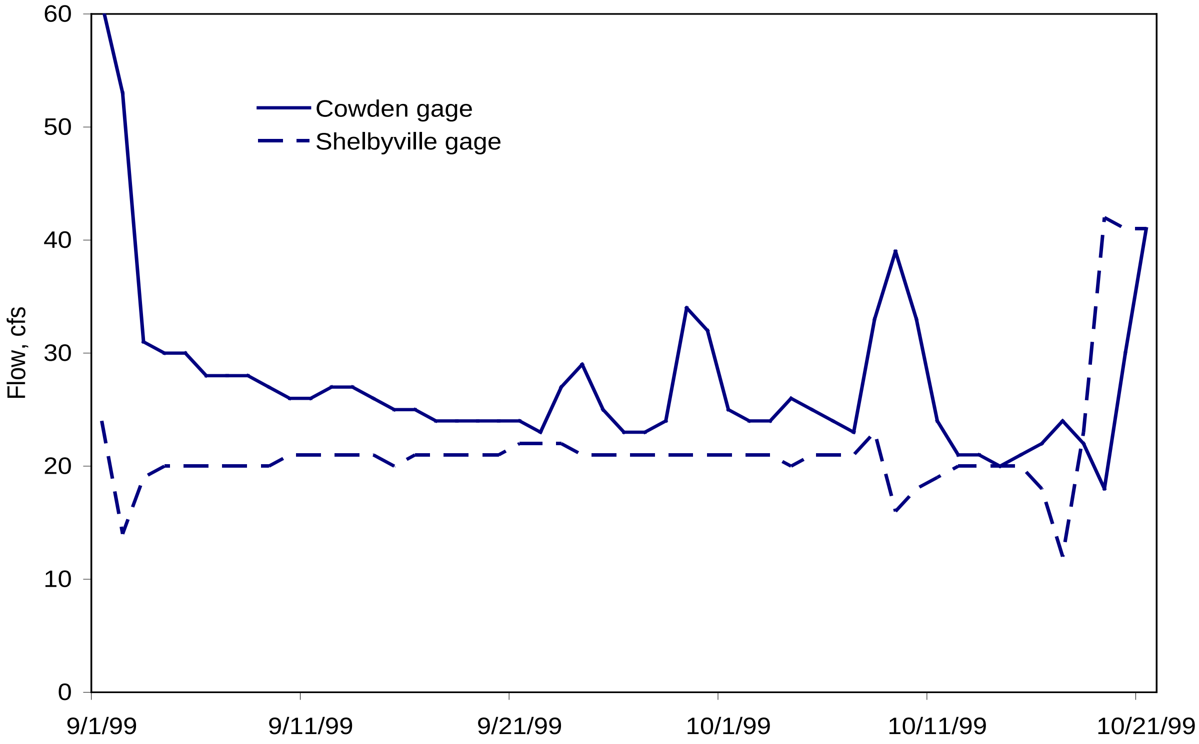

Figure 4.3. Observed daily flows in 1999 from the USGS gages at Shelbyville and Cowden

Observed Conditions during the 2012 Drought

During much of the summer of 2012 the flow observed by the USGS at the Cowden gage was periodically less than the amount of flow observed immediately downstream of Lake Shelbyville (Figure 4.4). Holland Energy withdrawals were assumed to be directly responsible for the reduction in streamflow between Shelbyville and the Cowden gage during these periods. When flow reductions occurred, they were often 4–5 cfs, but on nine separate days were greater than or equal to 7 cfs. If it is assumed that the natural inflow upstream of the Holland Energy intake on these days was about 3 cfs, then the withdrawals from the intake may be estimated to have effectively reduced the river’s flow by 7–10 cfs, or roughly 5–6 mgd. On only one day, September 22, 2012, the flow at the Cowden gage dropped below the 10 cfs threshold that restricts discharges from the power plant. If flows had fallen below the 10 cfs threshold for more days, it is expected that the Holland Energy facility would have needed to request a release of additional water from Lake Shelbyville to continue operations and satisfy the requirements of their NPDES permit.

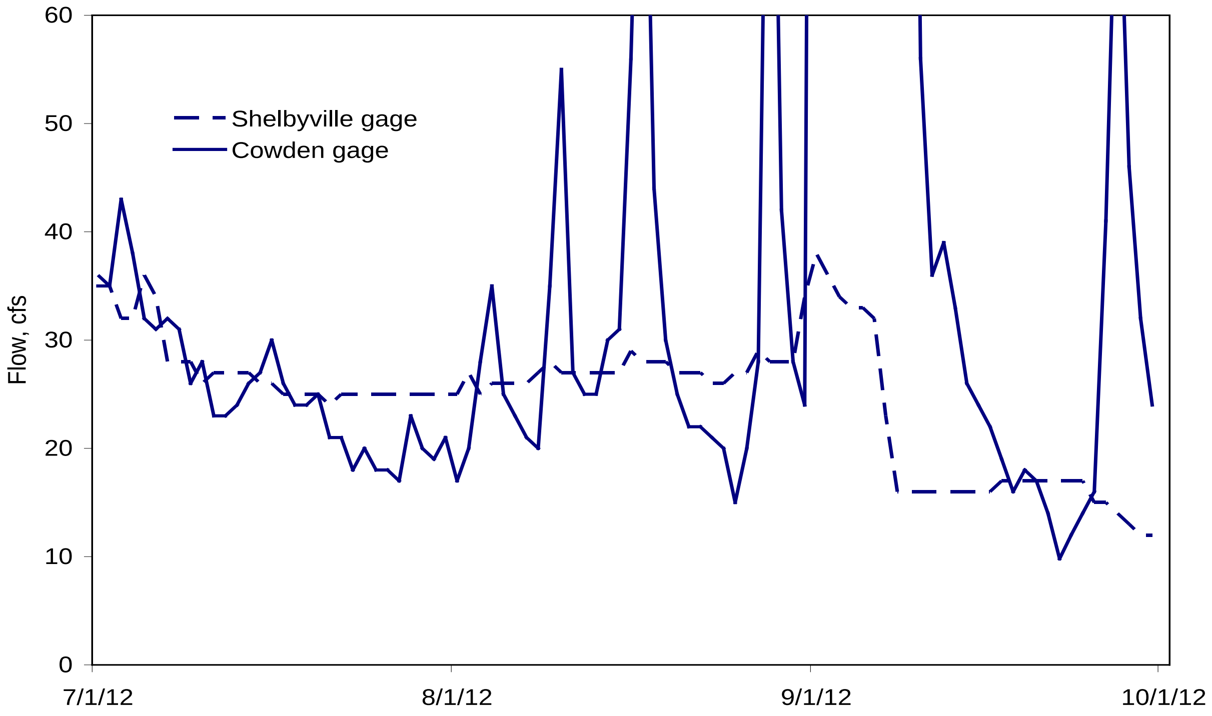

Figure 4.4. Observed daily flows in 2012 from the USGS gages at Shelbyville and Cowden

Simulated Flow for the 1953–1955 Drought of Record

Simulated daily flows for the Kaskaskia River at Holland Energy's intake location were generated for the August 1953–February 1955 drought period. One primary variable considered in simulating these flow amounts was the magnitude of the water quality release from Lake Shelbyville. Since this release has varied in previous drought episodes, "alternative" flow scenarios were also generated. Figure 4.5 shows daily flows for a scenario in which 1) the sustained water quality release from Lake Shelbyville during the 1953–1955 drought is 15 cfs, and 2) there are no designated water supply releases from the lake. Alternatively, if the sustained water release was 20 cfs, daily flow amounts at the Holland intake figure would be identical to those shown in Figure 4.5, except the amounts would consistently be 5 cfs higher. For flows in December 1953, the scenario assumes that the USACE will draw down the level in Lake Shelbyville from summer to winter pool during which the outlet facilities will release large amounts of flow. During such a drought condition, the USACE may instead designate a navigation release from the reservoir. Given the observed timing of low water levels on the Mississippi River in 1953–1955, such a navigation release would likely have occurred during the December 1953 and January 1954 time period.

As shown in Figure 4.5**,** most daily flows at the Holland intake during the 1953–1955 drought condition would be 17–22 cfs, representing an estimated natural inflow of 2–7 cfs above the simulated 15 cfs water quality release from Lake Shelbyville. The lowest values of natural

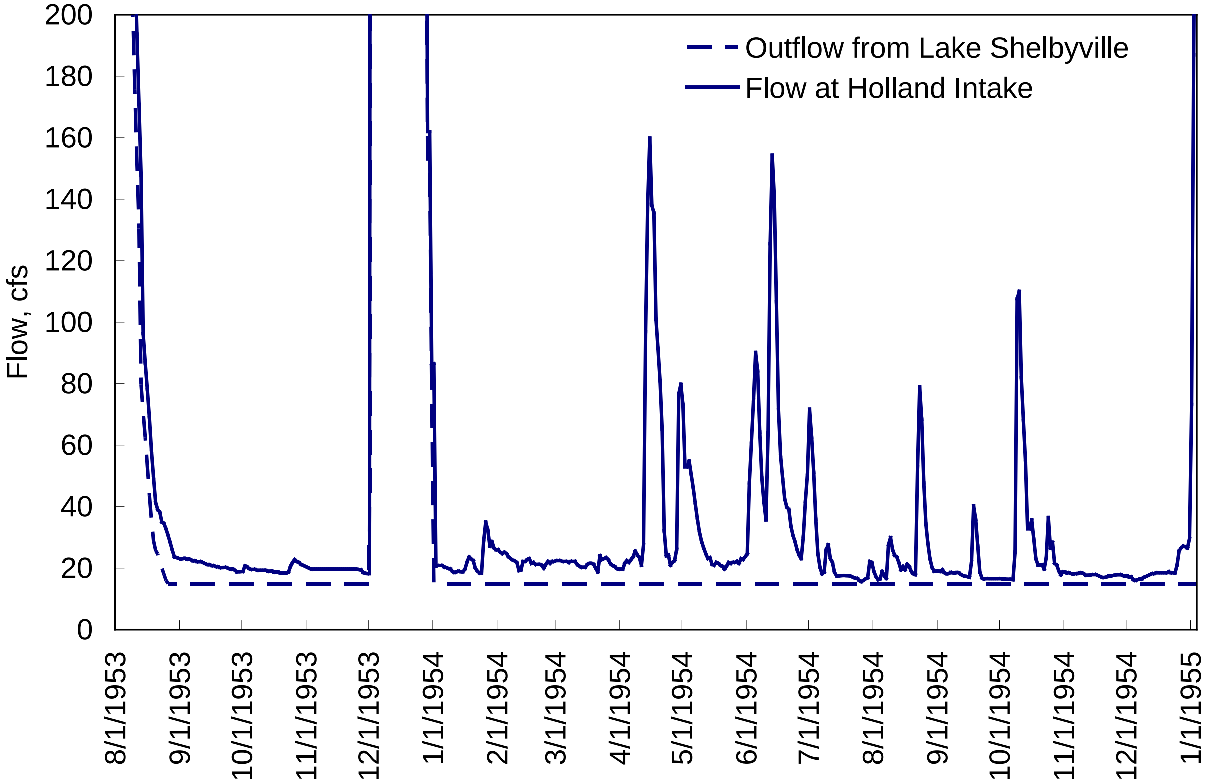

Figure 4.5. Simulated flows from Lake Shelbyville and at the Holland Intake during the 1953–1955 drought conditions assuming no water supply releases are made from Lake Shelbyville. During December 1953, flows were released to lower Lake Shelbyville to its winter pool.

inflow (2 cfs) are estimated to occur during the second summer of the drought period. These simulated flow amounts are consistent with the amounts of natural inflow observed from the Cowden flow records during the 1976, 1988, and 1999 droughts. As the 1953–1955 drought was the worst hydrologic drought on record, several notable differences are observed from each of the other drought episodes:

- It is estimated that during such an extreme drought the Lake Shelbyville water level would remain below its target pool for nearly 17 consecutive months. Thus with the exception of the water released from Lake Shelbyville during the December 1953 drawdown or the possibility of a navigation release, low flow conditions would exist downstream of the dam, and water supply releases could potentially be needed during much of this entire critical period of the drought. In comparison, low flow conditions are expected to occur for roughly nine consecutive months with the next worst drought episode examined here (1976–1977), roughly seven months for the 1988 drought and less than six consecutive months for the 1999–2000 and 2012 droughts.

- Between September 1953 and April 1954 there would essentially be no interruptions in the low flow conditions at Cowden, with the exception of the water released from Lake Shelbyville during the December 1953 drawdown. Not only were there relatively few heavy rainfall events during this extreme drought to cause natural inflows to increase at Cowden, but also the soil moisture conditions were sufficiently dry such that when heavy rainfall events occurred, they resulted in very little runoff.

THE EXPECTED NEED FOR WATER SUPPLY RELEASES DURING DROUGHT PERIODS

Water Supply Releases for Holland Energy

As described earlier, the Holland Energy allocation agreement does not have an expressed restriction on the company's withdrawal water from the Kaskaskia River; however, the plant's NPDES permit requires a river flow of 10 cfs for discharging effluent water into the river. For this analysis, assumedly the power plant cannot operate for long without the need to discharge effluent, and thus the 10 cfs minimum NPDES flow also becomes an effective restriction on withdrawals.

Tables 4.2 and 4.3 examine the conditions that are likely to cause the flow rate at Cowden to fall below 10 cfs and thus require Holland Energy to request a water supply release. Table 4.2 calculations are based on the natural inflows expected to occur in a 1953–1955 drought condition, and Table 4.3 is based on natural inflows occurring during a 1976–1977 drought condition. A number of factors influence the frequency at which releases might be needed during either of these drought conditions, including the Holland Energy withdrawal amount, the water quality release rate at Shelbyville dam, and the amount of water that the HRWS must also withdraw.

Table 4.2. Relationship between the Magnitude of the Lake Shelbyville Water Quality Release and the Number of Days Water Supply Releases Would be Required for the Holland Energy Facility During the 547-day Critical Period of the 1953–1955 Drought (August 22, 1953–February 19, 1955)

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for a 5 mgd withdrawal	
	Additional withdrawal by HRWS is:	
	1 mgd	5 mgd
10.0	358	409
12.5	271	394
15.0	155	369
17.5	29	327
20.0	0	221

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for an 8 mgd withdrawal	
	Additional withdrawal by HRWS is:	
	1 mgd	5 mgd
10.0	403	428
12.5	378	418
15.0	352	408
17.5	260	393
20.0	141	365

Table 4.3. Relationship between the Magnitude of the Lake Shelbyville Water Quality Release and the Number of Days Water Supply Releases would be Required for the Holland Energy Facility during the 271-day Critical Period of the 1976–1977 Drought (May 18, 1976–February 12, 1977)

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for a 5 mgd withdrawal Additional withdrawal by HRWS is: 1 mgd	 5 mgd
10.0	191	223
12.5	146	209
15.0	62	197
17.5	4	161
20.0	0	120

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for an 8 mgd withdrawal Additional withdrawal by HRWS is: 1 mgd	 5 mgd
10.0	222	238
12.5	210	230
15.0	187	222
17.5	148	205
20.0	43	197

If, for example, Holland Energy needs 8 mgd of water and the HRWS is also withdrawing 1 mgd (a total of 9 mgd or 14 cfs), the flow rate upstream of the Holland intake would need to be at least 24 cfs to maintain a flow rate at Cowden (downstream of the intake) in excess of 10 cfs. Under such a scenario and a water quality release rate of 15 cfs from Lake Shelbyville, Table 4.2 indicates that without a water supply release there would be insufficient flow to meet the needs of Holland Energy and HRWS for 352 of the 547 days during the 1953–1955 drought period. This indicates that a water supply release would be needed for Holland Energy roughly 64 percent of the time that it is in operation during such a drought. Under the same assumptions, Holland Energy would need a water supply release for 69 percent of the time (187 out of 271 days) during a 1976–1977 drought period (Table 4.3).

The maximum expected release during a 1953–1955 drought condition would occur if the water quality release from Lake Shelbyville is limited to only 10 cfs, and the HRWS's use increases to its full allocation of 5 mgd. Under such circumstances the percentage of time that Holland Energy would need to request a water supply release during an extreme drought could increase to as much as 78 percent of its operating time (428 out of 547 days), and the total volume of water released from Lake Shelbyville during such a drought would be 10,508 acre-feet (an 8 mgd release over 428 days). Because the release would not be needed for the full 547 days during the drought, the maximum expected release would be less than Holland Energy's effective maximum reserved volume, previously calculated to be 13,400 acre-feet.

The values in Tables 4.2 and 4.3 indicate that the percentage of time that Holland Energy would need a water supply release could fall substantially if either 1) the water quality release from Lake Shelbyville is increased, or 2) the sustained amount of water that Holland Energy needs to maintain its operations is less than 8 mgd. If the Holland Energy plant's water demand is 8 mgd every day for the duration of the drought, and the water quality release from Lake Shelbyville averages around 15 cfs (as has been assumed for most portions of this analysis), the total volume of water needed for additional water supply releases would be roughly 2840 million gallons (8 mgd times 355 days) or roughly 8700 acre-feet. If, however, the plant's average annual demand is 5.3 mgd, as stated in correspondence to OWR, the total volume of the release may be closer to 1882 million gallons (5.3 mgd times 355 days) or roughly 5800 acre-feet.

Water Supply Releases for the Holland Regional Water Supply

As shown in Figures 4.1 to 4.4, there were four drought episodes in the past 40 years in which the flow rate in the Kaskaskia River at Cowden had fallen below 29 cfs for various durations. For example, during the 2012 drought (most of which is shown in Figure 4.4), the flow rate downstream at the Cowden gage was less than or equal to 29 cfs for a total of 71 days. In particular, during the worst part of the 2012 drought between July 9 and August 8, the flow was below the 29 cfs threshold for 29 out of 31 days. The HRWS has a maximum capacity of up to 10 million gallons, an amount that was neither designed to provide a supplemental supply during extended low flow periods nor is sufficient for such a purpose.

The proportion of days during drought that the Cowden gage is expected to fall below 29 cfs is somewhat dependent on secondary factors such as 1) the magnitude of the water quality release at Shelbyville, and 2) the amount of water that is also being withdrawn for Holland Energy. Table 4.4 examines the relationship between those two factors and the number of days pumping would be required during the 1953–1955 drought of record condition. In most scenarios considered in this table, the flow at Cowden is at or below the 29 cfs threshold at least 75 percent of the time (409 days out of 547 days). When the water quality release at Shelbyville is 10 cfs and Holland Energy is also withdrawing water from the Kaskaskia River, that proportion can increase to over 84 percent of the time (462 out of 547 days).

The expected percentage time that a release would be required is only moderately affected by the operations of the Holland Energy facility (Table 4.4). Regardless of whether Holland Energy is operating (and having releases) or not, the flow at Cowden will most often be below 29 cfs, such that HRWS would be required to request a water supply release from Lake Shelbyville.

Table 4.5 is identical to Table 4.4 except that it looks only at the 365-day water year during the 1953–1955 drought that would be used to identify the allocation's maximum annual usage. In most scenarios, the proportion of days in which releases would be required by the allocation agreement is roughly 83 percent, and thus is not much different from the percentage for the entire drought.

Table 4.4. Relationship between the Magnitude of the Lake Shelbyville Water Quality Release and the Number of Days Water Supply Releases would be Required for the HRWS during the 1953–1955 Drought

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for a 1 mgd withdrawal	
	No Holland Energy withdrawal	Combined with Holland Energy withdrawal (8 mgd)
10.0	428	451
15.0	409	444
20.0	369	436
22.5	327	428
25.0	221	421

Shelbyville dam water quality release (cfs)	Number of days a water supply release would be required for a 5 mgd withdrawal	
	No Holland Energy withdrawal	Combined with Holland Energy withdrawal (8 mgd)
10.0	442	462
15.0	435	452
20.0	415	445
25.0	384	437

Table 4.5. Relationship between the Magnitude of the Lake Shelbyville Water Quality Release and the Number of Days Water Supply Releases would be Required for the HRWS during the Oct. 1, 1953–Sep. 30, 1954 Accounting Year

Release from Lake Shelbyville (cfs)	Number of days a water supply release would be required for a 1 mgd withdrawal	
	No Holland Energy withdrawal	Combined with Holland Energy withdrawal (8 mgd)
10.0	293	297
15.0	287	294
20.0	278	287
22.5	248	283
25.0	167	280

Release from Lake Shelbyville (cfs)	Number of days a water supply release would be required for a 5 mgd withdrawal	
	No Holland Energy withdrawal	Combined with Holland Energy withdrawal (8mgd)
10.0	301	305
15.0	287	298
20.0	278	294
25.0	264	287

DISCUSSION

The tables and figures presented in this chapter analyze the proportion of time in which flow rates in the Kaskaskia River, as influenced by the Holland Energy and HRWS water withdrawals, are likely to be insufficient to meet minimum flow requirements as specified by either IDNR allocation agreements or NPDES permits. During that time, those entities would need to request water supply releases from Lake Shelbyville to maintain their operations. Not specifically addressed in the analysis are additional operational considerations needed to maintain these minimum flows, including potential variations in Holland Energy's water demand and flow travel times between Shelbyville and Cowden or the Holland intake.

As shown in Figures 4.1 through 4.5, there are periodic situations within a drought when the Kaskaskia River flow rates at Cowden increase substantially, presumably as runoff from local rainfall events. In many of these cases the flows subside within two to three days. From an operational standpoint, it may be a nuisance to change reservoir releases for short periods, but more problematic is the expectation that it could take several days for a potential reduction in release rates at Shelbyville to affect the downstream location at the Holland intake, by which time the swell in tributary inflows may have subsided. It may thus be necessary to maintain constant water supply releases during such short periods when the river receives local runoff, and subsequently, the percentage of time when water supply releases would be required may be greater than that identified in Tables 4.1 through 4.4.

The simulations indicate that the only extended periods during a 1953–1955 drought episode when the flow at Cowden would be above 29 cfs are 1) when Lake Shelbyville is transitioning from summer pool to winter pool, and in the process, releasing high flow rates, 2) for roughly 40 days in the late spring of 1954 when natural tributary inflows downstream of the Shelbyville Dam would be expected to elevate the flow levels at Cowden, and 3) in the last few months of the critical drought period when natural tributary inflow downstream of the dam begins to recover. Based on these results, HRWS should reasonably be expected to plan on requesting water supply releases equal to its withdrawal rate for at least 80 percent, if not all of an extreme extended drought period, to address the minimum flow restriction specified in the IDNR contract. The only extended drought condition when this would not be the case is if the releases from Lake Shelbyville were sustained at high levels (such as 25 cfs or more). If the HRWS withdraws its allocated rate of 5 mgd between 80 and 100 percent of the drought's duration, then its total use during the 1953–1955 drought would be between 6715 and 8400 acre-feet.

Similarly, if the power production and water needs of the Holland Energy plant are variable over several consecutive days, it may be difficult to anticipate and coordinate water supply releases as needed to meet the changing needs of the power plant and also maintain the minimum flow requirements at the Cowden gage. During periods of the lowest flow conditions at Cowden, it is expected that Holland Energy should plan for a relatively constant release to support the flow needed for their peak rate of withdrawal. The minimum rate of that release would be the amount needed to maintain a 10 cfs or greater flow rate at the Cowden gage as required by the Illinois Environmental Protection Agency (IEPA) to maintain the company's return flow to the river. To this extent, the minimum amount of Holland Energy's water supply release would be dependent on the concurrent rate of flow being released from Lake Shelbyville by the USACE for maintaining water quality in the river. If the water quality release rate from Lake Shelbyville were as low as 10 cfs, for example, then the constant water supply release rate for Holland Energy might need to equal (or come close to) their peak rate of withdrawal. As indicated in Table 4.2, the Holland Energy's water supply release could potentially be needed throughout much of an extreme drought's duration, calculated to be as much as 78 percent of the time. For this analysis, the release rate would be assumed to be the full 8 mgd amount as permitted by the IDNR allocation agreement. Because a constant release rate may be needed during much of the drought, instead of being limited to specific days of need, there is the possibility, and perhaps likelihood, that the average annual release rate from Lake Shelbyville could exceed Holland Energy's projected 5.3 mgd average annual demand (equivalent to 8900 acre-feet) during a drought-of-record condition. If Holland Energy potentially requires 8 mgd for 78 percent of the drought's duration, as computed in this study, then its total usage during the 1953–1955 drought would be about 10,475 acre-feet. On the other hand, if Holland Energy were to require 8 mgd for 100 percent of the drought's duration, as calculated, then their total usage during the 1953–1955 drought would be about 13,400 acre-feet.

Finally, it should be acknowledged that this discussion focuses on water needs and releases during an extreme, extended drought, as represented by the 1953–1955 drought. Simulated conditions from the 1976–1977 drought (Table 4.3) illustrate that releases would be needed for noticeably fewer days. With Holland Energy withdrawing at a rate of roughly 8 mgd, the estimated flow at the Cowden gage could fall to as low as 10 cfs about 1 in 10 years, on average, triggering the need for reservoir releases. During most of such less-severe (10-year) drought episodes, releases would be needed for substantially fewer days than even that shown for the 1976–1977 drought. Since these less-severe drought events occur with much greater frequency than extreme events (like the 1953–1955 drought), when releases are first needed, it is much more likely that the total annual amount of water used (and its associated annual water supply costs) could be much less than the full allocated amount.

5. THE POTENTIAL FOR WATER SUPPLY RELEASES FROM CARLYLE LAKE DURING SEVERE DROUGHT

In evaluating potential water supply releases from Carlyle Lake, the focus is on water needs within the Kaskaskia Navigation Channel (i.e., the lowest 37 miles of the Kaskaskia River). The substantial amount of water stored in the navigation channel is also designated as the "navigation pool," and sometimes informally described as the "third" federal reservoir in the Kaskaskia River system. Because water is pooled behind the Kaskaskia Lock and Dam during low flow or drought conditions, all flows entering the navigation channel are collectively available for various competing uses, and the pool also provides a limited amount of storage which can be drawn upon when needed. The three largest water users from the navigation channel are the Prairie State Generating Company (Marissa facility), the Dynegy Midwest Generation (Baldwin facility), and the Kaskaskia Lock and Dam (Figure 5.1). The two electricity-generating facilities hold the two largest water supply allocations from both Lake Shelbyville and Carlyle Lake, and collectively account for roughly 28 of the 42 mgd allocated from the two federal reservoirs. Three community supply systems, Evansville, the Kaskaskia Water District, and Sparta, withdraw from the Kaskaskia Navigation Channel. Three upstream community systems have intakes on the river between Carlyle Lake and the navigation channel, namely Carlyle, Nashville, and the Summerfield Lebanon Mascoutah (SLM) Water Commission. The collective average withdrawal rate for all six community systems is slightly greater than 6 mgd, which is well within the range that can be provided by natural inflows. Nashville's intake on the Kaskaskia River is a supplemental source for emergency use.

Several factors affect the characteristics of potential water supply releases from Carlyle Lake:

- During times of low flow, the water need for lockages at the Kaskaskia Lock and Dam competes with the water needs for the two power plants. Thus a study of potential water supply releases from Carlyle Lake must also examine the potential water needs of the Kaskaskia Lock.
- Roughly 3000 square miles or 53 percent of the total drainage area of the Kaskaskia River watershed is located downstream of Lake Carlyle, and contributes flow to the navigation channel that is not controlled by releases from Carlyle Lake. As a result, there can be a considerable amount of "natural inflow" available for the power plants (as compared, for example, to the HRWS and Holland Energy withdrawals downstream of Lake Shelbyville). The Carlyle Lake water quality release alone is usually not sufficient to meet the combined water needs of the power plants and the Kaskaskia Lock; however, the combination of the water quality release and the natural inflows is often sufficient to meet these needs except during the more extreme drought conditions.
- By allowing the operation level of the Kaskaskia navigation pool to be lowered, storage in the pool can be made available to water users when a water supply deficit exists, i.e., when inflows alone are insufficient to meet water needs. For simulations conducted with this analysis, the navigation pool is allowed to fall 0.4 feet, producing roughly 1500 acre-feet of additional supply before there is a call for water supply releases from Carlyle Lake. This available in-pool storage is often sufficient to avoid the need for water supply releases during moderate drought episodes.

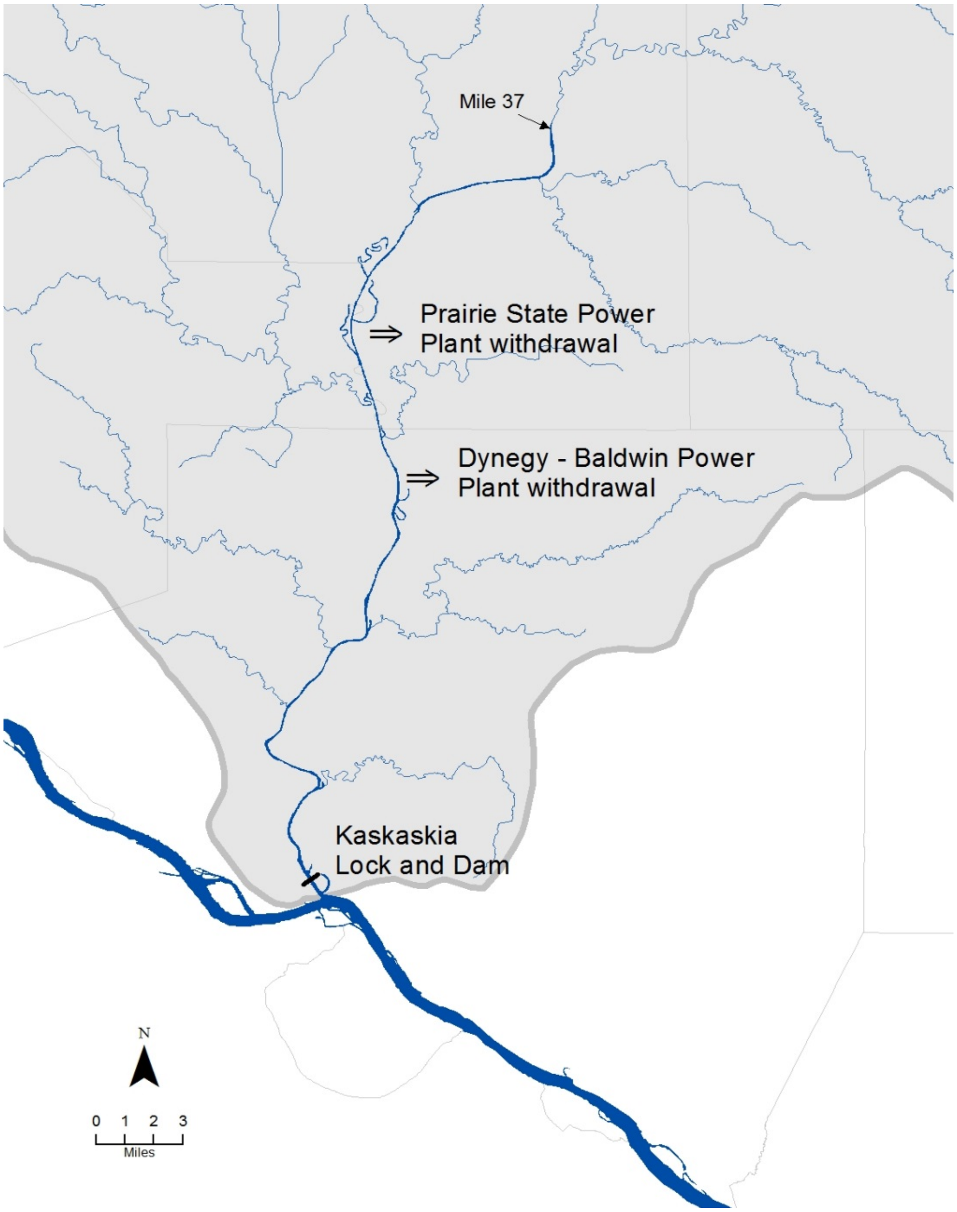

Figure 5.1. The Kaskaskia Navigation Channel and major users of water in the channel

WATER NEEDS FOR THE PRAIRIE STATE AND DYNEGY-BALDWIN POWER STATIONS

Prairie State Energy Campus

Although the OWR designates a portion of Prairie State's allocation from Lake Shelbyville, in practice, all of its needed releases will come directly from Carlyle Lake. During such conditions, the USACE is expected to release water from Lake Shelbyville to supplement Carlyle Lake as needed to balance out the joint water-level management of both lakes, but not as a direct response to Prairie State's allocation requests.

Water needed to cool the Prairie State generating units is provided by a raw water reservoir located on the Prairie State campus. The reservoir is roughly 40 feet deep, and at normal pool has a surface area of 65 acres and a reported capacity of 712 million gallons. The water level could potentially be lowered as much as 28 feet below normal pool, which could provide water for up to 20 days of operation during peak summer usage without replenishment, although the preferred operation would keep the reservoir near its full capacity. The Prairie State facility had not yet reached full operating capacity at the time this report was prepared; but at the projected full capacity, the average consumptive water use of the facility is expected to be 21.6 mgd, ranging from less than 19 mgd during the winter to over 25 mgd in summer. Peak water usage during the summer is expected to consume as much as 27.5 mgd. The four pumps located at the intake on the Kaskaskia Navigation Channel have a combined pumping rate of roughly 35 mgd. Effluent return flows to the navigation channel are small compared with the consumptive use, with a projected average return flow rate of 1.4 mgd.

Although its projected water needs exceed 20 mgd, Prairie State's allocation agreement with IDNR presently allows for a maximum release rate from Carlyle Lake of 18 mgd. As stated in the allocation agreement, Prairie State's withdrawals from the Kaskaskia River must be restricted to the maximum release amount (18 mgd) during minimum flow circumstances when the Kaskaskia River would otherwise fall below its specified protected flow level. However, no contract language restricts withdrawals to 18 mgd at other times. If an extended minimum flow circumstance occurred during the summer when Prairie State's water demand was high, the amount of water pumped from the navigation channel would not be sufficient to fully replace Prairie State's withdrawals from its raw water reservoir, leading to the possibility that the raw water reservoir could fall low enough to limit the facility's power production.

Table 5.1. Projected Water Consumption Estimates Provided by Prairie State Generating Company

Projected water consumption (mgd) by season	
Summer	25
Spring	23
Fall	23
Winter	19
Average	21.6
Maximum daily	27.5

During a severe drought event, the water that Prairie State withdraws from the Kaskaskia Navigation Channel will be supplied by a combination of natural tributary inflows to the Kaskaskia River, a portion of the water quality release from Carlyle Lake, and, when needed during deficit conditions, a requested release of water supply storage from Carlyle Lake. In its water supply agreement with IDNR, Prairie State has been allocated a maximum annual release rate of 13.35 mgd from storage in both federal reservoirs. As noted though, all requests for releases will effectively come from Carlyle Lake. The IDNR allocation potentially obligates about 22,400 acre-feet of water supply storage from the two reservoirs, an equivalent or effective maximum volume associated with using 13.35 mgd over the 547-day critical drought period during the 1953–1954 drought of record.

Dynegy-Baldwin Power Station

The water needs for the Dynegy Power Station at Baldwin, presented below, are prepared and analyzed based on data prior to 2016 when all three of the station's generating units were in operation, producing an output of roughly 1800 megawatts. In October 2016, one of the generating units (Unit #3) was idled, and it is reported that a second unit (#1) may be idled in 2018. The inactive generating unit is currently being kept in operable condition (mothballed). The discussion section at the end of this chapter includes a qualitative assessment of the changing water needs if one or two of the generating units were to be permanently shut down. However, all quantitative analysis presented here is based on the possibility that the power station will resume operating at full capacity in the future.

The primary source of cooling water for the Dynegy Power Station is Baldwin Lake, a 2000-acre rectangular man-made lake that has a capacity of roughly 26,000 acre-feet. On an average day the Baldwin station circulates roughly 1.3 billion gallons of water between the lake and its generating units to provide cooling for the units. The circulated water returns to Lake Baldwin at an elevated temperature, and the forced evaporation from the lake (the amount above the normal evaporation rate for the reservoir if it were not artificially heated) is expected to be roughly equivalent to 2 percent of the total amount of circulated water. Make-up water for the evaporative loss is predominantly supplied by withdrawals from the Kaskaskia Navigation Channel, although a small stream with a drainage area of less than 2 square miles also flows into the cooling lake and provides a small supplemental inflow primarily during wet periods. Water is also diverted for use in ash sluicing, and effluent water from that usage is returned to a settling basin and eventually discharged to the navigation channel. The average annual amount of return flow to the navigation channel is normally 4500 to 5000 million gallons, or an average rate of roughly 13 mgd. The return flows back to the Kaskaskia River are available for other water demands in the lower portion of the navigation channel.

The Baldwin facility withdraws an average of 26 million gallons per day from the Kaskaskia Navigation Channel, with the annual withdrawal rate in 1999–2012 varying from 17 to 34 mgd, as influenced by variations in plant production and weather conditions, with more make-up water typically needed during dry years. Since 1999, in only four years has Dynegy-Baldwin withdrawn more than an annual average of 31 million gallons per day from the navigation channel. Two of those years (1999 and 2007) were the driest years during the 1999–2011 period. Withdrawals during the 2012 drought year averaged only 19 mgd, but the Dynegy Operating

Company has indicated that during 2012 all water used for ash sluicing was redirected back to the cooling pond to conduct maintenance on their ash pond system, thereby substantially reducing the needed amount of make-up water. If that maintenance had not occurred in 2012, such that ash sluicing water had been returned to the navigation channel after settling, then Dynegy's average withdrawal rate for 2012 would likely also have been in excess of 31 mgd. Notably, Dynegy's withdrawal amount has increased over time, with reported annual withdrawals being roughly 10 percent greater in 1999–2012 than in the late 1980s when the ISWS last conducted a study of water needs in the navigation channel (Durgunoglu and Singh, 1989).

Table 5.2 shows the expected seasonal pattern in withdrawal amounts and effluent discharges during an average year and a severe drought condition. An estimated gross withdrawal amount during a particularly hot and dry summer month may be as high as 45 mgd. Dynegy has three pumps with a combined maximum pumping capacity of 58 mgd (90 cfs). As stated in the IDNR allocation agreement, Dynegy must cease pumping when the flow in the Kaskaskia River falls below its protected minimum flow level unless the plant requests releases from Carlyle Lake that are equivalent to their gross withdrawal rate.

During a severe drought event, the water that Dynegy withdraws from the navigation channel will be supplied by a combination of natural tributary inflows to the Kaskaskia River, a portion of the water quality release from Carlyle Lake, and, when needed during deficit conditions, a requested release of water supply storage from Carlyle Lake. In its water supply agreement with IDNR, Dynegy has been allocated a maximum annual release rate of 14.35 mgd from the storage in Carlyle Lake. The IDNR allocation potentially obligates about 24,100 acre-feet of water supply storage from the lake, which is the equivalent or effective maximum volume associated with using 14.35 mgd over the 547-day critical drought period during the 1953–1954 drought of record.

Table 5.2. Water Withdrawal Scenario for Dynegy's Baldwin Power Station (mgd)

Month	Average withdrawal	Severe drought withdrawal	Effluent flows during drought	Net withdrawal during severe drought
January	20	25	15	10
February	20	25	15	10
March	20	30	13	17
April	25	35	13	22
May	30	40	12	28
June	35	45	10	35
July	35	45	10	35
August	35	45	10	35
September	30	40	10	30
October	25	35	10	25
November	20	30	10	20
December	20	25	13	12
Annual	26	35	12	23

COMMUNITY WATER SUPPLY NEEDS FROM THE LOWER KASKASKIA RIVER

In addition to the two large withdrawals for Prairie State and Dynegy, five community water supply systems regularly withdraw water from the Kaskaskia River downstream of Carlyle Lake. The average collective water demand for the Kaskaskia Water District, SLM Water Commission, and the communities of Carlyle, Evansville, and Sparta is roughly 6 mgd. The three growth scenarios developed by Dziegiewleski and Thomas (2011) project that by 2050 the collective demand from these systems will increase 16 to 29 percent above their current use. Thus, the largest (More Resource Intensive, MRI) growth scenario indicates that collective withdrawals will be no more than 8 mgd by 2050. The City of Nashville, which has a water demand of 0.6 mgd, also has an emergency intake on the Kaskaskia River, and by the end of an extreme extended drought could potentially rely on the river for much of its supply. The collective demand for all of these community systems is substantially less than the estimated natural inflow to the river downstream of Carlyle Lake, which is described in more detail later in this chapter.

WATER NEEDS FOR THE KASKASKIA LOCK AND DAM

The Kaskaskia Lock allows for boats to be raised and lowered between the Mississippi River and the Kaskaskia Navigation Channel. The lock is 600 feet long, 84 feet wide, and can be operated up to a maximum lift of 29 feet (difference in elevation between the navigation pool and the Mississippi River). The navigation channel is typically maintained at an operating elevation of 368.8 feet. Under normal water level conditions in the Mississippi River, the elevation difference between the navigation channel and the river is often 5 to 15 feet. During these conditions, the amount of water needed to fill the lock ranges from 2 to 5 million gallons. At times of near maximum lift, such as when drought creates low water levels in the Mississippi River, as much as 10 million gallons may be needed for a single lockage.

Projected Recreational Traffic during a Severe Drought

Recreational boating activity along the navigation channel in any year is greatly influenced by weather conditions, and the volume of traffic is greatest in dry years. The numbers of vessels and lockages are expected to be the largest during summer drought periods, assuming that no restrictions are placed on those lockages because of a lack of available water in the navigation channel. Table 5.3 lists the number of recreational vessels and lockages over the past 15 years. The annual number of vessels moving upstream is roughly equal to those moving downstream and thus would be roughly half of the annual total listed in Table 5.3.

The number of recreational lockages was low in 2008–2011, generally as a result of wet summer weather. Over the years listed, lockages have also been reduced as a result of the construction of the upper boat ramp located immediately upstream of the lock and dam. Prior to the construction of that boat ramp, many vessels had to pass daily through the lock to reach the ramp located downstream.

Table 5.3. Number of Lockages and Recreational Vessels Passing through the Kaskaskia Lock, 1997–2012

		Number of Lockages		
Year	*Annual Number of Vessels*	*Annual*	*14-week Summer*	*Summer Holiday Weekends*
2012	2222*			
2011	n/a	413	305	
2010	1012	522	363	
2009	1984	831	507	
2008	1491	731	395	67
2007	**3301**	**1595**	**981**	**185**
2006	3183	1382	937	210
2005	n/a	1290	890	178
2004	n/a	1038	509	85
2003	n/a	1427	899	153
2002	n/a	1586	975	170
2001	n/a	1323	853	195
2000	n/a	1400	853	163
1998	6605	1767	n/a	
1997	7633	1964	n/a	

Data provided by the USACE
*amount for a partial year is listed

The peak number of recreational lockages during the past 10 years occurred in 2007. The recreational activity during that year was selected as the best available representation of the high activity to be expected during a severe drought, even though the event in 2007 was not considered a severe drought. In comparison, when the available data for the 2012 drought year is projected over a 12-month period, the number of total recreational vessels is estimated to be 2500 to 2600, roughly 20 to 25 percent lower than the number in 2007. It is not known if the recreational activity during the extraordinarily warm and dry conditions of 2012 (through the end of August) was suppressed as a result of the poor economy or other factors. Regardless, it was deemed appropriate to pattern potential lockages and associated water needs through the 2050 planning horizon using 2007 as the year having the greatest recreational activity.

On average, roughly eight recreational lockages per day occur in summer, mostly during the weekends. However, to create a water budget for the navigation channel, no distinction was made between weekdays and weekends, with summer values estimated herein representing the collective average of both. The only exception is for the three summer holiday weekends when recreational use tends to be extremely high.

The following distribution was developed to represent expected lockages during a severe drought episode under current conditions. The total annual number of lockages using the above distribution is 1517, somewhat less than the recorded number of lockages in 2007. These values do not reflect possible restrictions in lockage amounts that could be imposed by the USACE during such severe drought conditions.

Summer holiday weekends (Memorial Day, Labor Day, 4th of July)	24 per day
Remainder of the summer (between Memorial Day and Labor Day)	8 per day
Remainder of May and September	5 per day
April and October	3 per day
March and November	2 per day
December, January, and February	<1 per day

Note that the above numbers represent lockages for recreational vessels traveling in both upstream and downstream directions. The expected number of upbound lockages (those which require water from the navigation channel) is half of the amounts listed above.

To our knowledge, there are no projections or expectations pertaining to future changes in recreational traffic for the navigation channel. The 2050 projections required for this study have assumed no growth in recreational boating for both the Baseline and Less Resource Intensive (LRI) planning scenarios. For the More Resource Intensive (MRI) scenario, a modest increase in the number of summer recreational lockages (an additional two lockages per day or one upbound lockage) is assumed.

Scenarios of Projected Growth in Commercial Navigation

The amount of commercial navigation passing through the Kaskaskia Lock and Dam has varied considerably over the years, with the greatest rate of commodities (around 4 million tons per year) being transported through the lock in the late 1980s. In the decade prior to the completion of the Prairie State Energy Campus, the amount of traffic was slightly less than 1 million tons per year, but since has increased to 1.4 tons per year. The greatest increase in tonnage is associated with the shipment of scrubber limestone needed by the Prairie State Energy Campus.

The Kaskaskia Regional Port District's (KRPD) projections for the next 10 years show considerable potential for growth of commercial traffic, with projections of up to 10 million tons per year. Ed Weilbacher, General Manager of the KRPD, has indicated that this tonnage projection essentially represents the most optimistic scenario and would also provide a realistic cap to the expected growth through the remainder of the 2050 planning horizon for the regional water supply plan. If commercial traffic were to reach this amount, the predominant contributing factor would be the exportation of coal, although growth in grain exports could account for roughly 10 percent of this projected increase in tonnage. However, in recent years there has been a decline in the coal market, and most of the locally mined coal is being used by the two power plants instead of being exported. Over the past 35 years since the navigation channel has been in operation, the peak amount of commercial barge traffic passing through the Kaskaskia Lock was 4.4 million tons, which occurred in 1989.

To assess potential water needs for the Kaskaskia Lock during drought episodes, the following three different scenarios were created based on varying levels of projected commercial navigation growth.

- Less Resource Intensive (LRI) Scenario – Commercial navigation through 2050 is assumed to remain roughly at its current level with barges needed to bring scrubber limestone to the Prairie State generating facility. This corresponds to a total annual of 1.5 to 2.0 million tons per year.

- Baseline (BL) Scenario – The baseline scenario assumes that growth continues in the amount of coal and grain to be exported from terminals in the navigation channel. Commercial navigation is assumed to increase to between 4.0 and 5.0 million tons per year, similar to the tonnage observed in the late 1980s, but with additional barges for limestone.

- More Resource Intensive (MRI) Scenario – Commercial navigation is assumed to increase to between 8.0 and 10.0 million tons per year.

Relationship between Commercial Navigation and the Number of Lockages

Most loaded barges that pass through the Kaskaskia Lock and Dam generally carry 1400 to 1600 tons of goods or materials. Although the Kaskaskia Lock can generally accommodate four barges per lockage, the lockage records from the past decade indicate that there is typically an average of two barges per commercial lockage. If the total volume of barge traffic were to increase, a reasonable expectation is that the number of barges per lockage will also increase slightly, especially if much of the activity is coming from a single sector such as coal exportation. Thus for the MRI scenario, the number of barges per lockage was projected to increase to three. Most barges are expected to return empty (but still require a lockage).

Turnbacks

A turnback occurs when consecutive lockages are made in the same direction (either upbound or downbound) in between which the lock chamber needs to be emptied or filled without accepting any new vessels. During the 2007 water year, for example, when 2114 lockages were made, an additional 725 turnbacks were needed (or an average of two per day). Turnbacks are generally counted separately and are not included in lockage amounts, but must be accounted for in estimating water demands for the navigation channel. An analysis of Kaskaskia Lock records from the past 15 years indicates that, on average, a turnback is needed for every 4 commercial lockages and every 2.5 recreational lockages. Turnbacks often occur with summer recreational traffic, and as such their number might be reduced somewhat during drought conditions by restricting the frequency of recreational lockages.

Table 5.4. Projected Annual Total for All Lockages and Turnbacks (Upbound and Downbound) for the Three Scenarios

Less Resource Intensive Scenario (1.5–2 million tons per year)	
Total Lockages and Turnbacks	3299
Recreational	1517
Commercial	940
Turnbacks	842
Baseline Scenario (4–5 million tons per year)	
Total Lockages and Turnbacks	4749
Recreational	1517
Commercial	2100
Turnbacks	1132
More Resource Intensive Scenario (8–10 million tons per year)	
Total Lockages and Turnbacks	6969
Recreational	1719
Commercial	3650
Turnbacks	1600

Water Demand Scenarios for the Kaskaskia Lock and Dam

Three lockage scenarios, listed in Table 5.4, were created for the Kaskaskia Lock and Dam based on the scenarios of projected growth in commercial navigation through the year 2050. As noted earlier, the projected number of recreational lockages is kept constant except for the MRI scenario.

For each scenario, Table 5.5 provides an estimate of the average daily number of upbound lockages and turnbacks to determine water demands. Seasonal lockage numbers reflect differences in recreational boat traffic. Commercial navigation is expected to be roughly uniform throughout the year.

The water demand for each upbound lockage is also dependent on the lift needed between the tailwater level below the lock (essentially the water level in the Mississippi River) and the pool level of the navigation pool, which is normally maintained at an elevation of 368.8 feet. If, for example, the Mississippi River has a very low flow amount with an elevation of 345 feet, the amount of lift that a lockage must provide is nearly 24 feet and roughly 9 million gallons of water from the navigation channel would be needed to fill the lockage chamber for each upbound lockage. If an average of seven lockages per day were needed during such a period, the estimated total water needs for the lock and dam would be 63 mgd. In such a case, the 63 mgd needed for lockages would expectedly exceed the maximum net withdrawal of water from the navigation channel for operating both the Prairie State and Dynegy power stations.

Table 5.5. Projected Seasonal Upbound Lockage (and Turnback) Rates for the Three Scenarios

- Less Resource Intensive Scenario (LRI)

Summer holiday weekends (Memorial Day, Labor Day, 4th of July)	15 per day
Remainder of the summer (between Memorial Day and Labor Day)	7 per day
Remainder of May and September	5 per day
April and October	4 per day
March and November	3 per day
December, January, and February	2 per day

- Baseline Scenario (BL)

Summer holiday weekends (Memorial Day, Labor Day, 4th of July)	17 per day
Remainder of the summer (between Memorial Day and Labor Day)	9 per day
Remainder of May and September	7 per day
April and October	6 per day
March and November	5 per day
December, January, and February	4 per day

- More Resource Intensive Scenario (MRI)

Summer holiday weekends (Memorial Day, Labor Day, 4th of July)	20 per day
Remainder of the summer (between Memorial Day and Labor Day)	12 per day
Remainder of May and September	9 per day
April and October	8 per day
March and November	7 per day
December, January, and February	6 per day

Maximum Demands during Severe Drought

As evaluated in this study, future change to commercial barge traffic is the largest variable in projecting water demands from the navigation channel. Withdrawals for power plant use are held constant over the 2050 planning horizon, although the amount varies by season. Maximum demand rates occur during summer droughts and include an estimated 25 mgd maximum consumption rate from evaporation. With the LRI scenario, the maximum summer demand can approach 150 mgd (230 cfs). With the BL scenario, the maximum summer demand is 170 mgd (260 cfs), and with the MRI scenario, the maximum demand is 195 mgd (300 cfs).

AVAILABLE INFLOW TO THE NAVIGATION CHANNEL DURING SEVERE DROUGHT

Three sources or components define the amount of flow that enters the navigation channel: 1) water quality releases from Carlyle Lake, 2) natural inflows entering the Kaskaskia River downstream of Carlyle Lake, either from tributary streams or baseflow originating from groundwater sources, and 3) special releases from Carlyle Lake to meet downstream water supply or navigation needs. To date there have been no such special releases from Carlyle Lake;

however, as analyzed later in this chapter, the expected water supply releases (and possibly navigation releases) would occur during a severe drought condition. If a navigation release were to occur, during the time of that release there would be 1) a cessation of the water quality release, and 2) a requirement for concurrent water supply releases unless natural inflows alone were sufficient to meet all downstream water supply demands.

During some drought episodes that are not extreme, the combined flow from the natural tributary inflow and the water quality release from Carlyle Lake is often sufficient to meet water needs in the navigation channel. As indicated in the results, only during the more severe droughts might water supply releases be needed. This is in contrast to the projected releases from Lake Shelbyville (for HRWS and Holland Energy), whose need is anticipated for more frequent drought events such as a 10-year drought.

Water Quality Releases from Carlyle Lake during Drought Periods

The official minimum flow release at Carlyle Lake is 50 cfs. However, during periods of hot weather this release amount is sometimes insufficient to maintain desirable water quality in the river downstream, particularly in maintaining the IEPA standard minimum concentration for dissolved oxygen. For this reason, the amount of water the USACE releases during the summer from Carlyle Lake is typically a higher flow amount, and it is not uncommon for summer water quality releases to be between 60 and 100 cfs. During the 1988 drought, the release was increased to 100 cfs for much of the summer, and during the 2012 drought the summer release was increased to as much as 150 cfs. According to their representatives, the USACE is investigating the possibility of restructuring their outlet facilities at Carlyle Lake so that water used for the minimum release may originate from a cooler, deeper level within the lake that has the potential to maintain higher dissolved oxygen levels downstream at lower flow rates. Thus, in the future, the summer water quality release at Carlyle Lake could be less than what has been observed in recent drought periods and potentially could be as low as the required minimum release of 50 cfs.

As discussed later in this chapter, the amount of the summer water quality release from Carlyle Lake can have a substantial impact on the availability of flow for downstream uses such as that needed for the Prairie State and Dynegy-Baldwin withdrawals as well as the amount needed for commercial and recreational lockages. Because of the variation to date in summer water quality releases and the uncertainty in how those conditions may change in the future, scenarios were analyzed based on the possibility that future summer water quality releases might vary from 50 to 150 cfs.

Natural Inflows between Carlyle and the Kaskaskia Lock and Dam

Roughly 53 percent of the Kaskaskia River watershed (an area of 3050 square miles) drains into the river downstream of Carlyle Lake. As a result of this large contributing drainage area, usually a considerable amount of natural inflow reaches the river in the reach between Carlyle and the Kaskaskia Lock and Dam. Below the Carlyle dam, the Kaskaskia River flows roughly 58 miles before it reaches the head of the navigation channel at Fayetteville. Two of the three largest tributaries to the Kaskaskia River, Shoal Creek and Crooked Creek, flow into the river in this reach. Downstream of Fayetteville, the river forms the 36-mile long pool created by the Kaskaskia Lock and Dam. Silver and Richland Creeks are the largest tributaries in this reach.

Because of the pooled condition of the navigation channel, all inflows into the channel are generally considered available for any withdrawers from the channel to use. Thus in evaluating water availability and the possibility of deficits in availability occurring during drought periods, it is essential to consider the total inflows as they might be calculated at the most downstream point of the navigation channel, that being at the Kaskaskia Lock and Dam. However, there is no streamgage at this location, and flows must be analyzed using the two most downstream USGS gages located at New Athens and Venedy Station. The Venedy Station gage is located 20 miles upstream of the navigation channel and has been in operation since the 1970 water year. The New Athens gage is located within the navigation channel immediately downstream of its confluence of Silver Creek. A gage was operated at this location before the Kaskaskia Lock and Dam was constructed, in 1907–1912, 1914–1921, and 1935–1971, and provides a good record from which to estimate inflow conditions during several historical drought periods. The gage was most recently reactivated in 2009 with an acoustic velocity meter capable of determining flow amounts in a low-velocity pooled condition such as the navigation channel.

Observed Conditions during Historical Droughts from 1934 to 1970

For periods prior to the construction of Carlyle Lake and the navigation channel, the natural inflow to the Kaskaskia River downstream of Carlyle is evaluated by comparing the observed flow records at Carlyle and New Athens. Following the construction of Carlyle Lake, the natural inflow can be initially evaluated by comparing the flow records at Carlyle and Venedy Station. In both cases, it is necessary to also estimate inflows downstream of the respective gages to simulate a value of the total natural inflow into the navigation channel that is needed to evaluate total water availability.

Low flow conditions during a number of drought episodes from 1934 to the present (the period during which flow records are available at either the New Athens or Venedy Station gages) were examined to determine cases that would most likely cause the need for either deficit-driven or contract-driven water supply releases. The five worst drought episodes were selected for further analysis and presentation in this report, specifically the drought episodes in 1936, 1953–1955, 1964, 1976–1977, and 1988.

The 1930–1931 drought, which is the second worst drought of record as analyzed in estimating the yields of Lake Shelbyville and Carlyle Lake, is not included in the set of droughts used to analyze water use needs in the navigation channel. The only available gaging record in the Kaskaskia watershed for the 1930–1931 drought is from the gage at Vandalia. That gage location is considered to be too far from the navigation channel from which to estimate representative streamflow amounts for the channel.

<u>7-day low flows</u>. From the annual series of 7-day low flows for the Carlyle and New Athens records, the six lowest flow events from 1934 to 1970 were selected and are listed in Table 5.4. A comparison is made between the first ranked event for each location, regardless of the year of occurrence, with the difference calculated and shown in Table 5.6. Similarly, the flow

differences between the second through sixth events has also been calculated and shown in the table. The flow differences are attributed to natural inflow. If the difference between the Carlyle and New Athens flow amounts were calculated for every individual gaging year (such as for 1953 or 1964), the difference in the Carlyle and New Athens flows would show considerable variability, in part because of ordinary gaging (measurement and calculation) errors for each station. But when viewed statistically as ranked values within the broader context of both stations' records, the flow differences are very consistent, with differences generally ranging from 36 cfs for the most extreme low flow conditions to 43–44 cfs for more moderate low flow events similar to the 10-year low flow.

Table 5.6. Six Lowest Observed 7-day Low Flows (cfs) at Carlyle, 1938–1970, and New Athens, 1934–1970

Year	Carlyle	Year	New Athens	Difference
1954	13.1	1953	49.7	+36.6
1964	13.8	1954	50.1	+36.3
1953	20.6	1964	63.6	+43.0
1965	23.9	1940	67.0	+43.1
1940	26.6	1936	73.6	+47.0
1956	32.3	1955	76.1	+43.8

If it is thus assumed that 1) the natural inflow between Carlyle and New Athens adds 43 to 44 cfs of flow to the river during a 10-year drought condition, and 2) the release from Carlyle Lake is maintained at 50 cfs during periods of extended drought, then it can be estimated that the Q7,10 at New Athens is 93–94 cfs. This roughly matches the Q7,10 flow amount (92 cfs) estimated in 2002 by the ISWS (http://www.isws.illinois.edu/docs/maps/lowflow/images/maps/map7.gif). Although emphasis is often placed on the impacts of low flows during the summer when water demand and the potential for environmental impacts are typically greatest, the historical records show that the minimum flow conditions on the Kaskaskia River are most apt to occur during the late fall, in October and November.

Differences in daily flow. Figures 5.2 and 5.3 show the daily flow values for the Carlyle and New Athens gages during 1953–1954 and 1964 droughts, respectively, the two worst drought periods between 1939 and 1970. Observed flows from the Vandalia gage are added in this figure to give a broader perspective on the river's accumulation of flow as it moves downstream. During the 1953–1954 drought (Figure 5.2), there were two instances when the flow difference between Carlyle and New Athens was as small as 26 cfs (17 mgd), considered herein as the minimum natural inflow for the period of record. However, for most periods within the 1953–1955 drought, the natural inflow (flow difference) is 30 to 45 cfs. During the 1964 drought (Figure 5.3), the minimum daily flow difference was briefly reduced to 27–28 cfs, but for most of the drought period, the natural flow was in the range of 40 to 55 cfs.

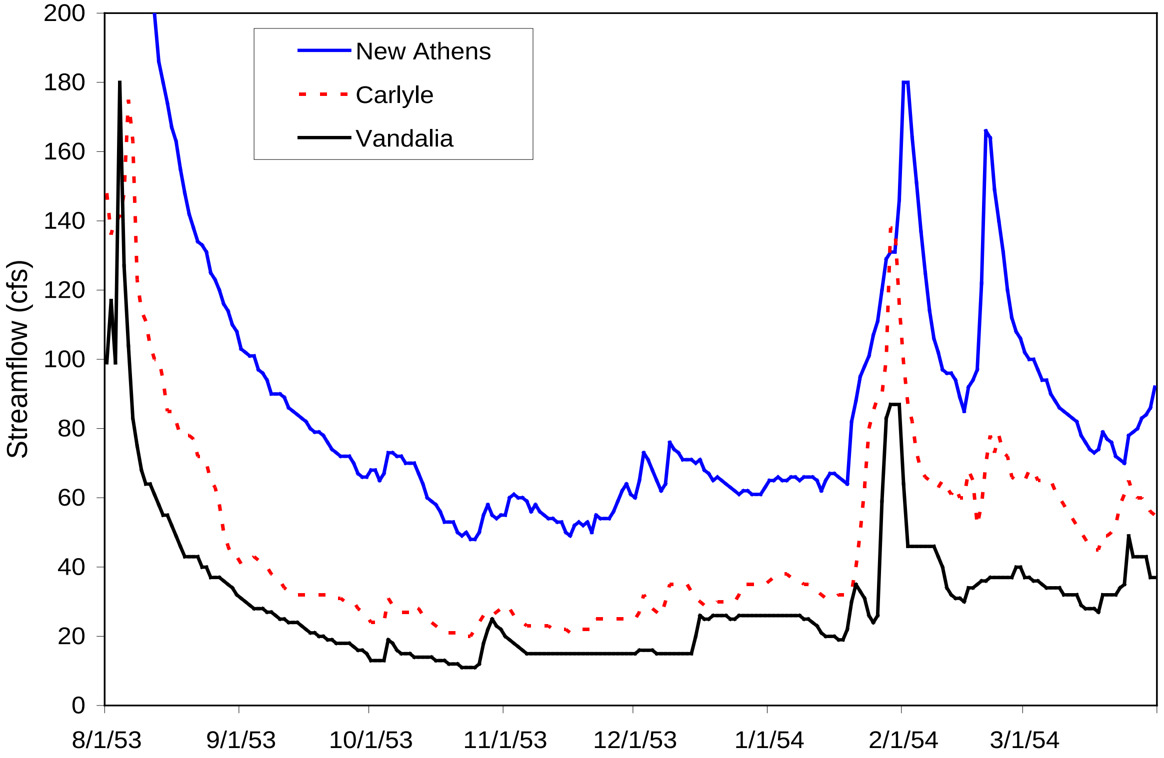

Figure 5.2. Observed daily flows in 1953–1954 at Vandalia, Carlyle, and New Athens

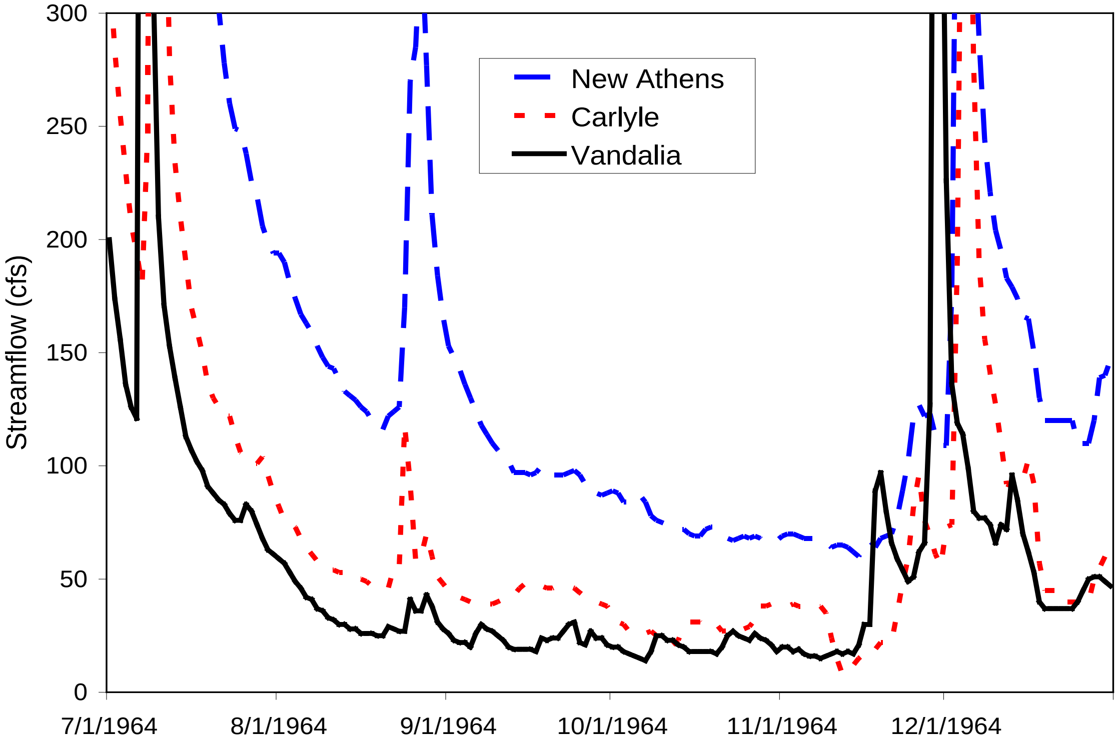

Figure 5.3. Observed daily flows in 1964 at Vandalia, Carlyle, and New Athens

Figure 5.4 shows the daily flow values at the Vandalia and New Athens gages during the 1936 drought when the Carlyle gage was not active. Although the low flow magnitudes were generally typical of less-severe drought episodes, the 1936 drought was unique because the lowest flows occurred during a summer period that was generally uninterrupted by watershed runoff from heavy summer rainfall events. Because the greatest water demands occur during the summer, the 1936 drought is projected to be one of the top events in the amount of water deficit that would occur in the navigation channel.

There are no streamflow gaging records for locations downstream of New Athens. Lacking data to indicate otherwise, the river is assumed to continue to accrete low flow as it moves downstream at approximately the same rate (proportional to drainage area) as occurred between Carlyle and New Athens. Downstream of New Athens, the river's watershed gains an additional 557 square miles, which is expected to provide an additional inflow rate of roughly 9–12 cfs for much of the duration of the 1953–1955 drought and an associated minimum inflow rate of 6 cfs. Thus the collective minimum inflow rate into the navigation channel (from both upstream and downstream of the New Athens gage) is expected to be 32 cfs (20 mgd), not counting human-induced inflows originating from wastewater treatment facilities within the watershed, coming primarily from communities in St. Clair and Madison Counties.

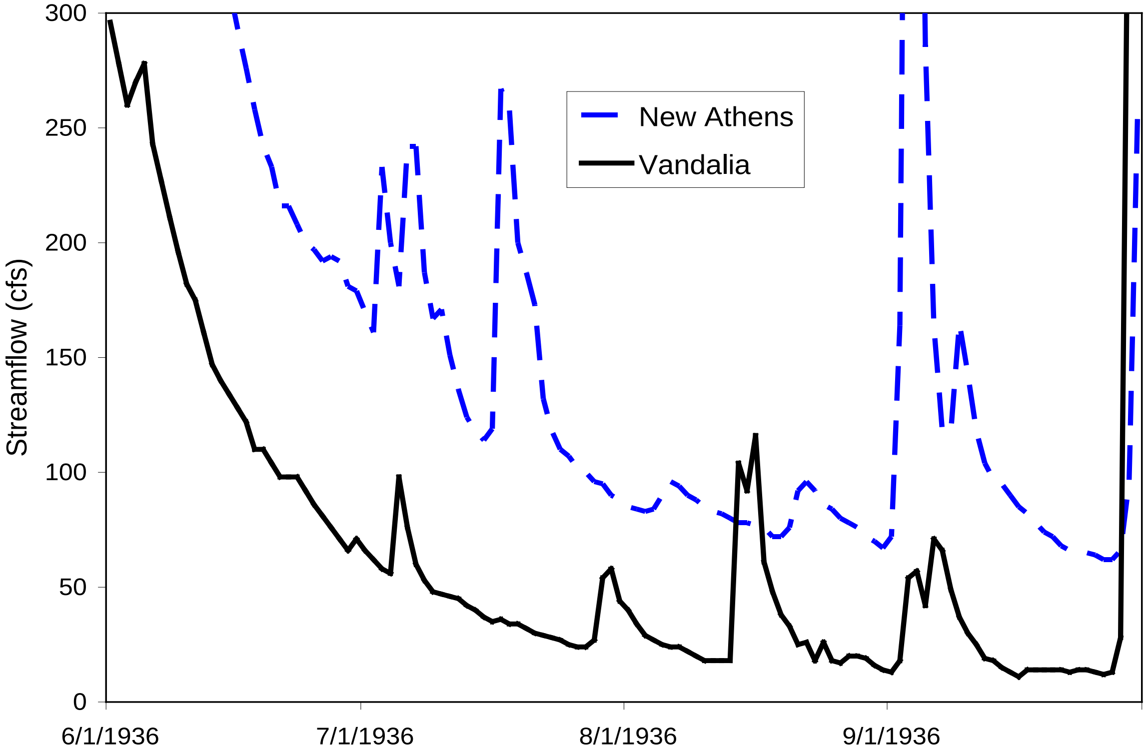

Figure 5.4. Observed daily flows in 1936 at Vandalia and New Athens

Observed Conditions during Historical Droughts from 1971 to 2012

Because the Kaskaskia River Navigation Channel was expected to pool water beyond the location of the New Athens gage, that gage was discontinued in 1971 (during the navigation channel construction) and essentially replaced by an alternate gaging location upstream at Venedy Station (established in the 1970 water year). In 2009, the New Athens gage was reactivated using acoustic velocity metering, which can estimate discharge during pooled conditions of low velocity and reverse flow. However, between 1971 and 2009, there was no direct measurement of the total flow to the navigation channel available, and natural inflows had to be extrapolated by comparing flows at the Carlyle and Venedy Station gages. During this period, the two droughts with the lowest flow conditions at the Venedy Station gage occurred in 1976–1977 and 1999–2000. The 1999–2000 drought produced the lowest flows observed at the Venedy Station gage since the navigation channel was completed (68 cfs for 5 days), and the 1976–1977 drought is the most persistent of this period. During the most recent 2012 drought, the southwestern portion of the Kaskaskia River watershed was never as dry as the remainder of the watershed; as a result, recorded flows at New Athens and Venedy Station were high compared with other drought periods.

Figure 5.5 shows the hydrographs in the fall and winter of 1976–1977. The minimum low flow at the Venedy Station gage was 70 cfs as observed on 27 consecutive days, roughly 23 cfs greater than the concurrent flow (47 cfs) observed upstream at Carlyle.

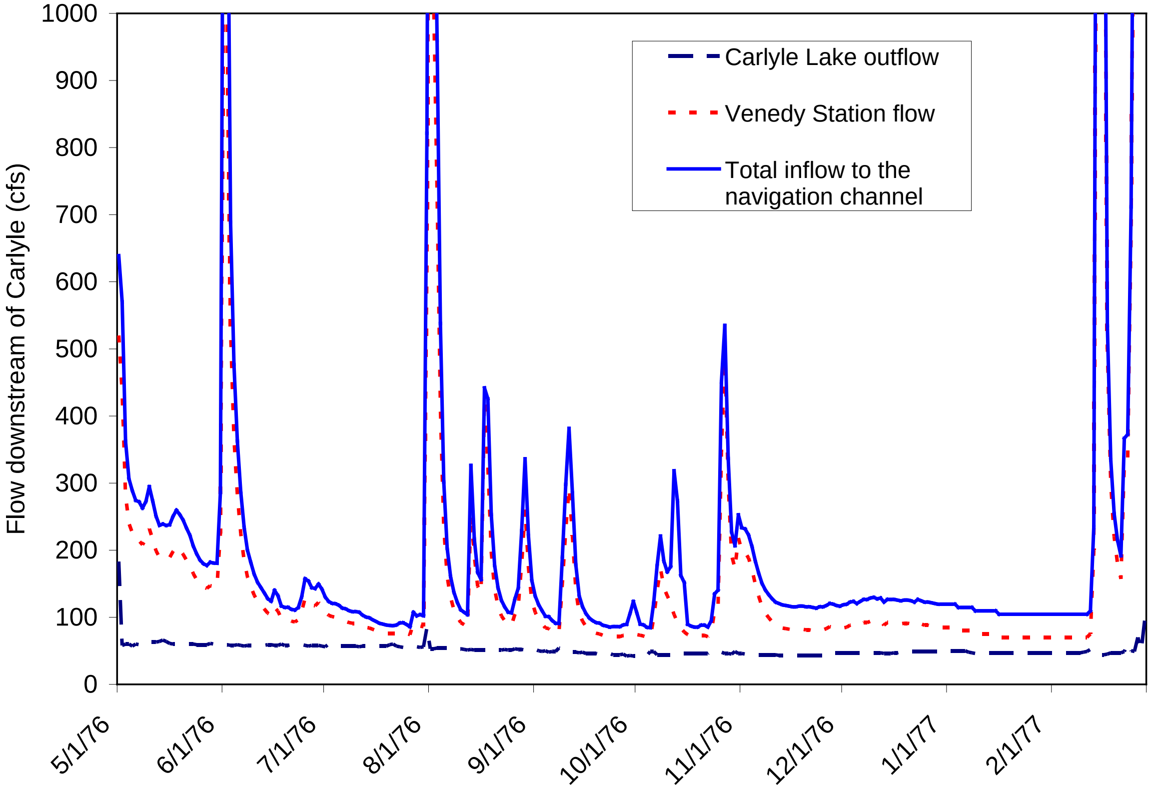

Figure 5.5. Observed daily flows in 1976–1977 at Vandalia, Carlyle, and New Athens

SIMULATED FLOWS TO THE NAVIGATION CHANNEL DURING SELECTED DROUGHT EPISODES

Analyzing potential needs for water supply releases required altering the historical flow records for the selected drought episodes to represent flows as calculated to exist if those droughts were to recur under present and future water demand scenarios and operational conditions. After such calculations were made on the flow records, it was then necessary to estimate the corresponding total daily inflows into the navigation channel for each drought. For the 1936, 1953–1955, and 1964 droughts, inflow into the navigation channel downstream of the New Athens gage was estimated to be proportional by drainage area to the lateral and tributary inflows to the Kaskaskia River between the Carlyle and New Athens gages. The total inflow also includes an additional 6 cfs to reflect effluent discharges into Richland Creek coming from the Belleville area. For the 1976–1977 and 1988 droughts, a similar computation procedure was taken, except for using the Venedy Station gaging record since the New Athens gage had been discontinued.

Figures 5.6 and 5.7 present the simulated flow conditions for the 1953–1955 drought of record condition under the operational scenario that the Carlyle outflow is at a constant 50 cfs for the duration of the drought (i.e, the period when the lake is below its target pool elevation). In addition to the Carlyle outflow, simulated flows are shown at the New Athens gaging location and for the total inflow into the navigation channel, i.e., coming from all tributary and lateral inflows upstream of the Kaskaskia Lock and Dam. From December 15, 1953 to January 15, 1954, the simulated flow values reflect the period of high release rate from Carlyle Dam during which Carlyle Lake would be lowered to its winter pool elevation.

Figures 5.8 through 5.11 present the same simulated flow conditions for the 1936, 1964, 1976–1977, and 1988 droughts, again assuming a constant 50 cfs release from Carlyle Lake during those periods when the lake is below its target pool level.

For additional operational scenarios, the summer water quality release from Carlyle Dam is assumed to be increased to either 100 or 150 cfs, similar to the observed operations at Carlyle Dam during recent summer drought episodes. For example, Figure 5.12 shows the simulated values for the 1976–1977 drought, assuming the summer water quality release is increased to 150 cfs. In this scenario, and as compared to Figure 5.10, the increase in the Carlyle water quality release is reflected in the flow at Carlyle and also at all downstream flow locations for the period from June 1 through September 15, 1976.

Table 5.7 describes the number of days in each selected drought period when the simulated flow for the navigation channel is below the Q7,10. This table provides a relative measure of the needs for contract-driven releases from Carlyle Lake during each of these drought periods. The need for deficit-driven demands must be analyzed using a water budget assessment of the navigation channel that considers both water availability and demand during the drought.

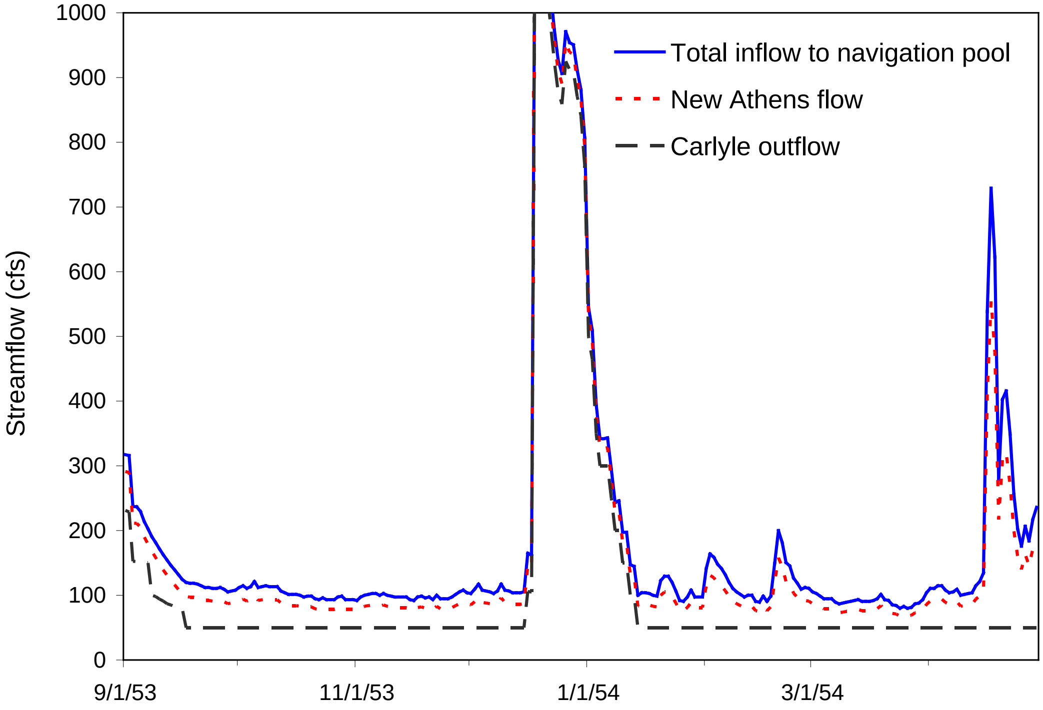

Figure 5.6. Simulated flows for the first half of the 1953–1955 drought assuming a constant 50 cfs release from Carlyle Dam

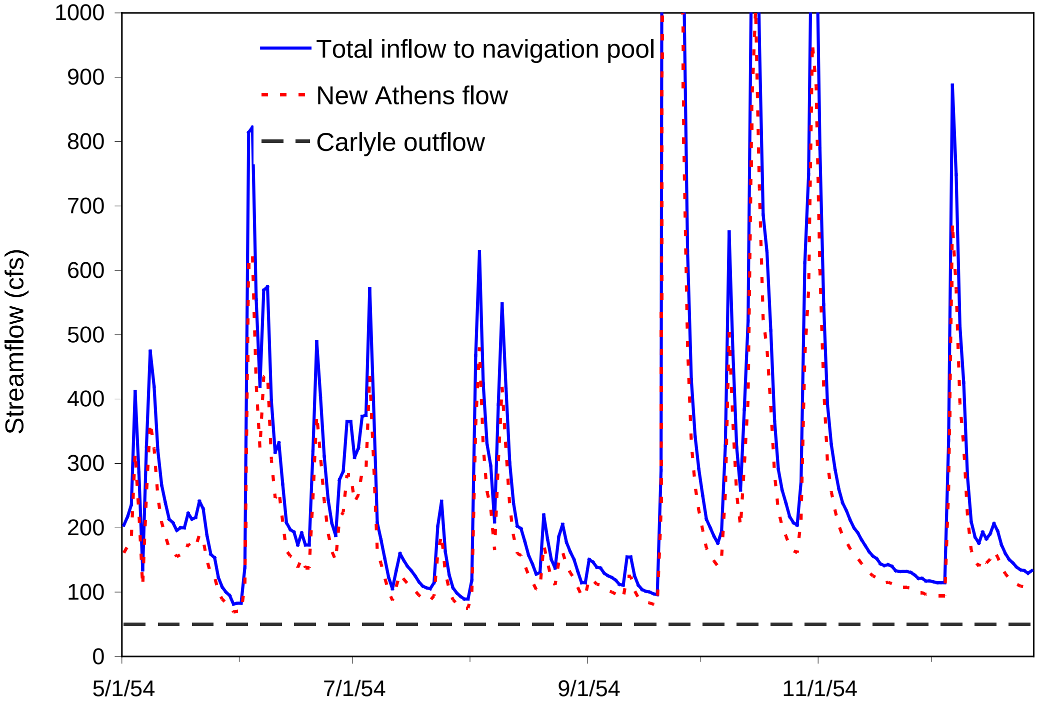

Figure 5.7. Simulated flows for the second half of the 1953–1955 drought assuming a constant 50 cfs release from Carlyle Dam

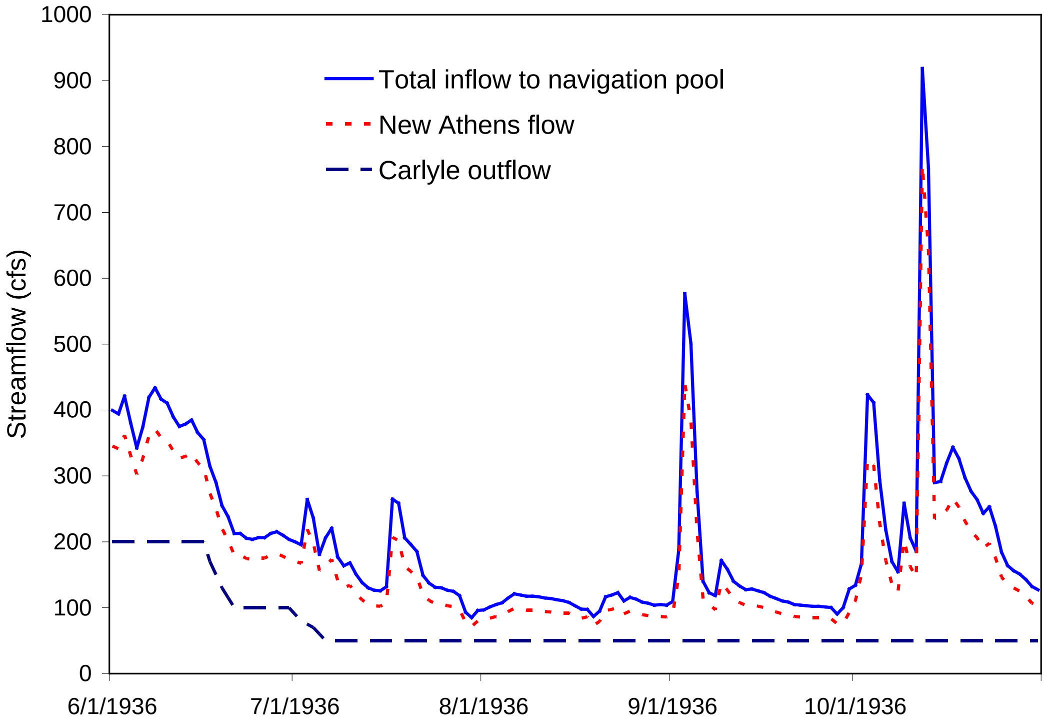

Figure 5.8. Simulated flows for the 1936 drought assuming a constant 50 cfs release from Carlyle Dam

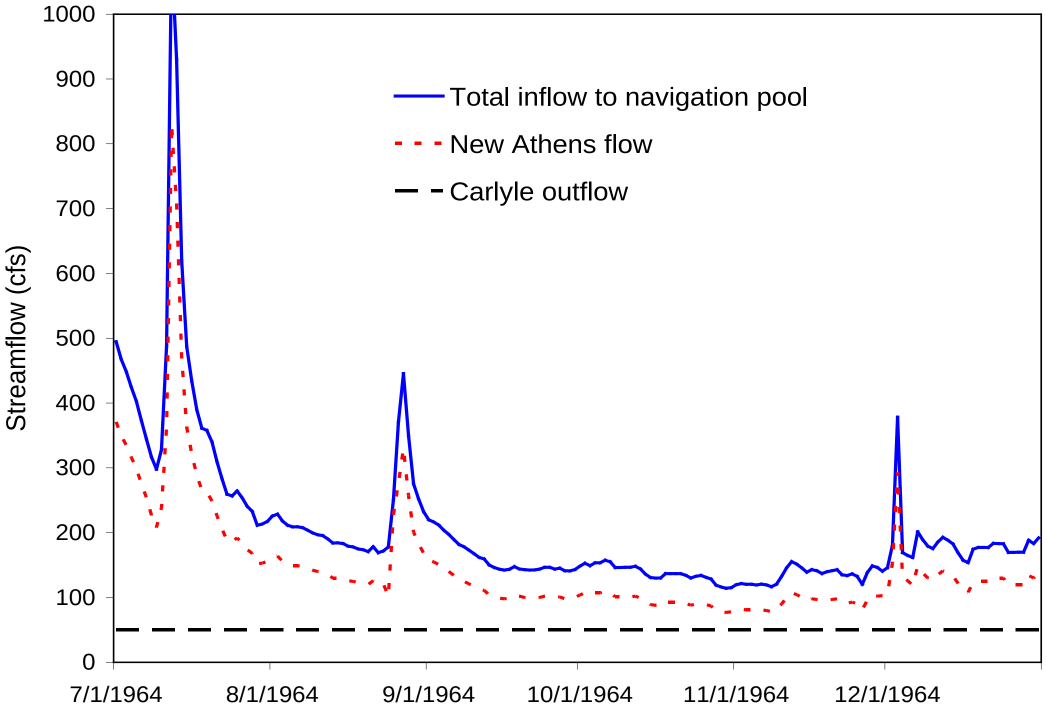

Figure 5.9. Simulated flows for the 1964 drought assuming a constant 50 cfs release from Carlyle Dam

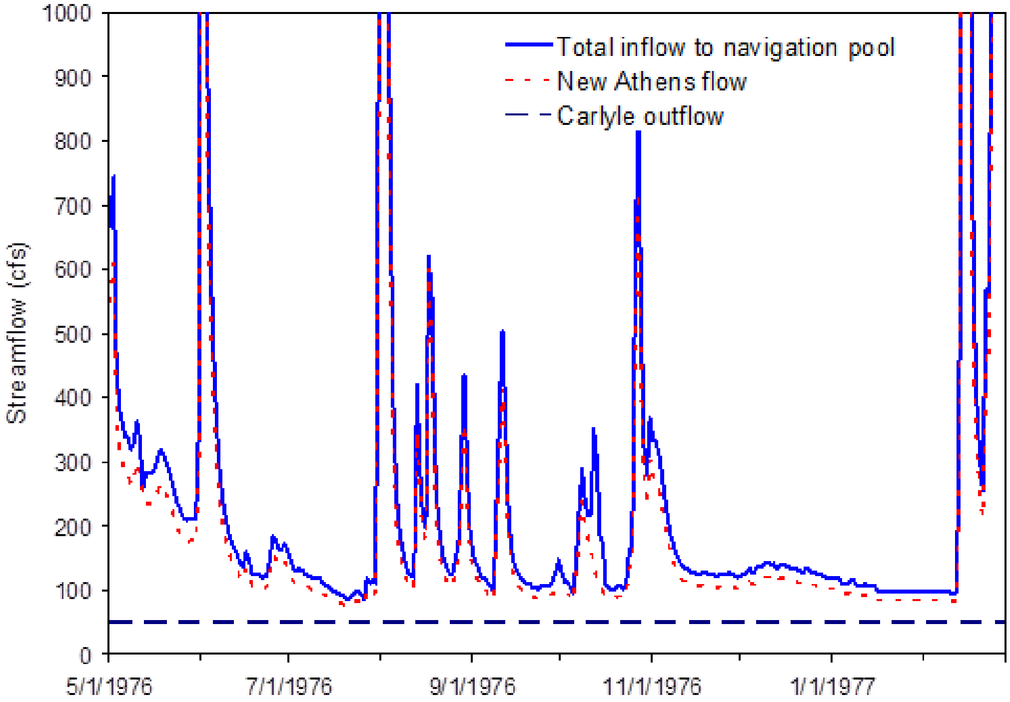

Figure 5.10. Simulated flows for the 1976–1977 drought assuming a constant 50 cfs release from Carlyle Dam

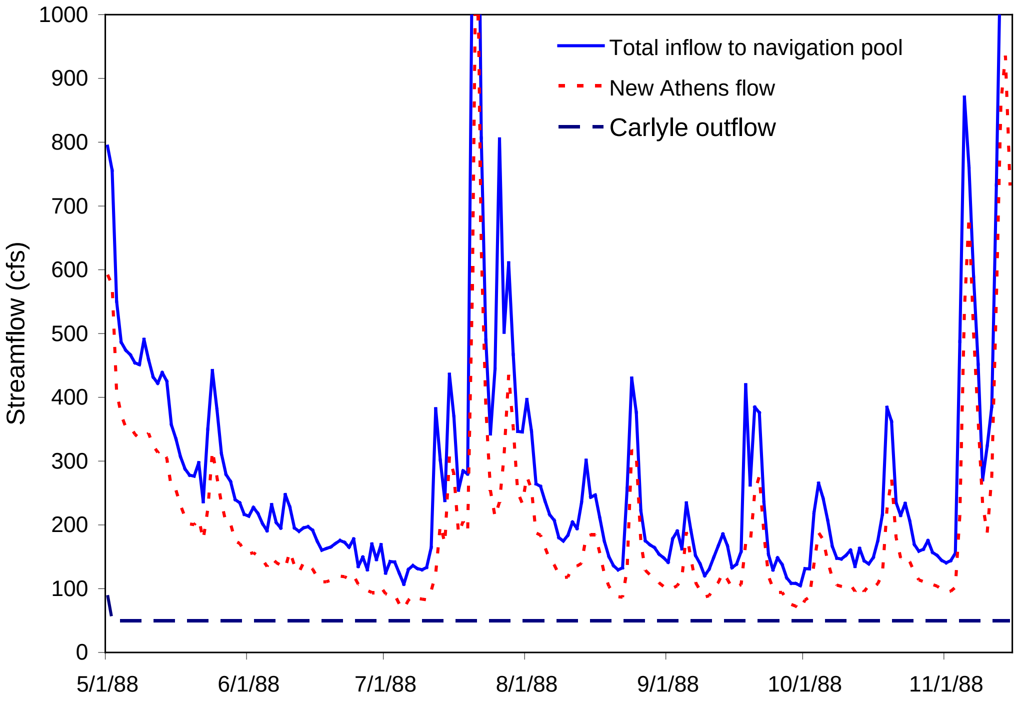

Figure 5.11. Simulated flows for the 1988 drought assuming a constant 50 cfs release from Carlyle Dam

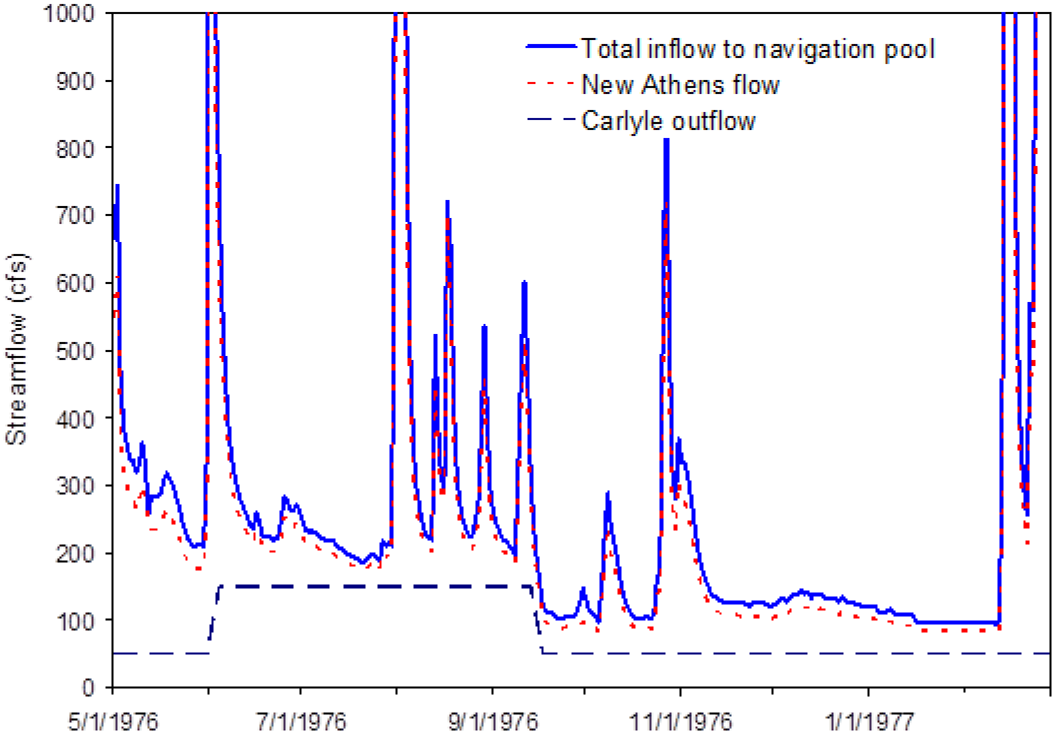

Figure 5.12. Simulated flows for the 1976–1977 drought assuming a 150 cfs summer water quality release from Carlyle Dam

Table 5.7. Number of Drought Days when the Simulated Flow in the Navigation Channel is below the Q7,10 (at a minimum Carlyle release rate of 50 cfs)

Drought episode	Number of total days	Maximum number of consecutive days
1953–1955	199	100
1964	44	28
1976–1977	63	35
1936	31	13
1988	6	6

WATER BUDGET OF THE NAVIGATION CHANNEL AND PROJECTED WATER SUPPLY RELEASES DURING SELECTED DROUGHT EPISODES

For each selected drought episode, a daily water budget analysis of the navigation channel was created to account for storage in the pool, simulated inflows, and water consumed by power plant withdrawals, lockages, and net evaporation from the pool. The analysis attempted to simulate operational decisions that the power companies and the USACE would face during each drought episode. As described earlier, during the onset of drought conditions, it is expected that a certain amount of storage use (drawdown) from the navigation channel would be accepted before there is a considered need for Carlyle Lake releases. Water supply and/or navigation releases from Carlyle Lake would be triggered whenever the pool level in the navigation channel approaches an elevation of 368.4 feet (0.4 feet below normal). The navigation channel, with an estimated surface area of 3663 acres, contains roughly 1465 acre-feet of water stored within its top 0.4 feet. Once the navigation pool approaches this trigger level, water supply releases from Carlyle Lake would begin. For most scenarios the water needed for lockages is equivalent to or exceeds power plant usage, in which case the analysis assumes that both navigation and water supply releases from Carlyle Lake would be needed proportional to their respective water demands. Water supply and navigation releases would be continued until the pool level in the navigation channel returns to normal.

During a moderately severe (10-year) drought, the flow rate in the navigation channel will fall below the Q7,10 threshold level for only a handful of days. Both Dynegy-Baldwin and Prairie State have storage reservoirs capable of meeting their water supply needs for such short time periods. Thus it is only during a more severe drought episode when the flow in the navigation channel remains below the Q7,10 for an extended time that water supply releases might be needed by these companies. Because Prairie State has a smaller amount of raw water storage relative to its water demands (compared to Dynegy), it is expected that Prairie State would likely be the first of the two companies to call for water supply releases from Carlyle Lake during such extended dry periods. As a result, the projected water supply releases for Prairie State during a contract-driven condition are often substantially greater than the projected amounts for Dynegy. Only at higher levels of demand, both Prairie State and Dynegy may need to release water during such low flow conditions. If the condition exists that Prairie State is not operating during a drought, then Dynegy would be responsible for all of the contract-driven water supply releases, and their total amount of required releases for the 1953–1955 drought could be great even during the LRI scenario (Table 5.8).

Water supply releases from Carlyle Lake have to date never been initiated. Prior to the occurrence of such a first release, the USACE and the power companies are expected to avoid the need for a release. Avoidance of a release may include steps such as 1) the USACE restricting recreational and commercial lockages during deficits, and 2) the power companies drawing down the levels in their storage reservoirs instead of pumping from the navigation channel. (The second strategy, in particular, if taken too far could be detrimental to the ability of that power company to maintain operations during a potential protracted drought condition.) But once the USACE and the power companies have called for releases from Carlyle Lake, in subsequent drought episodes there may be less aversion to initiating additional releases. Thus operational decisions under a less-averse condition are considered to represent the more likely long-term operational tendencies that are simulated in the analyses.

Potential Releases during an Episode Similar to the 1953–1955 Drought

Figures 5.13 and 5.14 compare the calculated inflow to the navigation channel (with a 50 cfs summer water quality release from Carlyle Lake) to its projected water demands during the simulated conditions associated with the core period of the 1953–1955 drought, that being the 16 months from September 1953 to December 1954. During that period, it is estimated that the

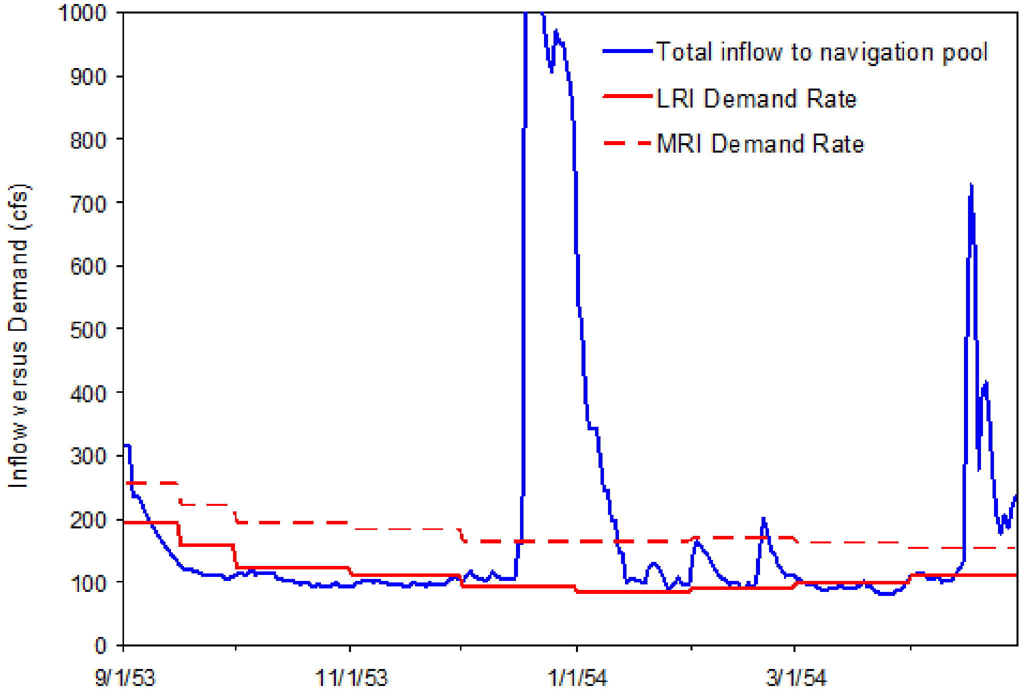

Figure 5.13. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, Sept. 1953–April 1954

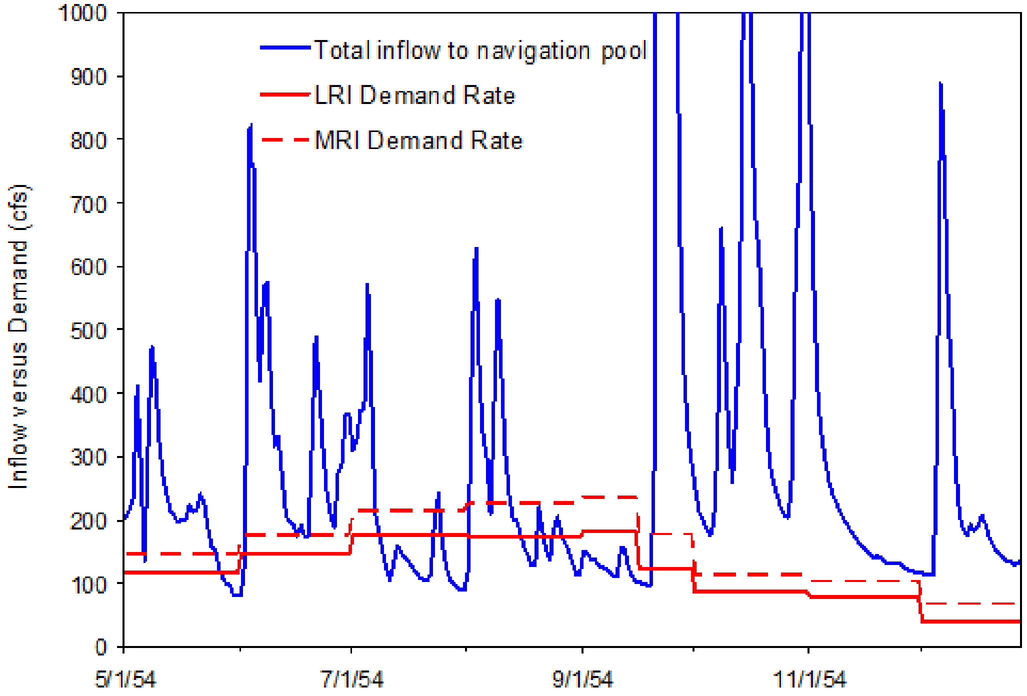

Figure 5.14. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, May 1954–Dec. 1954

flow in the Kaskaskia River falls below its 7-day, 10-year low flow (Q7,10) for 199 days. Of these days, 146 are associated with the period between mid-September 1953 and mid-April 1954.

In addition to those days when contract-drive releases could be required as a result of low flow conditions, Figure 5.13 shows that there would also be deficits between water demands and the available water in the Kaskaskia River during which the power companies would also likely need to call for deficit-driven releases from Carlyle Lake. Flow levels in the Mississippi River were very low during the winter of 1953–1954, which would correspond to an average lift of 24–25 feet between the Mississippi River and the navigation pool and a water use in excess of 9 mgd (14 cfs) per lockage. With the LRI demand scenario, such deficit-driven releases would occur only occasionally, but with the MRI demand scenario, deficit-driven releases would occur non-stop from September 1953 through April 1954 with a potential respite only in December 1953 when water is being released from Carlyle Lake as it transitions to winter pool. This respite assumes that the winter drawdown is not designated by the USACE as a navigation release, in which case the power companies could be required to maintain water supply releases during that month.

Impact of the Protected Minimum Flow on Projected Release Amounts

Tables 5.8 and 5.9 present simulated water supply release amounts from Carlyle Lake during the 1953–1955 drought conditions. The calculations in Table 5.8 assume that the power companies use the current Q7,10 flow value from the New Athens gage (92 cfs) as the trigger for initiating contract-driven releases. The calculations in Table 5.9 assume that the power companies use the 69.3 cfs flow value from the Venedy Station gage as the trigger to initiate contract-driven releases, a value initially identified in their allocation agreements. The 69.3 cfs amount was taken from a 1987 ISWS Q7,10 analysis (Singh et al., 1987) which had limited years of post-construction data from which to estimate low flows downstream of Carlyle Lake. But subsequent studies by the ISWS, including the current Q7,10 estimate used by the IEPA (http://www.isws.illinois.edu/docs/maps/lowflow/images/maps/map7.gif), have estimated the Venedy Station Q7,10 to range from 74 to 75 cfs. Although language in the allocation agreement infers that Prairie State and Dynegy may be required to use the higher low flow threshold at the downstream New Athens gage site (Table 5.8), simulated releases using the lower 69.3 cfs threshold at the Venedy Station gage (Table 5.9) are also provided for comparison. There is a considerable reduction in the number of required release days if the lower 69.3 threshold level at Venedy Station is used to trigger contract-driven releases.

Table 5.8. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1953–1955 Drought were to Recur, using the Current Q7,10 Value at New Athens (92 cfs) as the Protected Minimum Flow

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
<u>LRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	11711	10496	10496
Maximum annual rate (mgd)	10.0	8.9	8.9
Dynegy			
Storage released (acre-feet)	2836	1363	1363
Maximum annual rate (mgd)	2.5	1.2	1.2
<u>BL Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	12429	10496	10496
Maximum annual rate (mgd)	10.4	8.9	8.9
Dynegy			
Storage released (acre-feet)	5412	2192	2192
Maximum annual rate (mgd)	3.8	2.0	2.0
<u>MRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	13921	12595	11711
Maximum annual rate (mgd)	11.5	10.4	9.6
Dynegy			
Storage released (acre-feet)	15345	12368	11156
Maximum annual rate (mgd)	12.2	10.0	8.7

Estimated Releases for Dynegy if it is the Only Company in Operation

LRI Demand Scenario			
Storage released (acre-feet)	15729	12767	12767
Maximum annual rate (mgd)	14.0	11.4	11.4
BL Demand Scenario			
Storage released (acre-feet)	16174	12767	12767
Maximum annual rate (mgd)	14.3	11.4	11.4
MRI Demand Scenario			
Storage released (acre-feet)	15453	11769	11769
Maximum annual rate (mgd)	12.7	9.2	9.2

<u>Notes:</u>

1) Releases are calculated to occur in both the Oct 1952–Sept 1953 and Oct 1953–Sept 1954 water years, but maximum annual rates are associated only with Oct 1953–Sept 1954.

Table 5.9. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1953–1955 Drought were to Recur, using 69.3 cfs at Venedy Station as the Protected Minimum Flow

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
<u>LRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	5689	4198	4198
Maximum annual rate (mgd)	5.1	3.8	3.8
Dynegy			
Storage released (acre-feet)	3360	1074	1074
Maximum annual rate (mgd)	3.0	1.0	1.0
<u>BL Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	8010	4419	4419
Maximum annual rate (mgd)	6.5	3.5	3.5
Dynegy			
Storage released (acre-feet)	6798	2940	2940
Maximum annual rate (mgd)	5.0	1.8	1.8
<u>MRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	13921	12595	11711
Maximum annual rate (mgd)	11.5	10.4	9.6
Dynegy			
Storage released (acre-feet)	9944	7758	6064
Maximum annual rate (mgd)	7.4	5.5	3.9

Estimated Releases for Dynegy if it is the Only Company in Operation

	50 cfs	100 cfs	150 cfs
LRI Demand Scenario			
Storage released (acre-feet)	5524	3845	3845
Maximum annual rate (mgd)	4.9	3.4	3.4
BL Demand Scenario			
Storage released (acre-feet)	6491	3845	3845
Maximum annual rate (mgd)	5.4	3.4	3.4
MRI Demand Scenario			
Storage released (acre-feet)	12095	9440	9072
Maximum annual rate (mgd)	9.5	7.4	7.4

<u>Notes:</u>

1) Releases are calculated to occur in both the Oct 1952–Sept 1953 and Oct 1953–Sept 1954 water years, but maximum annual rates are associated only with Oct 1953–Sept 1954.

The simulated flow releases for the 1953–1954 drought given in Tables 5.8 and 5.9 assume that the power companies will hesitate to request releases from Carlyle Lake until releases are unquestionably required. Their reluctance to call for releases would almost certainly exist if such an extreme drought was the first drought event ever to require flow releases from the federal reservoirs, in other words, if there would be no previous drought requiring the companies to pay for water supply costs. On the other hand, if such annual maintenance costs have already been incurred because of water uses in previous droughts, there may be less hesitance to call for new releases.

If flow in the Kaskaskia Navigation Channel is at or below the protected flow threshold, both Prairie State and Dynegy are restricted in the amount of water that they can withdraw from the navigation pool, which cannot exceed the amount of water released from Carlyle Lake as intended for use by their company. On the other hand, if flow in the navigation channel remains above its protected flow level, the only restriction that the IDNR allocation agreements impose is the maximum amount of water that can be released from Carlyle Lake for use by each company. The IDNR agreements do not specifically restrict the amount of water that each company can withdraw from the river if the protected flow restriction is not in place. Specific descriptions for each company are given as follows:

- If the protected flow restriction is in place, Dynegy must release an amount of water that is equal to or exceeds their gross withdrawal from the navigation pool. If the protected flow restriction is not in place, it may be sufficient for them to request a release amount equal to their net use.
- If the protected flow restriction is in place, Prairie State must release an amount of water that is equal to or exceeds their withdrawal, and that amount may not exceed a maximum rate of 18 mgd. If the protected flow restriction is not in place, their maximum release rate is still restricted to 18 mgd, but there is no specific restriction on the withdrawal amount and possibly there may be sufficient natural inflow to the river to allow them to withdraw a greater amount without causing a water deficit in the navigation pool.

Relationship between the Projected Release Amounts for Prairie State and Dynegy

When flow in the Kaskaskia River first falls below the protected minimum flow, both Prairie State and Dynegy could possibly decide to discontinue their withdrawals to see if the river's flow would rebound, and they could avoid the need for a water supply release from Carlyle Lake. During that time, each company would use their on-site storage to provide their water needs. Eventually during an extended drought, however, as their available storage becomes depleted, one of the companies would need to request a reservoir release. This analysis assumes that Prairie State would be the first to call for the releases because it has less on-site storage than Dynegy. Within several days after initiating the water supply release and as a result of the additional flow provided by the release, the flow at both New Athens and Venedy Station would be expected to rise sufficiently to be above the Q7,10 minimum flow restriction. Under such circumstances, the second company (Dynegy) could feasibly then begin withdrawing water without requesting their own release as long as such withdrawal does not create a deficit condition. Thus the simulated release rates for Dynegy, shown in Tables 5.8 and 5.9, are noticeably lower than the release rates for Prairie State because under a contract-driven release condition, only one company (most likely Prairie State) would necessarily have to ask for releases to satisfy the minimum-flow requirement in their contract agreements. The potential difference in the frequency of pumping between the two companies becomes less marked for the MRI scenario as much more of the water supply releases are initiated because of deficits in water availability, not as contract-driven releases.

The maximum total release from the water supply storage in Carlyle Lake during this drought is calculated to occur with the MRI demand scenario and a summer water quality release rate of 50 cfs from the lake. From Table 5.8, the calculated release rate of that scenario during the October 1953–September 1954 water year is 23.7 mgd (11.5 mgd for Prairie State and 12.2 mgd for Dynegy). This calculated annual release rate is nearly as great as the maximum-allocated releases of 13.35 mgd for Prairie State and 14.35 mgd for Dynegy.

Releases if Dynegy were the Only Power Company in Operation

Tables 5.8 and 5.9 also show the projected release rate if Dynegy were the only company that needed to withdraw water from the Kaskaskia channel under the 1953–1955 drought conditions, and thus were responsible for the contract-driven releases needed to maintain the minimum protected flow rate in the channel. Whereas Dynegy potentially might not need much of its allocation during the 1953–1955 drought if both power companies were operating, it could easily need most of its allocation if the Prairie State plant were not operating or Dynegy otherwise, over the course of the drought, became the company primarily responsible for satisfying the minimum-flow requirement in the IDNR contract. [In contrast, if Prairie State were the only power company in operation, their water needs would be expected to be roughly the same as the scenarios when both companies are operating.]

As expected, the total volume of the anticipated releases increases as the demand rate increases from the LRI to BL conditions. However, with the high demand rates of the MRI scenario, it is possible that deficit-driven releases would be needed earlier in the drought and, if continued at a constant rate, would be sufficient such that the river's low flow would never fall below the Q7,10 level, in which case there might be few or no contract-driven releases. In a contract-driven condition, Dynegy is required to release an amount equal to their withdrawal, whereas in deficit-driven condition Dynegy never has to release more than their net demand, which credits the gain in flow (over 10 mgd) created by their effluent. As a result, Dynegy could request lower release rates (equal to net usage) and, over the course of the drought, release less volume of water even though such releases might need to occur more frequently in response to a deficit condition. This is reflected in the results shown in the last row (MRI scenario) of Table 5.8.

Total Volume of Releases during the Drought versus the Maximum Annual Rate

The projected water supply releases given in Tables 5.8 and 5.9 are listed as two separate amounts: 1) the total volume of projected releases during the drought's entire 547-day critical duration of deficit (August 22, 1953–February 19, 1955), and 2) the average annual rate of release (mgd) during the 1954 water year (October 1, 1953–September 30, 1954). The calculated annual average release rate for the 1954 water year is especially pertinent because most of the IDNR water supply allocation agreements specify a maximum annual rate of release, not the total amount of water used. In the Prairie State and Dynegy agreements, the specified maximum annual release rates are 13.35 and 14.35 mgd, respectively. For all scenarios presented in Table 5.8, the calculated maximum annual release rates during the 1954 water year fall below the respective allocated limits.

The values in Tables 5.8 (or Table 5.9) can also be used to show that almost all of the projected releases during the 1953–1955 drought occur during the 1954 water year. For selected scenarios, Table 5.10 compares the volume of the total projected releases during the 1953–1955 (547-day period) with the volume that would be released during the 1954 water year (365-day period), and results indicate that roughly 90 percent or more of the total releases could typically be expected to occur during the 1954 water year.

Table 5.10. Comparison of Water Supply Releases from Carlyle Lake during the Entire 1953–1955 Drought to that Portion Occurring October 1953–September 1954 (total release amounts are as previously provided in Table 5.8)

		Projected storage release (ac-ft) during	
		Entire drought (8/22/53-2/19/55)	*1954 Water Year (10/01/53-9/30/54)*
Summer water quality release rate = 50 cfs			
LRI Demand Scenario	Prairie State	11711	11214 (96%)
	Dynegy	1473	1473 (100%)
BL Demand Scenario	Prairie State	12264	11546 (94%)
	Dynegy	3589	2578 (72%)
MRI Demand Scenario	Prairie State	13921	12927 (93%)
	Dynegy	15345	13688 (89%)

Yield calculations for Lake Shelbyville and Carlyle Lake, presented in Chapter 2, are based on an assumption that water use and water supply releases occur uniformly throughout the 547-day duration of the drought's critical period of drawdown. The IDNR allocation of water supply using an average annual rate, described in Chapter 3, essentially maintains that assumption of a uniform rate of use. In contrast, the simulation of water supply releases from Carlyle Lake during the 1953–1955 drought of record, described herein, indicates that such releases would not be expected to be uniform in nature. Instead, roughly 90 percent or more of the releases are estimated to occur during the 12-month period from October 1953 through September 1954, which coincidentally corresponds to the water year used to calculate the maximum annual rate of usage.

As stated earlier in this chapter, the respective 13.35 and 14.35 mgd water supply allocations for Prairie State and Dynegy potentially obligate up to 22,400 and 24,100 acre-feet of water for these two companies over the entire duration of a 547-day drought (18-months), for a total of 46,500 acre-feet. However, because the water use for these companies is not uniform, and most of their use occurs during a 12-month period during that drought, the expected joint maximum use during a drought similar to the 1953–1955 drought would be 29,266 acre-feet (associated with the MRI scenario in Tables 5.8 and 5.10). This implies that roughly 17,234 acre-feet of water supply storage in Lake Shelbyville and Carlyle Lake that is effectively obligated in the current Prairie State and Dynegy allocation agreements would go unused during such an extreme drought. If commercial navigation use is less than the MRI scenario, the amount of unused water supply storage would be even greater.

Potential Effect of a Winter (Mississippi River) Navigation Release on Water Supply Releases

Providing water for navigation needs is one of the primary purposes of the two federal reservoirs, and, if needed, the USACE reserves the right to use all of the federal share of the joint-use pool for such a purpose. Navigation releases from the two reservoirs would not simply be used to provide water needs for the Kaskaskia navigation lock and dam; rather, the bulk of the federal storage would have the intended purpose of augmenting flow levels for most of the Middle Mississippi River (the 190-mile reach between St. Louis, MO and Cairo, IL) as needed to maintain sufficient water depths. To date, there has not yet been a "designated" navigation release from the federal reservoirs to benefit navigation conditions in either the Middle Mississippi River or the Kaskaskia Navigation Channel. In the winter following the 2012 drought, the USACE reportedly came close to executing such a release. However, because the water level and surplus storage in Carlyle Lake were unusually high, the winter drawdown release in December 2012 and January 2013 produced high flow rates in the Kaskaskia River that were sufficient to satisfy the need for additional low flow in the Mississippi River. Because water levels in federal reservoirs were never drawn below their normal winter pool levels, the USACE did not need to specifically designate the Carlyle Lake drawdown release as a navigation release.

During extreme drought conditions, potential navigation releases from Lake Shelbyville and Carlyle Lake would potentially be executed in the winter when minimum flow amounts could be expected to occur. Not only is winter the natural low flow season for this portion of the river, but also, prior to winter (through November), flow amounts in the Mississippi River during drought are already being augmented through releases from upstream reservoirs as needed to support the navigation season in both the Missouri and Upper Mississippi Rivers.

In examining the historical flow records during the 1953–1955 drought, it is expected that navigation releases from the Kaskaskia reservoirs would have potentially been needed for low-flow augmentation in the Middle Mississippi River during the period between mid-December 1953 and late February 1954. For the current analysis, a hypothetical scenario is examined in which roughly half of the available federal share within the joint-use pools in Lake Shelbyville and Carlyle Lake is released as part of a designated navigation release, but a residual 40 percent of the federal share (140,000 acre-feet) would be retained in reserve for potential uses later in the drought (such as for water quality releases). A rough analysis of the federal storage associated in this scenario is presented below for conditions similar to the 1953–1955 drought, using the MRI water use scenario in which a considerable amount of federal storage is also released throughout the drought as needed for lockages at the Kaskaskia lock and dam.

Total federal share of the joint-use pools = 353,000 acre-feet
Federal storage at the onset of the designated navigation release (late December 1953) = 287,000 acre-feet
Amount of storage released for low-flow augmentation = 147,000 acre-feet
Federal share held in reserve following the navigation release = 140,000 acre-feet

In this scenario, if water for low-flow augmentation is released from Carlyle Lake at a rate of 3500 cfs (roughly 7000 acre-feet per day), the navigation release would extend for roughly 21 days (from early through mid-January), after which navigation would likely be restricted on the Mississippi River (and thus also on the Kaskaskia River) unless other water sources were available to augment additional flow. The 3500 cfs rate roughly corresponds to a 0.5-foot increase in the flow depth of the Mississippi River under such low flow conditions. The joint 140,000 acre-feet reserve in Lake Shelbyville and Carlyle Lake following the navigation release in this scenario would roughly correspond to water elevations of around 588.0 and 438.5 feet, respectively. Under this MRI scenario, federal storage could potentially be reduced to 103,000 acre-feet (29 percent of capacity) as storage would continue to be reduced throughout the remainder of the drought, primarily as used for water quality releases, navigation releases for the Kaskaskia Lock and Dam, and reservoir evaporation losses. Lake levels during such a hypothetical scenario are examined in the following chapter, “Impacts of Water Releases on Lake Levels during Drought.”

Required Water Supply Releases during the Navigation Release. During the 26 days of the navigation release, water supplies that withdraw from the Kaskaskia River downstream of the two federal reservoirs would be required to restrict their withdrawals so as to protect (not lessen) the amount of the navigation release. During such time, only the computed natural inflows to the river would be available for water supply purposes unless users request additional reservoir releases specifically for water supply. Because the natural inflows downstream of Lake Shelbyville are relatively low (Chapter 4), Holland Regional and HRWS would likely need water supply releases during the time of a navigation release, although such releases would be routine during an extreme drought similar to the 1953–1955 drought as both water supply systems would otherwise be expected to require water supply releases throughout most of the entire drought.

Downstream of Carlyle Lake, the natural inflows into the Kaskaskia River during the December 1953–February 1954 period would be expected to be at least 36 cfs (Table 5.6). Meanwhile, the collective net water withdrawal rate from the river (from the Prairie State, Dynegy, and community water supplies) during a winter navigation release would expectedly be around 35 mgd (54 cfs). If one of the power companies requested a release for their own withdrawal at this time in the range of 19 to 20 mgd (30 cfs), then such a release would add sufficient flow in the river for all users so as not to interfere with the navigation release. Therefore, the navigation release would potentially require only an additional water supply release of roughly 520 million gallons (20 mgd over 26 days), equivalent to 1780 acre-feet or an increase in the annual average release rate of 1.4 mgd.

Potential Releases during an Episode Similar to the 1936 Drought

Figure 5.15 compares the simulated inflows to the navigation channel (50 cfs summer water quality release) to projected demands associated with the LRI and MRI demand scenarios. Compared with the other droughts evaluated in this study, the 1936 drought displays a consistently dry summer with deficit conditions that remain uninterrupted for much of the summer. The amount of water needed for lockages would also be great, as the historical records indicate that the Mississippi River's flow was very low during this summer. Except for the

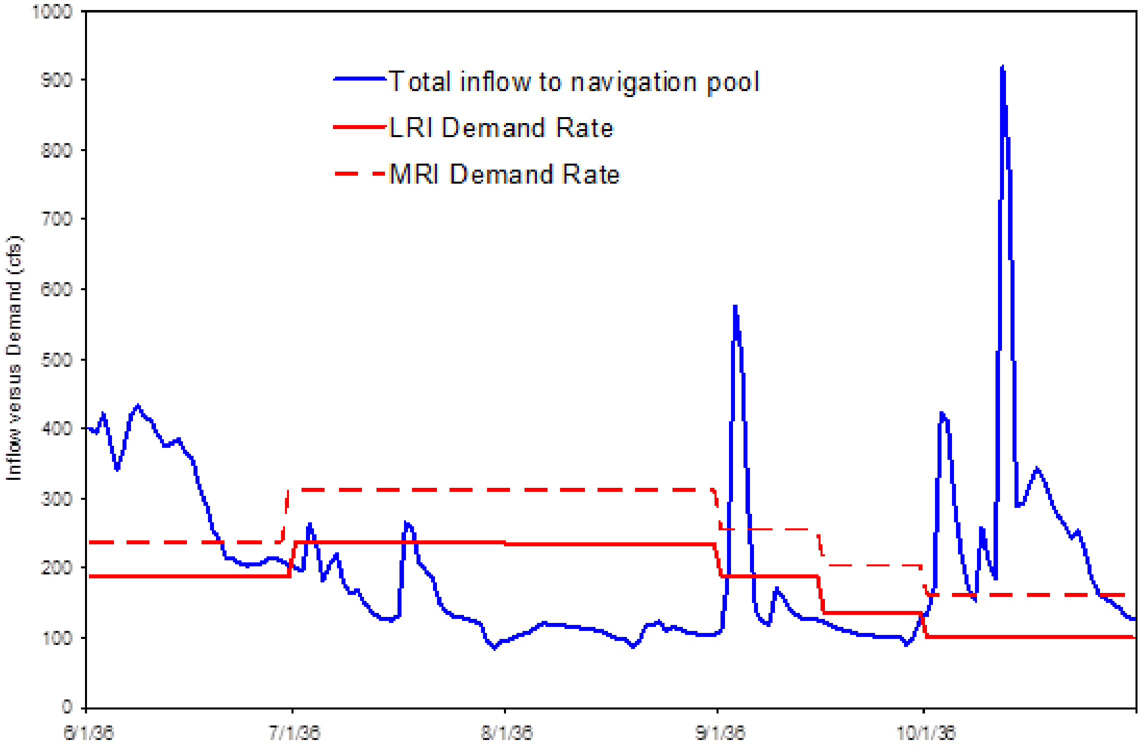

Figure 5.15. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, 1936 drought

few scenarios when the total water demand is relatively low and the Carlyle water quality release is high, the power companies would likely need to release water for most of July, August, and September.

Table 5.11 presents the calculated release amounts under the various scenarios studied. Of the droughts evaluated from 1935 to 2012, the simulated 1936 drought conditions provide the second highest annual release rate. Because most of the releases would be driven by a water deficit in the navigation channel, and not by contract-driven conditions, the choice of the New Athens versus Venedy Station low flow trigger has relatively little effect on the total release amount.

Table 5.11. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1936 Drought were to Recur

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
<u>LRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	3591	2541	939
Maximum annual rate (mgd)	3.2	2.3	0.8
Dynegy			
Storage released (acre-feet)	5985	4235	1565
Maximum annual rate (mgd)	5.3	3.8	1.4
<u>BL Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	3977	3645	2154
Maximum annual rate (mgd)	3.6	3.2	1.9
Dynegy			
Storage released (acre-feet)	6629	6353	3591
Maximum annual rate (mgd)	5.9	5.7	3.2
<u>MRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	4751	4033	3038
Maximum annual rate (mgd)	4.2	3.6	2.7
Dynegy			
Storage released (acre-feet)	7918	6721	1650
Maximum annual rate (mgd)	7.1	6.0	4.5

<u>Notes:</u>

1) All releases would occur within the Oct 1935–Sept 1936 water year
2) The release amount for either power company would be less if the other company were not operating that year.

Potential Releases during an Episode Similar to the 1976–1977 Drought

Figure 5.16 compares the simulated inflows to the Kaskaskia Navigation Channel (50 cfs summer water quality release) with projected demands associated with the LRI and MRI demand scenarios. The 1976–1977 drought provides a combination of conditions for water supply releases from Carlyle Lake, with deficit conditions during the first half of the 1976 summer and then very low flows and some contract-driven release conditions later in the fall and winter of 1976–1977.

Table 5.12 presents the calculated release amounts under the various scenarios studied. Because the water supply releases occur over both the 1975–1976 and 1976–1977 water years, the annual maximum release rate of any individual year is not as great, for example, as during the 1936 drought. But of the droughts studied, the 1976–1977 drought produces the second highest amount of total storage released (and thus reduction in the state storage in Carlyle Lake). Still, the total amount of storage used is considerably less than during the 1953–1955 drought conditions.

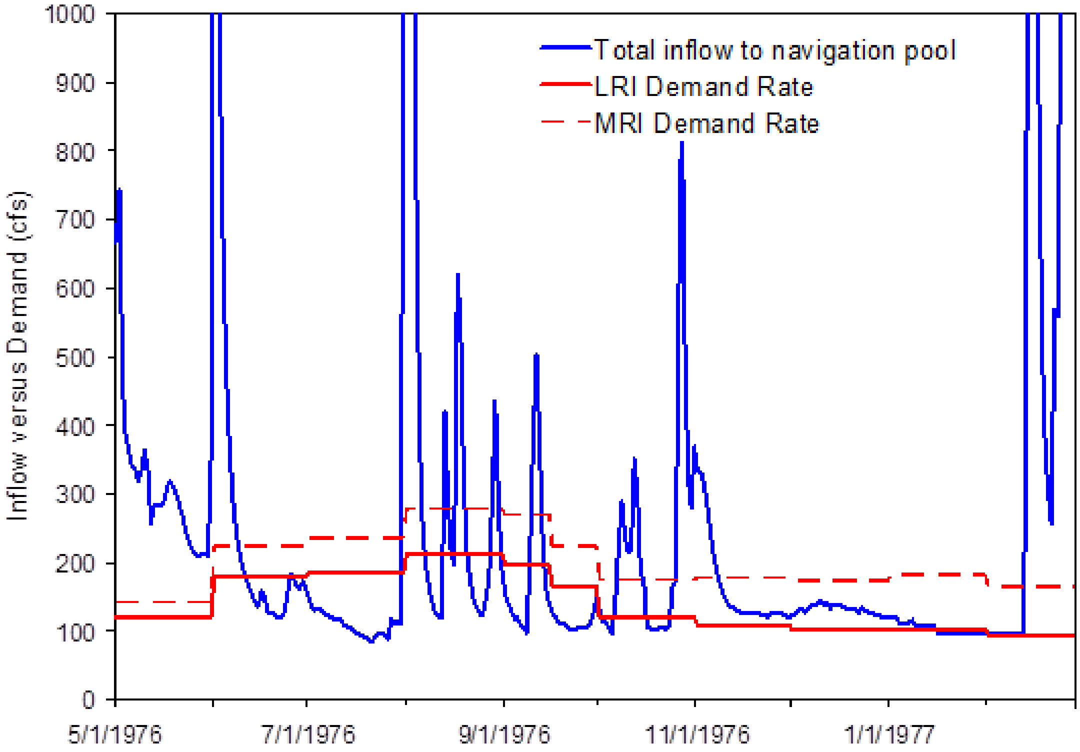

Figure 5.16. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, 1976–1977 drought

Table 5.12. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1976–1977 Drought were to Recur

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
LRI Demand Scenario			
Prairie State			
Storage released (acre-feet)	4475	3204	2762
Maximum annual rate (mgd)	2.1	2.1	2.1
Dynegy			
Storage released (acre-feet)	3238	859	0
Maximum annual rate (mgd)	2.9	0.8	0.0
BL Demand Scenario			
Prairie State			
Storage released (acre-feet)	5358	3646	2762
Maximum annual rate (mgd)	2.4	2.1	2.1
Dynegy			
Storage released (acre-feet)	5401	2685	859
Maximum annual rate (mgd)	4.3	2.4	0.8
MRI Demand Scenario			
Prairie State			
Storage released (acre-feet)	7955	6242	4861
Maximum annual rate (mgd)	3.7	3.6	3.6
Dynegy			
Storage released (acre-feet)	9753	7998	4830
Maximum annual rate (mgd)	6.3	3.8	3.6

Estimated Releases for Dynegy if it is the Only Company in Operation

LRI Demand Scenario			
Storage released (acre-feet)	6460	3545	3545
Maximum annual rate (mgd)	3.2	3.2	3.2
BL Demand Scenario			
Storage released (acre-feet)	6905	4726	3545
Maximum annual rate (mgd)	3.2	3.2	3.2
MRI Demand Scenario			
Storage released (acre-feet)	8305	6598	3545
Maximum annual rate (mgd)	4.8	3.2	3.2

Notes:

1) Releases may occur in both the Oct 1975–Sept 1976 and Oct 1976–Sept 1977 water years. Maximum annual rates may occur in either year depending on the scenario.

Potential Releases during an Episode Similar to the 1988 Drought

With regards to the navigation channel, the 1988 drought was an abbreviated drought which was essentially terminated by heavy regional rainfall in mid-July of that year. But because the levels of the Mississippi River were very low that summer, and because historical navigational use was near its peak in the late 1980s, to date it provides the best example of observed deficit conditions since the construction of the navigation channel. Although the USACE was able to substantially reduce demands during that drought, it is possible that deficits may still have occurred if drought conditions had continued without relief until later in the summer. Also, if at the time a second power plant such as Prairie State had existed and needed water from the channel, water supply releases would most likely have been needed. Although the observed summer water quality release from Carlyle Lake was 100 cfs throughout much of the summer or 1988, the simulated flow shown in Figure 5.17 is based on a release rate of 50 cfs.

An examination of Table 5.13 indicates that the potential need for water supply releases during drought conditions similar to 1988 is to a great extent dependent on the summer water quality release. For scenarios showing a need of less than 1 mgd or 1000 acre-feet, it seems feasible that releases could be avoided altogether through temporary reductions in either recreational lockages or power plant withdrawals.

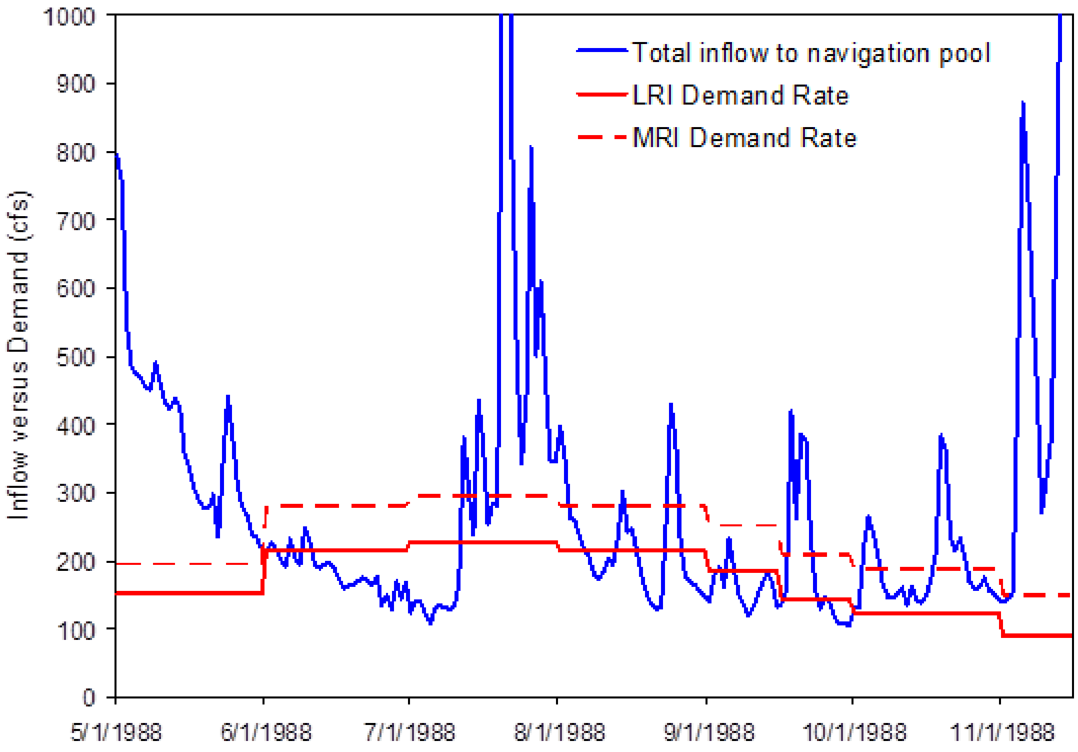

Figure 5.17. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, 1976–1977 drought

Table 5.13. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1988 Drought were to Recur

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
LRI Demand Scenario			
Prairie State			
Storage released (acre-feet)	1933	331	331
Maximum annual rate (mgd)	1.7	0.3	0.3
Dynegy			
Storage released (acre-feet)	2655	0	0
Maximum annual rate (mgd)	2.4	0.0	0.0
BL Demand Scenario			
Prairie State			
Storage released (acre-feet)	2651	829	331
Maximum annual rate (mgd)	2.4	0.7	0.3
Dynegy			
Storage released (acre-feet)	4082	967	0
Maximum annual rate (mgd)	3.6	0.9	0.0
MRI Demand Scenario			
Prairie State			
Storage released (acre-feet)	2762	1492	829
Maximum annual rate (mgd)	2.5	1.3	0.7
Dynegy			
Storage released (acre-feet)	4726	2900	967
Maximum annual rate (mgd)	4.2	2.6	0.9

Estimated Releases for Dynegy if it were the Only Company in Operation

	50 cfs	100 cfs	150 cfs
LRI Demand Scenario			
Storage released (acre-feet)	2823	644	644
Maximum annual rate (mgd)	2.5	0.6	0.6
BL Demand Scenario			
Storage released (acre-feet)	3100	644	644
Maximum annual rate (mgd)	2.8	0.6	0.6
MRI Demand Scenario			
Storage released (acre-feet)	4741	1719	644
Maximum annual rate (mgd)	4.2	1.5	0.6

Notes:

a) Nearly all releases occur during the Oct 1987–Sept 1988 water year.

Potential Releases during an Episode Similar to the 1964 Drought

Figure 5.18 illustrates that the August 1964 drought condition would result in deficit conditions in the navigation channel only with large demand rates. Most of the potential releases associated with the 1964 drought conditions, identified in Table 5.14, would be contract-driven releases during the 33 days in October and November when the river's flow rate falls below the Q7,10. If the power companies were using the 69.3 cfs threshold at Venedy Station as their trigger, water supply releases could be avoided altogether except at high (MRI) demand rates.

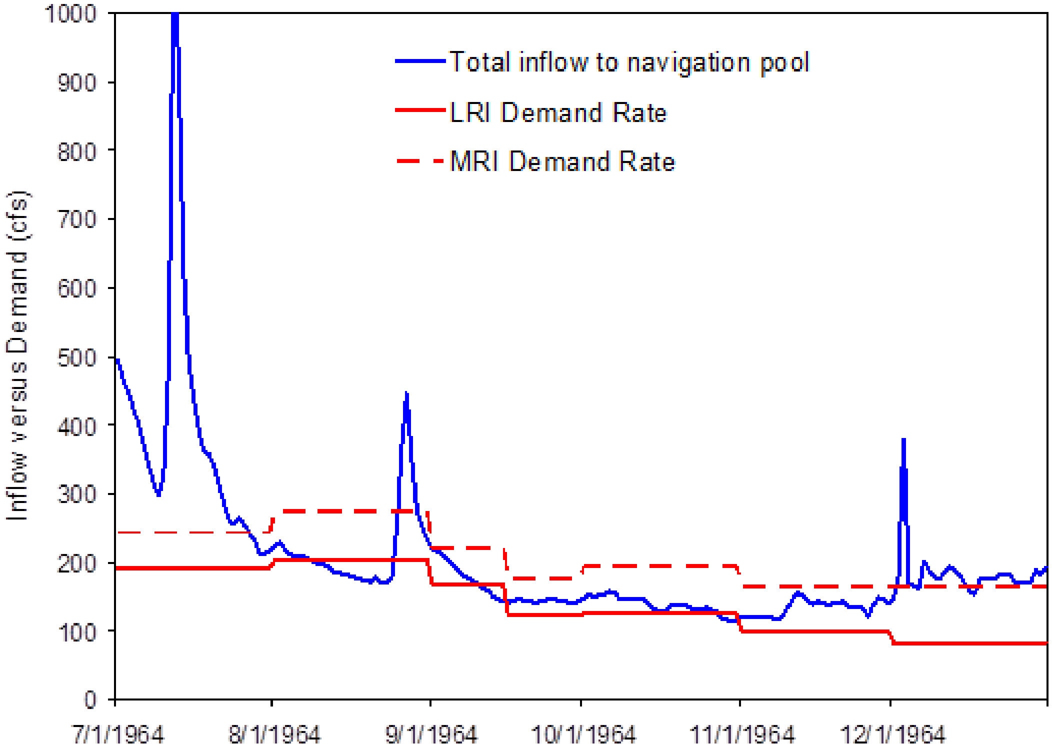

Figure 5.18. Comparison of potential water demands (water supply and navigation) in the Kaskaskia Navigation Channel to the simulated total inflow rate, 1964 drought

Table 5.14. Estimated Water Supply Releases from Carlyle Lake if Conditions Similar to the 1964 Drought were to Recur

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
<u>LRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	1823	1823	1823
Maximum annual rate (mgd)	1.6	1.6	1.6
Dynegy			
Storage released (acre-feet)	0	0	0
Maximum annual rate (mgd)	0.0	0.0	0.0
<u>BL Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	2099	1823	1823
Maximum annual rate (mgd)	1.6	1.6	1.6
Dynegy			
Storage released (acre-feet)	537	0	0
Maximum annual rate (mgd)	0.5	0.0	0.0
<u>MRI Demand Scenario</u>			
Prairie State			
Storage released (acre-feet)	3425	3366	2154
Maximum annual rate (mgd)	2.0	1.9	1.9
Dynegy			
Storage released (acre-feet)	4696	2672	2455
Maximum annual rate (mgd)	4.2	2.2	2.2

Estimated Releases for Dynegy if it Were the Only Company in Operation

LRI Demand Scenario			
Storage released (acre-feet)	2302	2302	2302
Maximum annual rate (mgd)	2.1	2.1	2.1
BL Demand Scenario			
Storage released (acre-feet)	2302	2302	2302
Maximum annual rate (mgd)	2.1	2.1	2.1
MRI Demand Scenario			
Storage released (acre-feet)	3161	2302	2302
Maximum annual rate (mgd)	2.1	2.1	2.1

<u>Notes:</u>
Nearly all releases occur during the Oct 1963–Sept 1964 water year.

NAVIGATION RELEASES FOR SPECIFIC USE BY THE KASKASKIA LOCK

As described earlier, the amount of water needed to operate the Kaskaskia Lock can often exceed 8 mgd per lockage during drought conditions when the level of the Mississippi River is low. With the present number of lockages, water needs for the lock during summer can equal or exceed the amount of water needed by the Prairie State and Dynegy power plants. If commercial navigation increases substantially in the future, the Kaskaskia Lock may require the largest amount of water from the navigation pool. For this reason, in the water budget simulations analyzed in this chapter, designated navigation releases from Carlyle Lake are assumed to accompany water supply releases generally whenever 1) accumulated deficit conditions exist in the navigation pool, and 2) the water quality release is not sufficient to meet the combination of water demands for the Kaskaskia Lock and net evaporation losses in the navigation pool.

Table 5.15 lists the total volume of navigation water expected to be released from Carlyle Lake for the selected drought periods. Values in Table 5.15 directly correspond to the water supply release amounts shown in Table 5.8 and Tables 5.11 through 5.14. A comparison of the

Table 5.15. Simulated Navigation Releases from Carlyle Lake for Use by Kaskaskia Lock (drought total in acre-feet)

	Summer water quality release rate		
	50 cfs	100 cfs	150 cfs
<u>1953-1955 Drought</u>			
LRI Scenario	0	0	0
BL Scenario	4895	4094	1933
MRI Scenario	40388	32408	32148
<u>1936 Drought</u>			
LRI Scenario	8747	6583	0
BL Scenario	14614	11632	7740
MRI Scenario	23539	21452	15876
<u>1976-1977 Drought</u>			
LRI Scenario	4425	1596	0
BL Scenario	9621	4312	1074
MRI Scenario	29063	21928	19089
<u>1988 Drought</u>			
LRI Scenario	1841	0	0
BL Scenario	3836	1719	0
MRI Scenario	11969	7058	2455
<u>1964 Drought</u>			
LRI Scenario	0	0	0
BL Scenario	0	0	0
MRI Scenario	7933	3744	0

simulated water supply and navigation releases indicates that navigation releases for the Kaskaskia Lock would exceed water supply releases if commercial navigation expanded greatly, such as that associated with the MRI scenario. With the BL scenario, navigation releases would be somewhat less but roughly comparable to water supply releases; with the LRI scenario, navigation releases would generally be small and much less than water supply releases.

Although the need for navigation releases is noticeably greater when the summer water quality release is low (50 cfs), the overall amount of water being released from Carlyle Lake for any given scenario (the combination water supply, navigation, and water quality releases) is greatest with the highest water quality release rate (150 cfs). With the MRI scenario, however, the combination of needed water supply and navigation releases throughout the summer is often as much or greater than the 150 cfs associated with the highest water quality release.

DISCUSSION

Based on the scenarios studied, the two primary influences on future water supply releases from Carlyle Lake are 1) water needs for commercial and recreational lockages at the Kaskaskia Lock and Dam, and 2) the quantity of the summer water quality release from Carlyle Lake. Except as noted, the projected water needs for the two largest water supply allocations, the Dynegy and Prairie State power plants, are considered in this report to be constant over the next 40 years. The largest variable in projected water needs for the Kaskaskia navigation pool is instead the potential increase in local commercial navigation, which produces the largest differences between the projected LRI, BL, and MRI scenarios. Increases in water needs for commercial navigation are not expected to affect the actual water needs and withdrawals of the two power plants; however, they will 1) increase the proportion of time that the navigation channel is in a deficit condition (when water needs exceed inflow), and thus 2) directly affect how often releases from Carlyle Lake (both navigation and water supply releases) will be needed to support the downstream water needs, as shown for the 1953–1955 drought in Tables 5.8 and 5.15.

During summer droughts, variations in the water quality release from Carlyle Lake can also affect the availability of flow for downstream uses, potential water deficits in the navigation pool, and the resulting need for water supply releases. Reportedly, the USACE is looking into the possibility of modifying the outlet facilities at Carlyle Dam to release cooler water that would have a lower oxygen demand, thus allowing the facilities to reduce the volume of the summer water quality release to as low as 50 cfs. This, in turn, would increase the potential need (both amount and frequency) for water supply and navigation releases during severe drought conditions. The summer season offers the greatest potential for water deficits in the navigation pool; however, it should be noted that water supply releases are often needed at other times during severe droughts that are unaffected by variations in the summer water quality release rate. During the 1953–1955 drought of record, for example, the dominant portion of the projected water supply releases occurs in the fall, winter, and spring.

Projected Frequency of Water Supply Releases

How often would releases from Carlyle Lake be needed in the future? It is estimated that contract-driven water supply releases would most likely be needed by one or both of the Prairie State and Dynegy-Baldwin power plants if droughts similar to the 1953–1954, 1964, and 1976–1977 droughts, and possibly also the 1936 drought, were to recur. For most drought episodes, such contract-driven water supply releases would be expected to occur during the fall and winter when the water quality release from Carlyle Lake would be at the minimum protected level of 50 cfs. Deficit-driven water supply releases are more likely to occur during the summer months when there are high water demands for navigation lockages, higher use rates by the two power companies, and high evaporative demands from the navigation channel. For most water demand scenarios, some deficit-driven water supply releases would have been needed during the aforementioned 1936, 1953–1954, 1964, and 1976–1977 droughts, with 1936 being the year with the greatest summer flow deficits. Thus releases may be needed during at least four separate drought episodes over an 80-year period (1934–2013). This implies that such releases would be needed in future drought episodes roughly once in 20 years on average for most scenarios examined.

Although the occurrence of low flows below the protected Q7,10 level would happen during moderately severe droughts more often than once in 20 years, they would occur only for short periods such that the major power plant users could satisfy their needs using on-site storage. If water demands were to increase substantially (to the BL and MRI conditions) and/or concurrent summer water quality releases from Carlyle Lake were low (such as 50 cfs), then there would be an expected need for additional deficit-driven releases for some lesser drought episodes such as the 1988 drought. Short-term deficits in the water budget of the navigation pool, which may occur during such lesser drought episodes, can normally be addressed without the need for water supply releases if the navigation pool elevation is temporarily drawn down by as much as 0.4 feet and if the power companies draw upon storage in their on-site reservoirs.

Potential Impact to Water Supply caused by Winter Navigation Releases

Potential navigation releases from both Lake Shelbyville and Carlyle Lake, when called upon to augment low flows in the Middle Mississippi River, are expected to have a relatively minor effect on water supply allocations. Such navigation releases for the Mississippi River would most likely occur during the winter (late-December through February) of an extreme drought. For this analysis, this type of navigation release is assumed to release more than half of the volume of the joint-use pool in both Lake Shelbyville and Carlyle Lake. Water released for this purpose would be subtracted from the federal share of water in the joint use pools, and as such, would not directly affect the IDNR share of the pools designated for water supply. However, users with an IDNR water supply allocation may be required to request their own water supply releases during the duration of the navigation release, which in the selected scenario is estimated to last roughly 26 days during the 1953–1955 drought. Under these circumstances, it is estimated that a total water supply release from Carlyle Lake of 1780 acre-feet, requested from either Dynegy or Prairie State, may be sufficient in itself to avoid any water users (downstream of Carlyle Lake) from interfering with the USACE's navigation release.

Potential Impact if Generating Units at the Dynegy Station were Permanently Shut Down

As noted earlier in this chapter, one of the generating units at the Dynegy Baldwin power station was idled in 2016, and the possibility exists that a second unit could also be idled in upcoming years. Unless these units are reactivated, the overall water needs of the Baldwin station as given in Table 5.2 will be reduced, presumably by either 33 percent (one unit being idle) or 67 percent (two units). This also would mean that 1) the amount of time the Baldwin station could use stored water from Baldwin Lake instead of withdrawing water from the navigation pool will be increased, and 2) the frequency and magnitude of water deficits in the navigation pool will be reduced. During an extreme drought (represented by the 1953–1954 drought), it is roughly calculated that Baldwin's need for Carlyle reservoir releases could be reduced in half if one of the generating units was permanently retired. If two generating units were retired, it is roughly calculated that Baldwin's average annual release rate during a 1953–1954 condition could be less than 4 mgd (MRI scenario). If two units are retired and the commercial navigation passing through the Kaskaskia never exceeds 4 million tons per year (the BL scenario) it is possible that the Baldwin station could operate continuously through a 1953–1954 drought condition without ever needing a reservoir release by using its on-site storage and withdrawing from the river when it has a sufficient amount of available natural inflow.

Adequacy of Current Allocations

The IDNR's annual allocation amounts appear to be adequate to meet the needs of all major water users analyzed in this study. The only perceived inadequacy in the current water supply allocations is the maximum allocation rate granted to the Prairie State Energy Campus. In its IDNR allocation agreement, the maximum water supply release rate for the Prairie State plant is designated to be 18 mgd; however, the analysis presented herein has instead used a value of 25 mgd, which represents that company's reported seasonal need during summer conditions as reported to the ISWS by Prairie State. The analysis indicates that if the Prairie State's maximum release rate were increased to either 25 mgd or their reported maximum daily amount of 27.5 mgd, the company would still use a lesser annual volume of water than that allocated in the IDNR agreement. Given that most of the contract-driven water supply releases occur during cool-season conditions, possibly the 18 mgd pumping limit might only occasionally impair Prairie State's operations in contract-driven conditions. The IDNR agreement also does not specifically limit Prairie State's withdrawal rate during periods of deficit-driven releases which typically occur in the summer (when maximum withdrawal rates would be needed). That said, if contract-driven releases were needed in the summer, the maximum release limitation in the current agreement could force the power plant to significantly restrict their operations. In summary, although Prairie State's allocation agreement provides an adequate maximum annual rate (13.35 mgd) for drought releases, the maximum release rate (18 mgd) is potentially restrictive to its operations without a known corresponding benefit to either environmental or flow conditions in the navigation channel. Thus, the company would benefit by an adjustment (increase) to that allowed peak rate. Under such conditions, it would not seem necessary to limit the number of days that Prairie State could pump or release at their maximum rate as long as the company's water needs remain the same as identified in Table 5.1. In such case, the plant's consumption rate and size of their raw water reservoir effectively determine and provide a limit to its overall withdrawal needs.

6. IMPACTS OF WATER RELEASES ON LAKE LEVELS DURING DROUGHT

The combination of dry conditions and sustained reservoir releases and withdrawals during an extreme drought will result in low water levels. Substantially low water levels in turn have the potential to negatively affect recreation and conservation uses of Lake Shelbyville and Carlyle Lake; emphasis herein is given to potential impacts on commercial activities during the summer associated with recreational boating. To understand the extent of potential impacts related to future water supply uses, it is necessary to identify how often and at what duration low water levels might be expected during drought conditions. This chapter presents simulated lake levels at selected scenarios of water use for two drought episodes: 1) the 1953–1955 drought of record; and 2) the 1976–1977 drought.

The 1953–1955 drought is the worst of three extreme multi-year drought episodes since the 1890s (with the others having occurred in 1894–1895 and 1930–1931), for which low water levels in the federal reservoirs would not be expected to fully recover during the spring following the initial year of drought. Such extreme droughts cause low water levels to occur during two consecutive summers, with low water conditions in the second summer typically being noticeably worse than in the first year. These extreme droughts are estimated to have recurrence intervals of 40 years or more. In all other historical droughts, such as the 1976–1977 drought, low water levels are typically only a concern during the drought's initial summer period. The 1976–1977 drought is the most severe historical drought since the federal reservoirs were constructed, but it is generally considered to have a recurrence interval of about 20 years.

Water-level impacts are examined for each drought for four scenarios of water use: 1) a hypothetical "No Releases" scenario in which there are no water supply or navigation releases from either Lake Shelbyville or Carlyle Lake, and direct withdrawals from the lakes are held at their current use, 2) the less resource-intensive (LRI) scenario, in which there is relatively little growth in either future water supply or commercial navigation such that water use is very similar to current conditions, 3) the more resource-intensive (MRI) scenario, in which the greatest amount of growth occurs in commercial navigation and with associate releases from Carlyle Lake for use by the Kaskaskia Lock, and 4) a navigation release (NAV) scenario, in which water use is similar to the MRI scenario, but which also includes a hypothetical winter release of water from Lake Shelbyville and Carlyle Lake to augment flow levels on the Middle Mississippi River. In the hypothetical NAV scenario, roughly half of the available federal share of the joint-use pools in Lake Shelbyville and Carlyle Lake is released as part of a designated navigation release, but 40 percent of the total federal share (140,000 acre-feet) is retained (some of which is used later during the extended drought).

SIMULATIONS FOR THE 1953–1955 DROUGHT

Figures 6.1 and 6.2 show simulated water levels for Lake Shelbyville and Carlyle Lake for each of the scenarios under the 1953–1955 drought condition. The simulated water levels for the LRI and MRI scenarios from Lake Shelbyville are very similar, and thus water levels for these two scenarios are shown together in Figure 6.1 with a single line. For all scenarios, water levels for Lake Shelbyville and Carlyle Lake at the end of the winter drawdown in December 1953 are expected to converge to 594.5 and 443.5 feet, respectively. These water levels are 0.5 feet higher than the normal targeted winter pool levels for these reservoirs, but are within the variability of operation allowed by the USACE.

No Releases Scenario

Although water levels from the No Releases scenario are influenced to a small degree by direct water withdrawals from the reservoirs, the two most dominant factors causing low water levels with this scenario are 1) evaporation from the reservoirs, and 2) the reservoir operations' winter drawdown. Once water levels are drawn down in December of the first year, very little recovery occurs in the water level over the next 12 months.

LRI and MRI Scenarios

Prior to the winter drawdown in 1953, the LRI/MRI water supply releases from Lake Shelbyville (for use by Holland Energy and the HRWS) would be expected to lower its water level by about 4 inches below that associated with the No Releases scenario. By the end of 1954, before drought recovery, the Lake Shelbyville water levels for the LRI and MRI scenarios are estimated to be roughly 1 foot below that for the No Releases scenario.

Prior to the winter drawdown in 1953, water levels for the LRI and MRI scenarios for Carlyle Lake are estimated to fall to 0.4 and 1.3 feet, respectively, below the water level for the No Releases scenario. During the winter drawdown, the water level in Carlyle Lake for these two scenarios is expected to be raised back up to the target pool elevation (443.5 feet) by the supplemental water released by Lake Shelbyville as it lowers its pool. By the end of 1954, before drought recovery, the Carlyle Lake water levels for the LRI and MRI scenarios are estimated to fall 0.5 and 1.4 feet, respectively, below that for the No Releases scenario.

NAV Scenario

An examination of Mississippi River flow records during historical droughts indicates that the river's lowest water levels are, in all cases studied, expected to occur during the winter months between mid-December and the end of February. The hypothetical navigation release in the 1953–1955 NAV scenario was projected to begin on January 1, 1954 and last for 21 days. The NAV scenario is classified herein as a hypothetical event, as the extent to which Lake Shelbyville and Carlyle Lake might be drawn down by the USACE under a real-life situation of this magnitude is not known. Regardless of how well this scenario represents the water levels during an actual future navigation release, the most pertinent consequence is that, for an extreme drought similar to that of 1953–1955, water levels in the two federal reservoirs may not recover for another year following the release.

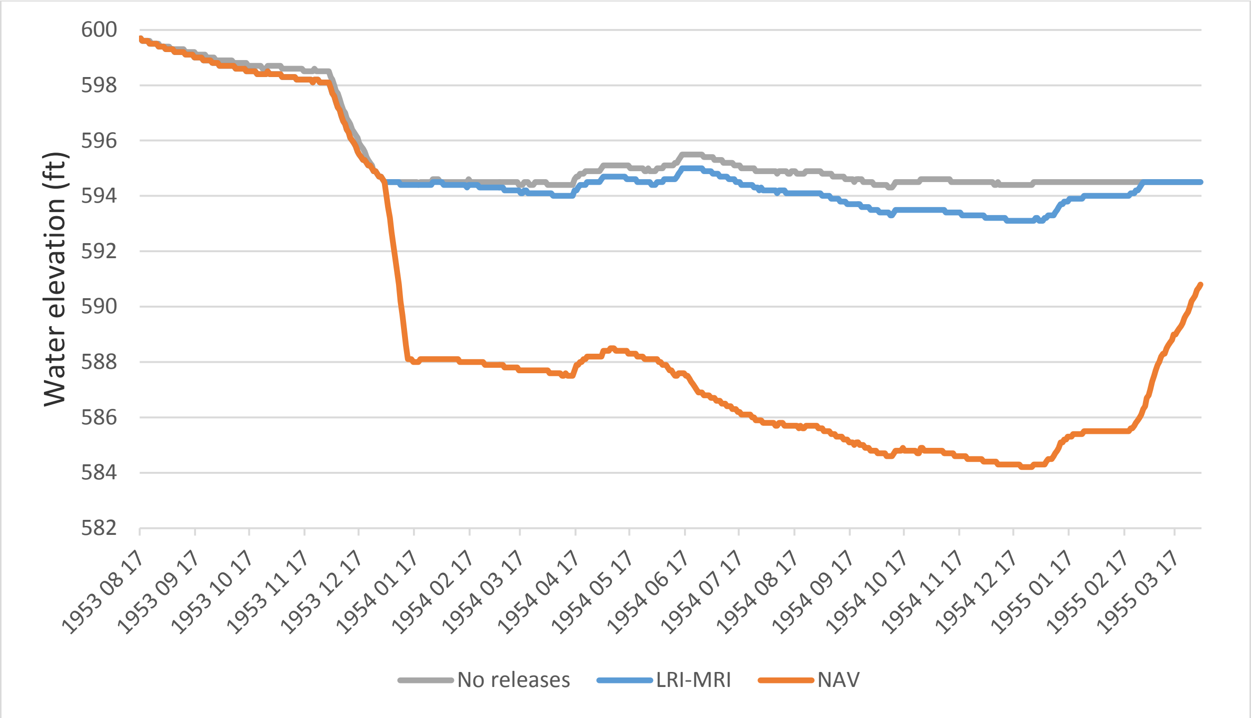

Figure 6.1. Simulated 1953–1955 water levels for Lake Shelbyville under selected scenarios

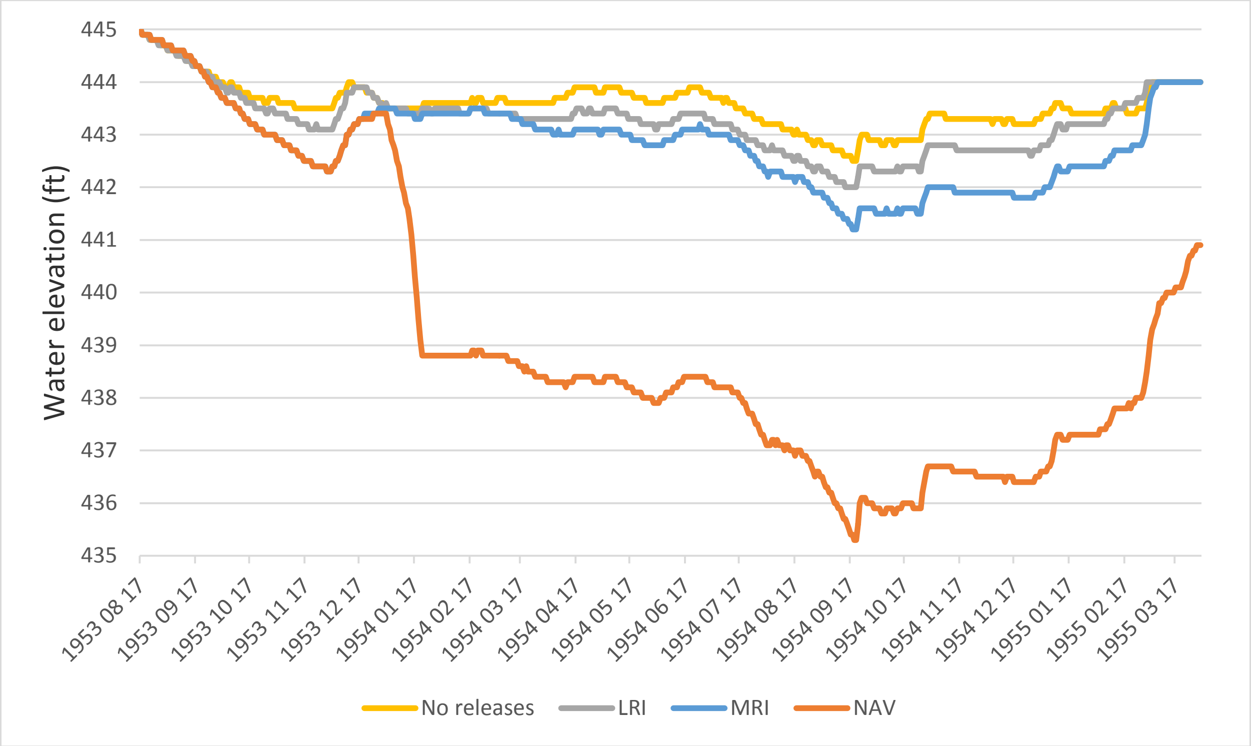

Figure 6.2. Simulated 1953–1955 water levels for Carlyle Lake under selected scenarios

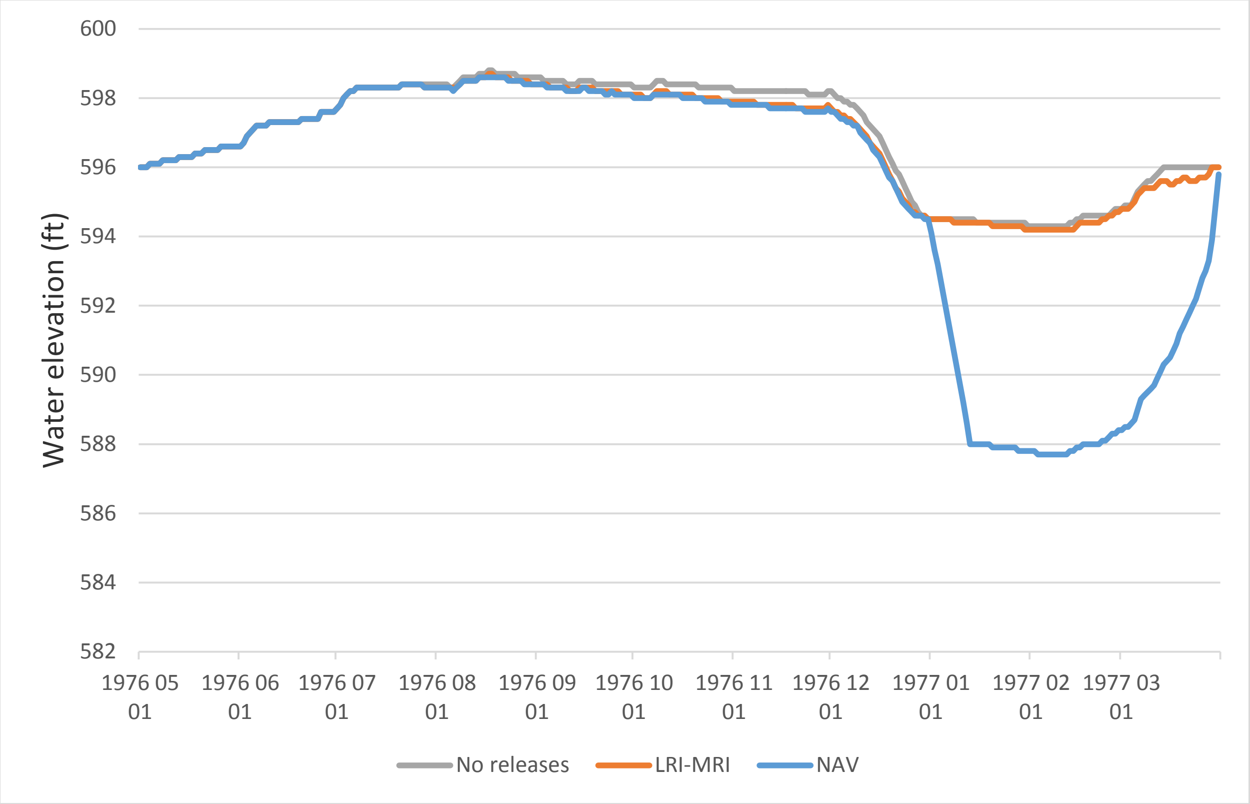

Figure 6.3. Simulated 1976–1977 water levels for Lake Shelbyville under selected scenarios

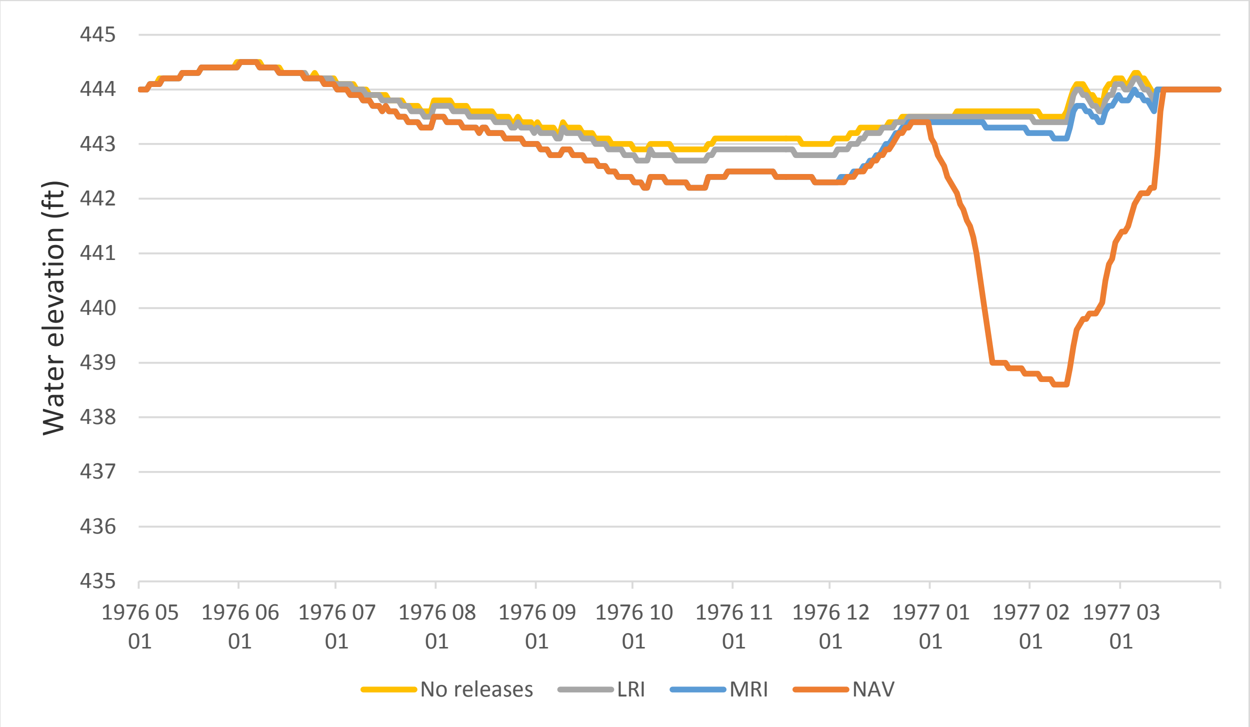

Figure 6.4. Simulated 1976–1977 water levels for Carlyle Lake under selected scenarios

SIMULATIONS FOR THE 1976–1977 DROUGHT

Figures 6.3 and 6.4 show the simulated water levels for Lake Shelbyville and Carlyle Lake for each of the scenarios under the 1976–1977 drought. This drought is considered an "early-season" drought because during its onset in early summer, there is insufficient inflow into Lake Shelbyville and Carlyle Lake to raise water levels to their target summer (full) pools of 599.7 and 445.0 feet, respectively. As shown in the simulations, the 1976 maximum pool level in Lake Shelbyville is roughly 1 foot below full pool. By the end of 1976 (prior to the winter drawdown) the water level for the No Releases scenario is nearly 2 feet below full pool. For Carlyle Lake (Figure 6.4), the 1976 maximum pool level is estimated to be roughly 0.5 feet below full pool in early summer, and for much of the fall season of 1976 the water level is estimated to fall to 2 feet below full pool (No Releases scenario).

Prior to the winter drawdown in 1976, the LRI/MRI water supply releases from Lake Shelbyville (for use by Holland Energy and the HRWS) would be expected to lower its water level by roughly 0.5 feet below that associated with the No Releases scenario. Prior to the winter drawdown, water levels for the LRI and MRI scenario for Carlyle Lake are estimated to fall to 0.2 and 0.7 feet, respectively, below the No Releases scenario.

In scenario simulations, the January 1977 water level conditions and reservoir inflow amounts are very similar to the respective conditions in the January 1954 simulations. However, over a 35-day period in late February and March 1977, portions of the Kaskaskia River watershed received over 10 inches of precipitation, such that there was sufficient runoff to fill both reservoirs back to their spring-season target level (596.0 feet for Lake Shelbyville and 444.0 feet for Carlyle Lake), even when depleted by a potential navigation release. With such a recovery, the impacts of a navigation release can be relatively short-lived, and because there have been relatively few historical drought episodes that have extended into a second summer season, it can be concluded that the water levels of the federal reservoirs will more often than not recover in the spring following most navigation releases. On the other hand, during droughts there are rarely reliable indications that can foretell whether or not a drought recovery is about to occur; thus there must also be the reasonable possibility that an extended drawdrawn period similar to the 1953–1954 conditions may occur.

WATER LEVELS DURING THE SUMMER RECREATION SEASON

Low water levels during summer are of particular interest because of the large amount of commerce centered on summer recreational activity, particularly recreational boating. Of the four marinas located on Carlyle Lake, for example, three are not able to operate when the water level falls 2 feet below normal pool, and the fourth marina would be restricted only to small boats.

Table 6.1 presents the range of water levels by scenario for the three summer periods shown in Figures 6.1 through 6.4. The simulated water levels consider only the periods during which Lake Shelbyville and Carlyle Lake fall below their target pool levels; therefore, the maximum water levels shown for the two reservoirs during the 1953 summer are listed as 599.7 and 445.0 feet,

Table 6.1. Simulated Ranges in Water Levels of Lake Shelbyville and Carlyle Lake during the Summer of Selected Drought Years (Memorial Day to September 15 of each respective year)

Lake Shelbyville

Water use scenario	*1953*	*1954*	*1976*
No releases	559.2 – 599.7	594.6 – 595.5	596.6 – 598.8
LRI	559.1 – 599.7	593.9 – 595.1	596.6 – 598.7
MRI	559.1 – 599.7	593.7 – 595.0	596.6 – 598.6
NAV *	559.1 – 599.7	585.2 – 588.1	596.6 – 598.6

Carlyle Lake

Water use scenario	*1953*	*1954*	*1976*
No releases	444.3 – 445.0	442.6 – 443.9	443.3 – 444.5
LRI	444.3 – 445.0	442.0 – 443.4	443.1 – 444.5
MRI	444.3 – 445.0	441.2 – 443.0	442.8 – 444.5
NAV *	444.3 – 445.0	435.5 – 438.4	442.8 – 444.5

* **Note:** The simulation is of a hypothetical navigation release for augmenting flow levels on the Middle Mississippi River. The actual management of navigation releases by the USACE, if initiated, and resulting reservoir levels during such drought conditions may be considerably different from that shown in this example.

respectively, even though higher levels are also expected to occur earlier in the summer. The 1953–1955 drought started late enough in the summer of 1953 that 1) low water levels would occur only at the end of the summer, 2) there would be a minimal impact on recreation, and 3) potential reservoir releases and differences in water use would have relatively little effect on summer water levels in the two lakes.

In contrast, by the second summer of that drought (1954) there are noticeable differences in potential water levels as impacted by projected water use (and associated water supply and navigation releases from the two reservoirs). The LRI scenario, which is roughly similar to current water use conditions, is estimated to lower the water levels in the second year of an extreme drought by as much as 0.7 feet in Lake Shelbyville, and 0.6 feet in Carlyle Lake, below that expected with the “No Releases” scenario. But regardless of the scenario, because water levels in a 1953–1955 drought condition are unable to recover from the previous winter drawdown, water levels are low enough to force all marinas from operating. As indicated previously, extreme drought conditions with continuing low water levels through a second summer would be expected to occur once in 40 years on average.

During an early-season drought, such as the 1976–1977 drought, water levels in early summer may never reach their target level. In the past 45 years since federal reservoirs were constructed, there have been at least two such early-summer droughts (1976, 1988) when both reservoirs did not reach their full pool. Table 6.1 indicates that low water levels might potentially impact marina operation during part of the 1976 summer even if there were no water supply or navigation releases from the lakes. For Carlyle Lake, the LRI and MRI water use scenarios would be expected to incrementally decrease the minimum water levels to be expected that summer (with reductions of 0.2 and 0.5 feet, respectively).

POTENTIAL IMPACT OF WATER LEVELS ON WILDLIFE MANAGEMENT OPERATIONS

During late September through October of most years, water is withdrawn from Carlyle Lake to flood 3500 acres of wildlife management areas located to the north of the lake. This water is typically returned back to the lake during the late winter and spring. The total volume of the withdrawal is typically as much as 5250 acre-feet (a water depth of 18 inches across the management areas). The withdrawal alone has the potential of dropping the water level in Carlyle Lake by 0.25 feet. But if the water level in Carlyle Lake falls below an elevation of 443.0 feet, the fixed pumping facilities that provide for the withdrawal begin to lose efficiency, and these pumps become inoperable below a lake elevation of 442.0 feet.

From the droughts examined in this study, water levels are expected to be too low and the management area's pumping facilities will be inoperable during the second year of an extended drought (such as the fall of 1954, 1931, and 1895). For certain early-season droughts, water levels in September and October could possibly fall below an elevation of 443.0 feet and thus restrict the extent to which the wildlife management areas may fill with water. For example, under the MRI scenario and the 1976–1977 drought conditions, the water budget simulations indicate that the management areas could only be partially filled before low lake levels limited the amount of water that could be pumped. In conclusion, there will likely only be a limited number of severe drought circumstances in which the wildlife management practices would be interrupted.

7. STORAGE ACCOUNTING AND POTENTIAL IMPLICATIONS TO WATER SUPPLY ALLOCATIONS

USE OF THE DROUGHT OF RECORD VERSUS THE 50-YEAR DROUGHT

In calculating the yield or water volume availability for the federal reservoirs, certain sets of conditions and assumptions must be adopted. The amount of water that IDNR has allocated to date from the federal reservoirs (42 mgd), as identified in the 2001 yield estimates, is based on the set of conditions associated with an artificial 50-year drought and an assumption that water use is uniform over the drought's duration. Based on these selected conditions, water supply storages in Lake Shelbyville and Carlyle Lake are expected to reach their minimum level in February 1955, with the critical duration of the drought calculated to be 547 days.

In contrast, the analyses presented in this report center around a drought condition that is identical to the worst hydrologic drought on record which occurred in 1953–1955. Water availability during the 50-year drought, on the other hand, is more closely comparable to conditions during the 1930–1931 drought, which is the second worst hydrologic drought in the Kaskaskia region over the past 100 years. The 1930–1931 drought was not analyzed in detail in this report because available hydrologic data for that drought is limited. Use of the 1953–1955 drought of record in this study for investigating water availability, instead of the 50-year drought, effectively reduces the calculated water availability for Lake Shelbyville and Carlyle Lake by a combined amount of roughly 10,400 acre-feet or a uniform rate of about 7 mgd used over the duration of the drought (Tables 2.1 through 2.4). However, as discussed later in this chapter and in previous sections of this report, water supply storage in the lake is still calculated to be sufficient to meet all allocation obligations during the drought of record.

In addition, analyses in Chapter 5 show that water supply releases from Carlyle Lake are not expected to be uniform or continuous during an extreme drought. In particular, for the 1953–1955 drought, it is calculated that no releases from Carlyle Lake would be needed during the final five months of the drought. With such a substantial reduction in the water needs during the latter stages of the drought, the combined water supply storages in the federal reservoirs are estimated to begin recovery prior to February 1955, essentially reducing the effective duration of the drought. In summary, the timeline and overall set of conditions used to define water supply yield are different from the actual operational conditions that would be encountered during an extreme drought.

Although the ISWS has recommended the use of the drought of record to determine drought vulnerability with many community water supply systems in Illinois, the management conditions are different with the two federal reservoirs because the designated water supply storage is a relatively small percentage of the total water stored in the joint-use pools. There is no intent herein to necessarily recommend a change in the drought severity used to allocate water from the two federal reservoirs. It is worthy to note that the 1953–1955 drought was not merely an extreme and lengthy drought for Illinois; the drought remains one of the worst historical droughts throughout large regions of the country, including the Midwest, Great Plains, and Southwest.

Most states in the Union were affected to some degree. If a similar drought were to happen in the future, it is not unreasonable to expect that some form of national drought emergency would be declared, and responses during such an event could potentially influence, reexamine, and possibly reshape the manner in which reservoir water is used.

WATER STORAGE ACCOUNTING

The USACE has initialized an accounting procedure of the federal and state components of storage from the reservoirs; although, since no releases have yet taken place, the only water supply use in the calculations to date is the Gateway Water Company's direct withdrawal from Carlyle Lake. The complete accounting procedures are expected to calculate total credits (reservoir inflow and precipitation over the reservoir surface), debits (water quality releases, navigation releases, water supply withdrawals and releases, and evaporation from the reservoir surface), and the resulting month-end balances in both the federal and state storages. The credit and debit amounts for water quality releases, inflows, precipitation, and evaporation are divided into proportionate shares for both the federal and state storages in the reservoirs. The proportionate share for the state water supply storage is 13.9 percent for Lake Shelbyville and 14.2 percent for Carlyle Lake, being equivalent to the respective percentage of the joint-use pool in each reservoir designated for water supply use. The remaining portion of storage in the joint-use pool is designated as federal storage. Both state and federal storage amounts in each reservoir are considered to be full whenever a reservoir's water level is above the target elevation of its joint-use pool; thus the monthly accounting procedure needs to be activated for those periods only when water levels are below their target elevations.

The amount of water supply storage in Lake Shelbyville and Carlyle Lake during a drought similar to the 1953–1955 drought of record was simulated using what is expected to be the same accounting principles that the USACE would use. Figure 7.1 shows the calculated water supply storage for those two reservoirs under the scenario that uses the most storage, i.e., the MRI water demand scenario combined with a summer water quality release from Carlyle Dam that is limited to 50 cfs. For this simulation, half of the water requested by the Prairie State Energy Campus, and released from Carlyle Lake, is debited to Lake Shelbyville's water supply storage as per IDNR's conceptual design in allocating water from the two federal reservoirs. This "paper transfer" of water in the accounting process (from Lake Shelbyville to Carlyle Lake) is designed to avoid negative values (over-allocation) in the water supply accounting for Carlyle Lake but does not alter the combined water storage balance for both reservoirs. As mentioned previously, during a drought the USACE may or may not choose to physically transfer (release) water from Lake Shelbyville to flow into Carlyle Lake as is its prerogative in its joint management of both reservoirs.

Figure 7.1 shows that the minimum water supply storage in Carlyle Lake during the 1953–1955 drought condition would occur in mid-September 1954; for the remainder of the drought, there would be no further releases from Carlyle Lake. The minimum water supply storage in Lake Shelbyville would occur later, near the first of January 1955, as water supply releases for Holland Energy and the HRWS would continue to draw on that lake's storage. The minimum combined storage for the two reservoirs would also occur near the first of January 1955.

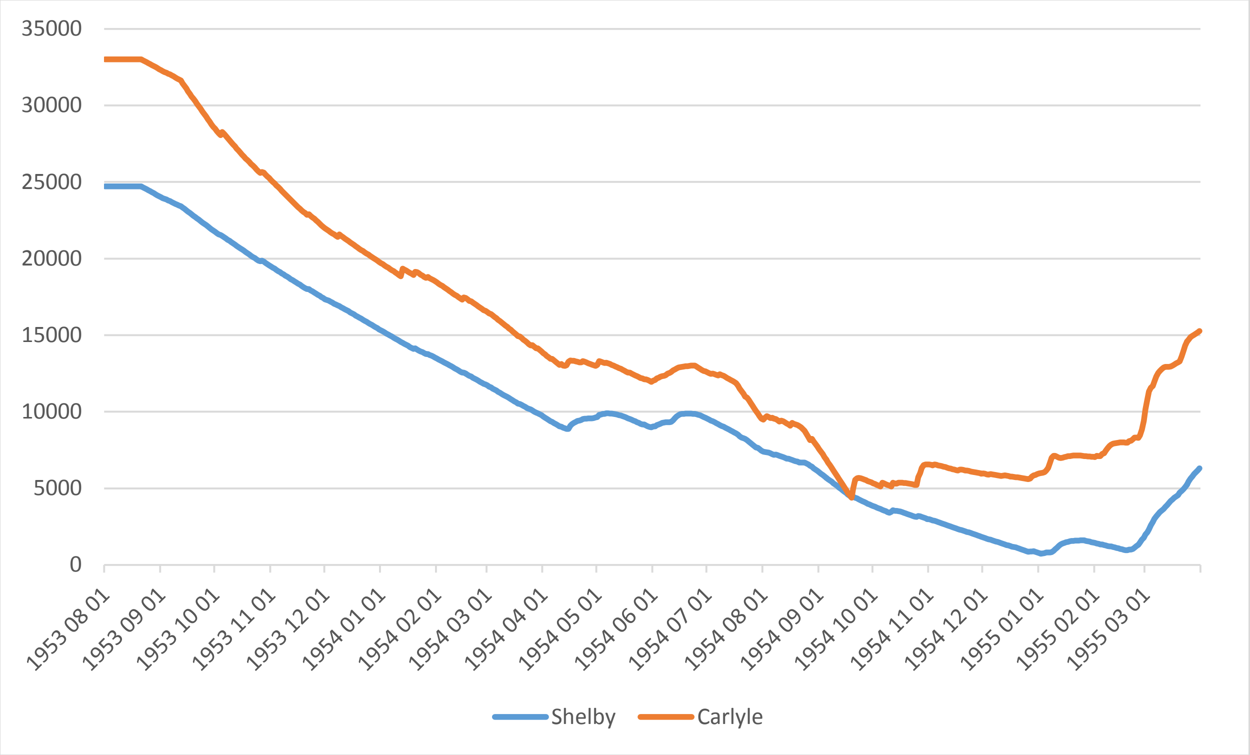

Figure 7.1. Simulated accounting of state storage (acre-feet) for the 1953–1955 drought; MRI water demand scenario, water quality release at Carlyle Dam limited to 50 cfs

Because the USACE accounting procedure is a monthly computation, the effective minimum storage and end date of the drought's *critical duration* would be December 31, 1954. For the onset of the drought, the USACE monthly accounting process would either begin with a partial month to cover the last 10 days of August 1953 (critical duration of 497 days) or begin on September 1, 1953 (critical duration of 487 days).

ACCOUNTING BALANCES FOR SELECTED SCENARIOS

Table 7.1 presents calculated water supply budgets for the combined state storages in both Lake Shelbyville and Carlyle Lake under a variety of selected water use scenarios. An accounting period of September 1, 1953 to December 31, 1954 is used for all calculations. The debits of state storage coming from releases and withdrawals assume uniform use rates for Holland Energy, HRWS, and Gateway Water Company. The variable use rates for Prairie State and Dynegy-Baldwin are as described in Chapter 5, with total release amounts as presented in Table 5.8. The volume of the water quality releases from Carlyle Lake and the obligated state share of such releases are reduced whenever there are navigation releases from that lake for the benefit of the Kaskaskia Lock or the Mississippi River. Navigation releases are assumed to be employed whenever: 1) the amount of water used by the Kaskaskia Lock is a dominant portion of the navigation channel's water budget, 2) there is a deficit condition in the navigation channel,

Table 7.1. Combined Water Supply Storage Accounting for Lake Shelbyville and Carlyle Lake; 1953–1955 Drought, Confidence Level = 50% (Best Estimate)

Accounting Period: September 1, 1953 to December 31, 1954 (487 days)
(all values in acre-feet except as noted)

a) MRI Scenario, Lake Carlyle summer water quality release = 50 cfs, YEAR 2010

Effective Volume Available:		
Water supply storage	57,406	
Inflows	14,607	
Precipitation	11,779	
Evaporation	-19,319	
	64,473	
Uses of Storage (Releases and Withdrawals)		
Dynegy Baldwin Power Station	-15,345	(from Table 5-8)
Prairie State Energy Campus	-13,921	(from Table 5-8)
Holland Energy	-11,957	(8mgd x 487 days)
HRWS	-7,473	(5mgd x 487 days)
Gateway Water Co	-5,978	(4mgd x 487 days)
State share of water quality releases	-4,476	
Remaining (unused) volume	5,323	

b) MRI Scenario, Lake Carlyle summer water quality release = 50 cfs, YEAR 2050

All values remain the same as (a) except for the water supply storage

Water supply storage	48,028
Effective volume available	55,095
Remaining (unused) volume	-4,055

c) BL Scenario, Lake Carlyle summer water quality release = 50 cfs, YEAR 2010

Uses of Storage (Releases and Withdrawals)	
Dynegy Baldwin Power Station	-3,589
Prairie State Energy Campus	-12,264
Holland Energy	-11,957
HRWS	-7,473
Gateway Water Co	-5,978
State share of water quality releases	-6,786
Remaining (unused) volume	16,426

Table 7.1. Concluded

d) BL Scenario, Lake Carlyle summer water quality release = 50 cfs, YEAR 2050

All values remain the same as (c) except for the water supply storage

Water supply storage	48,028
Effective volume available	55,095
Remaining (unused) volume	7,048

e) MRI Scenario, Lake Carlyle summer water quality release = 100 cfs, YEAR 2010

Uses of Storage (Releases and Withdrawals)	
Dynegy Baldwin Power Station	-12,368
Prairie State Energy Campus	-12,595
Holland Energy	-11,957
HRWS	-7,473
Gateway Water Co	-5,978
State share of water quality releases	-4,808
Remaining (unused) volume	9,294

f) MRI Scenario, Lake Carlyle summer water quality release = 100 cfs, YEAR 2050

All values remain the same as (e) except for the water supply storage

Water supply storage	48,028
Effective volume available	55,095
Remaining (unused) volume	-84

g) BL Scenario, Lake Carlyle summer water quality release = 100 cfs, YEAR 2010

Uses of Storage (Releases and Withdrawals)	
Dynegy Baldwin Power Station	-829
Prairie State Energy Campus	-10,496
Holland Energy	-11,957
HRWS	-7,473
Gateway Water Co	-5,978
State share of water quality releases	-7,095
Remaining (unused) volume	18,067

h) BL Scenario, Lake Carlyle summer water quality release = 100 cfs, YEAR 2050

All values remain the same as (g) except for the water supply storage

Water supply storage	48,028
Effective volume available	55,095
Remaining (unused) volume	8,689

and 3) water supply releases have been invoked. It is also assumed that a winter (Mississippi River) navigation release occurs in the December 1953 to January 1954 timeframe.

During the simulated conditions for the 1953–1955 drought of record, it is estimated that the Prairie State and Dynegy power plants combined would potentially need to release as much as 29,266 acre-feet of storage from Carlyle Lake to meet their water needs (Table 5.8, MRI scenario). In contrast, the effective amount of storage that IDNR has allocated to these two facilities from both federal reservoirs during an 18-month drought is roughly 46,500 acre-feet of storage (27.7 mgd for 547 days). The residual balance between the allocated amount (46,500 acre-feet) and maximum projected use amount (29,266 acre-feet) provides a large buffer that is primarily why the state storage is calculated to be sufficient for the most conservative MRI scenario during the most extreme drought of the 1950s (Table 7.1a).

The previously projected 5.3 mgd annual use attributed to the Holland Energy allocation could underestimate that facility's total use if the power plant is operated throughout much of an extended drought period. Simulation results shown in Table 4.2 indicate that reservoir releases for use by Holland Energy in the amount of 8 mgd could potentially be needed for as much as 78 percent of the 1953–1955 drought's duration, equivalent to an average annual use of 6.24 mgd and a total volume of 9326 acre-feet (over 487 days), in part because Holland Energy may need to maintain reservoir releases at times when power is not being generated at their facility. The extent of that power plant's operation during extreme drought conditions will likely not be known until experienced in some future drought episode. It is conceivable that Holland Energy's releases could surpass the estimated 78 percent duration since it may not be obvious to that company when they might reasonably discontinue their release based on the low flow condition at the Cowden gage. For this reason, it may be advisable for IDNR to conservatively assume that their 8 mgd reservoir release could continue through most, if not all, of an extreme drought period (leading to a projected total use of 11,957 acre-feet over 487 days).

In contrast, there is a fixed downstream control that provides for more direct management of the Dynegy and Prairie State releases: that control is the water level at the Kaskaskia Lock and Dam, which is monitored by the USACE. In drought situations when there no longer exists a water deficit in the Kaskaskia navigation pool, this study anticipates that the USACE would initiate the process to discontinue all deficit-driven water supply and navigation releases, and continue only the releases that are contractually required by the State of Illinois' allocation agreements. During the final eight months of 1954 (after April), natural tributary flows to the Kaskaskia River (in the reach where the navigation channel now exists) were sufficiently high such that there would have been only 40 days when the conditions in the navigation pool would require either Dynegy or Prairie State to request a deficit-driven or contract-driven release from Carlyle Lake. Regardless of potential changes in the way Dynegy and Prairie State might use their allocated water over the remainder of their 40-year contract period, the key factor that defines and limits their maximum use during a 1953–1955 drought or similar future drought condition is the peak period of use between October 1953 and April 1954, i.e., all during the 1954 accounting year (water year). It is believed that Dynegy and Prairie State would have no practical need for water supply releases for most of the remaining duration of such a drought.

POTENTIAL INFLUENCE OF COMMERCIAL NAVIGATION GROWTH

As previously discussed in Chapter 5, the amount of commercial navigation passing through the Kaskaskia Lock and associated water needs for lockages can directly affect the need for water supply releases from Carlyle Lake. Most of the discussion in this report has centered on the maximum water needs that would occur if commercial navigation reached its highest projected level of 10 million tons per year (MRI scenario). It has also been acknowledged that this is an optimistic projection for the growth of barge traffic which would involve a substantial increase in the exportation of coal from local mines. Most of the coal currently mined is instead consumed locally by the Prairie State and Dynegy plants. Projections of coal development might specifically ascertain if there would be sufficient local coal production to both serve the needs of the two power plants and provide the additional tonnage for exportation needed to increase the total tonnage to 10 million tons per year through the Kaskaskia Lock. In the future, if the maximum tonnage projections for commercial navigation through the Kaskaskia Lock were to lessen, it could reduce the maximum projected need for Lake Carlyle water supply releases, thus possibly freeing up some water supply storage in the federal reservoirs for other uses.

Table 7.1 compares the volume of water supply used by the (a) MRI and (c) BL water demand scenarios during the 1953–1955 drought condition. Both scenarios assume that the summer water quality from Carlyle Lake is 50 cfs, and all major water users will use water at their maximum allocated annual rates, as represented by reservoir releases from Lake Shelbyville and Carlyle Lake (except for the Gateway Water Company which withdraws water directly from Carlyle Lake). The amount of water use shown for Gateway, Holland Energy, and the HRWS is equal to their maximum allocated amounts. In contrast, the amount of water use shown for Dynegy and Prairie State varies because of the influence of commercial navigation on available flows and total water needs within the navigation channel. In comparing the MRI and BL scenarios from Table 7.1, the results of the BL scenario show an additional 11,103 acre-feet in the calculated “unused volume” of water in the two lakes, which is equivalent to an additional 7.4 mgd when computed over the 487-day accounting period.

INFLUENCE OF THE SUMMER WATER QUALITY RELEASE RATE

The minimum flow release from Carlyle Dam, 50 cfs, maintains water quality in the Kaskaskia River downstream of the dam. During the warmer conditions of summer, the release rate is typically increased to 100 cfs or more, as a higher flow amount is usually needed to maintain acceptable dissolved oxygen levels in the river. The USACE is reportedly looking into the possibility of modifying the dam’s outlet facilities to allow cooler water (from deeper in the lake) to be released during the summer; this would have the expected effect of causing improved (higher) dissolved oxygen levels in the summer at a lower flow amount.

When higher flow amounts are used for the summer water quality release at Carlyle Dam, it reduces the frequency during which water supply and navigation releases might be needed during severe and extreme drought. The extent of the effect varies depending on the water demand rate in the navigation channel and the amount of natural tributary inflow downstream of Carlyle Lake. For less-severe droughts combined with lower demand rates (LRI or BL demand scenarios), a higher water quality release (100–150 cfs) could make water supply and navigation releases unnecessary during such a drought. Even during the most extreme droughts and high demand rates (MRI demand scenario), a higher water quality release will reduce the need for releases, as shown in Table 7.1 for the 1953–1955 drought (comparing scenarios a–d to scenarios e–h). Examples from other drought episodes (Tables 5.11 to 5.14) show potential changes in the average water supply releases of 2 to 4 mgd during each drought.

POTENTIAL EFFECT OF DATA UNCERTAINTIES ON THE WATER BALANCE

Calculated needs for water releases and resulting effects on the water supply accounting, shown in Table 7.1, have been prepared using the best available hydrologic and climatic data from the Kaskaskia watershed during the 1953–1955 drought. As discussed in Chapter 2 regarding yield calculations, all such data are expected to have some inaccuracies and uncertainties that potentially could lead to an inaccurate representation of the water availability conditions that actually existed during that drought. For this reason, a second estimate of the water supply storage accounting process has been created to portray the assumption that the available hydro-climatological data have overestimated the true amount of water available to the federal reservoirs and, more importantly, to the navigation channel during the 1953–1955 drought. This second calculation, shown in Table 7.2, roughly identifies the lower 10th percentile confidence limit in the water supply storage accounting estimate. There exists a corresponding confidence of 90 percent that the “true” water storage balance would be greater than the amount calculated in Table 7.2. The accounting period of September 1, 1953 through December 31, 1954 is not affected by data uncertainties reflected in Table 7.2.

DISCUSSION

All water accounting and drought simulations examined in this study have assumed that each holder of an IDNR water supply allocation is given the opportunity to use its allocation to the fullest extent as provided in its IDNR contract agreement. Obviously, it is not guaranteed that all allocation holders will be able to expand their current operations to take advantage of the maximum usage rates provided in their agreements; regardless, that prospect is provided to them by those agreements into the early 2040’s. Based on available information regarding their water use practices, estimates show that the Prairie State and Dynegy-Baldwin power plants already can potentially approach or reach their maximum annual allocated usage during an extreme drought such as the 1950s, but not maintain that usage rate over the full duration of such a drought, thus identifying the possibility that there will effectively be some state water supply storage that will be unused during an extreme drought condition.

This chapter presents other factors aside from the allocation agreements that also affect the extent to which the two power companies will need to request the targeted release of water from Carlyle Lake during a severe drought. Specifically, two factors examined in this chapter are: 1) the maximum projected amount of commercial barge traffic through the Kaskaskia Lock, and 2)

Table 7.2. Combined Water Supply Storage Accounting for Lake Shelbyville and Carlyle Lake; 1953–1955 Drought, Confidence Level = 90%

Accounting Period: September 1, 1953 to December 31, 1954 (487 days)
(all values in acre-feet except as noted)

b) MRI Scenario, Lake Carlyle summer water quality release = 50 cfs, YEAR 2050

Effective Volume Available:	
Water supply storage	48,028
Inflows	13,141
Precipitation	11,127
Evaporation	-22,673
	49,623
Uses of Storage (Releases and Withdrawals)	
Dynegy Baldwin Power Station	-15,867
Prairie State Energy Campus	-14,197
Holland Energy	-11,957
HRWS	-7,473
Gateway Water Co	-5,978
State share of water quality releases	-4,452
Remaining (unused) volume	-10,301

f) MRI Scenario, Lake Carlyle summer water quality release = 100 cfs, YEAR 2050

Uses of Storage (Releases and Withdrawals)	
Dynegy Baldwin Power Station	-12,368
Prairie State Energy Campus	-12,595
Holland Energy	-11,957
HRWS	-7,473
Gateway Water Co	-5,978
State share of water quality releases	-4,808
Remaining (unused) volume	-5,556

the flow release rate needed from Carlyle Dam to maintain acceptable water quality during the summer seasons of a severe drought.

A third prevailing factor to be considered is the risk and uncertainty in determining the amount of water that will be made available through the allocation process. The probability that the water supply allocation may not be adequate is associated with 1) the frequency and severity of droughts, and 2) the accuracy of water availability estimates. In determining how much water to allocate from the two federal reservoirs, for example, IDNR must choose either to continue defining water availability using the 50-year drought conditions or instead choose the more extreme drought condition associated with the 1953–1955 drought of record. IDNR may also choose to define its water availability based on the traditional best hydrologic estimates (with a 50 percent chance of over-allocation) or instead on the more conservative 90 percent confidence estimate (with a 10 percent chance of over-allocation). Defining water availability using the more conservative approaches will reduce the potential that the water supply storage will be overused during an extreme drought condition, but also increase the potential that water supply storage in the two reservoirs could remain significantly underutilized.

As suggested in this chapter, the traditional allocation method using yield and assuming constant demand may not be the most appropriate model to identify and allocate water needs, particularly for the Kaskaskia River Navigation Channel and the associated need for reservoir releases from Carlyle Lake. Instead, water budget simulations of the allocation process during historical drought sequences, presented in this report, are recommended to provide a better opportunity to define the expected usage of state water supply storage during specified drought conditions.

Of all the scenarios and assumptions examined in this report, scenarios (a) and (b) in Table 7.1 represent the composite of the most conservative assumptions. Scenario (b) projects water needs in 2050, beyond the term of the current allocation agreements, and is the single scenario examined in which the state’s allotted water supply volume would potentially be insufficient to meet needs by 2050 with the current allocations in place. This Table 7.1(b) scenario involves the following set of assumptions and conditions:

- a drought comparable to the 1953–1955 drought of record is used to define the water availability for allocation;
- the water supply storage in the lakes is reduced proportionately to reflect sedimentation in the joint-use pool through 2050;
- commercial navigation moving through the Kaskaskia Lock and Dam grows to nearly 10 million tons per year (the MRI scenario);
- the USACE modifies the outlet at Carlyle Dam that provides the ability to restrict summer water quality releases to 50 cfs; and
- the Holland Energy plant requires continuous releases throughout the duration of the drought.

If IDNR desires to allocate using water availability defined with a 90 percent confidence level, then scenario (f) from Tables 7.1 and 7.2 also becomes a significantly negative balance scenario.

Less conservative scenarios, and all calculations based on a 50-year recurrence or similar drought event, exhibit water supply balances with varying degrees of surplus. For example, the scenario based on 1) the 50-year drought, 2) an assumption that commercial navigation never grows beyond the BL scenario, and 3) the USACE choosing not to modify the Carlyle release facilities, results in a remaining balance (surplus) in the two federal reservoirs that exceeds 19,000 acre-feet, equivalent to a uniform use rate of 12.7 mgd when calculated over the duration of an extended drought.

In concluding this discussion, two peripheral notes are presented. The first regards the Prairie State allocation, as previously discussed in Chapter 5. The maximum water supply release rate for the Prairie State plant is restricted to 18 mgd during protected low flow conditions, although that plant’s water needs are noticeably greater during the summer, spring, and fall. The designated maximum annual use rate from the IDNR allocation agreement, which appears to be the more important restriction related to total water use, on the other hand is calculated to be fully adequate for the company’s water needs during a drought-of-record condition. The suggestion is made that a higher allowed peak withdrawal rate during protected flow conditions, one that would not impair that company’s operation during drought, could be adopted in the future by IDNR agreement without overextending any other aspect of the existing agreement or adversely affecting any other users. A natural concern with increasing the peak release rate is that Prairie State might overuse their allocation; however, it is noted that the company’s expressed demands are restricted to the amount of water needed to fill their raw water reservoir, a fixed volume of water. Also, as illustrated in Figures 5.13 and 5.14, during an extended drought the protected low flow conditions often occur during the cooler season when the power plants’ water needs are lower, and there is no anticipated benefit for the company to release a greater amount than they can withdraw from the navigation pool during these cool months. However, IDNR could also choose to allow a higher withdrawal rate only during summer months when most needed by the power plant.

Second, this report has focused to a great degree on the release of water supply storage from Carlyle Lake to meet water needs in the navigation channel during extreme drought conditions. However, it should also be noted that a practicable alternative source of water exists that, if needed or desired, potentially could meet a portion of the water needs in the navigation channel. That source is the Mississippi River (as previously suggested by Durgunoglu and Singh, 1989). A large pumping station located near the base of the Kaskaskia Lock, capable of lifting water from the Mississippi River into the Kaskaskia River Navigation Channel (a height of 25 feet when the level of the Mississippi River is very low), could provide diverted water into the channel so as to offset the withdrawal needs of a power plant such as Prairie State, Dynegy-Baldwin, or some other user. If one of the power plants chose to develop such a pumping station, for example, it could be expected that it might not need any or much of its allocated water from Carlyle Lake. This approach could be financially advantageous if construction and operation costs for the pumping station were less than the long-term recurring annual maintenance costs to the USACE to which the power plant would otherwise be obligated upon their first use of Carlyle Lake water.

8. SUMMARY

This report examines the potential impact of future droughts on water supplies along the Kaskaskia River with specific emphasis on the State of Illinois' managed water supply storages in Lake Shelbyville and Carlyle Lake. Climatic and hydrologic records from historical drought episodes are used to identify a range of drought conditions that potentially could recur in the future. The worst drought episode for which hydrologic records are available, 1953–1955, is used as a benchmark condition to calculate the adequacy of available water supplies. Because the federal reservoirs were not constructed until the late-1960s, and because other water supply factors have changed over the past 60 years, the analysis presented herein does not attempt to replicate conditions that actually occurred during the 1953–1955 drought of record, but instead evaluates what would happen if a drought of similar severity were to recur juxtaposed with present-day or future water use and water resource conditions.

Roughly 14 percent of the storage volumes in Lake Shelbyville and Carlyle Lake are reserved for water supply uses, and the water from those storages are allocated and managed by the State of Illinois (through IDNR). In managing the water supply, IDNR limits the total amount of water allocated to various users so that the supply will not be overextended or exhausted during extreme drought conditions. The maximum amount of water currently allocated by IDNR, an annual average rate equivalent to 42 million gallons per day (mgd), is roughly based on a 2001 calculation of the 50-year drought yield for the state's share of storage within the two federal reservoirs. In contrast, the analysis in this report compares the effectiveness of these allocations during hydrologic conditions similar to the 1953–1955 drought of record, which is estimated to have a recurrence interval of approximately 100 years or greater. A similar detailed analysis for the 1930–1931 drought, which is estimated to have a recurrence interval of roughly 50 years, was not conducted because available hydrologic data for that drought are limited.

Water supply storage from Lake Shelbyville and Carlyle Lake has so far been allocated by IDNR to five major water users, those being two regional water supply systems (Holland Regional Water System and Gateway Water Company) and three electricity-generating plants (Dynegy Baldwin Power Station, Prairie State Energy Campus, and Holland Energy). The two largest allocations, to the Dynegy-Baldwin and Prairie State power plants, collectively account for two-thirds of the total allocation from Lake Shelbyville and Carlyle Lake.

Four of these major water users have intakes on the Kaskaskia River that are located downstream of Lake Shelbyville or Carlyle Lake. Holland Energy and the Holland Regional Water System (HRWS) share an intake on the Kaskaskia River that is situated roughly 22 miles downstream of Lake Shelbyville. The Dynegy-Baldwin and Prairie State power plants withdraw water from the Kaskaskia River Navigation Channel, for which both intakes are located more than 70 miles downstream of Carlyle Lake. When the river's flow at any of these intakes is below a specified minimum threshold, as stipulated in their contract agreement, the respective user(s) must request that water be released from the nearest upstream reservoir to meet their continued water needs. Such releases are charged against the annual amount of water that has been allocated to each respective user by IDNR. The Gateway Water Company withdrawals come directly from Carlyle

Lake; its water use is charged against its allocated amount only during drought conditions when Carlyle Lake's pool elevation falls below its target level.

If Holland Energy and the HRWS both use their maximum allowable rates of water, it is expected that each company will need to request flow releases from Lake Shelbyville throughout much of the duration of an extreme drought similar to the 1953–1955 drought. Because relatively little natural tributary inflow to the Kaskaskia River is accrued between Lake Shelbyville and the location of their shared intake, the water needs of both companies are greatly dependent on the amount of flow released from that reservoir and the standard water quality release from the reservoir is not sufficient alone to meet their maximum needs. For this reason, the needed water supply releases from Lake Shelbyville will be nearly the same as (and herein considered essentially equivalent to) the total amount of water used by the two companies during such an extreme drought.

Intakes for the Dynegy-Baldwin and Prairie State power plants, on the other hand, are located far downstream of Carlyle Lake in the Kaskaskia River Navigation Channel. The considerable portion of the Kaskaskia watershed that is located downstream of Carlyle Lake delivers natural tributary inflows to the river that provide a supplemental water source for downstream use by the two power plants as well as by community water supplies that also have intakes on the river. One or both of the power companies are expected to need to request water supply releases during major periods of an extreme drought (similar to the 1953–1955 drought). However, there will be other periods during that same drought when tributary inflows, combined with the standard water quality flow release from Carlyle Lake, will be sufficient to meet all known water needs downstream of the lake. Also considered within these water needs is the amount of flow needed by the Kaskaskia Lock to maintain the movement of commercial barge traffic between the Kaskaskia and Mississippi Rivers.

If the future amount of commercial navigation through the Kaskaskia Lock were to increase to around 4 million tons of commodities per year (the baseline or BL scenario considered in this report) or beyond, then the amount of flow needed to operate the Kaskaskia Lock would at many times during drought conditions be the largest "user" of water from the navigation pool, surpassing the combined water needs of the Dynegy-Baldwin and Prairie State power plants and the community water supplies. The analysis presented in this report assumes that the U.S. Army Corps of Engineers (USACE) will provide a designated navigational release from Carlyle Lake to meet the water needs of the Kaskaskia Lock whenever 1) there is a corresponding water supply release from the lake, and 2) the standard water quality release from the lake is insufficient to meet the needs of the lock. Both conditions are indicative of a *water deficit* in the Kaskaskia River Navigation Channel, in that the total flow coming into the navigation channel from all sources is insufficient to satisfy the needs for all water uses along the channel (water supply and navigation), thus requiring supplemental designated releases from Carlyle Lake.

Potential growth in commercial navigation and the corresponding amount of water needed to operate the Kaskaskia Lock is a major variable affecting the magnitude and frequency of water deficits in the navigation channel. If the amount of commercial barge traffic through the Kaskaskia Lock is not expected to grow substantially in the future (to the maximum projected potential of 10 million tons per year or MRI scenario examined in this study), then there will be more times when the navigation pool has a surplus of water, in which case the power plants may use flows that otherwise would be targeted to federal needs (navigation), reducing their dependence on water supply releases from Carlyle Lake.

The results of this study indicate that some of the water supply storage in Lake Shelbyville and Carlyle Lake will likely remain unused if a 50-year drought were to occur (the drought severity originally identified by IDNR as its allocation standard). Furthermore, if a very exceptional drought similar to the 1953–1955 drought of record were to occur, there are only a few combinations of conditions that could cause the water supply in the two lakes to be exhausted; specifically

1) By the year 2050 the total amount of the state's designated water supply storage has been reduced to reflect ongoing sedimentation losses in the two reservoirs,
2) The amount of commodities passing through the Kaskaskia Lock grows to a rate of 8–10 million tons per year (the MRI scenario),
3) The USACE alters the Carlyle Lake outlet facilities, allowing it to restrict the summer water quality release to only 50 cfs, and
4) Water usage by the HRWS and Gateway Water Company expands to their maximum allocated limit, and the average amount of water used by Holland Energy throughout the duration of the drought is around 8 mgd, rather than the 5.3 mgd originally estimated for allocation purposes.

If some of these specified conditions do not materialize, an unused balance (surplus) in the water supply storage of the federal reservoirs during such an extreme drought would be expected.

With results of this study, some consideration could potentially be given by IDNR to allow additional water supply allocations from the two reservoirs, particularly for smaller water needs. Any allocation decisions of this type are expected to ultimately require an assessment of risk regarding the comparative likelihoods that the available water supply storage could be either underutilized or over-allocated during a future extreme drought event. As stipulated in the existing allocation agreements, the greater burden placed on IDNR appears to be that of avoiding an over-allocation of the resource. For now, IDNR considers the water supply storage in Lake Shelbyville to be fully allocated.

Additional selected conclusions from this report are itemized below.

- The results of this study suggest that water availability from the federal reservoirs is more effectively described and allocated using the total volume of water expected to be withdrawn or released over the course of an extreme drought (acre-feet or million gallons) as opposed to a uniform rate of use (mgd).
- Projected rates of sedimentation and volume loss in the federal reservoirs are based on changes to reservoir capacity as measured in previous surveys. Whereas Carlyle Lake was surveyed in 1999, the capacity of Lake Shelbyville has not been surveyed since 1984. A new survey of Lake Shelbyville is needed to more accurately identify past and predict future sedimentation losses in that reservoir. Reportedly, funding for such a new survey is becoming available in the year following the publication of this report.

- It is natural to expect that water supply releases would occur during droughty summers, when larger water deficits occur in the navigation channel. However, analysis of the 1953–1955 drought indicates that most of the expected releases would instead have occurred during the cool season, when there might be little water deficit, but flows in the Kaskaskia River could be expected to fall below their 10-year low flow for extended periods, thereby triggering the minimum flow protection condition in the IDNR water allocation agreements. The need for extended cool-season releases of this type would be expected during the most exceptional droughts.
- A winter-navigation release to augment low flows on the Mississippi River could cause a substantial reduction in the lake level (federal storage), alone accounting for a 4–6-foot reduction in lake levels in the scenario examined in this report. Although it would also force some water supply releases to take place, such releases would likely occur for less than a month's duration and thus have a relatively small effect on the total water supply storage. During the most extreme droughts, it is possible that the water levels in the reservoirs might not begin to recover for another 12 months following such a navigation release.
- In the absence of such a Mississippi River navigation release, the standard drawdown of Lake Shelbyville and Carlyle Lake to winter pool levels is expected to have the next largest impact on water levels during a drought. It is possible that water levels in the reservoirs may not rebound during the second year of an extended drought, such that summer water levels during the second year are essentially similar to typical winter pool levels, limiting both recreational uses of the reservoirs and water withdrawals for the wildlife management areas.
- The cumulative effects of water supply releases and navigation releases (for specific use by the Kaskaskia Lock) have the potential to also depress water levels in the reservoirs in the later stages of an extreme drought, but to a much lesser extent than either a Mississippi River navigation release or the standard winter drawdown. Such water supply and navigation releases may cause additional decreases in pool levels of 0.5 to 1.5 feet at their maximum extent (depending in part on the future growth in commercial navigation through the Kaskaskia Lock), as mostly experienced during the second year of an extended and extreme drought.
- The analyses presented in this report have examined hydrologic records generally covering an 80-year period (1934–2013). For most of the water demand scenarios examined in this study, it has been calculated that water supply releases from Carlyle Lake would be needed during hydrologic conditions similar to four historical drought episodes during this 80-year period, those being the 1936, 1953–1954, 1964, and 1976–1977 droughts. Thus, for most projected water demand scenarios it may be implied that <u>water supply releases will be needed in future drought episodes roughly once in 20 years, as averaged over the long-term.</u>

Much of the existing and projected water needs in the Kaskaskia navigation pool center around coal production and use. Specifically, most of the projected growth in commercial navigation in future years is related to the exportation of locally mined coal, and the Prairie State and Dynegy plants, which account for much of the water supply allocation, are fueled by coal. But in recent years the coal market has been declining, and one of the generating units at the Dynegy plant has been idled. Without a reversal in these two trends, the overall amount of reservoir releases from Carlyle Lake could be less than that associated with the least-resource intensive (LRI) water demand scenario identified in this study.

The IDNR agreements for each of the five major water supply allocations from Lake Shelbyville and Carlyle Lake have a 40-year term, with all scheduled to expire or be renewed between 2040 and 2044. It is expected that the conditions of each allocation agreement will be reevaluated at that time, although an agreement could possibly be reviewed earlier by IDNR if the holder of that allocation (regional water supply or power plant) no longer showed a need for the full amount of their allocation. Preparation of an updated hydrologic evaluation of the water needs and releases from the federal reservoirs, similar to this report, would also be appropriate in the years prior to the 40-year contract reevaluation dates. In the twenty-plus years between now and then, there is a reasonable probability that a severe or extreme drought will occur that will lead to water supply releases from the federal reservoirs and thus better define the specific water needs of each of the five major water users.

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