Illinois State Water Survey
HYDROLOGY DIVISION

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MITIGATIVE MEASURES FOR AT-RISK PUBLIC SURFACE WATER SUPPLY SYSTEMS IN ILLINOIS

by
Krishan P. Singh and Sally A. McConkey-Broeren
Office of Surface Water Resources and Systems Analysis

Prepared for the
Division of Water Resources
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INTRODUCTION

More than 130 public water supply systems in Illinois depend on surface water for their supply. The Mississippi, Wabash, Ohio, Illinois, and Fox Rivers and Lake Michigan have ample water to meet the demand of the systems they currently serve. However, 90 systems withdraw water from intrastate streams and rivers that have periods of very low flow during dry years. Typically, water reserves from in-channel or side-channel impoundments are used to meet system water demands. Water demand tends to increase with time as a result of population growth, industrial and commercial development, and increases in per capita water use, while storage in in-channel impoundments decreases as sediments delivered by the inflowing stream or river accumulate. Because of changes in demand and/or supply, some surface water systems will suffer water shortages during droughts within the next 30 years.

Reservoir sedimentation is a significant problem in Illinois. In many water supply reservoirs, 50% or more of the original storage capacity is occupied by sediments. Sediment accumulation in in-channel reservoirs reduces their storage capacity and yield and limits their useful life if it is not controlled in some manner. Furthermore, the accumulated sediment behind the impounding dam increases the risk of dam failure as well as the potential for greater damage in the event of a failure. Alternatives for sediment management must be considered in evaluating existing reservoirs and in planning for new in-channel reservoirs.

The ability of surface water sources to meet the current and future demands of the public water supply systems they serve must be continually evaluated as part of water resources planning and management. In addition to increasing domestic and industrial water use, demands may develop for water for recreational use and for mandatory low-flow releases from reservoirs to maintain streamwater quality, ecology, and aquatic habitats. Alternatives for maintaining adequate, reliable water supplies must be devised so we can achieve optimal use of our water resources with minimum adverse impacts on stream and riverine ecology.

This report is the fourth part of a study of Illinois public surface water supply systems and the adequacy of their surface water sources to meet current and future demands. An inventory of public water supply systems using intrastate rivers, me populations they serve, sources of supply, and projections of water demands for 1990, 2000, 2010 and 2020 is given in *Future Water Demands of Public Surface Water Supply Systems in Illinois* (Singh et al., 1988). Sedimentation of in-channel impoundments is examined and future storage capacity projections for public water supply reservoirs are provided in the second report, *An Improved Methodology for Estimating Future Reservoir Storage Capacities: Application to Surface Water Supply Reservoirs in Illinois* (Second Edition) (Singh and Durgunoglu, 1990). A third report, *Adequacy of Illinois Surface Water Supply Systems to Meet Future Demands* (Broeren and Singh, 1989), provides an evaluation of the adequacy of the 90 public water supply systems that withdraw water from intrastate streams and rivers. Future water demand projections are compared to 20- and 50-year drought yields of the supply sources (on the basis of the storage capacity projections developed by Singh and Durgunoglu) to identify systems which may not have adequate supplies. On the basis of these comparisons, 27 public water supplies were found to be at-risk for experiencing water supply shortages in the event of a severe drought before 2020. The current report examines the problems of in-channel reservoir sedimentation, options for sediment management, and alternatives for water supply augmentation. Each of the 27 systems is evaluated individually. For each system, background information is provided; the nature of the water supply problem is presented; alternatives for augmenting the water supply to avoid the risk of future water supply shortages are discussed; and feasible options are identified.

Objectives and Scope

The overall objectives of this study were to identify those public water supply systems, among the 90 systems relying on surface water from intrastate streams and rivers, that may not have an adequate source of supply to meet future needs up to the year 2020; and to determine mitigative measures which they may undertake to meet demands. In this report, the processes that contribute to reduced water yields are first examined, and alternatives for managing surface water sources and for reducing demand are discussed. Each at-risk system is men evaluated individually, and feasible alternatives for achieving a reliable water supply are identified.

A water supply system consists of several major components: the source(s) of supply, the pumping system used to withdraw water from the source, storage facilities for raw and treated water, the water treatment facility, and the distribution system. The adequacy of the raw water source(s) for each of the 90 systems was studied. However, even if the source is adequate, water shortages can occur if any of the other components are inadequate. Components other than the raw water source were not examined in detail. Capacities of pumping systems used to fill side-channel reservoirs are discussed since me yield from the source is intrinsically linked to the water withdrawal system. Water quality was not examined in this study.

This report provides specific information for each of 27 systems whose present source of raw water supply may not be adequate to meet unrestricted future demands through 2020. Twenty-four of the systems have water supplies that may not meet average demands, and threee systems may suffer shortages if high drought-related water use causes demand to exceed the projected average demand. Care was taken to cross-reference identification numbers used in previous reports and to keep names, identifiers, and terminology consistent.

Terminology

The following terms are defined in the interest of clarity and consistency:

Public water supply system (PWS) denotes the supply source(s) and distribution networks that furnish water for drinking or general domestic use in incorporated or unincorporated communities in which 15 or more services or 25 or more people are served for at least 60 days per year. Public water supply systems serve domestic, commercial, and industrial users.

Service area population refers to the total number of people who are supplied from a water system and receive their water through the distribution network. This includes persons served by communities or water districts mat obtain their water from the source distribution system and own/operate their own individual metering and distribution system. It does not include customers who purchase bulk water at the treatment plant and haul the water to its final destination via ground transportation.

Average annual demand is the average daily water use for the system computed by dividing the total water withdrawals for a calendar year by the number of days in the year. Units of millions of gallons per day (mgd) are typically used. For the purposes of mis report the total raw water withdrawals were used to compute average annual demand. Billed water use is less.

Per capita water use expresses the average annual demand divided by the service area population. Water used for industrial, commercial, fire fighting, and other municipal needs is included in the per person use figure. Thus, per capita water use in mis report is not an indicator of individual domestic water use. Units of gallons per capita per day (gpcd) are used.

In-channel reservoir is an impoundment created by a structure built across a natural stream or river.

Side-channel reservoir is an impoundment located near a stream or river; water is pumped from an intake structure in the stream or river to the reservoir. Water may also be pumped from auxiliary or standby ground-water wells.

Optimal pumping system for delivering water from a stream or river to a side-channel reservoir may be operated at various speeds so mat water may be withdrawn over a broad range of flows. Use of such a system indicates mat minimum storage will be needed to supply a given level of demand, or conversely, mat maximum sustained yield will be achieved for a given storage volume. For the purposes of this report, the optimal pumping system is defined as having two variable-speed pumps mat can operate during flows from 0.25 to 8 times me gross water supply demand.

Direct withdrawal refers to water withdrawn from a stream or river and conveyed directly to the treatment plant without significant intermediate storage. Although a low in-channel dam is often constructed immediately downstream of me intake structure to keep the intake immersed, it creates only a small amount of in-channel storage. The stored water may be sufficient to meet demand for a few days or weeks during very low flows.

A 20-year drought is a design drought having a 1-in-20 chance of occurring in any given year.

A 50-year drought is a design drought having a l-in-50 chance of occurring in any given year.

Unaccounted-for losses are calculated as the difference between raw water withdrawals and billed finished water.

Acknowledgements

This study was jointly supported by the Division of Water Resources, Illinois Department of Transportation, and the Illinois State Water Survey (ISWS). Gary R. Clark of the Division of Water Resources served in a liaison capacity during the course of this study. This report was prepared under the general direction of Richard G. Semonin (Chief) and John M. Shafer (Head of the Hydrology Division), Illinois State Water Survey. Kathleen J. Brown typed and formatted the final report, and Gail Taylor edited it.

RESERVOIR SEDIMENTATION

Any reservoir on a stream or river in Illinois will gradually silt up, although the process may take a long time. The reservoir design storage should be adequate to meet the present and future water demands during the useful life of the reservoir, allowing for storage loss due to sedimentation. Inadequate design storage, unsatisfactory estimates of future demands, and underestimation of sediment deposition can result in a reservoir's not meeting water demands during a design or even lesser drought. That will be considered a hydrologic design failure of the water supply and reservoir system.

Geologic erosion and sediment transport by streams are parts of drainage processes. However, they are a multifaceted liability as far as storage reservoirs are concerned. When a dam is built across a stream, the flow cross section progressively increases and the flow velocity decreases toward the dam. This leads to a decrease in sediment transport capacity, causing deposition of sediments, first in the backwaters created by the reservoir and then in the reservoir. Coarse particles are deposited first, and silt and clay particles are deposited in the deep portions of the reservoir in the vicinity of the dam. Sediment deposition continues to reduce the useful storage capacity of the reservoir, so much so that after a. certain number of years, the reservoir may not be able to meet the purposes it was designed for. Because of entrapment of a large part of sediment inflow in the reservoir, the excess flows over the spillway carry only a small amount of sediment and erode the downstream streambed and banks to satisfy their sediment-carrying capacity. There are other associated impacts. Sediment deposition in a reservoir affects the water quality in two ways: 1) penetration of solar radiation into the water and photosynthetic activity are reduced because of turbid waters, and 2) recycling of nutrients and pollutants (carried with the sediments) from the lake bottom into the deep, overlying waters takes place, lowering the dissolved oxygen level to such an extent mat these waters become inhospitable for fish and other aquatic life. Seasonal thermal stratification makes the conditions worse. Usually mere is a significant reduction in the size and diversity of biotic communities.

Reservoir sedimentation affects dam safety in certain ways. If the dam has bottom outlets, they may be choked unless they are occasionally operated for short intervals. The pressure exerted by the sediments on the dam must be considered in dam design. The sediment deposits can complicate regular inspection and observation of the dam behavior.

Background Information

Sediment Delivery Ratio

Water entrains and transports eroded sediment particles, but all such particles are not transported out of the basin. A majority of them are deposited on the mild slopes, channel, and floodplain. Sediment delivery ratio, SDR, is the ratio of particles transported to the particles detached by erosive forces. It is related to drainage area:

$$SDR = aA^{-b} \quad (1)$$

in which a is a constant and b varies from 1/4 to 1/8 (Mahmood, 1987) up to drainage area, A, of about 400 sq mi. A drainage basin acts as a low-pass filter between the on-site erosion and sediment yield.

Water and Sediment Discharge

Stream sediment load, S, generally increases as a power function of streamflow or discharge Q:

$$S = aQ^{b} \quad (2)$$

in which a is a constant and b is an exponent. The parameters a and b are evaluated by statistical regression of the observed S and Q values. Conventionally, linear regression has been on log-transformed values:

$$\log S = \log a + b \log Q \quad (3)$$

However, as shown by Singh et al. (1987a, 1987b), a nonlinear regression using equation 2 greatly minimizes the sum of squares of residuals (S - S) where S is determined from the fitted equation 2 or 3. Underestimation of the annual sediment yield may vary from 20 to 60% with linear regression on log-transformed values of S and Q.

Sediment Measurements

Sediment is carried into a reservoir by streams and rivers as well as by overland flow entering the reservoir. To estimate the amount of sediment being retained in a reservoir, sediment inflow to the reservoir and the sediment outflow from it need to be determined for a number of years. The inflows and outflows can be calculated by measuring the flow rates and the sediment concentrations in the flow into and out of the reservoir. The suspended load can be sampled easily, but measurement of the bedload is rather difficult. The latter is usually considered a fixed percentage of the suspended load (5 to 15% of suspended load for most Illinois streams). The information from these measurements is used to derive sediment rating curves', typified by equations 2 and 3. The rating curves sometimes show definite seasonal shifts.

Studies by various researchers show that from 80 to 90% of the annual stream sediment load is associated wim me top five to eight flood events. Presently most sediment measurements are made during low flows, medium flows, and flows up to the 10% annual flow duration discharge, which account for only about 10 to 20% of the annual sediment load. For better definition of sediment rating curves for the range of flows carrying most of the sediment, field measurements may be drastically reduced for low flows, medium flows, and flows less than the 10% annual flow duration discharge, and greatly increased for high and flood flows.

The volume of sediment stored in a reservoir over a period of years can be obtained by conducting reservoir sedimentation surveys at the beginning and end of the period. Sediment volume can be converted to weight by sediment densities at various locations in the reservoir. The average annual sediment deposition can be obtained from the information developed from these surveys.

Reservoir Delta Formation

The sand and coarse fractions of the sediment load deposit first in the backwater while entering the reservoir. With the passage of years, the delta grows both upstream and downstream of the initial stream/reservoir interface. This delta formation raises the stream stage for a few miles upstream. The coarse fractions of the sediment are the main constituents of deltas. A profile of a typical reservoir delta (Mahmood, 1987) is shown in Figure 1. For most Illinois reservoirs, the coarse sediment fraction is about 5% or less of the total suspended load. Adding the bedload fraction, which is generally taken as about 10% of the suspended load, the total coarse sediment in the delta may be equivalent to 15% or less of the total suspended load. It is possible to excavate it economically by crawler tractor scrapers during droughts when the reservoir levels are low. This can alleviate flooding upstream and add to the normal useful reservoir storage.

Reservoir Bottom Deposits

Silt and clay particles are spread all over the reservoir bottom, although they show gradation with distance from me dam. Density currents have a major role in transport of these deposits from one end of the reservoir to the other. Reservoirs may develop density stratification as a result of temperature differences and an increase in sediment concentration toward the reservoir bottom. The underflow develops when the inflowing water is turbid and of greater density, or when it is much cooler and hence heavier, than the upper layers of warm water during summer. The density or turbidity currents are characterized by a plunge point or plane, physically marked by floating debris on the reservoir surface. Realizing the capacity of density currents to convey large concentrations of fine sediment from the inlet to the dam, Bell (1942) stressed selective withdrawals from reservoirs to mitigate siltation. Frequent operation of undersluices to pass excess flows downstream can result in great reduction of silt and clay sedimentation in a reservoir.

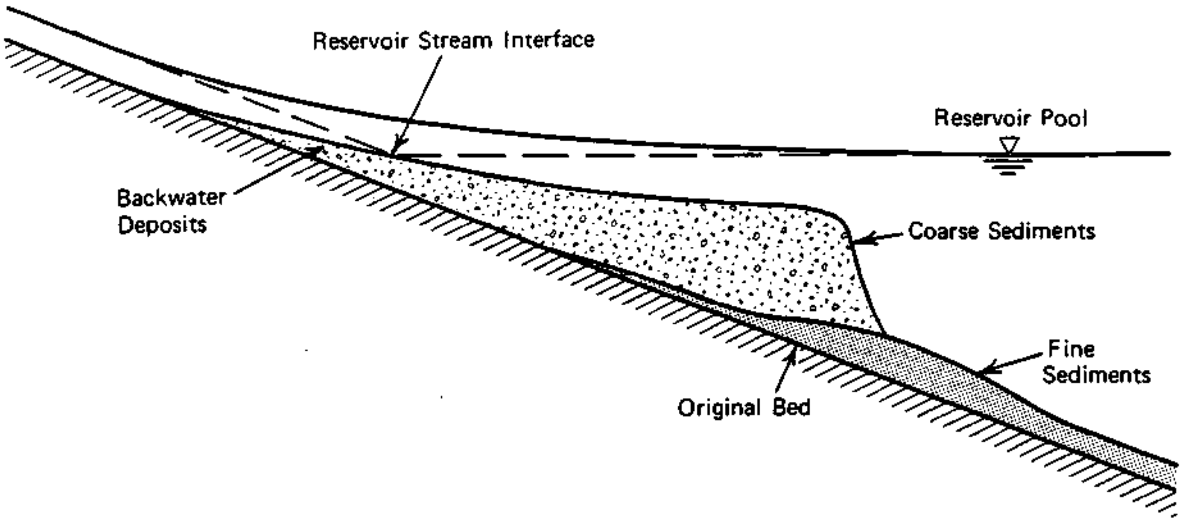

Figure 1. Typical reservoir delta formation (after Mahmood, 1987)

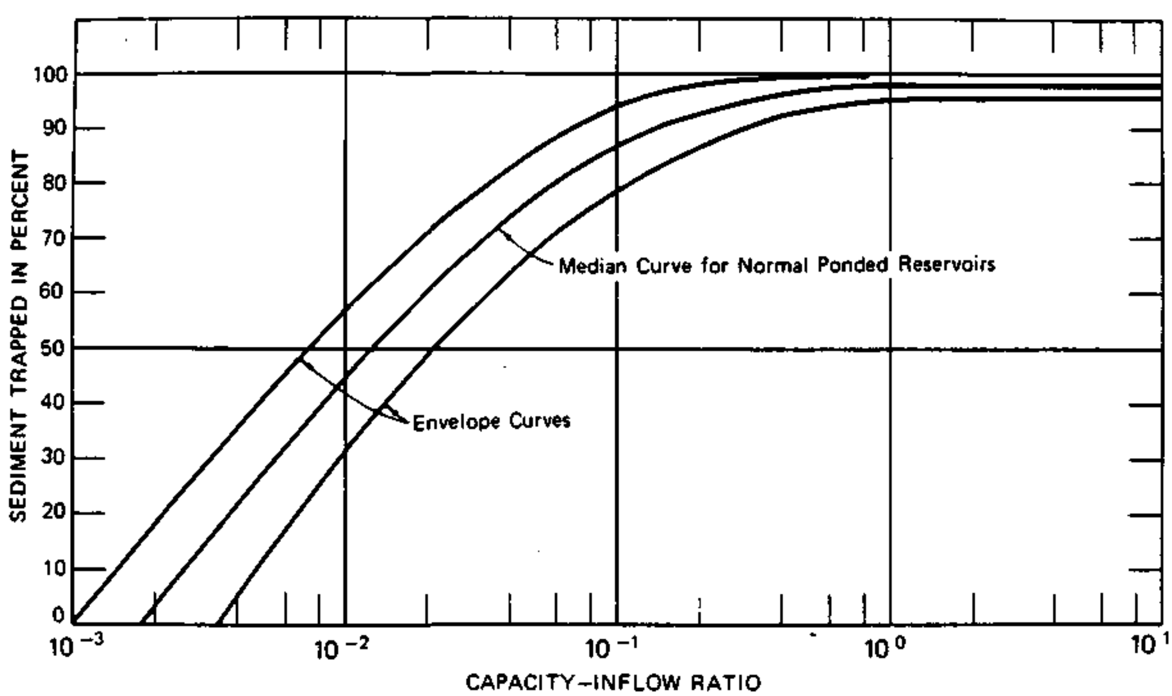

Figure 2. Reservoir sediment trap efficiency in percent versus capacity (after Brune, 1953)

Reservoir Trap Efficiency

All conventional reservoirs trap a large part of the sediment load transported by incoming flows and therefore experience a continual reduction in storage volume. The trap efficiency of a reservoir is usually determined from Brune's (1953) curve, shown in Figure 2. It defines the relation between trap efficiency and capacity-inflow ratio, C/I, where C is the reservoir capacity and I is the mean annual inflow to the reservoir, both in the same units, e.g., acre-feet or inches. If part of the gross reservoir storage is specially allocated to sediment storage, it is called dead storage or storage usually not available for other uses. Sedimentation in excess of dead storage will affect the capacity of the reservoir to meet the design water demands.

Trap efficiency values for some values of C/I are:

C/I	0.01	0.05	0.10	0.5	1.0
Trap efficiency	46%	77%	87%	96%	98%

For C/I = 0.01, the reservoir stores only about 1% of inflow but 46% of incoming sediment; for C/I = 0.05, the reservoir stores about 5% of inflow but 77% of incoming sediment; and with C/I increasing from 0.1 to 1.0, the sediment trapped varies from 87 to 98% of incoming sediment. It is evident that reservoirs with small C/I trap disproportionately large quantities of the annual stream sediment load. Because the relationship typified in Figure 2 was developed by Brune more than 35 years ago, it needs to be reinvestigated, validated, and updated on the basis of the vast amount of data and information obtained during these years.

Reservoir Sedimentation Surveys

Personnel of the Illinois State Water Survey have been conducting reservoir sedimentation surveys for more than 50 years. The amount of sediment accumulation between two surveys is essentially computed from the difference between the reservoir volumes corresponding to the normal pool level or some other specified elevation. These values are calculated from the bed elevations measured along a number of transects covering the entire reservoir. Unless the sediment accumulation is large, the accuracy of the results suffers because the volume of sedimentation is obtained as a difference between two rather large numbers which are subject to errors in observation and sounding-rod placement. A 15-year or even larger interval between two surveys will considerably reduce these sources of error, and me result will also be representative of a mix of below-normal, normal, and above-normal flow conditions. Allowances must be made for consolidation or compaction of sediments with time (Singh and Durgunoglu, 1988).

According to Bruk (1985), "Low level remote sensing has several main applications in the assessment of reservoir sedimentation. Contour maps prepared from aerial photographs can be used to determine sediment volumes provided the water level can be lowered greatly; aerial photography can be used to trace turbidity plumes which may help define the distribution of sedimentation, and airborne laser hydrography is being tested."

The average residence time of water in a reservoir is obtained as a fraction of the year equal to reservoir capacity divided by the annual inflow. This time varies not only from year to year because of changes in annual flow, but also from season to season because a great part of inflow occurrs in spring and early summer months. These are the months during which 80 to 90% of annual sediment inflow occurs. For better definition of residence time in reservoirs, consideration of these factors is needed in addition to the conventional use of C/I in estimating trap efficiency from Brune's curve.

Streambed Degradation Downstream

Water overflowing conventional spillways is relatively sediment-free because the reservoir traps practically all the bedload and most of me suspended load. This water has high potential for entraining suitably sized particles from me streambed, which becomes depleted of fine particles but enriched in coarse materials. The resultant bed is coarser, is more stable, and has become armored. Armoring also migrates downstream with time. The water course requires careful monitoring and possible installation of additional protective measures to ensure mat the newly degraded slopes do not undermine the toe of the dam through headward erosion. Some caving-in of the streambanks also takes place.

Mitigation Methods for Storage Preservation

Methods for controlling or reducing sedimentation in a reservoir can be considered under two broad categories:

1. Reducing sediment inflow to the reservoir. This can be achieved by:
   a. Watershed management and soil conservation
   b. Retention of coarse sediments in upstream debris dams
   c. Bypassing of heavily sediment-laden flows
   d. Trapping and retention of sediments by a vegetative screen
2. Reducing sediment entrapment in the reservoir. Some methods are:
   a. Reservoir drawdown and flushing
   b. Density current flushing
   c. Venting of sediments through undersluices
   d. Reservoir operation policy and design for sediment control
   e. Siphoning
   f. Dredging of sediments

Brief descriptions are provided below of various mitigative measures, their advantages and disadvantages, and requirements regarding any special site-specific conditions.

Watershed Management and Soil Conservation

The intent of watershed management and soil conservation measures is to substantially reduce erosion and thereby decrease the sediment input to the stream system. The distribution of erosion over the watershed is investigated, and the areas contributing excessive sediment to the streams draining into the lake or reservoir are demarcated. Conservation measures applied to these areas result in a significant reduction in sediment input to the lake. These measures include practices such as contour farming and terracing, strip cropping, crop rotation, no-till fanning, grassed drainageways, gully erosion control, and stabilization of critical areas by their return to grasslands or forests. An efficient planning agency and willing farmers and other landowners are necessary to the execution of a viable erosion control scheme.

Conservation measures take years to implement. Among the problems involved in instituting such measures are the relative costs of various measures to farmers, and the need for farmers to make significant changes in their usual style of farming. The efficiency of watershed management in reducing sediment inflow to the reservoir varies from a low of 5% to a high of 40% (Bruk, 1985; Mahmood, 1987). Not much information is available on the costs (whether paid by farmers, by natural resource agencies, or from grants) or on the number of years it would take to realize tangible benefits.

Retention of Coarse Sediments in Upstream Debris Dams

Debris dams are low dams built across the main sediment-contributing tributaries of reservoirs. These dams are designed to control sediment inflow into the reservoir. They create small reservoirs, which tend to silt up faster than the main reservoir (Mahmood, 1987). Economic feasibility is rather questionable because of their short life (or need for frequent dredging to maintain the storage capacity) and higher costs per unit of storage. However, debris dams retain the coarse fraction of the sediment and thus are helpful in reducing backwater deposits in the main reservoir. Rather extensive surveys are needed to identify tributaries contributing large portions of sediment inflow to the main reservoir and to determine the optimal locations for siting debris dams.

A small dam can be built a few miles upstream of the lake or reservoir to induce deposition of coarse sediments in the pool. These sediments can then be removed every two to three years during low-flow periods and used to raise nearby lands.

Bypassing of Heavily Sediment-Laden Flows

A great amount of sediment is carried by a stream or river during flood flows. A large part of such flow can be bypassed through a channel, tunnel, or pipes, significantly reducing silting in the reservoir. The bypass may consist of a barrage for diversion of floods and a bypass canal joining the main stream or river some distance downstream of the dam; or it may be a bypass tunnel instead of a bypass canal. Pipelines can be anchored in a low submerged weir near the stream/lake junction, can be placed along the lake bed or partially embedded in it, and can discharge downstream of the dam. The entry for the pipelines can be either through automatic controls or by operation of gates. This technique has been successfully applied in Italy (Roveri, 1981). It has the ability of removing sediment quickly under the full head of water.

The above measures can considerably reduce the input of coarse sediment to the lake, and this can inhibit extensive delta formation. The site conditions, topography, dam foundation, and economic analyses will determine the feasibility and practicality of this mitigative measure.

Trapping and Retention of Sediments by a Vegetative Screen

A vegetative screen at the head of a reservoir, whether artificial or natural, serves to reduce the velocity of incoming flow and to cause sediment deposition. Sediment deposits in an area of vegetation accentuate the problems associated with delta formation at the head of a reservoir. Farmlands may be adversely affected by the rising water table, and levees for flood protection may be needed.

As an example, the growth of tamarisk (salt cedar) along the Pecos River above Lake McMillan, New Mexico, resulted in a reduction in sediment deposition in the lake after 1915 (Stevens, 1936). Capacity loss during 20 years with tamarisk was only 14% of that in the previous 20 years. The vegetation does intercept the inflowing water, lowering the water supply to the lake by as much as 10%. A suitable vegetative screen should be chosen for a particular area on the basis of climate, soil, and other conditions.

Reservoir Drawdown and Flushing

The efficiency of drawdown of reservoir water level for flushing some sediments and/or inducing erosion of deposited sediments depends on reservoir bed topography, locations and capacities of bottom outlets, sediment characteristics, reservoir operation, duration of flushing, and flushing discharge. For sediment flushing to be effective, the reservoir is draw down to the extent mat flow conditions over the deposits approach original river conditions. If me inflow is high but within the discharge capacity of the outlets, sediment scour and movement are accelerated. Erosion starts at both ends of the delta and in the vicinity of the outlets and then progresses upstream. Effective sediment sluicing takes place when upstream- and downstream-end processes in the reservoir meet.

Sediment flushing was not effective for the Guernsey Reservoir on the North Platte River, Wyoming (Jarecki and Murphy, 1965). For the Zemo-Afchar Reservoir in Russia (Bruk, 1985), drawdown flushing was very effective, removing about 1.3 million cubic yards of sediments each year. The average annual sediment inflow is 5.23 million cubic yards. Sediment flushing was done for one or two days each year. The total width of two bottom outlets used for flushing was 49 feet. The flushing discharge was in the range of 0.5 to 3 times the average annual flow. Some conclusions from this operation are: 1) the optimum flushing discharge is 2 to 2.5 times the average annual flow, 2) most effective erosion occurs about 8 to 10 hours after the erosion begins, and 3) flushing efficiency can be restored by impounding water for a short duration, followed by complete drawdown of the water level.

Flushing flows carve out a deep channel which approaches the pre-dam width of the stream or river with periodic flushing. However, valley deposits generally cannot be removed. Thus sediment flushing may be resorted to before formation of considerable valley deposits. The outlet gates will require protection against abrasion by high sediment concentrations and blockage by sediment deposits.

Density Current Flushing

According to Wunderlich and Elder (1973), "Dependent on the density difference between the incoming water and the reservoir water, overflow, underflow, or interflow may result [these flow patterns are shown schematically in Figure 3]. Basically, any flow seeks its density level and moves along this level into storage position. If this level happens to be the withdrawal zone, the inflows will move directly through the reservoir. In other cases, water may be stored for considerable periods of time." A floating mass of debris can usually be seen where the muddy river plunges abruptly beneath the surface of a clear reservoir.

According to Bell (1942), "Those who are most familiar with sedimentation in American reservoirs are of the opinion that the lives of many of them may be substantially increased by making use of the transporting power of density currents. If the maximum benefit is to be obtained from the use of stratified flows as transporting agents, they should be put to work as soon as possible after storage has begun in a new reservoir." Venting sediments from the very beginning does not allow sediments to stabilize and maintains the bottom slope of the reservoir for efficient use of density currents (Singh, 1987).

Observations in Lake Mead (formed by Hoover Dam on the Colorado River) show that 18 to 39% of the suspended load is removed by density currents. An inflow sediment concentration of less man 1 % by weight is insufficient to maintain enough motion for density currents to reach

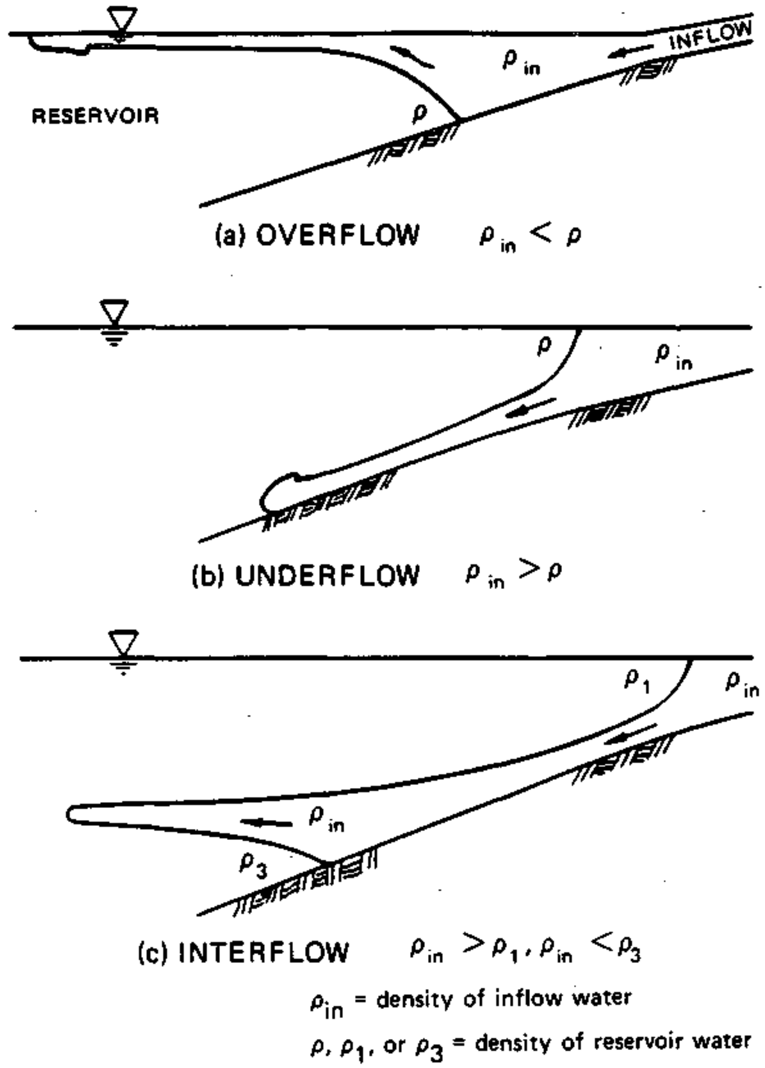

Figure 3. Schematic of overflow, underflow, and interflow patterns of incoming flow to a reservoir (after Wunderlich and Elder, 1973)

the dam in Lake Mead, which extends about 200 miles upstream of the dam. In the Iril Emda Reservoir in Algeria, between 45 and 60% of the annual inflowing sediment was vented out during the period 1953 to 1958 (Duquennois, 1959). Density currents are very active during floods when sediment concentration loads are quite high. For the Fengjiashan Reservoir in northwest China, because of density current flushing, the ratio of sediment outflow to sediment inflow for each flood peak (using measurements for 14 flood events) ranged from 23 to 65% according to the nature of the flood, length of the reservoir, and sediment characteristics of the inflow (Bruk, 1985). The topographic features of the reservoir and the hydraulic structures for sluicing are favorable for venting density currents. The original river channel has a steep slope, the inflowing sediments are composed primarily of fine materials, a relatively short distance of backwater exists, and the locations of the bottom outlets just above the river bed are favorable to density current flushing or venting. The Nebeur Reservoir in Tunisia (Abid, 1980) has two vents with a capacity of 440 cubic feet per second (cfs). A Balfour valve was fitted with a capacity of 35 cfs. When the density of flow to be discharged approximates 1.08, the two main valves start opening as necessary. When the density of flow falls below 1.02, the venting operation stops. During the period 1954 through 1980, the total amount of sediment discharged was 91 million tons. The draw-off efficiency varied from 59 to 64%.

Generally, more sediment will be vented from short and medium-length reservoirs with large incoming discharges; high density sediment concentrations; low, large-capacity outlets; and high outflow discharges. Provision of multilevel, multiple outlets improves the venting efficiency of the density currents.

Venting of Sediments through Undersluices

Undersluices and sluiceways can be incorporated in the design of the impounding structure or dam. The total capacity of these sluices should lie in the range of 0.3 to 1.0 times the maximum daily flood inflow. Many sediment deposition models can be used in identifying the most suitable locations for the sluices. Knowledge of the expected sediment distribution pattern in the reservoir is useful in sizing and locating the gated outlets. Frequent venting of sediments may be resorted to during the high-inflow season when the excess flows may all be routed dirough the sluices. This operation not only greatly reduces the sediment entrapment by drastically reducing the residence time but also substantially reduces the surcharge in the reservoir that occurs with an overflow type of spillway. This leads to less flooding of lowlands around the reservoir. Release of water and sediment dirough the bottom outlets reduces degradation of the bed and caving-in of banks downstream of the dam (Singh, 1987).

Sediment sluicing is distinct from sediment flushing because the main sediment load entering a reservoir is released downstream before it has time to settle down. The earliest and perhaps the most successful example of sediment sluicing is the Old Aswan Dam on the Nile River in Egypt. It was constructed in 1903, mainly for navigation purposes. The dam was provided with sufficient sluice-gate capability to pass the entire flood discharge of the Nile (Stevens, 1936). The sluice gates were opened at the beginning of the flood period, and the river flowed through the reservoir almost as if no dam existed. The gates were gradually closed after the flood peak had passed. Silting of the Aswan Reservoir was avoided with this operation. The efficiency becomes lower as the ratio of reservoir width to maximum dam height increases beyond approximately 100 (Mahmood, 1987).

This technique has been used in Spain since the sixteenth century. Large sluices were provided near the base of the dam for sudden releases of water stored in the reservoir or for bypassing flood flows through the sluices (Wegmann, 1927). This has kept the reservoirs relatively free of sediment deposits. These reservoirs generally have a bed slope of about 2% and a maximum reservoir width of 1000 feet.

The Zuni Reservoir near Black Rock in New Mexico was 80% filled with sediment by July 1931 when a 4-foot by 6-foot sluice gate was installed (Brown, 1943). In about three months, about 800,000 cubic yards of sediment were sluiced out of the reservoir.

The Sanmen Gorge Dam, near Sanmenshia in Shanshi Province, China, is the most downstream dam on the Yellow River. The high dam and power plant were completed in 1960. In the first 1-172 years of operation, 90% of the actual sediment load of 2.1 billion tons per year was trapped in the reservoir. The Chinese began sluicing through the dam in 1962 (Robinson, 1981). A diversion tunnel and some penstocks were converted to sluiceways in 1965. Additional diversion outlets, plugged after construction, were reopened in 1970, and power generation was reduced to 1/3 of that actually planned. The trap efficiency with these measures has been reduced from 90% to 20%.

Reservoir Operation Policy and Design for Sediment Control

The goal of reservoir operation and management is not only to adequately meet the design water demands, but also to release as much sediment as possible from the reservoir with the floodwaters so that the reservoir trap efficiency is reduced to as small a value as is economically and practically feasible. About 80 to 90% of the annual sediment load enters the reservoir during the flood season, whereas water inflow is only 40 to 60% during the same period. Lowering pool levels during flood season further increases the efficiency of the operation. Use of this type of operation on me Heisonglin Reservoir, located on a tributary to the Yellow River in China, reduced the annual sediment load trapped from 706,000 to 122,000 cubic yards (Zhang et al., 1976) and reduced the trap efficiency to 17% of the original. For the Sanmen Gorge Dam, the reservoir trap efficiency was reduced to about 20%.

If reservoir sedimentation is perceived as a serious problem, the flow releases from the bottom outlets should be considered in dam design together with a reservoir operation mat helps in maximizing flow-through of me incoming sediment. The outlets also help in drawing down reservoir levels during emergencies and repairs.

Siphoning

According to Bruk (1985), "Siphon dredging for desilting reservoirs differs from ordinary dredging in exploiting me hydraulic head difference between the upstream and downstream levels of me dam as the source of motive power for the suction dredging." The simplest successful type of device is the hydraulic siphon device installed at the Rioumajou Dam in France (Evrard, 1980). The siphon straddles the 70-foot-high gravity arch dam. The upstream branch of the siphon has a priming nozzle; omerwise, the siphon can operate automatically when the spillway functions. It can discharge 35 cfs with 33 pounds of sediment; it clears the sediment from the area where the intake and bottom outlet are located. The siphon pipe varies from 16 to 18 inches in diameter. At the Tianjiawan Reservoir built in 1960 in China (Bruk, 1985), a siphon dredger was installed in 1975. During the period from June 1977 through June 1978, the siphon dredger removed 0.42 million cubic yards but the sediment inflow was 0.39 million cubic yards. The dredger was operated for 695 hours, or 29 days' total time. The siphon pipe is about 22 inches in diameter; the suction head has scrapers, nozzles, and a rotating cutter. The siphon pipe is supported by pontoons, and the effective head for siphoning is 26 feet. Siphon dredging in the Tianjiawan Reservoir achieved a low dredging cost and no waste of water (outflows can be used in irrigation). The outflow slurry had a mean sediment concentration of 15.6% by volume. An improved design is suggested by Hannoyer (1974). The siphon outlet pipe passes through the bottom oudet. A long pipeline is provided to allow flexibility of movement via a pontoon for siphon dredging in various parts of me reservoir. No pump is needed in this installation.

Dredging of Sediments

Dredging is an expensive means of restoring the storage capacity of a reservoir unless a large part of the cost can be recovered by beneficial use of the dredged material. Dredging is used if other methods (such as flushing, bypass construction, and drawdown flushing) are not successful or feasible, and the dam cannot be raised or replaced. Various designs of dredgers are available. The usual ratio of water to silt by volume is 8:1 to 10:1. In Switzerland, a floating dredger is used to suck in me finest silt material near the dam and vent it through a floating pipeline via an outlet in me dam (Leichti and Haeberli, 1970). In Austria, the bedload settles close to the upstream limit of the backwater ponds, causing parts of the river bed to become narrower and shallower and impeding navigation and river flow (Kobilka and Hauck, 1982).

These deposits are periodically removed by dredging. The dredged deposits can be used in concrete.

In the case of wide reservoirs, hydraulic dredging can more efficiently remove overbank deposits than flushing and sluicing. It takes a smaller amount of water to remove a unit volume of deposits by dredging than by flushing. The dredging operation can be moved upstream from the dam to open a channel in the deposits to facilitate the movement of density currents toward the bottom outlet. Dredging may be done at fixed intervals for small or medium-sized reservoirs. It can also be an ongoing operation for some large reservoirs.

AUGMENTING SUPPLIES AND/OR REDUCING DEMAND

Reclaiming storage capacity of existing in-channel reservoirs occupied by sediment may not always be applicable or feasible, or it may not be sufficient to insure the adequacy of the public water supply system. Some other alternatives for augmenting the public water supply are described below. They include improving the existing system by raising lake levels to increase storage, providing supplementary storage by using in- or side-channel reservoirs, developing supplementary ground-water sources, and reducing demand through identification of unnecessary system losses or through conservation.

Raising Lake Levels

Useful reservoir storage capacity can be increased by raising the dam and thus increasing the pool level. In some cases, raising the dam may be very costly. . Provision of wicket gates on the masonry or concrete section and raising of earthen embankments may be feasible. Raising the normal pool will submerge more area, the extent of which will depend on the valley geometry and slope. The backwater will extend farther upstream, and some redistribution of sediment deposition will occur. The results of economic and environmental impact analyses and the urgency of the need for extra storage will determine where raising the lake level is technically sound and environmentally acceptable. Raising the lake level may increase the storage capacity to meet the demands during the next 15 to 25 years.

Providing Supplemental Storage

Supplemental storage can be provided by building a side-channel or in-channel storage reservoir. Many economic and environmental disadvantages are associated with small or supplemental in-channel storage reservoirs. Costly spillways, sedimentation, upstream delta formation, downstream bed degradation, and impairment of water quality are some of the disadvantages. A side-channel storage reservoir is an impoundment into which water is pumped from a stream during periods of sufficient streamflow (Knapp, 1982). These reservoirs are usually isolated from nearby drainage so that the water pumped and precipitation are the only sources of water entering the reservoirs. The relevant design factors and costs are given by Knapp (1982). His report provides information on the storage needed in terms of the design drought in years and the gross demand rate in percent of mean flow. Augmenting the existing inadequate supply system with a side-channel reservoir can be an economical and feasible measure, depending on the availability of water from nearby streams.

Conjunctive Ground-Water Use during Droughts

An existing water supply system, supported by a reservoir, may be adequate to meet the demands for a lesser drought than the design drought (say, a drought with a l-in-10 chance of occurrence in a given year instead of one with a l-in-50 chance). During the deficient years, the existing supply may be augmented by ground water, or by conjunctive use of surface and ground water. For this to be economically and practically feasible, suitable aquifers (though they may be of limited extent) should be available nearby. The well depth and yield should be such mat a few wells can augment the existing supply without incurring high initial costs.

Demand Reduction

Demand may be reduced either by reducing unaccounted-for water loss (unnecessary system losses) or by decreasing actual water use (conservation). Conservation of water may be categorized as either short-term emergency measures or long-term changes in water-using appliances and landscapes (Lund, 1987). The applicability and appropriateness of any of these options must be considered on a case-by-case basis.

The difference between the raw water withdrawals and the billed finished water is usually attributed to non-metered uses such as filter flushing at the water treatment plant, fire fighting and other municipal uses, and losses due to leaks in the water conveyance and distribution systems. Raw water withdrawals are typically not more than 20% higher than billed water volume and for many systems are only 10% higher. Systems reporting greater differences between raw and billed water figures may be able to reduce demand by locating and eliminating unnecessary system losses.

Emergency use restrictions may cover reduced lawn watering, limited car washing, staggering days for limited lawn watering from one area to the other, and so on. Emergency measures do subject the people served to reduced freedom of water use compared to their normal style of living. Such measures can be invoked infrequently, but an effort should be made to find and implement more durable and reliable measures to rectify the water shortage during drought periods. Mandatory water use regulations have proven to be effective in reducing water use, particularly elevated water use arising from the drought conditions. During me 1988-1989 drought, mandatory water use restrictions were adopted by several communities in Illinois. Bloomington PWS imposed mandatory water use restrictions in August 1988, and average water use dropped from over 14.0 mgd in June and July to 10.5 mgd in August even as dry conditions continued. Water use restrictions continued through 1989, and water use in June, July, and August of that year was less than 10.0 mgd. Decatur PWS water use averaged 43.0 mgd and 42.1 mgd in June and July 1988, respectively. Mandatory water use restrictions were imposed August 8, 1988, and average August water use dropped to 32.7 mgd.

Long-term conservation measures that involve the installation of water-saving devices are not immediately available during drought episodes and are the result of long-range planning. Installation of water-saving appliances, changes in landscapes, and adaptation of industrial processes to conserve or recycle water are examples of conserving water or reducing water need, as opposed to imposing emergency restrictions on water use. Water conservation would be most effective for those systems that anticipate possible shortages sometime in the future and that have adequate lead time to implement the necessary measures.

The mechanisms for motivating customers to reduce water use are usually water rate structures which must be imposed at the discretion of the municipal government. Most of the water supply systems studied are municipally owned, but there are a few exceptions. For example, Pontiac's public water supply is owned and operated by Northern Illinois Water Corporation. When the municipality does not own the water supply system, imposition of fines or deterrent rate structures must be negotiated between the owners and the municipality. Mandatory use restrictions have typically been enforced through fines levied for each violation such as lawn watering or car washing. During a drought period in 1984 and 1985, water rationing was implemented in Corpus Christi, Texas. Penalties were assessed when water use exceeded allotments, with service discontinued after repeated violations. Water use regulations appear to be most effective if adequate public education is provided to alert customers as to the severity of a pending water shortage. Emergency water use restrictions hold down high drought-related demand. In a study of the Corpus Christi experience, Shaw and Maidment (1988) observed some carryover of reduced residential water use. However, the greatest long-term impact of the water rationing in terms of reducing demand was achieved with industrial customers that were motivated to incur capital outlays for water-saving devices that remained in use after the restrictions were lifted.

Water use tends to vary seasonally, with highest demand during hot, dry weather. Fines and rate structure penalties appear to be effective in suppressing water use to base level (winter demand levels) in the face of pending water shortages. However, rate structures which are designed to promote water conservation and/or to defer system expansion cost may or may not be effective in long-term reduction of demand. The distribution of the types of customers (residential, industrial, commercial) and the proportion of total water use by each may influence the effectiveness of rate structure in reducing demand. Water charges tend to be a very small portion of total household expenditure. Significant increases in the rate structure would likely be needed to provide adequate incentive to consumers to reduce water use, either through practicing greater conservation or through installing water-saving devices. The long-term effectiveness of rate structure incentives is questionable as customers become acclimated to the higher cost and resume prior water use practices. The cost to residential customers of installing water-saving appliances must be weighed against the amount of water saved and thus the monetary savings. Water rates may have to be quite high to justify economically the installation of new water-saving devices. The likelihood of elected officials imposing and maintaining drastically higher water rates must also be evaluated.

AT-RISK SYSTEMS AND ALTERNATIVES FOR ENSURING ADEQUATE WATER SUPPLIES

Method of Identifying At-Risk Systems

The adequacy of the water supply source(s) for a public system may be ascertained by comparing the yield (sustained draft rate) of the source during a drought episode to the estimated demand; in other words, comparing the amount of water mat can be supplied from the source during the design drought to the expected water needs of the system. This comparison was made for the 90 public water supply systems in Illinois mat rely on surface water from intrastate rivers. The drought yield was calculated for each surface water supply source mat is used by a system on a regular basis. For systems mat regularly use more than one source, the cumulative yield of all sources was estimated. Design droughts with 20-year and 50-year recurrence intervals were considered in mis study. A drought with a 20-year recurrence interval has a l-in-20 chance of occurring in any given year. Similarly, a drought with a 50-year recurrence interval has a 1-in-50 chance of occurring in any given year. The design recurrence interval reflects the level of risk mat a water supply will be inadequate to meet demand.

Of the original 90 systems which rely on intrastate rivers, 39 rely on a single in-channel reservoir for water storage; 18 systems use two or more in-channel reservoirs; 7 systems use a single side-channel reservoir; 2 systems use two or more side-channel reservoirs; 7 systems have both in-channel and side-channel reservoirs; 5 systems have low in-channel dams with some in-channel storage; 7 systems use direct withdrawals from low in-channel dams with virtually no storage; and ground water provides a significant portion of the water supply for 4 additional systems mat also use in-channel reservoirs and for 1 system with a side-channel reservoir. Many systems have multiple water supply sources. This situation occurs as additional sources are developed to meet significant increases in demand after the original reservoir was constructed, or, more often, because the storage capacity of the original reservoir has declined significantly as a result of me accumulation of sediment.

Systems with in-channel reservoirs show declining yields wim time as sedimentation reduces storage capacity. Side-channel reservoirs typically are not subject to such sedimentation, and thus yields do not change significantly over time. However, the sustained yields from water supply systems using side-channel reservoir storage are dependent upon the pumping system used to withdraw water from the stream or river. Yields were calculated on the basis of bom the present pumping system and an optimal pumping system. For those systems relying on direct wididrawals, low-flow statistics were developed for the source stream or river.

Projections of future water demand were compared to projected drought yields for the years 1990, 2000, 2010, and 2020 for each system. On the basis of this comparison, 27 systems were identified for which demand may exceed yield by 2020. Twenty-four of these systems show either a 20- or 50-year drought yield less than the annual average demand. The remaining three systems may not have adequate water during a 20- or 50-year drought if water use increases significantly (20 to 30%) during the drought. Water use tends to increase during a drought, and the estimated increase in use was determined on the basis of water use trends observed during the 1988-1989 drought in Illinois. The systems were ranked according to the year and the severity of the drought when the system may be deficient. Table 1 shows the ranking of the 24 systems for which yields may be less than the average annual demand. Table 2 shows the ranking of the 27 systems based on a comparison of yields to high drought-related water use.

The methods and data used to develop a demand forecast for each system are explained in detail in *Future Water Demands of Public Surface Water Supply Systems in Illinois* (Singh et al., 1988). The methods and data used to calculate future yields of the various supply sources are explained in *Adequacy of Illinois Surface Water Supply Systems to Meet Future Demands* (Broeren and Singh, 1989). The details of calculating the drought yields for each system are discussed in full in that report. However, certain assumptions made in the course of developing the data warrant restatement to aid in the interpretation of information presented for the 27 systems discussed in this report. The yield of systems using in-channel or side-channel storage is a function of the capacity of the reservoir. When available, capacity data from actual surveys of the reservoirs were used. However, for many reservoirs, particularly the side-channel reservoirs, no survey has been performed, and the volume is strictly an estimate. Systems using multiple sources of water, such as those that pump water from a stream or river to an in-channel impoundment, require a detailed system analysis to accurately evaluate yields. The level of detail and the data required for this are beyond the scope of the present study. For systems with interdependent sources, yield was estimated for various scenarios of operation. The volume of storage provided for treated water was not considered, nor was the operating capacity of the water treatment plant. The quality of water in the reservoirs was not considered explicitly. However, a value of 90% of the known (or estimated) storage capacity was used to calculate the yield. This allows for 10% of the stored water to be inaccessible or unusable, even during a design drought.

Evaluation of Mitigation Measures

Various alternatives for insuring an adequate water supply were considered for each system. The options investigated for each system include: 1) improving the existing system by restoring or increasing storage capacity of the existing reservoir and/or improving pumping systems; 2) identifying system losses and reducing demand through conservation or other measures; 3) augmenting the present supply from already developed sources through means such

Table 1. Systems That May Experience Drought-Related Water Shortages

System number	*System name*	*Drought-recurrence interval (years)*	*Year (Drought yield < avg. annual demand)*
002	Sorento	20&50	1990
009	Flora	20&50	1990
020	West Salem	20 & 50	1990
032	White Hall	20&50	1990
041	No. Ill. Water Corp. (Pontiac)	20 & 50	1990
052	Shipman	20&50	1990
068	Coulterville	20&50	1990
076	Loami	20&50	1990
081	Georgetown	20&50	1990
088	Marion	20&50	1990
016	Oakland	20 & 50	2000, 1990
023	Farina	20 & 50	2000, 1990
060	Waterloo	20 & 50	2000, 1990
087	Wayne City	20 & 50	2000, 1990
045	Decatur	20&50	2010,2000
044	Bloomington	20 & 50	2020, 1990
028	Canton	50	1990
019	Paris	50	1990
050	Mt. Olive	50	1990
053	Staunton	50	1990
086	Fairfield	50	1990
051	Palmyra-Modesto Water Comm.	50	2000
047	Carlinville	50	2010
031	Greenfield	50	2020

Table 2. Systems That May Not Be Able to Meet Maximum Demands during a Drought

System number	*System name*	*Drought-recurrence interval (years)*	*Year (Drought yield- < 1.2 to 1.3 times avg. annual demand)*
002	Sorento	20&50	1990
009	Flora	20&50	1990
016	Oakland	20&50	1990
019	Paris	20&50	1990
020	West Salem	20&50	1990
023	Farina	20&50	1990
032	White Hall	20&50	1990
041	No. Ill. Water Corp. (Pontiac)	20 & 50	1990
045	Decatur	20&50	1990
052	Shipman	20&50	1990
053	Staunton	20&50	1990
060	Waterloo	20&50	1990
068	Coulterville	20&50	1990
076	Loami	20&50	1990
081	Georgetown	20&50	1990
087	Wayne City	20&50	1990
088	Marion	20 & 50	1990
044	Bloomington	20 & 50	2000, 1990
028	Canton	50	1990
031	Greenfield	50	1990
047	Carlinville	50	1990
048	Gillespie	50	1990
050	Mt. Olive	50	1990
051	Palmyra-Modesto Water Comm.	50	1990
086	Fairfield	50	1990
078	Springfield	50	2010
057	Kinmundy	50	2020

as obtaining rights to other existing reservoirs or cross-connecting with other public water supplies having surplus water; and 4) developing new sources of supply such as direct withdrawals from nearby streams and rivers, ground-water sources, or new side- or in-channel reservoir storage. The feasibility and adequacy of these alternatives are discussed for each system individually.

Constraints of location and accessibility were investigated. In-channel reservoirs more than a few miles from a major stream or river may not be good candidates for flushing sediments. Structures or roads along the perimeter of an existing lake may prohibit increases in spillway elevations to increase storage. Generally, only supplemental sources within about a five-mile radius were considered because of the cost of a conveyance system. The likelihood of developing an adequate ground-water source was investigated on the basis of available hydrogeologic information. Investigation of new in-channel reservoir sites was limited to those locations identified during prior studies by Roberts et al. (1957) and Dawes and Terstriep (1966a, 1966b, 1967). The previous studies of potential reservoir sites provide a statewide picture of feasible locations for in-channel reservoirs, although they are not all-inclusive.

The ranking of the systems shown in Tables 1 and 2 illustrates the immediacy of the problem in terms of when a shortage may occur and the risk of its occurrence in terms of the drought frequency. The severity of a possible water shortage in terms of what percentage of the demand may not be met was not considered in the ranking. The difference between the projected demand and anticipated drought yields of the supply source was considered in evaluating mitigation methods for the systems listed in this report. The adequacy and appropriateness of each alternative were considered in terms of the projected need. This consideration is particularly pertinent for systems whose current source of supply is adequate to meet a significant portion of the demand and for which mechanisms to reduce demand during a drought may be adequate to forestall water shortages.

Economic Considerations

The cost of establishing and operating a water supply system is a significant and often limiting factor affecting the size or scope of mitigation methods. Fundamental to the evaluation of the adequacy of the system to meet demand is definition of an acceptable risk factor. Common design practice for water supply systems is to establish an acceptable level of risk (that supply will not meet demand) in terms of the frequency of the drought event. The design is made on the basis of providing a reliable source of supply except during droughts more severe than the design drought. The longer the return period (e.g., 20 years, 40 years, 50 years), the less the risk of experiencing a water shortage in any given year. Typically, the lower the risk, the greater the system cost to provide a larger volume of water storage. Design droughts with 20- and 50-year recurrence intervals were used in this report to provide a common basis for comparison. The intent of this report is to identify feasible alternatives in terms of system adequacy to meet demands. While a detailed economic analysis was not performed, some general guidelines were followed in making recommendations for the most likely alternatives.

Reduction of demand to defer an expansion project may be feasible and economically very attractive under certain conditions. The nature or degree of the possible water shortage is a significant factor given some desired base level of service. This option was considered for those systems that may suffer shortages only if drought conditions are accompanied by elevated water use. In cases where the drought yield is only slightly less than the average demand or where unaccounted-for losses are significant, water use reduction also may be a feasible option.

Assuming that some additional source of supply is needed, refurbishing the existing system will typically have lower cost than development of a new source(s). The cost of a pumping station to withdraw water from another stream or river for conveyance to an existing reservoir is likely to have lower capitalization cost than the construction of a new reservoir. Generally, development of ground-water sources (if available) will be less costly man development of surface water sources. A detailed economic analysis which considers all cost factors as well as the expected useful life of a particular option is needed to evaluate the most cost-effective solution.

Descriptions of Systems and Feasible Options

Pertinent data, background information, and a discussion of mitigation methods are provided for each system, along with recommendations for the most likely alternatives for avoiding water shortages. Tabular information is given, and the abbreviated headings used are defined as follows:

System No. = identification number unique to mis series of reports

Dr. Area = drainage area of reservoir watershed in square miles (sq mi)

CAP = reservoir storage capacity in acre-feet (ac-ft)

SA = reservoir surface area in acres (ac)

Y_{20} = estimated sustained yield of surface water impoundment(s) during a design drought having a l-in-20 chance of occurrence in a given year

Y_{50} = estimated sustained yield of surface water impoundment(s) during a design drought having a l-in-50 chance of occurrence in a given year

mgd = millions of gallons per day

Q_{7DLF}, Q_{15DLF}, Q_{31DLF}, Q_{61DLF} = lowest 7-, 15-, 31- or 61-day average streamflow with return period as indicated in table

Q_{3MD} = lowest 3-month average streamflow with return period as indicated in table

System No.: 044
***System Name**:* Bloomington
County: McLean
Communities Served: Bloomington
Bloomington Township WD
Hickory Highlands
Hudson
Lake Bloomington & Bloomington area subdivisions
Towanda
Estimated 1990 Service Population: **56,369**

Water Supply Source(s)

River/Reservoir	Location	Dr. Area (sq mi)	Year	Estimated CAP (ac-ft)	SA (ac)
Lake Bloomington	NE1/4 S01	69.1	1990	7410.8	598.5
	T25NR02E		2020	6629.8	576.9
Lake Evergreen	SW1/4 S01	40.2	1990	11,705	695.9
	T25NR01E		2020	11,045	682.7
Mackinaw River	NE1/4 S01	410			
(pumping pond)	T25N R01E				

Lake Bloomington is an in-channel reservoir on Money Creek, tributary to the Mackinaw River. Lake Evergreen is an in-channel reservoir on Six-Mile Creek, another tributary of the Mackinaw River. The system of direct withdrawals from the Mackinaw River was on-line in December 1989 and is described in detail below.

Projected Water Use and Supply Yields

Demand	Reported 1988	1989	Estimated 1990	2000	2010	2020
Per capita, gpcd			180	190	190	190
Avg. annual, mgd	10.099	9.027	10.146	11.993	12.735	13.481
Supply Yield						
Lake Bloomington & Lake Evergreen only						
Y_{20}, *mgd*			13.88	13.66	13.41	13.19
Y_{50}, *mgd*			10.80	10.60	10.40	10.19

Background Information

The service area population and per capita water use are expected to increase over time. Recent industrial growth is creating an increase in water use through new industrial water demand and population growth spurred by the job market created. Both lakes have lost considerable water storage volume as a result of sediment accumulation. Lake Bloomington was constructed in 1929; the sum of the original capacity (6062 ac-ft) and additional storage volume created by raising the spillway around 1958 is over 9000 ac-ft without sediment deposits. Construction of Lake Evergreen began in 1968 and the reservoir was filled in 1971. The original storage capacity was 12,210 ac-ft. By 2020 it is estimated that for the two lakes combined a total of over 3500 ac-ft of original water storage capacity will have been lost as a result of sediment accumulation. During the 1988-1989 drought, bom lakes were drawn down to critically low levels. Bloomington is cross-connected with Normal's public water supply and was receiving about 2

MG per week for some months during 1989. Water use restrictions were imposed in August 1988 and were enforced through 1989. This significantly reduced water use, which had climbed to over 14 mgd in June and July 1988. In December 1989 water withdrawals from the Mackinaw River began via an inlet channel and an 11-ac-ft pumping pool constructed in the fall of 1989. The inlet channel is located just upstream of the confluence of Six-Mile Creek with the Mackinaw. Water from the Mackinaw River is pumped to Lake Evergreen.

Mitigative Measures

The inlet channel and pumping pool constructed by the city in .1989 were a direct response to the possibility of water shortages. Water from the Mackinaw River was pumped to Lake Evergreen, and the lake was at normal pool elevation in February 1990. The inlet channel conveys water from the river via a side-cut in the river channel. The pumping pool volume of about 11 ac-ft does not provide significant storage in terms of increasing yields during drought conditions. A two-stage pumping system is used to deliver water from the pool to the lake, operating at 11.5 mgd and 20 mgd. If flows in the Mackinaw fall to 20 cfs or below, no water is pumped. Because of the unique nature of the system, which is dependent on the flow from the channel to the pumping pool, traditional analysis used for other systems in this report does not apply. The engineering design report prepared by Farnsworth and Wiley of Bloomington, Illinois, presents an analysis of the pumping system given two extreme droughts of record. Their calculations, which are based on an analysis of flows in the Mackinaw in 1955-1957 and 1987-1988, indicate that over 40% of the system's water demand could have been supplied from the Mackinaw River. Future plans for ensuring the system's water supply include raising the spillway of Lake Evergreen to create more storage.

Other mitigative measures to assure a reliable water supply could be directed at restoring and/or maintaining the water storage capacity of the two reservoirs. The dams are each within a mile of the outlet stream's confluence with the Mackinaw River. The dams creating the reservoirs could be retrofitted with mechanisms for flushing sediment. Passing sediment-laden high flows through undersluices is another alternative for maintaining the present water storage volume.

The seasonal dynamics of flows in the Mackinaw and inflows to Lake Evergreen need to be examined via a system operation model to evaluate the yield and hence the reliability of the system. The environmental impact of water withdrawals from the Mackinaw must be examined, particularly in terms of the suitability of the 20 cfs reserved for instream flow needs. The environmental impact of flushing accumulated sediment out of the Mackinaw River would have to be examined if flushing sediments or passing sediment-laden high flows through undersluices is considered.

System No.: 028
System Name: Canton
County: Fulton
Communities Served: Canton
Cuba
Dunfermline
Norris
St. David
Estimated 1990 Service Population: **19,600**
(includes prison population)

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Canton City	NE1/4 S30	14.4	1990	2924.0	278
Lake	T07N R05E		2020	2357.5	259

Ground water	*Pumping Capacity*
Well #1	750 gpm,(1.08 mgd)*
Well #2	250 gpm,(0.36 mgd)*

*Production reported in 1989

Canton City Lake is an in-channel reservoir on West Branch Copperas Creek, Illinois River Basin. Well #1 is near the north end of the lake and well #2 is located at the south end of the lake hear the water treatment plant. Water is pumped from the wells into the lake.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			79	81	83	84
Avg. annual, mgd	1.680	1.390	1.548	1.448	1.384	1.380
Supply Yield						
Surface water only						
Y_{20}, mgd			1.95	1.86	1.76	1.68
Y_{50}, mgd			1.46	1.39	1.26	1.19

Background Information

Canton PWS water demand has increased over the last three or so years because of the addition of Cuba, Norris, and St. David to the system. Also, in 1989 service to the prison began. A population and water use forecast by Singh et al. (1988) did not include the prison or its impact on the service population. The projected water demand shown above is consistent with revised water use projections which include the prison population as well as some growth in the community. This water use was forecast by Broeren and Singh (1989).

Sedimentation is a significant problem at Canton City Lake. The 1939 storage capacity was 3513 ac-ft. The spillway was raised in 1972, adding approximately 504 ac-ft of storage;

however, in 1990 the estimated water storage capacity was 2924 ac-ft, and by 2020 over 500 ac-ft of storage is expected to be lost to further sedimentation. The projected 2020 capacity of 2358 ac-ft is only 60% of 1939 capacity plus the 504 ac-ft addition (or 3917 ac-ft). The 50-year drought yield of the lake alone is less than projected demand from 1990.

Prior to 1988, Canton City Lake was the sole source of supply for the Canton public water supply. During the 1988-1989 drought the lake was drawn down over 13 feet. Mandatory water use restrictions were imposed, and billed water over an allotted amount was charged at three times the regular rate. Two wells were drilled, the first in 1988 and the second in 1989. The combined production of these wells in 1989 was about 1.4 mgd during the period that water was being pumped from both wells. However, the second well was operated for only a part of 1989. Thus, total ground-water withdrawals during 1989 averaged over the entire year would be much less than 1.4 mgd. If these ground-water yields can be sustained, they provide an adequate back-up supply for the system.

Mitigative Measures

Ground water pumped from the wells is discharged into Canton City Lake. This has created some water quality problems, which can be dealt with by changing water treatment processes at the plant. Assuming production can be sustained by the wells, no other auxiliary source is needed.

System No.: 047
System Name: Carlinville
County: Macoupin
Communities Served: Blackburn College
Carlinville
Estimated 1990 Service Population: 7,974

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Lake Carlinville	NW1/4 S10	25.4	1990	1607	173
	T09NR07W		2020	1295.4	161.1

Lake Carlinville is an in-channel reservoir on Honey Creek, tributary to Macoupin Creek.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			96	97	97	98
Avg. annual, mgd	0.819	0.805	0.766	0.777	0.785	0.815
Supply Yield						
Y_{20}, *mgd*			1.78	1.73	1.67	1.62
Y_{50}, *mgd*			0.83	0.81	0.79	0.76

Background Information

Lake Carlinville is the sole source of supply for the system. Population growth in subdivisions outside the city limits has created a steady increase in water demand. Yield from the reservoir is projected to be less than demand in the event of a 50-year drought from about 2010. Drought yield from the reservoir, given its 1990 capacity, is adequate to meet the 2020 demand. Heightened demand, which often occurs in a drought situation, could be greater than yield during a 50-year drought at any time. The spillway was raised 3 feet in 1988, creating additional storage. The purchase of a lake two miles south of the present lake is currently being investigated by the city.

Mitigative Measures

The dam creating Lake Carlinville is located less than one mile upstream of the confluence of Honey Creek, with Macoupin Creek. Sediment accumulation over the next 20 or so years is expected to reduce storage capacity and hence yields. Sedimentation in the reservoir could be reduced through one of several mechanisms such as sediment venting, siphoning, or dredging. Smith Reservoir, which lies within a two-mile radius of Carlinville, has an estimated 40-year drought yield of 0.11 mgd given the 1980 estimated storage capacity of 1288 ac-ft. Withdrawals from this lake would be adequate to augment Lake Carlinville's yield to meet the average annual demand through 2020. Alternatively, water could be withdrawn from Macoupin Creek and discharged to Lake Carlinville. The drainage area of Macoupin Creek above its confluence with Honey Creek is on the order of 180 sq mi.

Under the present conditions the following alternatives are considered feasible:

1. Maintain and/or increase the storage capacity of Lake Carlinville by venting sediment or dredging.

2. Purchase Smith Reservoir, given that results of a sediment survey to determine capacity and a detailed hydrologic analysis indicate drought yields are adequate to augment the existing water supply.

3. Establish a pumping station to withdraw water from Macoupin Creek.

System No.: 068
System Name: Coulterville
County: Randolph
Communities Served: Coulterville
Estimated 1990 Service Population: 1,591

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Coulterville	N1/2 S11	1.22	1990	193.3*	27.2*
Reservoir	T04S R05W		2020	173.9*	26.3*

Coulterville Reservoir is an in-channel impoundment on a tributary of South Fork Mud Creek, Kaskaskia River Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			98	102	104	105
Avg. annual, mgd	0.223	0.212	0.156	0.160	0.163	0.167
Supply Yield						
Y_{20}, *mgd*			0.13*	0.13*	0.12*	0.12*
Y_{50}, *mgd*			0.10*	0.10*	0.10*	0.10*

* Cumulative spillway raises since between 1980 and 1989 increased reservoir normal pool by about 14 inches. Storage capacity and yields were adjusted to account for about 30 ac-ft increase in storage volume.

Background Information

A very slight decline in population is forecast for Coulterville on the basis of Illinois Bureau of the Budget population projections which indicate a county-wide decline in population. Modest increases in per capita consumption may cause demand to increase slightly with time. The water treatment plant supervisor reports that there are suspected numerous leaks in the distribution system. Losses in the system may account for around 50% of raw water withdrawals. Billed water in 1988 and 1989 was 0.089 mgd, around 40% of the reported raw water withdrawals. Average annual water withdrawals between 1975 and 1982 were around 0.12 mgd. Water withdrawals significantly increased in 1983 and continued to climb. Demand projections in the table were developed on the basis of increasing water usage through 1985; 1986 data were not used, as a water main break was reported that year. Major repairs and replacement of the distribution system were planned to begin in 1990. If unaccounted-for water can be reduced to around 20% of billed water, raw water demand could decline to around 0.107 mgd. The water demand projections listed in the table show an increase of 0.009 mgd between 1990 and 2020. These projections were made on the basis of apparent increases in per capita water use, which may have been largely attributable to leaks in the system. However, adding this increase in water use to the 0.107 mgd estimate would indicate a water demand of 0.116 mgd in 2020, and the 50-year drought yield could provide for over 86% of demand through 2020. The reservoir is expected to lose capacity as a result of sedimentation over time. However, the impact on yields is not significant, and the 50-year drought yield is not expected to decline greatly between 1990 and 2020.

Mitigative Measures

Raw water withdrawals are expected to decline significantly with the repair and replacement of the distribution system. Once the distribution system rehabilitation project is complete, the actual water needs of the system can be evaluated. Coulterville Reservoir was last surveyed in 1954. Given that the reservoir spillway has been modified, increasing storage capacity, and considering that yields are very nearly adequate to meet demand, a sediment survey and reevaluation of yields would be in order prior to pursuing alternative water sources. The original storage capacity of the reservoir was 200 ac-ft. Removal of accumulated sediment and maintenance of a storage capacity of 200 ac-ft would provide sufficient storage to sustain needs yields of about 0.12 mgd. There are two existing reservoirs within about five miles of Coulterville which eould possibly serve as emergency sources of water if the system could acquire access to them (U.S. Army Corp of Engineers, Chicago District, 1980). Lake Coulterville (at one time known as the I. C. Reservoir) northeast of Coulterville has a storage capacity of about 109 ac-ft although it may be downstream of their sewage outfall. Zeigler Coal Co. Lake has an estimated storage capacity of 498 ac-ft. Roberts et al. in their 1957 study of potential reservoir sites do not identify any sites near Coulterville. Sparta public water supply is a little more than five miles southwest of Coulterville. This system has access to water from the Kaskaskia River and could possbly serve as an emergency source of supply. It is not likely that a ground-water supply could be developed. Sand and gravel aquifers are generally absent from the vicinity, and bed rock is typically not water-yielding (Pryor, 1956).

Under the present conditions the following alternatives are considered feasible:

1. Complete repair and replacement of the distribution system, evaluate water demand, and conduct a sediment survey of the reservoir and estimate future yields.

2. If it is determined that an additional water supply should be obtained, investigate the option of accessing water from one of the existing reservoirs near Coulterville.

3. Investigate the possibility of securing water from Sparta's public water supply system.

System No.: 045
System Name: Decatur
County: Macon
Communities Served: Decatur
Mt. Zion
Estimated 1990 Service Population: **94,989**

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Lake Decatur	El/2 S22	925	1990	17,859	3041.7
	T16NR02E		2020	14,057	2810.6

Other
Ground-water wells — Multiple locations
Quarries-emergency sources

Lake Decatur is an in-channel reservoir on the Sangamon River. Two well fields have been developed; the locations and conditions of use of these and other emergency water sources are detailed below with other background information.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd	274			303	327	339
Avg. annual, mgd	32.46	30.90	26.027	28.242	30.301	32.266
Supply Yield						
Y_{20}, mgd			31.16	29.30	28.24	26.48
Y_{50}, mgd			28.58	26.16	2.71	23.66

Background Information

The high per capita water use for Decatur PWS is attributable to significant water use by two major industries that account for more than 30% of the total demand, as well as by numerous other commercial users. The demand for water is expected to continue to increase over time. Lake Decatur is the primary source of water. Periodically water is pumped from two wells located near the town of Cisco, about 20 miles from Decatur. Water from the wells is discharged into the Sangamon River and thus conveyed downstream to the lake. The wells produce between 4.5 to 5.0 mgd. During the 1988 drought Lake Decatur reached critically low levels, and emergency measures were taken to reduce water use and provide supplemental sources of water. During June 1988, demand rose to 43.0 mgd. In July 1988 mandatory water use restrictions were imposed. No water use restrictions were imposed in 1989. Water use in 1988 and 1989 was high compared to reported 1986 water use of 25.0 mgd. During 1988 approximately 900 MG of water was obtained by pumping from several abandoned quarries in the vicinity. Water was also pumped from the wells near Cisco. A.E. Staley, a large industrial water user, obtained a special permit to recycle 0.5 to 1.0 mgd of cooling water back to Lake Decatur.

The impact of the 1988 drought was clearly evident in the Sangamon Basin, where streamflows dropped to new record lows at some U.S. Geological Survey streamgaging stations. The recovery of the lake to normal pool elevation during the winter of 1988 was largely due to the considerable drainage area upstream of the Lake Decatur Dam (925 sq mi). The large drainage area enhances the likelihood of rain over one part or another of the basin. Furthermore, comparing the volume of the long-term average runoff from me watershed to the storage volume of the reservoir, the reservoir can be filled more than 20 times by the average runoff. Thus, runoff far below the average can be sufficient to fill the reservoir. However, the sediment load entering the reservoir is also considerable. Loss of storage capacity due to sedimentation and the accompanying decline in yields is the leading factor contributing to possible future water shortages. By 2020 the 50-year drought yield is expected to supply only about 73% of the average annual demand. The water use in 1988 and 1989 was considerably higher than the projected water use for 1990. This could be attributed to drought-related increases in water use, or it could signal a trend of higher water use. In either case, water use at this rate would indicate that shortages could occur earlier than indicated by the projected supply and demand values.

In addition to the supplementary water sources used in 1988, Decatur is in the process of developing a ground-water well field in DeWitt County, tapping the Mahomet aquifer. The ground water may be discharged to Friends Creek, a tributary of the Sangamon River upstream of Lake Decatur. A pipeline is also being considered to convey the water to the treatment plant. The ground water would serve as an emergency source of supply. The planned development of this source is to drill a total of eight wells with an anticipated yield of 25 mgd.

Mitigative Measures

Projections of water use and drought yields for Lake Decatur indicate that by 2020 the yield from the lake during a 50-year drought could average around 9 mgd less than demand. The expected duration of a 50-year drought is about 7 months. Increased drought-related water use can add to this deficit. A significant supplementary water supply source is needed to avoid future water shortages. The present plans to access ground-water sources may provide sufficient additional water. However, some water losses must be anticipated if the ground water is conveyed to the reservoir via Friends Creek and the Sangamon River, and is men pumped to the treatment plant from the reservoir. During drought periods when the ground water would be needed, low streamflow conditions may result in some water losses in the creek because of seepage and evaporation.

The Lake Decatur dam was originally constructed in 1922. The spillway was raised in 1956, after which the computed storage capacity was 22,200 ac-ft. The difference between the projected 2020 storage capacity and the computed 1956 capacity shows 8000 ac-ft of storage lost because of sediment accumulation in this time period. Venting accumulated sediment from the reservoir could increase the storage volume and increase yields to meet drought demand.

There are no other existing reservoirs or potential reservoir sites mat would provide an adequate supplemental water supply source other than the abandoned quarries used during the 1988 drought. The recharge rate of these quarries is unknown.

Under the present conditions the following alternatives are considered feasible:

1. Conduct an in-depm study of possible losses in Friends Creek. Conduct a systems study to develop an optimal operation policy and system configuration (e.g., the desirable capacity of new wells to be developed) considering available wells near Cisco, a large abandoned quarry near the treatment plant, Lake Decatur, and new wells.
2. Investigate the recharge rate of existing impoundments (abandoned quarries) used during the 1988 drought to determine their reliable yield.
3. Investigate the feasibility and environmental impact of venting incoming and some accumulated sediment.

System No.: 086
System Name: Fairfield
County: Wayne
Communities Served: Boyleston WD
Fairfield
Golden Gate
New Hope WD
Estimated 1990 Service Population: 7,220

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
River/Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Little Wabash River	SW1/4 S05 T92S R09E	1,792			
Side-channel reservoir			1990	276	56

Water is pumped from the Little Wabash River to the side-channel reservoir using two variable speed pumps each having a maximum pumping capacity of 1000 gpm.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			151	154	155	156
Avg. annual, mgd	1.062		1.090	1.131	1.151	1.205

	Pumping System	
Supply Yield	*Optimal*	*Existing*
Y_{20}, *mgd*	2.28	2.19
Y_{50}, *mgd*	1.10	0.91

Background Information

Fairfield is expected to have a steady increase in population through 2020. The population increase together with gradually rising per capita water use would cause demand to increase with time. The per capita water use for Fairfield is high compared to that for other communities of similar size. In 1988 billed water was only 69% of water withdrawals, leaving 31% unaccounted for. This trend has persisted for some time. In 1985 approximately 30% of water withdrawals were not accounted for. The city reports one major commercial user. Adjusting for the commercial water use, the presumed primarily domestic use of water remains high. Reducing unaccounted-for water to 20% of raw water withdrawals could reduce demand in 2020 to about 1.1 mgd. The 50-yr drought yield, adjusted for the current pumping system, could supply 76% of the projected average annual demand for 2020, and about 83% if water use can be reduced. Whether or not demand is reduced, some additional water supply source may be required to avoid water supply shortages during a severe drought.

Mitigative Measures

Flows in the Little Wabash are adequate to meet the public water supply demand if adequate storage is provided. An additional 80 ac-ft of storage capacity would increase the drought yield adequately to meet a demand of 1.205 mgd in 2020. A smaller increase in water storage would be required if measures can be taken to reduce water use. Unaccounted-for water loss may be the result of breaks or leaks in the distribution system, and appropriate repairs would reduce losses and hence demand. Two existing in-channel reservoirs within approximately 5 miles of Fairfield are the Old Fairfield Reservoir and Cox Lake. The yields of these reservoirs are not sufficient to adequately augment the water supply, but the lakes could be used to store water pumped from the Little Wabash. Dawes and Terstriep (1966a) indicate one potential reservoir site near Fairfield on Pond Creek. Yields from the reservoir would be more than adequate to augment the present supply, but reservoir costs are expected to be high. Ground water for municipal supply may be available from sand and gravel deposits in the bottomlands of the Little Wabash River (Pryor, 1956).

Under the present conditions the following alternatives are considered feasible:

1. Identify sources of unaccounted-for water. Proceed with any indicated repairs or maintenance of the distribution system and reevaluate current and future water needs. Investigate the use of water restrictions or price incentives to reduce water use during extreme droughts. Evaluate whether these measures are adequate to reduce demand to a level that can be met by expected yields from the supply system.

2. Investigate the development of additional water storage facilities for water pumped from the Little Wabash. Existing reservoirs may serve this purpose.

3. Investigate the development of ground-water wells near the Little Wabash River to augment the surface water supply. The possibility that these sand and gravel aquifers are hydrologically connected to the Litde Wabash and the effect of water table drawdown on streamflow should be considered.

System No.: 023
System Name: Farina
County: Fayette
Communities Served: Farina
Estimated 1990 Service Population: **596**

Water Supply Source(s)

River/Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
East Fork Kaskaskia R.	3.26				
Borrow pit (side-channel reservoir)	T05N R04E	NW1/4 S32	1990	108	4.5

Stand-by	*Pumping Capacity*
7 wells	57 gpm (0.082 mgd)

Water is pumped from the East Fork Kaskaskia River, Kaskaskia River Basin, to a borrow pit which serves as a side-channel reservoir.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			198	207	209	208
Avg. annual, mgd	0.117	0.209	0.118	0.123	0.125	0.129

Supply	*Yield*	*Pumping System: Optimal*	*Pumping System: Existing*
Y_{20}, mgd		0.078*	0.037*
Y_{50}, mgd		0.037*	0.026*

* Surface water source only; yields from standby wells not included

Background Information

Opening of a new industry in 1987 created a dramatic increase in water use. The annual average water use reported in 1986 was 0.067 mgd; in 1988 water use increased to 0.117 mgd. Reported water withdrawals of 0.209 mgd in 1989 were elevated because of water quality problems, algae, and turbidity. The water treatment facility was expanded in anticipation of the increase in demand. The upgrade of the plant was completed in November 1988. However, no changes have been made to the raw water source.

Prior to 1982, when the surface water facilities were put on-line, ground water served as the sole source of supply. Seven wells with a combined pumping capacity of 57 gpm are available as a stand-by source. Two fixed-speed pumps with 1250 gpm pumping capacities are used to pump water from the East Fork Kaskaskia River to the borrow pit. Considerably more reservoir storage will be required to meet a given level of demand using one or two fixed-speed pumps compared to other possible system arrangements (i.e., variable speed pumps) because fixed-speed pumping systems are the least efficient and least flexible in conveying streamwater to the reservoir (Knapp, 1982). A fixed-speed pumping system with one or two pumps has some advantage over variable-speed pumping systems in reliability because of its simplicity. The drought yield for the Farina water supply was calculated on the assumption that an optimal pumping system was operational (variable-speed pumping over a range of 0.25 to 8 times the water supply gross demand). The 20- and 50-year drought yields are given in the table. The drought yields with the present pumping system were estimated by using the pumping system adjustment ratio proposed by Knapp (1982). These ratios reflect broad averages, and the performance of a specific pumping system may differ somewhat from that predicted.

Given an optimal pumping system, the combined yields of surface and ground water are adequate to meet demand during a 20-year drought through 2020, but given the existing pumping system, they may fall short of demand by 2000. During a drought comparable to a 50-year event, the combined yield of ground water and an optimal pumping system may not be sufficient to meet demand by 2000 and, given the present system, yield is less than the predicted average annual demand from 1990. With an optimal pumping system, the combined 50-year drought yield is about 92% of projected 2020 average annual demand. However, as illustrated by the raw water use in 1989, considerably more raw water may be needed as a result of drought-related conditions. Thus, some auxiliary supply may be needed during extreme droughts.

Mitigative Measures

Installation of a more efficient pumping system for water withdrawals from the East Fork Kaskaskia will more fully utilize the existing water supply source and reduce the difference between projected yields and demands. Sand and gravel aquifers as well as shallow Pennsylvanian sandstones suitable for domestic or farm supplies are present throughout Fayette County (Selkregg et al., 1957). If additional ground-water sources are sought to supplement the existing supply, several wells may be needed to significantly reduce the risk of shortages during a severe drought. An additional side-channel reservoir could possibly be constructed to provide additional storage. The location of the pump intakes could be moved a little farther downstream to benefit from increased drainage area. However, me sewage treatment plant outfall which discharges to the East Fork Kaskaskia downstream of the present intakes would need to be moved to pursue this option. There are no existing reservoirs or lakes adequate to supplement supplies within about a 5-mile radius of Farina. Patterson Lake (Clay County), which is around 6 miles from Farina, has a 40-year drought yield of 0.10 mgd on the basis of an estimated 1990 capacity of 270 ac-ft (Broeren et al., 1989) which would be more than adequate to supplement the existing supplies. No potential reservoir sites were identified by Dawes and Terstriep (1966a) within 5 miles of Farina when they conducted their investigation of likely locations for development of surface water resources. There are no major public water supplies in the vicinity of Farina with supply in excess of demand for a possible back-up supply.

Under the present conditions the following alternative are considered feasible:

1. Investigate a more efficient surface water pumping system and augment water supplies with additional ground-water wells.

2. Investigate a more efficient surface water pumping system and provide additional raw water storage with an additional or larger side channel.

3. Develop a plan to deliver water from Patterson Lake to Farina during extreme droughts.

System No.: 009
System Name: Flora
County: Clay
Communities Served: Flora, Xenia
Estimated 1990 Service Population: 6,009

Water Supply Source(s)

River	*Location*	*Approx. Dr. Area (sq mi)*
Low channel dam across Little Wabash River	NE1/4 S36 T04N R06E	750

The low-channel dam is approximately 10 to 15 feet high and on the order of 20 feet wide. The primary function of the dam is to keep the pump intakes submerged. The pool created by the dam provides little storage.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			126	131	134	136
Avg. annual, mgd	0.770	0.698	0.757	0.784	0.803	0.848
Supply Yield			Q_{7DLF}	Q_{15DLF}	Q_{31DLF}	Q_{SMD}
Y_{20}*, mgd*			0.15	0.23	0.67	2.59
Y_{50}*, mgd*			0.04	0.12	0.21	0.70

Background Information

Flora PWS withdraws water from the Little Wabash River at a location (about 5 miles north of Flora) where the drainage area is approximately 750 sq mi. There is no facility such as an in-channel or a side-channel reservoir which can provide significant storage of raw water to augment withdrawals during low-flow conditions. A small pool is created by a low channel dam to keep the pumping facility intakes submerged, but no significant water storage is created. As there is no reservoir, the availability of water for Flora during a severe drought is demonstrated by using low-flow statistics for the Little Wabash River. Low-flow statistics for the 7-, 15-, and 31- day low flows (Q_{7DLF}, Q_{15DLF}, Q_{31DLF}), and the 3-month drought (Q_{3MD}) for 20- and 50-year return intervals are given in the above table. Flora's pumping station is located downstream of Louisville's pumping station, and flows at Flora's pumping station may be reduced depending on withdrawals and returns from Louisville. Flora's water needs are expected to increase gradually with increasing population growth and some increase in per capita water use. During droughts which have 20-year and 50-year return periods, the average 7-, 15-, and 31-day low flows are considerably less than the estimated demand for 1990. The average 3-month low flow with a 50-year return period was also considerably less than demand. Some additional storage or auxiliary supply is needed to meet demands during severe droughts.

Mitigative Measures

Flora is currently considering plans for a new in-channel reservoir at a site located 4 miles west of Flora, north of Illinois Route 50 on Raccoon Creek. Raccoon Creek flows into the Elm River, which joins the Little Wabash River downstream of any public water supply withdrawal sites. The exact size of the reservoir is not as yet determined. Dawes and Terstriep (1966a) identify a potential reservoir site on Raccoon Creek at approximately the same location as the site which is now being considered. The potential reservoir site is described as an excellent water storage dam site. A reservoir with a drainage area of 15 sq mi and a storage capacity of 11,700 ac ft has a calculated 40-year drought yield of 4.3 mgd, which is more than enough to supply all of Flora PWS demands through 2020.

There are two existing lakes within approximately a 5-mile radius of Flora: Charlie Brown Park Lake (40 ac-ft) and Trago Lake (68 ac-ft). Drought yields from these lakes would probably not be adequate to augment withdrawals from the Little Wabash during extreme low flows. Water could be pumped from the Little Wabash during high-flow periods and stored in a side-channel reservoir. The side-channel reservoir would need to have a fairly large storage capacity, on the order of 100 ac-ft. Locating water-bearing sand and gravel aquifers or bedrock aquifers in the vicinity of Flora is not likely, as glacial materials are relatively thin in the western two-thirds of Clay County (Selkregg et al., 1957). Louisville and Clay City, the two closest public water supplies, also rely on direct withdrawals from the Little Wabash.

Under the present conditions the following alternatives are considered feasible:

1. Investigate the possibility of constructing a side-channel reservoir to provide supplementary water during low-flow periods.

2. Investigate the feasibility of constructing a dam and reservoir on Raccoon Creek sufficient to meet system future demands without pumping water from the river. This can maintain low flows in the Little Wabash River. Also, the design may consider obligatory flow releases below the new dam to protect stream ecology and aquatic habitats. The incorporation of sediment-entrapment reduction measures may be considered an integral part of design for improved lake water quality, smaller initial size of reservoir, and reduced bed degradation downstream.

System No.: 081
System Name: Georgetown
County: Vermilion
Communities Served: Georgetown
Olivet
Estimated 1990 Service Population: 5,045

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
City reservoir	SE1/4 S06	159	1990	165.0	43.8
(low channel dam)	T17NR11W		2020	67.4	32.6

The reservoir storage is created by a low-channel dam across the Little Vermilion River.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			83	84	84	84
Avg. annual, mgd	0.459		0.419	0.429	0.433	0.451
Supply Yield						
Y_{20}, *mgd*			0.35	0.26	0.17	0.10
Y_{50}, *mgd*			0.16	0.10	0.06	0.04

Background Information

A gradual increase in population is expected and will likely cause water demand to increase with time. Water demand may be slightly less than the projections, as repairs to the distribution system completed in 1989 may reduce losses from 30% of demand to 12%. Only minor storage is created by the low-channel dam, and during severe droughts yield is projected to be less than demand. The water supply demand is less than 1% of the mean annual discharge of the river at this location. The margin of error in the yield estimates is somewhat greater than in cases when the ratio of demand to average flow is higher. However, the system is on the Illinois Environmental Protection Agency critical list. During the 1988 drought, mandatory water use restrictions were imposed. Sedimentation is a significant problem as more than half the 1990 estimated storage capacity, nearly 100 ac-ft of storage, is projected to be lost because of sediment accumulation between 1990 and 2020. The reservoir was dredged as recently as 1983; however, the 1990 storage capacity may be insufficient to sustain a draft rate adequate to meet demand during a 20-year drought in 1990. The current water supply system will probably require some auxiliary source to meet future demands.

Mitigative Measures

The Little Vermilion River has adequate flows to serve the public water supply demand if water reserves of around 190 ac-ft are maintained. The principal problem with the present reservoir is the rapid rate of sedimentation. Increasing the spillway elevation to gain storage would only delay the eventual silting of the reservoir. An alternative to routine maintenance dredging would be to retrofit the dam with sluices to vent the sediment. Side-channel storage could provide a long-term solution. There are no other existing reservoirs within five miles of Georgetown. An adequate potential reservoir site is shown by Dawes and Terstriep (1966b) on Yankee Branch near Georgetown. However, given the sedimentation rate at the Georgetown reservoir, this site may have the same problem and not offer a long-term solution. Ground water may be available from sand and gravel aquifers which underlie the area. The chances of wells yielding 20 gpm or more are good (Visocky et al., 1978).

The demand is such a small percentage of the average streamflow that some extrapolation was necessary to use the available data and the standard method of yield analysis adopted for this study. An in-depth evaluation of the potential yield and needed storage capacity of the reservoir using streamflow data collected from the Little Vermilion River would be appropriate to more accurately determine the storage requirements prior to initiating plans to augment the supply.

Under the present conditions, the following alternatives are considered feasible on the basis of estimated yields from the existing facility:

1. Investigate the feasibility of retrofitting the dam with sluices to vent the sediment.

2. Determine if side-channel storage could be created and evaluate the needed pumping system to optimize yield and minimize storage requirements.

3. Investigate the possibility of developing ground-water wells to augment streamflow during droughts.

System No.: 048
System Name: Gillespie
County: Macoupin
Communities Served: Benld
Dorchester
Edgarville
Spring Creek WD
East Gillespie
Gillespie
Mt. Clair
Sawyerville
Wilsonville
Estimated 1990 Service Population: 7,441

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*SA (ac)*
Old Gillespie	SW1/4 S10	5.73	1990	596.6	67.0
Lake	T08NR07W		2020	518.2	63.9
New Gillespie	SE1/4 S08	12.25	1990	2,252.4	212.0
Lake	T08NR07W		2020	2,074.3	206.3

New Gillespie Lake is located just downstream of Old Gillespie Lake on a tributary of Dry Fork Macoupin Creek.

Projected Water Use and Supply Yields

Demand	*Reported 1988*	*1989*	*Estimated 1990*	*2000*	*2010*	*2020*
***Per** capita, gpcd*			94	96	98	100
Avg. annual, mgd	0.745	0.737	0.699	0.697	0.702	0.724
Supply Yield						
Y_{20}, *mgd*			1.79	1.76	1.72	1.70
Y_{50}, *mgd*			0.80	0.78	0.77	0.75

Background Information

The service area population for Gillespie PWS is expected to remain fairly constant, decreasing somewhat from 1990 to 2010 and then increasing again by 2020. Demand may increase slightly with increasing per capita water use. Drought yields from the present water supply sources are adequate to meet the projected average annual demand. However, if demand is elevated as it is typically during drought conditions, water shortages could occur. The drought-related increase in water use is illustrated by comparing demand during the drought conditions of 1988 and 1989, listed in the table, to the reported 1986 demand of 0.700. The two lakes are the sole source of water supply for the system. A combined loss of approximately 250 ac-ft of storage is expected in the two lakes between 1990 and 2020 as a result of sedimentation. The 1990 storage capacities and resulting yields are somewhat inadequate to meet the elevated demand (20% above average) through 2020.

Mitigative Measures

If water use restriction or pricing incentives are adopted during dry or drought periods to keep water use near average, no alternative water supply sources are needed. However, it may not always be possible to institute timely restrictions to reduce water use. In the interest of reducing the risk of water shortages, some emergency water supply sources should be identified or management plans adopted to increase yields from the existing sources. The dam creating New Gillespie Lake (farthest downstream) is several miles from the confluence of Dry Fork with Macoupin Creek, and venting of accumulated sediment during high flows may have an adverse impact on the downstream tributary. Routine maintenance dredging could alleviate the need to acquire an additional source. There are three existing reservoirs near Gillespie (U.S. Army Corps of Engineers, 1980) which are not used for a public water supply: Whitfield Lake (estimated 1980 capacity 122 ac-ft), Royal Lake No. 1 (estimated 1980 capacity 95 ac-ft), and Shad Lake (estimated 1980 capacity 100 ac-ft). Development of a new in-channel reservoir is a possibility, but given the small demand it likely would not be the most cost-effective means of obtaining an emergency supply. Several nearby communities (Staunton, Mt. Olive, and Shipman) have marginal water supply sources. A joint venture with one of these communities to develop a new source could be considered. Ground-water resources are scarce in the region (Woller, 1976). Some sand and gravel deposits associated with the Macoupin Creek valley may be suitable for obtaining limited quantities of water.

Under the present conditions the following alternatives are considered feasible:

1. Develop a drought plan which may include policies to avoid excessive increases in water use during dry periods, use restrictions, and pricing incentives. A detailed evaluation of the lake volume and yields together with a water budget analysis would be useful for early identification of possible drought conditions.

2. Investigate the use of an existing reservoir for an emergency water source.

3. Investigate the possibility of maintenance dredging of the lakes.

System No.: 031
System Name: Greenfield
County: Greene
Communities Served: Greenfield
Rink Subd.
Estimated 1990 Service Population: 1,097

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Greenfield Lake	SW1/4 S03	1.11	1990	546.6	51.7
	T10NR10W		2020	503.4	503

Greenfield Lake is an in-channel reservoir on Rubicon Creek, Macoupin Creek Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			84	85	86	86
Avg. annual, mgd	0.084	0.080	0.092	0.089	0.088	0.091
Supply Yield						
Y_{20}, mgd			0.24	0.23	0.23	0.22
Y_{50}, mgd			0.09	0.09	0.09	0.08

Background Information

County-wide projections by the Illinois Bureau of the Budget (1987) show a decline in population until about 2020. On the basis of these projections, a slight decrease in population was forecast for Greenfield until about 2020. Assuming a modest increase in per capita water use, demand is expected to remain fairly constant through 2020.

Prior to the construction of Greenfield Lake, the public water supply relied exclusively on ground water obtained from four wells. These wells were filled and capped in 1968. Greenfield abandoned the wells, which were producing 10 to 40 gpm (0.014 to 0.058 mgd) each, because the supply was neither reliable nor adequate. Prior to construction of the lake, water had to be hauled into the treatment plant as the wells had gone dry. It is common for sand and gravel aquifers associated with the tributary valleys of Macoupin Creek to be shallow and limited in areal extent. This reduces the quantities of water available, and yield from these aquifers may decline in response to drought conditions (Woller et al., 1990).

Greenfield Lake is the sole source of supply for the system. Projected sediment accumulation in the reservoir will result in slowly declining yields. Yields are expected to be adequate to meet average demand until about 2020 when the lake supply may be inadequate to meet demand during a 50-year drought event. In the event of a 50-year drought in 2020, the yield from Lake Greenfield is expected to be about 88% of the projected average annual demand. During a severe drought, water use may increase 1.2 to 1.3 times the average annual demand. If demand escalates during a 50-year drought, water shortages could occur even in 1990.

Mitigative Measures

Greenfield's supply is marginal only in the event of an extreme drought and elevated water use until 2020. Thus, to minimize the risk of water shortages, an emergency source of supply may be needed. Restricting water use to average levels may be effective in avoiding a water shortage in the event of a severe drought if the situation is recognized in time.

Information is not available on the original capacity of the lake, which would be necessary to evaluate if reclaiming and maintaining the original water storage volume would provide a supply adequate to meet demand in excess of the projected average demand. However, periodic dredging of the reservoir to maintain the 1990 capacity would maintain yields sufficient to meet the projected average annual demand. Raising the spillway about 1.5 feet would provide additional storage needed to meet drought-related increases in water use during a 50-year event through 2020. Additional storage could be provided with a side-channel reservoir.

Ground water is available in the vicinity, as evidenced by the abandoned wells. The shallow sand and gravel aquifers could possibly serve as a back-up supply if water were routinely pumped from the wells to the lake to maintain the lake level. There are two existing reservoirs within about two miles of Greenfield: Coles Lake (52 ac-ft) and Shady Eight Acres Lake (68 ac-ft). The 40-year drought yield of Coles Lake, determined on the basis of an estimated 1990 capacity of 44.5 ac-ft, is 0.01 mgd (Broeren et al., 1989). Neither of these lakes has an adequate yield for development as a supply source. Provision of a side-channel reservoir receiving water pumped from Rubicon Creek, which flows adjacent to Greenfield and has a drainage area of 5.58 sq mi, could provide an adequate stand-by source. Taylor Creek, which is about two miles east of Greenfield, has a drainage area of 9.63 sq mi near the reservoir. Another option would be pumping from Rubicon Creek or Taylor Creek to the existing reservoir. The success of this option would be very sensitive to the installation of a pumping system capable of operating over a range of discharges. There are no other public water supplies in the vicinity which have an excess of water to supplement Greenfield's supply.

Under the present conditions the following alternatives are considered feasible:

1. Develop stand-by ground-water wells.

2. Dredge Greenfield Lake to maintain adequate storage capacity.

3. Withdraw water from either Rubicon Creek or Taylor Creek to a suitable side-channel reservoir or to Greenfield Lake.

System No.: 057
System Name: Kinmundy
County: Marion
Communities Served: Alma
Kinmundy
Estimated 1990 Service Population: 1,420

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Kinmundy Res.	NE1/4 S28	0.55	1990	136.9	23.2
	T04NR03E		2020	125.3	22.5
Borrow pit	SW1/4 S15		1990	200	10
	T04N R03E		2020	200	10

Kinmundy Reservoir is an in-channel impoundment on a tributary of the East Fork of the Kaskaskia River. Water is. pumped from me reservoir to a borrow pit.

Projected Water Use and Supply Yields

	Reported			*Estimated*		
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			75	78	80	81
Avg. annual, mgd	0.125		0.107	0.111	0.115	0.119
Supply Yield						
Y_{20}*, mgd*			0.17	0.17	0.17	0.17
Y_{50}*, mgd*			0.14	0.14	0.14	0.14

Background Information

Water demand for the Kinmundy system is expected to increase slightly with time. The calculated yields shown in the table are greater than the average annual demand. However, if water use during a drought period increases significantly (say, by 20%) the yields will not be able to meet demands by 202.0. The side-channel reservoir provides almost two-thirds of the raw water storage for the system. The side-channel storage was obtained because the in-channel reservoir was losing storage capacity as a result of sediment accumulation. The yield analysis was performed on the assumption that the borrow pit would be kept full by pumping from the in-channel reservoir (Kinmundy Reservoir); thus the two impoundments would operate as one large in-channel reservoir. Given that the borrow pit (side-channel) storage is nearly double the in-channel storage, this analysis may overestimate yields. Therefore, this system was included in this study.

Mitigative Measures

The volume of the side-channel reservoir has been estimated on the basis of limited data. Prior to initiating any plans to augment the existing system, the present system should be analyzed in greater detail. The volume of the side-channel reservoir needs to be accurately determined. A systems analysis considering the pumping system capacity, in-flow patterns to the in-channel reservoir, demand, and water treatment plant capacity needs to be performed to accurately evaluate the yield of the system during a drought. The capacity of the reservoir in 1902 was 174.1 ac-ft. Dredging of this reservoir could possibly provide sufficient additional storage to insure that no water shortages occur in the future. Possible water shortages could be avoided through early identification of drought conditions and implementation of water use restrictions or price incentives to keep demand from escalating during a drought. There are several existing reservoirs within about seven miles of Kinmundy which could be considered for an emergency source of water.

Under the present conditions the following alternatives are considered feasible:

1. Perform a detailed analysis of the system including an accurate determination of the borrow pit volume, pumping system, streamflows, and demand.

2. If the present system cannot meet demands during drought conditions, investigate a program of maintenance dredging for the in-channel reservoir.

3. Investigate the possibility of accessing water from other existing reservoirs during drought emergencies.

System No.: 076
System Name: Loami
County: Sangamon
Communities Served: Loami
Estimated 1990 Service Population: 807

Water Supply Source(s)

River/Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
City Reservoir	NE1/4S15 T14NR07W	0.083	1990	69.2	9.94
			2020	50.3	8.94
Lick Creek-direct	NE1/4 S15 T14N R07W	32.7			

Loami City Reservoir was originally a side-channel impoundment. In 1979 the embankment of the side-channel reservoir was extended to impound water from a tributary to Lick Creek. Water is pumped from Lick Creek to the reservoir.

Projected Water Use and Supply Yields

Demand	*Reported 1988*	*Reported 1989*	*Estimated 1990*	*Estimated 2000*	*Estimated 2010*	*Estimated 2020*
Per capita, gpcd			81	86	88	88
Avg. annual, mgd	0.050	0.056	0.065	0.072	0.077	0.079
Supply Yield	*Pumping System*					
Y_{20}, mgd	optimal		0.08	0.08	0.07	0.06
Y_{20}, mgd	existing		0.05	0.04	0.04	0.04
Y_{50}, mgd	optimal		0.07	0.07	0.06	0.06
Y_{50}, mgd	existing		0.04	0.04	0.03	0.03

Background Information

A combination of rising population and per capita water use is expected to cause demand to increase with time. The yield figures presented in the table were determined on the assumption that the reservoir operates as a side-channel reservoir. Actual yields may be somewhat higher if inflow from the 0.083 sq mi drainage area tributary is taken into consideration. An analysis of the reservoir operating as an in-channel impoundment with an 0.083 sq mi watershed shows a 20-year drought yield of 0.02 mgd and a 50-year drought yield of 0.01 mgd. The actual yield of the system will be somewhat less than the sum of the yields calculated for the two independent scenarios of operation. The Y_{20} and Y_{50} values indicate the raw water available for both an optimal pumping system with multi-stage pumping capacities, and the present pumping system. The decline in yields with time is a result of sedimentation of the reservoir from the tributary inflow. A detailed assessment of the yield which incorporates the various features such as multiple sources of water, streamflows, and pumping capacities is beyond the scope of this report. A detailed analysis is needed to acurately assess the yield for the system and determine the quantity of water needed from an auxiliary source. On the basis of the optimal pumping system yields, demand may exceed yields by 2010 for both a 20-year and a 50-year drought. By 2020 the 50-year drought yield may meet only about 76% of demand. Presently the existing pumping system may not be capable of withdrawing a sufficient quantity of water to meet demand during a severe drought. During the 1988-1989 drought the reservoir was drawn down over 10 feet and mandatory water use restrictions were imposed. The city is currently considering several options for augmenting their supply.

Mitigative Measures

The pumping system used to deliver water from Lick Creek is a significant factor affecting yields. Use of a multi-stage pumping system could increase yields by more than 40%. Improving the pumping system alone will not guarantee yields sufficient to meet demand during droughts through 2020 but would considerably reduce the difference between yields and demand. Sediment accumulation in the reservoir is a result of extending the embankment across the Lick Creek tributary. Between 1990 and 2020 approximately 19 ac-ft of storage capacity will be lost to sedimentation. However, even if the 1990 capacity were maintained, the 50-year drought yield could fall short of demand by 2020. The water supply system will require implementation of some ameliorative measures. Increasing the storage capacity of the existing impoundment is a viable alternative. The additional storage needed will depend on the pumping system from Lick Creek. With the present pumping system the reservoir capacity may need to be as great as 170 ac-ft. However, an improved pumping system using two different speed pumps could reduce the needed storage to around 120 ac-ft. An optimal pumping system would require only about 73 ac-ft of storage. Alternatively, Sudduth Lake is an existing reservoir within five miles of Loami. This lake has an estimated 40-year drought yield of 0.1 mgd, which would be adequate to augment Loami's supply. An alternative being considered by the city is to join the Springfield public water supply system. This option is contingent upon Springfield's plans to increase their raw water supply through the construction of a new in-channel reservoir. The chances of developing a ground-water supply are poor as water-yielding deposits are scarce in the vicinity (Selkregg and Kempton, 1958).

Under the present conditions the following alternatives are considered feasible:

1. Conduct a detailed analysis of the system, considering the interaction of the inflow from the tributary and pumping from Lick Creek. As part of this study, identify a higher-yielding pumping system. This analysis may demonstrate mat the combination of an improved pumping system, a small increase in storage (which may be accomplished through dredging), and a rate structure that discourages high water use during droughts may be sufficient measures to provide an adequate water supply through 2020.

2. Evaluate the possibility of increasing reservoir storage by raising the spillway elevation.

3. Assess the cost of joining the Springfield public water supply system.

System No.: 088
System Name: Marion
County: Williamson
Communities Served: Marion
Wye WD
Estimated 1990 Service Population: 15,953

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Marion Res.	NE1/4 S02	6.48	1990	1,395.1	217.6
	T10SR02E		2020	1,280.9	211.6

Marion Reservoir is an in-channel impoundment on Limb Branch of Crab Orchard Creek, Big Muddy River Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			106	110	112	114
Avg. annual, mgd	1.724	1.696	1.691	1.788	1.844	1.952
Supply Yield						
Y_{20}, *mgd*			1.29	1.27	1.24	1.22
Y_{50}, *mgd*			0.94	0.92	0.90	0.88

Background Information

The city population is growing steadily, and water demand is expected to continue to increase. Yields from Marion Reservoir are expected to slowly decline as sediment accumulates. Drought yields are less than demand from 1990. Prior to 1985 the city relied on Crab Orchard Lake for a standby water source. However, Crab Orchard Lake was found to be contaminated with PCBs and not acceptable for a potable water supply source. Alternative water sources are being considered by the city. Due to water quality problems with the Marion Reservoir, the Illinois Environmental Protection Agency has recommended mat another source be secured.

Mitigative Measures

There are numerous existing reservoirs in the county. Three major reservoirs are Lake of Egypt, Devils Kitchen Lake and Little Grassy Lake. These reservoirs are more than five miles but less man 15 miles from Marion. They are somewhat closer to Marion Reservoir, which is located south of the city. Lake of Egypt, which is only five miles from Marion Reservoir, is currendy used for public water supply by the Southern Illinois Electric Cooperative (formerly Lake of Egypt Water District). Estimated drought yields from Lake of Egypt in 2020 are: 20-yr, 16.82 mgd; and 50-yr, 12.45 mgd. The projected 2020 demand for the Cooperative is only 1.198 mgd. Thus, water reserves are more than adequate to meet all of Marion's demand. On die basis of the estimated 1980 storage capacities of the lakes, the 40-yr drought yields for Devils Kitchen Lake and Little Grassy Lake are 7.75 mgd and 6.40 mgd, respectively (Broeren et al., 1989). A potential reservoir site identified by Roberts et al. (1957) on the Saline River could likely supply Marion. The 40-year yield calculated by Roberts et al. is 4.4 mgd. However, this site is downstream of Lake of Egypt. Yields will be lower when the impact of Lake of Egypt is considered. Nearby rivers do not have sufficient flows to augment the water supply with direct pumping, and it is not feasible to develop the necessary volume of side-channel storage. Ground-water sources are limited. Glacial deposits are thin and generally not water-yielding, except for some thin and discontinuous deposits associated with river valleys (Pryor, 1956). Chances of developing wells yielding 10 gpm or more from bedrock are poor (Visocky et al., 1978).

Under the present conditions the following alternatives are considered feasible:

1. Pursue acquisition of rights to withdraw water from Lake of Egypt or one of the other existing reservoirs, as the yields from these reservoirs are more than adequate to meet demands.

2. Investigate the development of a ground-water source to augment the surface water supply.

3. Investigate the possibility of building another in-channel reservoir.

System No.: 050
System Name: Mount Olive
County: Macoupin
Communities Served: Carlsberg
Mount Olive
Staunton Co-op.
White City
Estimated 1990 Service Population: 2,476

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Old Mt. Olive	Nl/2 S03	0.70	1990	375.3	33.1
Reservoir	T07NR06W		2020	353.5	32.4
Mt. Olive Lake	SE1/4 S28	5.21	1990	249.5	52.6
	T08NR06W		2020	148.2	44.3

Old Mt. Olive Reservoir is an in-channel impoundment on Sugar Creek, tributary to Cahokia Creek, Mississippi River Basin. Mt. Olive Lake is an in-channel impoundment on Panther Creek, tributary to Cahokia Creek, Mississippi River Basin. As reported in 1990, facilities are available to pump water from Mt. Olive Lake (New Lake) to Old Mt. Olive Reservoir.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			101	102	102	103
Avg. annual, mgd	0.223*	0.219*	0.250	0.245	0.240	0.243
Supply Yield						
Y_{20}, mgd			0.44	0.41	0.34	0.31
Y_{50}, mgd			0.24	0.23	0.20	0.18

* Billed water

Background Information

A slight decrease in population is projected on the basis of Illinois Bureau of the Budget projections of a county-wide population decline from 1990 to 2010. Although per capita water use may increase slightly, water demand is expected to decline somewhat with the decrease in population. The Mt. Olive public water supply obtains water from two sources, both in-channel reservoirs, called Old Mt. Olive Reservoir and Mt. Olive Lake. Yield from the two reservoirs is expected to decrease over time as inflowing sediments occupy more of the reservoir space. Sedimentation in Mt. Olive Lake is a pronounced problem, and on the order of 100 ac-ft of water storage volume is projected to be lost between 1990 and 2020. The storage volume of Old Mt. Olive Reservoir is greater than that of Mt. Olive Lake; however, me watershed area of Mt. Olive Lake is over 7 times mat of Old Mt. Olive Reservoir. During 1988 water was pumped from Mt. Olive Lake to Old Mt. Olive Reservoir. This would increase the combined yields from the two sources. Drought yields presented in me table are calculated on the basis of independent operation of the two lakes. On the basis of these values, demand could exceed yield during a 50-

year drought from 1990 onward. By 2020 the 50-year drought yield is projected to be about 74% of the average annual demand. High drought-related water use could reduce this percentage.

Mitigative Measures

Provided the pumping system capacity from Mt. Olive Lake (drainage area 5.21 sq mi) to Old Mt. Olive Reservoir is adequate, this system provides a marginally adequate water supply. Given the watershed drainage area of Mt. Olive Lake, additional storage volume could be provided by raising the spillway elevation and thus the lake level. Alternatively, maintenance of the 1990 storage capacity by instituting a regular program of dredging could insure an adequate water supply through 2020. Both reservoir dams are fairly close to Cahokia Creek. However, the drainage area of Cahokia Creek is only around 50 sq mi; thus the increase in the sediment load in Cahokia Creek would have to be carefully studied before any action was taken to vent accumulated sediment. Lake Ka-Ho, located about 1/2 mile north of Old Mt. Olive Reservoir, could possibly serve as a standby source of water; however, its volume is not known. Development of another in-channel reservoir is not particularly favorable. Much of the area has been undermined, and subsidence may be a problem. Use of some streams may be limited because of water quality problems related to excessive iron oxide deposits in streambeds, which are residual from mining operations. One site on East Fork Cahokia Creek is noted by Dawes and Terstriep (1966a). The yield from this site could be adequate to supply Mt. Olive as well as some neighboring public water supplies such as Gillespie and Staunton which have marginal supply sources. Water quality, cost, and the possibility of a joint venture would need to be carefully examined to determine the feasibility of this project. Water-yielding sand and gravel deposits may be present in the Cahokia Creek valley (Woller, 1976). However, considerable test drilling may be necessary to locate a part of the aquifer suitable for furnishing moderate quantities of water. The low yield of ground-water wells has led other communities in the county to develop surface water supplies.

Under the present conditions the following alternatives are considered feasible:

1. Evaluate the pumping system arrangement between Mt. Olive Lake and Old Mt. Olive Reservoir to determine the long-term reliable yield.

2. Investigate the most cost-effective method of providing additional storage capacity at the Mt. Olive Lake site, by either raising the spillway or dredging to increase or maintain the 1990 storage volume.

3. Determine me volume and the drought yield of Lake Ka-Ho and investigate the possibility of withdrawing water from it during droughts.

System No.: 016
System Name: Oakland
County: Coles
Communities Served: Oakland
Estimated 1990 Service Population: 1,019

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Oakland Lake	Wl/2 S18	14.31	1990	91.1	20.7
	T14N R11E		2020	57.0	17.8

Oakland Lake is an in-channel reservoir located on Hog Branch (tributary to the Embarras River).

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			115	117	119	121
Avg. annual, mgd	0.100	0.109	0.117	0.117	0.121	0.130
Supply Field						
Y_{20}, *mgd*			0.15	0.11	0.09	<0.05
Y_{50}, *mgd*			<0.05	<0.05	<0.05	<0.05

Background Information

Oakland Lake is the sole source of supply for the city of Oakland. Water demand is expected to increase slightly with population growth and moderate increases in per capita consumption. Sedimentation is a severe problem. The reservoir was originally constructed in 1937 with an original capacity of 94 ac-ft. The reservoir was dredged during 1954 and 1970. The spillway elevation may have been increased around 1970. On the basis of a 1973 capacity of 115 ac-ft, sediment accumulation is projected to reduce the water storage capacity to 57 ac-ft by 2020, a 37% decrease from the estimated 1990 capacity. The yield from the reservoir will likewise decrease. During a drought comparable to a 20-yr return interval event, yield may be slightly less than the average annual demand by the year 2000; estimated yield during a 50-yr drought is less than projectred demand for 1990. By 2020 the 50-yr drought yield will be less than 38% of average annual demand. During droughts water use often increases, resulting in higher than average demand, increasing the likelihood of water shortages if the drought is severe. The Environmental Protection Agency has rated the supply for this system as marginal. The differences in raw water use and billed water in 1988 and 1989 are fairly large because of line breaks in those years.

Mitigative Measures

The reservoir dam is located less than three miles upstream from the confluence of Hog Branch with the Embarras River. The approximate drainage area of the Embarras at this juncture is 518 sq mi. Thus, this site may be a good candidate for sediment venting and/or bypassing of highly sediment-laden flood flows. However, even if the reservoir storage capacity were returned to the larger reported volume of 115 ac-ft and maintained at that volume, some additional storage or supply source is needed to meet the projected demand for 2020. If a storage capacity of about 100 ac-ft could be maintained at Oakland Lake, a moderate-sized side-channel reservoir (about 30 ac-ft) could provide sufficient additional storage and more fully utilize the present water source. There are numerous structures bordering Oakland Lake; therefore increasing the spillway elevation to create more storage is probably not feasible. During the drought of 1988 the reservoir level dropped 22 to 23 inches. Periodic rains over the watershed provided inflow to the reservoir, and no water shortages occurred.

In the vicinity of Oakland (in approximately a five-mile radius) mere are two existing reservoirs in Coles County, neither of which is large enough to adequately augment the current supply. In Douglas County, Walnut Point State Park Lake (675 ac-ft) is sufficiently large to provide an adequate additional water supply. However, the city has investigated this option and reports that they would be able to pump only 1000 gpd (0.001 mgd), which is not adequate to meet the need. The Embarras River west of Oakland (approximate drainage area 518 sq mi) could meet the entire demand through 2020 with some supplementary storage provided by a side-channel reservoir. A ground-water source was sought by the city about 1976. However, a suitable aquifer was not located. The U.S. Geological Survey (Selkregg and Kempton, 1958) reports that shallow aquifers capable of producing adequate water to supply a community are not likely to exist in the area around Oakland except possibly in the buried valley of the Embarras River. Poor water quality may be a problem in deeper bedrock formations. In 1986 only 0.512 mgd was pumped from ground-water sources in the entire county (Kirk, 1987). The only other public water supply which could provide an emergency back-up is Charleston, which is about 15 miles south of Oakland. Because of the geologic conditions, it is questionable if a dam could be constructed at even the most likely potential reservoir sites in the vicinity (Dawes and Terstriep, 1966a). Project costs are expected to be fairly high.

Under the present conditions the following alternatives are considered feasible:

1. Withdraw water from the Embarras River during medium- and high-flow conditions to a new side-channel reservoir constructed to provide sufficient storage to supplement supply during low-flow periods.

2. Remove sediment from Oakland Lake, establish a program to maintain the lake capacity (by retrofitting sediment venting features if technically feasible), and augment storage with a side-channel reservoir.

System No.: 051
System Name: Palmyra-Modesto Water Commission
County: Macoupin
Communities Served: Modesto
Palmyra
Scottville
Estimated 1990 Service Population: 1,537

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Palmyra-Modesto Lake	NW1/4 S35 T12NR08W	1.7	1990	496.6	34.6
			2020	458.1	33.7

Palmyra-Modesto Lake is an in-channel reservoir on a tributary to Nassa Creek, which joins Otter Creek above Otter Creek's confluence with Macoupin Creek, Illinois River Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			74	75	75	76
Avg. annual, mgd	0.126	0.132	0.114	0.121	0.123	0.129
Supply Yield						
Y_{20}, *mgd*			0.26	0.26	0.25	0.24
Y_{50}, *mgd*			0.11	0.10	0.10	0.10

Background Information

The city of Scottville joined the system in 1988. Water use projections for 1990-2020 include Scottville's demand. Water use in 1988 and 1989 is higher than the projected 1990 use by as much as 15%. This may be a result of high water use during the drought period or could indicate that future water use may be greater than forecasted. Water use is projected to increase over the years, primarily as a result of an increasing service area population. While some sedimentation of the reservoir is projected, drought yields are only slowly declining over time. The water commission has purchased 20 acres of land north of the lake and has plans to install check dams to reduce sediment inflow into the lake. Soil conservation measures are also being implemented on the acreage to reduce soil erosion and subsequent deposition in the lake. However, the 50-year drought yield in 1990 is less than the demand, and preservation of the current storage capacity will not insure an adequate supply during an extreme drought in future years.

Mitigative Measures

Additional storage capacity and/or an alternate source of supply is needed to augment yields from Palmyra-Modesto Lake. Storage greater than the original capacity of the lake, about 534 ac-ft, is needed to develop drought yields sufficient to meet demand through 2020. To provide the needed storage, the normal reservoir level would have to be increased around 4 feet.

This may not be a practical option, as O'Neal Cemetery is near the present lake shoreline. Direct water withdrawals from Nassa Creek (drainage area approximately 20 sq mi) could possibly provide sufficient additional water to meet average annual demand. The increase in yields from pumping water from Nassa Creek to Palmyra-Modesto Lake would depend on the pumping capacity of the system. Otter Lake (1990 storage capacity 16,188 ac-ft) is located about 3 miles east of Palmyra-Modesto Lake. It provides the water supply for the ADGPTV Water Commission. The projected 2020 50-year drought yield of Otter Lake is 2.6 mgd, while demand for the system is estimated to be 1.78 mgd in 2020. Thus there is an ample reserve to supplement yields from Palmyra-Modesto Lake. A potential reservoir site on Solomon Creek (drainage area 13.3. mi), which lies west of Palmyra, could be developed (Dawes and Terstriep, 1966a). A 3,030 ac-ft reservoir has an estimated 40-yr drought yield of 1.2 mgd, which would be much more than needed to meet demand. Prior to 1965 Palmyra and Modesto each had their own water supply system, which used ground water. The last reported average daily pumpage from Palmyra's six wells and Modesto's two wells is less than needed to augment their surface water supply. Most of the wells have been abandoned.

Under the present conditions the following alternatives are considered feasible:

1. Arrange to purchase water from the ADGPTV water commission, and pump water from Otter Lake to the Palmyra-Modesto system.

2. Investigate possible yields achieved by raising the spillway a foot or so and establishing a pumping system to withdraw water from Nassa Creek during droughts.

3. Reactivate abandoned wells and evaluate possible yields for short-term pumping during drought conditions.

System No.: *019*
System Name: Paris
County: Edgar
Communities Served: Paris
Estimated 1990 Service Population: 9,515

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Twin Lakes*	SE1/4 S25	21.7	1990	1483.2*	226.1*
	T14NR12W		2020	1266.1*	218.1*

* Combined storage capacity and surface area of both lakes

The "new" lake constructed in 1961 inundated the "old" lake, also referred to as the "west" lake. Twin Lakes now operate as one reservoir. Drainage area given is for the downstream dam. The inflowing stream is Sugar Creek, Wabash Basin.

Projected Water Use and Supply Yields

Demand	*Reported 1988*	*Reported 1989*	*Estimated 1990*	*Estimated 2000*	*Estimated 2010*	*Estimated 2020*
Per capita, gpcd			130	134	136	138
Avg. annual, mgd	1.28	1.20	1.237	1.241	1.245	1.286
Supply Field						
Y_{20}, *mgd*			1.47	1.42	1.36	1.31
Y_{50}, *mgd*			0.93	0.89	0.84	0.82

Background Information

Twin Lakes serves as the sole source of supply for Paris. Paris is not expected to realize any dramatic increases in water use. One industrial water user closed its plant early in 1989. On the basis of water use trends since 1986, the closing of the plant may result in water use being about 0.05 mgd less than shown in the table above. Sediment accumulation in Twin Lakes is expected to gradually reduce yields. In the event of a drought comparable to the 20-yr design drought, yields should be adequate to meet average needs through 2020, but high water use, which often occurs during drought conditions, may create shortages. Yields are likely to fall short of average demand from 1990 during a drought comparable to a 50-yr return interval event, with existing supplies meeting about 64% of projected demand. During the 1988 drought supplies were adequate under restricted lawn watering. As of June 1989 the city was considering plans to dredge the "old" reservoir, which is the smaller of the two. This action may be contingent upon receiving funds through the Environmental Protection Agency clean lakes program.

Mitigative Measures

Dredging of the "old" lake may provide some additional storage. As of June 1989 specific engineering work had not yet begun, and information is not available on the quantity of material to be removed. Several hundred acre-feet of sediment would need to be removed to provide storage capacity sufficient to increase yields adequately to meet future demand. Given the estimated 1990 storage volume of the "old" lake (approximately 121.5 ac-ft), removal of sediment from this lake alone may not provide adequate storage. Projections indicate that between 1990 and 2020 approximately 217 ac-ft of sediment is expected to accumulate in Twin Lakes. Lake management plans need to account for future sediment inflow. Alternatives to maintenance dredging include bypassing highly sediment-laden flood flows or sediment venting. The main dam is located approximately 20 miles upstream of the confluence of Sugar Creek with me Wabash River. The downstream impact on Sugar Creek of venting existing sediment would have to be investigated. Given the projected sediment accumulation, the lake level would have to be raised approximately 3 to 4 feet to provide adequate storage for both water needs and unabated sediment accumulation at the present site. This is not a likely alternative as numerous structures and roads would be affected. A multifaceted approach including sediment removal, reduction of future sediment entrapment, a small increase in the spillway elevation, and restructuring of water rates to decrease water use could be considered. According to quantities reported to the Illinois State Water Survey, in 1988 billed water accounted for only 74% of the raw water withdrawals. This difference is rather high compared to other public water supplies. Identification of the source(s) of unaccounted-for losses could lead to measures that reduce these losses.

Within an approximate 5-mile radius of Paris there are no existing reservoirs whose yield would be sufficient, no other major public water supplies to which Paris can be cross-connected; and no major rivers for direct withdrawals of water to supplement the current water supply in the event of a severe drought. Within approximately 9 miles of the city a potential in-channel reservoir site on Coal Creek has been identified which would have a sufficient yield to meet demand during extreme drought events well into the future (Dawes and Terstriep, 1966a). The site has the potential for construction of an in-channel reservoir of approximately 4200 ac-ft with a 40-yr drought yield of 2.0 mgd. This site is described as a reasonable site likely to have normal project costs. Shallow sand and gravel aquifers may be present west of Paris (Woller, 1974). If ground water could be located, several wells would likely be required to provide sufficient water to supplement the surface water yields.

Under the present conditions the following alternatives are considered feasible:

1. Locate and develop shallow ground-water aquifers.

2. Coordinate a combined approach of sediment removal, reservoir management to reduce accumulation, a raise in the spillway of 1 to 1.5 feet, a change in water rates, and reduction in unaccounted-for losses.

3. Design and construct an environmentally acceptable new in-channel reservoir to supplement the existing source.

System No.: 041
System Name: Northern Illinois Water Corporation - Pontiac
County: Livingston
Communities Served: Pontiac
Pontiac Correctional Center
Estimated 1990 Service Population: 13,709

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
River/Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Vermilion River	T28N R05E				
flow channel dam)	SE1/4 S22	579	1990	153	38
Abandoned quarry			1990	1535 (approx.)	

The low channel dam across the Vermilion River serves to keep the pump intakes submerged, estimated storage of 153 is minimal. The storage volume of the quarry is estimated.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			136	140	143	145
Avg. annual, mgd	2.017	1.860	1.864	1.961	2.030	2.122
Supply Yield			Q_{7DLF}	Q_{15DLF}	Q_{31DLF}	Q_{61DLF}
Vermilion River only						
20-yr, mgd			1.3	1.5	1.7	2.3
50-yr, mgd			1.0	1.1	1.3	1.7

Background Information

Pontiac's population is projected to increase slowly from 1990 to 2020. The population increase and a modest increase in per capita water use are expected to create an increase in raw water demand. Prior to 1988, the Vermilion River was the sole source of supply used by Northern Illinois Water Corporation (NEPC) to provide water for Pontiac and the Pontiac-Correctional Center. Low-flow statistics for the Vermilion River at Pontiac are presented above. The 20-year return period 7-, 15- and 31-day low flows are less than even the demand for 1990. There is a 1 in 50 chance every year that flows less than demand may last for more than 2 months. During the summer of 1988 river flow practically ceased, and emergency measures were taken to reduce water use and access other water sources, including pumping from local quarries to the river. However, water use in 1988 was still fairly high compared to that in other years. Presently, NIPC is in the process of purchasing an abandoned quarry to augment their water supply from the Vermilion River. The storage volume of the impoundment is estimated to be 500 million gallons (1535 ac-ft). The storage volume is equivalent to 235 days of demand projected for 2020. Ground-water seepage into the impoundment will provide an additional source of water. Alternatively, given the storage volume of the impoundment, it could also be used as a side-channel reservoir to store water pumped from the Vermilion River during high flows.

Mitigative Measures

Assuming the 500-million-gallon impoundment is purchased, no additional measures need be taken.

System No.: 052
System Name: Shipman
County: Macoupin
Communities Served: Shipman
Estimated 1990 Service Population: 634

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Shipman Res.	NW1/4 S24	0.46	1990	108.7	12.6
	T08NR09W		2020	95.6	12.1

Shipman Reservoir is an in-channel impoundment on a tributary of Coop Branch of Macoupin Creek.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			98	101	101	101
Avg. annual, mgd	0.060	0.071	0.062	0.065	0.065	0.066
Supply Yield						
Y_{20}, *mgd*			0.06	0.05	0.05	0.05
Y_{50}, *mgd*			0.02	0.02	0.02	0.02

Background Information

Shipman's population is expected to remain fairly stable. A slight increase in per capita water use is projected. While water demand is projected to increase slightly from 1990 to 2020, yields from the reservoir are also expected to decline slightly. Yield during a 20-year drought may not be sufficient to meet needs from 1990 on. In the event of a more severe drought such as the 50-year drought, yield from the reservoir may meet only about one-third of the demand.

Mitigative Measures

During a 50-yr drought event, the yield from Shipman Reservoir falls far short of meeting demand. At the present site, over 300 ac-ft of storage would be required to meet the demand in 2020 during a 50-year event. An alternate source of water supply is needed to augment withdrawals from Shipman Reservoir. There are three existing reservoirs within about 5 miles of Shipman. Shad Lake has an estimated capacity of 100 ac-ft (1980), and the 40-year drought yield given this storage volume is 0.06 mgd (Broeren et al., 1989). Full use of this lake could provide an adequate auxiliary supply. Two other lakes identified by the U.S. Army Corps of Engineers (1980) are Royal Lake No. 1 (estimated capacity 95 ac-ft) and an unnamed lake identified as Ilnoname #2042 (estimated capacity 95 ac-ft). These reservoirs could be used as emergency backup supplies. A potential reservoir site is identified by Dawes and Terstriep (1966a) on Coop Branch, a tributary of Macoupin Creek. The site could be used to construct a reservoir with storage capacity of 12,000 ac-ft having a 40-year drought yield of 4.8 mgd. This reservoir would be considerably larger than needed. Direct withdrawals from Coop Branch could provide an adequate supplementary supply if side-channel storage is created. The needed storage will vary depending on the type of pumping system installed. If an optimal pumping system is used, about

45 ac-ft of storage would be required. Ground-water wells in the area typically have such low yields that this source does not provide adequate water for municipal use. Water yielding deposits are scattered. The most likely source of ground water would be sand and gravel deposits associated with the Macoupin Creek Valley (Woller, 1976).

Under the present conditions the following alternatives are considered feasible:

1. Explore the possibility of obtaining the use of one or two of the nearby existing reservoirs.

2. Evaluate the possibility of creating sufficient side-channel storage to utilize flow in Coop Branch. Determine the appropriate pumping system to minimize required storage and cost.

3. Investigate the possibility of building a new in-channel impoundment.

System No.: 002
System Name: Sorento
County: Bond
Communities Served: Sorento
Estimated 1990 Service Population: 760

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
River/Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
Sorento Res.	NW1/4 S09	0.55	1990	96.2	13.3
	T06NR04W		2020	84.5	12.8
Direct pumping	NE1/4 S09	365 (approx.)			
(Shoal Creek)	T06N R04W				

The facilities to pump directly from Shoal Creek were not previously reported and were not noted or analyzed in previous reports. Sorento Reservoir is located on a tributary to Shoal Creek, Kaskaskia Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			89	90	90	90
Avg. annual, mgd	0.057	0.051	0.068	0.068	0.067	0.070
Supply Yield						
Sorento Reservoir only						
Y_{20}, *mgd*			0.060	0.060	0.060	0.060
Y_{50}, *mgd*			0.040	0.030	0.030	0.030
Shoal Creek - existing pumping system						
Y_{50}, *mgd*			1.4*			

*Yield from Shoal Creek using the Sorento Reservoir as a side-channel reservoir, adjusted for current pumping capacity from Shoal Creek of 350 gpm. An optimal variable-speed pumping system would produce higher yields.

Background Information

Sorento is not expected to have any dramatic increases in water demand. A slight drop in demand around 2010 will be a product of declining populations projected for the county as a whole. Reservoir sedimentation is projected to claim approximately 11.7 ac-ft of storage capacity between 1990 and 2020, or about 12% of the estimated 1990 storage capacity. Yields from the reservoir, determined on the basis of inflow from the natural drainage area of 0.55 sq mi, fall below demand for both the 20- and 50-year droughts. The yield values are shown in the table above and were first reported by Broeren et al. (1989). Since publication of that report it has been determined that Sorento also has developed facilities to pump water directly from Shoal Creek. The drainage area of Shoal Creek near Sorento is about 365 sq mi. As Sorento Reservoir is available for water storage, an estimation of the yield from Shoal Creek, with the reservoir used as though it were a side-channel reservoir, was made for a 50-year drought. The capacity of the reservoir in 2020, the highest projected demand of 0.07, and the present pumping system were used in the calculations to represent the most critical case. As noted in the table above, the yield during a 50-year drought is far in excess of demand. Therefore no additional sources are expected to be needed through 2020.

Mitigative Measures **- None needed**

System No.: 078
System Name: Springfield
County: Sangamon
Communities Served: Chatham
Grandview
Jerome
Leland Grove
Rochester
Sherman
Springfield
Estimated 1990 Service Population: 145,709

Water Supply Source(s)

River/Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Lake Springfield	SE1/4 S12 T15N R05W	265	1990	52,391	3993
			2020	49,106	3885
South Fork Sangamon River	NW1/ S20 T15N R04W	867 (approx.)			

Lake Springfield is an in-channel impoundment on Sugar Creek, Sangamon River Basin. Water is also withdrawn from the South Fork Sangamon River and discharged into Lake Springfield.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			146	148	149	150
Avg. annual, mgd	22.38	19.99	21.274	21.755	22.103	22.980
Supply Yield						
Lake Springfield only						
Y_{20}, *mgd*			41.59	41.29	40.70	40.11
Y_{50}, *mgd*			26.56	26.16	25.67	25.18

Background Information

Water demand for the Springfield system is expected to increase slowly over time with increasing population growth. Lake Springfield is the primary water supply source for the system. In addition to the public water supply demand listed in the table, water is withdrawn from Lake Springfield by the city power plant for its operations. Water withdrawals for power generation range from 3.5 to 5.0 mgd. Most of the water withdrawn for the power plant is being returned to the lake now. The higher temperature of the recycled water will increase evaporation. Yields from Lake Springfield are expected to slowly decrease over time as sediment accumulates. However, compared to many in-channel reservoirs the rate of reservoir capacity loss is rather low. Water is routinely withdrawn from the South Fork Sangamon at the Horse Creek Pumping Station to maintain the lake level. The calculated drought yields for Lake Springfield alone are given in the table above. The yields are greater than the predicted average annual demand. High water usage during an extreme drought could create shortages around 2000 if no water use restrictions are imposed and only yields from the lake are considered. However, with auxiliary pumping from the South Fork Sangamon, the water supply may be adequate to meet even high drought-related demand.

Several studies of Springfield's water use and water supply yields have been conducted. The predicted reservoir yield and water availability from the South Fork Sangamon vary depending on the streamflow data used to make the analysis and the method of analysis. One factor not considered in this report is the recreational use of the lake. An established lake level to provide for recreational use during droughts would reduce storage allocated for public water supply, and thus projected yields would be less.

A project to construct another in-channel reservoir, Hunter Lake, is under investigation. The reservoir could be in service for water supply by the year 2000. Estimated yields from mis reservoir would be more than adequate to meet Springfield's needs well into the future. If the lake is also to serve recreational purposes, anticipated yields should be determined on the basis of the volume of lake storage reserved for water supply. Another consideration to be accounted for in the design and operation of Hunter Lake is minimum flow releases which may be required for new in-channel reservoirs to meet instream flow needs.

Mitigative Measures

With the total water use less than 30 mgd in 2020 during a 50-year drought and the yield of Lake Springfield and Horse Creek Pumping Station more man 40 mgd, other demands need to be identified for the construction of a new reservoir. Such needs may include recreational use of Lake Springfield, resulting in the desirability of keeping a higher minimum lake level; recycling of cooling water from the power plant, resulting in increased evaporation; and provision of low-flow releases from Lake Springfield. An integrated system study is needed not only to develop configurations of optimal operating systems to meet various desired low and high lake levels and demands, but also to identify the most economic operation of such systems.

System No.: 053
System Name: Staunton
County: Macoupin
Communities Served: R.R. 1 Water Assoc.
Staunton
Williamson
Estimated 1990 Service Population: 5,717

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Staunton Res.	NE1/4S20	3.68	1990	1008.2	87.3
	T07N R06W		2020	909.1	84.4

Staunton Reservoir is an in-channel impoundment on East Creek, Cahokia Creek Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			90	92	95	97
Avg. annual, mgd	0.528	0.465	0.515	0.522	0.540	0.568
Supply Yield						
Y_{20}, *mgd*			0.61	0.60	0.57	0.56
Y_{50}, *mgd*			0.35	0.35	0.34	0.34

Background Information

The service area population is expected to increase gradually with time; this, in combination with a moderate increase in per capita water use, will result in rising water demand over time. Staunton public water supply relies on Staunton Reservoir as its sole source of supply. The reservoir drought yields are projected to slowly decrease as water storage capacity is lost as a result of sedimentation. The 50-year drought yield is less than projected demand from 1990 onward, and by 2020 it will be only about 60% of the projected average annual demand. During the 1988-1989 drought the reservoir level reached 5 feet below normal pool elevation. Voluntary water restrictions on lawn watering and car washing reduced water use, as reflected in reported average annual demand for 1989. In 1986-1987 a study was made to evaluate the cost of dredging versus the cost of raising the dam level. Currently, the feasibility of raising the dam 9 feet is being studied.

Mitigative Measures

The estimated demand in 2020 is 0.568 mgd. To meet this demand during a 50-year drought, the system will need water reserves in excess of 2100 ac-ft at the present reservoir site. The projected 2020 storage capacity of the existing reservoir is about 900 ac-ft; thus approximately 1200 ac-ft of additional storage will be needed in 2020. The topography of the site, the feasibility of raising the dam height, and sediment management are all factors which will determine whether sufficient storage can be achieved at the Staunton Reservoir site.

Other existing reservoirs in the vicinity are either inadequate to supplement Staunton's supply or already committed to other water supplies. Dawes and Terstriep (1966a) identify four potential reservoir sites within about a 5-mile radius of Staunton. One site on the upper portion of West Fork Cahokia Creek (SW1/4 SW1/4 S3 T7N R7W) is described as having the potential for development of a good 1,920 ac-ft reservoir with a 40-yr drought yield of 0.6 mgd at moderately low cost. This site has the greatest possibility for development and could possibly serve to augment water supplies for the Mt. Olive and Gillespie public water supply systems, which may also experience shortages in the next 30 years. A variety of problems may preclude reservoir development at any of the sites described by Dawes and Terstriep. These problems include possible subsidence and water quality problems created by pollution of the streambeds by mining operations in the area. Water quality problems in Cahokia Creek and some of its tributaries are primarily characterized by heavy contamination of the streambeds with iron oxide. Illinois water quality standards for use of surface water for public supply set a maximum total iron concentration of 1000 µg/1 (micrograms per liter). In Water Year 1988, seven of nine water samples taken at the USGS water quality station on Cahokia Creek at Edwardsville {drainage area 212 sq mi, downstream of Staunton) showed total iron concentrations in excess of the 1000 µg/1 maximum allowable for use by public water supplies (Stahl et al., 1989). Water quality problems may preclude direct withdrawals from Cahokia Creek near Staunton (drainage area 71 sq mi) as well. Ground-water sources in Macoupin County are not plentiful.. Water-yielding sand and gravel deposits may be present in the Cahokia Creek valley (Woller, 1976). However, considerable test drilling may be necessary to locate a part of the aquifer suitable for furnishing moderate quantities of water. The low yield of ground-water wells has led other communities in the county to develop surface water supplies.

Under the present conditions the following alternatives are considered feasible:

1. Conduct a detailed evaluation of the structural and hydrological feasibility of augmenting the water storage by raising the Staunton Reservoir dam and controlling sedimentation.

2. Investigate the possibility of a joint venture with other public water supply systems to develop a new in-channel reservoir.

3. Explore development of a ground-water source for water supply.

System No.: 060
System Name: Waterloo
County: Monroe
Communities Served: Waterloo
Estimated 1990 Service Population: 5,480

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Korte Lake	SE1/4 S35	0.53	1990	560.8	33.7
	T02SR10W		2020	537.4	33.2
Schorr Lake	NW1/4 S36	0.17	1990	49.0	10.2
	T02SR10W		2020	40.8	9.6
Old Lake	SE1/4S35	0.02	1990	62.0	7.0
	T02SR10W		2020	62.0	7.0
Direct					
Fountain Creek	SE1/4 S35	16.8			
	T02N R10W				

Schorr and Old Lakes are on the same Fountain Creek tributary; Old Lake is gravity-fed from Schorr Lake. Old Lake's storage capacity is not expected to change appreciably as sediment is intercepted by Schorr Lake. Korte Lake is on another nearby Fountain Creek tributary. Water from Fountain Creek can be pumped to both Schorr and Korte Lakes. Fountain Creek is a tributary of the Mississippi River.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			92	100	104	106
Avg. annual, mgd	0.495	0.486	0.504	0.579	0.621	0.663
Supply Yield						
Y_{20}, *mgd*			0.56	0.56	0.55	0.54
Y_{50}, *mgd*			0.49	0.48	0.48	0.47

Yields shown were calculated on the assumption mat all three reservoirs function as side-channel reservoirs storing water pumped from Fountain Creek. They are not adjusted for the present pumping system, but reflect an optimum pumping system. Yields decrease with time as natural runoff carries sediment into the reservoirs.

Background Information

A combination of increasing service population and slowly increasing per capita water use is expected to create a steady increase in water demand over time. The raw water supply system for Waterloo has several unique features which preclude a straightforward analysis of yields. Factors such as the flow rate between Schorr and Old Lakes, which may vary with inflow to Schorr Lake, and the pumping capacity from Fountain Creek will influence yields. Without pumping from Fountain Creek, me combined yields from Schorr and Korte Lakes are projected to be 0.19 mgd during a 20-yr drought and 0.16 mgd for a 50-yr drought in 2020. The yield values shown above demonstrate drought yields if all three reservoirs functioned as side-channel storage facilities for water pumped from Fountain Creek. Adjusting the yield values for the present pumping system would reduce them by more than one-half, but natural runoff to the lakes tends to compensate. During the 1988 drought it did become necessary to impose mandatory water restrictions. On the basis of the tabulated values, water supplies could be insufficient to meet demand in 2000 for a 20-year drought event and could have been insufficient in 1990 for a 50-year drought. The city is considering plans to dredge all three lakes and to purchase land for another impoundment sometime in the next ten years.

Mitigative Measures

The interdependent operation of the reservoirs in conjunction with pumping from Fountain Creek requires a more in-depth analysis to provide an accurate estimate of drought yields. A detailed evaluation of the system is recommended prior to initiation of plans to augment the current supply. The projected combined sediment accumulation between 1990 and 2020 is only about 32 ac-ft. Dredging or venting of sediment may not provide sufficient additional storage to maintain drought yields adequate to meet demands. Raising the spillway at one or more of me existing reservoir sites to create more storage for water pumped from Fountain Creek, as well as installation of a multistage pumping system, could increase yields sufficiently to meet demands through 2020. There are no other existing reservoirs within a five-mile radius which could provide adequate water to augment the existing system. There are two potential reservoir sites identified by Dawes and Terstriep (1966a) near Waterloo. One site on Kopp Creek (drainage area 3.2 sq mi) has an estimated 40-year drought yield of 0.9 mgd; the other site on Rockhouse Creek (drainage area 8.7 sq mi) has a 40-year drought yield of 2.2 mgd. No extraordinary problems with reservoir development are anticipated at either site. Ground-water sources are not plentiful. Sand and gravel deposits are generally absent in the vicinity of Waterloo (Selkregg et al., 1957). Bedrock aquifers are a possible source of supply but generally are thought to be adequate only for farm or domestic supplies.

Under the present conditions the following alternatives are considered feasible:

1. Perform a detailed evaluation of the water supply system performance during droughts to determine needed auxiliary supply requirements. In particular, evaluate the benefit of dredging the existing lakes.

2. Investigate the possibility of increasing the storage capacity of the existing lakes for increasing yields. Given the fairly low sedimentation rate of the lakes, they could function quite well as side-channel reservoirs (with some increase in storage capacity) to store water pumped from Fountain Creek. An adequate pumping system would be needed.

3. Identify a site for a new impoundment either to provide additional storage for water from Fountain Creek or to operate as an in-channel reservoir.

System No.: 087
System Name: Wayne City
County: Wayne
Communities Served: Keenes
Sims
Wayne City
Estimated 1990 Service Population: 1,602

Water Supply Source(s)

River/Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
Skillet Fork low channel dam	SW1/4 S07 T02S R06E	464			
Side-channel reservoir	SE1/4 S12 T02S R05E		1990	34.7	11

The low channel dam, approximately 4 ft high, across the Skillet Fork creates some minor storage. Its primary function is to keep the 600 gpm pump intakes submerged. Water is pumped from the Skillet Fork to the side-channel reservoir. The Skillet Fork is a tributary to the Little Wabash River.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			123	125	125	126
Avg. annual, mgd	0.167	0.167	0.197	0.205	0.208	0.219

Supply Yield	*Pumping System*	
Side channel reservoir only	*Optimal*	*Existing*
Y_{20}, *mgd*	0.201	0.121
Y_{50}, *mgd*	0.128	0.076

Background Information

On the basis of the Illinois Bureau of the Budget county population projections, the Wayne City service area population would be expected to increase as shown by the figures in the table. However, over the last few years an estimated 150 to 200 people have left the service area. Two hundred people represent about 12% of the estimated 1990 service population and, at the rate of 125 gpd per person, 0.025 mgd. Water demand has declined as shown by the 1988 and 1989 reported values. Water demand was projected to increase on the basis of the population increase and a modest increase in per capita water use. Given the loss of customers, the water use projections could be reduced about 0.025 mgd. However, the estimated adjusted yields during both the 20- and 50-year droughts are still less than the reduced demand. The supply yield figures given in the table were determined on the basis of the capacity of the side-channel reservoir only. Some storage is created by the low channel dam. This storage is roughly estimated as less than 50 ac-ft on the basis of limited available data.

Mitigative Measures

Future water demand may be less than shown because of the decline in the service area population. The decrease in water use accompanying the change in population is about 0.025 mgd. The decrease in water use has a significant effect on the amount of storage needed to meet demand. The Skillet Fork has adequate flows to serve the Wayne City public water supply if sufficient water storage is available to tide over the city low streamflow periods. The pumping system employed to deliver water from the Skillet Fork to side-channel storage will affect the yield. The present fixed-speed pump cannot pump water over the entire range of flows in the Skillet Fork. The volume of additional storage required will depend on the pumping system used as well as demand. Given the present pumping system, about 190 ac-ft of storage may be needed by 2020 if demand increases as indicated in the table. If a pumping system is installed with two adjustable speed pumps, the needed storage decreases to about 105 ac-ft because of the more efficient pumping system. If demand remains lower than projected, the storage requirements with the two-pump system could be only about 80 ac-ft. A detailed evaluation of the appropriate pumping system made on the basis of actual flows in the Skillet Fork, as well as careful examination of future population trends, are needed to determine additional storage requirements. There are no existing reservoirs within 5 miles of Wayne City. A potential reservoir site (Dawes and Terstriep, 1966a) on Crooked Creek about 4.5 miles north of Wayne City has an estimated 40-year drought yield of 1.6 mgd. The reservoir is larger than needed to supply Wayne City, and costs are expected to be somewhat higher than average. Ground-water resources are scarce in the vicinity of Wayne City (Pryor, 1956). Sand and gravel deposits are generally absent in the area except for some scattered deposits associated with the Skillet Fork Valley. Bedrock in the area is generally not water-yielding. There are no other major public water supplies within 5 miles of Wayne City.

Under the present conditions the following alternatives are considered feasible:

1. Using available gaging station data at the Skillet Fork near Wayne City, determine the appropriate pumping system to optimize water supply yields and reduce storage requirements. An evaluation of future water demand is an essential aspect of this investigation. Provide additional side-channel storage as indicated by the system study.

2. Explore the possibility of developing wells along the Skillet Fork.

3. Investigate the possibility of an in-channel reservoir on a nearby tributary to the Skillet Fork.

System No.: 020
System Name: West Salem
County: Edwards
Communities Served: West Salem
Estimated 1990 Service Population: 1,301

Water Supply Source(s)

				Estimated	
		Dr. Area		*CAP*	*SA*
Reservoir	*Location*	*(sq mi)*	*Year*	*(ac-ft)*	*(ac)*
New Reservoir	SW1/4S07	0.74	1990	167.2*	23.6*
	T01NR14W		2020	147.2*	22.7*
Old Reservoir	SW1/4 S07	1.20	1990	18.8	2.4
	T01N R14W		2020	2.0	1.4

The New Reservoir is located just upstream of the Old Reservoir on a branch of Crooked Creek, tributary to Bonpas Creek, Wabash Basin.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			91	94	97	100
Avg. annual, mgd	0.109	0.109	0.118	0.130	0.141	0.154
Supply Yield						
Y_{20}, mgd			0.12*	0.11*	0.11*	0.11*
Y_{50}, mgd			0.09*	0.08*	0.08*	0.08*

* Revised to reflect increased storage created by raising spillway elevation 2 ft at New Reservoir in 1989.

Background Information

The spillway elevation of the New Reservoir was raised approximately 2 feet in 1989. The estimated increase in storage capacity is approximately 45 ac-ft. Thus, the revised values for reservoir capacity and yields noted above differ from those in prior reports. The storage capacities of the two reservoirs were estimated on the basis of volumes reported by the city water department which apparently were determined from a survey performed by or for the city in 1968. The reported 1968 capacities used in the projections are 138.0 and 36.8 ac-ft for the New and Old Reservoirs, respectively. Various sources report the capacity of me Salem New Reservoir to be as much as 270 ac-ft.

Forecasted moderate population growth as well as moderate increases in per capita water use indicate a gradual increase in water demand with time. The combined estimated yields from the New and Old Reservoirs in the event of a 20-yr or 50-yr drought are given in me table above. By the year 2000 projected yields during a 20-yr drought are less than projected water demand, and in the event of a 50-yr drought yields are expected to be less man demand from 1990. By 2020, the 50-yr drought yield is only about 52% of projected demand. Demand during drought periods may be 20 to 30% higher man the annual average. Reservoir sedimentation is a significant problem for both reservoirs. The New Reservoir is expected to lose 20 ac-ft of storage in the 30-year period from 1990 to 2020. Projected sediment accumulations in the Old Reservoir are expected to result in declining yields, with a yield of practically zero during a severe drought by 2020. Reported billed water was 98% of reported raw water withdrawals in 1989 and 99% of raw water withdrawals in 1990.

Mitigative Measures

The 1989 increase in spillway elevation provided much-needed storage, reducing the risk of water supply shortages and reducing the difference between expected future demand and supply yields. However, there is still the possibility that water shortages could occur during a severe drought, and to reduce this risk some additional measures may be needed. Sediment could be removed from the existing reservoirs by dredging or venting. However, even if all the sediment is removed and further accumulation circumvented to maintain the 1968 capacities, the yield during a 50-yr drought may still be less than demand. Given the broad range of reported capacities for the New Reservoir, the first course of action would be to perform a survey of the reservoirs for an accurate assessment of storage volume and yield. If the storage capacity of the reservoir(s) is greater than the current estimate, the feasibility of augmenting storage at the existing site with a side-channel reservoir could be explored.

Water-bearing sand and gravel deposits associated with pre-glacial and me present-day valleys of Bonpas Creek may be present near West Salem (Woller and Sanderson, 1978). Well yield may be in the range of 25 to 100 gpm. Currently three other public water supplies in Edwards County use ground water from shallow sand and gravel aquifers. If an aquifer can be found near West Salem, development of mis back-up supply is likely to be the least expensive and most desirable alternative. Direct water withdrawals from Bonpas Creek (at approximate drainage area 150 sq mi), which lies east of West Salem, in conjunction with additional storage provided with a side-channel reservoir, is another possible backup source of supply. Another in-channel reservoir could be constructed to provide additional water. A potential reservoir site on Buck Creek (drainage area 2.0 sq mi) south of West Salem has been identified as a good site which should result in a moderately low-cost project (Dawes and Terstriep, 1966a). The in-channel reservoirs described would provide more man enough water. Within approximately a five-mile radius of West Salem mere are no other existing reservoirs that have sufficient drought yields to augment West Salem's supply or omer public water supplies to which West Salem's system can be cross-connected.

Under the present conditions the following alternatives are considered feasible:

1. Locate and develop ground-water sources.

2. Design and construct a side-channel reservoir and withdraw water from Bonpas Creek.

3. Design and construct a new in-channel reservoir.

System No.: 032
System Name: White Hall
County: Greene
Communities Served: White Hall
Estimated 1990 Service Population: 2,750

Water Supply Source(s)

Reservoir	*Location*	*Dr. Area (sq mi)*	*Year*	*Estimated CAP (ac-ft)*	*Estimated SA (ac)*
White Hall Reservoir	NW1/4 S36 T12N R12W	0.97	1990	**576.2***	**38***
			2020	**552.2***	**38***

White Hall Reservoir is an in-channel impoundment on a tributary of Wolf Run Creek, which drains to Apple Creek and then to the Illinois River.

Projected Water Use and Supply Yields

	Reported		*Estimated*			
Demand	*1988*	*1989*	*1990*	*2000*	*2010*	*2020*
Per capita, gpcd			85	90	93	95
Avg. annual, mgd	0.219	0.223	0.234	0.234	0.233	0.241
Supply Yield						
Y_{20}, mgd			**0.24***	**0.24***	**0.24***	**0.23***
Y_{50}, mgd			**0.09***	**0.09***	**0.09***	**0.09***

* Revised to account for a spillway elevation raise in 1954 which previous investigations did not disclose.

Background Information

A slight decline in White Hall's service population is forecasted between 1990 and 2010 on the basis of Illinois Bureau of the Budget population projections which show a county-wide decline in population. Allowing for a modest increase in per capita water use, demand is projected to remain fairly stable through 2020. White Hall Reservoir is the sole source of water supply. Information on storage capacity and yields given in prior reports (Broeren et al., 1989; Singh and Durgunoglu, 1988, 1990; Singh et al., 1988) did not include an increase in storage capacity created by raising the spillway and dam in 1954. The reservoir storage capacity and drought yields given in the table above have been revised to account for the additional 200 ac-ft increase in storage effective in 1955. However, the revised yield figures show that the reservoir will not provide sufficient water storage to meet demand in 2020 for the 20-year drought, and yield calculated for a 50-year drought is less than demand from 1990 onward. The rank of this system changes relative to other systems included in this report, but the system remains at risk.

During the 1988-1989 drought, White Hall Reservoir was drawn down to a critical level. Water use restrictions were enforced from July 1988 through May 1990. At mat time the reservoir had risen to 1.5 feet below normal pool elevation. The restrictions reduced individual water use; however, high turbidity in the lake water required frequent flushing of filters and hence use of finished water in the plant. Raw water withdrawals averaged 0.22 mgd in 1988-

1989, which is slightly less than reported water use in 1986 of 0.244 mgd. The city has initialed several plans to augment their water supply.

Mitigative Measures

White Hall Reservoir's original capacity plus the 1954 addition of 200 ac-ft is 659 ac-ft. Even if all the accumulated sediment were removed to restore the full water storage volume, the 50-year drought yield would still fall short of demand by 2020. The reservoir is large compared to the watershed area of 0.97 sq mi, as indicated by the capacity inflow ratio of 1.32. The inverse of this ratio, 0.75, is the number of times per year the reservoir could be filled given the long-term average runoff from the watershed. A value less than 1 indicates that recovery from a large drawdown will be slow as evidenced by the reservoir performance in 1988-1990. Alternative sources are needed to augment the present supply.

The city has initiated plans to install a pipeline to convey pumped water from Apple Creek, which lies about 3.5 miles south of White Hall Reservoir. The drainage area of Apple Creek at a point just south of White Hall is on the order of 300 sq mi. The flow in Apple Creek is adequate to augment White Hall's water supply, and with some storage, Apple Creek could meet White Hall's entire demand through 2020. The city is also seeking funding to construct a transmission line from the Illinois River which is around 12 miles west of the city. Flows in the Illinois River are more than adequate to meet White Hall's water demand; however, development costs may be higher than for other options. Other surface water sources near White Hall are Wolf Run Creek and Seminary Creek, with drainage areas under 20 sq mi. Some additional storage facilities would likely be required for either of these sources to develop a supply adequate to augment the current supply.

Ground-water availability is variable in Greene County. Some shallow sand and gravel deposits have been developed for public water supplies by communities in the county. However, yields from wells in the shallow aquifers have a history of significant reduction during droughts. There is some potential for development of a municipal supply from deposits associated with the Apple Creek valley or bedrock aquifers in the Burlington-Keokuk Limestone which is present in the vicinity of White Hall.

Under the present conditions the following alternatives are considered feasible:

1. Continue with plans to construct a pipeline between Apple Creek and White Hall Reservoir to convey water pumped from Apple Creek.

2. Explore development of ground water sources.

3. Construct a transmission line from the Illinois River possibly as a county-wide project to provide a backup supply for multiple communities.

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