

Neosho Basin High Priority Issue

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Issue

Evaluation of surface water supply, demand, management and conservation is needed to improve reservoir sustainability and provide adequate public water supply to meet long-term needs in the Neosho basin.

Increasing population and development in portions of the Neosho basin, along with aging reservoirs and public water supply infrastructure, indicate a need to evaluate the long-term water system capacity to meet demands in the basin. The viability of the river to support aquatic life and meet minimum desired stream flows needs to be maintained, while balancing the availability of water for public water supply.

In 2007, the Kansas Water Office (KWO) initiated an analysis of water supply and demand in several eastern Kansas river basins. The analysis utilized historic climate and flow and current census information to predict the total water supply and demand in the Neosho basin over time. The preliminary finding for the basins is that in those counties primarily served by the Neosho River and tributaries, demand could exceed supply during a two percent probability drought by the year 2012. This analysis did not include the far southeastern counties in the basin in which ground water and the Spring River are the primary water supplies. See the [Ozark Aquifer](#) issue for information on that area.

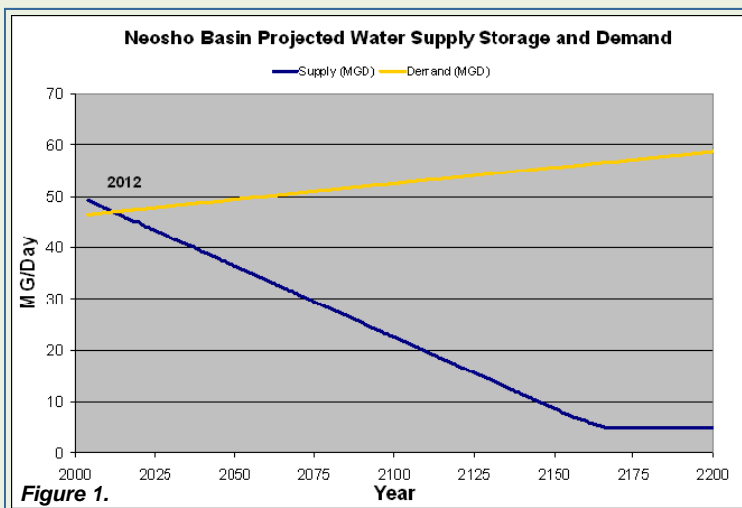


Figure 1.

Of the four major southeastern Kansas river basins evaluated with this method, the Neosho basin has predicted water supply shortfalls the soonest. Enhanced modeling is underway to better understand where shortages could occur in specific reaches and to develop a means of evaluating alternatives and scenarios for water

management, conservation and development that can be used for future planning and operations of the system.

When this section of the Neosho Basin Plan was adopted in January 2009, the following recommendations were made for this basin priority issue (BPI):

- Continue the calibration of the OASIS (Operational Analysis and Simulation of Integrated Systems) basin model with location specific supply and demand information.
- Identify options for supply and demand management: reservoir pool raise, pool reallocation, dredging, off-channel storage, new supplies, modify reservoir operations, conservation measures and reverse levee operations.
- Refine model to reflect possible outcomes of identified options and share results.
- Implement the most beneficial and cost-effective options.
- Begin incorporation of water demand management into utility operating plans. Demand management should also include education of and interaction with the development community and include existing local authorities.

Due to the urgency of water supply conditions in the Neosho basin, it was selected as the highest priority to address in the Reservoir Roadmap (RRM), a document requested by the Kansas legislature to evaluate and provide recommendations for reservoir sedimentation issues. Since 2009, extensive work to address the above recommendations has been accomplished. This update provides additional information related to the recommendations based on evaluation using the OASIS model.

RECOMMENDATION: CONTINUE THE CALIBRATION OF THE OASIS BASIN MODEL WITH LOCATION SPECIFIC SUPPLY AND DEMAND INFORMATION.

Water Supply and Demand

Water supply in the basin is provided primarily by three federal reservoirs, Marion, Council Grove and John Redmond, along with numerous multipurpose or city owned small lakes, and natural stream flows. The federal reservoirs were constructed by the U.S. Army Corps of Engineers (Corps) and are authorized for water supply purposes. The State of Kansas through the KWO has purchased storage in each of the reservoirs from the Corps which is then available to contract with municipal and industrial users in the basin.

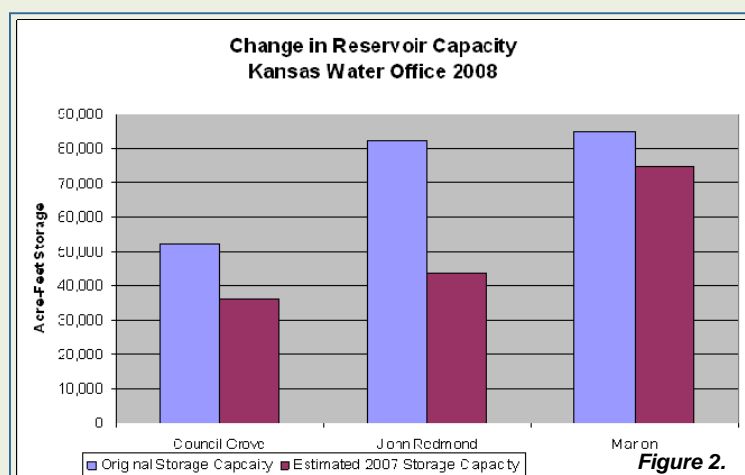
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Marion Reservoir is a 6,200 acre reservoir used as a source of water supply for the cities of Hillsboro, Marion and Peabody; and the Cottonwood and Neosho River Basins Water Assurance District #3 (CNRBWAD #3). The largest towns in the watershed and their population include Canton, 850; Lehigh, 211 and Durham 111. A small percentage of north Hillsboro (population 3,000) is also in the watershed, but the majority of the drainage from the town is south of the watershed. Marion Reservoir has an approximate capacity of 86,700 acre-feet and is losing capacity at an average rate of 250 acre-feet per year due to sedimentation. Outflow is controlled by three 40-foot by 40-foot tainter gates and one 24-inch gate valve.

Council Grove Reservoir is a 2,700 acre reservoir used as a water supply source for the cities of Emporia and Council Grove; and the CNRBWAD #3. Council Grove Reservoir has an approximate capacity of 47,000 acre-feet and is losing capacity at an average rate of 170 acre-feet per year due to sedimentation. Outflow is controlled by two 17-foot by 7.5-foot tainter gates and one 24-inch gate valve.

John Redmond Reservoir is an 8,400 acre reservoir used as a water supply source for the Wolf Creek Nuclear Generating Station and the CNRBWAD #3. John Redmond Reservoir has an approximate capacity of 53,500 acre-feet and is losing capacity at an average rate of 650 acre-feet per year due to sedimentation. Outflow is controlled by 14 40-foot by 35-foot tainter gates, two 24-inch gate valves, and one 30-inch gate valve.



Two city-owned reservoirs also provide water supply in the Neosho basin. These reservoirs do not have the storage capacity to serve multiple users but are important as a more localized water supply. Council Grove City Lake is a 434 acre lake used as a source of water

supply for the City of Council Grove. Council Grove City Lake has an approximate capacity of 7,200 acre-feet and is losing capacity at an average rate of 20 acre-feet per year due to sedimentation. Outflow is controlled by the spillway elevation of 1,344 feet and several valves at lower elevations.

Parsons City Lake is a 980 acre lake used as water supply source for the City of Parsons. Parsons City Lake has an approximate capacity of 8,300 acre-feet and is losing capacity at an average rate of 25 acre-feet per year. Outflow is controlled by the spillway elevation at 925 feet and one 12-inch valve.

Wolf Creek Lake (Coffey County State Lake) supplies cooling water for the Wolf Creek Nuclear Generating Station. The lake is approximately 5,200 acres and has an approximate capacity of 116,000 acre-feet at its spillway elevation of 1,088 feet. Wolf Creek operations state that the plant will have to shut down if the lake elevation drops below 1,075 feet. Wolf Creek maintains a lake elevation of approximately 1,088 feet by pumping from their water right on the Neosho River when flows are sufficient and from their water marketing contract from John Redmond Reservoir when Neosho River flows are not sufficient to use their water right.

Bathymetric Surveys

Bathymetric surveys of each of the public water supply lakes in the Neosho basin have been completed by the Kansas Biological Survey (KBS). Each survey was performed using an acoustic echo-sounding apparatus linked to a global positioning system. The bathymetric surveys were geo-referenced and compared with original pre-impoundment maps to estimate sediment accumulation. In addition, sediment samples were extracted and analyzed at each reservoir. Results of the surveys for the three federal reservoirs in the basin are summarized in Table 1. Figure 2 graphically shows capacity changes

Comparison of the 2008 bathymetric survey data for Parsons Lake to a 1957 pre-impoundment map suggests that while the surface area of the reservoir has not been markedly reduced in the 51-year period. The capacity of the reservoir at the 927 foot elevation pool has been reduced from 10,916 acre-feet to 9,183 acre-feet.

Marketing and Assurance

Reservoirs are used, in part, to provide dependable water supplies in streams with highly variable flow. The 1958 Federal Water Supply Act made storage in federal

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Reservoir	Top of Conservation Pool (Feet)	Original Storage Capacity (Acre-feet)	Capacity at most recent survey (Acre-feet)	Estimated Current Capacity (Acre-feet)	Design Sedimentation Rate (Acre-feet/Year)	Actual Sedimentation Rate (Acre-feet/Year)	Loss of Capacity to Date
Council Grove	1,274.0	54,832 (1963)	47,093 (2008)	46,935	206	172	14%
John Redmond	1,039.0	82,230 (1963)	53,927 (2007)	51,966	404	643	37%
Marion	1,350.5	96,757 (1967)	86,711 (2008)	86,485	94	245	11%

Table 1. Sedimentation estimates for federal reservoirs in the Neosho basin.

reservoirs available to local governments if the local entities agreed to repay the cost of construction, operation and maintenance of the water supply storage. Through purchase of water supply storage in each of the federal reservoirs, all three reservoirs support both the Water Marketing and the Water Assurance Programs.

In 1985, through a Memorandum of Agreement between the State of Kansas and the U.S. Army Corps of Engineers (Corps), water quality storage in all three federal reservoirs in the basin was reallocated to water supply storage and purchased by the state at the original cost of storage. The state purchased the maximum amount made available in the reallocation. In exchange for the significant reduction in cost, the state agreed to obtain water reservation rights for water quality storage and to protect water quality releases from diversion by water right holders. In addition, the state developed the Water Assurance Program to operate the reservoirs as a coordinated system, maximizing use of the water. A Water Assurance District was formed in 1993 by the municipal and industrial water rights holders on the Cottonwood and Neosho Rivers. The Water Assurance District has purchased a portion of the state-owned storage in all three reservoirs and repays the state's capital cost investment along with annual operation and main-

tenance costs. Operations agreements under the Water Assurance Program allow the municipal and industrial water right holders in the Neosho basin to own storage that is released during dry periods to support their water rights.

Municipal and Industrial Demand

Water demand associated with population projections is based on municipal water use as gallons per capita day usage (gpcd) reported to the Kansas Department of Agriculture-Division of Water Resources (DWR) for 2000 through 2004 by suppliers in the Neosho basin. In the 2007 evaluation, to develop the projected water use from industry, commerce, agriculture, and recreation, all non-municipal surface water points of diversion within five miles of the main stem of each basin were selected. Water demand by county in the basin is displayed below in Figure 3.

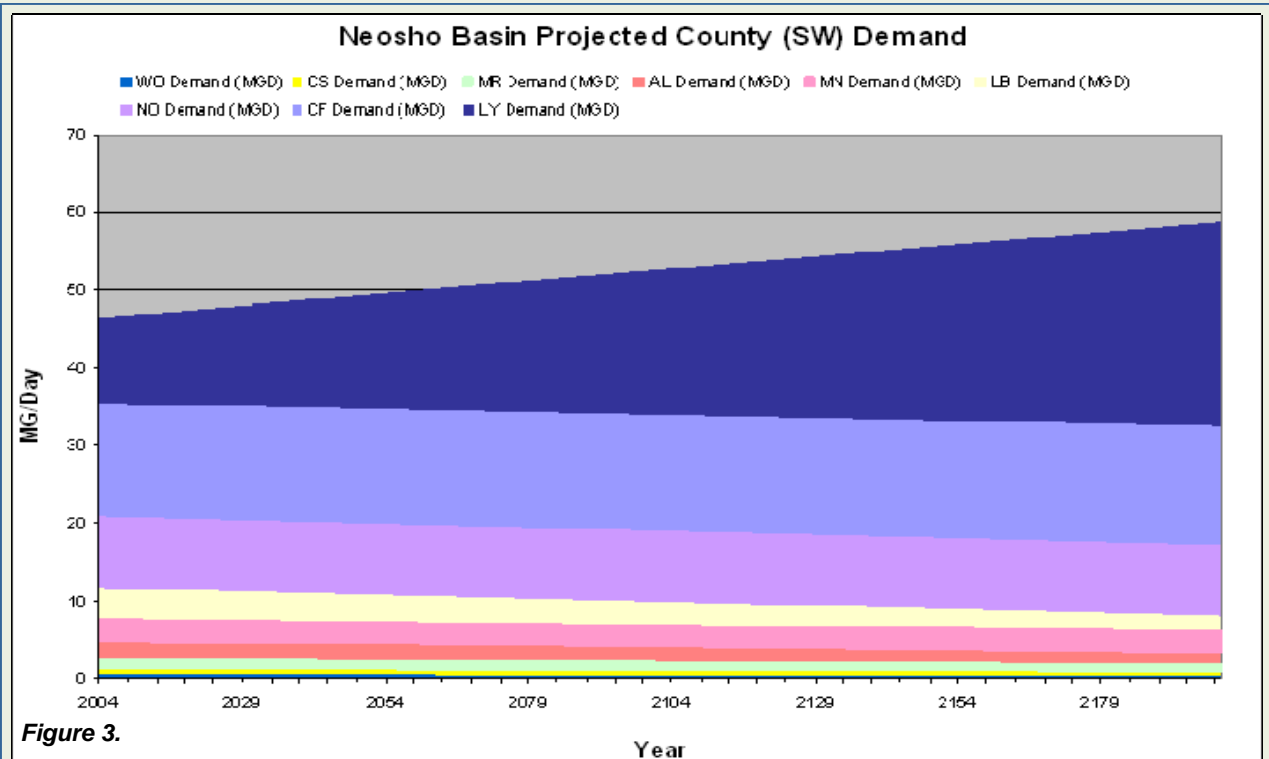


Figure 3.

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The surface water demand increase on the Neosho River corridor is primarily associated with the anticipated demand increase of Lyon County, specifically the industrial sector growth seen in Emporia in the past 12 to 15 years. Also considered is future demand by the Wolf Creek Nuclear Power Generating Plant. Although a significant increase in demand was demonstrated in Neosho County, specifically in the recreational sector in the last 12 -15 years, growth was limited to current levels. There is likely little to no desirable land remaining near the main stem in Neosho County that has not already been developed for recreational use. Crawford and Cherokee counties were excluded from the future demand projections because of the ground water supplies and the supply from Spring River available to them.

Location Specific Demand

Nearly all the growth and associated water demand in the Neosho basin is associated with the expansion of the Emporia area. In the southern part of the Neosho basin, interest in expansion of the old Army Ammunition Plant might add demand in that area. Depending on the results of location specific modeling, communities may need to consider water demand of future industries based on the projected supply.

A conclusion of the 2007 assessment was that a more complex model is needed to further refine projections and situations where projected demand may exceed supply on a more local scale, temporally and spatially, within each watershed. The KWO selected the OASIS model to analyze water supply and demand in greater detail. The OASIS model has the ability to simulate the interaction of multiple reservoirs and rivers in a system; simulate system management issues; identify areas of concern in a system; and evaluate alternative improvements to the system. Minimum desirable stream (mds) flows for aquatic and wildlife support are accounted for in the model. To assist with developing the model, KWO staff worked directly with water supply utilities, industries, other water users, and the Neosho Basin Advisory Committee, to obtain detailed information on expected water demand in the future.

Input to the OASIS model includes historic climatic and hydrologic data covering the period between 1950 to 2007. Also included, among other inputs, are sedimentation rates derived from bathymetric surveys. The model is calibrated using these measured inputs. The model can then be used to simulate how the reservoirs and rivers would react in response to changing demands for water through time. Other variables include construction

of new reservoirs, sedimentation effects, and management of the entire river-reservoir system. Reservoir and stream water levels that result from the various simulations are an important indicator of water supply reliability. The discussion below summarizes model results.

Water supply reliability can be determined by analyzing reservoir elevations and/or storage capacities as well as stream flows at United States Geological Survey (USGS) gages. Municipalities typically use reservoir information as a major component of their conservation plans to trigger drought watches, warnings and emergencies. Another way to determine water supply reliability is to estimate the potential for water supply shortages for an individual user or group of users during a drought period.

Analysis of reservoir elevations is also important for in-lake recreation. As elevation decreases, boat ramps become unusable and structures normally covered with water become boat hazards. Figures 4-6 (pages 4-5) illustrate the percentage of time during the OASIS model drought simulation that each reservoir exceeds a given elevation.

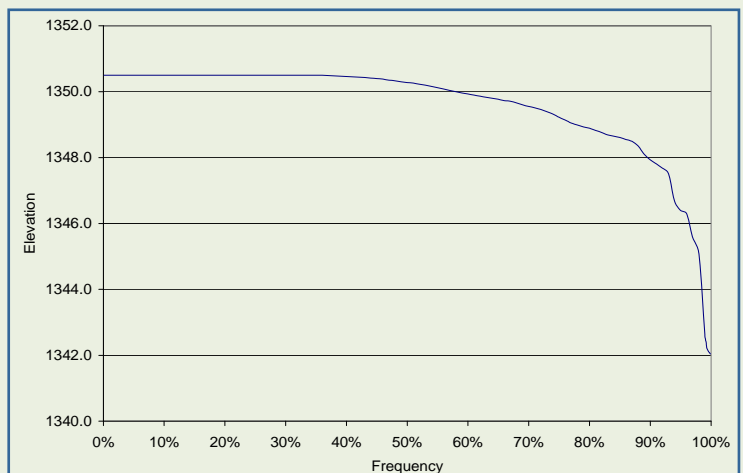


Figure 4. Marion Reservoir Elevation Frequency.

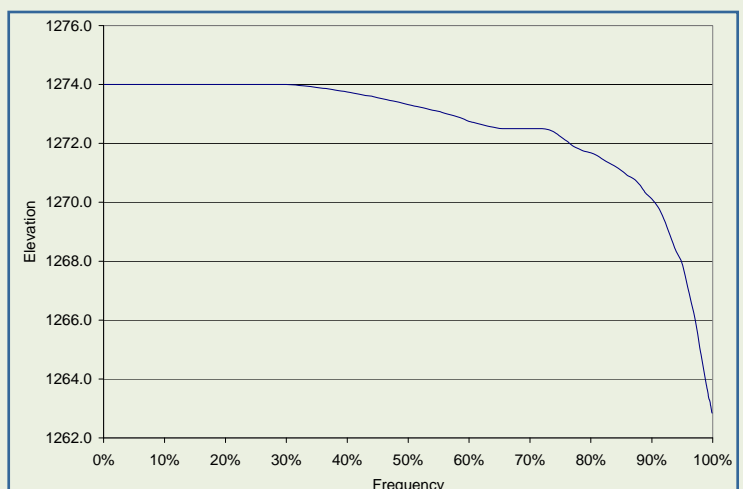


Figure 5. Council Grove Reservoir Elevation Frequency.

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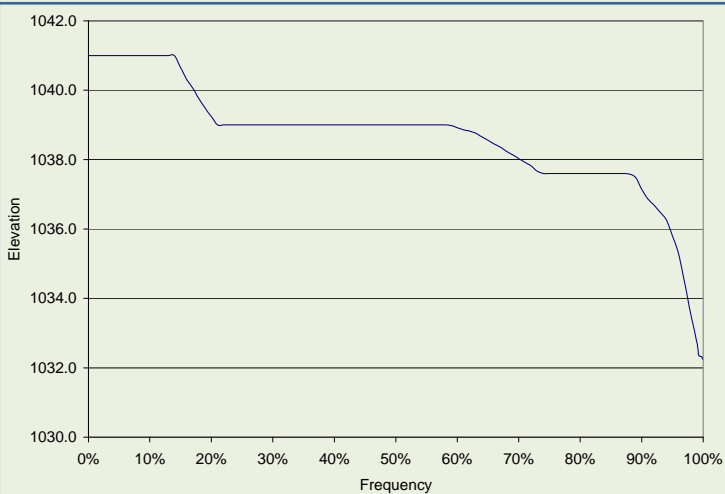


Figure 6. John Redmond Reservoir Elevation Frequency.

Figures derived from the OASIS model show that nearly 90% of the time during the simulations under various climatic and hydrologic conditions, reservoir elevations are within a few feet of the conservation pool elevation. However, the elevations drop significantly in the remaining 10% of model simulations. The 10% of the conditions during which this occurs are during simulations of droughts.

To determine how reservoir capacities may influence downstream water users, information that may be used in their conservation plans is considered. For the purposes of this analysis, a drought watch goes into effect when a reservoir's conservation storage is less than 75%, a drought warning when storage is less than 50% and a drought emergency when storage is less than 33%. Figures 7-9 (below and to the right) illustrate the percentage of time during the OASIS model simulation each reservoir exceeds a given capacity, and compares the capacities remaining when a drought watch, warning, and emergency may be triggered.

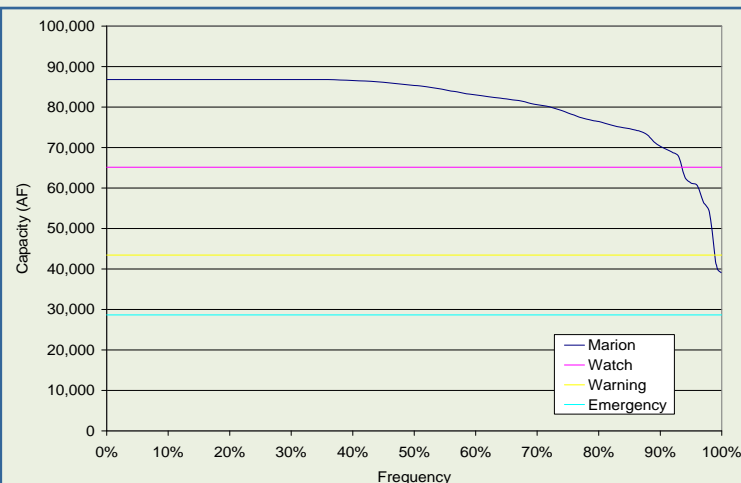


Figure 7. Marion Reservoir Capacity Frequency.

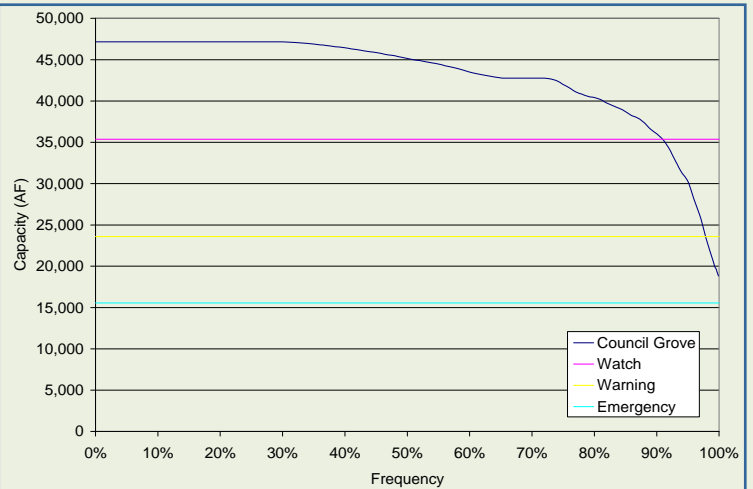


Figure 8. Council Grove Reservoir Capacity Frequency.

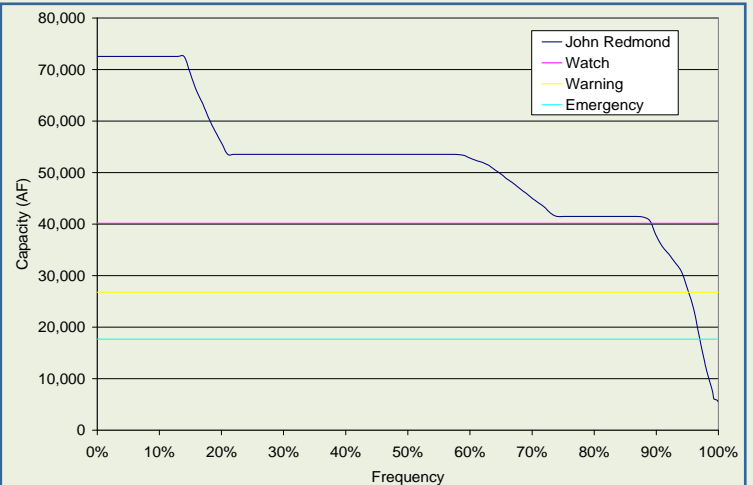


Figure 9. John Redmond Reservoir Capacity Frequency.

John Redmond is the only reservoir that goes into a drought emergency during the 1950's drought magnitude model simulation. Marion and Council Grove reservoirs both have some time when their storage is less than half of full capacity, but it is minimal. The reserve capacity storage in each of the reservoirs increases the percentage of storage remaining because that storage is not used to meet downstream demands. Analyzing each storage pool in the reservoirs is informative in understanding how marketing and assurance customers may be affected, as well as instream water quality. If a marketing or assurance storage pool empties, releases for those customers will not be made and customer shortages may occur for a period of time. If a quality storage pool empties, minimum releases may not be made and downstream targets may not be met. Minimum and maximum storage capacities for each pool are listed in Table 2.

The most significant results shown in the table are the effects on John Redmond Reservoir's quality and mar-

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keting pools. The quality storage is nearly emptied each year by the lake level management plan in which the conservation pool elevation fluctuates from 1037.6 to 1041.0 feet. The marketing storage briefly empties twice during the 1950's magnitude drought which is significant because it is used to supply the Wolf Creek Nuclear Generating Station's cooling lake.

	Marion		Council Grove		John Redmond	
	Min	Max	Min	Max	Min	Max
Quality	8,700	31,100	800	10,700	0	31,800
Marketing	21,700	39,700	4,400	20,500	0	29,900
Assurance	200	400	5,300	7,000	700	3,800
Reserve	8,500	15,600	6,900	9,000	4,300	7,100

Table 2.

RECOMMENDATION: IDENTIFY OPTIONS FOR SUPPLY AND DEMAND MANAGEMENT: RESERVOIR POOL RAISE, POOL REALLOCATION, DREDGING, OFF-CHANNEL STORAGE, NEW SUPPLIES, MODIFY RESERVOIR OPERATIONS, CONSERVATION MEASURES, REVERSE LEVEE OPERATIONS.

Inventory of Restoration Approaches Background

Although reservoirs in the Neosho basin vary in many aspects, they are all important due to their water supply functions. Sedimentation and poor water quality are affecting these reservoirs and have the potential to reduce their reliability as a source of water. One option to ensure water supply storage capacity in the basin is to construct new reservoirs as the existing reservoirs continue to fill with sediment and decline in water quality; however, most of the best sites for reservoirs have already been utilized. Therefore, restoration of the existing reservoirs may provide the best value to restore water supply reliability. This section identifies potential restoration approaches appropriate for each of the water supply reservoirs in the Neosho basin and strategies for prioritizing the restoration activities.

Potential Restoration Approaches

There are numerous potential restoration alternatives that could be applicable for each reservoir, depending on the type and severity of problems at the reservoir. Alternatives include sediment removal, reallocation of water storage pools and structural restoration (dams, diversion structures, treatment facilities).

Sediment Removal

Sediment is typically removed from a reservoir by dredging. Dredging is the process of excavating sediment from the bottom of the reservoir and disposing of the sedi-



Sediment Removal.

ment at a different location. There are several different types of dredges that are typically mounted on a boat or barge for operation in the reservoir. The collected sediment is usually pumped into a sediment basin where it settles out of suspension allowing much of the water in the dredge slurry to return to the reservoir system. Benefits of dredging include significant removal of sediment to maintain existing reservoir capacity. Potential drawbacks include cost, time required to restore reservoir storage capacity, and environmental concerns with sediment disposal. Initial assessments of the viability of dredging by the Corps suggest that the cost of dredging is too high for the benefits gained from the additional storage. Dredging is a potential option in all of the reservoirs in the Neosho basin; however, the benefit per cost may be greatest in reservoirs that have a lower sedimentation rate.

Another method of removing sediment from a reservoir is flushing. Flushing is the process of drawing down the reservoir to create river-like flow conditions in the reservoir, re-suspending sediment that has deposited on the reservoir bottom and transporting it through the gates in the dam to the river downstream. There are several potential problems with using flushing to remove sediment from the reservoir, including a lack of inflow refilling the evacuated storage in a timely manner and the fate of the re-suspended sediment as it travels downstream.

Reallocation

Reallocation of storage is a potential restoration option only in the three federal reservoirs in the Neosho basin. In a reallocation of storage the Corps changes the designation for a specified portion of storage in a federal res-

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ervoir. In the interest of restoring or increasing water supply storage, storage could be reallocated from water quality storage, flood pool storage, or another storage owned by the Corps. If storage is reallocated from flood pool to water supply, a permanent increase in the conservation pool elevation typically results.

A reallocation study by the Corps compares the benefits of increased water supply storage to the potential detriments caused by lost flood or water quality storage capacity, shoreline effects caused by the higher permanent pool and environmental effects due to increased backwater upstream of the reservoir. In 1996 the KWO requested that the Corps reallocate storage in John Redmond Reservoir from the flood pool to the conservation pool to regain water supply storage lost due to sedimentation in the conservation pool. When complete, the reallocation will result in a two-foot pool rise at the reservoir, increasing the conservation pool storage capacity by approximately 20,000 acre-feet. A comparison in Figure 10 of the 2008 storage frequency and the 2048 storage frequency after the pool rise shows that an increase in storage this significant would likely give the water supply use of the reservoir an extra 25 to 30 years of life.

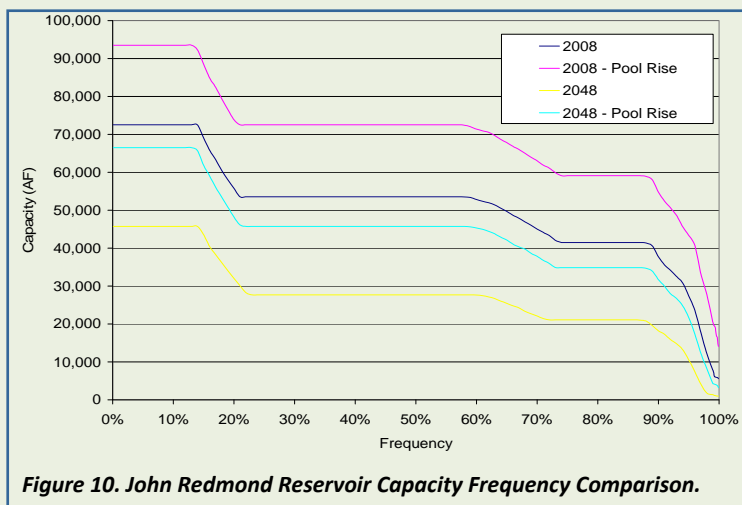


Figure 10. John Redmond Reservoir Capacity Frequency Comparison.

Structural Restoration

Structural restoration is applicable for any structure associated with the reservoir or required to provide water supply from the reservoir, including the dam, water supply diversion structures and water treatment facilities. Structural restoration most likely to occur at the federal reservoirs is restoration of the gates, valves and other associated mechanical equipment that will reduce the amount of water lost downstream due to leakage. The Corps is currently restoring the tainter gates at John Redmond Reservoir.

Increasing the dam height at a federal reservoir is unlikely for several reasons. An increase in dam height requires the Corps to obtain additional land to compensate for the increase in potential flood storage. Costs associated with land purchase, permits and construction can be significant. Increasing dam height may be the only way to increase the pool elevation at city lakes with no flood pool. The condition of the dam is an important consideration in these lakes because they may be older than the federal dams or not as well constructed. Some of the same factors must also be considered before increasing the dam height of a city lake, especially if the new lake elevation will encroach on private property near the lake. For example, Council Grove City Lake is surrounded by approximately 350 houses, so raising the lake elevation is probably not feasible.

Strategies for Prioritizing Restoration Alternatives

The effectiveness of restoration approaches varies depending on the needs of each reservoir. Factors affecting prioritization include feasibility and benefits of the restoration approach, rate of water supply lost due to sedimentation, projected growth of demands, cost of restoration and alternative sources of water supply. KWO has initiated a study with the Corps and an engineering consultant to evaluate alternatives to improve water supply availability in the Neosho basin. Some of the alternatives to be studied will include those discussed above. Alternatives will be evaluated based on numerous criteria, including:

- Effectiveness—How effective is the alternative at improving and maintaining water supply reliability for specific users and the Neosho basin as a whole?
- Economic—What are the capital costs for the alternative and what are future operation and maintenance requirements?
- Environmental—What permitting requirements are necessary for the alternative?
- Schedule—How much time is required for the alternative to be implemented?

Results of this study may provide recommendations that will help prioritize the restoration alternatives. Several public water suppliers in the Neosho basin have contracted with engineering firms to evaluate their water supply reliability. These studies may include an analysis of restoration alternatives to their water supply reservoirs. This information will also be used to prioritize the restoration options.

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Operation and Management Changes to Improve Supply

This section discusses potential operation or management changes for each drinking water reservoir in the Neosho basin.

Reservoir Operational Changes

Operational decisions and management practices of the three federal reservoirs in the Neosho basin can be evaluated for the purpose of improving water supply. The difficulty lies with making changes to these operations because of their potential effects on flood control and environmental issues. The Corps requires significant study before an operational change can be made to a federal reservoir.

Operational changes that improve water supply can be made by increasing the amount of water stored in the reservoir or by reducing the amount of sediment that settles in the reservoir. The amount of water stored in the reservoir can be increased by changing the minimum release schedule and the lake level management plan.

Reservoir Minimum Releases

The minimum release schedule for a federal reservoir is typically set to meet instream flow requirements for wastewater discharge and fish and wildlife support. In the Neosho basin, Marion and Council Grove reservoirs have the following cubic feet per second (cfs) minimum release schedules. John Redmond Reservoir does not have a minimum release schedule; instead releases are made to meet the following minimum flow requirements in the Neosho River at Chanute, Kansas, which were recommended by the Public Health Service in 1952 in Table 3.

Month												
	J	F	M	A	M	J	J	A	S	O	N	D
Target (cfs) at Chanute	21	21	21	24	30	39	48	48	36	24	21	21
Month												
Reservoir	J	F	M	A	M	J	J	A	S	O	N	D
Marion	cfs	1	1	1	2	7	9	13	13	9	7	1
Council Grove	cfs	4	4	4	4	5	7	8	8	6	4	4

Table 3.

Minimum releases are typically met by inflows that are bypassed through the reservoirs; however, if inflows are not sufficient to meet the required minimum releases, stored water is released. Typically, releases are made from water quality storage. As indicated, minimum re-

lease schedules for many of the federal reservoirs in Kansas were created over 50 years ago, usually for dilution of a city's wastewater downstream of the reservoir. While wastewater treatment requirements have increased, so have the wastewater treatment technologies. Improved treatment allows for a constant stream flow at the point of wastewater discharge instead of a widely varying release schedule required historically. New release schedules for federal reservoirs based on either the probability of meeting a downstream target or using continuous monitoring and adjustment of releases to meet the target are more efficient ways to manage the reservoir's storage than a set minimum release schedule.

While the target at Chanute is based on wastewater treatment requirements, there are several other instream water quality requirements as well. MDS are established to maintain instream benefits in the location where the MDS is set. If the average daily streamflow at the MDS gaging station falls below the MDS for a period of seven consecutive days, the Chief Engineer has the ability to administer water rights with a priority date after April 12, 1984. The Neosho River has MDS at the Americus, Iola, and Parsons gages. The Cottonwood River has MDS at the Florence and Plymouth gages as shown in Table 4.

Gage	River	MDS (cfs)
Florence	Cottonwood	10
Plymouth	Cottonwood	20
Americus	Neosho	5
Iola	Neosho	40
Parsons	Neosho	50

Table 4.

Neosho River streamflows downstream of John Redmond Reservoir have historically been below MDS for periods of time during droughts. The MDS values are relatively high in comparison to the minimum flow target at Chanute and there are a significant number of water users downstream of John Redmond. MDS is typically met on the Neosho River above John Redmond and on the Cottonwood River because of significant gains of natural flow, fewer water users, and lower MDS values.

Lake Level Management Plans

Figures 11, 12 and 13 show water levels for Lake Level Management Plans (LLMPs) in the federal reservoirs. LLMPs are seasonal fluctuations in the reservoir surface elevation with the goal of increasing the beneficial use of the reservoir. LLMPs are developed through a coordinated effort between the KWO, the Corps, and the KDWP, each receiving input from stakeholders with an

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interest in the reservoirs.

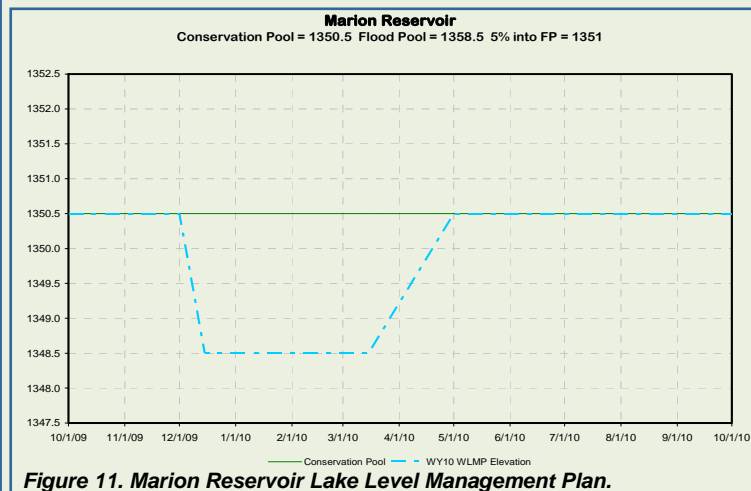


Figure 11. Marion Reservoir Lake Level Management Plan.

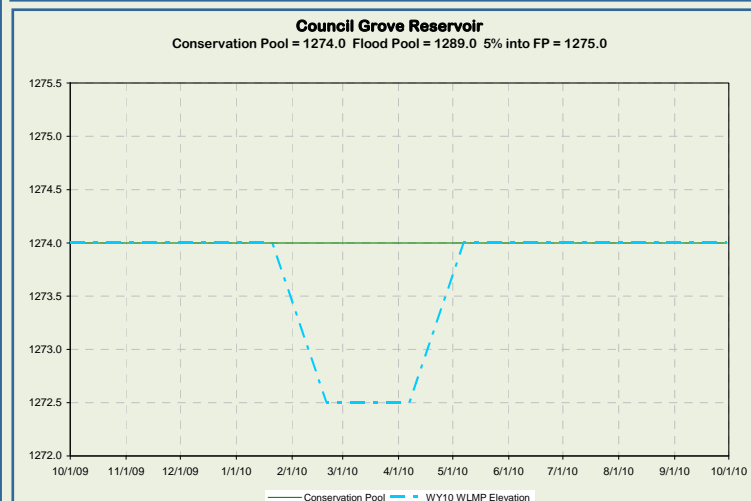


Figure 12. Council Grove Reservoir Lake Level Management Plan.

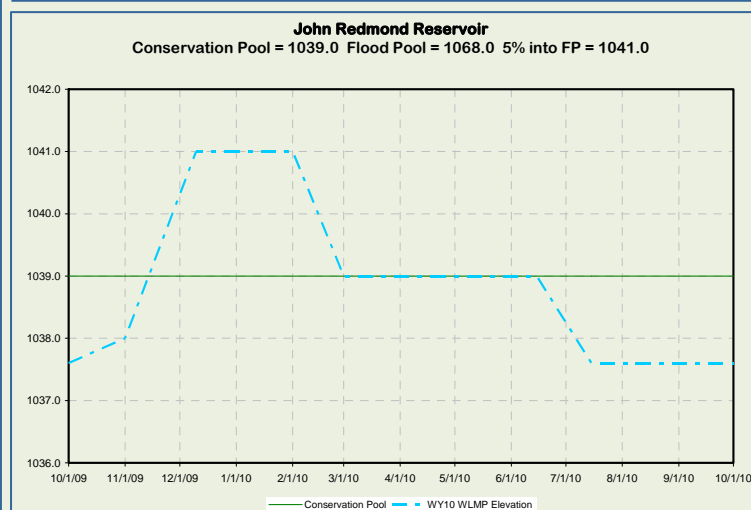


Figure 13. John Redmond Reservoir Lake Level Management

Table 5 lists guidelines of a typical LLMP. In each of the three federal reservoirs, storage is evacuated below the normal conservation pool for a period of time during the year. Although most of the evacuated water is from water quality storage, it can affect the amount of water sup-

ply remaining. The LLMP at John Redmond Reservoir has an inflow trigger that must be met prior to evacuation of storage. The trigger requires that more than 200,000 acre-feet of inflow enters the reservoir in the months of March, April, and May, which effectively eliminates the drawdown during drought years. Triggers could also be effective at Marion and Council Grove reservoirs. Triggers ensure that water is not being evacuated during a time when a drought could be developing.

Time Period	Action	Benefits
Spring	Raise water level elevation to inundate shoreline vegetation	Enhance spawning habitat Increase forage Fish production
Late Spring to Summer	Stable water level	Additional spawning area Boat ramp access Reduce shoreline erosion
Mid to late Summer	Draw down	Revegetation Control of rough fish
Fall	Gradual rise	Food and cover for waterfowl season
Winter	Draw down	Reduce ice and wave damage Additional storage capacity for spring inflows

Table 5. Lake Level management Plan Guidelines.

Reservoir Sedimentation Management

Reservoir sedimentation management strategies can include one or more of the following techniques:

- Reducing sediment inflows
- Managing sediment in the reservoir
- Removing sediment from the reservoir
- Replacing lost storage
- De-commissioning the reservoir

The focus of this section is reservoir operational changes. Operational techniques for preventing sediment from settling when sediment laden water enters the reservoir or removing accumulated sediment include multilevel selective withdrawal, changes in lake level management plans, inflow routing, sluicing, density current venting, and flushing. Each of these techniques is described in detail by Baker & deNoyelles. Most of the techniques involve reducing the residence time of sediment laden water in the reservoir, thereby reducing sedimentation. Data show that the greatest amount of sediment entering the reservoir is during high flow (flood) events. This is typically the time when reservoir operators want to store the water to avoid downstream flooding, so in order to implement some of these techniques, flood control would be compromised. These methods of

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sediment management will require significant study and changes to the Corps' reservoir water control manuals.

Sediment Yield and Modeling Mean Annual Sediment Yield

In 2009, in response to requests to update previous mean annual sediment yield estimates in the state, KWO reevaluated Neosho basin suspended sediment yields. The primary data sources used in the 2009 reevaluation are KDHE stream chemistry sampling network's total suspended solids data (1990-2008), the unique contributing areas (watersheds) formed by the ambient surface water quality monitoring network and USGS stream statistics for the registered surface waters of Kansas.

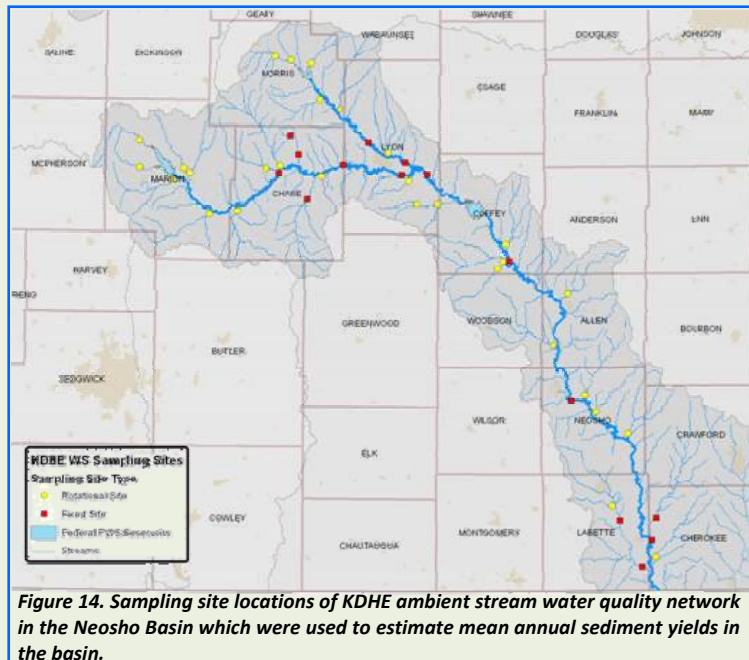


Figure 14. Sampling site locations of KDHE ambient stream water quality network in the Neosho Basin which were used to estimate mean annual sediment yields in the basin.

In addition, when available, USGS instantaneous flow gage data and USGS suspended sediment concentration data were used to calculate mean annual sediment yields. Mean annual sediment yields in the Neosho basin were created based upon the method described in the publication "Sediment Engineering" for estimating long-term sediment yields by flow duration-sediment rating curves.

Due to a number of factors outlined within the 2009 yield assessment report (available online at www.kwo.org), the uncertainty and potential sources of error for many of the updated mean annual sediment yield estimates remain high. The resulting estimated yields should only be used at the planning level (final estimates are shown on the map). The assessment found the sediment yields of the Neosho and Cottonwood Rivers are significantly higher than that of the tributaries feeding into them. This

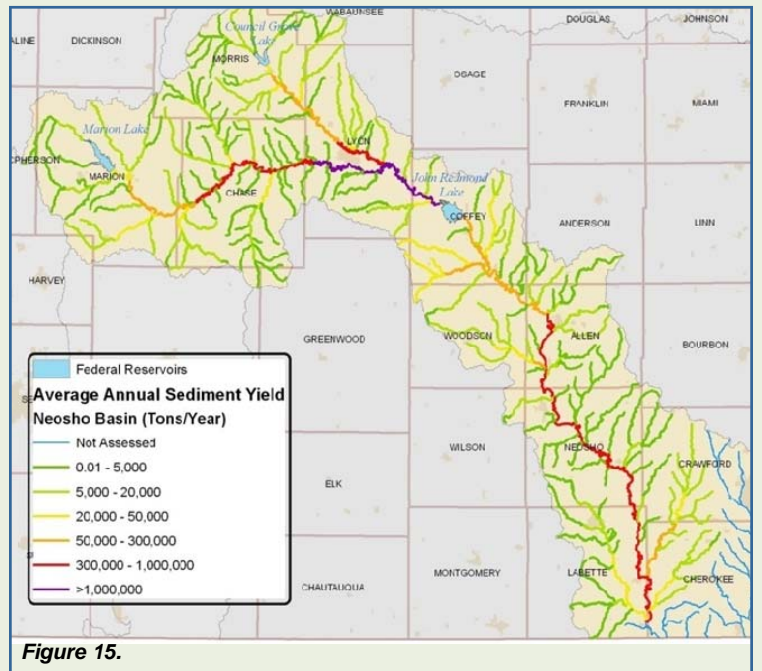


Figure 15.

finding reinforces other recent studies performed in the John Redmond drainage area which have pointed to streambank sources along those main stems as being the primary sources of the sediment in the basin.

Sediment Modeling in the Neosho Basin Above John Redmond Reservoir

Kansas State University (KSU) recently produced a report for the Soil and Water Assessment Tool (SWAT) model developed as part of the John Redmond Feasibility Study (available online at www.kwo.org). The SWAT model, whose domain was the John Redmond drainage area below Marion and Council Grove reservoirs, was calibrated to high flow events recorded at USGS stream gages on the Cottonwood River near Plymouth and the Neosho River at Americus.

The calibration to high flow events is significant in this study. Most SWAT modeling efforts are directed toward calibration of average flows. Since almost all annualized sediment loads are produced by flow events exceeded 10% of the time or less, KSU spent a considerable amount of time calibrating their model to those higher flows that transport sediment in the watershed. In addition to flow data collected at gages on the Cottonwood and Neosho rivers, USGS collected two years of continuous suspended sediment data at the gage sites.

When KSU compared their high flow calibrated SWAT model to the USGS suspended data they found a very large discrepancy (under prediction) between the SWAT model's predicted sediment concentrations and the con-

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centrations observed at the USGS gage monitoring locations. SWAT only accounts for sources of sediment generated from the land surface, such as croplands or grasslands, and does not account for streambank erosion sources. KSU made numerous adjustments to the land surface model factors within the SWAT model to try and simulate the observed sediment concentrations of high flow events. The land surface sources alone could not account for the observed sediment concentrations of high flow events. The inability of the KSU SWAT modeling effort to use land surface sources to account for the observed sediment concentration in the watershed, in conjunction with other recent studies of the potential sources of sediment loads in the John Redmond drainage area, supports the conclusion that streambanks are a primary sediment source in the watershed.

Reservoir	Sediment Removal	Pool Rise	Reallocation	Structural Restoration
Marion	X	X	X	X
Council Grove	X	X	X	X
John Redmond	X	X	X	X
Council Grove City Lake	X			X
Parsons City Lake	X			X
Wolf Creek Lake	X			

Table 6. Summary of Potential Restoration Approaches.

Identification of Reservoirs Not Built

One method of reducing the potential vulnerability to drought in the Neosho basin is to evaluate ways to enhance storage capacity. This can be accomplished by reviewing past information about previously determined reservoir sites that were never built or using existing topographic information, more accessible by today's standards, to locate entirely new potential reservoir sites.

Previously Identified Reservoir Sites Review: Cedar Point Lake

Cedar Point Lake was a federally authorized project from the Flood Control Act of 1950 and Water Supply Act of 1958. Its proposed location was on mile 4.2 of Cedar Creek, a tributary to the Cottonwood River above John Redmond Reservoir, about six miles east of Florence, Kansas in Chase County. The primary purposes of the project were flood control and water supply, but other purposes listed were mitigation of fish losses and recreation. As of 1982, the project is in deferred status pending resolution of water supply repayment assurances by the State. Preconstruction planning for the reservoir was completed.

Using information about the proposed location of Cedar Point dam and the originally planned conservation pool elevation, KWO, using Geographic Information System (GIS) techniques, created a model of the proposed lake (Figures 16 & 17). Based upon flow data collected on Cedar Creek from a USGS gage at the proposed site, mean annual sediment yield estimates developed by the KWO, and resulting volume and area data from the previous GIS step, the estimated 2% drought water supply yield 40 years after initial reservoir fill from Cedar Point Reservoir would be about 16 million gallons per day.

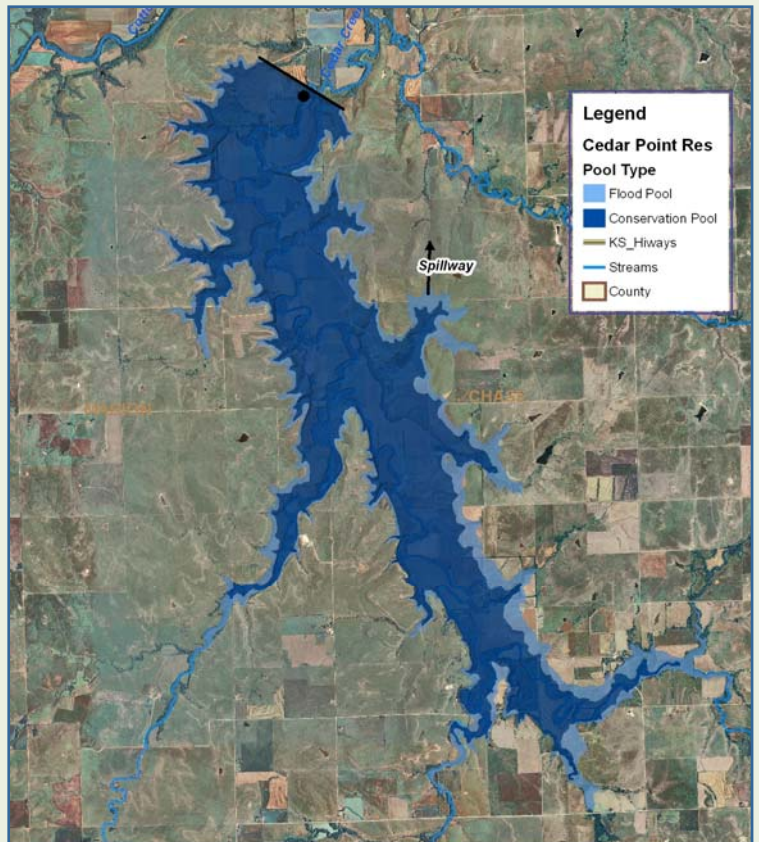


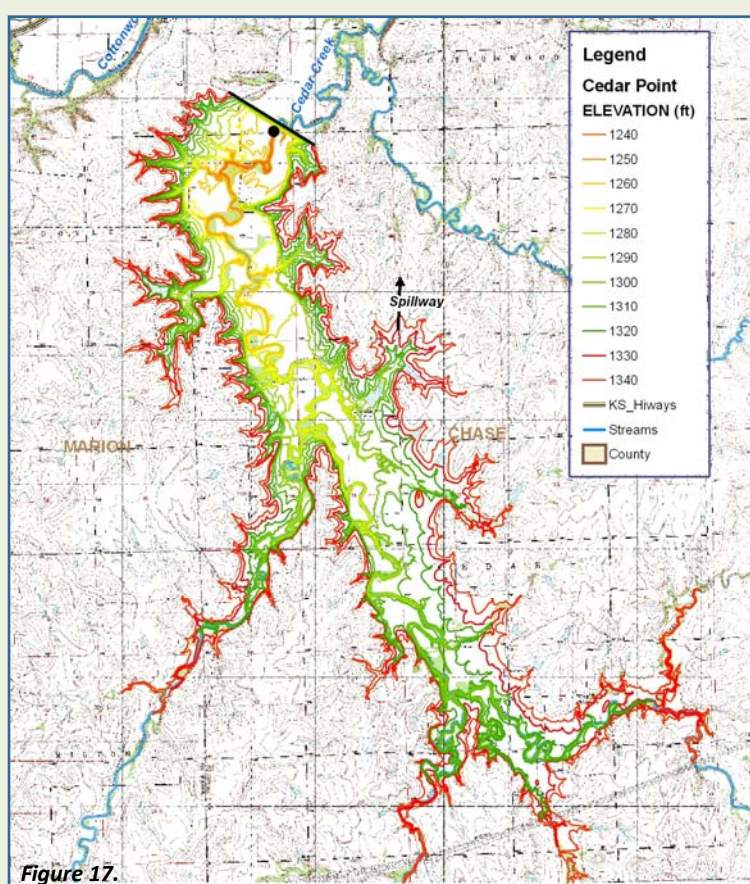
Figure 16.

New Reservoir Site Review

To review entirely new reservoir sites that were not previously located through another plan, KWO has entered into a Planning Assistance to States (PAS) agreement with the Tulsa District of the Corps to perform a Neosho basin water supply study. A portion of that agreement will be for the Corps subcontractor to evaluate alternatives to improve water supply reliability in the basin. Those alternatives would include off-stream storage facilities that collect runoff or are filled by pumping water from a river and new reservoir site identification; including size, location and potential designated uses for new sites. The evaluation criteria include effectiveness at improving and maintaining water supply reliability for end

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users; initial capital costs plus future operation and maintenance requirements; environmental permitting requirements; and time required to implement the various alternatives.

RECOMMENDATION: BEGIN INCORPORATION OF WATER DEMAND MANAGEMENT INTO UTILITY OPERATING PLANS. DEMAND MANAGEMENT SHOULD ALSO INCLUDE EDUCATION OF AND INTERACTION WITH THE DEVELOPMENT COMMUNITY AND INCLUDE EXISTING LOCAL AUTHORITIES.

Water Conservation

The objective of water conservation is to achieve efficient use of the State's limited water resources through cost-effective practices to curtail the waste of water and to ensure water use does not exceed reasonable needs. Water conservation is the most cost-effective and environmentally sound way to reduce demand for water. In the Neosho basin, conservation includes efficiency management in public water supply along with maintaining existing reservoir storage and water supply. See the [Watershed Restoration and Protection Strategy \(WRAPS\) BPI](#) in this section for additional information about efforts underway to improve water quality and preserve storage capacity of reservoirs in the basin.

Local land use planning and zoning authorities provide cities and counties with effective tools to minimize the potential impacts of development on water resources. Counties with planning and zoning regulations often require landscape plans for new development. While landscaping can provide aesthetic and environmental benefits, heavily irrigated landscape designs can increase demand on public water supplies.

Demand management is an important component of extending water supplies but has not typically been incorporated into water utility operations. With recognition of the potential for future water shortages, water suppliers and communities should begin to incorporate this concept into operational planning. Demand management may include less water intensive landscaping, low water use plumbing, conservation design for urban areas, water reuse, and other elements including responsible use of water. A movement beyond excessive use of water into more sustainable long-term management is needed. Increases in consumptive use cannot occur under existing, vested, or otherwise fully perfected water rights. If a municipality is considering substantial changes in their system to reuse water, the DWR must be consulted.

Conservation has been a priority for the State of Kansas for a number of years. The Kansas Water Resources Planning Act provides statutory authorization for addressing water quantity management in the *Kansas Water Plan*. This Act established long-range goals for the management, conservation and development of the waters of the state, including:

- The prevention of the waste of the water supplies of the state, and;
- The protection and conservation of the water resources of the state in a technologically and economically feasible manner.

In October 1998, the Kansas Water Authority (KWA) approved objectives for the year 2010 as part of the *Kansas Water Plan*. Additional objectives for the year 2015 were added to the FY 2004 *Kansas Water Plan* update. An assessment of current conditions related to each objective provides information for targeting of state program resources to areas of greatest need and benefit.

Kansas Water Plan 2010 and 2015 Objectives

- By 2010, reduce the number of public water suppliers with excessive unaccounted for water by first targeting those with 30 % or more unaccounted for water.

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- By 2010, reduce the number of irrigation points of diversion for which the amount of water applied in acre-feet per acre (AF/A) exceeds an amount considered reasonable for the area.
- By 2015, all non-domestic points of diversion meeting predetermined criteria will be metered, gaged or otherwise measured.
- By 2015, conservation plans will be required for water rights meeting priority criteria under K.S.A. 82a-733 if it is determined that such a plan would result in significant water management improvement.

Maintaining or increasing a reservoir's storage is important in ensuring its reliability as a water supply source, but restoration approaches can be quite expensive and are more likely to be long term solutions. There are times when the availability of water supply needs to increase quickly, inexpensively or temporarily. Opportunities for water conservation to improve water supply reliability are discussed below.

the regional average may improve water supply reliability by implementing conservation practices. Municipalities with a high percentage of unaccounted for water will likely reduce their water use by reducing the amount of unaccounted for water.

Municipal User	2007 GPCD	2007 Regional Avg. GPCD	2007 % Difference	2007 % UA For	5 Year Avg. GPCD
Large					
Emporia	176	135	+31	18	176
Parsons	118	130	-9	11	134
Medium					
Burlington	115	101	+14	14	123
Chanute	130	98	+33	12	126
Chetopa	103	98	+5	4	104
Cottonwood Falls	96	101	-5	4	90
Council Grove	91	101	-10	13	106
Erie	101	98	+3	11	104
Hartford	89	101	-11	26	81
Humboldt	110	98	+12	15	111
Iola	137	98	+40	21	111
Marion	123	101	+22	19	118
Oswego	94	98	-4	4	102
Saint Paul	86	98	-12	7	98
Woodson Co. RWD #01	73	101	-27	15	76

Table 7. Summary of Water Use for Municipal Users in the Neosho Basin OASIS Model.

Municipal and Other Public Water Suppliers Conservation Plans

Conservation plans, as currently prepared and implemented, provide a management tool for the public water supplier that improves efficiency, but may or may not reduce the quantity used. To be most effective the plans must be implemented and maintained. Of the 111 public water suppliers in the Neosho basin, 85 have developed a water conservation plan. Currently, municipal water conservation goals are based on a system's size and the average water consumption in gallons per capita per day (GPCD) for the region. GPCD calculations are based on amounts of water sold for residential and commercial uses, free uses and unaccounted for water, but do not include sales of municipal water to industries using over 200,000 gallons per year. For this analysis, large utilities are those serving 10,000 people or more; medium utilities are those serving 500 to 9,999 people; and small utilities are those serving fewer than 500 people. The Neosho basin OASIS model includes municipal users that either have a water right on the Neosho or Cottonwood rivers or have a marketing contract with the State of Kansas. A summary of water use for large and medium municipal users in the OASIS model is included in Table 7. Municipalities with a high water use relative to

Technical Assistance

The Kansas Rural Water Association (KRWA) under contract with KWO provides technical assistance to public water supply operators, managers and local administrators on issues critical to public water systems. The program includes on-site technical assistance for rural water districts and municipal water systems. KRWA provides bookkeeping assistance, water rate structuring, water conservation plan development, distribution system and treatment plant reviews/analyses, leak detection, meter testing, well and distribution line cleaning and emergency assistance.

Drought Triggers

Public water supply conservation plans include locally determined response to drought triggers. These triggers are developed by and for the local water system. The 2007 Kansas Municipal Water Conservation Plan Guidelines provide suggestions for this planning. The guidelines also include triggers for water marketing reservoirs. Municipal drought stage triggers indicate certain levels of water shortage or other drought conditions have been reached. Triggers may be storage or distribution system capacity, peak demand, or some other utility determined

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condition. Each trigger acts as a signal to begin implementation of appropriate actions for that stage and specific goals are identified as the desired outcome for each stage. Appropriate conservation practices in the areas of education, management and regulation are developed and set under each stage. A public water supplier should enact the appropriate stage whenever a trigger is reached. Delay in action may lead to a major disruption of the water supply system at a later time.

Three to four stages are considered appropriate in response to drought to trigger practices or actions. The first three stages; water watch, water warning and water emergency are appropriate for all public water suppliers. A fourth stage, water rationing, is for possible use by public water suppliers in an extreme emergency. Goals for a water warning and a water emergency should be quantifiable, specifically describing the water status and targeting water user awareness, reducing overall demand, and reducing peak demand.

Evaluation of Conservation

The effects of demand management through conservation practices by municipalities were evaluated using the OASIS model. Results of the model runs for Council Grove Reservoir are shown in Figure 18 below. The model was run with municipal demands reduced by 10% and 20% based on estimates of potential conservation capabilities provided by municipalities in the Neosho basin. Council Grove Reservoir responded the most to conservation practices due to the relatively large use of storage by the City of Emporia. Marion and John Redmond reservoirs did not respond as much because of the low municipal use from each of those reservoirs.

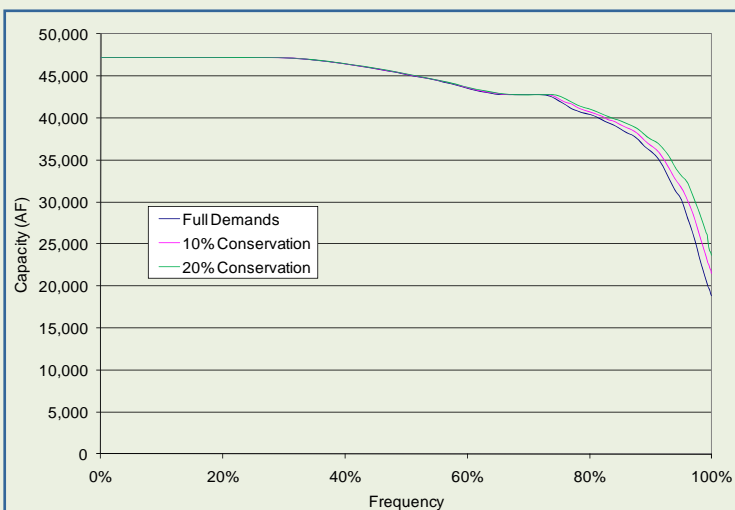


Figure 18. Council Grove Reservoir Capacity Frequency Comparison

Industrial Water Use

The 1986 Kansas Industrial Water Conservation Plan Guidelines were prepared for use by industrial water users to assist in developing a water conservation plan. As members of the CNRBWAD #3, four industrial users in the Neosho basin are required to have water conservation plans. These plans are somewhat limited in total conservation because these industries typically cannot reduce the amount of process water used without reducing production or shutting down.

Irrigation Water Use

While irrigators make up only about eight percent of the water use in the Neosho basin, they influence water availability in the system during specific months of the year. Irrigation water conservation plan guidelines were revised in 2006. Conservation plans are generally only required by DWR for irrigators who are not in compliance with the terms of their water right; however, continued improvements to irrigation technology may reduce their water use.

Recreation Water Use

Recreational water users also account for about eight percent of the water use in the Neosho basin and influence water availability in the system during specific months of the year. Most recreational users in the Neosho basin pump water from the river to create habitat for water fowl. These users coordinate with DWR to ensure there is sufficient water available for them to pump; conservation measures are not typically required. Water conservation plan guidelines have not been developed for recreational water use.

RECOMMENDATION: REFINE MODEL TO REFLECT POSSIBLE OUTCOMES OF IDENTIFIED OPTIONS AND SHARE RESULTS.

Activities are still underway in the basin to gather additional information to refine the model. As this information becomes available the model will be modified and refined to provide the best information possible to make management decisions.

RECOMMENDATION: IMPLEMENT THE MOST BENEFICIAL AND COST-EFFECTIVE OPTIONS.

Based on additional information and the refined model, the most beneficial and cost-effective options will be implemented.

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RECOMMENDATIONS FOR WATER SUPPLY MANAGEMENT AND CONSERVATION IN THE NEOSHO BASIN

This BPI discussion provides an overview of the current and projected condition of the Neosho River basin and its reservoirs. Also contained is a comprehensive discussion of many alternatives for approaching reservoir sustainability in the basin. Alternatives for improving water supply reliability in the basin that were evaluated include sediment removal, reallocation, structural restoration, demand management, reservoir operational changes, new reservoirs, off-stream storage and watershed management. A combination of many of these actions is necessary for securing, protecting and restoring a sustainable water supply in the Neosho basin. Below is a summary of the recommended approach to reservoir sustainability in the Neosho basin.

Reallocation

Reallocation of storage is a potential restoration option only in the three federal reservoirs in the Neosho basin. KWO and the Corps are currently engaged in a review of a reallocation of storage for water supply at John Redmond Reservoir. Although the project is delayed, both parties are committed to completion of the reallocation request. When complete, the reallocation will result in a two-foot pool rise in John Redmond Reservoir, increasing the conservation pool storage capacity by approximately 20,000 acre-feet.

Reservoir Operational Changes

Operational decisions and management practices of the three federal reservoirs in the Neosho basin can be evaluated for the purpose of improving water supply. The following actions related to changes in reservoir operations are recommended for the Neosho basin:

- Develop triggers for implementation of lake level management plans at Marion and Council Grove reservoirs similar to that at John Redmond Reservoir.
- Coordinate with the Corps to study the use of reservoir operational techniques to reduce sedimentation in the reservoirs.

Structural Restoration

Structural improvements of the gates, valves, and other associated mechanical equipment in each of the reservoirs in the basin may reduce the amount of water lost downstream due to leakage. Restoration of the tainter gates at John Redmond Reservoir should continue and

structural improvements at the other reservoirs in the basin should be evaluated.

Demand Management

Water conservation, or demand management, is a tool that can provide multiple benefits. Water conservation is the most cost-effective and environmentally sound way to reduce demand for water. Based on OASIS model analysis, Council Grove Reservoir responded the most to conservation practices due to the relatively large use of storage by the City of Emporia. Marion and John Redmond reservoirs did not respond as much because of the low municipal use from each of those reservoirs.

To enhance and continue opportunities for demand management in the basin, the following items should be implemented:

- Continue aid to public water suppliers in developing and maintaining water conservation plans.
- Continue technical assistance to public water suppliers in determining the source of unaccounted for water.
- Develop drought triggers for water marketing customers.
- Coordinate with the CNRBWA D#3 to develop consistent water conservation plans and drought triggers for each of their members.

Potential Restoration Approaches Needing Additional Assessment

The BPI discussion also included an analysis of alternatives, such as structural modifications, operational changes, and construction of new reservoir sites, which will need additional analysis. KWO has initiated a study with the Corps and an engineering consultant to evaluate alternatives to improve water supply availability in the Neosho basin. Several public water suppliers in the Neosho basin have contracted with engineering firms to evaluate their water supply reliability. These studies may include an analysis of restoration alternatives to their water supply reservoirs. Information from these studies will be used to prioritize future restoration options.

Recommended Actions

1. Continue working with public water suppliers in the basin to improve water supply reliability.
2. Use the results from the Corps and public water supplier studies to prioritize restoration alternatives.
3. Continue aid to public water suppliers in developing

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and maintaining water conservation plans.

4. Continue technical assistance to public water suppliers in determining the source of unaccounted for water.
5. Develop drought triggers for water marketing customers.
6. Coordinate with the CNRBWAD#3 to develop consistent water conservation plans and drought response.
7. Develop triggers for implementation of lake level management plans at Marion and Council Grove reservoirs similar to that at John Redmond Reservoir.
8. Coordinate with the Corps to study the use of reservoir operational techniques to reduce sedimentation in the reservoirs.

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