APPENDIX S

RESERVOIR SIZING ANALYSIS AND DESCRIPTION OF PROJECT COSTS

All information presented in this appendix derives from the *Feasibility Study For the Jackson County Lake Project and Alternatives*, prepared for the Jackson County Lake Project Group, Jackson County Empowerment Zone (EZ) Community, Inc., December 2000 (JCEZ, 2000). The study, which was authorized by a contract between the Jackson County EZ Community, Inc. and Kenvirons, Inc., evaluates and compares the costs associated with potential alternative plans for increasing the long-term water supply in Jackson County.

Reservoir Sizing Analysis

The amount of storage that must be provided within a reservoir is a function of the total demands and the inflow into the impoundment. Mathematically this may expressed as:

$$SD_i = (O_i - I_i)$$

where SD_i = storage deficiency during the time interval *i*
O_i = total outflow volume during the time interval *i*
I_i = total inflow volume during the time interval *i*

From the above equation it can be seen that a storage deficiency will result when the outflow exceeds the inflow, i.e., stored water must be released from the reservoir to meet the demand or outflow for the time interval being analyzed. Because the natural inflow to any impoundment is often highly variable from year to year, season to season, or even day to day, the purpose of the reservoir is to redistribute the inflow over time so that all the projected demands, or outflows, are satisfied.

The total outflow, O, is typically equal to the demands imposed upon the reservoir by the various types of uses, i.e., drinking water, but it may also include volumes for evaporation, transpiration, flood discharges, low flow augmentation, and seepage through the impounding structure. The total outflow used for this study was equal to the supply deficiencies, 1.33, 2.19, and 3.5 million gallons of water per day (mgd), plus an allowance for low flow augmentation. The low flow augmentation was estimated by evaluating the stream flow data from the South Fork Kentucky River stream gauge for years 1940 to 1997 to determine the seven day low flow with a recurrence of ten years (7Q10). The data indicated a 7Q10 flow of 1.74 cubic feet per second (cfs) for the stream. This value was proportioned to the study sites using the drainage areas as the controlling factor.

For the sizing analysis conducted herein, the reservoir inflows were estimated based on historical stream gauge readings. Daily stream flow data was obtained from the U.S. Geological Survey (USGS) Water Resources Data for the South Fork Kentucky River at Booneville, Kentucky gauging station. This gauging station was used since it was the closest one to the alternative reservoir sites containing flow data for the drought of 1930. The 1930 drought has been documented as the most severe drought of record for the Kentucky River Basin with a return period slightly greater than 100 years. The data from the gauging station was adjusted proportionately to reflect the drainage area into the alternative reservoir sites. This can be expressed mathematically as follows:

$I_{reservoir} = I_{stream} \times (DA_{reservoir} / DA_{stream})$

Where $I_{reservoir}$ = Reservoir Inflow

I_{stream} = Stream flow

$DA_{reservoir}$ = Drainage area into the reservoir

DA_{stream} = Drainage area of the stream at the gauging station

After the outflow and inflow values are determined, the storage deficiency for the time interval can be calculated. The time interval used for this study was one day since the stream gauge provided daily flow records. The reservoir sizing analysis used data for the periods from 1925 to 1931 and 1939 to 1997, or 64 years. The following is an example of the tabulation for the reservoir located on War Fork with a yield of 2.19 mgd:

Drainage Area of Proposed Reservoir	10.85 sq. miles
Drainage Area to Stream Gauge	722.00 sq. miles
Ratio for the Projected Inflow	0.0150

Drinking Water Demand	2.19 mgd = 6.72 ac-ft
Estimated 7Q10	0.06 ac-ft
Total Outflow	6.78 ac-ft

Date	Historical Stream Flow (cfs)	Projected Reservoir Inflow (cfs)	Projected Reservoir Inflow (ac-ft)	Total Outflow (ac-ft)	Daily Deficiency (O – I) (ac-ft)	Cumulative Deficiency (O – I) (ac-ft)
2/1/31	37.00	0.56	1.10	6.78	5.68	1,500.40
2/2/31	30.00	0.45	0.89	6.78	5.89	1,506.29
2/3/31	30.00	0.45	0.89	6.78	5.89	1,512.18
2/4/31	30.00	0.45	0.89	6.78	5.89	1,518.06
2/5/31	30.00	0.45	0.89	6.78	5.89	1,523.95
2/6/31	30.00	0.45	0.89	6.78	5.89	1,529.84
2/7/31	30.00	0.45	0.89	6.78	5.89	1,535.72
2/8/31	30.00	0.45	0.89	6.78	5.89	1,541.61
2/9/31	30.00	0.45	0.89	6.78	5.89	**1,547.50**
2/10/31	880.00	13.22	26.23	6.78	-19.45	1,528.05
2/11/31	880.00	13.22	26.23	6.78	-19.45	1,508.60
2/12/31	515.00	7.74	15.35	6.78	-8.57	1,500.03

The above tabulation depicts how the reservoir's storage volume is depleted and recharged on a daily basis. At the start of the analysis the "Cumulative Deficiency" is recorded as zero. The maximum value calculated for the "Cumulative Deficiency" is the usable volume the reservoir would have to store to meet the outflow demand during the analysis period. At the War Fork site, the analysis determined that a volume of 1,547.5 acre-feet would have to be stored in order for the reservoir to supply 2.19 mgd. An allowance of 10 percent was added to the calculated results to account for the gauging stations inaccuracies and seepage around the impounding structure.

A sedimentation volume was estimated for each of the alternative reservoir sites. The rate of sedimentation used for the study was 0.74 acre-feet/square mile/year. This is the average sediment rate reported by the U.S. Army Corps of Engineers for reservoirs located in central and eastern Kentucky (Buckhorn, Taylorsville, Cave Run, and Carr Creek Reservoirs). The sediment volume for the alternative reservoirs was estimated by multiplying the average sediment rate by the drainage area of the alternative reservoir, and then multiplying the result by 50 years.

An additional provision that was incorporated into the reservoirs was the allocation of stored water for environmental use. This volume may be used to augment downstream flows during dry periods and/or maintain the habitat created by the impoundment. In order to compare the alternatives, each reservoir was allocated a volume equal to 40 percent of the storage deficiency. Further consultation with the appropriate federal and state agencies will be needed to precisely determine the volume or flow required to minimize the environmental impacts.

The following table is a summary of the reservoir sizing analysis:

Reservoir Site	**Sturgeon Cr.**	**War Fork**	**War Fork**	**War Fork**
Drink. Water Capacity, mgd	3.50	3.50	2.19	1.33
Drainage Area, sq. miles	15.62	10.85	10.85	10.85
Storage Deficiency, acre-feet	2,764	2,870	1,703	952
Sedimentation, acre-feet	576	396	396	396
Environmental Storage, ac-ft	1,106	1,148	681	380
RESULTS, NORMAL POOL				
Total Storage, acre-feet	4,446	4,414	2,780	1,728
Surface Elevation, msl	980	982	960	946
Surface Area, acres	275	118	88	65
RESULTS, LOW POOL				
Total Storage, acre-feet	1,682	1,544	1,077	777
Surface Elevation, msl	965	949	934	927
Surface Area, acres	117	62	48	40

The surface elevations and areas were determined from stage-storage and stage-area curves generated for the reservoir sites. USGS topographical maps were used to develop the curves.

Land Acquisition and Relocation Costs

A potentially significant cost, especially for the reservoir alternatives, is the acquisition of land and the relocation of families and cemeteries. In order to determine the area of land that would be purchased, a flood and buffer zone was established which encompassed an area 300 feet horizontally and 20 feet above the reservoir's normal pool. The study assumed that all privately owned land within the flood and buffer zone would be purchased. It was further assumed that the U.S. Forest Service would retain ownership of their land located within this zone. Land acquisition costs for the reservoirs were estimated at $800 per acre for the War Fork site and $1,200 per acre for the Sturgeon Creek site. The reason for the different unit prices relates to the general type of land located around the alternative reservoirs. The terrain at War Fork is very steep and wooded while the land at Sturgeon Creek is rolling and partially cleared for agricultural use.

All of the non-reservoir alternatives were evaluated by assuming that an acre of land would be purchased for all permanent structures such as tanks, pump station, and intakes. A unit price of $1,200 per acre was used for the non-reservoir alternatives.

Other acquisition and relocation costs incorporated into the study were the number of houses, trailers, barns, etc. that are located in the flood and buffer zone, title searches, surveys, insurance, appraisals, family relocations, and cemetery relocations.

Reservoir Costs

After the storage capacity of the alternative reservoirs was determined, the costs to construct the impounding structures and reservoirs were estimated. The study assumed a roller compacted concrete (RCC) dam would be constructed for the impoundment and the timber and underbrush would be cleared from the majority of the normal pool area. Each RCC dam alternative was assumed to have a vertical upstream face and a downstream side slope of 1:1. Fill volumes, access road lengths, areas to be cleared, and other construction items were estimated for the specific sites based on USGS topographical maps.

Transmission Main Costs

The transmission facilities were sized based upon the water supply needs of 3.50, 2.19, or 1.33 mgd. The transmission mains and appurtenances were sized to limit the operating pressures below 250 pounds per square inch (psi), an allowable working pressure for most ductile iron pipe, fittings, and valves. The route of the pipeline utilized the existing network of roadways. Transmission main lengths, stream crossings, road crossings, and other construction items were estimated from USGS topographical maps.

The transmission facilities from both the reservoir and non-reservoir alternatives were evaluated. The major components of the transmission facilities from the reservoir alternatives consisted of a pump house at the dam, pipeline to the existing treatment plant, and a meter vault for monitoring purposes. The intake, or withdrawal structure, would be an integral part of the RCC dam and is included in the reservoir construction cost.

The transmission facilities for the non-reservoir alternatives included some construction items not required for the reservoir alternatives. These additional items consisted of a storage tank/basin and a booster pump station. These items will be needed in order to maintain the working pressures of the system below 250 psi.

Miscellaneous Costs

Utility relocations, preliminary engineering, and environmental studies were included in the cost for the various alternatives. The costs associated with relocating the electric and telephone lines were obtained from the local utility providers, Jackson Energy Cooperative and Peoples Rural Telephone. The waterline relocation lengths were estimated from the Jackson County Water Association's (JCWA) system maps. The length of line was then multiplied by an appropriate unit cost to determine the total cost.

Costs for preliminary engineering and environmental studies were estimated based on the current expenditure to prepare the DEIS.

Administration and Legal Cost

Administration costs were included to reflect the fees associated with preparing funding applications and monitoring the funds throughout the project's construction. Area Development Districts (ADD) are typical project administrators. For this study, the administration costs were estimated at 0.80 percent of the total project cost.

Legal services will be required from attorneys for title opinions, execution of easements, review of contracts, and issue of bonds. Local Counsel and Bond Counsel fees were estimated using schedules prepared by the U.S. Department of Agriculture, Rural Development.

Total Project Cost

The total project cost was estimated by adding the costs for the various aspects of each alternative, i.e., land acquisition, reservoir cost, transmission main cost, etc. Engineering, inspection, and contingencies were also included in the total cost.

Present Worth Analysis of Operation, Maintenance, and Replacements Costs

In order to compare the various alternatives, the operation, maintenance, and replacement (OM&R) costs must be included in the decision process. These recurrent costs can be a critical factor when selecting one alternative over another. The analysis conducted herein evaluated the OM&R costs for each year of the alternatives life, 50 years. These future OM&R costs were related back to the present using the appropriate interest factors. The "present worth" of the annual OM&R costs were then totalized. The totalized present worth value can be viewed as the amount of money that would be placed in an interest bearing account in order to pay for the alternative's OM&R costs during the 50-year life. This value is then added to the alternative's development cost for comparison with the other alternatives.

The following criteria was used to conduct the present worth analysis of the OM&R:

- System Use: The amount of water supplied through the alternative was increased linearly from 0.5 mgd to the projected water supply need, i.e., 3.50, 2.19, or 1.33 mgd, over the 50-year design period.

- System Horsepower: The total horsepower required to pump the water supply need was determined from hydraulic profiles generated for the transmission main routes. It was assumed that the pump system had an overall efficiency of 75 percent. Pump horsepower was computed using the following equation:

  Hp = (Q x H) / (3960 x eff.)
  Where: Hp = Horsepower

Q = Design Flow, or 50-year Water Supply Need, gpm
H = Total Dynamic Head, or Pump Lift, feet
eff. = system efficiency

- Annual Hours of Operation: The pumping system was designed to produce the long-term projected water supply need over a 24-hour period. Since the water supply need is less for the initial years, the pumps will only operate part of the time during a normal day. Therefore, the annual hours of operation were calculated as follows:

  $HRS_i = (Q_i \text{ x } 365 \text{ days/year}) / (Q_{50} / 24 \text{ hours/day})$
  Where: HRS_i = Hours of operation for Year "i"
  Q_i = System Use for Year "i", mgd
  Q_{50} = 50-year Projected Water Supply Need, mgd

- Electrical Power Cost: The cost for electrical power will be the primary operational cost associated with the alternatives. The annual cost for electrical service was estimated using the following equation:

  $E = Hp x (0.746 KW / Hp) x HRS x ($0.06 / KW-Hr)
  Where: $E = Electrical Cost
  KW = Kilowatt
  Hp = Horsepower
  HRS = Annual Hours of Operation
  KW-Hr = Kilowatt-Hour, unit price for electricity

- Maintenance Costs: The annual cost to maintain the transmission main was estimated using a unit cost of $100 per inch-mile of water line. This unit cost is multiplied to the size and length of the transmission main to determine the annual maintenance cost. The transmission main size is referenced in inches and the length is referenced in miles.

  Based on discussions with the operators at Winchester Municipal Utilities and the JCWA, both owners of small impounding structures, it was assumed that the annual maintenance cost for the alternative reservoirs were negligible compared to the transmission main maintenance cost.

  Repainting of the storage tanks was included as a maintenance cost. The analysis assumes that the storage tanks will be repainted every 20 years.

- Replacement Costs: The analysis used the following replacement schedule for the equipment portion of the various alternatives. The replacement price for the equipment was the same value used in the original cost estimates for the transmission mains.
  1. Pumps were replaced every 15 years.
  2. Electrical Controls were replaced every 25 years.

Jackson County Water Association's Water Plant Expansion

The JCWA is currently preparing to expand its water treatment capacity. JCWA has submitted funding applications to the following agencies for the amount indicated:

Community Development Block Grant -	$1,000,000
Appalachian Regional Commission -	500,000
Economic Development Administration -	500,000
Rural Development, Grant -	1,020,000
Rural Development, Loan -	880,000
	$3,900,000

The estimated total cost for the water treatment plant (WTP) expansion is $3,900,000. By including the WTP expansion project in the analysis, a complete picture for providing potable water to Jackson County will be developed.

Present Worth Analysis of Water Production Costs and Water Purchase Costs

The Wood Creek alternative consisted of constructing a potable water transmission main to Jackson County. This is different from the other alternatives evaluated since it transports potable water and connects directly into JCWA's distribution system. The reservoir and Kentucky River alternatives transport raw water to JCWA's plant for treatment and eventual use in the distribution system. In order to compare the alternatives, the costs associated with treating the water at JCWA's WTP and/or purchasing potable water from WCWD must be included in the decision process. To accomplish this goal, a present worth analysis was conducted. The analysis was similar to the study performed for the OM&R costs.

The Wood Creek Water District (WCWD) must increase their treatment capacity prior to selling any significant volumes of water to JCWA. WCWD is currently planning to expand its water treatment plant because of growth in its service area. Preliminary estimates for the WTP expansion indicate a total cost $4,500,000, and the District is planning to fund the entire project through a Rural Development loan. WCWD will have to increase their rates in order to generate the revenue for the WTP expansion. WCWD currently wholesales water to the East Laurel Water District and the West Laurel Water Association at the rate of $1.24 per 1,000 gallons. The following calculations were performed to estimate WCWD's wholesale rate after the expansion of their WTP:

Debt Service for Loan, Annual Loan Payment - ($4,500,000 @ 5% for 38 years)	$266,760
Loan Coverage, (10% of Debt Service) -	26,676
Depreciation, ($4,500,000/(2 x 40)) -	56,250
Annual Revenue Required for Project -	$349,686

Total Water Sale (1999 Annual Report) -	867,571,400 gallons
Estimated Minimum Sales to JCWA (0.50 MGD) -	182,500,000 gallons
Estimated Annual Water Sales	1,050,071,400 gallons
Increased Cost per 1,000 gallons ($349,686 / 1,050,071,400) -	$0.33 / 1,000 gallons
Estimated Wholesale Rate After WTP Expansion-	$1.57 / 1,000 gallons

The estimated wholesale rate of $1.57 per 1,000 gallons was used in this study for water purchases from WCWD.

From the JCWA *1999 Annual Report to the Public Service Commission*, the costs associated with treating the raw water were as follows:

Salaries -	$36,510
Chemical -	53,965
Electrical (assumed 30% of total) -	18,220
Total Cost to Treat Water -	$108,695
Total Gallons Produced -	291,852,000

Treatment Cost per 1,000 gallons = $108,695 / 291,852 = $0.37 per 1,000 gallons

The treatment cost of $0.37 per 1,000 gallons was used in this study for water produced by JCWA.

The present worth analysis assumes that JCWA will use 0.80 mgd the first year the alternative is operational. The water use was increased linearly from 0.80 mgd to the projected water supply need over the 50-year design period.

For the reservoir and Kentucky River alternatives, the annual cost to treat the water was calculated by multiplying the “total system use” by the unit treatment cost. For example, if the water demand were 0.80 mgd, then the annual cost to produce this water would be:

800,000 gal./day x 365 days/years x $0.37 / 1,000 = $108,040

For the Wood Creek Alternative, it was assumed that 0.50 mgd would be the minimum amount of water to be purchased from WCWD. This assumption was made to minimize any water quality problems that may result from prolonged detention times in the transmission facilities. The existing WTP owned by JCWA was utilized to produce the difference between the total system demand and the quantity purchased from WCWD. Additional volumes were purchased from WCWD once the capacity of JCWA’s supply reservoir was reached.

User Rate Impact

The primary purpose for the proposed alternatives is to increase the water supply of Jackson County. Therefore, it has been assumed that the main water service provider, JCWA, will be required to finance the project, and the revenue needed will be generated through JCWA's rates.

As stated earlier, JCWA has applied for funding to expand its WTP. The estimated total cost for the plant expansion is $3,900,000 and the amount of loan money to be reimbursed is $880,000. The long-term indebtedness incurred for the WTP expansion project was included in the user rate study.

JCWA's unit treatment cost of $0.37 per 1,000 gallons and WCWD's estimated wholesale rate $1.57 per 1,000 gallons were used in the analysis of the user rates. These prices were applied to the volume of water that would be purchased from WCWD. The following example demonstrates how the wholesale rate and unit treatment cost were applied in the user rate analysis.

> For the Wood Creek Alternative with a capacity of 2.19 mgd it was estimated that a minimum volume of water of 500,000 gallon per day (gpd) would be transported through the system during the first year of operation. Therefore, the annual cost to purchase the water from WCWD is calculated as follows:
>
> Annual Purchase Cost = 500 x 365 days/year x $1.57 per 1,000 gallons
> = $286,525
>
> Since the Jackson County Water Association did not produce this water, the cost associated with its treatment was not incurred. The forgone cost is calculated as follows:
>
> Forgone Treatment Cost = 500 x 365 days/year x $0.37 per 1,000 gallons
> = $67,525
>
> The net result of purchasing 500,00 gpd from WCWD would be an increase in annual expenditure of $219,000 ($286,525 less $67,525).

The following additional data and/or criteria was used to evaluate the user rate impacts:

- Projected Operating Budget of JCWA for Year 2002: In September 2000, JCWA had a *Preliminary Engineering Report* prepared for the WTP expansion. Contained in the report is a projected operating budget for the Year 2002. The projected budget is based on JCWA's *1999 Annual Report to the Public Service Commission* and accounts for customer growth, salary increases, etc. to estimate the future operating budget. From the *Preliminary Engineering Report*, it is projected that for Year 2002 the Association will generate $1,534,606 from water sales and their total annual income will be $1,592,913. It is also projected that the total annual expenditure will be $1,064,294 prior to the WTP expansion. Subtracting the income from the expenditure leaves a "balance available for depreciation" of $528,619. The analysis contained herein assumes that the water user rates will be increased appropriately to maintain the "balance available for depreciation".

- Funding for the Alternative: The Jackson County EZ Community, Inc. received a $5,000,000 grant to implement the alternative selected. Additional funding will have to be acquired in order to fully develop the alternative. For the user rate impact analysis, it was assumed that the additional funding would be obtained with a grant to loan ratio of 1:1, i.e., 50 percent grant and 50 percent loan.

- Annual Expenditure for the Alternative: Since the loan money will be used to implement the selected alternative, the annual payment on this loan must be included in the user rates. The study assumes that the term of the loan will be for 38 years with an interest rate of 5 percent, the typical loan conditions from Rural Development. Coverage on the loan was calculated as 10 percent of the annual payment. Depreciation was estimated by dividing the total project cost by the life of the alternative. Only half of the depreciation value was used in the analysis since a significant portion of the funding was assumed to be grants. The OM&R cost for the first year operation was also included in the annual expenditure for the alternative.

- Annual Expenditure for the WTP Expansion: The annual expenditure for the WTP expansion was calculated in a similar fashion as the alternative.

- Water Purchase and Treatment Costs: As described earlier, water would be purchased if the Wood Creek Alternative were selected. The cost to purchase the water was included in user rate analysis. Since the water being purchased is potable, JCWA will not incur the cost to treat the water at its own facility.

- Total Additional Annual Expenditure: The total additional annual expenditure incurred by JCWA for the selected alternative was calculated as follows:

  Annual Expenditure for the Alternative
  \+ Annual Expenditure for WTP Expansion
  \+ Annual Cost for Purchased Water
  \- Annual Cost Forgone to Produce Water
  Total Additional Annual Expenditure

  This value represents the additional revenue that must be generated in order to implement the selected alternative and the WTP expansion.

- Rate Increase Needed to Maintain Current Level of Depreciation: For the user rate analysis it was assumed that JCWA must maintain their "balance available for depreciation". The rate increase was estimated by dividing the "total additional annual expenditure" by the "water sales" projected for Year 2002.