A Study for:

Culpeper County, Virginia

CULPEPER COUNTY
RESERVOIR STUDY

Submitted to:

Culpeper County, Virginia
306 N. Main Street
Culpeper, VA 22701

Wiley & Wilson
ARCHITECTS ENGINEERS PLANNERS
An Employee-Owned Company

Lynchburg, Virginia

Comm. No. 200156.00 March, 2001

TAB

March 27, 2001

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ARCHITECTS ENGINEERS PLANNERS
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Mr. Paul Howard
Director of Environmental Services
Culpeper County
306 N. Main Street
Culpeper, VA 22701

Re: Culpeper County Reservoir Study
W&W Commission No. 200156.00

Dear Mr. Howard:

We are pleased to submit our report regarding the Culpeper County Reservoir Study. As outlined in the project description, this report covers the results of:

1. Preliminary site selection
2. Stream flow analysis
3. Schematic dam and reservoir layout
4. Diversion pumping stations
5. Permitting

1. PRELIMINARY SITE SELECTION

Area of Interest

This study evaluates reservoir sites in the northern and eastern portion of Culpeper County. The study area is shown in Figure 1. The Rappahannock River forms the northeast border of the County. The study area extended as far south as Route 3 and as far west as the Rappahannock County line. The Rappahannock River was considered as the primary source for the reservoirs. Due to their size, the Thorton and Hazel Rivers, major tributaries to the Rappahannock River, were also considered.

Thirteen sites were selected and evaluated regarding volume, dam height, location, and conflicts with historic areas or major utilities. The four most promising sites are presented in this report.

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Reservoir Sites

The results of this study focus on four possible reservoir sites for Culpeper County. These sites can be found on the Reservoir Location map, Figure 2. Reservoir size and cost data is summarized in Table 1. Appendix D contains detailed cost analysis.

Site No. 3 & 3A: Reservoirs No. 3 and 3A would entail the construction of a dam on Indian Run, just west of Route 229.

- The water to fill this reservoir would be pumped from the Hazel River near Rixeyville and inflow directly from the watershed of Indian Run.
- The dam at this site would have a maximum height of 64 feet and crest length of 1,300 feet. The normal pool elevation would be at 393 feet, with 7 feet of freeboard, normal pool surface area of 461 acres, and a normal pool volume of 3,149 million gallons.
- The earthwork volume required for the dam embankment would be 380,000 cubic yards.
- The maximum yield of this reservoir would be 7.5 MGD with diversion pumping from the Hazel River. The yield based on the Indian Run watershed without pumping would be 4.8 MGD.
- The maximum yield of the reservoir is dictated by the drought years of 1981 to 1982, where the mean daily flow in the Hazel River was below the mean annual flow for 340 consecutive days.
- The reservoir is located on the border of a granite and a granite/gneiss area with deep soils.
- The reservoir would impact 64 land parcels and 3,375 feet of roadway (Appendix B). The reservoir impacts a number of residential home sites; however, the property impact could be minimized by reducing the size of the dam, if a lower yield would be acceptable.

Site No. 7: Reservoir No. 7 would entail the construction of a dam on Beaverdam Run, just west of Route 623.

- The water to fill this reservoir would be pumped from the Rappahannock River, directly to its east.
- The dam at this site would have a maximum height of 61.2 feet and crest length of 1,600 feet. The normal pool elevation would be at 360 feet, with 7 feet of freeboard, a normal pool surface area of 227 acres and a normal pool volume of 1,331 million gallons.
- The earthwork volume required for the dam embankment would be 390,000 cubic yards.
- The maximum yield of this reservoir would be 2.8 MGD. The maximum yield of the reservoir is dictated by the drought years of 1981 to 1982, where the mean daily flow in the Rappahannock River was below the mean annual flow for 340 consecutive days.
- It is located in an area that is dominated by metabasalt geology with deep soil containing mica schist silts.
- The reservoir would impact 16 land parcels and approximately 1,030 feet of roadway (Appendix B).

Site No. 10 &10A: Reservoir No. 10 and 10A would entail the construction of a dam on Muddy Run, to the west of Route 265.

- The water to fill this reservoir would be pumped from the Hazel River, directly to its east and inflow directly from the watershed of Muddy Run.
- The dam at this site would have a maximum height of 33.0 feet and crest length of 408 feet. The normal pool elevation would be at 313 feet, with 7 feet of free board, a normal pool surface area of 243 acres, and a normal pool volume of 763 million gallons.
- The earthwork volume required for the dam embankment would be 33,900 cubic yards.
- The maximum yield of this reservoir would be 3.5 MGD with or without diversion pumping. This indicates that the Muddy Run Watershed is adequate to fill the reservoir and that pumping is unnecessary.
- The maximum yield of the reservoir is dictated by the drought years of 1965 to 1966, where the mean daily flow in the Hazel River was below the mean annual flow for 311 consecutive days.

- It is located in an area that is dominated by metabasalt geology with deep soil containing mica schist silts.
- The reservoir would impact 27 land parcels (Appendix B).

Site No. 13: Reservoir No. 13 would entail the construction of a dam on Mill Run and would pump its water from the Rappahannock River, directly to the east.

- The dam at this site would have a maximum height of 67.1 feet and crest length of 960 feet. The normal pool elevation would be at 280 feet, with 7 feet of freeboard, a normal pool surface area of 115 acres, and a normal pool volume of 705 million gallons.
- The earthwork volume required for the dam embankment would be 156,000 cubic yards.
- The maximum yield of this reservoir would be 2.6 MGD.
- The maximum yield of the reservoir is dictated by the drought years of 1965 to 1966, where the mean daily flow in the Rappahannock River was below the mean annual flow for 314 consecutive days.
- The reservoir is located in the Northern Piedmont area which is characterized by severely metamorphosed, sofeet bed rock with lots of mica and silt present.

Table 1: Summary of Reservoir Statistics

Site #	Source River	Normal Surface Area (acres)	Normal Volume (MG)	Watershed Area (acres)	Diversion Pump Capacity (MGD)	Max Yield (MGD)	Total Cost (mill $)	Cost per MGD (mill $ /MGD)
3	Hazel & Indian Run	461	3,149	4,897	77.6	7.5	15.1	2.01
3A	Indian Run	461	3,149	4,897	0	4.8	5.89	1.23
7	Rappahannock	227	1,331	1,360	90.5	2.8	7.25	2.59
10	Hazel	243	763	5,957	90.5	3.5	6.91	1.98
10A	Muddy Run	243	763	5,957	0	3.5	2.85	0.81
13	Rappahannock	115	705	1,706	97.0	2.3	5.32	2.31
Roanoke County, Spring Hollow Project*		158	3,200	540	80.0	17	33.0	1.94

* *Yield and Cost Statistics for Roanoke County's Spring Hollow Reservoir are included for comparative purposes.*

Drought Year Behavior

The maximum reservoir yield is dictated by the reservoir behavior in drought years. Table 2 summarizes each reservoir's performance during drought years. Dividing the available water yield by the number of days with no pumping generates the theoretical maximum. The values for theoretical maximum yield are similar to those generated in the watershed model and provide a good verification of the model results. Draw-down curves for each of the reservoirs, during their most severe drought years, are shown in Figures 3 through 6.

Table 2: Reservoir Performance in Drought Years.
ET (net evaporation), Seepage, Pump, and Watershed flow are the sum of these values over the number of days with low pumping.

Reservoir #	Drought Years	Max Days Low pump	Reservoir Losses (MG)	Inflow from Pump (MG)	Inflow from Watershed flow (MG)	10% Min. Pool (MG)	Volume at beginning of No Pump (MG)	Available Water (MG)	Theo Max Yield (MGD)
3	Feb 81 – Feb 82	340	75	78	738	314.9	2,150	2,576.1	7.6
7	Feb 81 – Feb 82	340	37	37	0	133.1	1,108	974.9	2.9
10	Apr 65 – Feb 66	311	34	61	584	76.3	763	1,297.7	4.2
13	Apr 65 – Feb 66	314	32	57	146	70.5	705	805.5	2.6

2. STREAM FLOW ANALYSIS

The average daily stream flow data for this study was gathered from four USGS river gauging stations in the area: on the upper Rappahannock River near Warrenton (gauge station number 01662000), on the lower Rappahannock River near Remington (gauge station number 01664000), on the Thorton River near Laurel Hills (gauge station number 01663000), and on the Hazel River near Rixeyville (gauge station number 01663500). Data for these gauging stations is available on the USGS website (www.usgs.gov). Table 3 summarizes the available gauge station data. Flow duration curves for the gauging station are shown in Figure 7.

Table 3: Gauging Station Characteristics

Location	Drainage Area (mi^2)	Mean Annual Flow (cfs)	Median Flow, 50% Exceedance (cfs)	Average Annual Yield Above MAF (MG)*	Lowest Annual Yield Above MAF (MG)*	1 Day 30 Year Low Flow, 1Q30 (MGD)
Rappahannock River at Warrenton (#01662000)	195	195	122	28,230	4,845 [1]	0.39
Rappahannock River at Remington (#01664000)	620	699	421	101,780	19,313 [1]	2.74
Thorton River at Laurel Hills (#01663000)	142	159	97	22,740	10,879 [2]	0.39
Hazel River at Rixeyville (#01663500)	287	338	212	48,061	10,933 [1]	1.00

* *Yield above mean annual flow available for diversion*
[1] *(April 1965-March 1966)*
[2] *(April 1954-March 1955), record for gauging station on the Thorton River ended in Sept. 1956*

Correlation Of The Stream Flow Data

The gauging station records were used to estimate the stream flow at each reservoir and river diversion. The gauge data was adjusted using an area ratio to account for differences in the watershed area at the gauge station and the reservoir diversion. The area ratio was also used to fill in the gaps in the record at some of the stations. For example, the data from the Hazel River gauging station was moved upstream to the Thorton River Gauging station to fill in the gaps in time. The data from the Remington gauging station on the Rappahannock River was moved upstream to the gauging station at Warrenton to fill in gaps in that data. The formula used was:

$$Q_j = Q_i\{A_j/A_i\}^x$$

Where:

Q	=	daily average stream flow at point in stream (cfs)
A	=	drainage area to point in stream (mi^2)
i	=	point at which full data record is known
j	=	point at which daily average stream flow is to be determined
x	=	experimentally determined exponent

The selection of the exponent was based upon a statistical comparison of calculated stream flows with recorded stream flows. In *USGS Water-Supply Paper 2374, Low-Flow Characteristics of Streams in Virginia,* an exponent of 1.2 was determined to most accurately predict low flows. In *USGS, Water-Resources Investigation Report 94-4148, Methods for Estimating the Magnitude and Frequency of Peak Discharges of Rural, Unregulated Streams in Virginia,* a value of 0.7 was determined to most accurately predict peak flows. A range of exponent values, from 0.7 to 1.2, was statistically analyzed for manipulating the data available for use. Independent studies were done for moving data up the Rappahannock River and for moving data from the Hazel to the Thorton River. In both cases, an exponent value of 0.7 was chosen with greater that 95 percent confidence. This makes sense in light of the fact that this study is interested in capturing the peak river discharges. An exponent of 1.0 was used for the watershed areas providing direct inflow to the reservoirs to account for the small size of these watersheds relative to the drainage area to the gauging station.

Reservoir Operation

The model generated to study reservoir yield had the following features:

- Water was only pumped from the source river in cases where the mean daily flow exceeded the mean annual flow. The amount of water pumped was also limited by the pump capacity. In addition, the first day of flow after a storm event was not pumped into the reservoir in an attempt to limit water quality issues.

- Seepage through the earthen dam was determined based upon calculations in the Appendix.
- The net evaporation was determined to be due to evaporation (as found in *the U.S. Department of Commerce, Weather Bureau, Technical Paper No. 37, Evaporation Maps for the United States*) minus the precipitation (as found in NOAA records for precipitation). The seasonal dependence of evaporation and precipitation was factored into the model. Additionally, for reservoirs with large surface areas the evaporation rates were calculated to vary with varying surface areas. For reservoirs with smaller surface areas, the evaporation rates were only varied with season.
- Each of the proposed reservoirs had a local watershed that fed directly into the reservoir. The flow into the reservoir from its local watershed was calculated based upon the area of the local watershed as described in the section on stream flow correlation.
- The volume in the reservoir was never allowed to go below 10 percent of the normal pool volume.

A copy of representative model results is included in Appendix A.

3. SCHEMATIC DAM AND RESERVOIR LAYOUT

The dams investigated in this study would be greater than 25 feet in height and 50 acre feet in capacity. Therefore, the dams would be regulated under the Virginia Dam Safety Act. The estimated construction costs in this study are based on structures that would meet the requirements of the Virginia Impounding Structures Regulations (Regulations). A typical section for a zoned earth embankment, which conforms to the Regulations, is shown in Figure 8. The design would include a cut-off trench, clay core, chimney drain, and toe drains. The crest width would range from 20 to 22 feet and the side slope would be 3.5:1 (horizontal:vertical). The soils available for the dam embankment would be predominantly low strength mica silts, therefore, the side slopes of the dam would be relatively flat. The dams would have principal spillways designed to handle the 100-year flood and emergency spillways designed for the 0.5 Probable Maximum Flood (0.5 PMF). The principal spillways for Sites 3, 7, and 13 would consist of rectangular concrete towers (drop

spillways) and concrete outlet pipes. Site 10 has a large drainage area that would require a concrete chute spillway 100 feet in width. The emergency spillways for all sites would consist of a trapezoid channel with riprap erosion protection and a concrete crest sill. The reservoir layouts showing the limits of the maximum pool for each reservoir are found in Figure 2.

4. DIVERSION PUMPING FACILITIES

The pumping facilities would be used to divert water from the main stem of the river to the proposed reservoir site. The diversion pump facilities would be required at Site No. 7 (Beaverdam Run) and Site No. 13 (Mill Run) because these sites have small watershed areas. Sites No. 3 and No. 10 have large watershed areas, and were evaluated both with and without the pumping.

The pumping facilities would consist of the river intake, pump station, transmission piping to the reservoir, and the electrical service for the pumps. The operation of the pumps would be limited to river flows greater than the MAF. The flow duration curves in Figure 7 show that the pumps could operate less than 32 percent of the time during an average year. This means the pumps would have to transfer a large amount of flow during a short period of time to fill the reservoir. The pump station would have four pump units with a total capacity of 70 to 90 MGD. These are very large pumps but they would only be able to capture about 7 to 20 percent of the average river yield above MAF.

The river intake would consist of multiple wedgewire tee screens with compressed air backwash cleaning systems. The pump station would include a wet well, four vertical turbine pumping units, discharge piping, pump control valves, pump circuits, and electrical controls. The pump units would be housed in a reinforced concrete structure located above the 100-year flood. The transmission pipes from the pump station to the reservoir would consist of two 42-inch concrete cylinder or welded steel pipelines. The duplex pipelines would permit control of velocities in the pipes for all flow conditions and would allow continued operation in the event one of the pipelines is out of service for repair.

5. PERMITTING

Permits will be required for the construction of new dams and the withdrawal of surface water using new diversion facilities. The regulatory agencies include the Corps of Engineers, the Virginia Department of Environmental Quality (VDEQ), the Virginia Marine Resources Commission (VMRC), and the Virginia Dam Safety Office. The permits for the Corps, the VDEQ, and the VMRC can be obtained through a joint permit process administered by the State. The joint permit process requires a single permit application for all three agencies. Sometimes, the agencies waive the requirement for the permits; however, the size and complexity of the projects described in this report would probably require an individual permit from each agency. A 30-day public notice and comment period will probably be required for these projects. One year should be allowed to complete the permit process. The permits are described below and referenced to the applicable improvement alternative.

Corps of Engineers 404 Permit

The 404 permit is required for the placement of fill material into the waters of the United States. The definition of the waters of the United States would include the tributaries of the Rappahannock River such as Beaverdam Run, Mill Run, Muddy Run, and Indian Run.

Virginia Department of Environmental Quality (VDEQ) Water Protection Permit

The Water Protection Permit is required to ensure the water quality in the state is not adversely impacted by the project (401 certification). The Water Protection Permit will establish surface water withdrawal criteria and downstream release requirements.

Virginia Marine Resources Commission (VMRC)

The VMRC requires a permit for encroachment on streambeds which are considered to be the property of the State.

Virginia Department of Soil and Water Conservation - Dam Safety

The dam safety section requires a permit for construction and operation of dams greater than 25 feet in height and 50 acre feet (16.3 MG) in capacity. The design and construction of the dam must conform to approved standards. The spillway size is determined by an evaluation of the downstream hazard which would occur if the dam failed. The dams described in this report would probably be Class II Medium size impounding structures. The Class II designation means there is a possible loss of life and appreciable property damage in the event of the failure of the dam. The spillways for the Class II Medium dams must be designed for the 0.5 PMF or 1.0 PMF depending on the downstream hazard.

Other

Permits will be required for erosion and sedimentation control and construction of pipelines across public right of ways.

RECOMMENDATIONS

The four alternatives presented in this report are feasible and merit further detail. Extended analysis should include a more detailed geotechnical assessment of the sites and a detailed evaluation of property acquisition, relocation costs, and raw water delivery costs via pumping and pipeline. These costs added to those contained in this study would enable a more thorough evaluation of the actual feasibility.

Based on cost efficiency, reservoir site number 10 with no pumping has the lowest cost per unit of yield. Reservoir site number 3 with pumping generates the largest yield, but has the second highest cost per unit yield.

Property acquisition is a major factor to be considered in the selection of a suitable site. At the current dam elevation, reservoir 3 encroaches on approximately 64 land parcels in a residential neighborhood. The number of properties effected could be minimized by adjusting the dam height. Reservoir site number 7 impacts the fewest number of land parcels.

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The distance from the reservoir to the treatment plant and the point of distribution will determine the raw water delivery cost for pumping and pipelines. The reservoir site closest to the U.S. 29 corridor is number 10. Reservoir site numbers 3, 7, and 13 are about equally distant from the U.S. 29 corridor.

A final factor to be considered is the environmental impact of the proposed reservoirs due to inundation of protected wetlands. The off-channel reservoirs with smaller watersheds (for example, reservoir number 13) will have less environmental impact than the on-channel reservoirs with extensive watersheds (for example, reservoir number 10).

Thank you for this opportunity to assist you. Please call if you have any questions regarding these findings.

Sincerely,

WILEY & WILSON

A. Redding

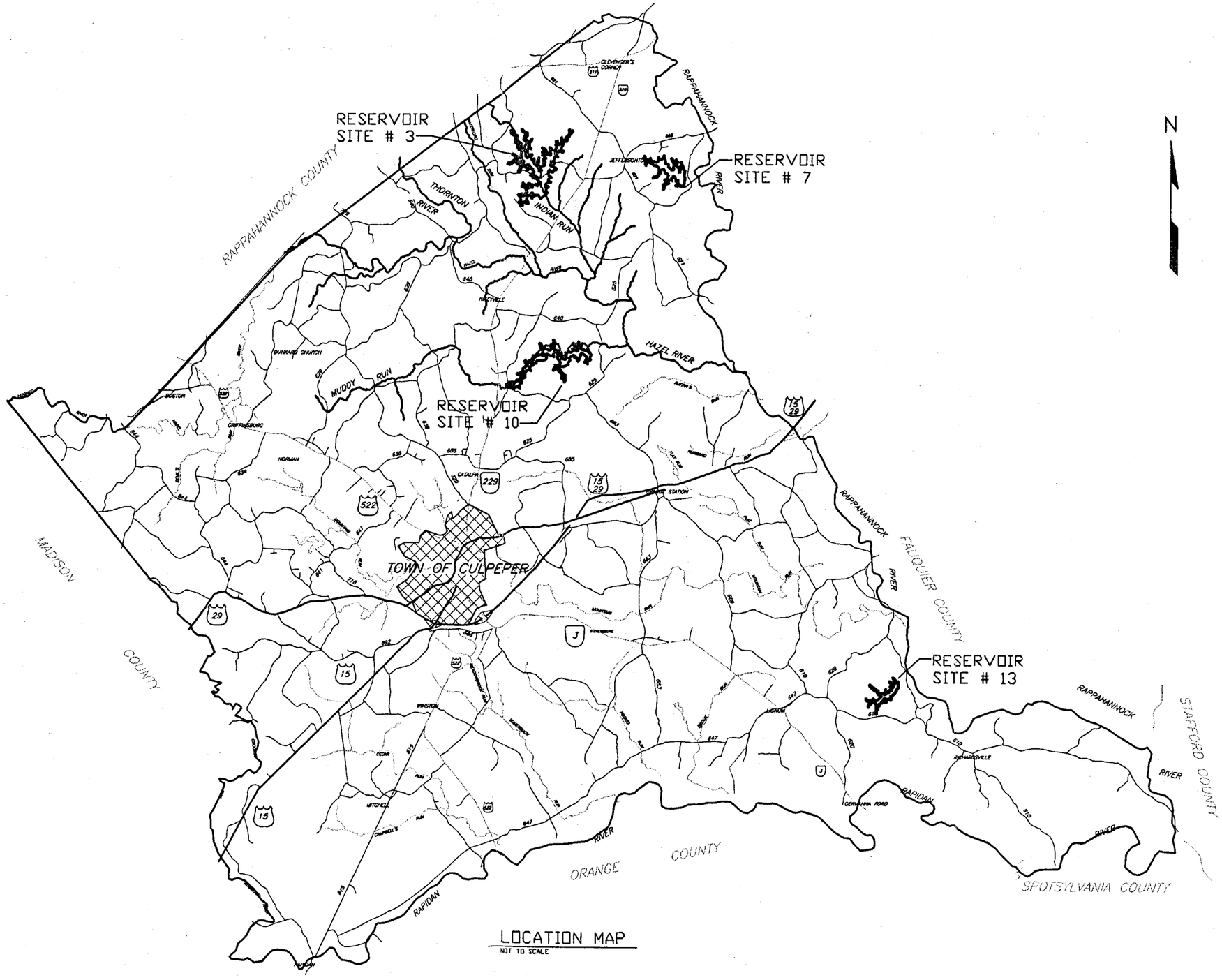
Andria Redding, EIT
Design Engineer

Walter E Hancock

Walter E. Hancock, Jr., P.E.
Vice President

John D Allis Jr

John D. Allis, P.E.
Senior Engineer



LOCATION MAP
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OVERLAY CONTROL					
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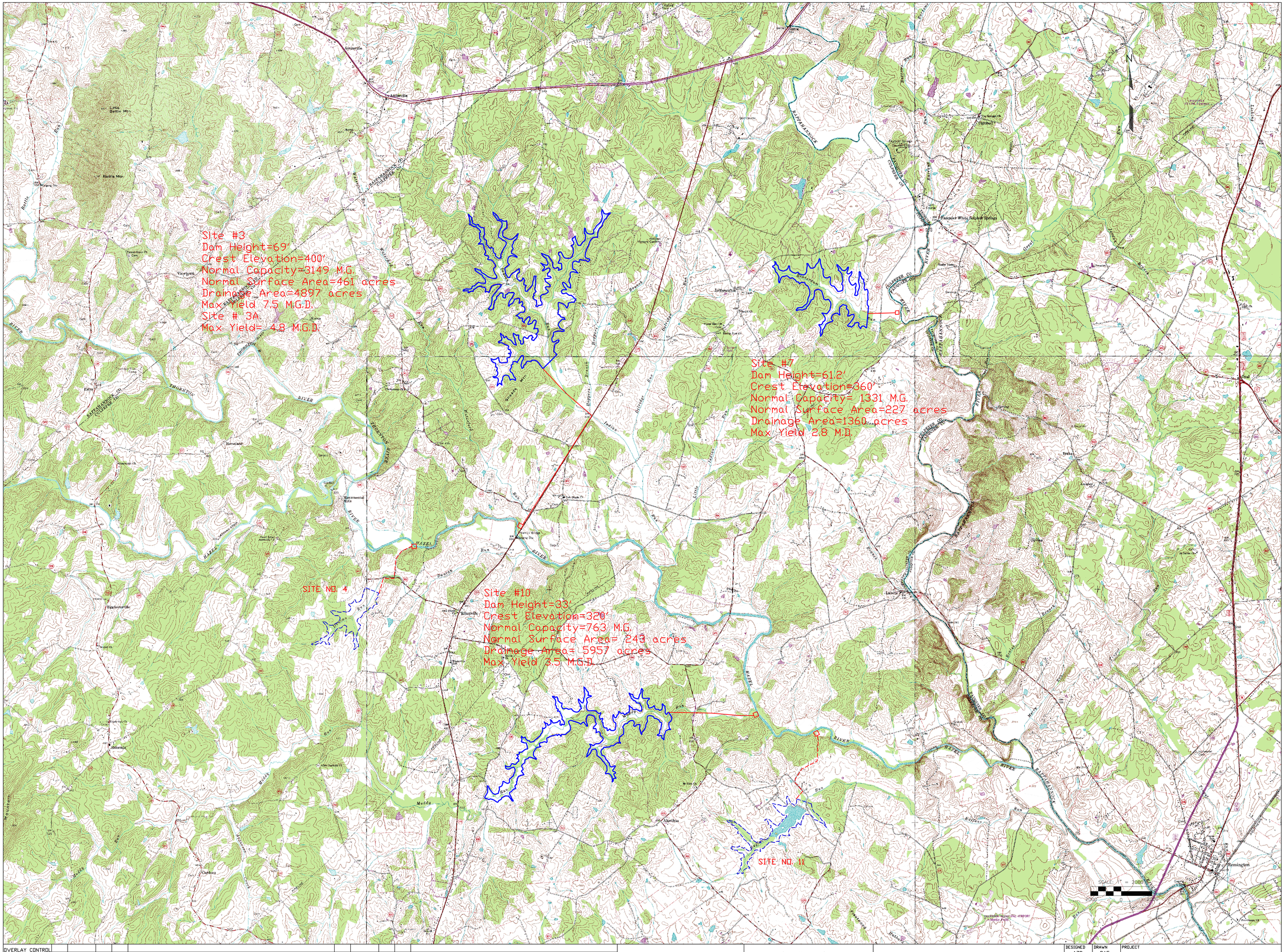
APPROVED	FILE NO.	REFERENCE
COMM. NO. 200156.00		TITLE: Figure 1: Study Area Map
DATE		DWG. NO. / SHEET NO. / REV.



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COMM. NO. 200156.00		TITLE	FIGURE 2A: RESEVOIR LOCATION MAP
DATE 03-16-01		DWG. NO. C-1	SHEET NO. 1 OF 2 REV. 0

SITE NO. 4

Site #10
Dam Height=33'
Crest Elevation=320'
Normal Capacity=763 M.G.
Normal Surface Area= 243 acres
Drainage Area= 5957 acres
Max Yield 3.5 M.G.D.

SITE NO. 11

SITE NO. 12

Site #13
Dam Height=67.1'
Crest Elevation=287'
Normal Capacity=705 M.G.
Normal Surface Area=115 acres
Drainage Area=1706 acres
Max Yield 2.3 M.D.

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APPROVED	FILE NO.	REFERENCE: CIVIL
COMM. NO. 200156.00		TITLE: FIGURE 2B: RESEVOIR LOCATION MAP
DATE 03-16-01	DWG. NO. C-2	SHEET NO. 2 OF 2 — REV. 0

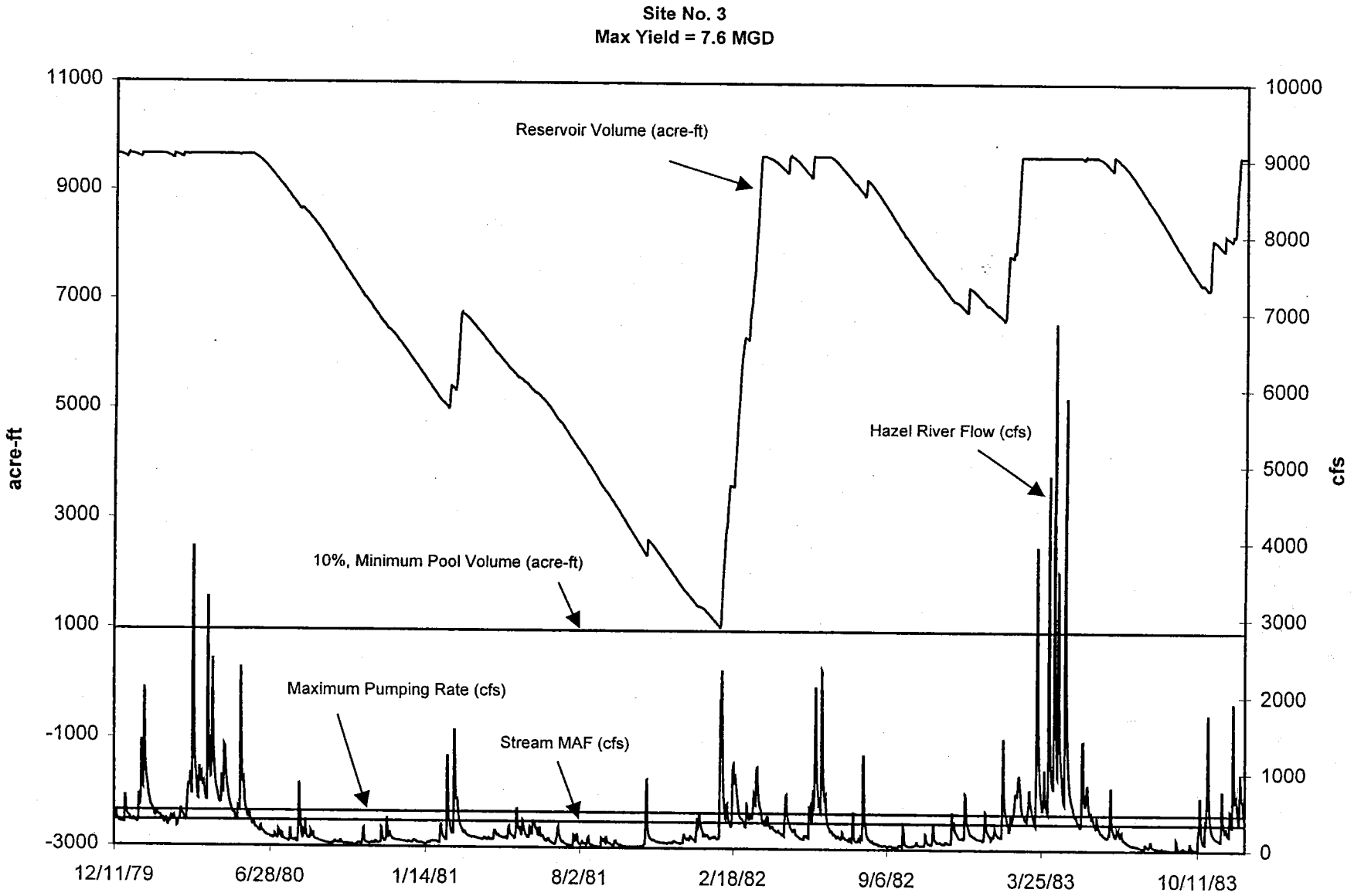

Site No. 3
Max Yield = 7.6 MGD
11000
9000
7000
5000
3000
1000
-1000
-3000
acre-ft
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
cfs
Reservoir Volume (acre-ft)
Hazel River Flow (cfs)
10%, Minimum Pool Volume (acre-ft)
Maximum Pumping Rate (cfs)
Stream MAF (cfs)
12/11/79
6/28/80
1/14/81
8/2/81
2/18/82
9/6/82
3/25/83
10/11/83

Figure 3.

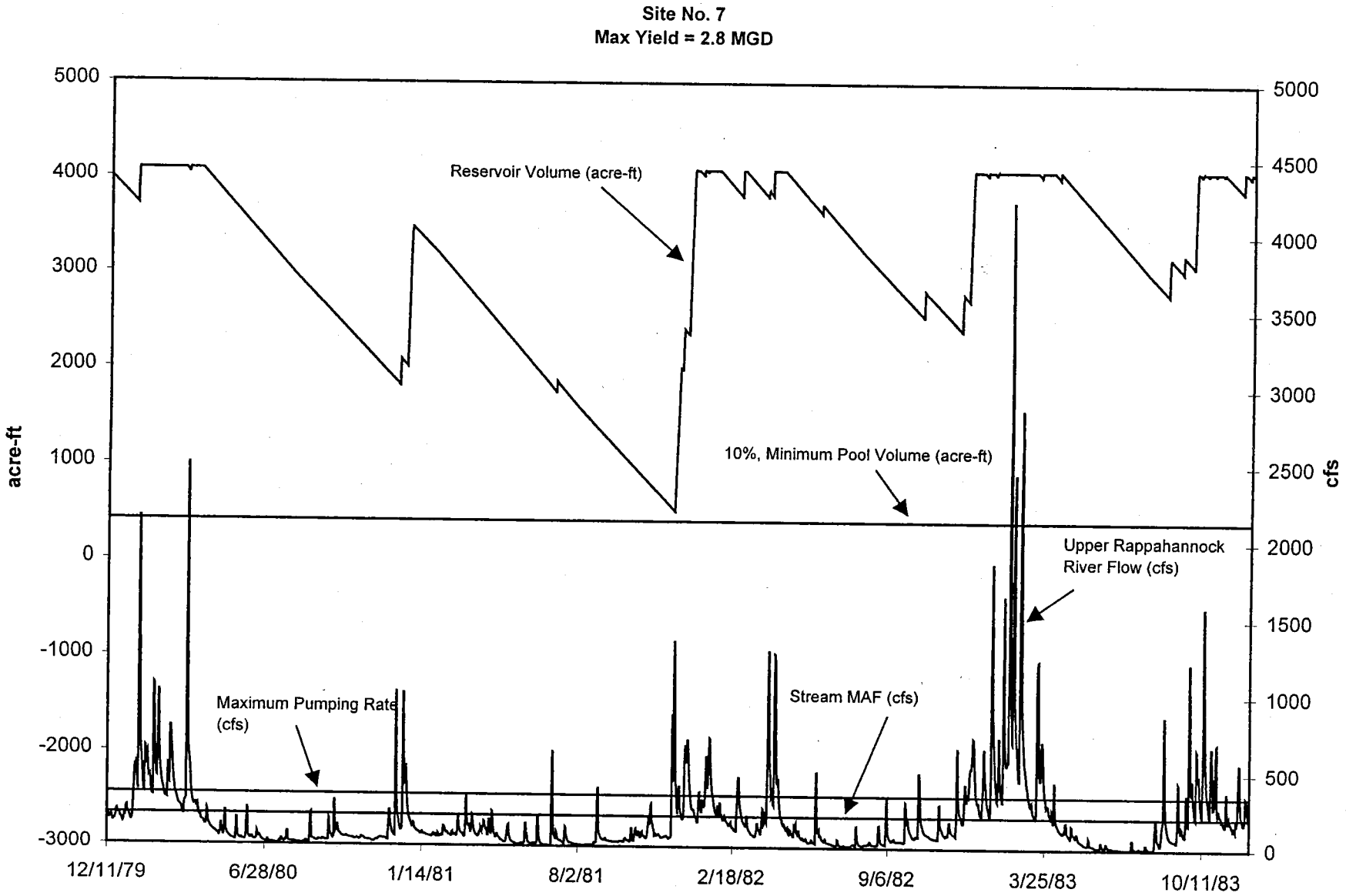

Site No. 7
Max Yield = 2.8 MGD
acre-ft
cfs
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
4500
3500
2500
1500
500
Reservoir Volume (acre-ft)
10%, Minimum Pool Volume (acre-ft)
Upper Rappahannock River Flow (cfs)
Maximum Pumping Rate (cfs)
Stream MAF (cfs)
12/11/79
6/28/80
1/14/81
8/2/81
2/18/82
9/6/82
3/25/83
10/11/83

Figure 4.

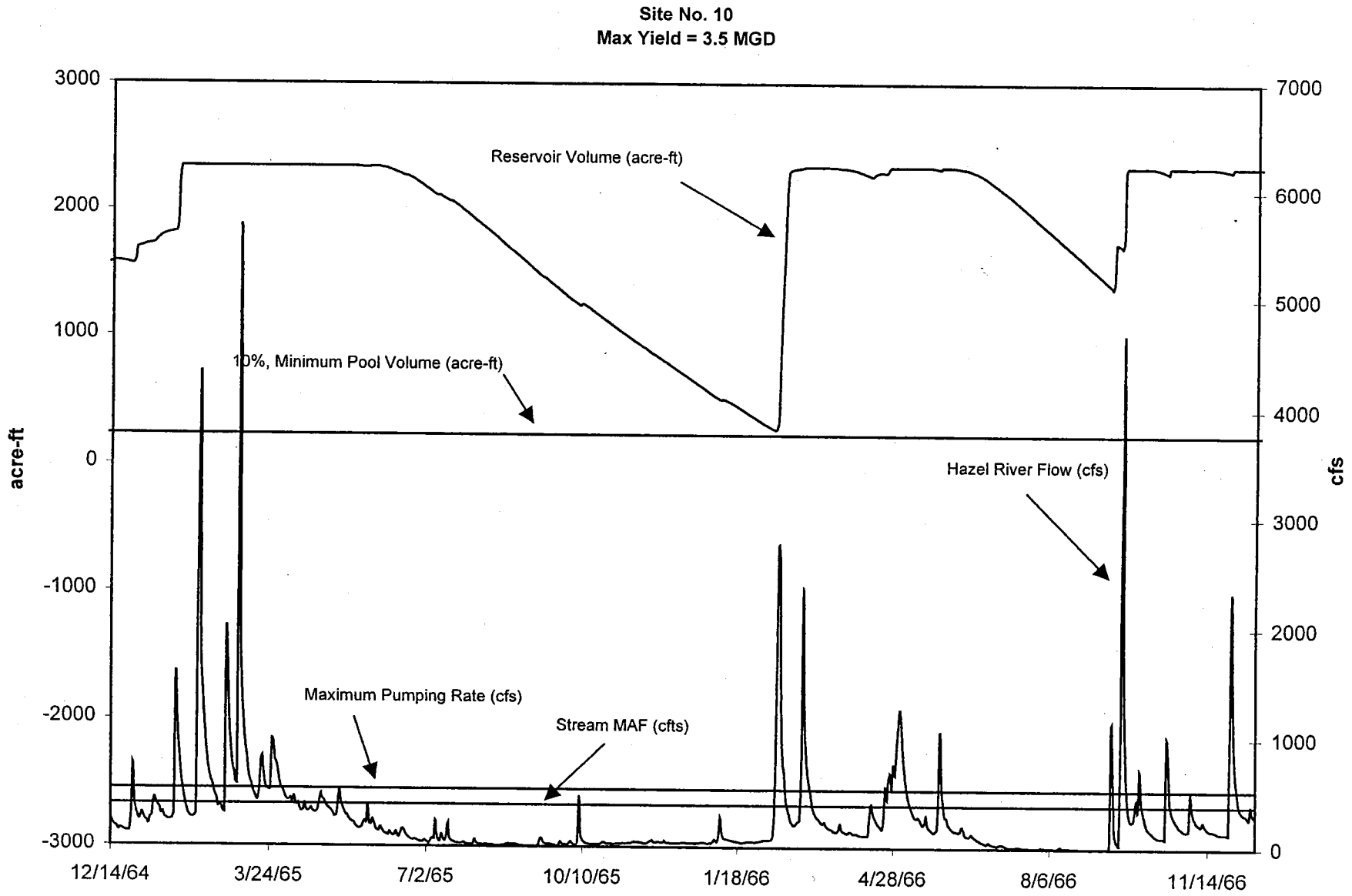

Site No. 10
Max Yield = 3.5 MGD
Reservoir Volume (acre-ft)
10%, Minimum Pool Volume (acre-ft)
Hazel River Flow (cfs)
Maximum Pumping Rate (cfs)
Stream MAF (cfts)
acre-ft
cfs
3000
2000
1000
0
-1000
-2000
-3000
7000
6000
5000
4000
3000
2000
1000
0
12/14/64
3/24/65
7/2/65
10/10/65
1/18/66
4/28/66
8/6/66
11/14/66

Figure 5.

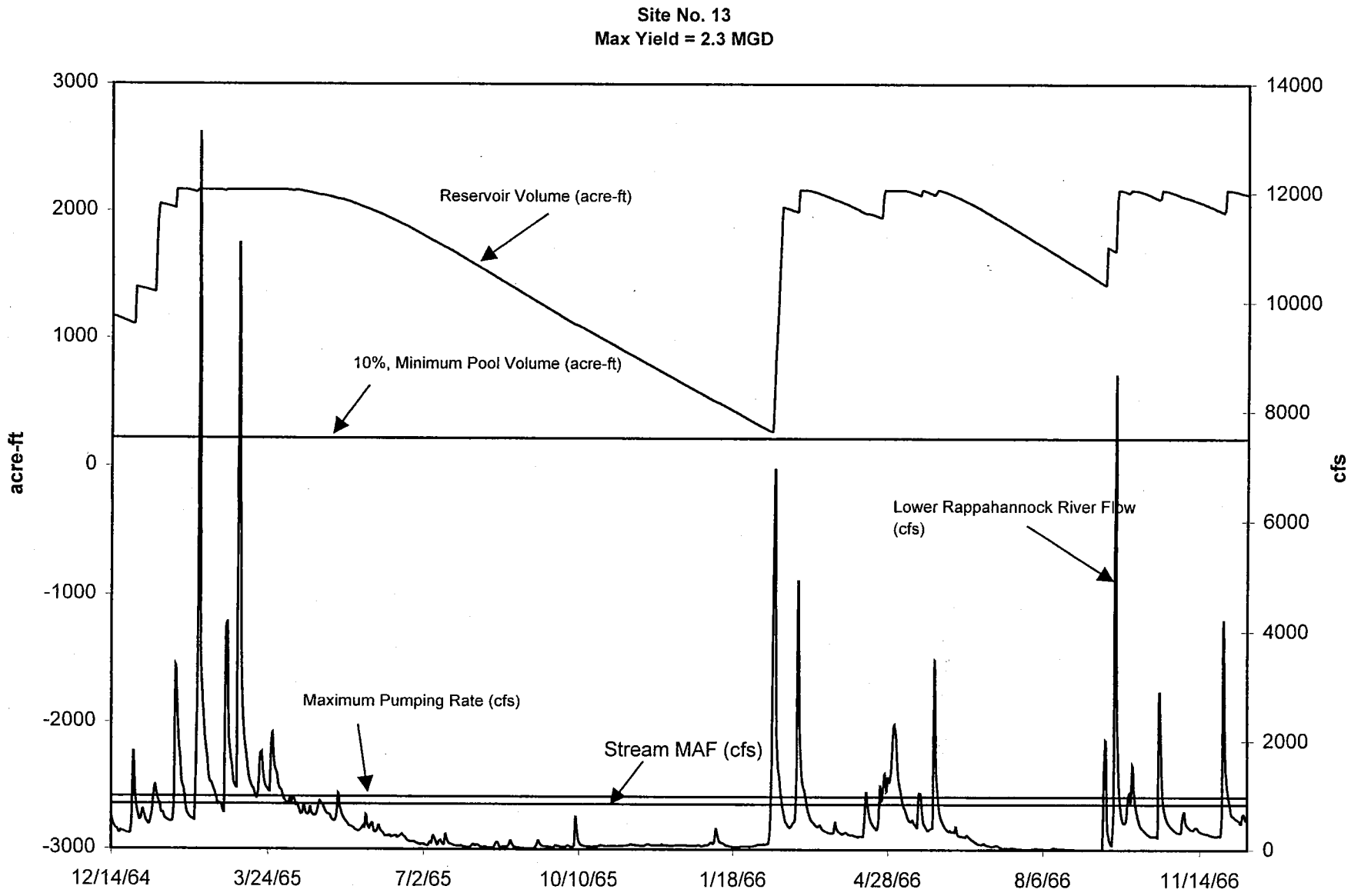

Site No. 13
Max Yield = 2.3 MGD
3000
2000
1000
0
-1000
-2000
-3000
acre-ft
14000
12000
10000
8000
6000
4000
2000
0
cfs
Reservoir Volume (acre-ft)
10%, Minimum Pool Volume (acre-ft)
Lower Rappahannock River Flow (cfs)
Maximum Pumping Rate (cfs)
Stream MAF (cfs)
12/14/64
3/24/65
7/2/65
10/10/65
1/18/66
4/28/66
8/6/66
11/14/66

Figure 6.

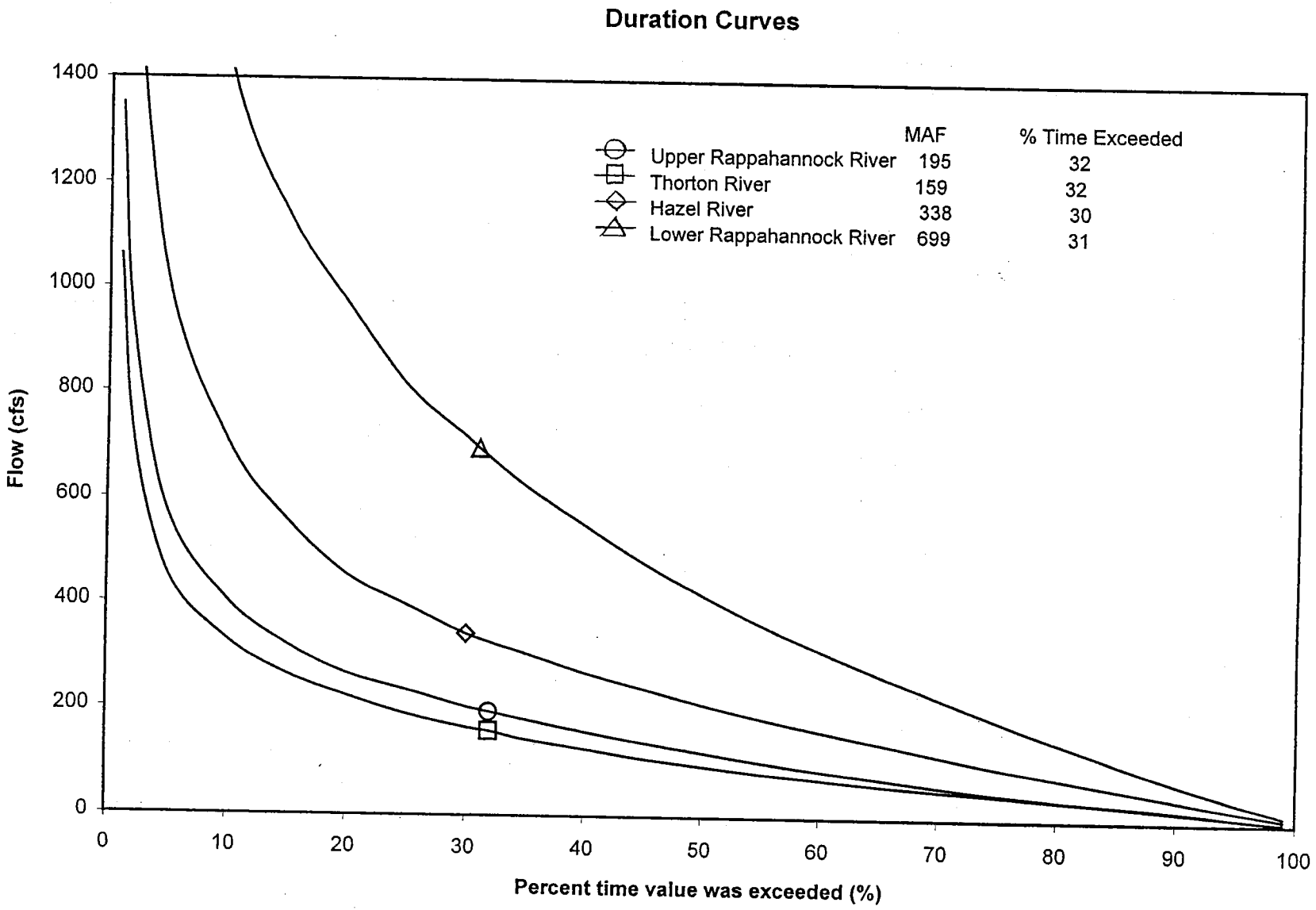
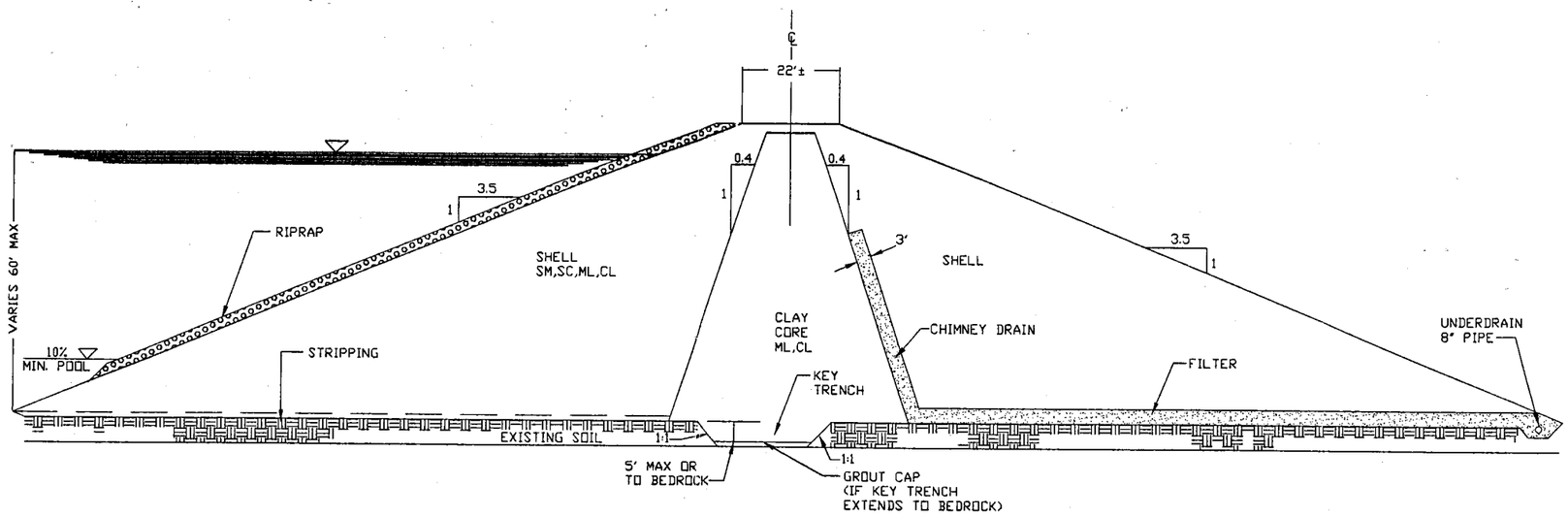

Duration Curves
MAF
% Time Exceeded
Upper Rappahannock River 195 32
Thorton River 159 32
Hazel River 338 30
Lower Rappahannock River 699 31
Flow (cfs)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100
Percent time value was exceeded (%)

Figure 7



TYPICAL SECTION
ZONED EARTH EMBANKMENT

NO SCALE

OVERLAY CONTROL	REV.	DATE	BY	APP.	DESCRIPTION

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COMM. NO. 200156.00		TITLE: FIGURE: 8 TYPICAL SECTION EARTH DAM
DATE	DWG. NO.	SHEET NO. / REV.

TAB

Culpeper Reservoir Study

Reservoir #:	13			
Reservoir drainage area (acres):	1706.0			
Base Gauge station used:	# 1664000			
gauge station drainage area (acres):	396800			
corrected inlet point drainage area (acres):	504492			
flow correction factor (CF)	1.183			
inlet MAF (cfs)	826.9419			
watershed flow correction factor	0.004299			
max reservoir vol (acre-ft):	2165.2			
average reservoir area (acre-ft):	115.1			
average reservoir volume (acre-ft)	2165.2			

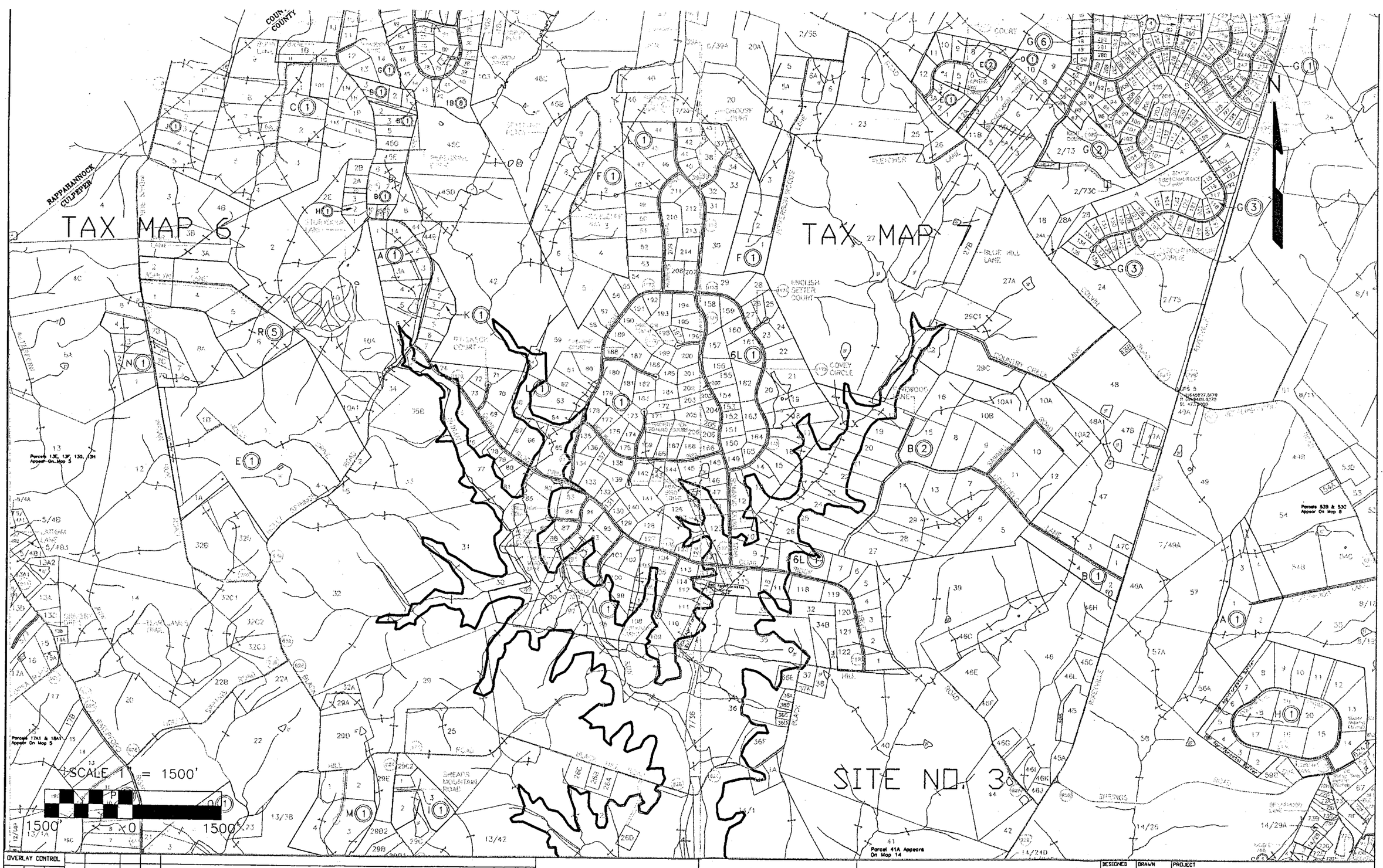
			(acre-ft/day)
Seepage (cfs):	0.09	0.178512397	
ET:	May - Oct	Nov - April	
"/day	0.034	-0.012	
acre-ft/day	0.33	-0.1151	
Individual Pump Capacity (cfs):	35.00	(acre-ft/day)	69.42
Demand	(MGD)	(acre-ft/day)	
	2.3	7.06	

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
month	day	year	date	Recorded Gauge Station Flow (cfs)	Corrected Flow = gauge station flow x CF (cfs)	Available Flow = Corrected Flow - Inlet MAF (cfs)	Pump 1 (cfs)	Pump 2 (cfs)	Pump 3 (cfs)	Pump 4 (cfs)	Sum of Pumped water (acre-ft/day)	Flow to Avoid First Flush (acre-ft/day)	Seepage (acre-ft/day)	Evapotranspiration (acre-ft/day)	Flow from Reservoir's own watershed (acre-ft/day)	Demand (acre-ft/day)	Initial Vol (acre-ft)	Final Vol (acre-ft)	Over Flow (acre-ft)
10	1	42	10/1/42	720	852	25	25	0	0	0	50	50	0.18	-0.12	6.14	7.06	2165	2165	49
10	2	42	10/2/42	600	710	0	0	0	0	0	0	0	0.18	-0.12	5.12	7.06	2165	2163	0
10	3	42	10/3/42	550	651	0	0	0	0	0	0	0	0.18	-0.12	4.69	7.06	2163	2161	0
10	4	42	10/4/42	490	580	0	0	0	0	0	0	0	0.18	-0.12	4.18	7.06	2161	2158	0
10	5	42	10/5/42	470	556	0	0	0	0	0	0	0	0.18	-0.12	4.01	7.06	2158	2155	0
10	6	42	10/6/42	460	544	0	0	0	0	0	0	0	0.18	-0.12	3.92	7.06	2155	2152	0
10	7	42	10/7/42	400	473	0	0	0	0	0	0	0	0.18	-0.12	3.41	7.06	2152	2148	0
10	8	42	10/8/42	360	426	0	0	0	0	0	0	0	0.18	-0.12	3.07	7.06	2148	2144	0
10	9	42	10/9/42	320	379	0	0	0	0	0	0	0	0.18	-0.12	2.73	7.06	2144	2139	0
10	10	42	10/10/42	290	343	0	0	0	0	0	0	0	0.18	-0.12	2.47	7.06	2139	2135	0
10	11	42	10/11/42	260	308	0	0	0	0	0	0	0	0.18	-0.12	2.22	7.06	2135	2130	0
10	12	42	10/12/42	230	272	0	0	0	0	0	0	0	0.18	-0.12	1.96	7.06	2130	2125	0
10	13	42	10/13/42	240	284	0	0	0	0	0	0	0	0.18	-0.12	2.05	7.06	2125	2120	0
10	14	42	10/14/42	7500	8873	8046	35	35	35	35	278	0	0.18	-0.12	63.96	7.06	2120	2165	289
10	15	42	10/15/42	36000	42589	41762	35	35	35	35	278	278	0.18	-0.12	307.00	7.06	2165	2165	578
10	16	42	10/16/42	64000	75714	74887	35	35	35	35	278	278	0.18	-0.12	545.78	7.06	2165	2165	816
10	17	42	10/17/42	14000	16562	15736	35	35	35	35	278	278	0.18	-0.12	119.39	7.06	2165	2165	390

Appendix A - Model Documentation

Reservoir #	
Reservoir drainage area	Manually determined
Base Gauge station used	Closest USGS gauge station to reservoir inlet
Gauge station drainage area	Published USGS data
Corrected inlet point drainage area	Drainage area to reservoir inlet point
Flow correction factor (CF)	Determined by the method of ratios of areas, equal to (corrected inlet point drainage area/gauge station drainage area)$^{0.7}$
Inlet MAF	Equal to the gauge station MAF multiplied by the correction factor
Watershed flow correction factor	Determined by method of ratios of areas with an exponent = 1
Maximum reservoir vol (acre-feet)	Determined from stage storage curve
Average reservoir area (acre)	Determined from stage storage curve with 7 feet of freeboard below max water elevation
Average reservoir volume (acre-feet)	Determined from stage storage curve with 7 feet of freeboard below max water elevation
Seepage	Seepage through an earth filled dam as determined by the equations on the attached sheet
ET	Evapotranspiration as determined by the method on the attached sheet
Individual pump capacity	Determined by considering the length of diversion and elevation head to be overcome by pump
Demand	Varied to achieve the maximum yield. Criteria used for determining max yield was that the water level in the reservoir was to never go below 10 percent of the average reservoir volume.

Column	Description
1	Month
2	Day
3	Year
4	Date
5	Average daily flow at closest gauge station from USGS website
6	Average daily flow at diversion point obtained by spatial manipulation of USGS data by the ratio of areas method as previously discussed
7	Available flow at diversion point (equal to the average daily flow at the diversion point minus the MAF at the diversion point)
8	Pump control statements: each of the four pumps will turn on in sequence to capture the available flow
9	
10	
11	
12	Total that can be pumped during the day (equal to sum of pump control statements)
13	Control statement to delay the start of pumping by a day after available flow rises above the inlet MAF
14	Daily seepage through the dam
15	Daily net evapotranspiration from the reservoir surface
16	Daily flow from reservoirs own watershed
17	Daily demand which is varied based upon the input in the area above
18	Reservoir volume at the beginning of the day (equal to the reservoir volume at the end of the previous day)
19	Reservoir volume at the end of the day equal to columns (13+16)-(14+15+17)
20	Overflow in the case that the final reservoir volume is greater than the maximum reservoir volume

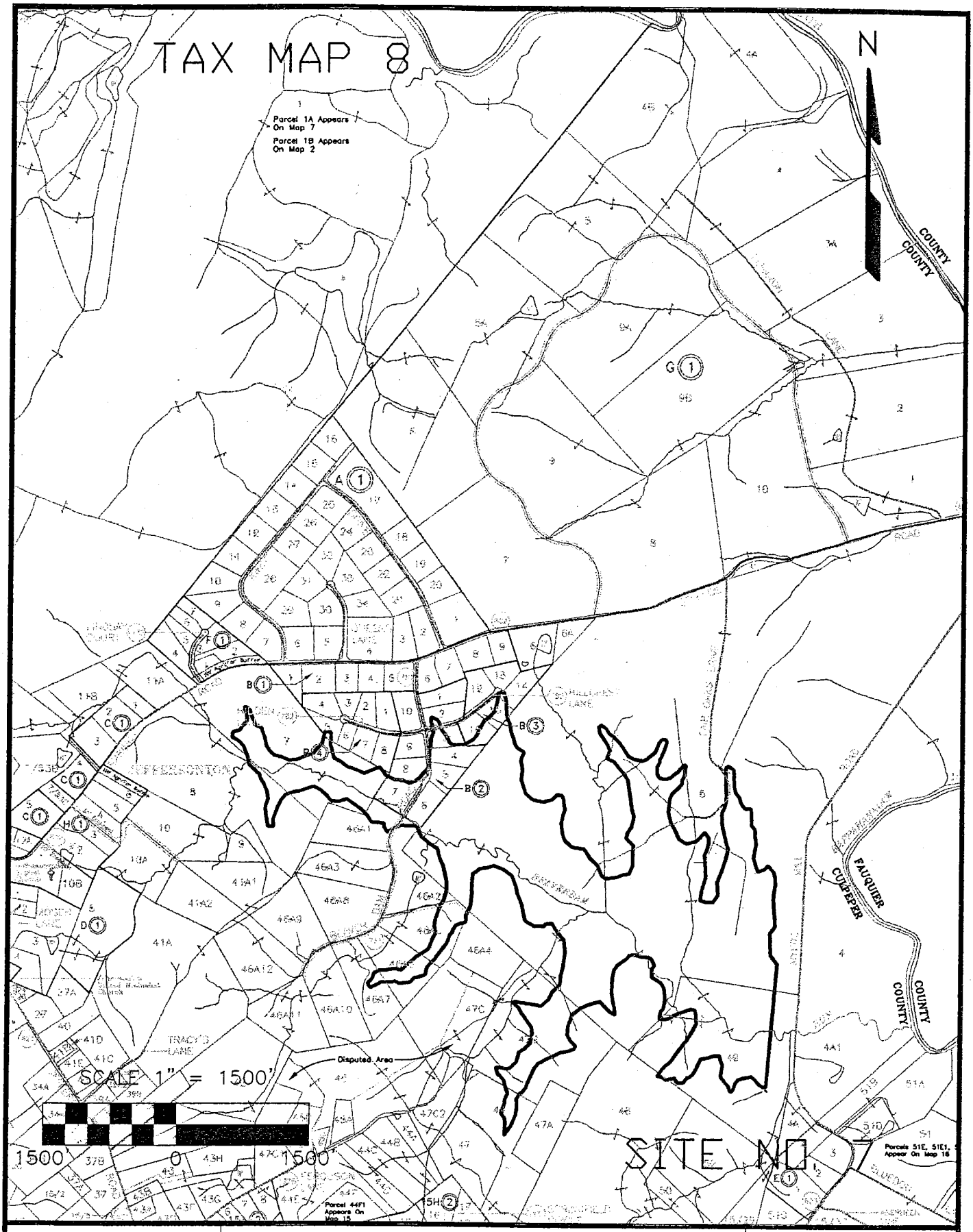


OVERLAY CONTROL				
REV.	DATE	BY	APP.	DESCRIPTION

Wiley & Wilson
ARCHITECTS ENGINEERS PLANNERS

A PROFESSIONAL CORPORATION
2310 LANGHORNE ROAD LYNCHBURG, VIRGINIA
24505-0877

DESIGNED	DRAWN	PROJECT: CULPEPER RESERVOIR STUDY
CHECKED	REVIEWED	
APPROVED	FILE NO.	REFERENCE
COMM. NO. 200156.00		TITLE: Site No. 7 Property Impact
DATE		DWG. NO. / SHEET NO. / REV.



DATE:	SITE NO. 7 PROPERTY IMPACT	
DRAWN BY:		NUMBER:
APPROVED BY:	WILEY & WILSON, INC.	SCALE:

TAX MAP 21

TAX MAP 22

SITE NO. 10

SCALE 1" LINE = 1500'

1500' 0 1500'

Parcel 7 Appears On Map 32

Parcels 14A, 14C, 14D Appear On Map 22

Parcel 63A Appears On Map 32

Parcel 95A Appears On Map 31

Parcels D(1) 1-5 Appear On Map 32

OVERLAY CONTROL

REV.	DATE	BY	APP.	DESCRIPTION

Wiley & Wilson
ARCHITECTS ENGINEERS PLANNERS
A PROFESSIONAL CORPORATION
2310 LANGHORNE ROAD LYNCHBURG, VIRGINIA
24505-0877

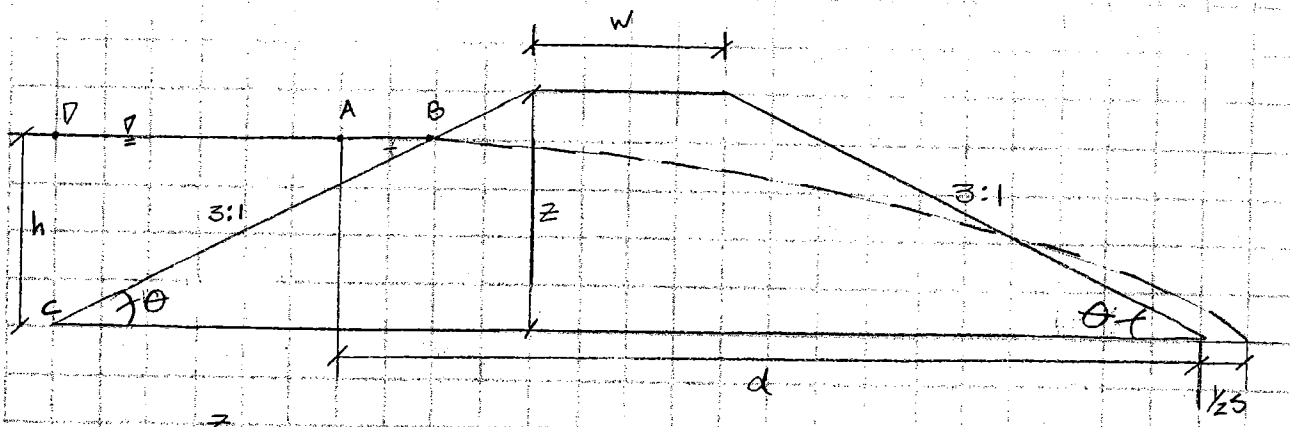
DESIGNED	DRAWN	PROJECT: CULPEPER RESERVOIR STUDY
CHECKED	REVIEWED	
APPROVED	FILE NO.	REFERENCE
CONN. NO. 200156.00		TITLE: Site No. 10 Property Impact
DATE	DWG. NO.	SHEET NO. / REV.

Appendix C.

Wiley & Wilson Architects . Engineers . Planners

DESIGN CALCULATIONS

SEEPAGE ESTIMATE:



$w = \frac{z}{5} + 10$ $\theta = \tan^{-1} 1/3$

3

$\overline{BC} = \sqrt{h^2 + (3h)^2}$

$\overline{AB} = 0.3\overline{BC}$

$d = w + \frac{z}{\tan\theta} - \frac{h}{\tan\theta} + \overline{AB} = w + 3z - 3h + \overline{AB}$

$S = \sqrt{d^2 + h^2} - d$

$Q = K S L$

$K = 1E\text{-}5$ ft/sec

$L =$ site specific

Net ET = Evap - Precip

ET estimate: (evapotranspiration) Precip

annual ET in Culpeper = 36"

% of annual from May - Oct = 70% = 25.2" — 19"

" " " Nov - April = 30% = 10.8" — 13"

∴ from May - Oct ⇝ 0.034 /day

Nov - Apr ⇝ -0.012 "/day

Project Culpeper Reservoir Comm. No. 200156.00

By A. Redding Date Sept 7, 2000 Sheet No.

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 3
NEW RESERVOIR AT INDIAN RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	7025	C.Y.	$4.00	$28,099
4. CLEAR RESERVOIR SITE	373	AC.	$1,800.00	$671,400
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	6031	C.Y.	$6.00	$36,185
7. EMERGENCY SPILLWAY CREST SILL	119	C.Y.	$200.00	$23,704
8. GROUT CAP	482	C.Y.	$120.00	$57,897
9. EMBANKMENT	377808	C.Y.	$4.00	$1,511,233
10. RIPRAP	10426	C.Y.	$40.00	$417,037
11. DROP SPILLWAY	345	C.Y.	$400.00	$138,074
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	50	L.F.	$160.00	$8,000
15. 60 INCH OUTLET PIPE	470	L.F.	$375.00	$176,250
15. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	3319	C.Y.	$40.00	$132,741
17. FILTER BLANKET & CHIMNEY DRAIN	21093	C.Y.	$20.00	$421,865
18. TOE DRAIN	1303	L.F.	$20.00	$26,053
20. SEEDING	11	AC	$2,500.00	$26,794
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	4600	L.F.	$60.00	$276,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
24. RIVER INTAKE PIPING AND SCREENS	1	L.S.	$125,000.00	$125,000
25. DIVERSION PUMP STATION	1	L.S.	$700,000.00	$700,000
26. 42 INCH DIVERSION PIPING	13200	L.F.	$500.00	$6,600,000
SUBTOTAL				$11,714,331
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$12,137,981

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$2,913,115
2. ENVIRONMENTAL MITIGATION	$606,899
TOTAL PROJECT COST	$15,051,097

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 3A, NO PUMPING
NEW RESERVOIR AT INDIAN RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	7025	C.Y.	$4.00	$28,099
4. CLEAR RESERVOIR SITE	373	AC.	$1,800.00	$671,400
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	6031	C.Y.	$6.00	$36,185
7. EMERGENCY SPILLWAY CREST SILL	119	C.Y.	$200.00	$23,704
8. GROUT CAP	482	C.Y.	$200.00	$96,494
9. EMBANKMENT	377808	C.Y.	$4.00	$1,511,233
10. RIPRAP	10426	C.Y.	$40.00	$417,037
11. DROP SPILLWAY STRUCTURE	345	C.Y.	$400.00	$138,074
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	50	L.F.	$160.00	$8,000
15. 60 INCH OUTLET PIPE	470	L.F.	$375.00	$176,250
15. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	3319	C.Y.	$40.00	$132,741
17. FILTER BLANKET & CHIMNEY DRAIN	21093	C.Y.	$20.00	$421,865
18. TOE DRAIN	1303	L.F.	$20.00	$26,053
20. SEEDING	11	AC	$2,500.00	$26,794
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	4600	L.F.	$60.00	$276,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
SUBTOTAL				$4,327,929
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$4,751,579

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$1,140,379
2. ENVIRONMENTAL MITIGATION	$237,579
TOTAL PROJECT COST	$5,891,958

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 7
NEW RESERVOIR AT BEAVERDAM RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	8661	C.Y.	$4.00	$34,645
4. CLEAR RESERVOIR SITE	133	AC.	$1,800.00	$239,400
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	10399	C.Y.	$6.00	$62,392
7. EMERGENCY SPILLWAY CREST SILL	41	C.Y.	$200.00	$8,296
8. GROUT CAP	832	C.Y.	$120.00	$99,827
9. EMBANKMENT	390364	C.Y.	$4.00	$1,561,456
10. RIPRAP	11394	C.Y.	$40.00	$455,759
11. DROP SPILLWAY	273	C.Y.	$400.00	$109,345
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	50	L.F.	$160.00	$8,000
15. 42 INCH OUTLET PIPE	439	L.F.	$200.00	$87,840
15. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	1082	C.Y.	$40.00	$43,265
17. FILTER BLANKET & CHIMNEY DRAIN	25223	C.Y.	$20.00	$504,470
18. TOE DRAIN	2246	L.F.	$20.00	$44,922
20. SEEDING	16	AC	$2,500.00	$40,253
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	1000	L.F.	$60.00	$60,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
24. RIVER INTAKE PIPING AND SCREENS	1	L.S.	$125,000.00	$125,000
25. DIVERSION PUMP STATION	1	L.S.	$700,000.00	$700,000
27. 42 INCH DIVERSION PIPING	1800	L.F.	$500.00	$900,000
SUBTOTAL				$5,422,870
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$5,846,520

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$1,403,165
2. ENVIRONMENTAL MITIGATION	$292,326
TOTAL PROJECT COST	$7,249,685

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 10
NEW RESERVOIR AT MUDDY RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	1174	C.Y.	$4.00	$4,698
4. CLEAR RESERVOIR SITE	325	AC.	$1,800.00	$585,000
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	1889	C.Y.	$6.00	$11,334
7. EMERGENCY SPILLWAY CREST SILL	130	C.Y.	$200.00	$26,074
8. GROUT CAP	151	C.Y.	$120.00	$18,135
9. EMBANKMENT	33904	C.Y.	$4.00	$135,615
10. RIPRAP	1245	C.Y.	$40.00	$49,792
11. DROP SPILLWAY	118	C.Y.	$400.00	$47,052
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	270	L.F.	$220.00	$59,400
14. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
15. SERVICE SPILLWAY	2700	C.Y.	$250.00	$675,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	1882	C.Y.	$40.00	$75,289
17. FILTER BLANKET & CHIMNEY DRAIN	3290	C.Y.	$20.00	$65,799
18. TOE DRAIN	408	L.F.	$20.00	$8,161
20. SEEDING	3	AC	$2,500.00	$6,770
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	1000	L.F.	$60.00	$60,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
24. RIVER INTAKE PIPING AND SCREENS	1	L.S.	$125,000.00	$125,000
25. DIVERSION PUMP STATION	1	L.S.	$700,000.00	$700,000
26. 42 INCH DIVERSION PIPING	4320	L.F.	$500.00	$2,160,000
SUBTOTAL				$5,151,118
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$5,574,768

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$1,337,944
2. ENVIRONMENTAL MITIGATION	$278,738
TOTAL PROJECT COST	$6,912,713

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 10A, NO PUMPING
NEW RESERVOIR AT MUDDY RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	1174	C.Y.	$4.00	$4,698
4. CLEAR RESERVOIR SITE	173	AC.	$1,800.00	$311,400
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	1889	C.Y.	$6.00	$11,334
7. EMERGENCY SPILLWAY CREST SILL	130	C.Y.	$200.00	$26,074
8. GROUT CAP	151	C.Y.	$120.00	$18,135
9. EMBANKMENT	33904	C.Y.	$4.00	$135,615
10. RIPRAP	1245	C.Y.	$40.00	$49,792
11. DROP SPILLWAY	118	C.Y.	$400.00	$47,052
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	270	L.F.	$220.00	$59,400
14. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
15. SERVICE SPILLWAY	2700	C.Y.	$250.00	$675,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	1882	C.Y.	$40.00	$75,289
17. FILTER BLANKET & CHIMNEY DRAIN	3290	C.Y.	$20.00	$65,799
18. TOE DRAIN	408	L.F.	$40.00	$16,321
20. SEEDING	3	AC	$2,500.00	$6,770
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	1000	L.F.	$60.00	$60,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
SUBTOTAL				$1,900,679
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$2,324,329

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$557,839
2. ENVIRONMENTAL MITIGATION	$116,216
TOTAL PROJECT COST	$2,882,168

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION

CULPEPER COUNTY
RESERVOIR SITE STUDY
RECONAISSANCE LEVEL COST ESTIMATE - SITE NO. 13
NEW RESERVOIR AT MILL RUN
10/03/2000

A. CONSTRUCTION COST

	QUANTITY	UNIT	UNIT PRICE	COST
1. MOBILIZATION	1	L.S.	$150,000.00	$150,000
2. STREAM DIVERSION	1	L.S.	$45,000.00	$45,000
3. STRIP, STOCKPILE AND REPLACE TOPSOIL	3521	C.Y.	$4.00	$14,083
4. CLEAR RESERVOIR SITE	115	AC.	$1,800.00	$207,180
5. DEWATERING	1	EA.	$75,000.00	$75,000
6. CUT OFF TRENCH	3854	C.Y.	$6.00	$23,126
7. EMERGENCY SPILLWAY CREST SILL	107	C.Y.	$200.00	$21,333
8. GROUT CAP	308	C.Y.	$120.00	$37,002
9. EMBANKMENT	156230	C.Y.	$4.00	$624,922
10. RIPRAP	4505	C.Y.	$40.00	$180,219
11. DROP SPILLWAY	276	C.Y.	$400.00	$110,590
12. LOW LEVEL DRAIN INLET STRUCTURE	20	C.Y.	$400.00	$8,000
13. 36 INCH LOW LEVEL DRAIN PIPE	50	L.F.	$160.00	$8,000
15. 54 INCH OUTLET PIPE	443	L.F.	$320.00	$141,664
15. OUTLET STRUCTURE	25	C.Y.	$400.00	$10,000
16. EMERGENCY SPILLWAY EROSION PROTECTION	2805	C.Y.	$40.00	$112,187
17. FILTER BLANKET & CHIMNEY DRAIN	10359	C.Y.	$20.00	$207,183
18. TOE DRAIN	833	L.F.	$20.00	$16,651
20. SEEDING	6	AC	$2,500.00	$15,609
21. EROSION AND SEDIMENT CONTROL	1	L.S.	$30,000.00	$30,000
22. ACCESS ROAD	1000	L.F.	$60.00	$60,000
23. SOIL TESTING	1	L.S.	$20,000.00	$20,000
24. RIVER INTAKE PIPING AND SCREENS	1	L.S.	$125,000.00	$125,000
25. DIVERSION PUMP STATION	1	L.S.	$700,000.00	$700,000
26. 42 INCH DIVERSION PIPING	1840	L.F.	$500.00	$920,000
SUBTOTAL				$3,862,748
CONTINGENCY @ 15 PERCENT				$423,650
TOTAL CONSTRUCTION COST				$4,286,398

B. RELATED COSTS

1. ENGINEERING, PERMITTING, AND CONSTRUCTION MANAGEMENT	$1,028,736
2. ENVIRONMENTAL MITIGATION	$214,320
TOTAL PROJECT COST	$5,315,134

NOTE: COSTS DO NOT INCLUDE LAND ACQUISITION OR STRUCTURE RELOCATION