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FINAL REPORT TO PAT HARRISON WATERWAY DISTRICT

FEASIBILITY STUDY FOR A LOW-HEAD HYDROELECTRIC INSTALLATION ARCHUSA CREEK DAM

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FINAL REPORT

TO

THE PAT HARRISON WATERWAY DISTRICT

FEASIBILITY STUDY FOR A LOW-HEAD HYDROELECTRIC INSTALLATION AT ARCHUSA CREEK DAM

BY

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ACKNOWLEDGEMENT

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ABSTRACT

The rising cost, uncertain future supply, and environmental problems associated with energy sources have resulted in serious investigation of energy sources that have not previously been considered economically and technically feasible. One such source involves low-head hydroelectric generation. The Department of Energy has funded several feasibility studies for the installation of hydroelectric generators at existing low-head dams. This report deals with such a feasibility study for the Archusa Creek Dam near Quitman, Mississippi. The study indicates that there are no apparent technical difficulties to prevent such a project and that a suitable turbine-generator could be obtained. The study further indicates that the project should be economically feasible for the Pat Harrison Waterway District (owners of the dam and lake) to construct if arrangements could be completed for interconnecting with the local utility and selling the energy to the utility. The utility (Mississippi Power Company) has expressed interest in such an arrangement.

I. INTRODUCTION

The feasibility study reported here is one of several studies funded by the Department of Energy for the purpose of determining the economic and technical feasibility of installing hydroelectric generating systems of limited capacity (50kW to 15MW) at existing low-head dam sites. The increased cost and possible shortage of primary fuel sources justify a new look at hydroelectric potential at locations which would not have merited serious consideration in the past. The possibilities of low-head hydro installations appear even more promising when the probable continued inflation of energy costs are considered.

The Pat Harrison Waterway District had primary responsibility for the performance of the feasibility study at the Archusa Creek Dam, but much of the technical and economic analysis was subcontracted to Mississippi State University. The report includes the following topics:

1. Proposed configuration and capacity of hydropower facility, including expected average annual energy production and peak energy production.
2. An economic and marketing potential analysis.
3. Effect of proposed installation on environment, safety, and other water resource needs.

There is at present no hydropower in the state of Mississippi because of the wide valleys and resulting relatively low heads available in areas of significant flow. Electric power rates in Mississippi have historically been low enough that hydroelectric power under these conditions has not been economically attractive. With the renewed interest in hydropower, an installation such as that proposed at Archusa Creek would be unique in the state and could provide a technical and economic model for the possible application to other similar type facilities.

Description of Existing Facilities

The Archusa Creek dam and lake is located in Clarke County, Mississippi, along the Archusa Creek and near Archusa Creek's junction with the Chickasawhay River and in the city limits of Quitman. The dam and impoundment was completed in 1970. The best knowledge available to the Pat Harrison Waterway District indicated that the Archusa Creek dam and discharge structure are in good condition. Both the dam and discharge structure are subject to a perpetual maintenance program with only one minor problem in the eight years since project completion.

The dam is of earth-fill type, while the discharge structure is constructed of concrete and is of the free overflow type with an inflatable bag that could cause variations in the lake level of elevations between 210.0' msl and 215.0' msl. The spillway was designed so that the inflatable bag would automatically release to elevation 210.0'msl should the Chickasawhay River cause backwater to that elevation. During periods of extreme high water on the Chickasawhay River, back waters may back through the spillway at the Archusa Creek dam and into the Archusa Creek lake. The spillway has always functioned in an as-designed manner with no known problems and is considered in excellent condition.

Since the dam was completed in 1970, the dam is now about eight years of age. The Archusa Creek project is owned and operated by the Pat Harrison Waterway District, an agency of the state of Mississippi, a water-management district with broad powers for water resources, management and development in a 15-county area that drains to the Pascagoula River. The project was constructed in cooperation with the Bureau of Outdoor Recreation (BOR) for water-oriented overnight and day-use recreational facilities. Cost-sharing was gained from the BOR at the rate of about 50% of total construction. There are no known restrictions from this agreement with the BOR that would prohibit construction of a low-head generating unit unless variations in lake level are such that the facilities would not maintain the recreational integrity. Rights to the water and storage behind the Archusa Creek dam are those of the Pat Harrison Waterway District. As previously stated, the reservoir is partly used as a recreational reservoir with water skiing, fishing and swimming being the primary direct use of the water. Because of the closeness of reservoir property taking lines, it is unlikely that the reservoir could be increased in elevation to increase storage for power generating purposes. Water rights throughout the state of Mississippi are under the riparian law and withdrawal for consumptive use are under the jurisdiction of the Mississippi Board of Water Commissioners.

The surface area of the lake is approximately 450 acres and the drainage area approximately 55 square miles. The average annual flow as determined from data that is based on a correlation from other stream gaging sites over a period of eleven years is approximately 90 cfs. The maximum flood of record occurred in April, 1974, with a flow of 3285 cfs. The minimum flow of record occurred in September, 1972, with a flow of 16 cfs. The summer and fall months (June-October) have the smallest average flow.

The location of the Archusa Creek Water Park is shown on Figure 1. Figure 2 shows a sectional view with the fabridam inflated. A sectional view along the centerline of the spillway is shown in Figure 3.

II. CONFIGURATION AND CAPACITY OF THE HYDROPOWER FACILITY

In order to achieve economy and simplicity of operation, several guidelines were tentatively decided early in the study. These included the following:

1. An induction generator would be used. Arrangements for paralleling the output with a local utility have been discussed with utility personnel, and it appears that this can be done. The utility would purchase the generated power.

2. Starting and shut-down of the unit would be accomplished automatically.

3. A fixed blade turbine would be used and the level of the lake varied by as much as one foot to provide some storage for peaking purposes.

4. The installed capacity would be chosen to provide optimum peaking power rather than continuous power.

The configuration of the dam and lake is shown in Figure 4. The hydropower unit would be located on the northwest side of the primary spillway with the tailrace being constructed along the path of an existing gully to the main creek bed. This arrangement would provide an average head of about 25 feet. The power house would be waterproof to protect the equipment from occasional (once every two or three years) flooding when the Chickasawhay River floods the area and flows over the fabridam into the lake. The alternatives would be to use a bulb type unit or to run a drive shaft from the turbine to a generator located on top of the dam. A drive shaft from the turbine to the top of the dam would result in a loss of power, so this option was not chosen. The bulb type unit was not chosen because of higher installation and maintenance costs. Figure 5 shows the preliminary details of the proposed hydroelectric installation.

The connection with the Mississippi Power Company 12 kV system is illustrated in Figure 6. Approximately 500 feet of single phase line from the Clarke County Hospital to the lake would be converted to three phase and 1600 feet of underground single phase line serving the pump house at the spillway would be converted to a three phase overhead line on steerhorns. A capacitance bank of 0.5 per unit KVAR would be installed at the generator to provide a part of the reactive vars required by the induction generator. The effect of the capacitance bank on power factor is shown on Figure 7. A 4160 volt to 12 kV transformer plus the necessary breakers and protective relaying would be provided at the connection with the Mississippi Power Company system.

Several sizes of hydro installations from 100kW (approximately 60 cfs) to 500 kW (approximately 300 cfs) were considered. Based on initial cost and on the percentage of time that peaking power at rated output could be provided, the recommended capacity is 250 kW. An analysis of the performance of a 250 Kw unit under expected stream flow conditions is presented in the next section.

III. ESTIMATED PERFORMANCE CHARACTERISTICS

Although some of the values used in the analysis of the proposed system will vary from actual system values, the results should provide an acceptable indication of the economic and energy producing capability of the system. The analysis is based on the following:

1. The average head would be 24.5 feet.
2. An overall efficiency of 80% was assumed.
3. An allowable variation of 1 foot from the normal water level was assumed for energy storage.
4. In order to provide maximum peaking energy during days of maximum system demand, a five day per week operating schedule was assumed except during periods when the water would flow over the spillway if not utilized for generation during the week-end.
5. It is assumed that the generated electrical energy would be purchased by a local utility (see Section V).
6. The analysis is based on the eleven year estimated flow data provided by the Pat Harrison Waterway District.
7. It was assumed that the unit would be down for maintenance during the month of October. Actual down time would probably be considerably less during most years.
8. The required downstream flow is not significant.

The choice of the 250 kW unit was based on a computer study utilizing the flow data and assumptions listed above. Programs were run for a year of least rainfall, a year of average rainfall, and a year of highest rainfall. The output of primary interest involves the peaking capability and the average energy production. These are summarized in Table I.

The results given in Table I indicate that, under the conditions assumed above, the 250 kW unit could provide at least 6 hours of peaking power every weekday (this does not include all week-ends) during the year except possibly for the month of October. It could provide at least 9 hours of peaking power every day except for 4 days during a year of least rainfall. The data for 12 hours and 15 hours of peaking power can be interpreted in a similar manner. It should be noted that the days during which the least peaking power can be provided occur during the summer months when the Mississippi Power Company's peak demand is highest. Assume that there are 105 working days during the period from June through September, inclusive. This means that during a year of average rainfall, at least 9 hours of peaking power could be provided 100% of the time, at least 12 hours 83% of the time, and at least 15 hours 67% of the time.

IV. EXPECTED IMPACT ON OTHER WATER RESOURCE NEEDS

Archusa Creek Lake is primarily a recreational facility- boating and skiiing, fishing, swimming, camping, and picnicing. It is not anticipated that the proposed hydropower installation will have a significant effect on these activities. Because of the dam's proximity to the junction of the Chickasawhay River, the required downstream flow is not considered to be a significant amount.

	Capacity (kW)	Required Flow (cfs)	Annual Energy (kWh)	Plant Factor	Number of Days Annually ≤ x hours of Peaking Capacity Available.			
					x = 6	x = 9	x = 12	x = 15
Year of Least Rainfall	250	151	726,000	0.36	0	4	35	64
Year of Average Rainfall	250	151	1,185,000	0.59	0	0	18	35
Year of Highest Rainfall	250	151	1,344,000	0.67	0	0	3	11

TABLE I. Estimated Peaking Capability and Annual Energy Production. October is omitted from the analysis and a 5 day per week operation is assumed except during times of excess flow.

V. MARKETING POTENTIAL FOR POWER

Because of the desirability of using an induction generator and the need of an assured market for the output of the proposed facility, the attitude of the local utility (in this case, the Mississippi Power Company) toward the project is an essential factor in the feasibility analysis. Although no final arrangements have been agreed upon, the Mississippi Power Company has shown every indication of a willingness to pursue the possibility of paralleling the hydropower unit's output with the company's 12 kV distribution system, and has provided a tentative offer of what they would pay for the power. Thus, the marketing potential appears very favorable, and this enhances significantly the feasibility of the hydropower facility.

This marketing approach is quite different from the original proposal to use the power to supply the Archusa Park electrical power needs. This would require the construction of a considerable distribution system plus switching and purchasing arrangements with the local utilities, which presently supply the park's electrical needs, to provide backup power. In addition, a synchronous generator would be required and there would be no use for power in excess of the park's needs. For these reasons, it is desirable to sell the energy to the Mississippi Power Company and to continue to purchase power for the park's needs under existing arrangements.

VI. FINANCIAL ANALYSIS

Since there are no apparent technical or environmental considerations which negate the feasibility of the proposed hydropower facility, economic considerations become the deciding factor. The following observations and data will provide help in understanding the value and meaning of the financial analysis summarized in Table II.

1. Because of the uncertainties in the present inflationary economy and in future energy supplies, it is impossible to predict with assurance the effect of inflation on potential income and on operation and maintenance cost over the assumed 40 year lifetime of the facility. This becomes a critical factor since continued inflation would have a positive effect on economic feasibility, while zero inflation makes the economic feasibility doubtful in terms of the cost and marketing figures that have been obtained.
2. There is a definite economic advantage for the Pat Harrison Waterway District to build the facility rather than a private utility. Funds are already allocated for maintenance of the dam and it is possible that the present employees might be used for such routine operations as station logging and cleaning of the trash racks. In addition, the Waterway District can obtain money at a cheaper rate. The rate used in the analysis is 7%, which is a little higher than the interest rate the District currently pays. Any profits from the operation could go toward defraying the

ORIGINAL INVESTMENT	STARTING O & M COST	ANNUAL INFLATION RATE	BENEFIT-COST RATIO
$300,000	$6500	4%	1.16
300,000	6500	3%	1.07
300,000	6500	5% first 5 yrs. 4% second 5 yrs. 3% other yrs.	1.14
360,000	6500	4%	1.02
360,000	6500	3%	0.94
360,000	6500	5% first 5 yrs. 4% second 5 yrs. 3% other yrs.	1.00
300,000	7800	4%	1.09
300,000	7800	3%	1.02
300,000	7800	5% first 5 yrs. 4% second 5 yrs. 3% other yrs.	1.07
300,000	6500	7% first 5 yrs. 6% second 5 yrs. 5% for other yrs.	1.64

TABLE II. Benefit-Cost Ratio for Various Combinations of Original Cost, Operation & Maintenance Cost, and Inflation Rate.

operating cost of existing facilities at Archusa Creek Park.

3. Depending upon the type of turbine installed, the cost of a 250 kW unit including installation and auxiliary equipment is estimated to range from about $280,000 to a little under $400,000. The lower value is for an Ossberger unit and includes the following:

(a)	Cost of turbine, generator, and auxilliary equipment.	$195,000
(b)	Cost of transformer, capacitors, and distribution line.	$ 18,000
(c)	Cost of construction (including materials).	$ 65,000
	TOTAL ESTIMATED COST	$278,000

If the estimated cost is raised to $300,000 to compensate for possible errors, the unit cost would be $1200/kW.

4. The lifetime of the facility is estimated to be forty years and a straight line depreciation over this period is assumed.

5. The estimated rates at which the energy might be marketed are based on information provided by the Mississippi Power Company. The rates are probably realistic for base power generation, but lower then the cost of peaking power. Based on the average year's production of 1,185,000 kWh, the rates amount to 5.689 mils/kWh for capacity plus 16.936 mils/kWh for energy, or a total of 22.625 mils/kWh. The inflation rate assumed in the analysis was applied only

to the 16.936 mils/kWh for energy.

6. An insurance cost of approximately 0.5% annually is assumed.

7. The analysis is based on the estimated 1,185,000 kWh produced in an average rainfall year.

8. The benefit-cost ratio of Table II is calculated from the present worth of the initial investment (depreciated over forty years at a 7% discount rate), the operation and maintenance costs, the insurance, and the income from energy sales.

9. First year operations and maintenance expense has been estimated at $6,500. This includes station logging and supplies, routine and preventive maintenance, and trouble calls. The estimate was made this low on the assumption that park personnel could handle the routine day-to-day operations of station logging and cleaning trash racks. In addition, dam maintenance, except for that part which would involve strictly the hydropower installation, is already provided for. The operation and maintenance expense is assumed to inflate at the same rate as the price at which the energy is marketed. Actually, there are indications that the cost of energy in the near future will probably have a higher inflation rate than operation and maintenance costs.

10. The best estimate of cost and income is considered to consist of an initial cost of $300,000, an operation and maintenance cost of $6,500 for the first year, an average market

value of 22.625 mils/kWh for the first year, and an inflation rate of 5% for the first five years, 4% for the second five years, and 3% for the next thirty years. However, other figures are also shown in Table II in order to indicate the effect of errors in the estimates.

The conclusions drawn from the economic analysis are as follows:

1. The project appears feasible, but the margin is not overly impressive when the uncertainties are considered.
2. The importance of inflation is indicated from the fact that all the estimates show a deficit in the first few years. For example, using the estimates of Item 10 above, for an average year, the cost of power (fixed annual charge plus operating and maintenance costs) is 25.738 mils/kWh during the first year while the market value is 22.625 mils/kWh. With the assumed rate of inflation, the cost will increase to 45.575 mils/kWh. in the fortieth year while the market value will increase to 67.270 mils/kWh. The deficit during the first year might be eliminated if a higher value for the peaking power, especially during the summer months, could be justified.

VII. ENVIRONMENTAL IMPACT

The fact that the dam already exists and that no major water flow requirements exist in the short distance from the dam to the point where Archusa Creek flows into the Chickasawhay River indicates that the hydropower installation should have a minimum impact on the environment.

VIII. SAFETY HAZARDS

No known safety hazards would result from the hydropower facility.

IX. INVESTIGATION OF SUITABLE TURBINES AND GENERATORS

There are a number of suitable turbines and generators available for hydropower installations similar to that proposed at Archusa Creek Dam. Several manufacturers and manufacturer's representatives were contacted. These included Allis-Chalmers, Bofors-Nohab, Inc., The James Leffel & Company, Northern Water Power, and Keating Associates and Fred Stapenhorst (Ossberger Turbines).

Once the decision was made to use an induction generator, the major choice left involved the type of turbine to be recommended. The Ossberger Turbine is recommended primarily on the basis of initial cost. It also has the advantages of being a fixed blade turbine with some capability for providing outputs other than the rated output. More specifically, it can operate with approximately the same efficiency at rated output, two-thirds rated output, and one-third rated output. This is accomplished by the operation of gates at the input to the turbine. Although the performance and economic analyses are based on the unit operating at rated output or not at all, some flexibility is added to the operation by the capability of obtaining outputs at three different levels.

X. CONSTRUCTION SCHEDULE

Information from the manufacturers indicate that it will take approximately ten months from the time an order is placed before the turbine-generator unit can be delivered. Final design, field work, and the construction of the intake, penstock, powerhouse, tailrace, and interconnecting lines with the Mississippi Power Company could be accomplished during this time. A tentative schedule is shown in Table III. It should require approximately fourteen months to get the system on-line once the decision is made to install it.

XI. CONCLUSIONS

The conclusion based on the discussion above is that it would be feasible to install a hydropower unit at the Arthusa Creek Dam under the following conditions:

1. The unit would be installed and owned by the Pat Harrison Waterway District. This is important for two reasons. First, the Pat Harrison Waterway District owns the dam and lake and, second, the lower rates at which a government agency can obtain money improves the economic feasibility.
2. The unit would be interconnected with the Mississippi Power Company's 12-kV system and the energy purchased by the Mississippi Power Company. This would make it possible to use an induction generator and the accompanying simpler controls and would also provide a market for the energy generated.

There are at present no hydropower installations in the State of Mississippi. A unit such as the one proposed here could serve as a pilot project and provide useful data for determining whether such installations at other existing dam sites would be

DESIGN AND FIELD WORK	ADVERTISE	CONSTRUCTION OF INTAKE, PENSTOCK, POWERHOUSE, AND TAILRACE
100 DAYS	30	200 DAYS

ADVERTISE	MANUFACTURE TURBINE - GENERATOR UNIT	INSTALL UNIT	TESTING
30	300 DAYS	60 DAYS	30

<— 400 DAYS —>

TABLE III. Schedule for Design and Construction feasible. It could also serve as an example for the marketing of externally generated power to electric utility companies.

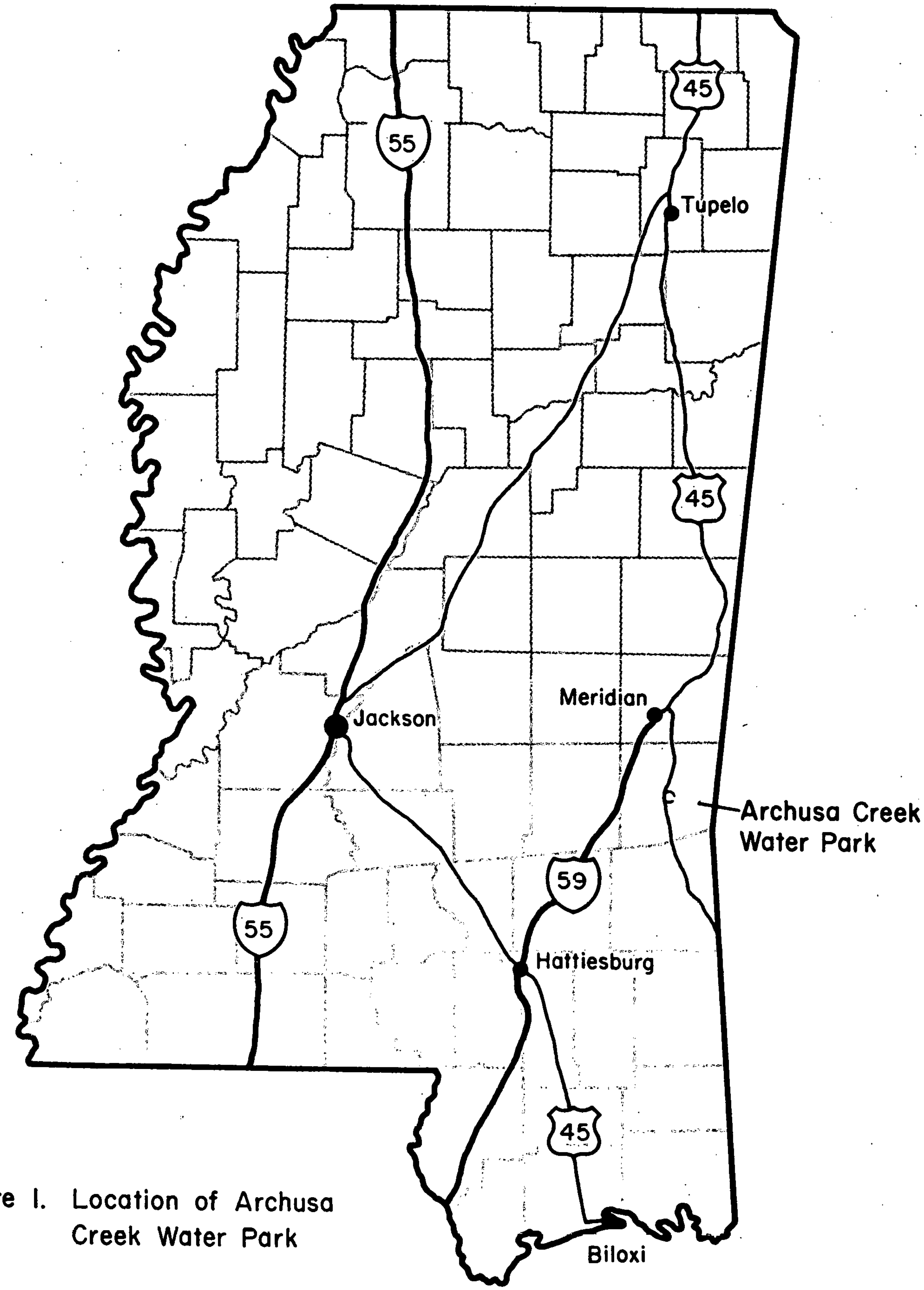


Figure I. Location of Archusa Creek Water Park

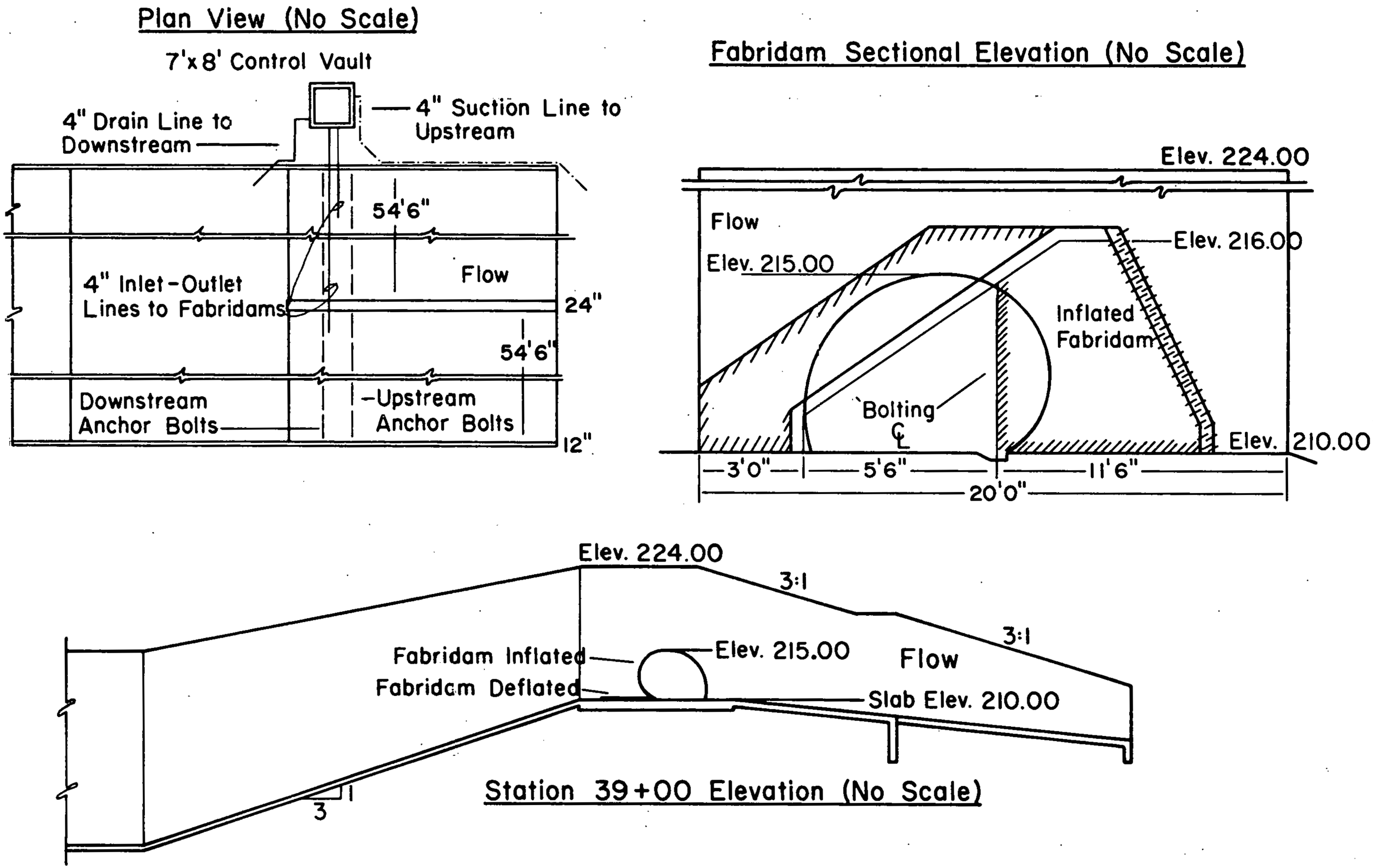


Figure 2. Archusa Creek Water Park Fabridam - Plan, Elevation, & Sectional View

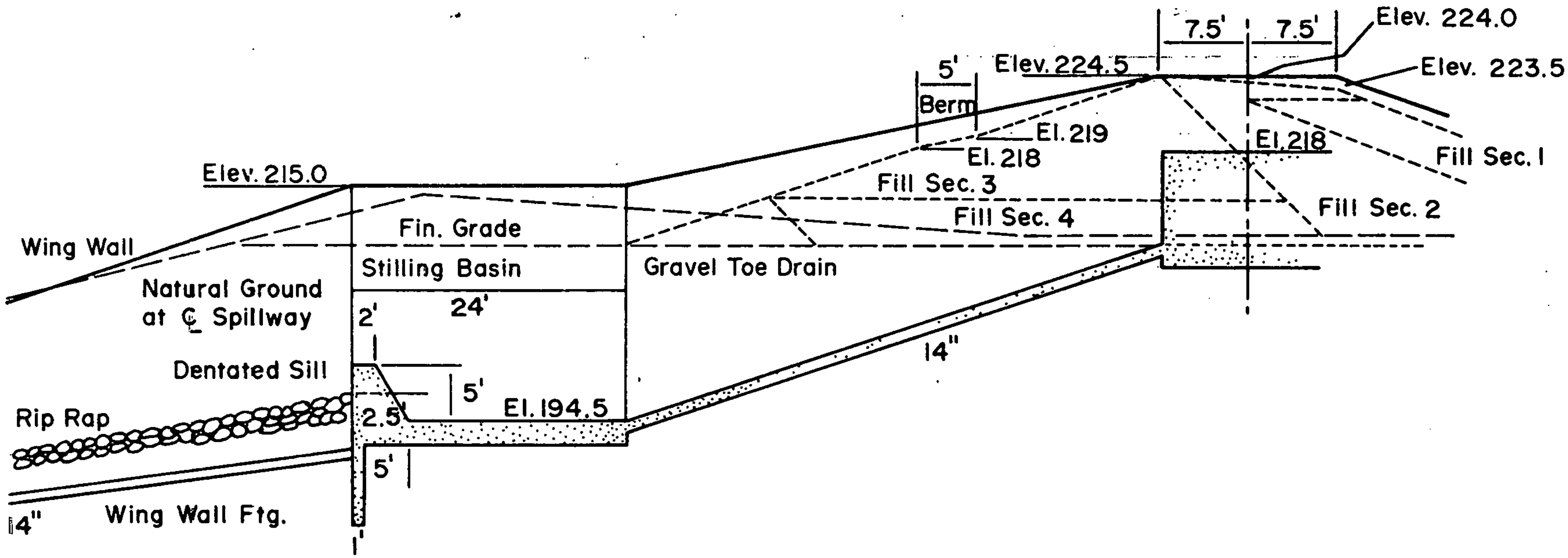


Figure 3. Section Along ℄ Spillway, Archusa Creek Reservoir

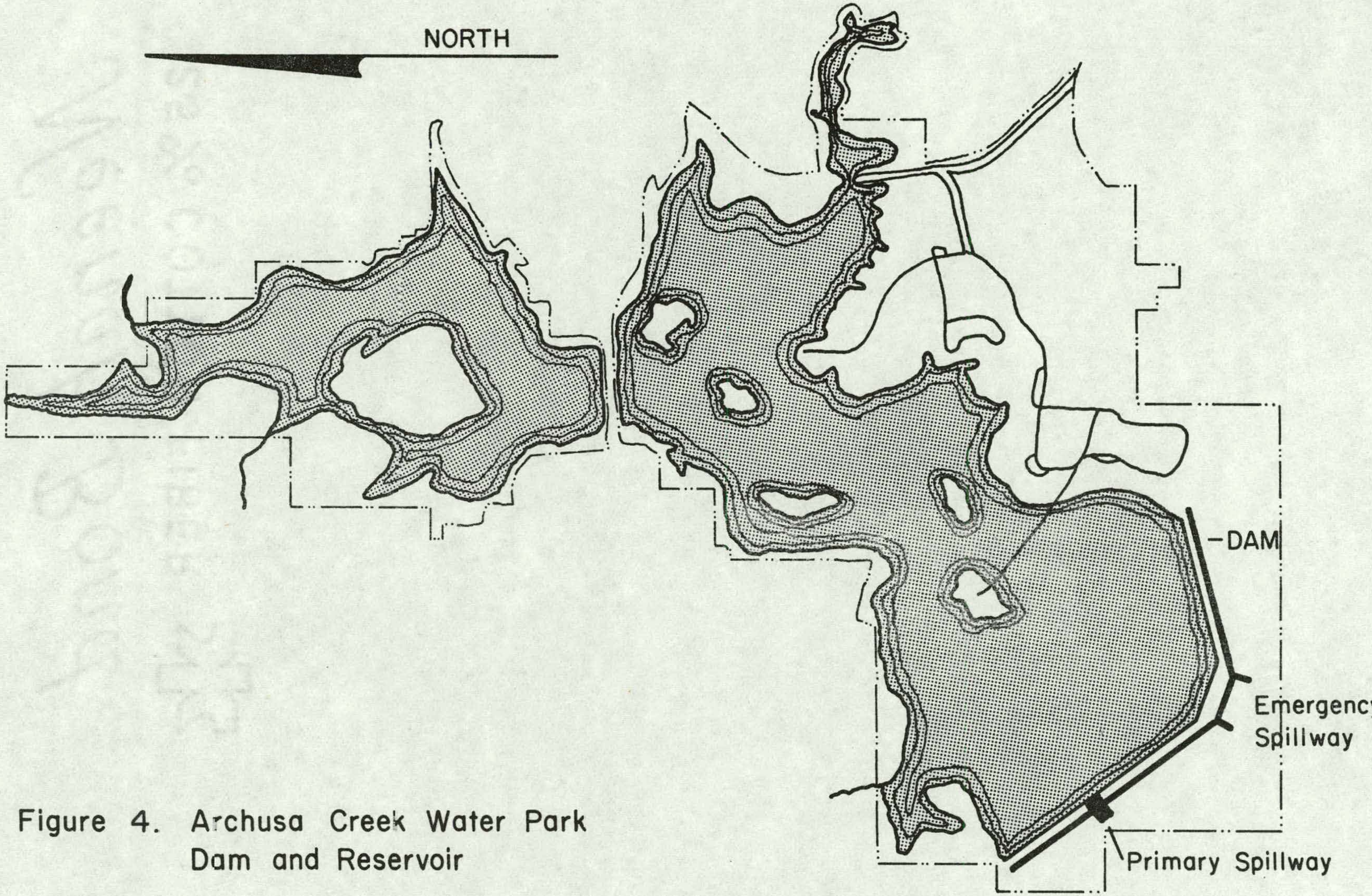
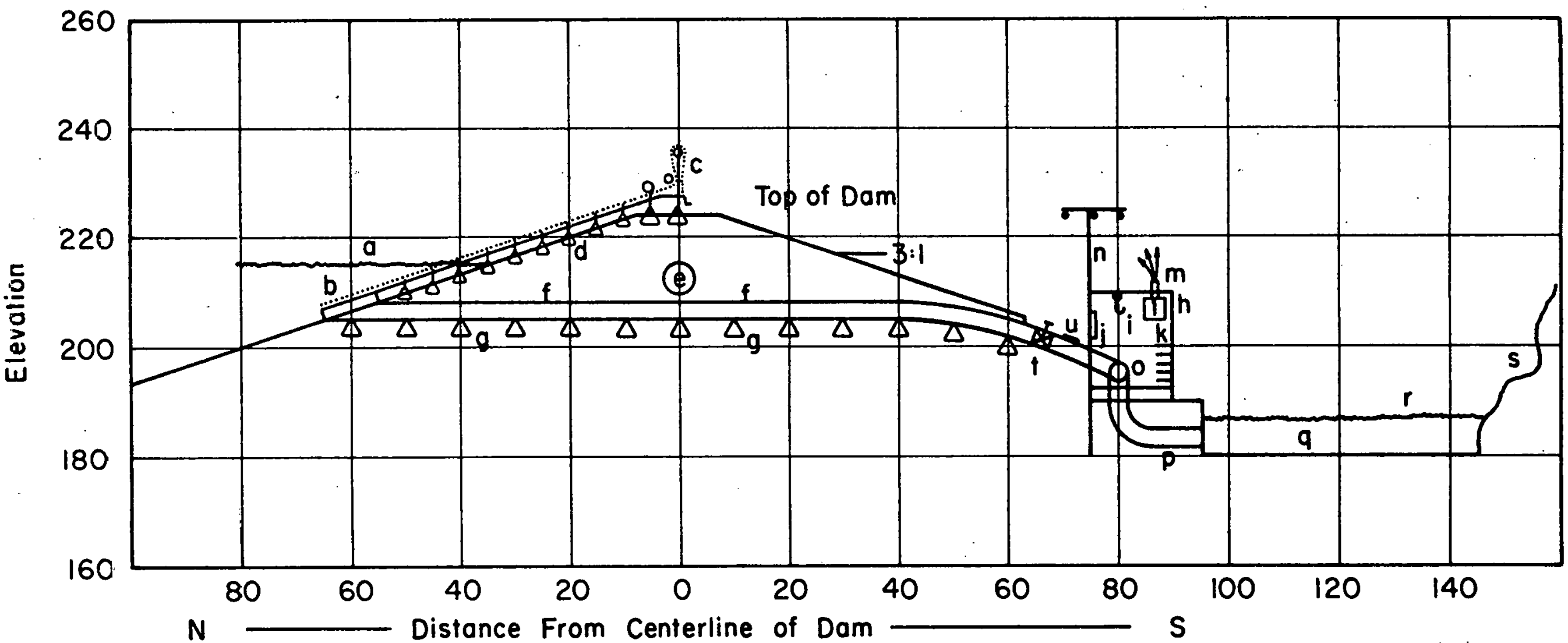


Figure 4. Archusa Creek Water Park Dam and Reservoir



LEGEND

a	Forebay	g	Conduit Supports	l	3Ø Switch	q	Tailwater Reservoir
b	Trash Rack Assembly	h	Waterproof Powerhouse	m	Exit for 3Ø Conductors	r	Tailwater
c	Trash Rack Hoist	i	Powerhouse Hoist	n	Distribution Pole	s	Bank of Gully
d	Trash Rack Supports	j	Control Console	o	Turbine-Generator	t	Valve
e	Fabridam	k	Steps	p	Draft Tube	u	Manhole
f	42" Conduit						

Figure 5. Section View of Hydro-Electric Installation, Archusa Creek Water Park

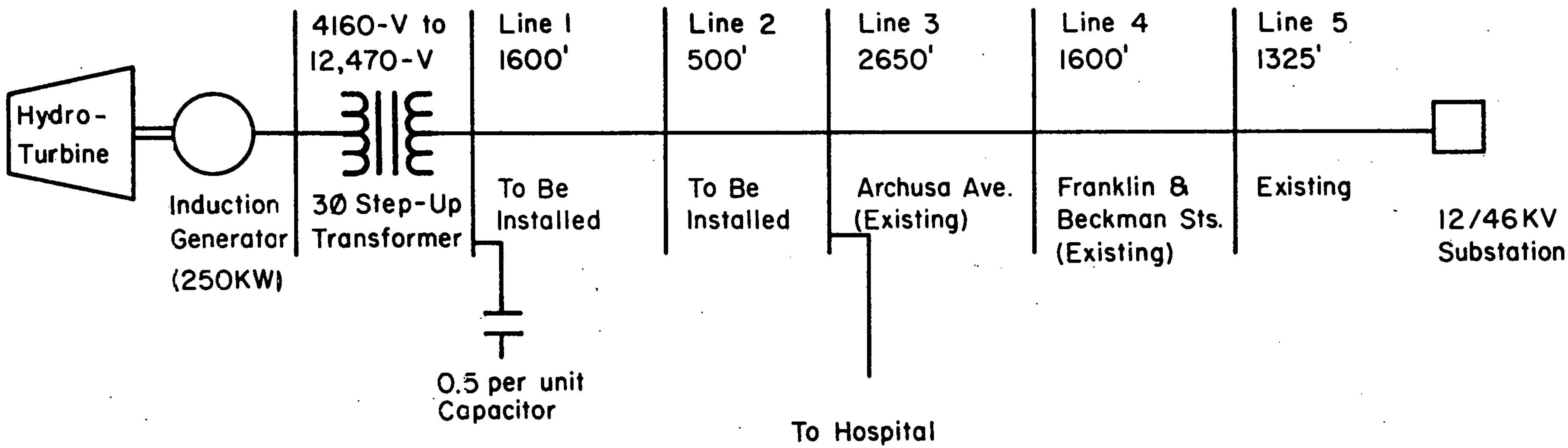


Figure 6a. One-Line Diagram of the Proposed Hydro-Electric Installation, Archusa Creek Dam

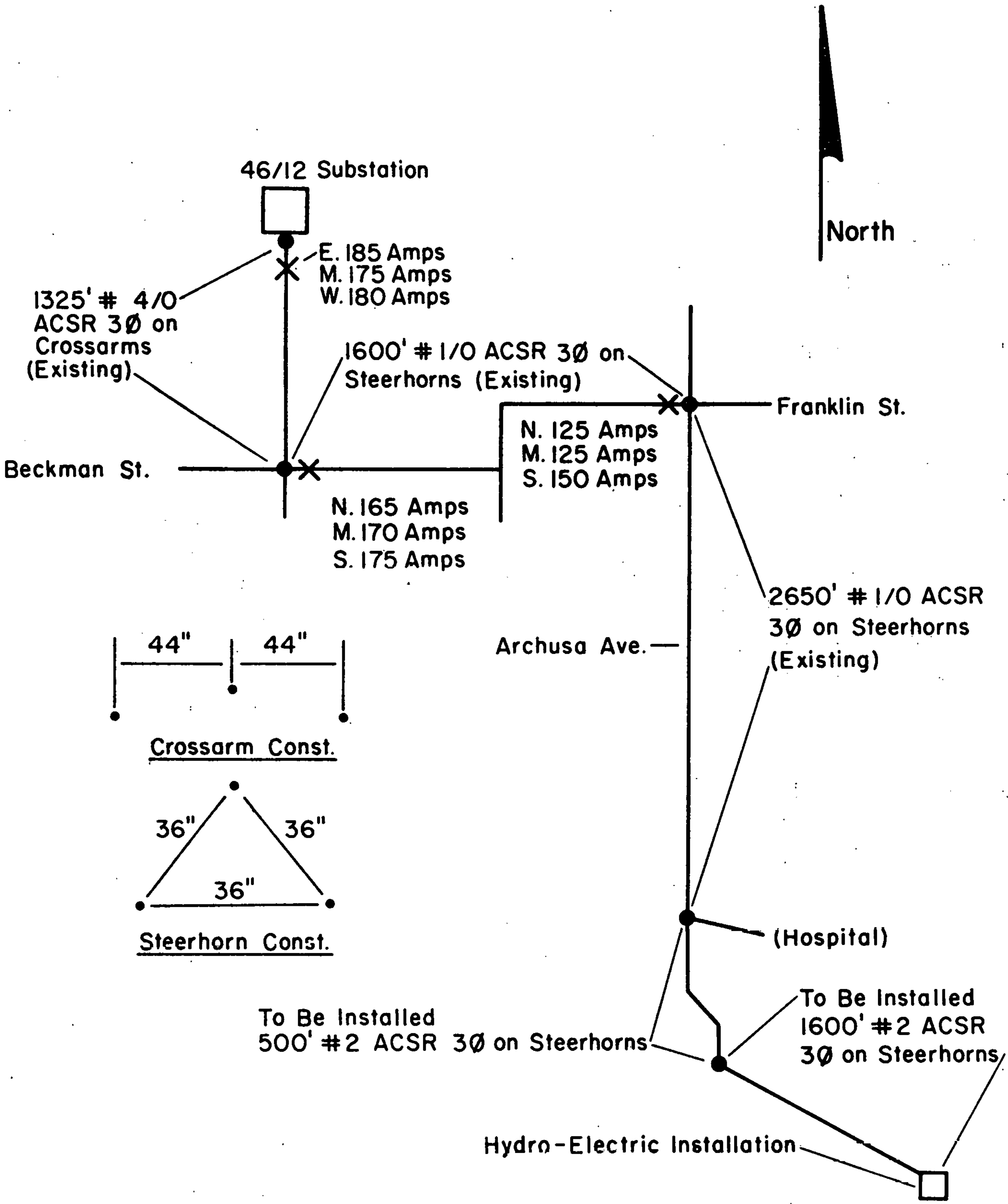


Figure 6b. Mississippi Power Company Distribution System Between 12KV Substation and Hydro-Electric Installation

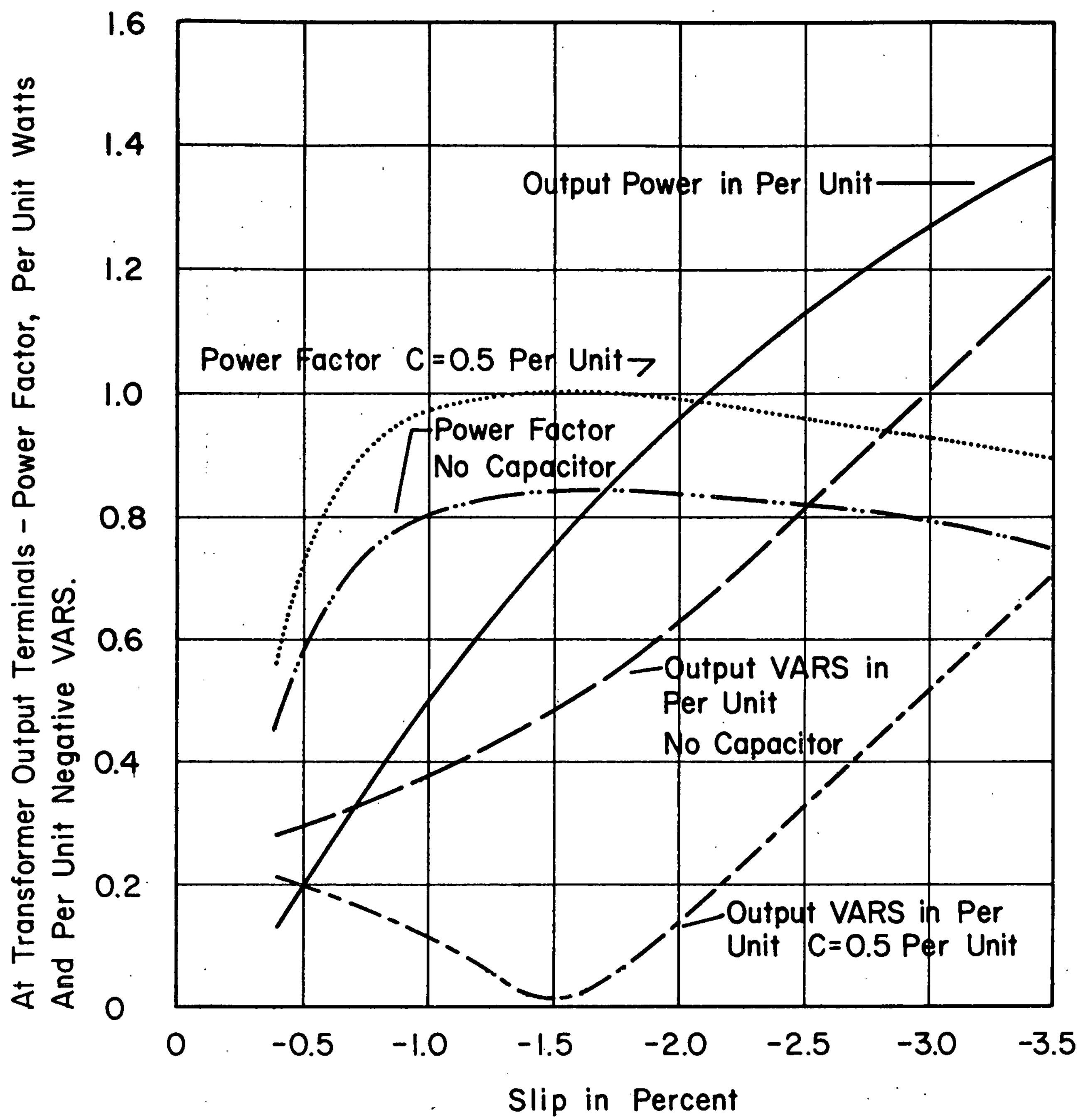


Figure 7. Output Characteristics at Transformer Secondary Terminals of the Hydro-Electric Induction-Generator Installation.