[redacted]

Increasing Water Supply Pumping Capacity at Folsom Dam

Prepared for:

the City of Roseville
Department of Environmental Utilities

in cooperation with

San Juan Water District, City of Folsom, and
Sacramento Area Flood Control Agency

Prepared by:

ESA Consultants Inc.
201 San Antonio Circle, Suite 102
Mountain View, California 94040

Prepared in Association with:

Murray, Burns and Kienlen
1616 29th Street, Suite 300
Sacramento, California 95816

and

SAI Engineers, Inc.
1290 Oakmead Parkway, Suite 301
Sunnyvale, CA 94086

ESA Project 043.9501

January 1996

EXHIBIT FOLSOM-19

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Water Supply Pumping Capacity
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REGISTERED PROFESSIONAL ENGINEER
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January 31, 1996
043.9501

Mr. Joseph D. Countryman, President
Murray, Burns and Kienlen
1616 29th Street, Suite 300
Sacramento, CA 95816

Re: Increasing Water Supply Pumping Capacity at Folsom Dam; Final Report

Dear Mr. Countryman:

The final report for the referenced project is attached. Per our scope of work, it documents hydraulic analyses and presents a conceptual design and cost estimate for increasing water supply delivery capacity from the Folsom Project.

Installing two additional pumps in available positions in the existing Folsom Pumping Plant can achieve the immediate objective of a total system flow rate of 400 cubic feet per second (cfs) when the lake is at Elevation 392. Per the criteria established prior to our study, this is sufficient to implement Roseville's option to increase their peak flow entitlement to 150 cfs. The pumps have also been selected to provide a substantial increase in system capacity at low reservoir elevations (high pumping heads). The agencies served by the Folsom Pumping Plant and the U.S. Bureau of Reclamation (USBR) have expressed general agreement with the above findings. Specific written comments on our draft report were received from the USBR and from the City of Folsom's consultant, Robert W. Miles. These comments have been included in Appendix B and will be considered as design proceeds.

ESA Consultants Inc. has been pleased to collaborate with Murray, Burns and Kienlen on this project. We look forward to working with you and our clients to refine the design concept and to implement the resulting facility improvement plan.

Sincerely,

ESA Consultants Inc.

Will B Betchart

Will B. Betchart, P.E.
Project Manger

Attachment

INCREASING WATER SUPPLY PUMPING CAPACITY FROM FOLSOM

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1. SUMMARY

The engineering study documented in this report has examined alternatives for increasing the Folsom Project water supply delivery capacity to 400 cfs from its present nominal capacity of 315 cfs. Such an increase is necessary for Roseville to exercise its present contractual option to receive a peak flow of 150 cfs -- which is an 85 cfs increase over its present maximum. Initially, the reservoir levels which pertain to these capacities were undefined. Thus, parts of the previous study and this study addressed that topic.

The present study examined a number of hydraulic changes that might contribute to or be necessitated by Roseville's increase. The results of these analyses focused attention on the pumping plant and the opportunity to increase capacity by installing additional pumps in two pump locations that are part of the initial pumping plant layout, but do not presently have pumps installed. Pumps were identified that will fit in the available positions and will achieve the project objectives.

Specifically, installation of two pumps with the capabilities identified will raise the project delivery capability to 400 cfs when the Folsom Lake water surface is at approximately Elevation (El.) 392. Figure 1-1 presents the system capacity curve (versus lake level) that the two additional pumps are estimated to provide when operated in combination with the existing pumps.

Furthermore, if delivery of 400 cfs at lower lake levels is required in the future, similar pumps can be installed at other pump positions replacing the more modest pumps already present. Such a program, extending the approach developed herein, could provide a system capacity of 400 cfs even at very low lake levels (approaching minimum pool).

A major consideration in developing a conceptual design is deciding between three distinct methods for driving the new pumps, namely

- Single speed motors
- Two speed motors
- Variable speed motors.

Analyses demonstrated that two markedly different project needs create a dilemma. Low head pumps suit the project well most of the time because lake levels are generally above El. 380. However, when lake levels are lower, the project must still have the capability to deliver substantial flows. To do so, the project pumps must have high head capability. However, using high head pumps when reservoir levels are high can waste large amounts of energy. The conclusions resulting from our analyses are the following:

- Additional single speed pumps are simply unworkable for the Folsom Project, given presently installed pumps and the variety of pumping requirements encountered. The project needs a substantial increase in high-head capacity. But a single speed pump for high head situations is too wasteful of energy at the low-head conditions that generally exist.

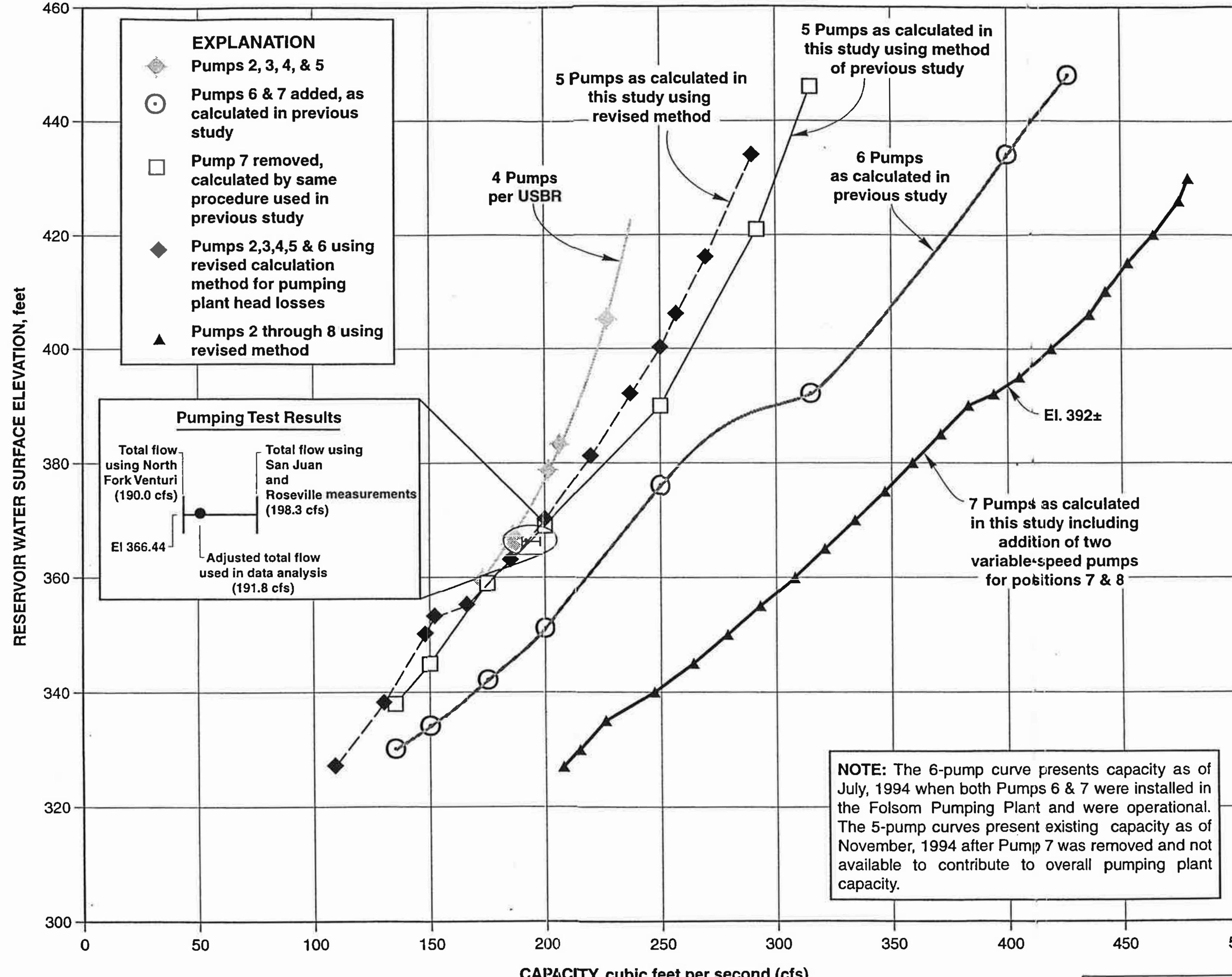
- Two speed pumps seemed to offer an approach for providing both high head and moderate to low head capacity enhancements. However, the substantial savings expected in equipment cost did not materialize. When the lower speed of the two speed pump is larger than half the high speed, two windings are required in the motor. This substantially raises the cost of a two speed motor. Decreasing to half speed, although more economical, is not satisfactory either. The decrease in pump capability is simply too dramatic.

- Variable speed pumps offer the best solution to deal with the dilemma. The increase in cost over two speed motors is modest, and they provide tremendous flexibility to deliver a variety of flows at differentpumping heads without wasteful throttling.

Accordingly, installation of two additional pumps with variable speed motors is recommended. Pumps, motors and variable frequency drives have been researched and a practical system for installation in the existing pumping plant has been identified. Details are presented in Section 5. Other issues that were addressed in the work and the resulting conclusions are:

- The 60 inch valve located in the intake line does not need to be replaced based on increasing system flows to 400 cfs. However, this valve could become a significant system restriction at higher flows. There is a more important question, however, relating to this valve's capability for emergency closure (e.g., if there were a line break between the dam and the pumping plant as the result of an earthquake). The valve was rated for a 75 psi working pressure when it was new in 1952. If an emergency closure event occurred when Folsom Reservoir were full (El. 466), the valve would be faced with a maximum working pressure of 70 psi. Failure to achieve emergency closure would be unacceptable. Such failure could mean extreme drawdown of the reservoir to achieve closure and a prolonged outage of water supplies during reservoir drawdown and pipeline repair. Accordingly, ESA recommends that the water agencies request or otherwise initiate a detailed review of the emergency closure capability of both the 60" intake valve and the 42" (Natoma) intake valve (which has the same importance). Details are discussed in Section 6.
- The potential for vortex development at the intake was reviewed. Based on available literature, the potential for vortex problems does not appear to be significant with either the existing pumping capacity or that proposed with addition of two new pumps. If additional capacity were added beyond that proposed above, vortexes might develop at very low reservoir levels--approaching minimum pool. It is recommended that further consideration of vortex issues be delayed until such subsequent expansions are proposed.
- Other potential flow restrictions in the water delivery system were considered --such as the North Fork line venturi meter. At a system flow of 400 cfs, such contractions and expansions are not a significant concern.

In summary, a substantial improvement of system capacity can be achieved by adding two pumps with variable speed motors. The estimated construction cost for this improvement is $ 1.9 million (including a 15 percent allowance for contingencies). Inclusion of allowances for engineering, construction supervision and Bureau of Reclamation reviews raises the total to $ 2.3 million. The above estimates reflect mid-1995 price levels.



ESA Consultants
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

PUMPING CAPACITY WITHOUT AND WITH TWO ADDITIONAL PUMPS

Checked By *Peter V. Jacke*	Date *1/26/96*	Project No.	Figure No
Approved By *[illegible]*	Date *1/31/96*	043.9501	1-1

2. BACKGROUND

The city of Roseville receives its raw water supply from the United States Bureau of Reclamation (USBR) water supply facilities at Folsom Dam. The relative locations of Roseville and Folsom Lake are shown in the vicinity map presented in Figure 2-1. Roseville is presently authorized to receive up to 65 cubic feet per second (cfs) of flow. Roseville's contract with USBR contains an option to increase this peak flow rate to 150 cfs. Roseville wishes to implement this increase because of its projected water demand. In pursuing that objective, Roseville is cooperating with the other water supply agencies served by the Folsom Project (San Juan Water District, Folsom State Prison, and the City of Folsom) and with other interested agencies including Placer County Water Agency, Sacramento Area Flood Control Agency, and the USBR. Various relevant water supply facilities are highlighted in the location map presented in Figure 2-2. A schematic diagram of the project water distribution facilities is presented Figure 2-3.

A first phase of study was performed previously to develop and present information on the physical/technical features and limits of the Folsom Dam water supply facilities and to characterize the needed facility improvements to implement the flow increase. That study produced a report (ESA Consultants, November 1994) documenting Folsom Project water supply topics including:

- Peak flow entitlements and needs.
- History of Folsom Dam water supply facilities development and improvement.
- Basis for project design flows.
- Water supply system delivery capacity at various reservoir levels.
- Prospective facility improvements.

One issue that the previous study specifically set out to address was the perception by some that water flow rates were limited because they cannot be allowed to exceed a velocity of 10 feet per second (Spink, 1992). The consequence of such a limit would be that flows through the initial leg of the water supply system (i.e., through the dam) would be constrained. However, no technical basis for such a velocity constraint was found. Rather it is believed to be a rule-of-thumb used by designers to select pipe sizes that would then be found to have acceptably low head losses. When a pipe is already in place, however, higher velocities (and head losses) are tolerable (to some extent and under appropriate conditions) before replacing or supplementing the pipe.

In the case of the 84-inch diameter pipe extending through Folsom Dam and to the pump station, implementing Roseville's option for a peak flow rate of 150 cfs would require a total flow rate of 400 cfs (to serve all Folsom Project users) and a velocity of 10.4 feet per second-- only slightly exceeding the rule-of-thumb. The head loss due to slightly exceeding 10 feet per second in this short length of pipe is trivial (approximately 0.35 feet). Even the total head loss to the pumping plant at 400 cfs is relatively minor, amounting to less than 5 feet. Furthermore, this velocity would occur only rarely-- for a few days or weeks in midsummer while all the water agencies were experiencing their peak demands. Thus, it was concluded that head loss is not a limitation.

The initial work also concluded that there is no danger of cavitation or coating erosion at this modest velocity (assuming the coating was properly applied). Indeed, the authors believe that somewhat higher velocities are acceptable, as long as the associated head losses can be accommodated. This means that there is no need for a new or bigger "hole in the dam" to implement Roseville's peak flow increase to 150 cfs. Such an improvement may ultimately be required as demands continue to grow, but it is not necessary at this stage.

Thus, the overall conclusion of the initial work was that Roseville's option for increasing its peak flow can be implemented through appropriate modifications to pumping capabilities at the Folsom Project Pumping Plant. It was further stated that these modifications could be accomplished within the existing pumping plant without major changes to the suction or discharge piping. That is, the existing pump locations should prove adequate.

The purpose of the present work is to follow through on that conclusion by developing a conceptual design and a cost estimate for the needed improvements. This purpose was given more specific meaning in terms of the following project objective:

> To implement Roseville's option for increasing its peak flow entitlement from 65 cfs to 150 cfs by using the existing pumping plant and major piping and achieving total Folsom Dam water supply delivery capacity (including Roseville, San Juan, Folsom, and the prison) of 400 cfs at the lowest practical reservoir water surface elevation (as close to the minimum operating pool, El. 327, as is reasonably possible).

Tasks identified for pursuit of this objective included the following:

- Performance of a system pumping test to verify or refine the head loss calculations performed during the initial study.

- Research of records for additional specifics regarding aspects of the water supply facilities, particularly regarding electrical aspects.

- Performance of additional calculations on hydraulic arrangements to narrow in on the changes that need to be implemented.

- Development of a facility plan itemizing specific changes to be implemented.

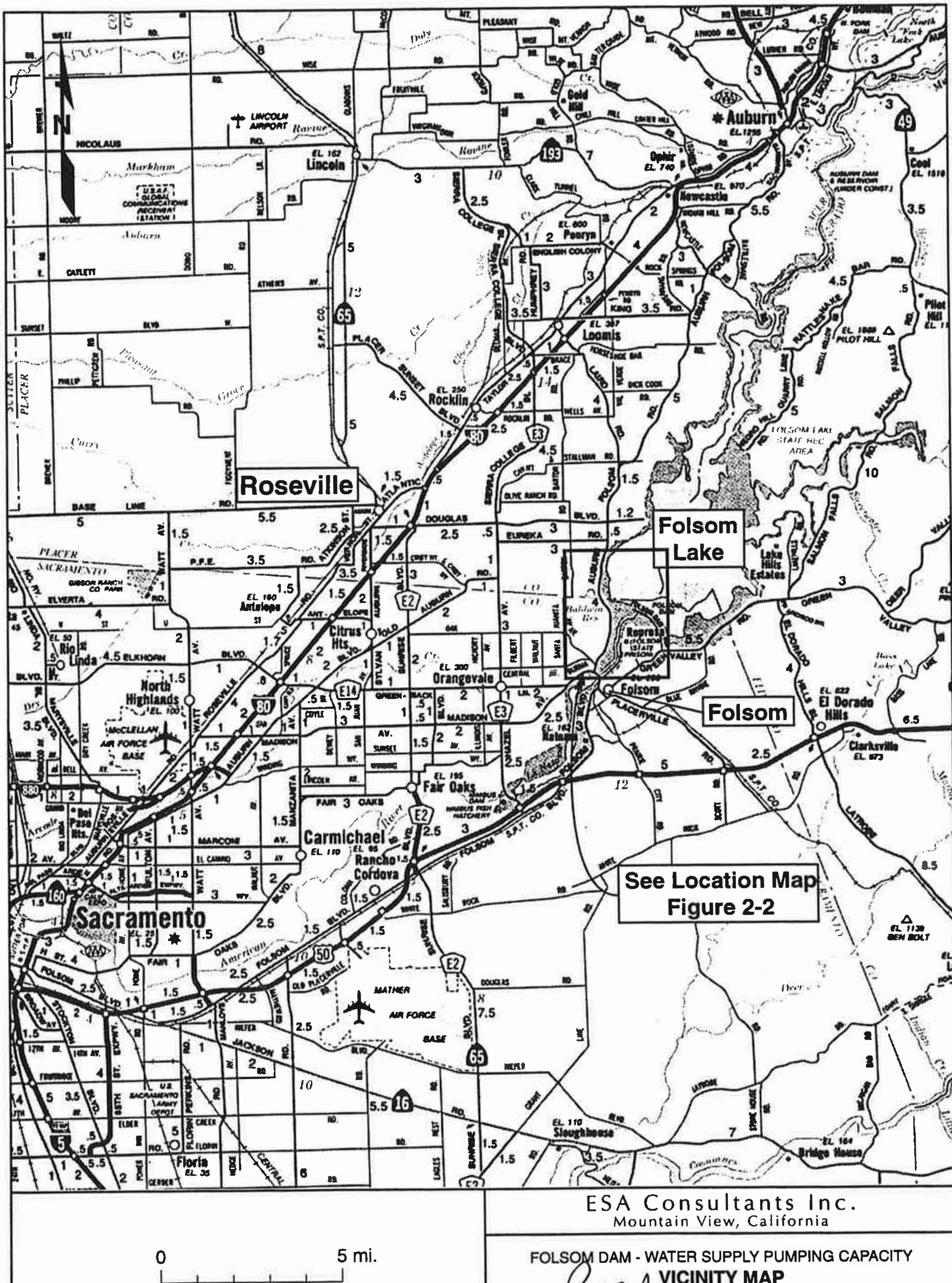
- Provision of a cost estimate for accomplishing the identified improvements.

The following sections of this report document the analyses performed and the resulting facility improvements recommended. ESA wishes to acknowledge and express appreciation for the cooperation and the contributions of many agencies and individuals with whom discussions occurred during this study. Personnel from the Bureau and Corps were very helpful and provided material that was difficult to locate. Bill Joye, Bill Sanford and Bob Beingessner of the Bureau's Folsom office were particularly helpful. The various water supply agencies that use the Folsom Dam water supply facilities (San Juan Water, City of Folsom and Placer County Water Agency, in addition to Roseville) were also cooperative and provided information regarding their facilities and operations. Derrick Whitehead was particularly helpful as the City of Roseville representative responsible for project direction.

Mark Fortner and Joseph Countryman of Murray, Burns and Kienlen provided liaison with the parties mentioned above, obtained most of the data required to perform this study, and organized performance of the system pumping test. They also developed background information on the institutional relationships involved in operation and improvement of the Folsom Project water supply facilities and provide helpful comments on the draft report.

ESA's subconsultant was SAI Engineers, Inc. Ishwar Thakur provided leadership on the electrical issues and was assisted by Harminder Singh. SAI also provided the expertise of Gordon Needham who contributed helpful comments from a mechanical viewpoint.

For ESA, Will Betchart served as Project Manager and Project Engineer, directing the needed hydraulic analyses and preparation of his report. He was assisted by D. "Mike" Namikas who provided the benefit of his many years of hydraulic engineering experience and his familiarity with pumping plant design and operation. Peter Jacke performed most of the hydraulic calculations and, with David O' Shea, produced the technical illustrations that are a central component of this report. Shannon Valera provided word processing services.

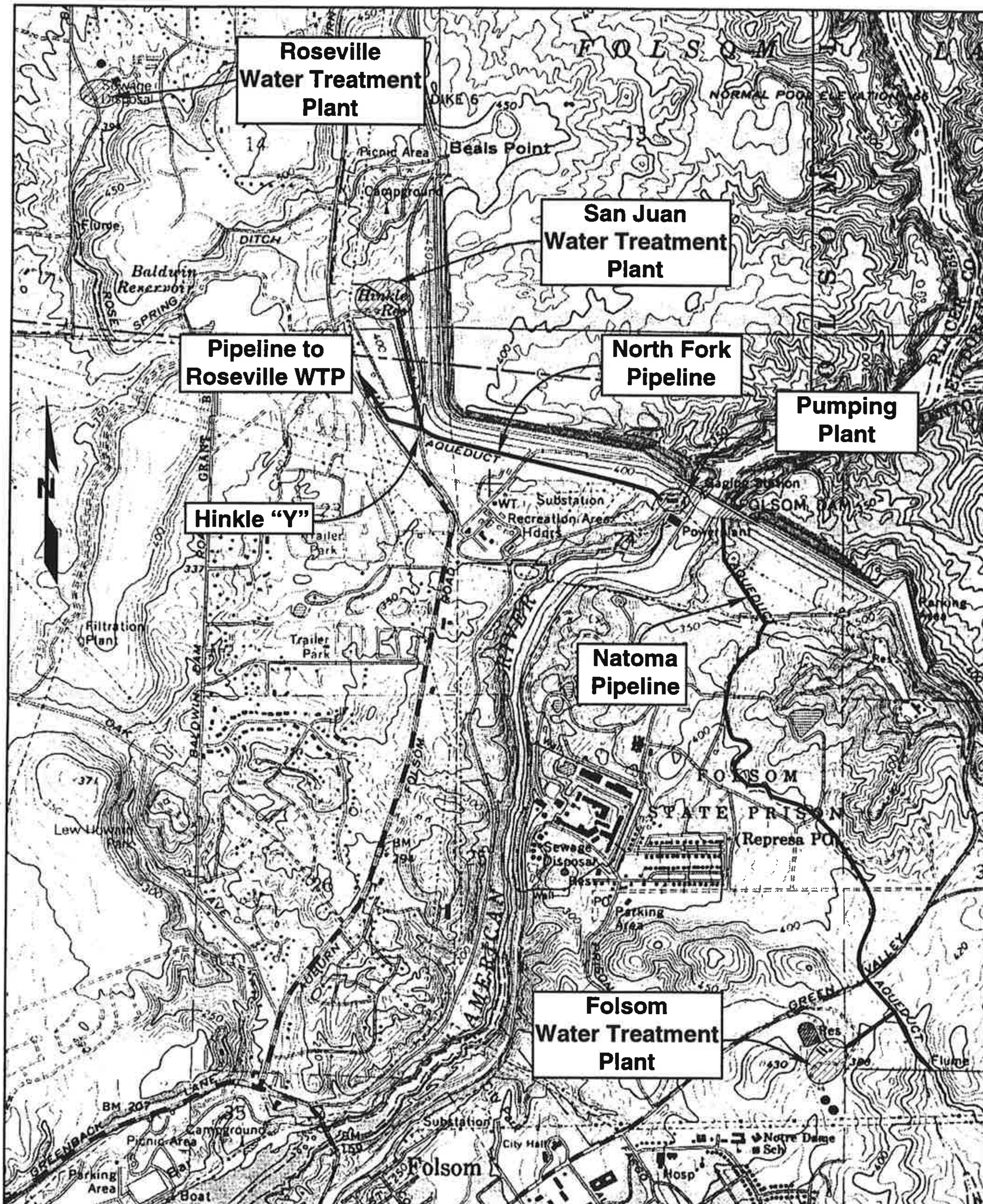


ESA Consultants Inc.
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

VICINITY MAP

Checked By Peter V. Jackson Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	2-1



0 2000 4000 ft.

Scale 1:24,000

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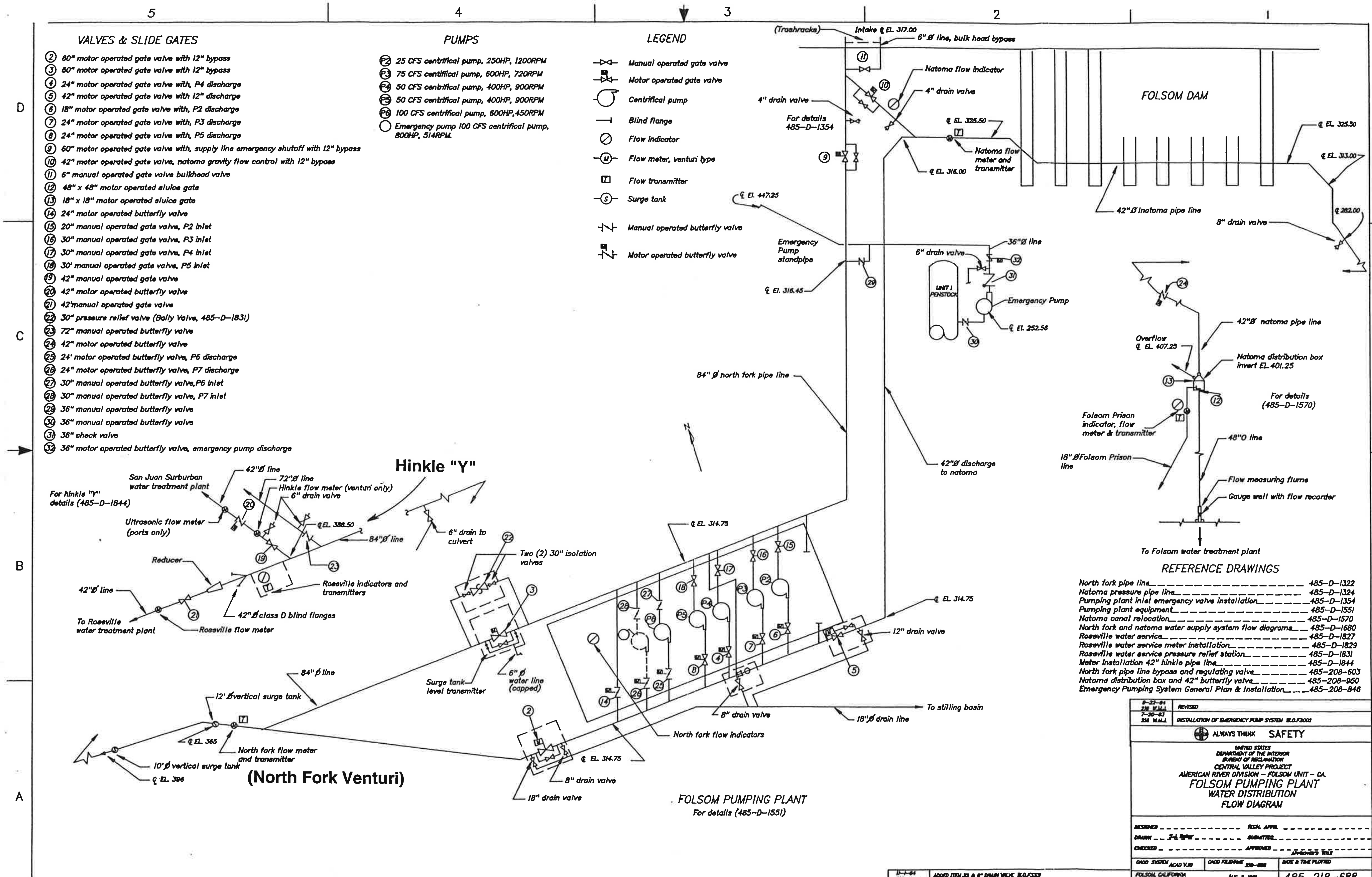
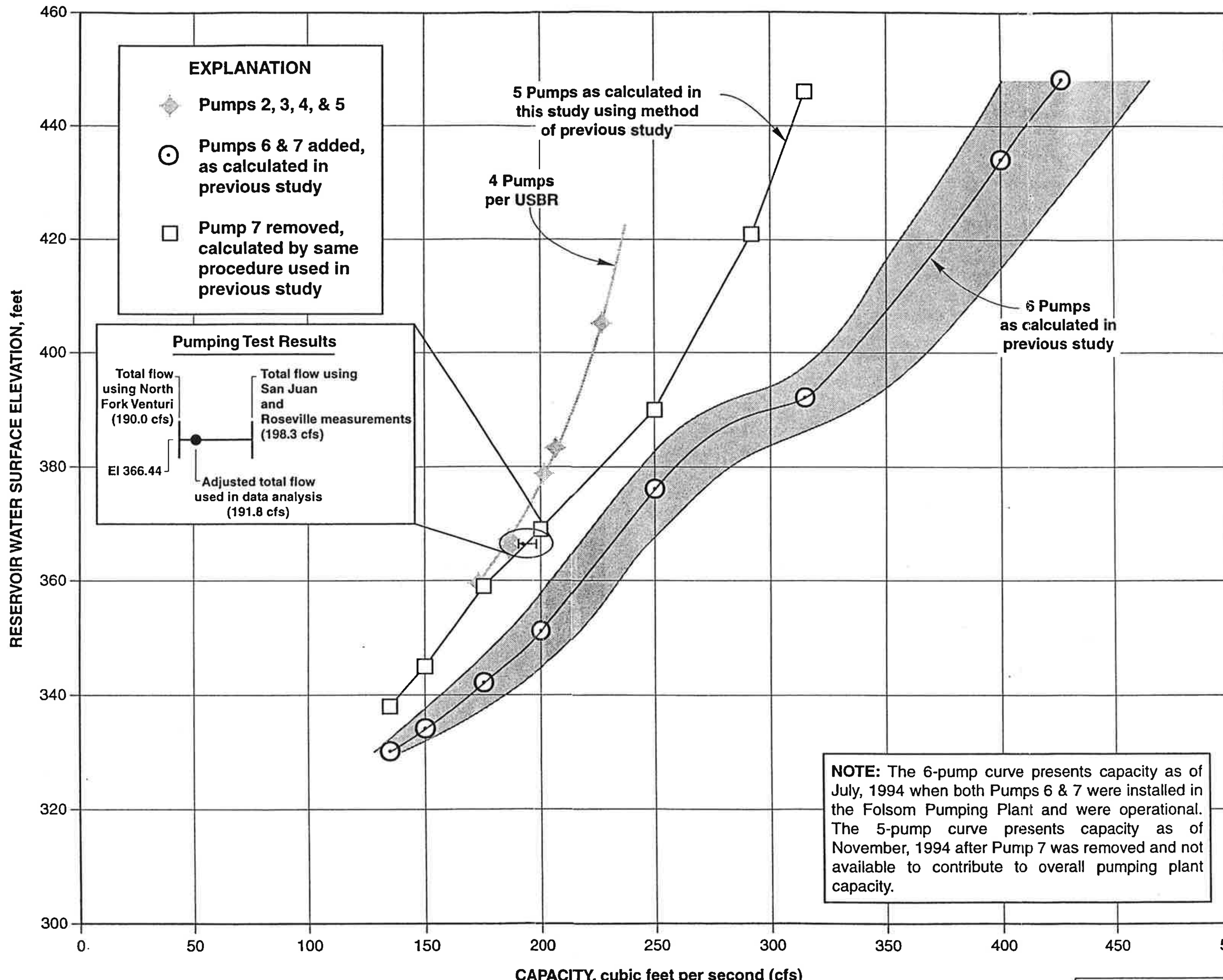
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
LOCATION MAP

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	2-2



Folsom Dam Water Supply System: Updated Flow Diagram (from USBR) Figure 2-3



NOTE: The 6-pump curve presents capacity as of July, 1994 when both Pumps 6 & 7 were installed in the Folsom Pumping Plant and were operational. The 5-pump curve presents capacity as of November, 1994 after Pump 7 was removed and not available to contribute to overall pumping plant capacity.

ESA Consultants
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

EXISTING PUMPING CAPACITY AND PUMPING TEST RESULTS

Checked By Peter V. Jacke	Date 1/26/96	Project No. 043.9501	Figure No. 3-1
Approved By B	Date 1/31/96		

3. PUMPING TEST

A pumping test of the Folsom Dam Project water supply system was conducted on November 18, 1994. The details of the test, including preparations, data, and data analyses, are documented in Appendix A. The following summarizes the results.

The primary purpose of the test was to confirm or refine the calculated delivery capacity and head loss findings reported in an earlier study (ESA Consultants, November 1994). Because one of the pumps (Pump No. 7) included in that study had been removed from the pumping plant prior to the test, an initial step was to recalculate the system capacity curve using only the pumps actually available-- i.e. Pumps 2, 3, 4, 5, and 6. The result of the recalculation is presented in Figure 3-1 and the overall result of the pumping test is plotted for comparison.

The total pumping capacity with the reservoir at El. 366.44 was found to be between 190 and 198.3 cfs, depending on whether the measurement from the USBR North Fork venturi was used (190 cfs total) or the summation of Roseville and San Juan flow measurements (198.3 cfs total). The 10 cfs flow to Natoma is included in both totals. For analyzing the pumping test data, a compromise value of 191.8 cfs was used. In any case, the measured capacity was very close to that calculated using the Corps' (1951) predictive calculations of system head losses and the pump manufacturers' discharge versus head curves. The primary sources of variation from the calculated results are thought to be the limited precision in measurements of flow and pressures.

The main conclusions from the pump test are the following:

- The basic calculation approach used in the previous study (ESA Consultants, November 1994) is valid and provides useful results.

- The Corps of Engineers' (1951) head loss predictions for the original portion of the system are remarkably close to actual system performance. The pumping test head loss measurements provided valuable confirmation of the Corps predictions, but the measurements were too variable to refine the Corps predictions. Thus, the Corps calculations continue to be used as the basic head loss characterization for the system. Detailed comparisons of pumping test results with the Corps calculations are provided in Appendix A.

- The test provided an additional basis for calculating the head loss between Hinkle "Y" and San Juan, a portion of the system that was substantially revised and extended after the original system installation. Thus no 1950's Corps head loss calculations are available for this segment of the system. The test data confirmed the approximate magnitude of the head losses previously calculated and were used for minor refinement of the Hinkle "Y" to San Juan head loss parameter.

- The test provided a substantially improved basis for calculating the head loss between Hinkle "Y" and

Roseville. In the previous study, pipe length and rule-of-thumb head loss factors were used to obtain a preliminary estimate. The pump test result shows that head loss in the Roseville line is significantly higher than initially estimated. The most important implication of this measurement is that head loss to Roseville could become the governing factor for system pumping needs under some circumstances. The following examples are indicative:

- If the San Juan system remains unchanged and has peak day flows of 180 to 190 cfs (116 to 123 mgd) as now anticipated, a second 48" diameter pipe to the Roseville Water Treatment Plant (with the same head loss characteristics as the existing Roseville line) and a total flow of 150 cfs for Roseville would result in total head losses that required approximately four feet more pumping head for Roseville than would be required for San Juan.

- If the San Juan system remains unchanged with peak-day flows as above and Roseville installs a 54" diameter second pipe, the resulting head losses with a total flow to Roseville of 150 cfs would likely leave San Juan in the governing position relative to pumping head requirements-- i.e., the pumping head to serve San Juan would continue to exceed that required to serve Roseville..

- If the San Juan system were modified to reduce head losses (e.g., by paralleling the existing segment of single 54" raw water line), then Roseville might have to install an even larger second line in order to avoid the governing position.

Thus, there is an economic issue involving pumping capacity and energy costs to be considered by Roseville when sizing its new raw water line.

4. RECALCULATIONS OF PRESENT SYSTEM HEAD LOSSES

Several developments since the previous study (ESA, November 1994) resulted in the need to refine the calculation approach used to estimate system head losses. These include:

- The removal of Pump 7 from the pumping plant.
- Performance of the pumping test to obtain measurements of head loss.
- Refinements to the data used as a basis for previous calculations.
- The need for a more precise characterization of pumping plant head losses so that alternative improvements to the pumping plant can be evaluated appropriately.

The refined calculation approach is used to specify the system pumping head needed for various flows at any specific reservoir level and, thereby, select additional pumps or modify existing pumps as needed to develop the required increase in pumping capacity.

4.1 Calculation Overview

System head loss occurs in several distinct components in the Folsom Project water supply system. Only those that govern pumping head requirements are addressed here. Those components are:

- The intake/piping system from Folsom Reservoir to the suction header at the pumping plant. The Corps (1951) characterization of head loss was used for this portion of the system.
- The piping and pump system that takes water from the suction header, applies pumping energy and conveys the water into the discharge header. The three subcomponents of this system for each pump are:
    - Suction piping(including turning, entrance, contraction, valve and piping to the pump)
    - Pump (i.e. flange to flange, as characterized by the manufacturer's pump curve)
    - Discharge piping (including piping, valve, expansion and exit)

The head losses through these subcomponents are not dependent on total system water flow, but on the flow through each pump. This, in turn, is dependent on which pumps are running and the total head against which they are pumping. To address this complexity, it is convenient to consider this plant head loss component within the context of each pump's head capacity curve. The manufacturer's pump curve already incorporates head losses within the pump itself. The remainder of the pumping plant losses can be included by adjusting each pump curve for the head loss in that pump's piping system. The calculation of the relevant head losses and development of adjusted pump curves is addressed in more detail in the next section.

- The discharge header and piping system to the junction with the gravity feed bypass. The Corps (1951) characterization was used for this system component.
- The 84" North Fork pipe line from the discharge/gravity junction to Hinkle "Y". The Corps (1951) characterization was used for this system component.
- The feeder line to San Juan from Hinkle "Y". The head loss factor derived from the pumping test results was used for this segment of the system.

Head loss calculations for this study assumed no system hydraulic modifications except in the pumping plant and the installation of a parallel line to Roseville. It was assumed that Roseville's parallel line would be large enough in diameter so that San Juan would continue to govern system pumping requirements, even when Roseville was drawing a full 150 cfs.

In calculating system head losses, it is necessary to assume a specific distribution of flows to the various end users. The present study focuses on enhancing system capacity to 400 cfs responsive to Roseville's increase from 65 cfs to 150 cfs. Thus, the assumed flow distribution was the same as developed for the previous report and was oriented toward this change by using the distribution set forth in Table 4-1. Note that Roseville takes the full increase (85 cfs) as system flow increases from 315 cfs to 400 cfs.

Except for the head loss across the pumping plant, the system head losses under the above flow distribution can be calculated as a function of total system discharge (see Figure 4-1). Then, since the static head change from the reservoir to San Juan can also be calculated for each flow (if the reservoir surface elevation is known), these two components can be combined into a series of curves showing required pumping head versus flow for several reservoir levels (see Figure 4-2).

Note that the required pumping head is referred to as the "adjusted pumping head required". This means that we are referring to the net increase in head supplied by the pumping plant, after allowing (adjusting) for the head losses in the pump's piping system. The actual total pumping head required of each pump will be this adjusted head plus the head losses in that pump's suction and discharge piping. The adjusted pumping head required will be approximately equal for all pumps operating at a given time. The actual total pumping head will vary slightly from pump to pump depending on differences in their piping head losses.

4.2 Head Loss Across Pumping Plant

The Corps (1951) developed calculations for head losses due to the initially installed piping and valves for each pump at one given pump discharge. Based on these calculations, head losses can be estimated for each pump as a function of discharge. The calculated head losses are shown in Figure 4-3. A similar curve for the head loss associated with Pump 6 piping has been developed and included.

The pump manufacturer's head capacity curve for each pump was then taken and adjusted (at each discharge) to show the net head the pump would develop after deducting the head losses across the plant. Thus, the adjusted curve shows the head increase between the suction header and the discharge header. Both the original and the adjusted curves are shown in Figure 4-4. These adjusted curves and the parallel arrangement of the pumps means that the net (adjusted) head across the plant will be essentially equal for all pumps running for a given operating condition. Figure 4-4 allows us to estimate the flow from each pump and sum those flows to obtain the total system capacity for that adjusted head. For example, at 50 feet of "adjusted" pumping head (see Figure 4-4):

Pump 2 = 27.5 cfs
Pump 3 = 65.9 cfs
Pump 4 = 46.8 cfs
Pump 5 = 46.8 cfs
Pump 6 = 62.4 cfs

Total Flow = 249.5 cfs

4.3 Cumulative Head Capacity Curves for the Existing System

Using the adjusted head capacity curves presented in Figure 4-4, a head capacity curve for the existing system as a whole can be developed. Figure 4-5 presents the resulting diagram showing the contribution of each pump (the shaded areas) and the cumulative discharge for the indicated combination of pumps at various adjusted pumping heads.

This curve can then be combined with the system head loss curve to show the system pumping capacity available and required at various reservoir levels. The resultant combined graph is shown in Figure 4-6. Based on a given reservoir level, one can find the flow rate that will be delivered for all pumps operating or a combination of several pumps as indicated in the figure. The system will operate at the intersection of the system curve (for the given reservoir elevation) and the relevant cumulative head-capacity curve (for the combination of pumps operating).

The upper boundary of this curve can be translated into a system capacity curve as developed in the previous ESA study. Figure 4-7 presents the newly calculated system capacity curve in that format showing the curve presented in Figure 3-1 and the pumping test result for comparison. Note that the modified approach for assessing head losses across the pumping plant results in estimates of slightly lower capacities at high and low reservoir levels.

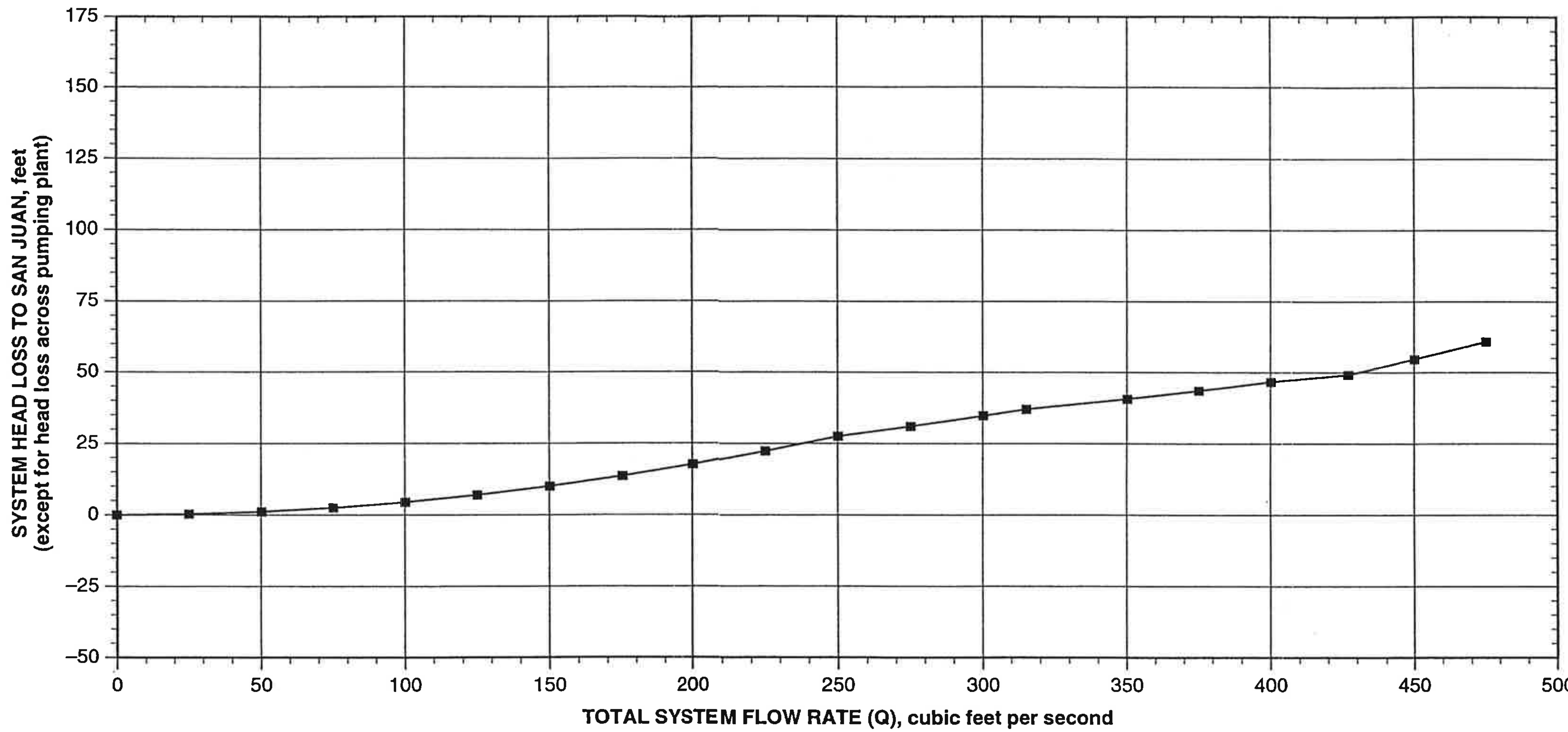
TABLE 4-1

ASSUMED DISTRIBUTION OF SYSTEM FLOW*

Total System Flow Rate	Flow to San Juan		Flow to Roseville		Flow to Natoma	
(cfs)	(cfs)	(%)	(cfs)	(%)	(cfs)	(%)
135	87	64.4%	29	21.5%	19	14.1%
150	97	64.7%	32	21.3%	21	14.0%
175	113	64.6%	37	21.1%	25	14.3%
200	129	64.5%	43	21.5%	28	14.0%
250	161	64.4%	54	21.6%	35	14.0%
315	185	58.7%	65	20.6%	65	20.7%
400	185	46.3%	150	37.5%	65	16.2%
427	190	44.5%	150	35.1%	87	20.4%
> 427		44.5%		35.1%		20.4%

* Flows are based on existing and expected contract amounts.

Note: In review the draft of this report, the City of Folsom's consultant (Robert M. Miles) provided information on water rights, Central Valley Project obligations and non-project water deliveries that could result in a somewhat different distribution table for system flows. Although this would slightly change the head loss calculations presented here, it would not change the study recommendations for pumping plant capacity improvements to address Roseville's objective of increasing their maximum delivery capacity to 150 cfs.



Notes:
1) The head losses included in this curve are those from the reservoir to the centerline pumping plant suction header and from the centerline of the pumping plant discharge header to San Juan.
2) The head losses across the pumping plant (which are not included in this curve) are those that occur in the small diameter pipes to and from the pumps, including entrance, expansion, contraction, valve, and exit losses.
3) Flow proportioning for the system head loss curve is based on existing and proposed contract amounts (see Table 4-1).

ESA Consultants Inc.
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM HEAD LOSS TO SAN JUAN FOR PUMPED FLOW

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
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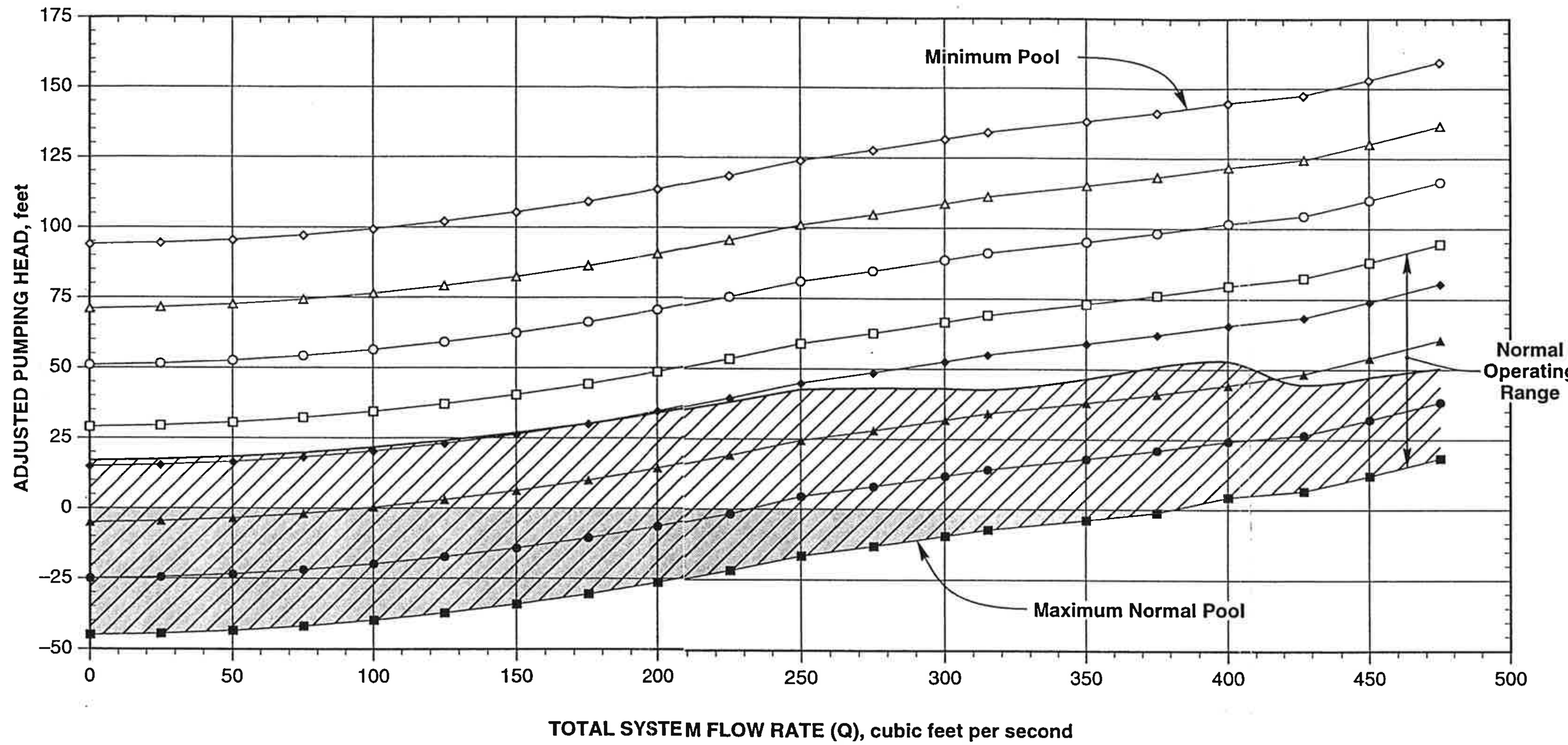

EXPLANATION

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Conditions where gravity flow to Natoma (El 404) are possible.

Conditions where gravity flow to San Juan (El 421-425) are possible.

Note:
1) System curves do not include head losses across the pumping plant.
2) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
3) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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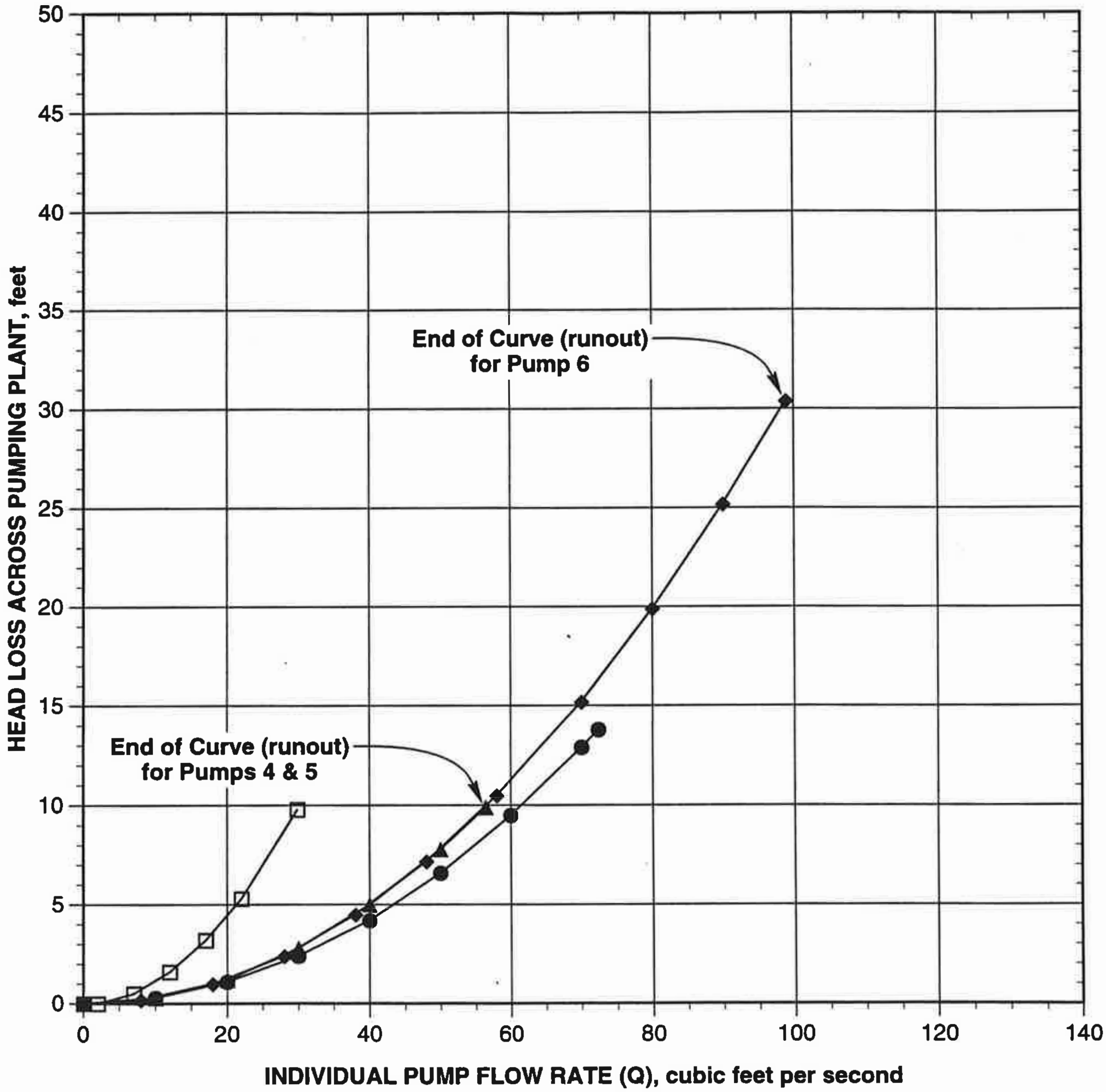
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

SYSTEM CURVES --

ADJUSTED PUMPING HEAD REQUIREMENTS

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	4-2

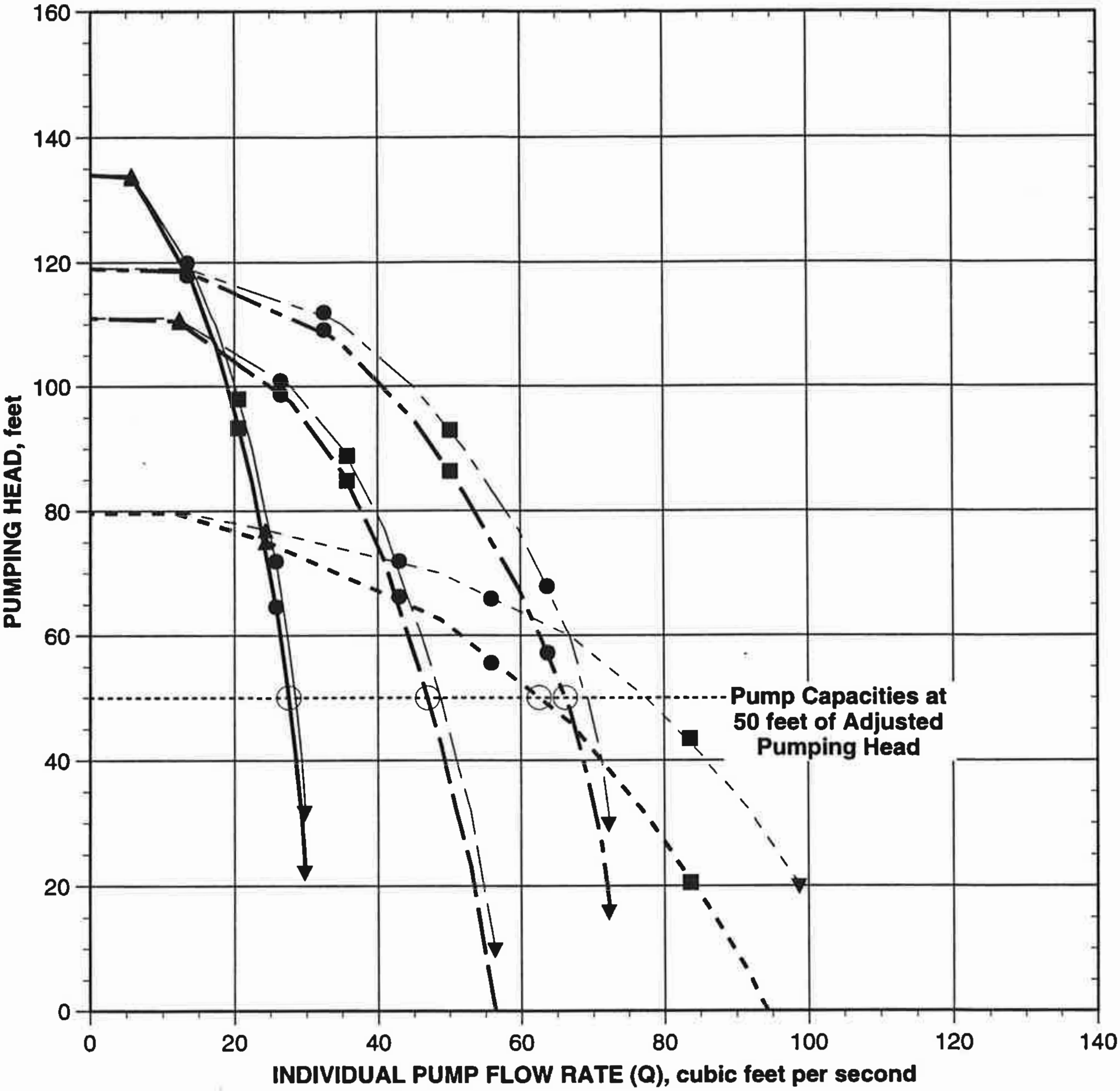


EXPLANATION

- Pump 2
- Pump 3
- Pumps 4 and 5
- Pump 6

Note: 1)The head losses across the pumping plant are those that occur in the small diameter pipes to and from the pumps, including entrance, expansion, contraction, valve, and exit losses.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **HEAD LOSS ACROSS PUMPING PLANT vs. FLOW FOR EXISTING CONDITIONS**		
Checked By Peter J. Jarder Date 1/26/96 Approved By Date 1/31/96	Project No. **043.9501**	Figure No. **4-3**



EXPLANATION

Pump 2 (total)
Pump 2 (adjusted*)

Pump 3 (total)
Pump 3 (adjusted*)

Pumps 4 and 5
Pumps 4 and 5 (adjusted*)

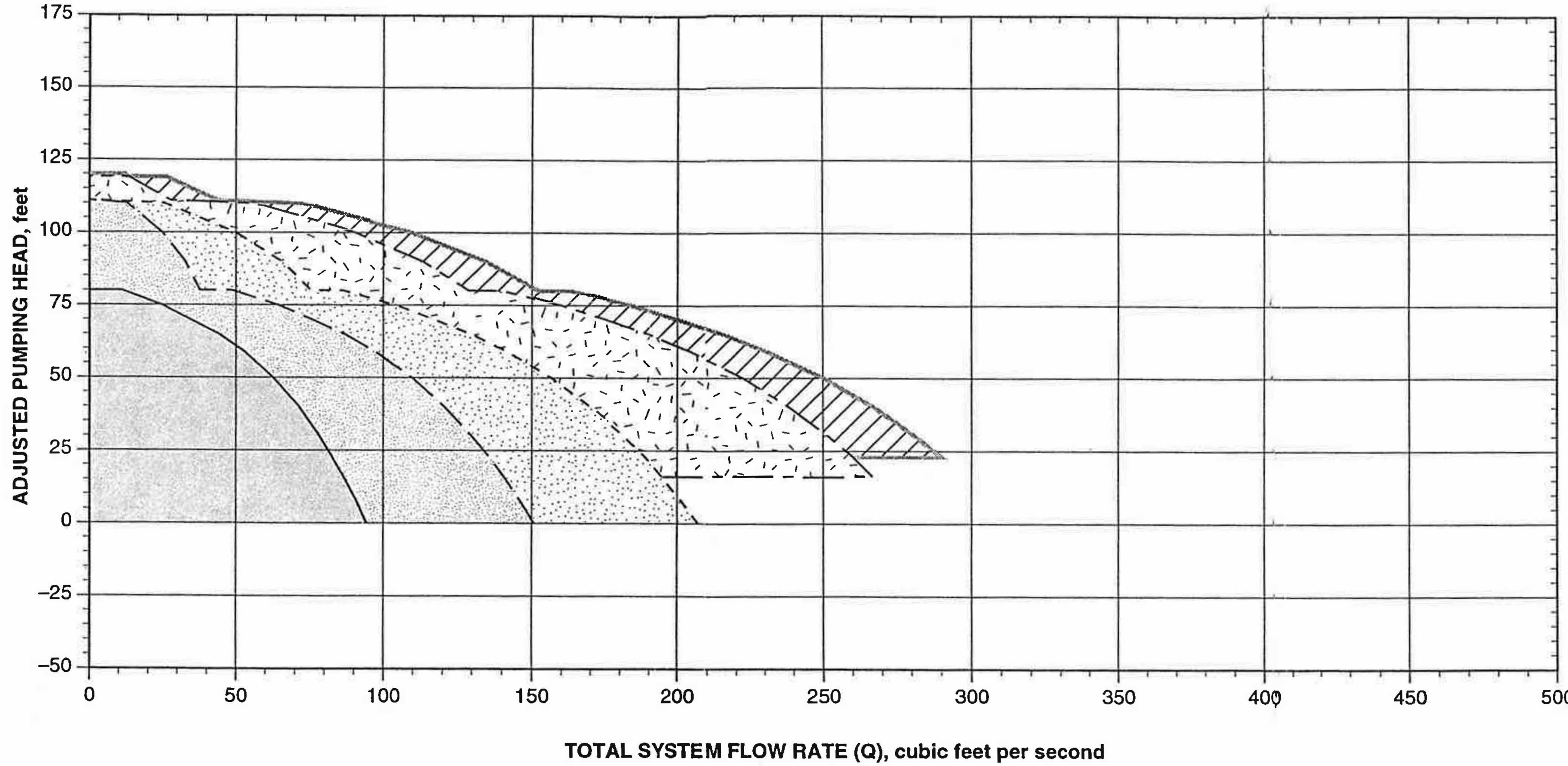
Pump 6 (total)
Pump 6 (adjusted*)

*See Note 1

■ Best Efficiency Point
● 80% Efficiency
▲ Shut Off
▼ Runout

Notes: 1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve (see Figure 4-3).
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **INDIVIDUAL PUMP HEAD-CAPACITY CURVES ADJUSTED FOR PUMPING PLANT HEAD LOSSES**		
Checked By Peter V. Jache Date 1/26/96 Approved By [signature] Date 1/31/96	Project No. 043.9501	Figure No. 4-4



EXPLANATION

Cumulative Head-Capacity Curves		Capacity Contributed By Each Pump	
———	Pump 6		Pump 6
— — —	Pumps 6 & 5		Pump 5
- - - -	Pumps 6,5 & 4		Pump 4
— - - —	Pumps 6,5,4 & 3		Pump 3
━━━	Pumps 6,5,4,3 & 2		Pump 2

Notes: 1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.

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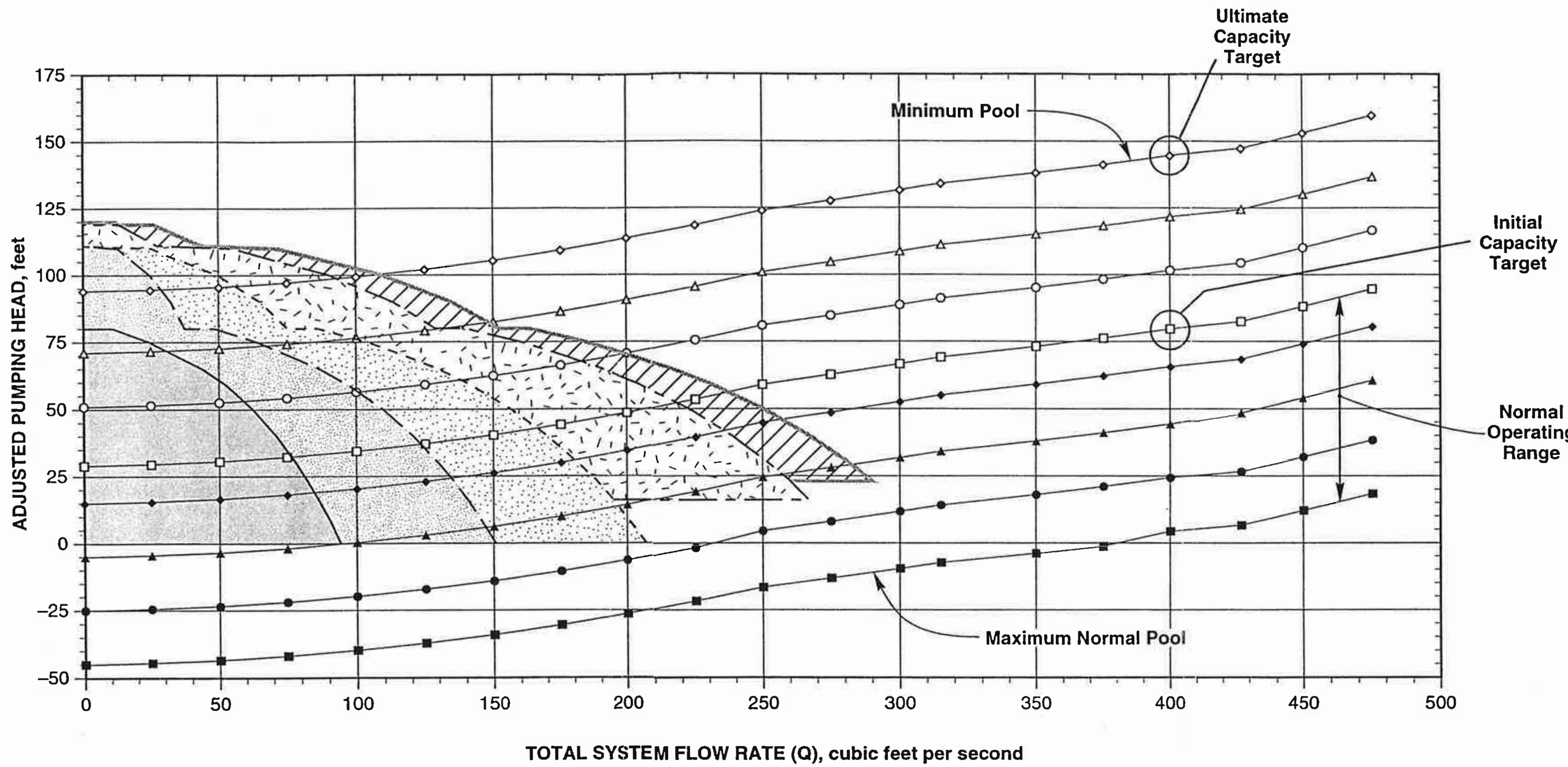
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
EXISTING HEAD-CAPACITY CURVES

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	4-5



EXPLANATION

Cumulative Head-Capacity Curves	Capacity Contributed By Each Pump	System Curves
Pump 6	Pump 6	Maximum pool - Res. El. 466
Pumps 6 & 5	Pump 5	Res. El. 446
Pumps 6,5 & 4	Pump 4	Res. El. 426
Pumps 6,5,4 & 3	Pump 3	Res. El. 406
Pumps 6,5,4,3 & 2	Pump 2	Res. El. 392
		Res. El. 370
		Res. El. 350
		Minimum pool - Res. El. 327

Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) System curves do not include head losses across the pumping plant.
4) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
5) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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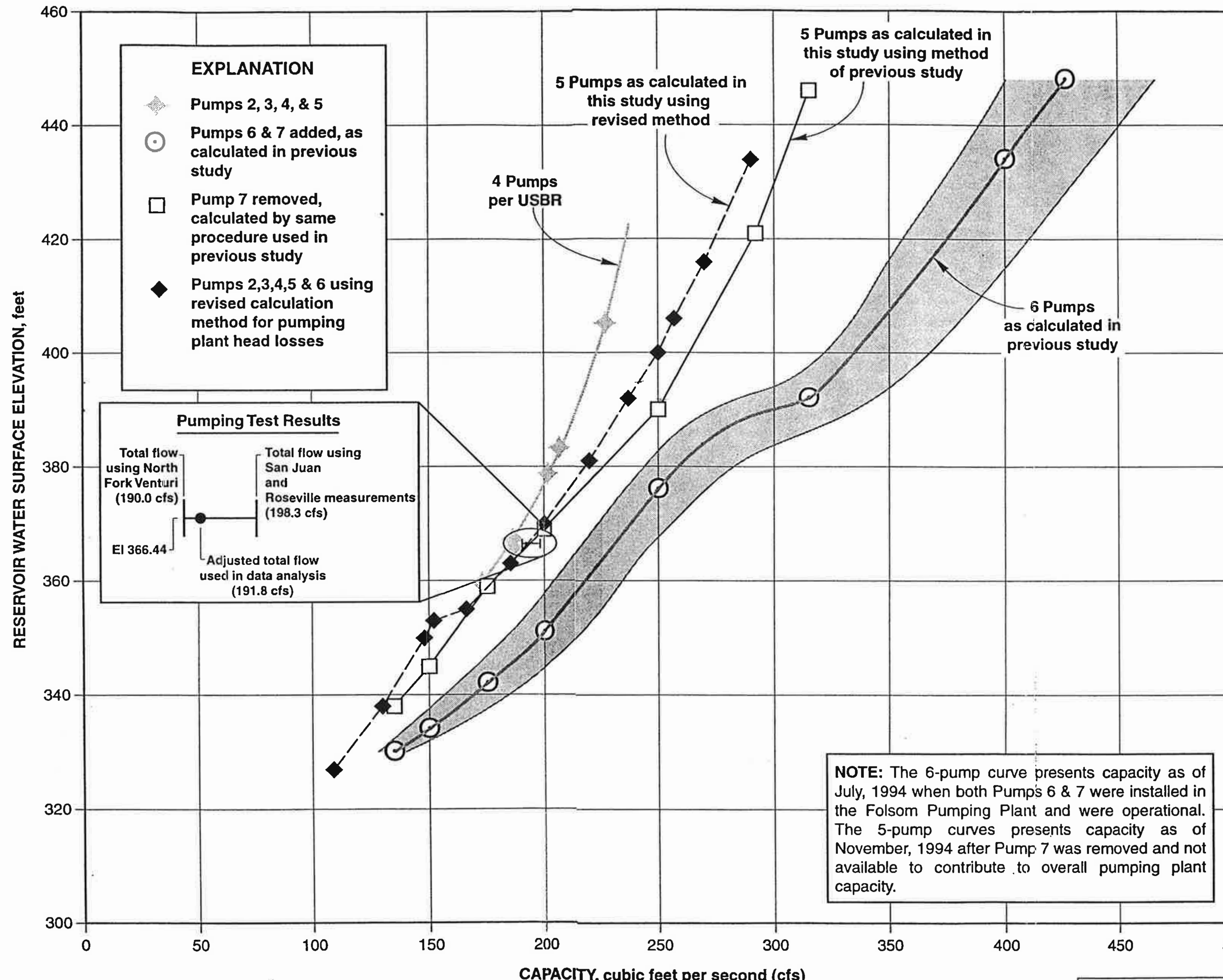
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
EXISTING HEAD- CAPACITY AND SYSTEM CURVES

		Project No.	Figure No.
Checked By Peter V. Jacke	Date 1/26/96	043.9501	4-6
Approved By B	Date 1/31/96		



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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
EXISTING PUMPING CAPACITY (REVISED) AND PUMPING TEST RESULT

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By	Date 1/31/96	043.9501	4-7

5. PUMPING CAPACITY IMPROVEMENTS

Preliminary calculations indicated that the vast majority (if not all) of the needed pumping capacity improvements should occur within the pumping plant. Two specific targets were established based on the previous study (ESA Consultants, November 1994) and the scope of work for the present study:

- 400 cfs of delivery capacity when the reservoir is at El. 392. This was based on the system capacity (including Pump 7) that was estimated in the previous study to be 315 cfs at El 392. The idea was that increasing Roseville's peak flow by 85 cfs should not lessen the system's present capability to deliver peak flows under existing contracts. Both the removal of Pump 7 and the revised calculation procedure for head losses would result in changes to this target (see Table 5-1). However, the target of 400 cfs at El. 392 was maintained as stated.

- 400 cfs of delivery capacity when the reservoir is at minimum pool (or as close to minimum pool as practical). The idea of this target was to provide a full water supply contract delivery capability for the potential circumstances where aggressive operation of Folsom Reservoir could result in low water levels much more frequently than experienced in the past.

5.1 Additional Pumps

Primary attention was focused on providing increased pumping capacity by installing additional pumps in the two large-pump positions that are presently not occupied (Nos. 7 and 8).

Pumps from two different manufacturers (Ingersoll-Dresser and Gould) were identified as examples that would be suitable for installation in these positions. The types of pumps to be used would be similar to the existing pumps; they would be:

- single stage
- horizontal shaft
- horizontally split casing
- double-suction
- dual volute
- centrifugal pumps

Required pump capabilities with respect to the performance targets were set as follows:

- For the combination of two added pumps to boost system pumping capacity to 400 cfs at reservoir El. 392, each would need to deliver 118 cfs at 80 feet of adjusted pumping head (see Figure 4-6).

- For the two added pumps to contribute to an ultimate capability of providing 400 cfs at reservoir El. 327, each pump would need to deliver approximately 60 cfs at 140 feet of adjusted pumping head. This assumes an ultimate installation of six large pumps (at 60 cfs each like the two now being considered) and two smaller pumps which combine to provide an additional 40 cfs.

Since the above requirements are indicated in adjusted pumping head, conversions to total pumping head were necessary for discussions with pump manufacturers. Accordingly, the performance targets ultimately developed in terms of total pumping head are:

- 118 cfs at 98 feet
- 60 cfs at 146 feet

Manufacturers identified their applicable pumps as follows:

- Ingersoll-Dresser 750-LNE-1050
  - maximum speed 600 rpm
  - impeller diameter range 32.6 inches to 41.7 inches
  - 36" suction and 30" discharge

  An initial rating was discussed based on 524 rpm and an impeller diameter of 39.9 inches. This rating requires a maximum power of 1415 hp. After detailed hydraulic calculations, slight increases in performance (i.e., 118 cfs at 98 feet)were needed. Within the 1500 hp rating used for electrical considerations this pump can get very close to the target. This can be accomplished by increasing speed or impeller diameter or a combination of both and will be fine tuned during detailed design.

- Gould Pump Model 3420
  - maximum speed 600 rpm
  - impeller diameter range 34" to 46"
  - 42" suction and 30" discharge

  Again, an initial rating was discussed that was slightly less than that required after detailed hydraulic calculations. Within the 1500 hp rating used for electrical aspects, some further fine tuning on speed and impeller diameter will be required to optimize this pump's ability relative to the performance targets. Such fine tuning will occur during detailed design.

All subsequent calculations and analyses have been based on the Ingersoll- Dresser pump as initially rated, simply because that information was available first.

5.2 Pump Performance Curves

Based on data from the manufacturer, pump performance characteristics can be estimated for various pump speeds and impeller diameters. For example, Figure 5-1 shows the curves for the Ingersoll- Dresser pump (750-LNE-1050) at various speeds with a 39.9 inch impeller. Similar curves are shown for a slightly lower speed and larger impeller diameter in Figure 5-2 and a higher speed and smaller impeller diameter in Figure 5-3.

Based on these curves, the pump can be oriented toward the specific application of concern in order to optimize its response to the pump performance targets. Optimizing the choice of speed and impeller diameter in relation to pump power requirements will be addressed in final design.

Of special importance in this study, is consideration of the operating capability of the pumps in terms of the driver (motor system) used. Three major types of drivers are available:

- single speed motors
- two speed motors
- variable speed motors

Figure 5-4 shows the head capacity curve for the pump with a single speed motor (at 590 rpm). The operating range of the pump in this type of installation is along the curve. If the pump is needed for a total pumping head of less than 80 feet, it produces 80 feet of head (or more) and a throttling valve is used to control the system output to the lesser head needed. Similarly, if a lower flow is needed at a particular head, throttling is used to reduce the discharge. With throttling, the pump can serve the combination of heads and discharges shaded in Figure 5-4. However, the throttling dissipates (or wastes) a portion of the energy applied to the hydraulic system by the pump.

Figure 5-5 shows the head-capacity curve for the pump with a two speed motor (at 590 rpm and 505 rpm). The operating range of the pump at its higher speed is identical to the single speed pump discussed above. What the second speed offers is the ability to run at some lower combinations of head and discharge with less throttling (or energy waste). The bold line in Figure 5-5 indicates the capacity of the two speed pump at any given pumping head with no throttling. The pump can still serve the indicated shaded areas under the curves (a slightly larger total area than for the single speed pump). However, the area under the lower speed curve can be served with significantly less energy waste.

Figure 5-6 shows the head-capacity curve for the pump with a variable speed motor (maximum speed of 590 rpm). The operating range of the pump at maximum speed is the same as for the previous examples. However, with the variable speed pump the combinations of head and discharge that can be achieved without throttling are substantial (as indicated by the shading). Similarly, the area indicating combinations that require throttling is much reduced. In the areas that still require throttling, the quantities of energy wasted are also reduced.

Choice of the drivers to be used for the two additional pumps is one of the most significant decisions for conceptual design of the increased pumping capacity at Folsom.

5.3 Pumping Plant Head Loss

Significant head losses are associated with the suction and discharge piping for the two additional pumps. Figure 5-7 shows the across the plant head losses estimated for additional pumps in positions 7 and 8. Cases for existing and enlarged piping sizes are shown. With the existing piping sizes for suction (30 inch) and discharge (24 inch) lines, head losses would amount to nearly 31 feet at 100 cfs and would increase to 43 feet at the 118 cfs target capacity. These head losses are so large that they simply must be reduced where practical.

The other curve in Figure 5-7 shows the maximum practical piping modification to reduce head losses. This would include use of larger pipes and valves (36 inch for suction and 30 inch for discharge) and cutting back the existing cones that connect to the suction and discharge headers. The greatest potential for reducing head loss is from changing the piping sizes (including the header cones) as indicated in Figure 5-8. Of the piping changes, the more important (from a head loss viewpoint) is on the discharge side of the pump because of the large exit loss when flow enters the discharge header. This piping and cone diameter modification to reduce exit velocity will be essential and, fortunately, is relatively easy to accomplish from a constructibility viewpoint; it can be scheduled to occur during a period of gravity operation. On the suction side, the piping modification to the existing cone is less critical and more difficult from a scheduling/constructibility standpoint. If the suction side cones were not modified, but all other modifications were implemented, approximately 1.5 feet of the indicated head loss improvement (at 118 cfs) would be foregone. This can be fine tuned during the final design, based primarily on other construction needs relative to draining the suction header.

For the present study, the total and adjusted head capacity curves for Pumps 7 and 8 were adopted as indicated in Figure 5-9, based on 36 inch piping and valves for suction and 30 inch piping and valves for discharge and including modification of both cones.

5.4 Cumulative Head Capacity Curves

The pump performance curves presented in Section 5.2, as adjusted by the cross plant head loss estimates developed in Section 5.3 can now be used to develop cumulative adjusted pumping head versus capacity curves for the plant. The three different drivers result in distinct head-capacity curves as follows:

- Single speed: Figure 5-10
- Two speed: Figure 5-11
- Variable speed: Figure 5-12

The system head loss curves are also shown on these figures indicating in each case that the proposed pump additions come very close to meeting the target of 400 cfs when the reservoir is at El. 392. Figure 5-13 presents the same information as Figure 5-12, but puts Pumps 7 and 8 on the left side of the figure. This is to facilitate looking at the curves from the viewpoint of operation, assuming that the proposed additional pumps would be operated preferentially because of the flexibility and energy efficiency provided by the variable speed capability.

5.5 Pumping Demand

Although the foregoing sections have provided extensive information on present and prospective pumping capacity, little has been presented on pumping needs. To provide perspective on this topic, the following analysis was performed.

- The 1995 and expected 2020 annual demands for each agency were obtained or estimated (Table 5-2)

- The distribution of each agency's annual demand by calendar month was obtained or estimated (Table 5-2). This distribution was assumed to apply for both 1995 and 2020.

- Based on these inputs, the monthly average demands for total Folsom Dam water supply deliveries could be estimated for 1995 and 2020 (Table 5-3).

- Based on the monthly average demand, the system head loss to San Juan (except across the pumping plant) could be estimated.

- The simulated Folsom monthly storage levels for 70 years of hydrologic record were obtained. The data base used was obtained from Murray Burns and Kienlen and is the output from a computer run dated June 20, 1994 (Run number 4671c) assuming a reoperation flood control pool of 467,000 acre-feet (but allowing for appropriate credits for space available in upstream reservoirs). The input data are set forth in Table 5-4.

- The end of month storage numbers obtained were converted to average storage for each month and then to average lake level for each month. The lake level data are presented in Table 5-5.

- The average lake level was converted to average static pumping head, using San Juan at El. 423.

- The system head losses to San Juan for each calendar month (1995 or 2020) could then be combined with the 70 years of monthly static pumping head requirements to obtain a frequency distribution of adjusted pumping head required versus monthly average total flow rates. The results are presented as follows:

    - 1995 demand in Table 5-6 and Figure 5-14
    - 2020 demand in Table 5-7 and Figure 5-15

- These results can be converted into a contour-type diagram of pumping conditions as demonstrated for the 1995 results in Figure 5-16. Note that where adjusted total pumping head is zero or less, gravity flow conditions prevail and pumping is not needed. The system head loss curves can then be added to the diagram as demonstrated in 5-17 for the 1995 results.

- Finally, the distribution of pumping requirements can be compared to pumping capabilities as shown in Figure 5-18 for 1995 and 5-19 for 2020. These curves show the pumping capability for Pumps 7 and 8, assuming variable speed pumps. Figure 5-20 and 5-21 show the 2020 demands with the single speed and two-speed pumps respectively.

5.6 Comparison of Drive Alternatives

The important observation from the figures presented and discussed above is that installing the variable speed pumps will provide substantial flexibility to serve the pumping needs in the normal reservoir operating range with relatively little throttling and energy waste. However, with either the single speed or two speed pumps, substantial throttling and energy waste will continue.

As one example of the energy efficiency, consider a demand of 400 cfs at reservoir El. 446, which will likely become a relatively normal (post-2020) summer time pumping condition. For this condition an adjusted pumping head of 25 feet is indicated in Figure 5-19. With variable speed pumps 7 and 8, this particular point can be served without throttling, by running pumps 3 through 8 and slightly decreasing the speeds on pumps 7 and 8 from the maximum speed indicated for that pumping head (see Figure 5-19). In contrast, both the single speed (Figure 5-20) and two speed (Figure 5-21) pumps would require significant throttling-- the system, with single speed pumps would have to run at 80 feet of adjusted pumping head and, with the indicated two speed pumps, the system would have run at 65 feet of adjusted pumping head. Energy calculations reveal the comparison of power and energy requirements shown in Table 5-8. The differences are substantial. They indicate that the throttling energy costs can easily amount to tens of thousands of dollars per month.

There are other problems with operating the system at 400 cfs and 25 feet of pumping head. The above calculation (Table 5-8) assumed that the present practice of throttling at San Juan would continue. However, both the single speed and two speed throttling heads indicated above would create too much system head. They would overflow the standpipes and trip the system. Standpipe extensions may not even solve the problem, since exceeding the existing maximum might eventually over pressurize the system. Thus, a different throttling approach that addresses Pumps 7 and 8 individually would be required. First stage throttling would need to be performed using the discharge line valves for these two pumps. Although this would significantly increase the complexity of system operation, it would have the advantage of less throttling energy waste. The existing pumps could be operated near the 25 feet of adjusted pumping head required and only the two new pumps would be throttled. In fact, only one of the new pumps would be needed. With the new single speed pumps, a (pre-throttling) adjusted pumping head of 80 feet would be needed on one pump to throttle to 110 cfs and with the new two speed system, Pump 8 (with its higher low speed) could provide the needed flow at approximately 45 feet of (pre-throttling) adjusted pumping head. The marked changes in power and energy requirements due to individual pump throttling are shown by Table 5-9 (which can be compared to Table 5-8). Although the wasted energy and its cost are reduced by 86 percent and 73 percent in the two speed and single speed cases (respectively), they still constitute $8,400 and $23,000 per month for this operating point. Furthermore this two speed case is one of the more energy efficient throttling circumstances that can be expected.

A specific operating mode (which pumps are on and which pumps are throttling) can be defined for each relevant combination of flow and adjusted pumping head for the three drive alternatives. The power and energy differences could be calculated and summed over the 70 years of monthly operating points available for the two demand years (1995 and 2020). However, even without this effort some conclusions seem obvious:

- High-head pumps with single speed drives are unreasonable. Large amounts of energy would be consumed while throttling these pumps in order to supplement system capacity throughout most of the normal reservoir operating range. If single speed drives are desired, then lower head pumps should be considered even though pumping capacity would be augmented less for low reservoir levels.

- Even with two speed pumps, a new throttling strategy will be required to conserve energy. System flow needs to be limited by throttling a minimal number of pumps in the pumping plant, while avoiding or minimizing throttling at San Juan.

- The difference in cost estimated herein for two two-speed drives compared with two variable speed drives is $290,000 (See Section 10). Using a 25-year life and 8 percent discount rate, the amortization of the cost difference is only $2,240 per month. For reference, this is equivalent to energy consumed for throttling 100 cfs to waste 5.7 feet of head (assuming $0.05/kwh) or 9.5 feet of head (assuming $0.03/kwh). Even if near-term energy savings are modest, there will be some. Furthermore the energy savings are bound to grow as demand increases over time. When convenience of operation is also considered, there is little question that variable speed drives are the system choice.

Detailed water demand data were only recently obtained in refined form. A rigorous assessment of throttling energy cost savings could now be developed to confirm the tentative direction set forth above, if desired.

ESA believes our client's interests are best served by the variable speed drives. We believe detailed analysis to assess future energy savings is not necessary.

TABLE 5-1
SYSTEM CAPACITY BENCHMARKS
UNDER VARIOUS CIRCUMSTANCES

	System Capacity (cfs)	Reservoir Elevation (feet)
As estimated by ESA, November 1994 for Pumps 2 through 7	315	392
Same calculation method; without Pump 7	315 or 253	446 or 392
Revised calculation method; without Pump 7	315 or 237	N/A* or 392

* The existing pumping plant (per pump manufacturer's operating rules and the revised calculation procedure) is not capable of delivering 315 cfs. The maximum pumping capability is 290 cfs at reservoir El 434 (or higher). Under gravity operation, 315 cfs can be delivered when the reservoir is above approximately El 455.

TABLE 5-2
FOLSOM PROJECT WATER
SUPPLY DEMANDS

A. Annual Demand

	1995		2020	
	acre feet	(cfs)	acre feet	(cfs)
Roseville	17,855	24.67	46,950	64.87
San Juan	53,100	73.36	82,200	113.57
City of Folsom	15,500	21.41	34,400	47.52
Folsom Prison	2,172	3 ±	2,900	4 ±
Total	88,627	122.44	166,450	230.0

B. Monthly Demand
(% of annual; estimated)

	Roseville	San Juan	City of Folsom	Folsom Prison
January	4.1	4.2	5.0	7.7
February	3.9	3.5	4.9	7.5
March	4.7	5.5	6.5	7.8
April	6.8	7.7	7.0	8.1
May	10.0	9.3	9.6	8.5
June	11.8	13.6	11.2	8.8
July	13.9	15.4	12.3	9.1
August	13.9	14.5	12.3	9.2
September	11.6	11.5	10.4	8.9
October	8.9	7.7	8.7	8.5
November	5.8	3.6	6.7	8.1
December	4.7	3.6	5.5	7.8
Total	100	100	100	100

TABLE 5-3
MONTHLY AVERAGE TOTAL
SYSTEM DEMANDS*

	1995 (cfs)	2020 (cfs)
January	63.6	119.2
February	62.6	119.1
March	80.2	149.3
April	110.2	204.1
May	136.2	257.9
June	189.6	350.7
July	207.3	384.5
August	199.8	373.1
September	167.6	314.6
October	117.1	223.2
November	70.0	138.1
December	61.4	118.4
Annual Average	122.4	230.0

* Monthly average total system demands are presented only to illustrate typical pumping requirements. Maximum pumping requirements are dictated by peak day demand and are often estimated to be between 2.0 and 2.3 times average annual demand. For 2020, this would indicate peak day demand between 460 and 530 cfs. Per water agency estimates, 2020 peak day demand for the Folsom Project is expected to be approximately 172(San Juan) + 143(Roseville) + 96(Folsom) + 9(prison) = 420 cfs.

TABLE 5-4
FOLSOM END-OF-MONTH STORAGE
(Folsom Reoperation Study, Run No. 4671c; 467,000 Flood Control Pool)

(in thousand Acre Feet)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	425.0	418.9	502.4	527.0	575.0	631.0	800.0	975.0	975.0	843.6	750.7	608.1
1923	586.8	574.0	575.0	575.0	575.0	613.1	800.0	975.0	946.5	777.4	566.2	512.7
1924	375.0	346.0	318.5	283.6	312.5	280.1	327.6	377.3	375.0	360.0	378.1	400.7
1925	362.3	361.8	362.3	355.2	575.0	668.1	800.0	975.0	810.7	615.1	401.6	291.3
1926	200.0	234.8	270.0	269.5	466.2	520.7	800.0	838.1	680.0	450.0	275.0	256.2
1927	255.7	407.5	472.9	574.9	575.0	680.0	800.0	975.0	975.0	793.8	623.5	500.0
1928	480.9	540.8	573.9	575.0	575.0	631.0	800.0	885.6	633.6	555.4	450.0	449.2
1929	415.2	386.2	368.6	329.7	364.6	419.2	497.5	631.3	647.7	652.5	637.3	620.4
1930	571.0	415.7	502.7	542.9	575.0	668.6	768.7	828.4	733.0	475.3	275.0	257.6
1931	242.2	278.0	270.0	281.6	298.3	334.9	347.0	380.5	386.5	359.9	343.0	334.4
1932	299.7	305.9	389.4	465.4	575.0	650.0	750.2	925.4	975.0	950.0	800.0	650.0
1933	600.0	574.0	555.8	512.8	494.0	536.4	610.1	788.4	861.7	842.7	799.9	650.0
1934	600.0	517.6	559.4	575.0	575.0	650.1	687.1	667.6	635.8	603.0	570.5	541.0
1935	484.0	470.9	444.1	497.5	575.0	622.4	800.0	975.0	975.0	789.8	509.0	400.0
1936	375.0	370.0	364.5	575.0	575.0	654.0	800.0	954.7	975.0	811.8	606.4	408.1
1937	375.0	356.0	343.5	342.5	575.0	636.0	800.0	975.0	949.0	750.9	541.7	482.2
1938	375.0	396.0	574.0	575.0	575.0	631.0	800.0	975.0	975.0	950.0	800.0	650.0
1939	600.0	574.0	573.4	561.0	558.8	654.6	747.7	795.5	806.0	794.9	550.7	511.2
1940	476.1	435.0	270.0	575.0	575.0	631.0	800.0	953.8	798.5	600.0	450.0	395.1
1941	387.7	393.6	574.0	575.0	575.0	680.0	800.0	975.0	975.0	946.6	800.0	650.0
1942	600.0	574.0	575.0	575.0	575.0	671.0	800.0	975.0	975.0	950.0	800.0	650.0
1943	600.0	572.0	564.0	554.0	553.0	642.0	800.0	975.0	957.2	787.0	585.7	500.0
1944	478.9	468.8	459.2	441.8	510.8	630.8	694.2	886.0	863.2	655.4	436.7	415.3
1945	378.2	436.1	492.6	504.2	575.0	650.1	750.2	925.4	880.0	691.2	479.3	400.0
1946	375.0	460.0	575.0	575.0	575.0	680.0	800.0	890.1	702.0	600.0	400.0	347.3
1947	341.1	417.8	451.3	415.9	495.9	660.8	792.7	797.2	675.7	450.0	275.0	200.0
1948	231.1	255.9	257.2	322.7	354.4	390.5	720.9	975.0	975.0	798.8	645.8	475.9
1949	385.8	360.3	374.8	354.8	382.7	599.9	799.8	974.9	887.2	641.4	426.7	366.9
1950	353.6	356.5	270.0	485.3	575.0	680.0	800.0	975.0	975.0	810.5	691.9	555.2
1951	442.2	337.0	305.0	306.0	309.0	587.0	800.0	975.0	807.7	600.0	450.0	399.1
1952	409.7	471.6	574.0	575.0	575.0	632.0	800.0	975.0	975.0	950.0	800.0	650.0
1953	600.0	574.0	574.0	575.0	575.0	616.8	767.5	942.6	975.0	950.0	800.0	650.0
1954	600.0	574.0	574.0	575.0	575.0	654.0	800.0	943.5	797.0	600.0	450.0	450.0
1955	420.0	409.9	479.4	557.0	575.0	608.9	695.0	791.3	736.0	468.7	275.0	205.4
1956	207.2	241.0	541.0	398.0	426.0	571.6	750.5	975.0	975.0	950.0	800.0	650.0
1957	600.0	574.0	574.0	572.6	575.0	680.0	752.0	974.0	974.0	818.3	762.2	650.0
1958	600.0	574.0	574.0	575.0	575.0	631.0	800.0	975.0	975.0	950.0	800.0	650.0
1959	600.0	574.0	558.4	575.0	575.0	642.9	759.4	826.0	735.6	600.0	400.0	385.7
1960	358.4	326.3	275.8	297.3	570.9	678.0	800.0	870.5	723.0	450.0	275.0	200.0
1961	200.0	240.8	288.5	278.0	336.7	385.8	475.3	597.0	618.2	450.0	275.0	244.8
1962	226.4	218.2	229.8	228.7	573.2	680.0	800.0	915.5	828.8	600.0	400.0	393.5
1963	600.0	574.0	574.0	575.0	535.0	617.4	800.0	975.0	975.0	778.8	707.5	595.0
1964	583.6	574.0	574.0	575.0	575.0	586.1	684.7	803.6	775.7	507.3	292.4	206.5
1965	209.3	283.1	335.0	330.0	352.0	452.8	800.0	975.0	975.0	821.8	780.2	650.0
1966	600.0	574.0	574.0	575.0	575.0	664.9	795.2	887.7	740.8	600.0	400.0	378.2
1967	351.9	377.8	551.3	575.0	575.0	652.0	800.0	975.0	975.0	950.0	800.0	650.0
1968	600.0	574.0	574.0	575.0	575.0	652.1	744.8	779.5	672.4	552.7	400.0	374.4
1969	346.7	399.7	483.1	575.0	575.0	680.0	800.0	975.0	975.0	950.0	800.0	650.0
1970	600.0	574.0	565.0	336.0	353.0	543.8	644.2	693.0	600.0	565.8	450.0	421.5
1971	388.6	504.6	575.0	575.0	575.0	680.0	799.6	975.0	975.0	931.1	800.0	650.0
1972	600.0	574.0	574.0	575.0	575.0	680.0	780.1	934.6	769.4	600.0	516.0	400.0
1973	375.0	424.0	550.4	575.0	575.0	680.0	787.6	975.0	774.7	600.0	450.0	407.1
1974	398.2	561.0	556.0	452.0	515.0	631.0	800.0	975.0	975.0	950.0	800.0	650.0
1975	600.0	574.0	574.0	575.0	575.0	631.0	740.1	975.0	975.0	950.0	800.0	650.0
1976	600.0	567.0	560.9	535.5	524.3	531.0	535.1	550.6	463.3	360.0	337.7	309.2
1977	272.1	250.8	196.1	156.0	129.6	132.8	146.6	164.3	155.2	131.3	109.9	96.4
1978	89.4	100.8	216.7	575.0	575.0	662.0	800.0	975.0	975.0	806.8	638.1	587.8
1979	548.5	535.3	527.7	575.0	575.0	680.0	793.1	975.0	903.7	682.7	598.4	535.8
1980	523.6	545.4	574.0	421.0	373.0	618.0	783.7	958.8	958.8	950.0	800.0	650.0
1981	600.0	574.0	574.0	575.0	575.0	646.1	744.8	740.8	636.3	450.0	275.0	240.6
1982	213.2	528.0	332.0	356.0	309.0	570.0	800.0	975.0	975.0	950.0	800.0	650.0
1983	600.0	498.0	513.0	523.0	523.0	631.0	800.0	975.0	975.0	975.0	833.9	673.9
1984	600.0	333.0	305.0	308.0	330.0	529.8	660.8	836.3	743.8	600.0	450.0	408.1
1985	369.2	446.2	499.7	493.3	552.3	627.4	727.6	740.6	573.9	450.0	275.0	284.2
1986	247.6	264.3	354.7	546.7	358.0	570.0	766.8	936.2	940.6	728.5	538.8	495.4
1987	435.3	386.2	329.7	297.8	374.7	468.7	517.9	523.5	496.5	423.9	275.0	233.3
1988	174.9	128.8	185.4	281.3	342.7	359.9	374.5	413.6	374.8	359.9	349.9	359.4
1989	284.3	274.8	279.8	298.4	361.1	631.0	800.0	836.9	678.3	463.3	307.6	272.3
1990	246.7	264.5	273.8	303.3	355.9	463.0	519.2	450.0	392.9	359.9	349.9	337.8
1991	309.7	274.9	237.2	206.1	196.6	387.2	499.7	616.5	655.4	643.7	627.2	609.1

TABLE 5-5
MID MONTH FOLSOM LAKE LEVELS
(Folsom Reoperation Study, 4671c; 467,000 Flood Control Pool)
(ft Above MSL)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	406.5	406.0	411.0	418.0	422.5	428.5	440.5	457.5	465.5	459.5	449.0	437.0
1923	428.0	426.0	425.5	425.5	425.5	427.5	440.0	457.5	464.5	455.0	436.0	421.0
1924	409.0	397.0	392.5	387.0	386.5	386.0	387.5	395.5	399.5	398.0	398.0	401.0
1925	400.0	397.0	397.0	396.5	412.0	430.5	442.5	457.5	458.0	440.5	417.5	394.5
1926	376.5	371.0	378.0	381.5	398.0	415.5	435.0	451.0	445.0	424.0	397.0	380.5
1927	379.0	392.0	408.5	419.5	425.5	431.5	443.0	457.5	465.5	457.5	440.0	424.0
1928	415.0	417.5	423.5	425.5	425.5	428.5	440.5	453.5	445.0	427.5	416.5	409.5
1929	407.5	403.0	399.5	395.0	395.0	401.5	411.0	424.0	432.5	434.0	433.0	431.5
1930	427.5	415.5	411.0	419.0	423.5	430.5	441.0	449.0	447.5	428.5	399.0	381.0
1931	377.5	379.5	382.0	382.5	385.0	390.0	394.0	397.5	400.5	399.0	395.5	393.5
1932	390.0	387.5	395.0	406.5	419.0	429.5	439.0	453.0	463.5	464.5	456.5	441.5
1933	431.0	426.5	424.0	420.5	416.5	418.0	425.0	439.0	451.5	454.0	451.5	441.5
1934	431.0	423.5	421.0	424.5	425.5	429.5	436.0	436.5	434.0	430.5	426.5	423.0
1935	418.0	413.5	411.0	412.5	421.0	428.0	440.5	457.5	465.5	457.0	433.5	410.5
1936	401.0	398.5	398.0	412.5	425.5	430.0	442.0	456.5	464.5	458.0	440.0	417.0
1937	401.5	397.5	395.0	394.0	411.0	429.0	441.0	457.5	464.5	454.0	433.5	418.0
1938	407.0	400.5	414.5	425.5	425.5	428.5	440.5	457.5	465.5	464.5	456.5	441.5
1939	431.0	426.5	425.0	424.5	423.5	429.0	439.0	446.5	449.5	449.5	436.0	420.0
1940	415.5	410.5	395.5	406.0	425.5	428.5	440.5	456.5	456.5	439.0	419.5	406.0
1941	401.5	401.5	414.0	425.5	425.5	431.5	443.0	457.5	465.5	464.5	456.0	441.5
1942	431.0	426.5	425.5	425.5	425.5	431.0	443.0	457.5	465.5	464.5	456.5	441.5
1943	431.0	426.5	424.5	423.5	423.0	428.0	441.5	457.5	465.0	456.0	437.5	421.5
1944	415.0	413.0	411.5	410.0	413.0	425.0	435.0	448.0	456.5	445.0	422.0	406.5
1945	402.5	404.0	411.5	416.0	421.0	429.5	439.0	453.0	459.0	448.0	426.5	408.5
1946	401.0	405.5	418.5	425.5	425.5	431.5	443.0	453.5	449.0	434.0	416.5	399.0
1947	394.5	400.0	407.5	407.5	410.5	425.5	442.0	448.5	443.0	424.0	397.0	375.0
1948	370.5	376.5	379.0	385.0	393.5	398.5	423.0	454.0	465.5	457.5	441.5	423.5
1949	407.0	399.0	398.0	397.5	398.0	415.0	439.0	457.5	461.5	445.5	420.5	402.5
1950	397.0	396.0	389.0	399.5	420.0	431.5	443.0	457.5	465.5	458.0	444.5	431.0
1951	416.0	401.5	390.5	388.0	388.0	409.5	438.5	457.5	458.0	439.5	419.5	406.5
1952	403.5	408.5	419.0	425.5	425.5	428.5	441.0	457.5	465.5	464.5	456.5	441.5
1953	431.0	426.5	425.0	425.5	425.5	428.0	438.5	454.5	464.0	464.5	456.5	441.5
1954	431.0	426.5	425.0	425.5	425.5	430.0	442.0	456.0	456.0	439.0	419.5	410.0
1955	407.5	405.0	409.0	418.5	424.5	427.5	434.0	443.5	445.5	428.5	398.5	375.5
1956	368.0	372.0	401.5	412.5	404.5	416.0	435.0	455.0	465.5	464.5	456.5	441.5
1957	431.0	426.5	425.0	425.0	425.0	431.5	441.0	455.5	465.5	458.5	448.5	439.5
1958	431.0	426.5	425.0	425.5	425.5	428.5	440.5	457.5	465.5	464.5	456.5	441.5
1959	431.0	426.5	424.5	424.5	425.5	429.0	439.0	448.5	447.5	435.5	416.5	402.0
1960	398.5	394.0	387.0	384.5	407.5	431.0	443.0	452.5	449.0	426.5	397.0	375.0
1961	366.5	371.5	380.5	384.0	388.0	397.0	407.0	420.5	429.0	420.5	397.0	379.5
1962	374.5	372.0	372.0	373.5	403.0	431.0	443.0	455.0	456.0	440.5	416.5	402.5
1963	416.0	426.5	425.0	425.5	423.0	425.5	440.0	457.5	465.5	456.5	443.5	434.0
1964	427.0	426.0	425.0	425.5	425.5	426.0	432.0	443.5	448.0	433.0	403.0	377.5
1965	368.5	377.0	388.5	392.5	394.0	403.0	431.0	457.5	465.5	458.5	449.5	440.5
1966	431.0	426.5	425.0	425.5	425.5	430.5	442.0	453.0	450.5	436.0	416.5	401.0
1967	397.5	397.5	411.5	424.0	425.5	429.5	442.0	457.5	465.5	464.5	456.5	441.5
1968	431.0	426.5	425.0	425.5	425.5	429.5	439.0	445.5	442.0	429.5	413.5	401.0
1969	397.0	399.0	408.5	420.0	425.5	431.5	443.0	457.5	465.5	464.5	456.5	441.5
1970	431.0	426.5	424.5	410.0	394.5	409.5	427.5	436.0	433.5	426.5	417.5	408.0
1971	403.5	409.5	421.0	425.5	425.5	431.5	443.0	457.5	465.5	463.5	455.5	441.5
1972	431.0	426.5	425.0	425.5	425.5	431.5	442.0	454.5	454.0	437.5	423.5	411.0
1973	401.0	402.5	414.5	424.0	425.5	431.5	442.5	457.0	456.5	438.0	419.5	407.0
1974	403.0	413.5	423.5	417.0	414.0	425.0	440.5	457.5	465.5	464.5	456.5	441.5
1975	431.0	426.5	425.0	425.5	425.5	428.5	437.5	455.0	465.5	464.5	456.5	441.5
1976	431.0	426.5	424.0	422.0	420.0	419.5	420.5	421.5	417.0	404.5	395.0	391.0
1977	385.0	380.0	372.0	360.5	351.0	347.0	350.0	354.5	356.0	351.0	343.0	336.0
1978	331.5	332.5	355.5	402.0	425.5	430.5	442.5	457.5	465.5	458.0	441.5	429.5
1979	424.5	421.5	420.0	422.5	425.5	431.5	443.0	457.5	462.5	448.5	432.5	424.5
1980	420.0	420.5	423.5	416.0	402.5	415.5	439.0	456.0	464.0	463.5	456.5	441.5
1981	431.0	426.5	425.0	425.5	425.5	429.5	438.5	443.5	438.0	421.5	397.0	379.0
1982	373.0	398.5	407.0	394.5	392.5	408.5	437.5	457.5	465.5	464.5	456.5	441.5
1983	431.0	422.5	417.0	418.5	419.0	425.5	440.5	457.5	465.5	465.5	459.0	444.5
1984	432.5	412.0	390.0	388.0	390.0	407.0	427.5	444.0	448.0	436.0	419.5	407.0
1985	401.0	404.0	413.0	416.0	419.0	427.0	436.5	442.5	434.5	418.0	397.0	383.0
1986	380.5	379.0	388.5	410.0	410.0	411.5	435.5	454.0	462.5	452.5	432.0	418.5
1987	412.0	404.5	396.5	389.5	393.0	406.0	415.5	419.0	417.5	411.0	395.0	378.5
1988	367.5	353.5	355.0	374.0	389.0	395.5	398.0	402.0	402.0	398.0	396.0	396.0
1989	390.5	383.0	383.0	385.0	392.0	416.0	440.5	451.0	445.0	425.0	400.5	385.0
1990	379.5	378.5	381.5	385.0	392.0	404.0	415.0	414.5	406.0	399.5	396.0	394.0
1991	391.0	385.5	379.0	371.5	367.0	385.5	409.0	423.5	432.0	433.5	432.0	430.5

TABLE 5-6
1995 PUMPING DEMAND FREQUENCY DISTRIBUTION*
(based on Folsom reoperation and 70 years of record)

Adjusted Pumping Head Ranges (ft)	Average Monthly Q Ranges (cfs)								
	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250
100-110	0	0	0	0	0	0	0	0	0
90-100	0	1	0	1	0	1	1	1	0
80-90	0	0	0	0	0	0	1	0	0
70-80	0	2	1	1	1	0	0	0	0
60-70	0	3	0	2	0	0	0	0	0
50-60	0	10	0	7	0	10	0	0	0
40-50	0	17	0	5	0	4	14	4	0
30-40	0	33	3	8	2	9	6	2	0
20-30	0	38	6	19	1	11	15	2	0
10-20	0	41	7	11	2	9	5	11	0
0-10	0	48	8	10	4	6	16	14	0
-10-0	0	87	45	31	3	19	19	5	0
-20--10	0	0	0	45	11	1	30	15	0
-30--20	0	0	0	0	46	0	33	16	0
-40--30	0	0	0	0	0	0	0	0	0

*Note: Values indicate the number of months a given pumping condition is expected to be encountered out of 70 years (840 months) assuming Folsom reoperation and 1995 average monthly demands.

TABLE 5-7
2020 PUMPING DEMAND FREQUENCY DISTRIBUTION*
(based on Folsom reoperation and 70 years of record)

Adjusted Pumping Head Ranges (ft)	Average Monthly Q Ranges (cfs)							
	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450
120-130	0	0	0	0	0	0	2	0
110-120	0	0	0	0	0	1	0	0
100-110	0	0	0	1	0	0	1	0
90-100	0	1	0	0	0	0	0	0
80-90	0	1	0	1	1	0	0	0
70-80	0	4	0	1	0	10	15	0
60-70	0	1	0	7	0	3	10	0
50-60	0	11	0	5	0	10	12	0
40-50	0	24	0	6	3	11	22	0
30-40	0	40	0	17	0	8	28	0
20-30	0	42	0	16	4	6	15	0
10-20	0	49	0	6	2	20	48	0
0-10	0	152	0	32	3	1	31	0
-10-0	0	25	0	48	13	0	26	0
-20--10	0	0	0	0	44	0	0	0
-30--20	0	0	0	0	0	0	0	0

*Note: Values indicate the number of months a given pumping condition is expected to be encountered out of 70 years (840 months) assuming Folsom reoperation and estimated 2020 average monthly demands.

TABLE 5-8
PUMP DRIVE COMPARISON
ASSUMING THROTTLING AT DELIVERY POINT
(at 400 cfs and 25 ft of adjusted head)

	Adjusted Head Before Throttling (ft)	Power Required (MW)	Monthly Energy Required (million kwh)	Extra Monthly Energy Required for Throttling (million kwh)	Extra Monthly Energy Cost for Throttling (@ 5¢/kwh)
Variable Speed	25	1.06	0.76	base	base
Two Speed*	65	2.75	1.98	1.22	$61,000
Single Speed**	80	3.38	2.44	1.68	$84,000

* With two new two-speed pumps and throttling at San Juan (and other delivery points), all the pumped water would be lifted 65 feet, then at least 40 feet of head would be dissipated by throttling.

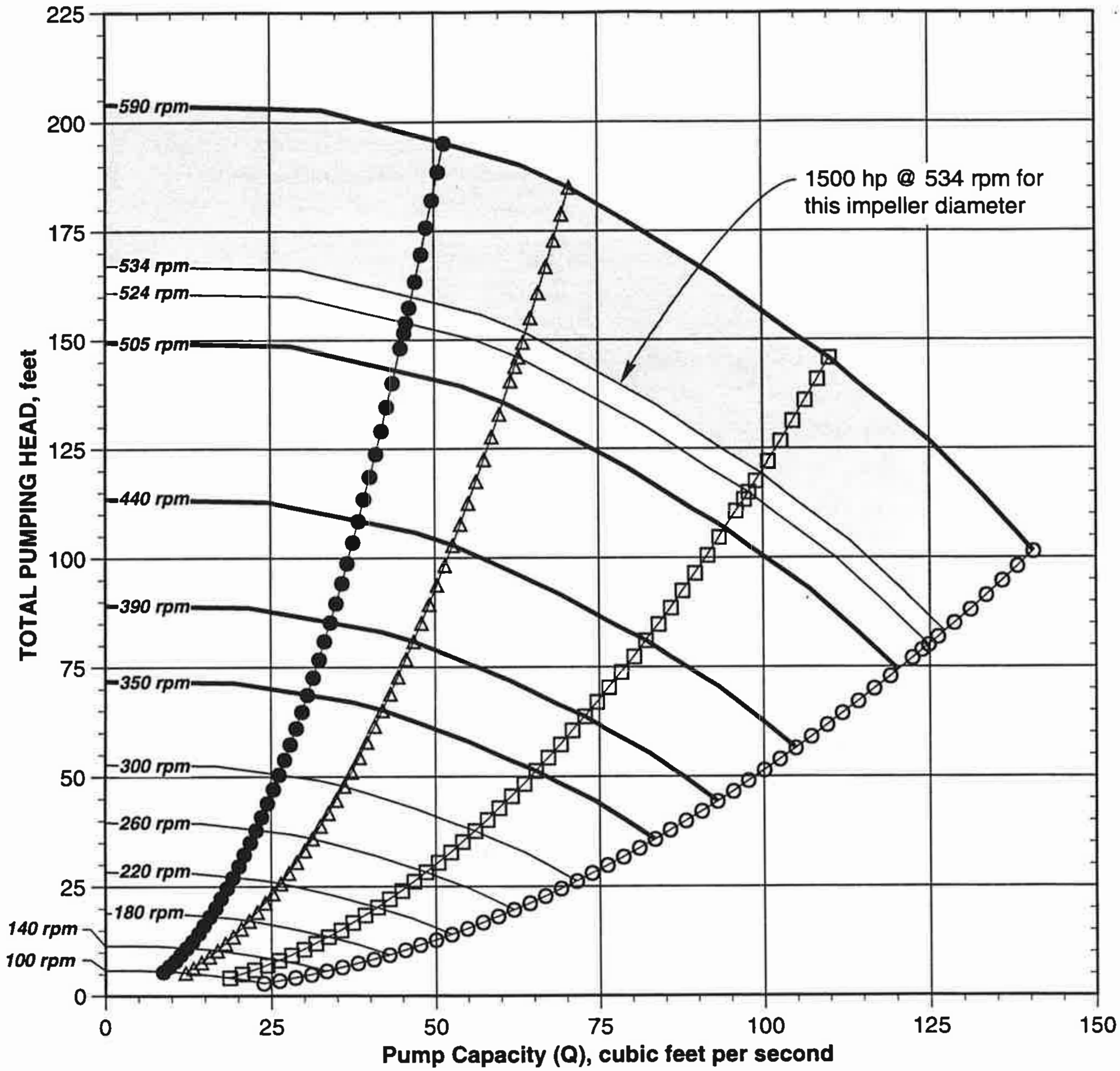
** With two new single-speed pumps and throttling at San Juan, all the pumped water would be lifted 80 feet, then at least 55 feet of head would be dissipated by throttling.

TABLE 5-9
PUMP DRIVE COMPARISON
ASSUMING THROTTLING OF INDIVIDUAL PUMPS
(at 400 cfs and 25 ft of adjusted head)

	Adjusted Heads Old/New Pumps (ft)	Power Required (MW)	Monthly Energy Required (million kwh)	Extra Monthly Energy Required for Throttling (million kwh)	Extra Monthly Energy Cost for Throttling (@ 5¢/kwh)
Variable Speed	25/25	1.06	0.76	base	base
Two Speed*	25/45	1.29	0.93	0.17	$8,400
Single Speed**	25/80	1.70	1.22	0.46	$23,000

* With throttling of individual pumps at the pumping plant and no throttling at San Juan, only one of the new two speed pumps would need to operate; it could operate at its lower speed and provide 45 feet of adjusted pumping head (of which 20 feet would be dissipated by throttling). However, all of the existing pumps could be operated at 25 feet of adjusted pumping head and high flow, with no throttling.

** One single speed pump would operate at 80 feet of adjusted pumping head and its flow would be throttled in the pumping plant to dissipate 55 feet of head. However, all of the other pumps could contribute high flows without throttling.



EXPLANATION

Best Efficiency Point

80% Efficiency

Shut Off

Runout

Operation in this range will be limited by motor horsepower.

Notes: 1) Based on manufacturer's curve for 750-LNE-1050 Pump; 524 rpm; 39.9" impeller; maximum power 1415 hp.

2) Values of total pumping head are not adjusted for head losses across the pumping plant.

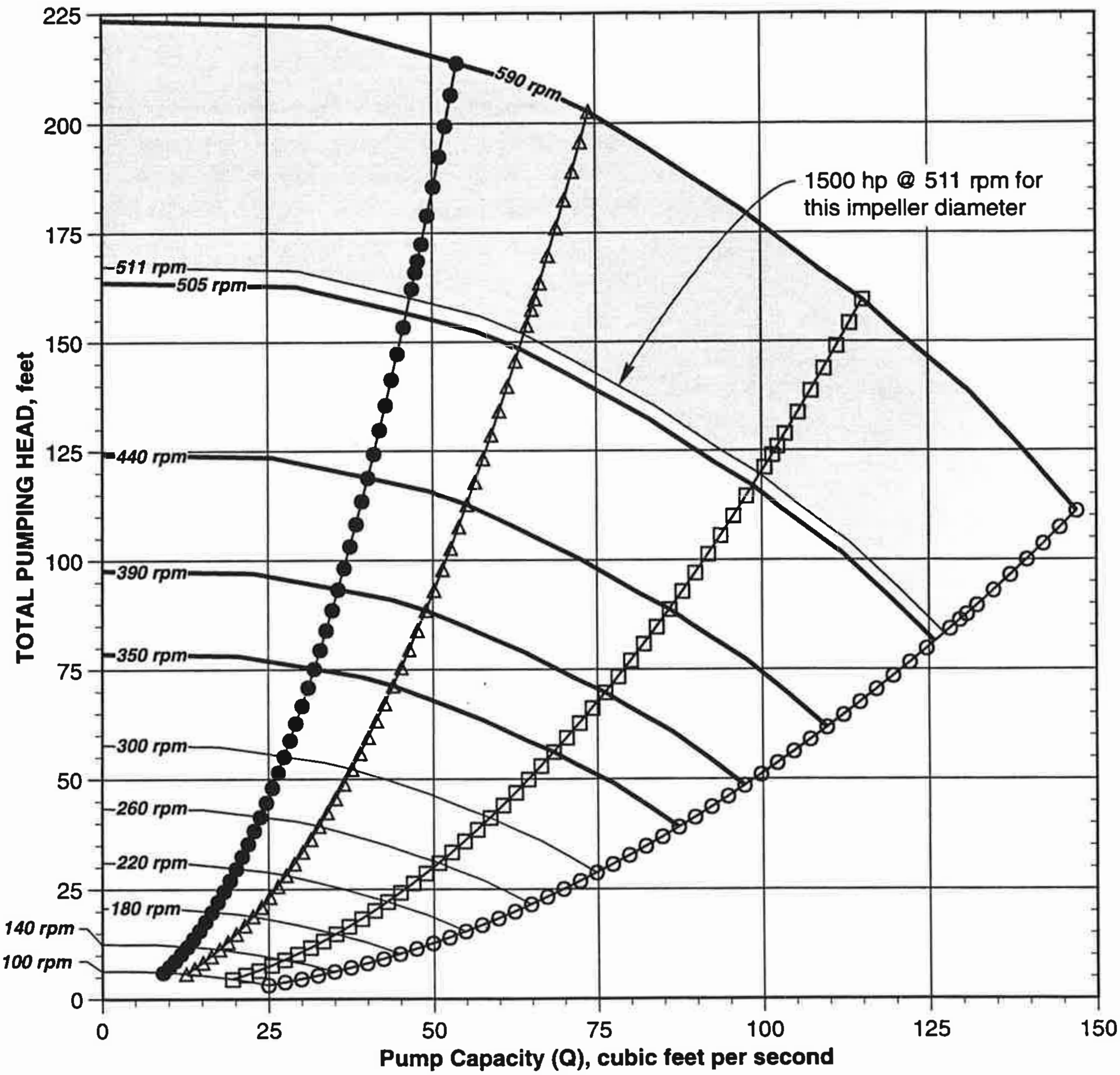
ESA Consultants Inc.
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

VARIABLE SPEED PUMP PERFORMANCE CURVES

39.9 INCH IMPELLER

Checked By *Peter V. Jocher*	Date *1/26/96*	Project No.	Figure No.
Approved By *B*	Date *1/31/96*	**043.9501**	**5-1**



EXPLANATION

Best Efficiency Point

80% Efficiency

Shut Off

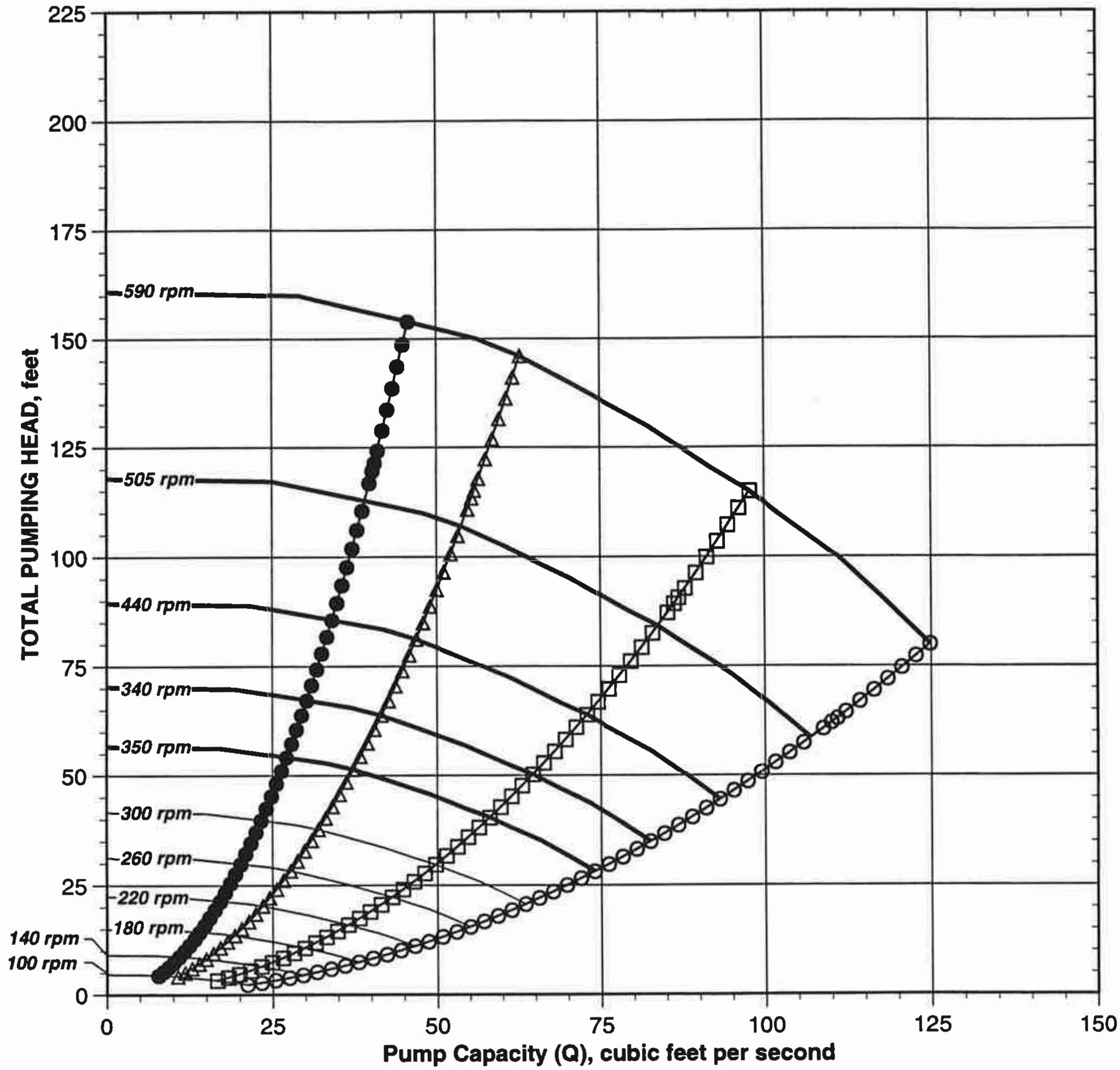
Runout

Operation in this range will be limited by motor horsepower.

Notes: 1) Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); converted to show 505 rpm and 41.7" impeller; maximum power 1454 hp.

2) Values of total pumping head are not adjusted for head losses across the pumping plant.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **VARIABLE SPEED PUMP PERFORMANCE CURVES** **41.7 INCH IMPELLER**		
Checked By Peter V. Jude Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	**043.9501**	**5-2**

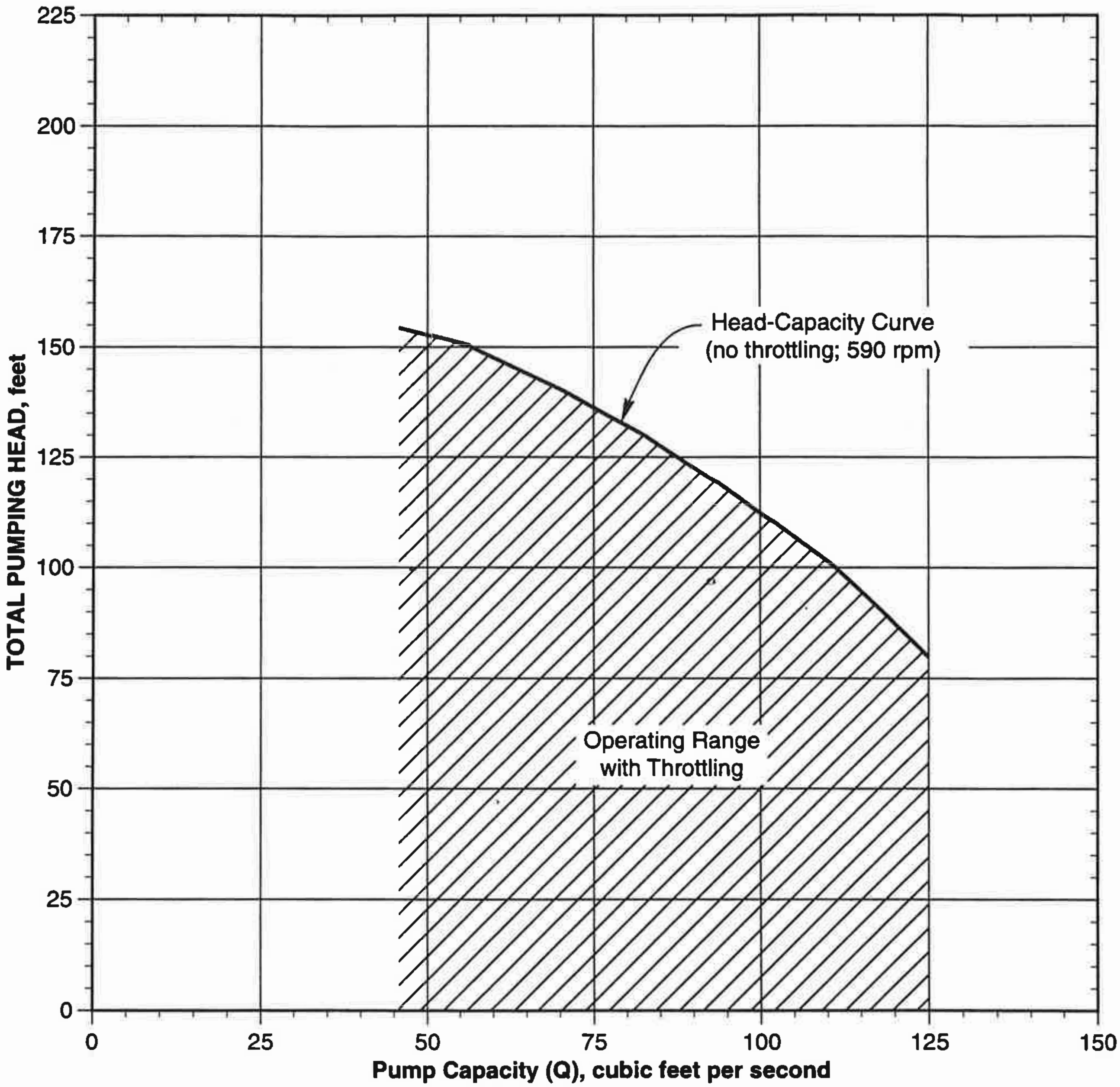


EXPLANATION

- Best Efficiency Point
- 80% Efficiency
- Shut Off
- Runout

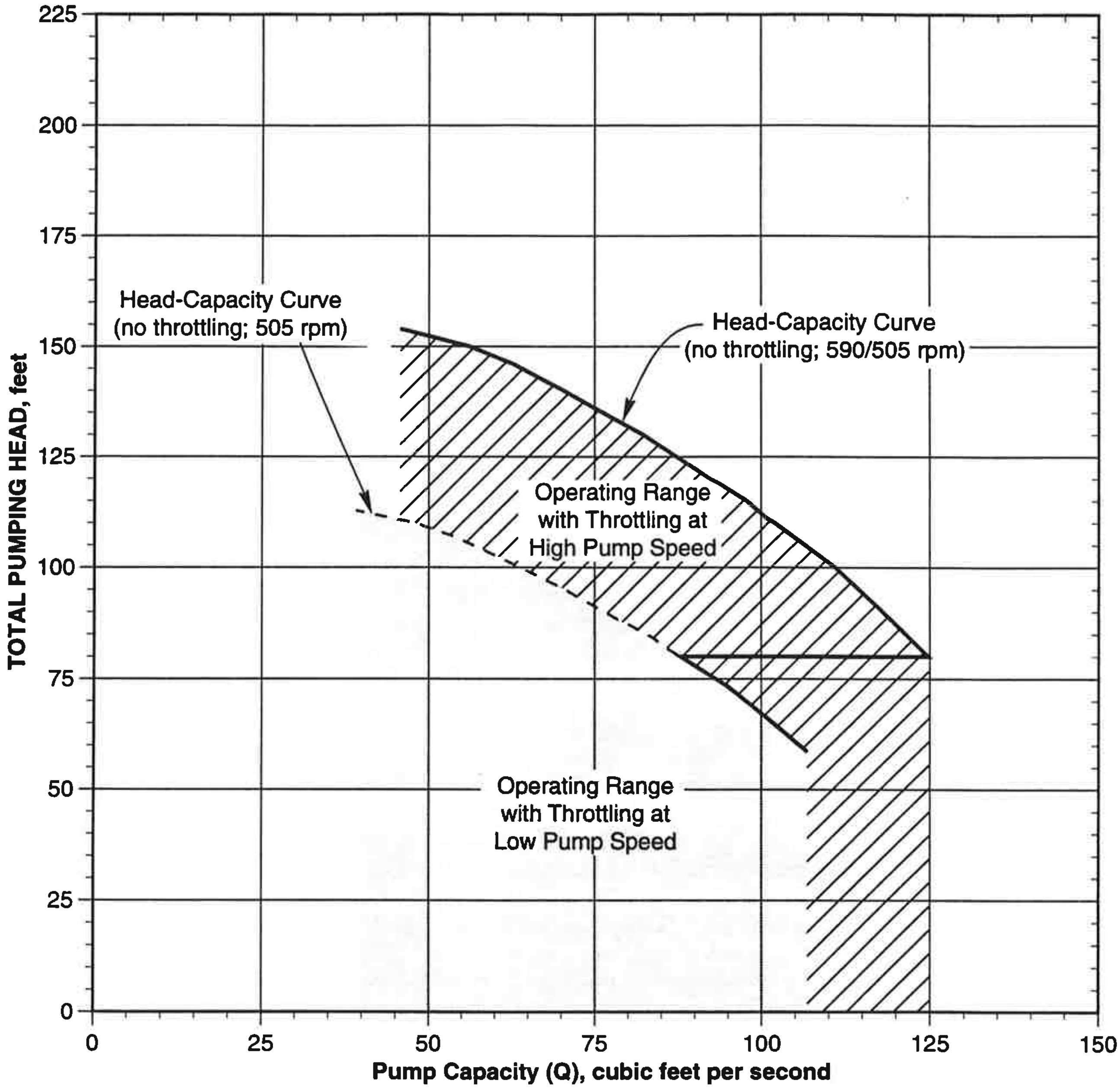
Notes: 1) Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); converted to show 590 rpm and 35.4" impeller; maximum power 1500 hp.
2) Values of total pumping head are not adjusted for head losses across the pumping plant.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **VARIABLE SPEED PUMP PERFORMANCE CURVES** **35.4 INCH IMPELLER**		
Checked By Peter V. Jacke Date 1/26/96 Approved By B Date 1/31/96	Project No. **043.9501**	Figure No. **5-3**



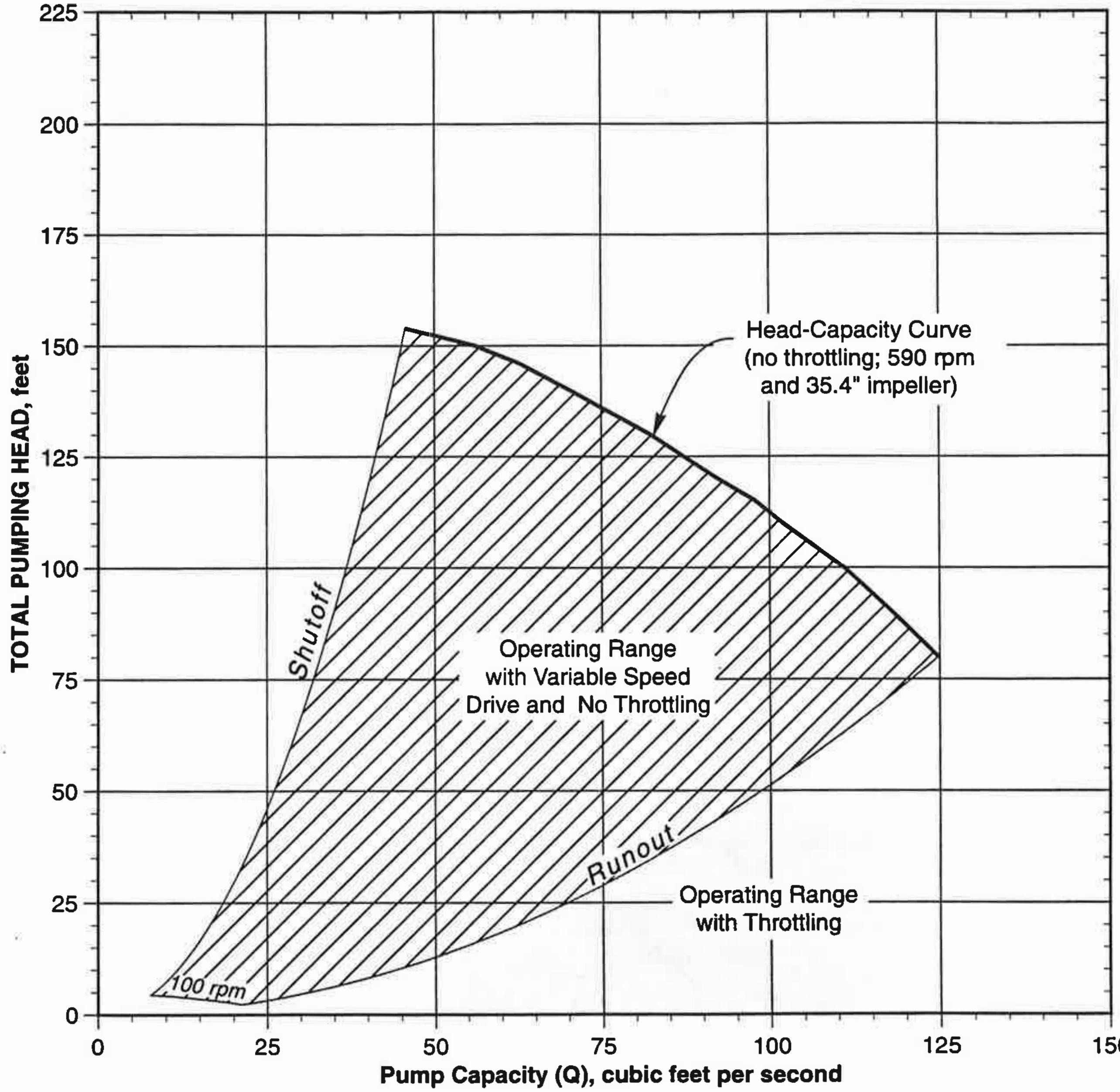
Notes: **1) Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); converted to show 590 rpm and 35.4" impeller; maximum power 1500 hp.**
2) Values of total pumping head are not adjusted for head losses across the pumping plant.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **SINGLE-SPEED PUMP OPERATING RANGE**		
Checked By Peter V. Yoder Date 1/26/96 Approved By B Date 1/31/96	Project No. **043.9501**	Figure No. **5-4**



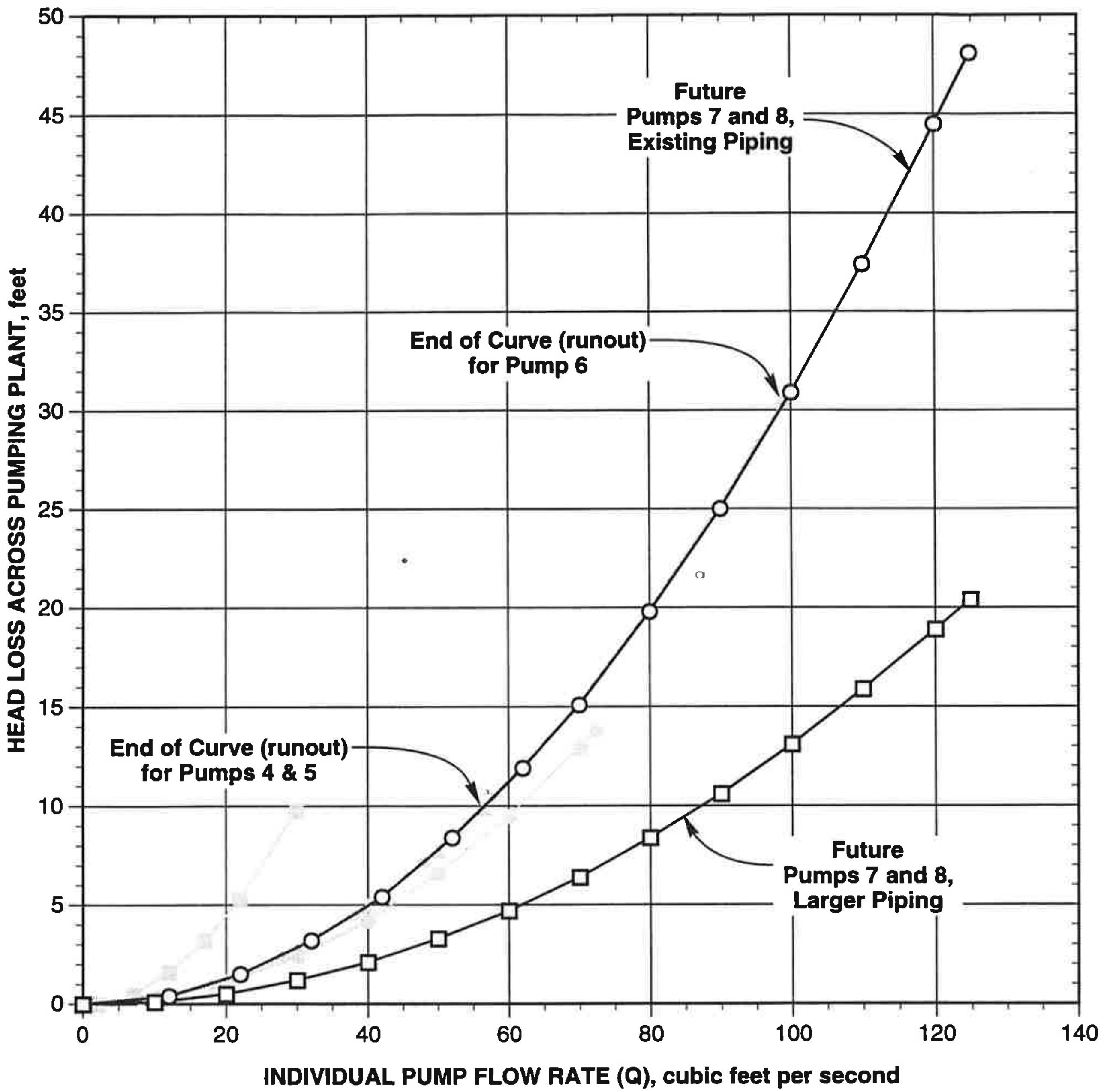
Notes: 1) **Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); converted to show 590 rpm and 505 rpm and 35.4" impeller; maximum power 1500 hp.**
2) **Values of total pumping head are not adjusted for head losses across the pumping plant.**

ESA Consultants Inc. Mountain View, California			
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **TWO-SPEED PUMP OPERATING RANGE**			
Checked By Peter V. Jache Date 1/26/96		Project No.	Figure No.
Approved By [signature] Date 1/31/96		043.9501	5-5



Notes: 1) Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); converted to various values between 100 and 590 rpm and 35.4" impeller; maximum power 1500 hp.
2) Values of total pumping head are not adjusted for head losses across the pumping plant.

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **VARIABLE-SPEED PUMP OPERATING RANGE**		
Checked By Peter V. Yade Date 1/26/96 Approved By B Date 1/31/96	Project No. 043.9501	Figure No. 5-6



EXPLANATION

Pump 2

Pump 3

Pumps 4 and 5

Pump 6

Pumps 7 and 8 (36" & 30" pipes and valves)

Pumps 7 and 8 (30" & 24" pipes and valves)

Note: 1)The head losses across the pumping plant are those that occur in the small diameter pipes to and from the pumps, including entrance, expansion, contraction, valve, and exit losses.

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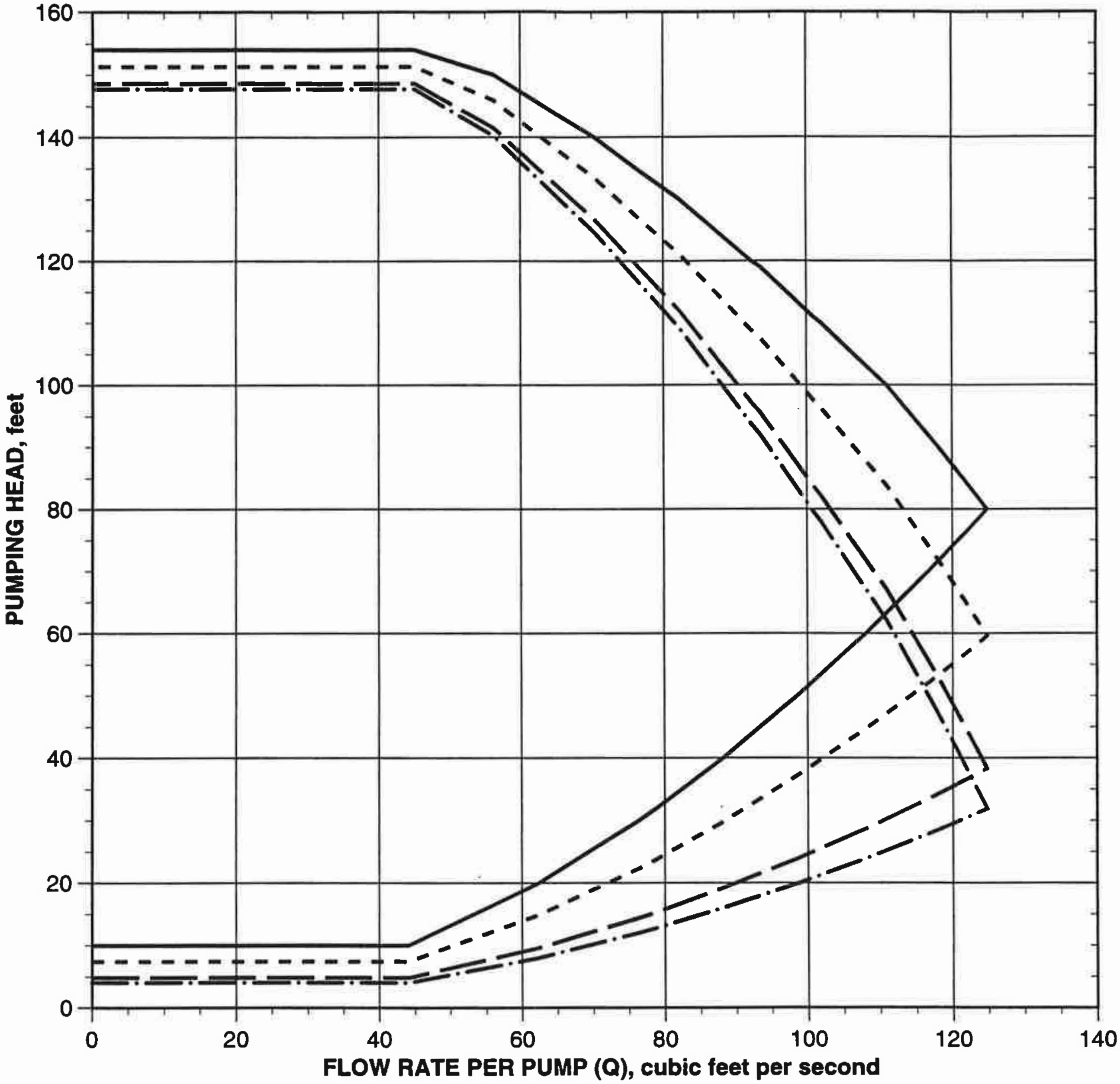
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
HEAD LOSS ACROSS PUMPING PLANT vs. FLOW FOR TWO NEW PUMPING UNITS IN POSITIONS 7 & 8

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By [signature]	Date 1/31/96	**043.9501**	**5-7**



EXPLANATION

- Solid line: Pump 7 (pump only with no adjustment for head losses, see note 1)
- Dash-dot line: Pump 7 (adjusted for losses with 30" & 24" cones, pipes and valves, see note 2)
- Long-dash line: Pump 7 (adjusted for losses with 30" & 24" cones and 36" & 30" valves, see note 2)
- Short-dash line: Pump 7 (adjusted for losses with 36" & 30" cones, pipes and valves, see note 2)

Notes: 1) Based on manufacturer's curve for 750-LNE-1050 Pump (see Figure 5-1); 524 rpm; 39.9" impeller; maximum power 1415 hp.

2) Adjusted head-capacity curves are developed by subtracting head losses in the pumping plant piping from the manufacturer's pump curves.

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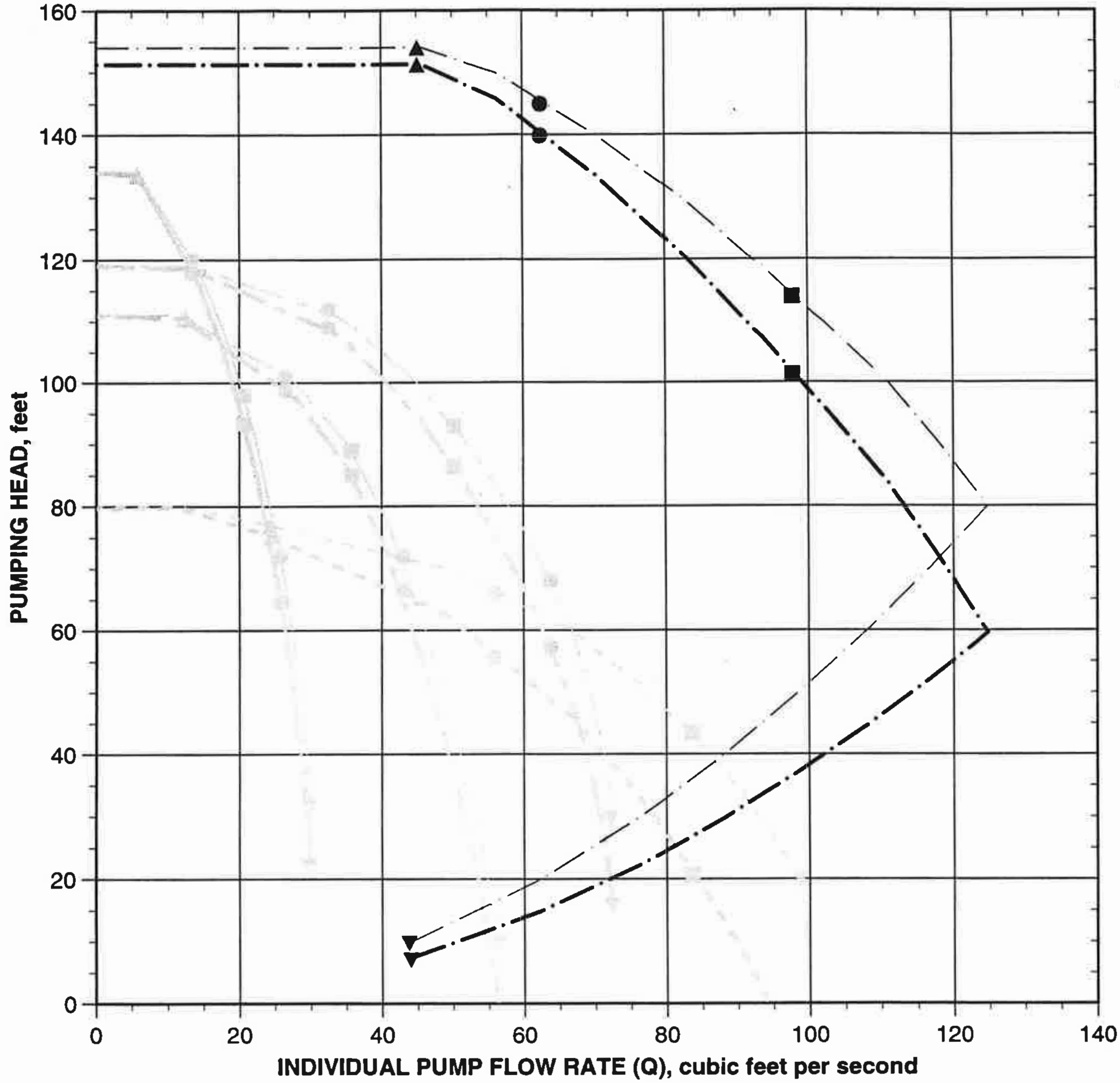
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

PUMPS 7,8 HEAD-CAPACITY CURVES ADJUSTED FOR VARIOUS PIPING SCENARIOS

Checked By Peter V. Jache	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	5-8



EXPLANATION

Pump 2 (total)
Pump 2 (adjusted*)
Pump 3 (total)
Pump 3 (adjusted*)
Pumps 4 and 5
Pumps 4 and 5 (adjusted*)
Pump 6 (total)
Pump 6 (adjusted*)
Pumps 7 and 8 (total)
Pumps 7 and 8 (adjusted*; 36" & 30" pipes and valves)

*See Note 1

■ or ■ Best Efficiency Point
● or ● 80% Efficiency
▲ or ▲ Shut Off
▼ or ▼ Runout

Notes:
1) **Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.**
2) **The end points of all pump curves have been defined to reflect the expected normal pump operating range.**

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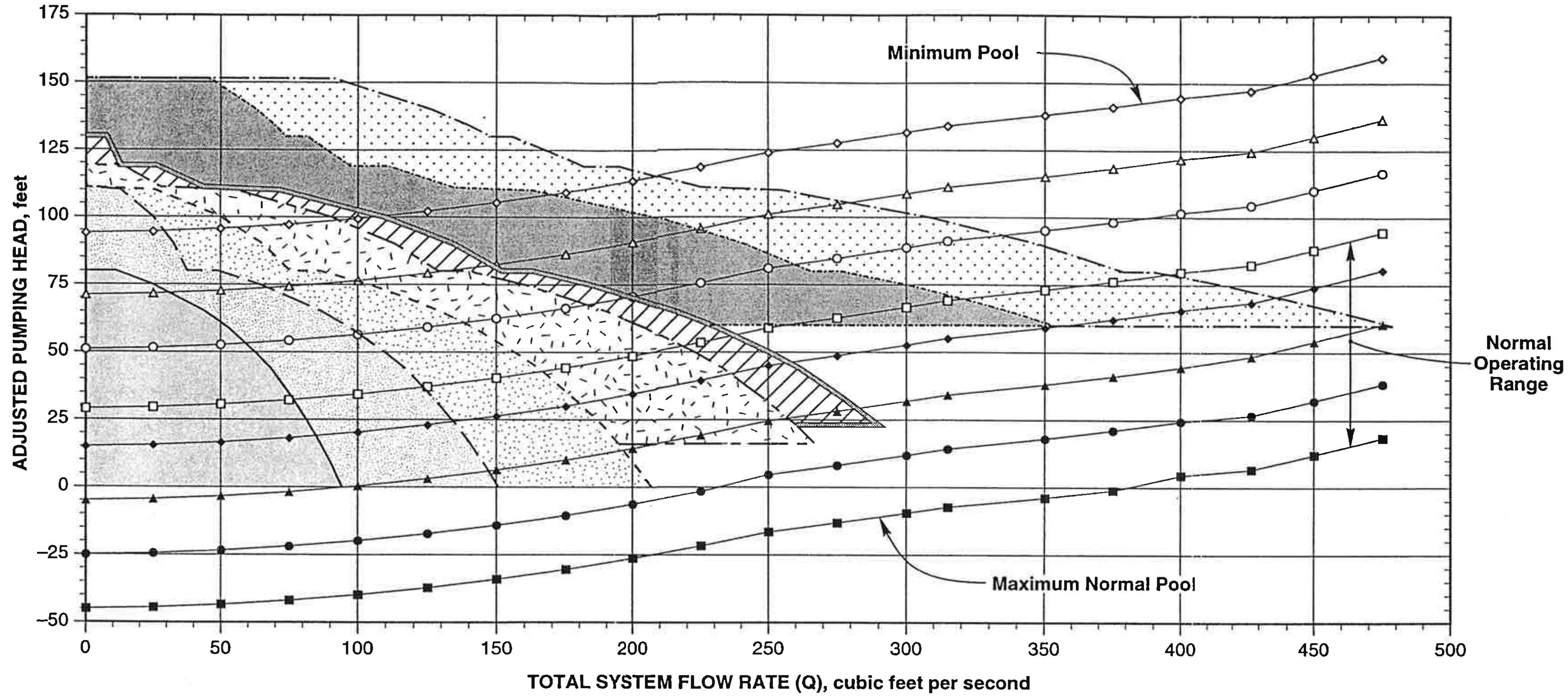
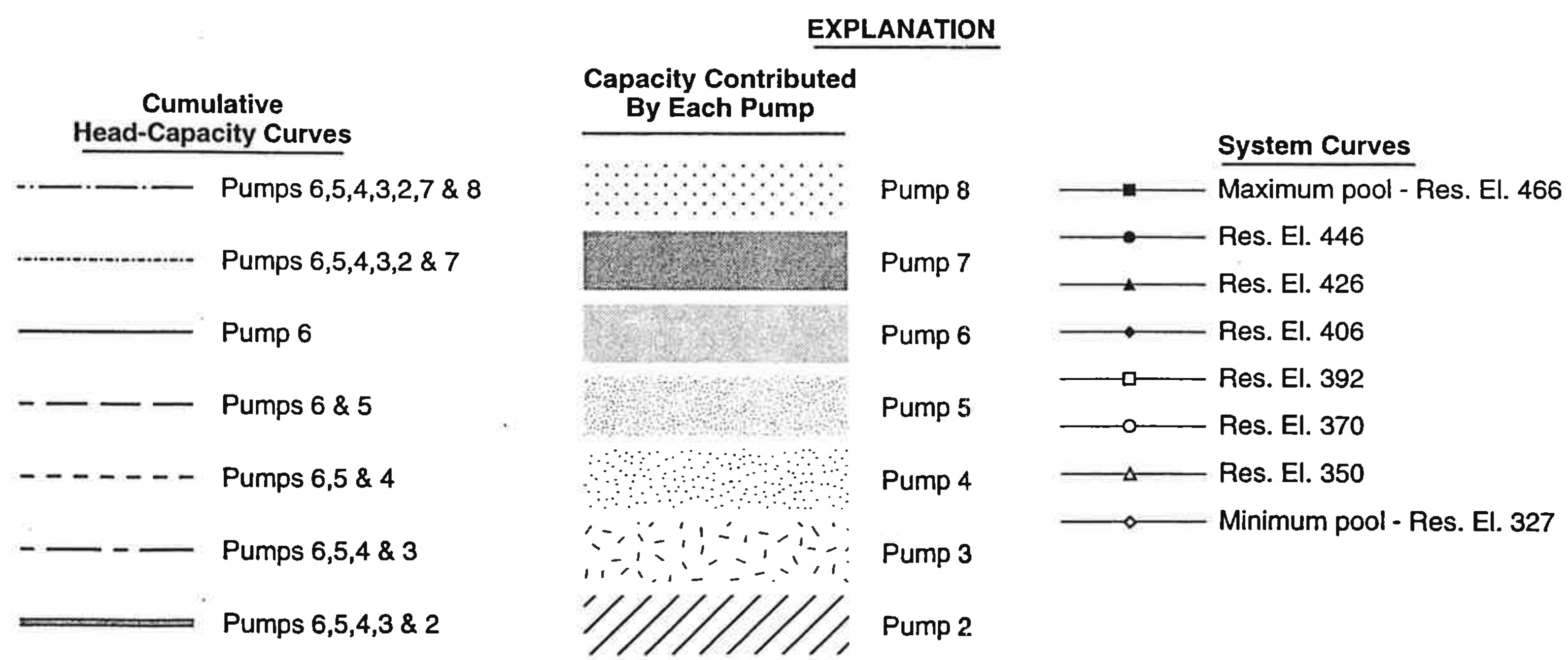
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
INDIVIDUAL PUMP HEAD-CAPACITY CURVES ADJUSTED FOR PUMPING PLANT HEAD LOSSES

		Project No.	Figure No.
Checked By Peter V. Jenkins	Date 1/26/96		
Approved By [signature]	Date 1/31/96	043.9501	5-9





Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump; 590 rpm; 35.4" impeller; maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been adjusted to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) System Curves are adjusted to reflect head losses occuring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
6) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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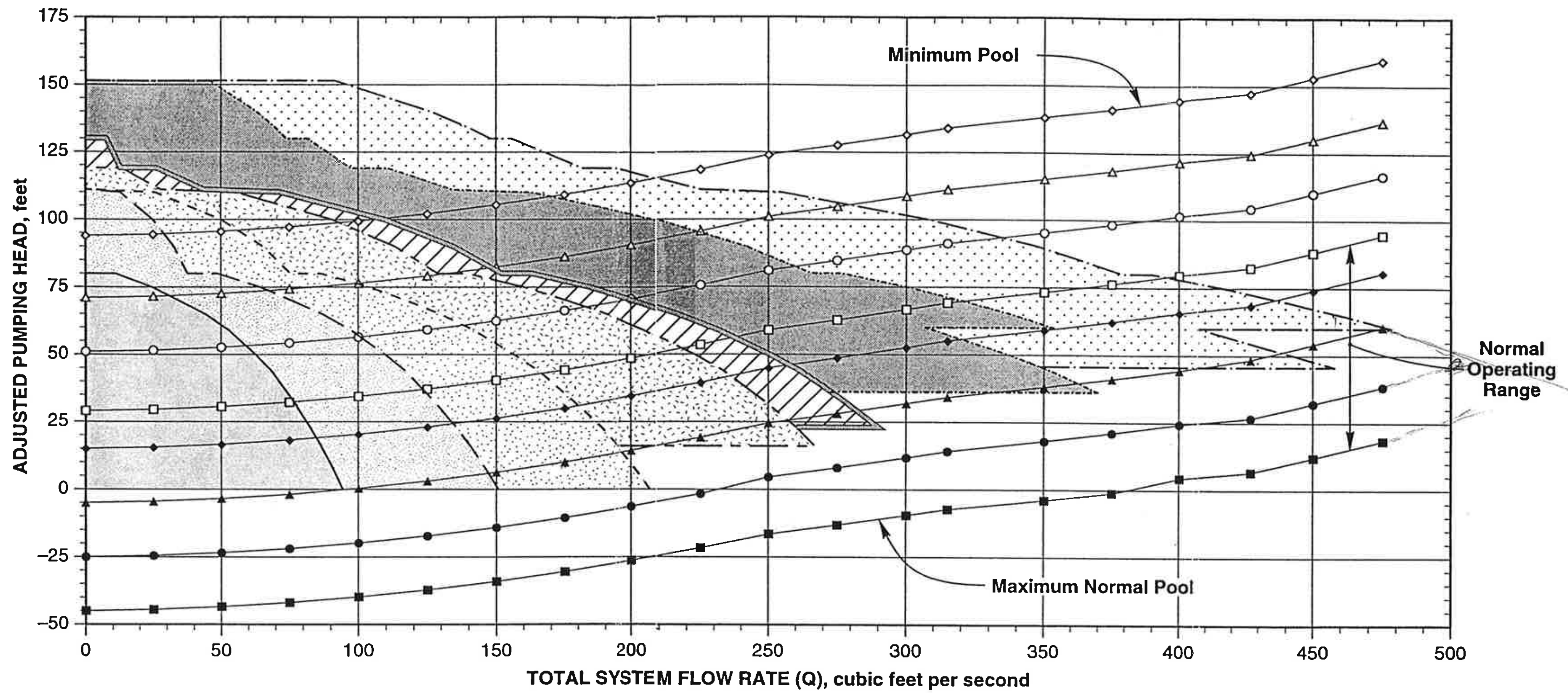
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES AND HEAD-CAPACITY CURVES WITH SINGLE-SPEED PUMPS FOR 7 AND 8

Checked By Peter V. Jacke Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	5-10



EXPLANATION

Cumulative Head-Capacity Curves	Capacity Contributed By Each Pump
Pumps 6,5,4,3,2,7 & 8	Pump 8
Pumps 6,5,4,3,2 & 7	Pump 7
Pump 6	Pump 6
Pumps 6 & 5	Pump 5
Pumps 6,5 & 4	Pump 4
Pumps 6,5,4 & 3	Pump 3
Pumps 6,5,4,3 & 2	Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Notes:

1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump; 590 rpm; 35.4" impeller; maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been adjusted to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) System Curves are adjusted to reflect head losses occuring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
6) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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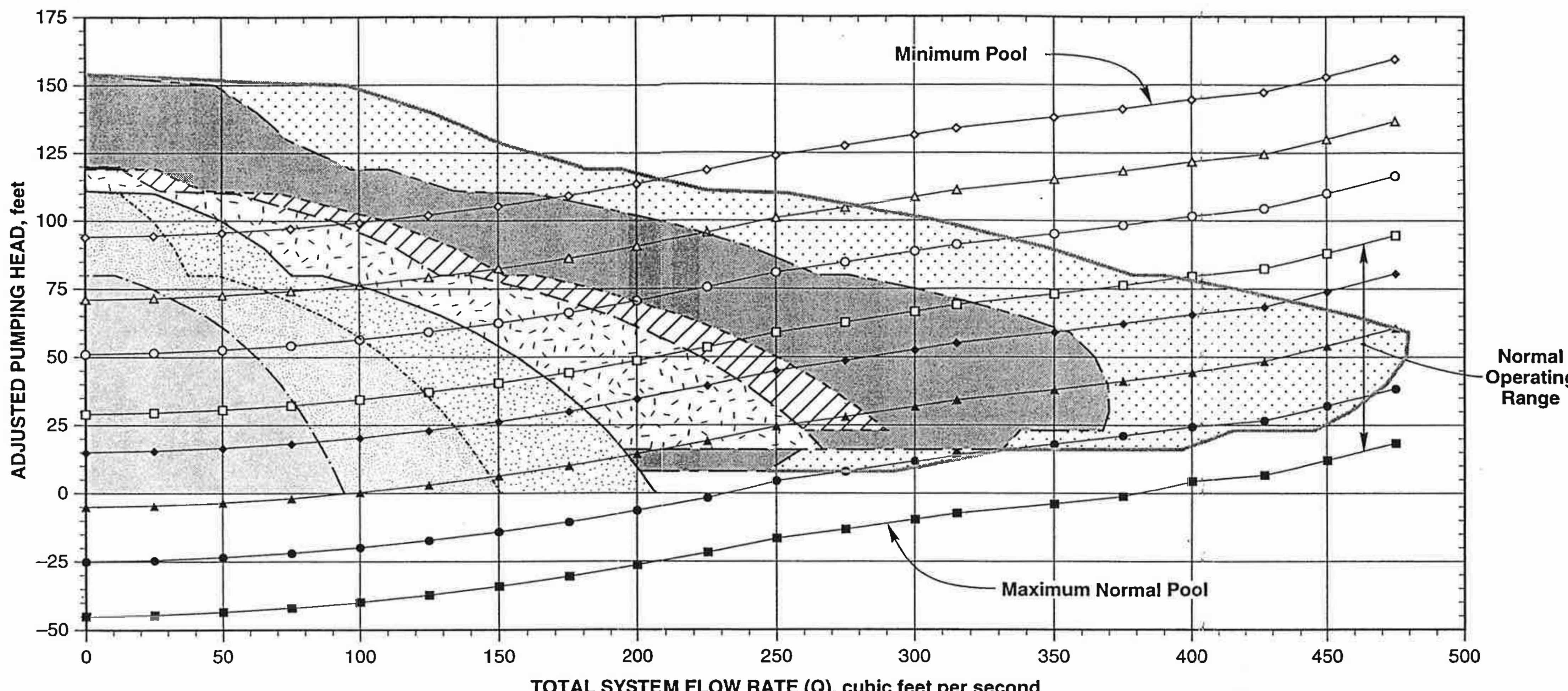
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES AND HEAD-CAPACITY CURVES WITH NEW TWO-SPEED PUMPS FOR 7 AND 8

		Project No.	Figure No.
Checked By Peter V. Jacke	Date 1/26/96	043.9501	5-11
Approved By B	Date 1/31/96		



EXPLANATION

Cumulative Head-Capacity Curves

- Pumps 6,5,4,3,2,7 & 8
- Pumps 6,5,4,3,2 & 7
- Pump 6
- Pumps 6 & 5
- Pumps 6,5 & 4
- Pumps 6,5,4 & 3
- Pumps 6,5,4,3 & 2

Capacity Contributed By Each Pump

- Pump 8
- Pump 7
- Pump 6
- Pump 5
- Pump 4
- Pump 3
- Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) System curves do not include head losses across the pumping plant.
4) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been adjusted to 36" and 30" respectively.
5) System Curves are adjusted to reflect head losses occuring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
6) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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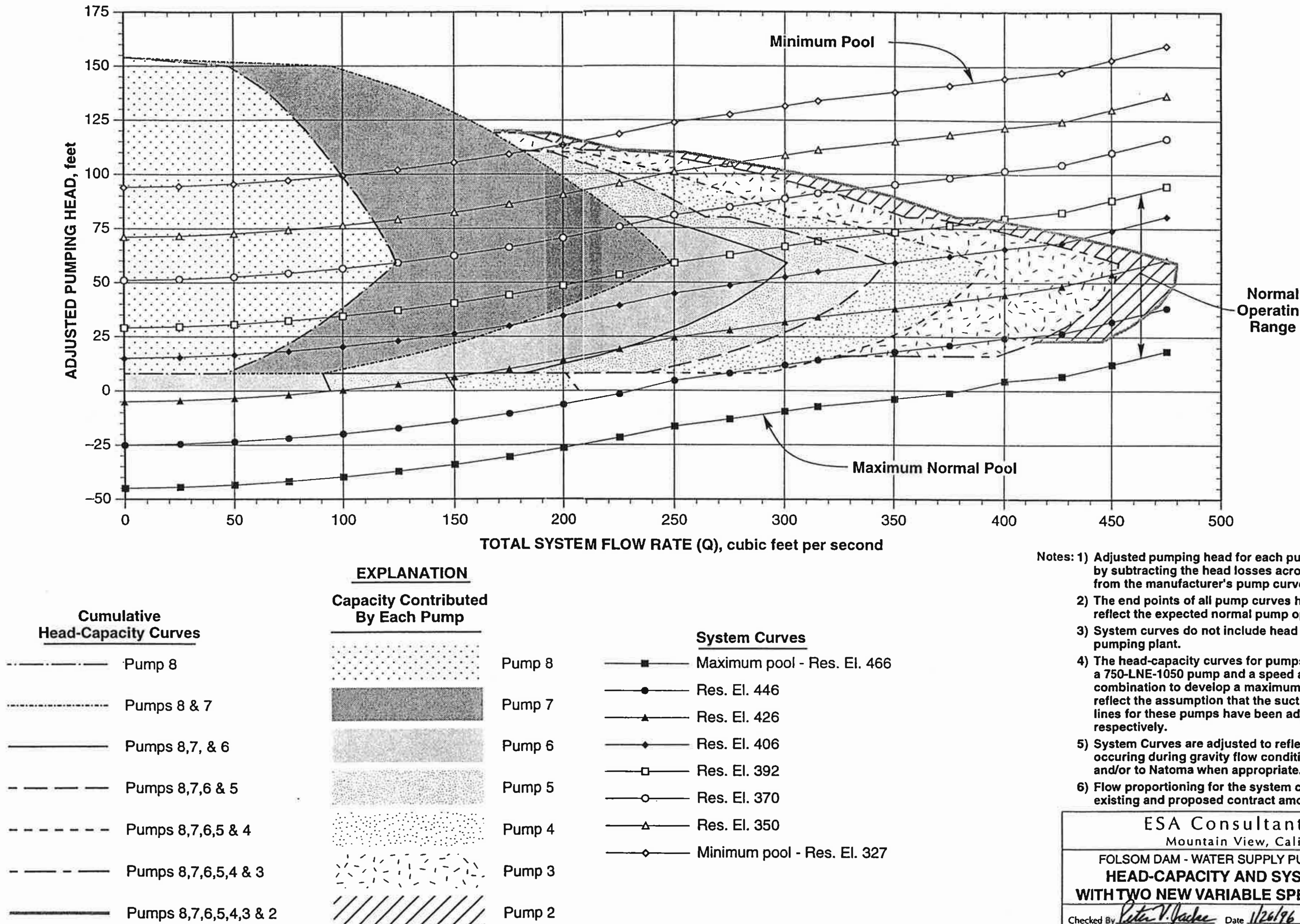
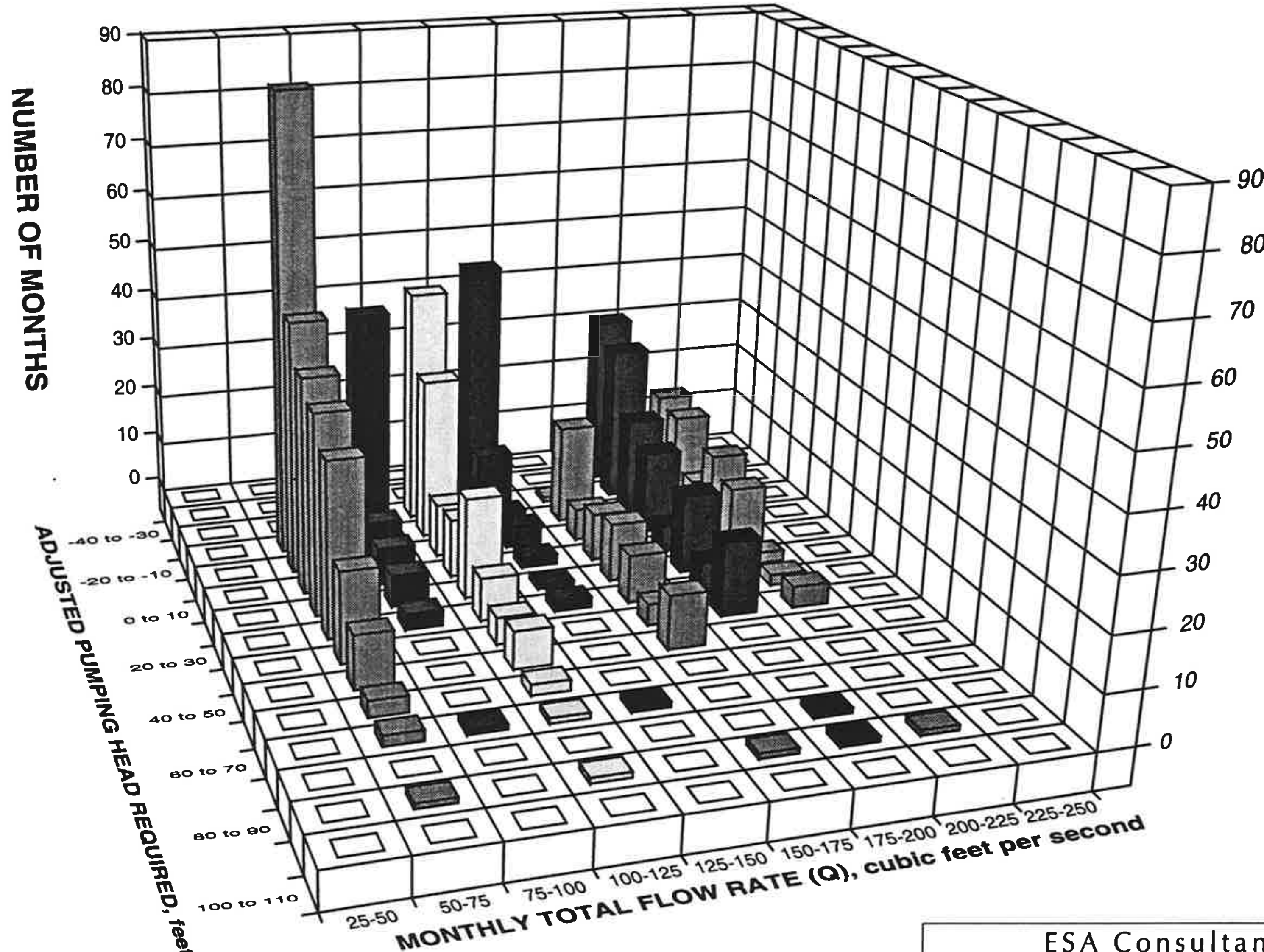
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
HEAD-CAPACITY AND SYSTEM CURVES WITH TWO NEW VARIABLE SPEED PUMPS

		Project No.	Figure No.
Checked By Peter V. Jacke	Date 1/26/96	043.9501	5-12
Approved By B	Date 1/31/96		



Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) System curves do not include head losses across the pumping plant.
4) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been adjusted to 36" and 30" respectively.
5) System Curves are adjusted to reflect head losses occuring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
6) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

ESA Consultants Inc. Mountain View, California			
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **HEAD-CAPACITY AND SYSTEM CURVES WITH TWO NEW VARIABLE SPEED PUMPS (ALT.)**			
Checked By Peter V. Jackes	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	5-13



Notes: 1) Monthly total flow rate is calculated as a monthly average based on an estimate of each agency's total annual demand and a percentage allocation to each calendar month.

2) Adjusted pumping head required for a month is calculated by adding the system head losses (excluding head losses across the pumping plant) to that month's static head difference between the reservoir and San Juan (at El. 423).

3) Frequency distribution of monthly demand versus adjusted pumping head is based on estimated 1995 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.

4) An unfilled cell indicates a value of zero months.

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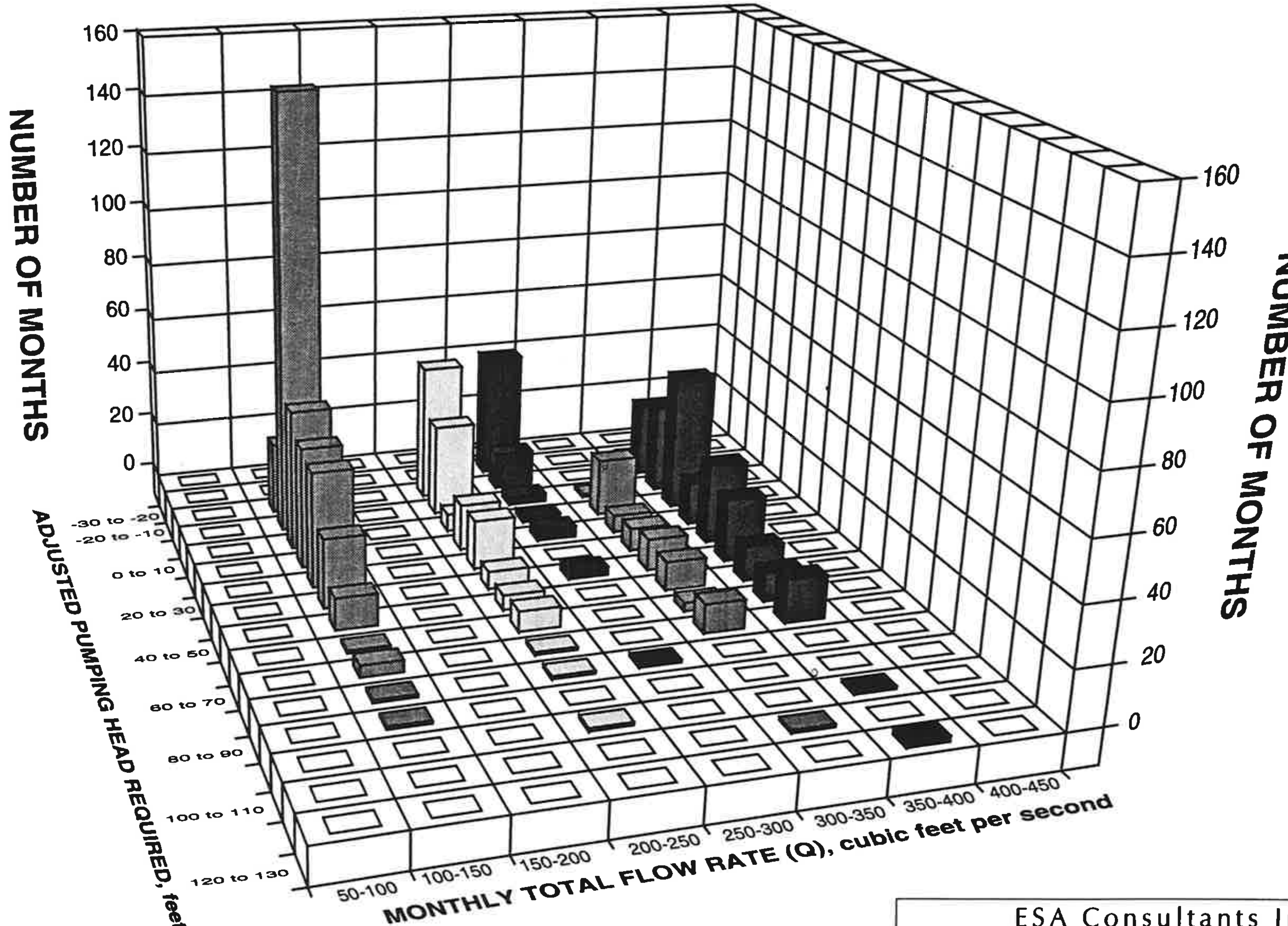
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

FREQUENCY DISTRIBUTION OF 1995 MONTHLY DEMAND VERSUS ADJUSTED PUMPING HEAD

		Project No.	Figure No.
Checked By Peter J. Jacher	Date 1/26/96	043.9501	5-14
Approved By B	Date 1/31/96		



Notes: 1) Monthly total flow rate is calculated as a monthly average based on an estimate of each agency's total annual demand and a percentage allocation to each calendar month.

2) Adjusted pumping head required for a month is calculated by adding the system head losses (excluding head losses across the pumping plant) to that month's static head difference between the reservoir and San Juan (at El. 423).

3) Frequency distribution of monthly demand versus adjusted pumping head is based on estimated 2020 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.

4) An unfilled cell indicates a value of zero months.

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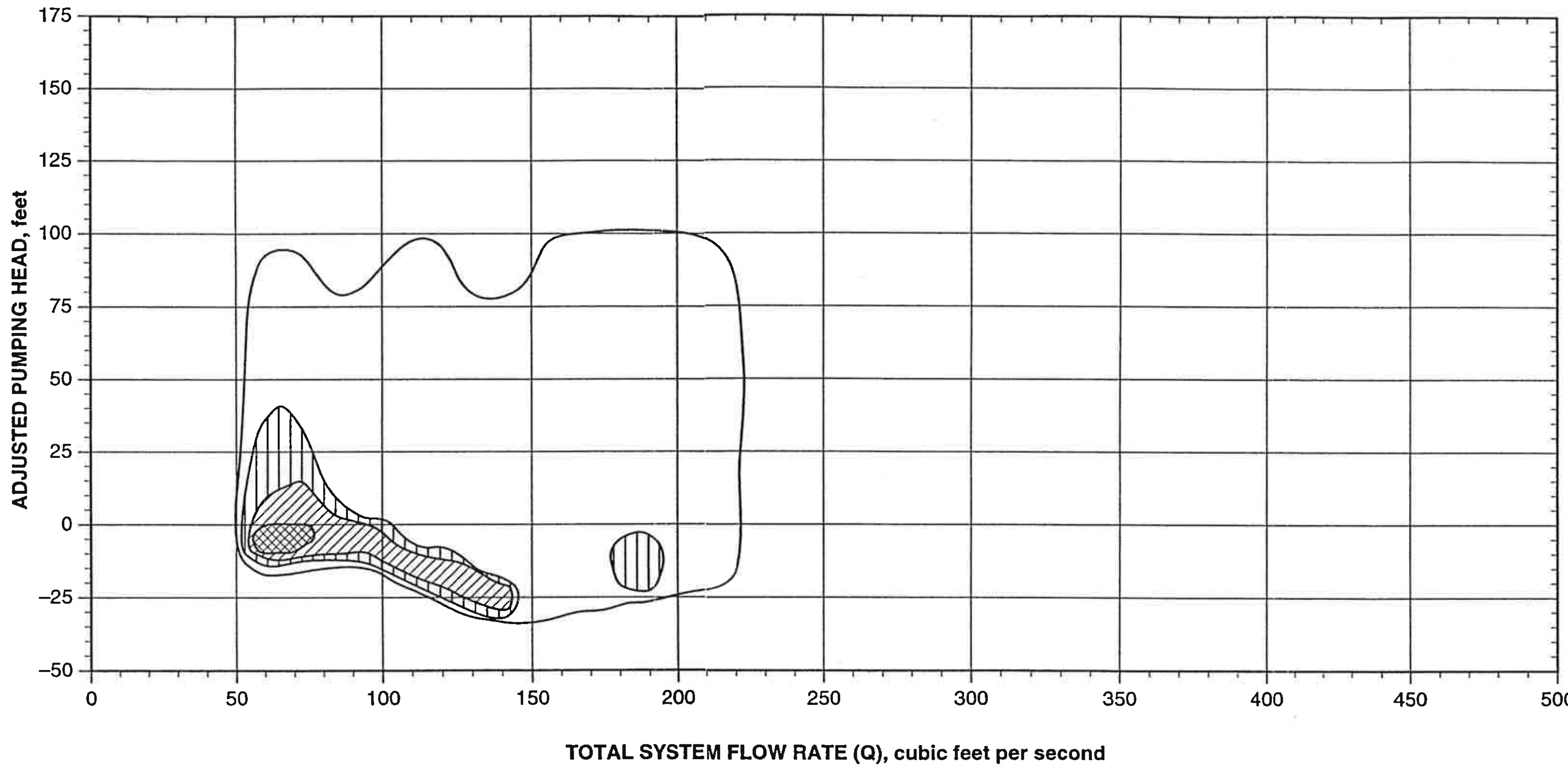
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
FREQUENCY DISTRIBUTION OF 2020 MONTHLY DEMAND VERSUS ADJUSTED PUMPING HEAD

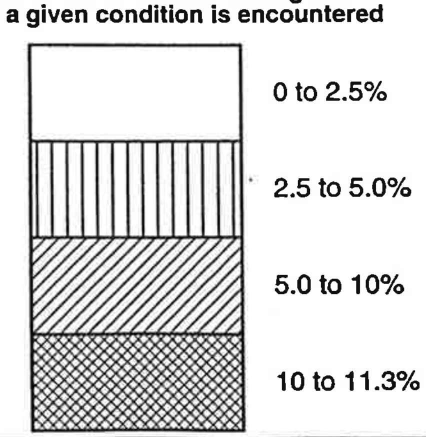
Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	5-15



EXPLANATION

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered



Notes: 1) Distribution of pumping conditions is based on estimated 1995 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.

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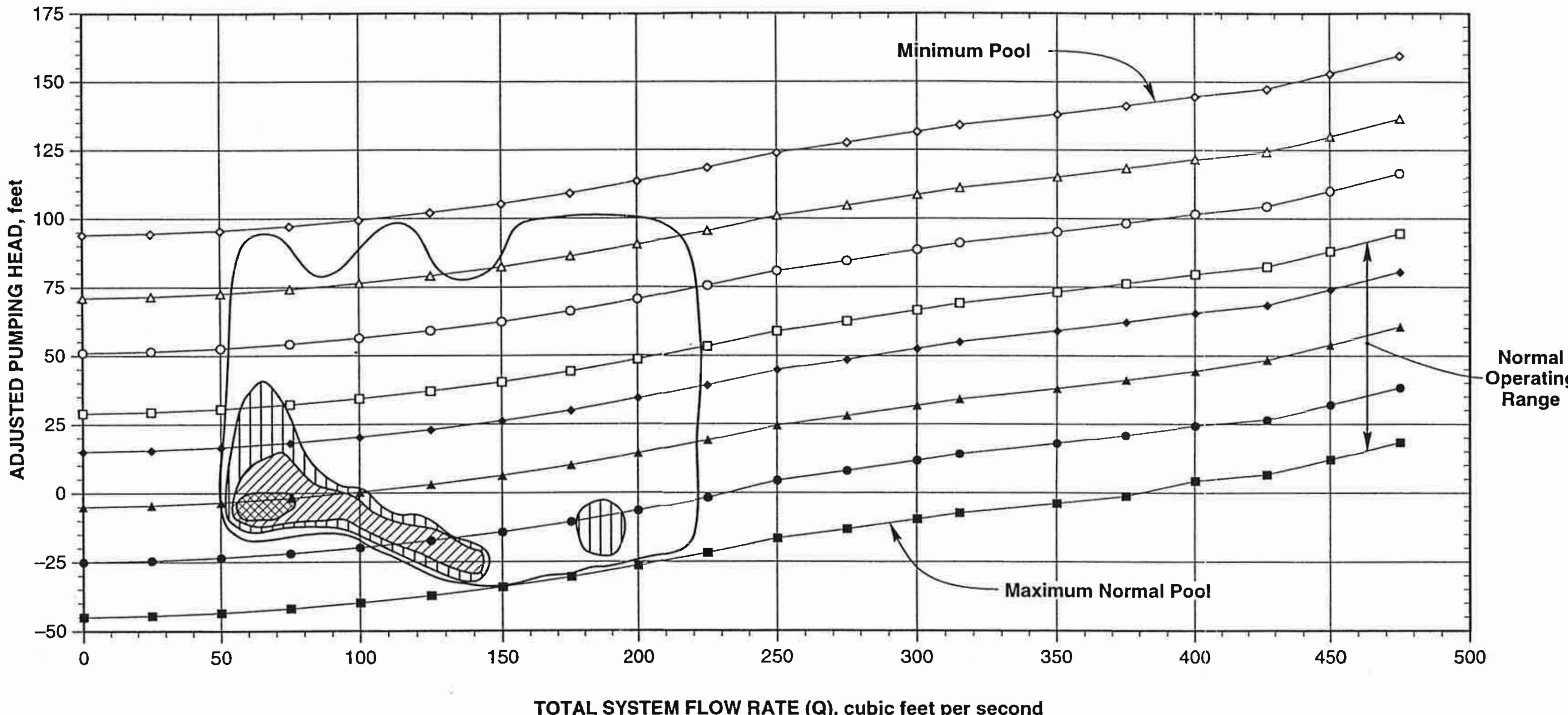
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
DISTRIBUTION OF 1995 PUMPING CONDITIONS

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	5-16



EXPLANATION

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered

- 0 to 2.5%
- 2.5 to 5.0%
- 5.0 to 10%
- 10 to 11.3%

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Notes:
1) System curves do not include head losses across the pumping plant.
2) Distribution of pumping conditions is based on estimated 1995 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.
3) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
4) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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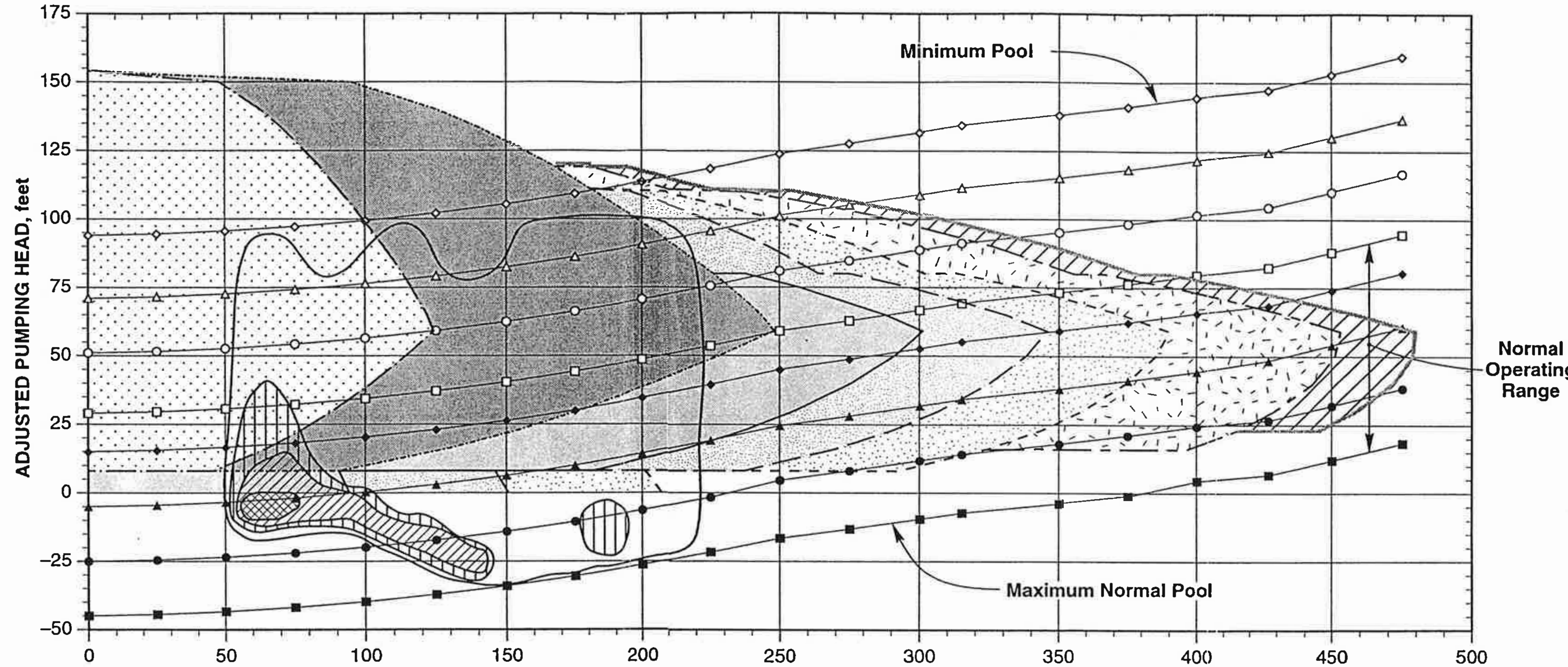
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

DISTRIBUTION OF 1995 PUMPING CONDITIONS AND SYSTEM CURVES

Checked By Peter V. Jacke	Date 1/26/96	Project No.	Figure No.
Approved By	Date 1/31/96	043.9501	5-17



EXPLANATION

Cumulative Head-Capacity Curves

- Pump 8
- Pumps 8 & 7
- Pumps 8,7, & 6
- Pumps 8,7,6 & 5
- Pumps 8,7,6,5 & 4
- Pumps 8,7,6,5,4 & 3
- Pumps 8,7,6,5,4,3 & 2

Capacity Contributed By Each Pump

- Pump 8
- Pump 7
- Pump 6
- Pump 5
- Pump 4
- Pump 3
- Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered

- 0 to 2.5%
- 2.5 to 5.0%
- 5.0 to 10%
- 10 to 11.3%

Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been modified to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) Distribution of pumping conditions is based on estimated 1995 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.
6) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
7) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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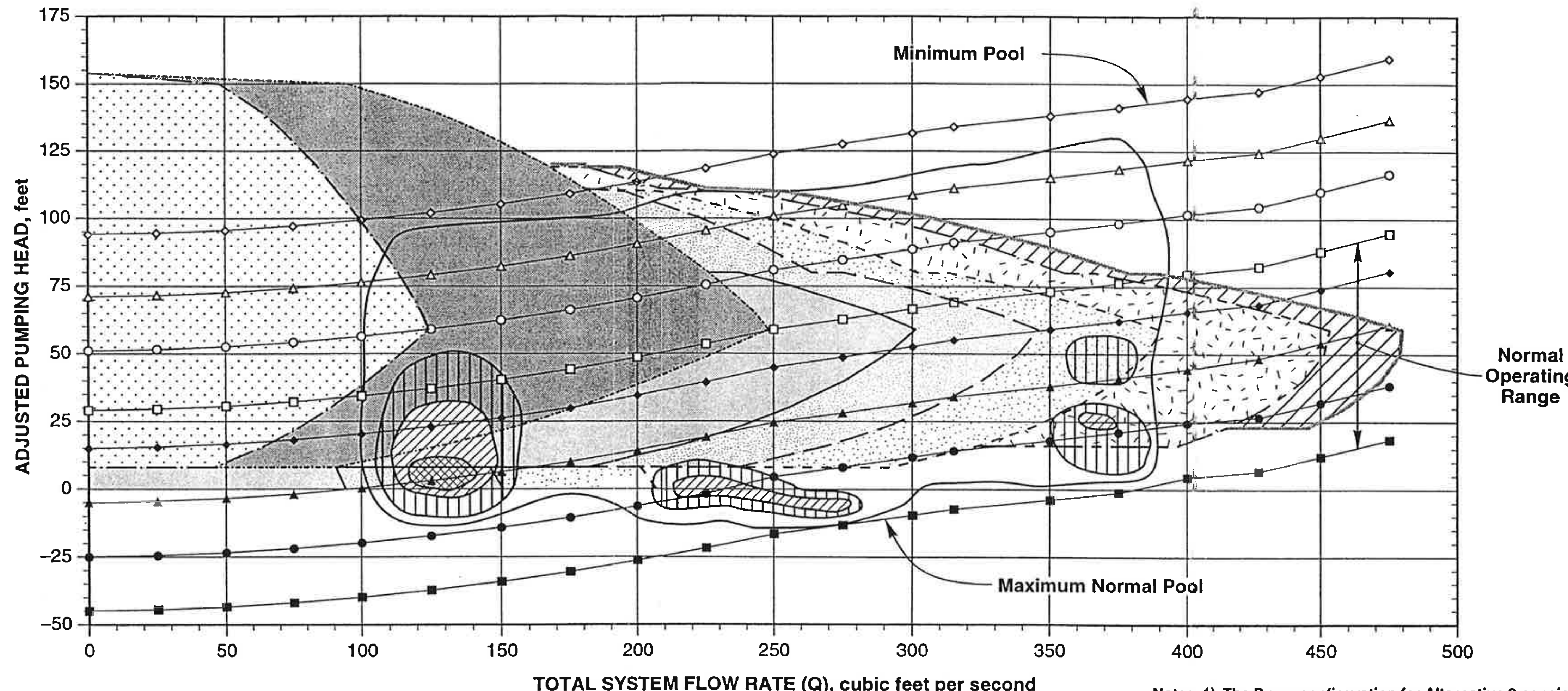
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES, DISTRIBUTION OF 1995
PUMPING CONDITIONS, AND HEAD-CAPACITY CURVES
WITH TWO NEW VARIABLE SPEED PUMPS

Checked By Peter V. Jacke Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	5-18



EXPLANATION

Cumulative Head-Capacity Curves

- Pump 8
- Pumps 8 & 7
- Pumps 8,7, & 6
- Pumps 8,7,6 & 5
- Pumps 8,7,6,5 & 4
- Pumps 8,7,6,5,4 & 3
- Pumps 8,7,6,5,4,3 & 2

Capacity Contributed By Each Pump

- Pump 8
- Pump 7
- Pump 6
- Pump 5
- Pump 4
- Pump 3
- Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered

- 0 to 2.5%
- 2.5 to 5.0%
- 5.0 to 10%
- 10 to 18.1%

Notes:
1) The Pump configuration for Alternative 2 consists of a new pump 7 with a two-speed (590 and 505 rpm) motor
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been adjusted to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) Distribution of pumping conditions is based on estimated 2020 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.
6) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
7) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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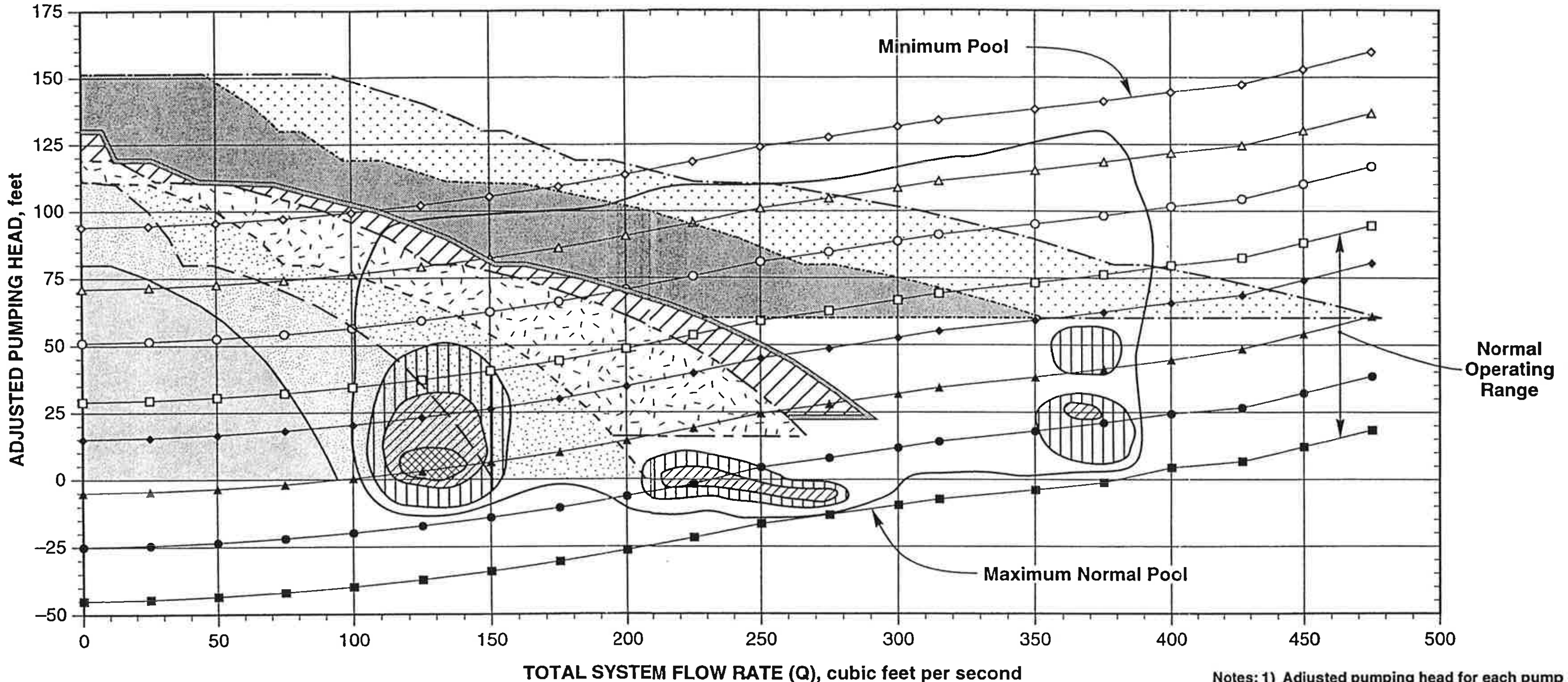
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES, DISTRIBUTION OF 2020
PUMPING CONDITIONS, AND HEAD-CAPACITY CURVES
WITH TWO NEW VARIABLE SPEED PUMPS

Checked By Peter V. Jache	Date 1/26/96	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	5-19



EXPLANATION

Cumulative Head-Capacity Curves

- Pump 8
- Pumps 8 & 7
- Pumps 8,7, & 6
- Pumps 8,7,6 & 5
- Pumps 8,7,6,5 & 4
- Pumps 8,7,6,5,4 & 3
- Pumps 8,7,6,5,4,3 & 2

Capacity Contributed By Each Pump

- Pump 8
- Pump 7
- Pump 6
- Pump 5
- Pump 4
- Pump 3
- Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered

- 0 to 2.5%
- 2.5 to 5.0%
- 5.0 to 10%
- 10 to 18.1%

Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump; and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been modified to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) Distribution of pumping conditions is based on estimated 2020 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.
6) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
7) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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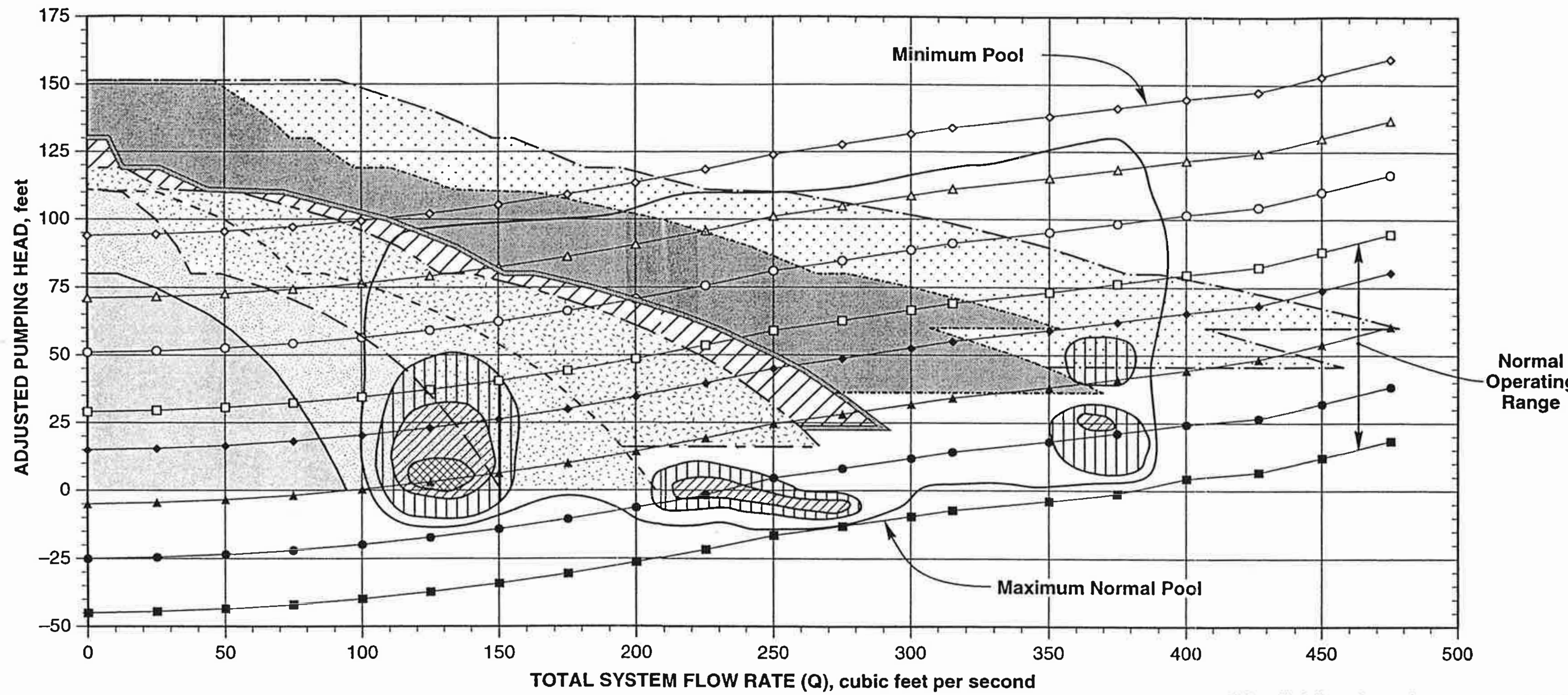
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES, DISTRIBUTION OF 2020 PUMPING CONDITIONS AND HEAD-CAPACITY CURVES WITH SINGLE-SPEED PUMPS FOR 7 AND 8

Checked By Peter V. Jach Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	5-20



EXPLANATION

Cumulative Head-Capacity Curves

- Pump 8
- Pumps 8 & 7
- Pumps 8,7, & 6
- Pumps 8,7,6 & 5
- Pumps 8,7,6,5 & 4
- Pumps 8,7,6,5,4 & 3
- Pumps 8,7,6,5,4,3 & 2

Capacity Contributed By Each Pump

- Pump 8
- Pump 7
- Pump 6
- Pump 5
- Pump 4
- Pump 3
- Pump 2

System Curves

- Maximum pool - Res. El. 466
- Res. El. 446
- Res. El. 426
- Res. El. 406
- Res. El. 392
- Res. El. 370
- Res. El. 350
- Minimum pool - Res. El. 327

Distribution of Pumping Conditions

Percent of months during which a given condition is encountered

- 0 to 2.5%
- 2.5 to 5.0%
- 5.0 to 10%
- 10 to 18.1%

Notes:
1) Adjusted pumping head for each pump curve is calculated by subtracting the head losses across the pumping plant from the manufacturer's pump curve.
2) The end points of all pump curves have been defined to reflect the expected normal pump operating range.
3) The head-capacity curves for pumps 7 and 8 are based on a 750-LNE-1050 pump; and a speed and impeller diameter combination to develop a maximum power 1500 hp and reflect the assumption that the suction and discharge lines for these pumps have been modified to 36" and 30" respectively.
4) System curves do not include head losses across the pumping plant.
5) Distribution of pumping conditions is based on estimated 2020 average monthly demands and 70 years of hydrologic record assuming Folsom reoperation.
6) System curves are adjusted to reflect head losses occurring during gravity flow conditions to San Juan and/or to Natoma when appropriate.
7) Flow proportioning for the system curves is based on existing and proposed contract amounts (see Table 4-1).

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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
SYSTEM CURVES, DISTRIBUTION OF 2020 PUMPING CONDITIONS AND HEAD-CAPACITY CURVES WITH NEW TWO-SPEED PUMPS FOR 7 AND 8

Checked By Peter V Jacke Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	5-21

6. SIXTY INCH INTAKE GATE VALVE LOCATED IN DAM

The 84" diameter intake line from the reservoir to the pumping plant includes a 60" diameter gate valve (see Figures 6-1, 6-2 and 6-3 from Corps Drawing AM-1-9-414 / 2). With an increase of maximum flow to the pumping plant from 315 cfs to 400 cfs the question arises whether this valve becomes a significant restriction for flow. The Corps (1951) calculations show the following flow conditions and head loss calculations for the originally visualized 315 cfs:

- 84" Velocity: 8.19 ft/sec
- 84" Velocity Head: 1.04 ft
- 60" Velocity: 16.04 ft/sec
- 60" Velocity Head: 4.00 ft
- Head Loss for Contraction/Valve/Expansion:
  0.1(4.00-1.04)+0.19 x 4.00 + 0.2 (4.00-1.04) = 1.65 ft

Figure 6-4 presents the hydraulic and energy grade lines for the intake portion of the piping under this flow, assuming that the reservoir water surface is at minimum pool (El. 327).

Increasing the intake flow to 400 cfs would create the following flow conditions, using the same calculation procedures:

- 84" Velocity: 10.39 ft/sec
- 84" Velocity Head: 1.68 ft
- 60" Velocity: 20.40 ft/sec
- 60" Velocity Head: 6.45 ft
- Head Loss for Contraction/Valve/Expansion:
  0.1(6.45-1.68)+0.19 x 6.45 + 0.2 (6.45-1.68) = 2.66 ft

Figure 6-5 presents the hydraulic and energy grade lines for the intake portion of the piping with 400 cfs of flow, again assuming that the reservoir water surface is at minimum pool (El. 327).

An additional 1.01 feet of head loss due to the flow increase to 400 cfs does not represent a significant restriction of flow from a head loss viewpoint.

A second question is whether the valve is suitable for such a flow. The valve was originally specified as follows (quoted from Corps specifications 1532r1, pp. 16-9 to 16-10):

> 16-12 VALVES IN MAIN PIPE LINES: The following valves, suitable for the service required and complete with required appurtenances, shall be furnished and installed where shown on the drawings and/or specified herein.
>
> a. 60-Inch Valve: One valve shall be installed in the pumping plant inlet emergency valve chamber, and 1 valve shall be installed in each of valve pits Nos. 2 and 3 at the pumping plant, all as shown. These valves shall be standard, iron body, bronze mounted, flanged, electrically operated gate valves, faced and drilled with double discs and parallel seats, O.S. and Y, and square bottom construction - suitable for 120 lb. non-shock cold water pressure - for installation in a vertical position in a

horizontal pipe line - equipped with a 12 inch O.S. and Y hand-operated bypass valve. The opening or closing speed shall be approximately 1 foot per minute and the limits of travel shall be governed by a mechanical torque responsive switch such as Limitorque Type SM or approved equal, having ample capacity for the service, complete with all appurtenances, including valve position indicator and three "open, stop, close" pushbutton controls. The available electric service in the valve chamber is 440 volts, 3-phase, 60 cycle. The available electric service near the pumping plant is 208 volts, 3-phase, 60 cycle. The maximum static head with the valve closed is approximately 160 feet and 100 feet on the supply and delivery sides respectively, assuming the opposite side of the valve drained in each instance. These valves shall be designed for throttling operation throughout their full travel, and under a maximum hydrostatic pressure differential of 30 p.s.i.

The valve was purchased from the A.P. Smith Mfg. Co. (order No. 90524; April 4, 1952) as Item No. 11. Three 60" valves were ordered as follows (direct quote from the order):

> 60" D.F. 150# test Vertical Electrically operated Rising Stem square bottom case and disc Valve with 12" O.S. & Y. by-pass 35" face to face Standard Drilling. Electrical Equipment to consist of SM-4 60 ft. # Limitorque Motor Unit mounted on Valve. size 1 NEMA I Controller, AS 3B/2L NEMA I push button station.__Valves for 440 volt 3 phase 60 cycle__Valves for 208 Volt 3 phase 60 cycle. 26# unbalanced pressure. 75# static pressure. B.M.#G2S3-A4 Open Left.

Thus, the valve specification language was apparently relaxed in two ways prior to purchase-- the 120 psi static pressure requirement was reduced to 75 psi (combined with a 150 psi test) and the 30 psi pressure differential for throttling was reduced 26 psi.

There is no apparent velocity or flow rating for the valve from the above language. Based on the 26 psi of unbalanced pressure (60 feet of head) for throttling throughout the full range of valve travel, one can infer high flow rates for a wide open valve-- i.e., velocities exceeding 60 feet/second. Based on this inference, a 400 cfs flow rate (V=20.40 ft/sec) would not be considered excessive.

It is noted that for this valve and the flow range being considered, transients created during valve closure are not significant. This is because of the slow closure speed (one foot per minute) and primarily because of the valve location, in close proximity to the reservoir.

The next question is whether the higher velocity in the 60" segment will lead to flow separation within the downstream flow expansion. The expansion length is only 5 feet. A useful rule of thumb is that the expansion section should have a length equivalent to 3 times the Froude Number (for the smaller diameter section) for each unit increase in radius. The following calculations apply:

• Froude Number (60" diameter @ 400 cfs)

$$= \frac{V}{\sqrt{gd}}$$

$$= \frac{20.40}{\sqrt{32.2 \times 5}}$$

$$= 1.61$$

• Safe expansion length:

$$= 3\ Fr \times 0.5\ (7\text{-}5)$$

$$= 4.82$$

Thus, with a 5 foot expansion length, no flow separation is expected at 400 cfs.

A final question regarding the existing 60" gate valve is its capability for emergency closure if there were a rupture downstream. Such a rupture is conceivable in the context of a strong earthquake. If such a rupture occurred between the dam and the pumping plant, it could not be repaired until the flow was shut off and the 60" valve would be the only means of shut-off. This is because the intake stoplog was designed to be placed only under balanced head (zero flow) conditions. Water supply deliveries would be interrupted until the flow was shut-off and downstream repairs were made.

The primary emergency closure evidence provided by the specifications and purchase language set forth above is the indications that the valve is capable of throttling (and presumably closure) under up to 26 psi of unbalanced pressure (or 60 feet of head) through its full range of disc travel. If the reservoir were full at the time of rupture and emergency closure, the actual unbalanced hydrostatic pressure would be approximately 160 feet of head or 70 psi. This appeared to raise uncertainty as to whether emergency closure could be achieved. The manufacturer was contacted and indicated that, when new, the valve should have been capable of emergency closure under a 75 psi differential, based on its rated working pressure. The manufacturer did express concern about the valve's age and lack of knowledge about operation and maintenance activities.

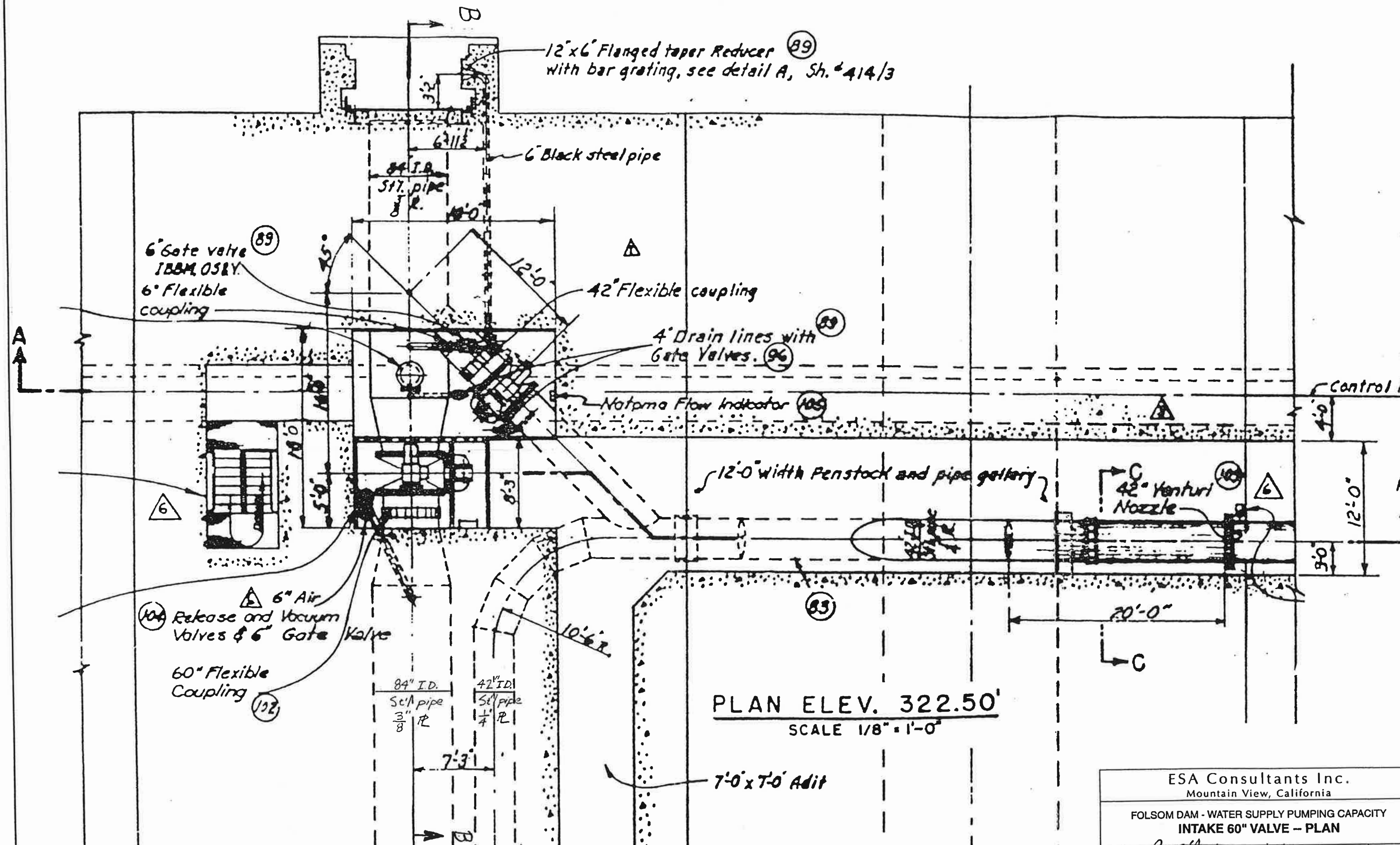
Even if the internal parts of the valve proved capable of closure under the above described conditions, there is a further uncertainty as to whether the actuator has been designed to deliver the required torque. Torque calculations likely were based on the 30 or 26 psi of unbalanced pressure. Furthermore the electrical actuator has been specifically designed to limit torque delivery to 60 ft-lbs. This is to limit damage in case of disc blockage. The relevant calculations have not yet been located for review during this study.

The emergency closure issue is not really impacted by the primary focus of the present study-- the increase of Folsom Dam water supply system capacity from 315 cfs to 400 cfs. The valve either is or is not capable of emergency closure at 160 ft (70 psi) of differential pressure and the answer will be the same whether the system's nominal capacity is 315 cfs or 400 cfs. Given the need for reservoir drawdown and the interruption of water supply deliveries that could occur with a downstream rupture and failure of efforts to close the valve, it seems that a full review of emergency closure capability is advisable. Such a detailed review is beyond the scope of the present study.

Should a review of emergency closure capability indicate that valve replacement is necessary, consideration should be given to a larger diameter replacement valve to provide lower velocities, less head loss and the possibility of future capacity increases.

It should be noted that the same emergency closure question applies to the 42" valve that is located in the dam to provide gravity feed to the Natoma Line. In this case, however, the valve is rated for throttling at least 40 psi (92.3 feet) of differential pressure according to the A.P. Smith Manufacturing Co. order document. It is also a 75 psi working pressure valve so, presumably, it was capable of emergency closure when new. This valve was used extensively for throttling of Natoma gravity flows until the mid 1970's. According to Joye (1995) of the USBR, a pin failed within the valve opening/closing mechanism, making the valve inoperable until repaired. Mr. Joye attributes the failure primarily to the throttling service.

More detailed information has been requested on the operation and maintenance history of both these valves.



Note: Figure abstracted from Corps Drawing AM-1-9-414/2.

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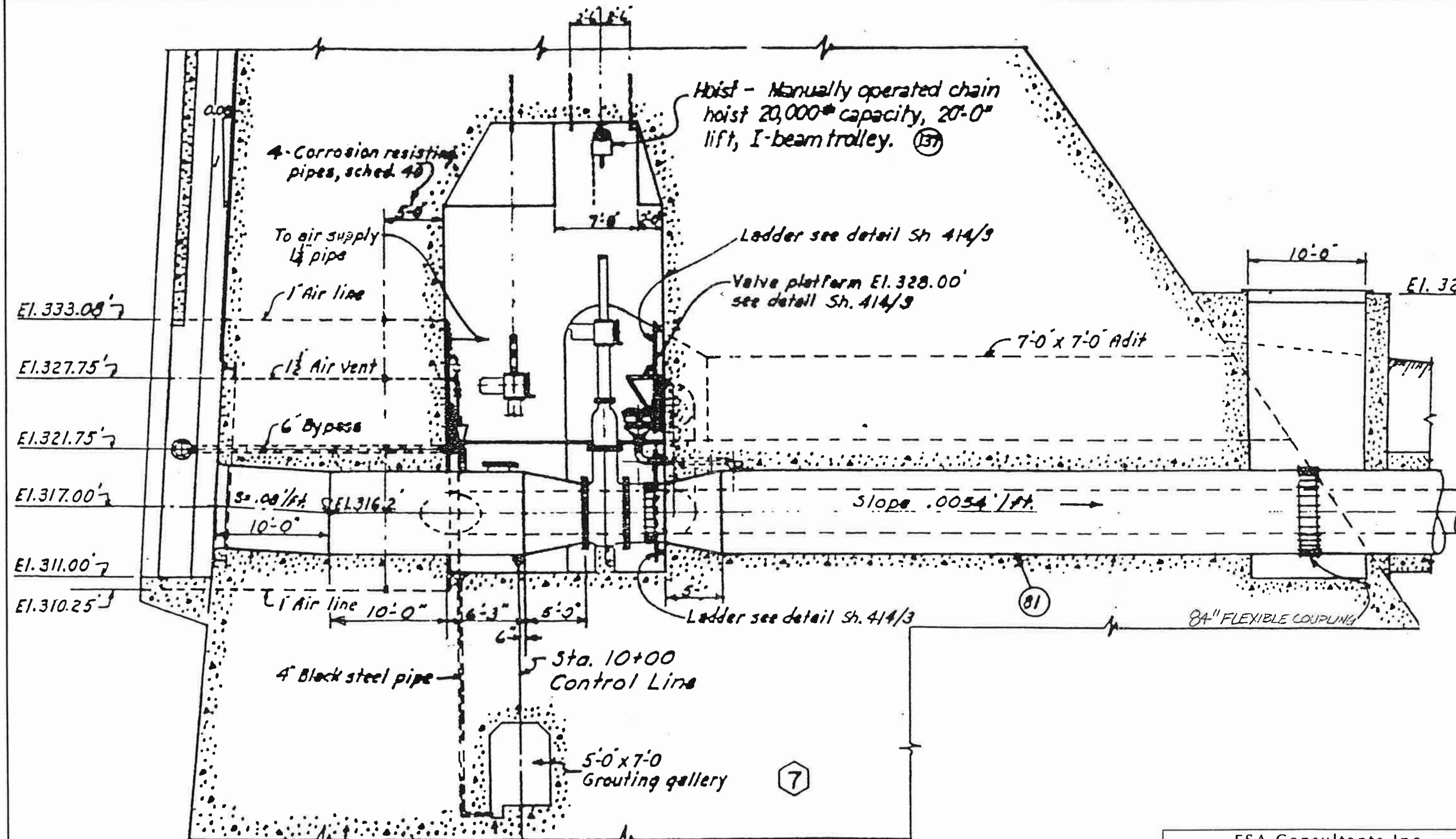
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
INTAKE 60" VALVE -- PLAN

	Date	Project No.	Figure No.
Checked By [signature]	Date 1/26/96	043.9501	6-1
Approved By [signature]	Date 1/31/96		



SECTION B-B

SCALE 1/8" = 1'-0"

Note: Figure abstracted from Corps Drawing AM-1-9-414/2.

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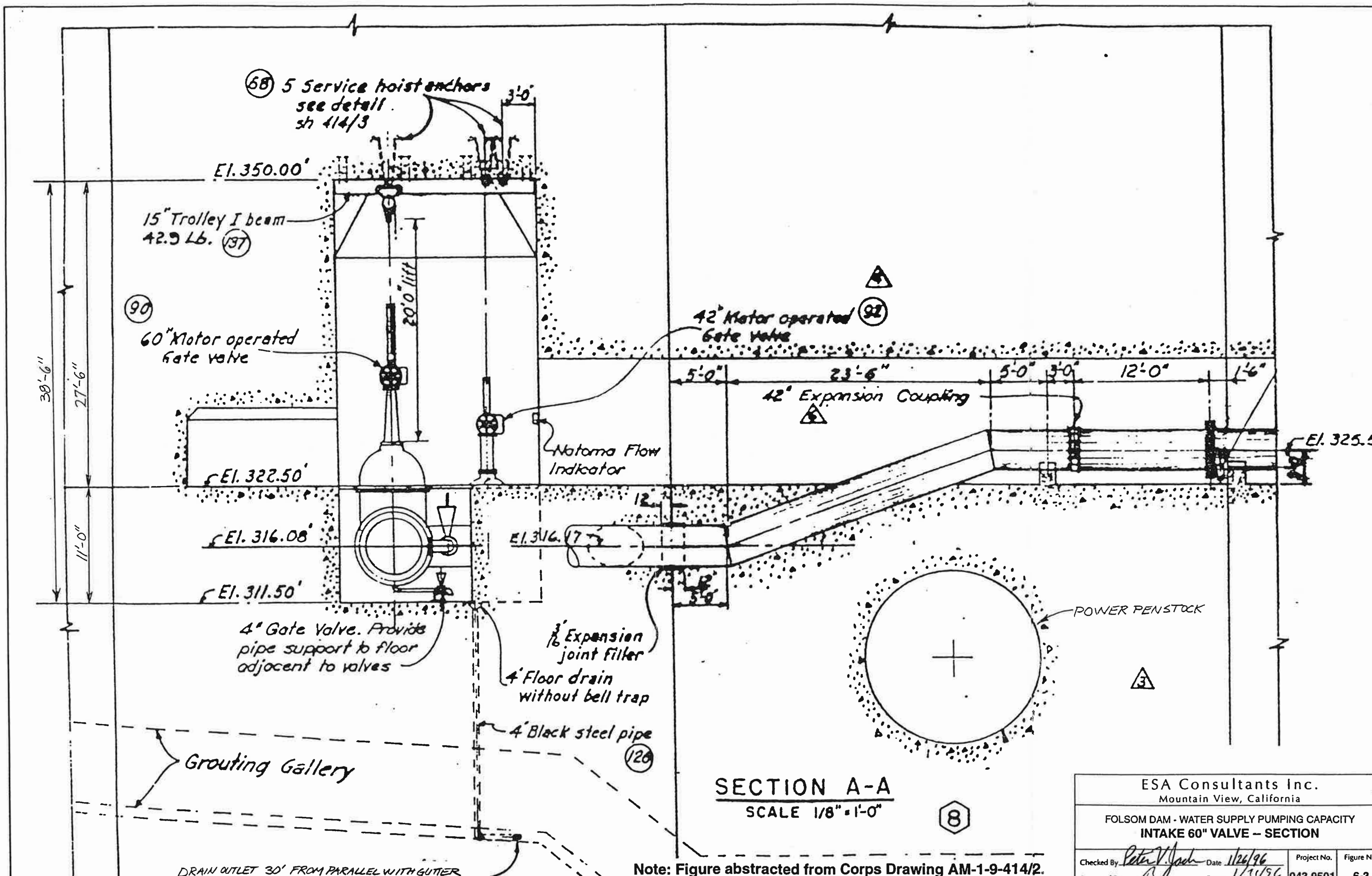
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **INTAKE 60" VALVE – PROFILE**		
Checked By Peter V. Jacobs Date 1/26/96 Approved By [signature] Date 1/31/96	Project No. 043.9501	Figure No. 6-2



SECTION A-A

SCALE 1/8" = 1'-0"

8

Note: Figure abstracted from Corps Drawing AM-1-9-414/2.

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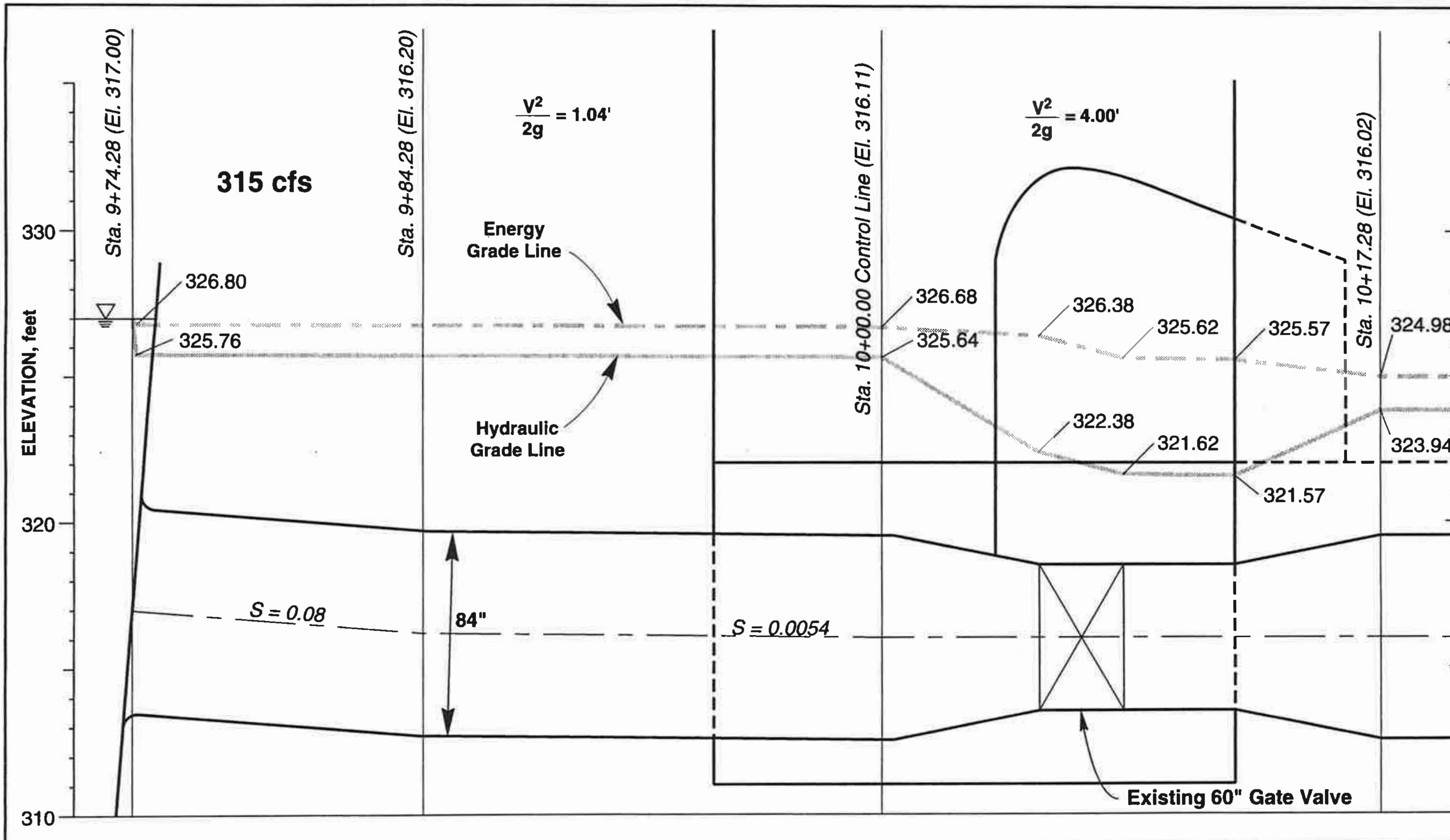
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **INTAKE 60" VALVE -- SECTION**		
Checked By Peter V. Jech Date 1/26/96; Approved By B Date 1/31/96	Project No. 043.9501	Figure No. 6-3



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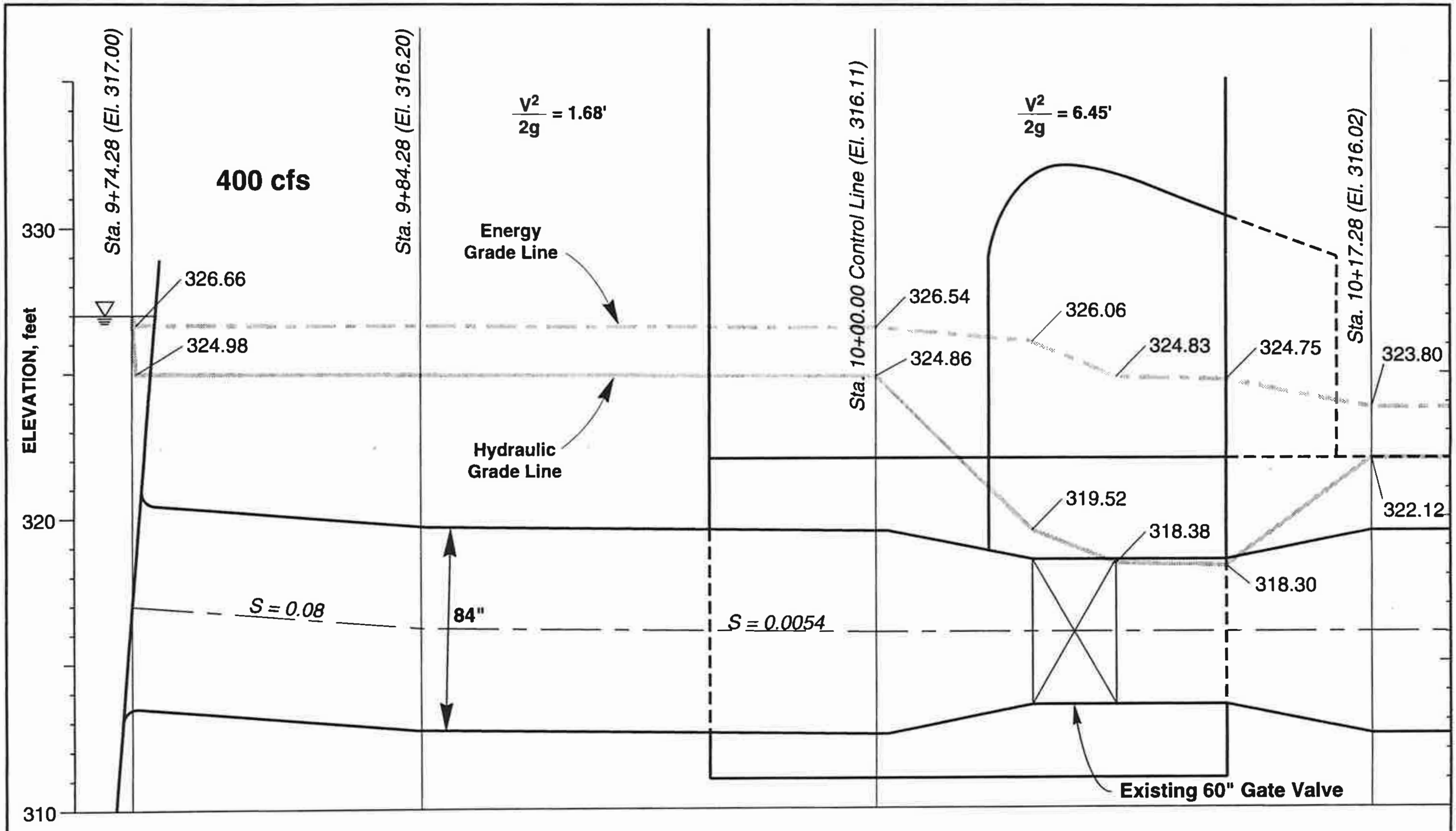
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

INTAKE ENERGY AND HYDRAULIC GRADE LINES FOR 315 CFS

		Project No.	Figure No.
Checked By Peter V. Jacke	Date 1/26/96	043.9501	6-4
Approved By B	Date 1/31/96		



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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
INTAKE ENERGY AND HYDRAULIC GRADE LINES FOR 400 CFS

Checked By Peter V. Jacka	Date 1/26/96	Project No. 043.9501	Figure No. 6-5
Approved By [signature]	Date 1/31/96		

7. VENTURI METER IN THE NORTH FORK LINE

The original equipment for flow measurements in the North Fork Line is an 84" x 49" Venturi meter located a short distance downstream of the pumping plant at El. 327.05 (Corps, 1951; see Figure 7-1). With an increase of maximum flow in the North Fork Line from 250 cfs to 335 cfs (recognizing the diversion of 65 cfs to the Natoma line), the question arises whether this flow meter becomes a significant restriction for flow. The Corps (1951) calculations show the following flow conditions for the originally visualized 250 cfs:

- 84" Velocity: 6.5 ft/sec
- 84" Velocity Head: 0.66 ft
- 49" Velocity: 19.09 ft/sec
- 49" Velocity Head: 5.66 ft
- Differential Velocity Head: 5.00 ft
- Head Loss: 0.2 (Differential) = 0.2 x 5.0 = 1.0 ft

With a flow of 335 cfs, the following flow characteristics will pertain:

- 84" Velocity: 8.70 ft/sec
- 84" Velocity Head: 1.18 ft
- 49" Velocity: 25.58 ft/sec
- 49" Velocity Head: 10.16 ft
- Differential Velocity Head: 8.98 ft
- Head Loss: 0.2 (Differential) = 0.2 x 8.98 = 1.80 ft

Thus, with an increase of only 0.8 feet in head loss, the venturi meter is not a significant restriction from a head loss viewpoint.

The next question is whether the higher velocity in the venturi throat will lead to flow separation within the downstream flow expansion. The expansion length is approximately 14 feet. A useful rule of thumb is that the expansion section should have a length equivalent to 3 times the Froude Number (for the smaller diameter section) for each unit increase in radius. The following calculations apply:

- Froude Number (49" diameter @ 335 cfs):

$$= \frac{V}{\sqrt{gd}}$$

$$= \frac{25.58}{\sqrt{32.2 \times \frac{49}{12}}}$$

$$= 2.23$$

- Safe Expansion Length:

$$= 3Fr \times 0.5 \left(7 - \frac{49}{12}\right)$$

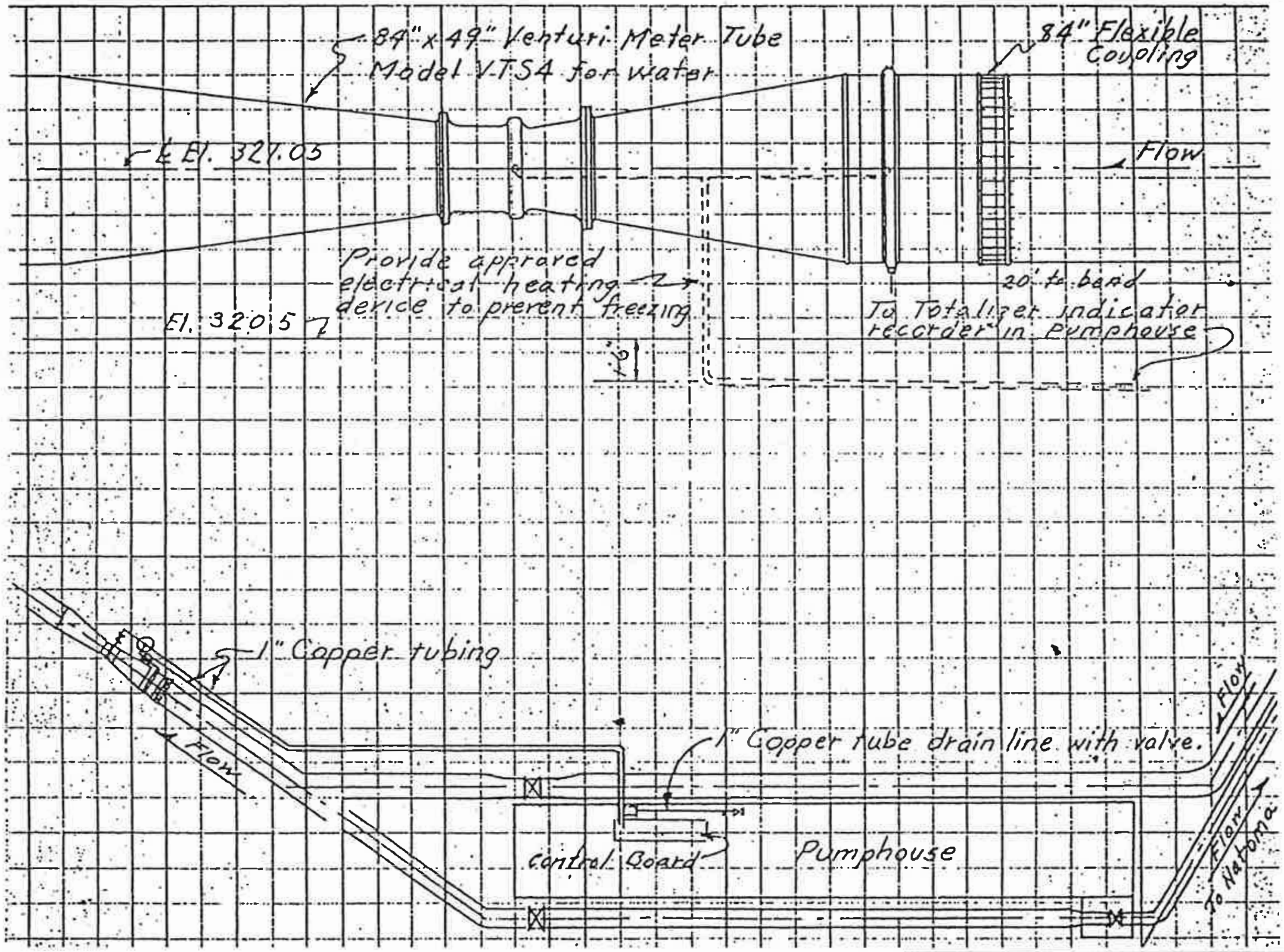
$$= 6.69 \times 1.46$$

$$= 9.76 \text{ feet}$$

Thus, with a 14 foot expansion length, no flow separation is expected.

Finally, there is the question of whether the venturi will still perform effectively its function as a flow meter. All that will be required is to extend the effective range of the transducers and to recalibrate or replace the conversion functions in the rest of the instrumentation system.

In summary, except for the need to extend the range of the instrumentation capability, no action is foreseen relative to the venturi.



Note: Figure from Corps 1951 Calculations.

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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **NORTH FORK 84" LINE VENTURI METER**		
Checked By Peter V. Jacke Date 1/26/96 Approved By B Date 1/31/96	Project No. 043.9501	Figure No. 7-1

8. VORTEX FORMATION

The USBR has expressed concern about the possibility of vortex formation as reservoir water surface elevations fall below El. 340 to 335 and then approach minimum pool (El. 327). They have installed a special pump at a tap in one of the penstocks to provide an alternative to the normal water intake, in case vortex problems become so severe as to drastically limit pumping capabilities. They have indicated that modeling studies may be required to fully characterize vortex formation potential at the pool elevations of concern. Although the USBR has expressed concern about vortex formation, no instance of vortex formation has yet been observed, even under the relatively low reservoir conditions that prevailed during the late 1980's and early 1990's drought (Sanford and Joye, 1995).

Vortex formation potential is a function of intake geometry and flow (or velocity), as well as reservoir water surface elevation (or intake submergence). At very low flow rates (e.g. 50 cfs), and the 6.5 feet of submergence available for the Folsom water supply intake at minimum pool, no vortex formation would be expected, even recognizing the unsymmetric geometry of the approaching flow.

Figure 8-1 presents various definitions of the approximate boundary between the zones where vortex formation is likely versus unlikely, based on hydraulic conditions. Many of these relationships have been developed in terms of Froude Number (Fr). Some of these definitions are more conservative than others and some assume very severe geometries. For example, Reddy and Pickford (1972) indicated the submergence (s) over diameter (d) relationship $s/d = 1+Fr$ to define an envelope line above which vortexes would not be expected even in rectangular sumps. Although the Folsom intake approach is unsymmetric, it is not as confined as a sump. The two relationships that are likely to best represent the Folsom water supply intake are those by Gordon (1970, unsymmetric) and Knauss (1987). They have been given bolder lines in Figure 8-1.

Various pumping capacities for the Folsom Project water supply system are also shown on the diagram-- the present capacity, the proposed capacity with two additional pumps, and the prospective ultimate capacity of 400 cfs at minimum pool. The relationships generally indicate the following:

- Vortex formation is extremely unlikely with the existing pumping facility, even at minimum pool (El. 327), because of the limited delivery capacity (about 108 cfs).

- The potential for vortex formation is slightly greater when the two new pumps are added, but a vortex still may not occur (even at minimum pool) . This is because delivery capacity (at about 208 cfs) is still relatively modest when compared to the intake diameter and submergence.

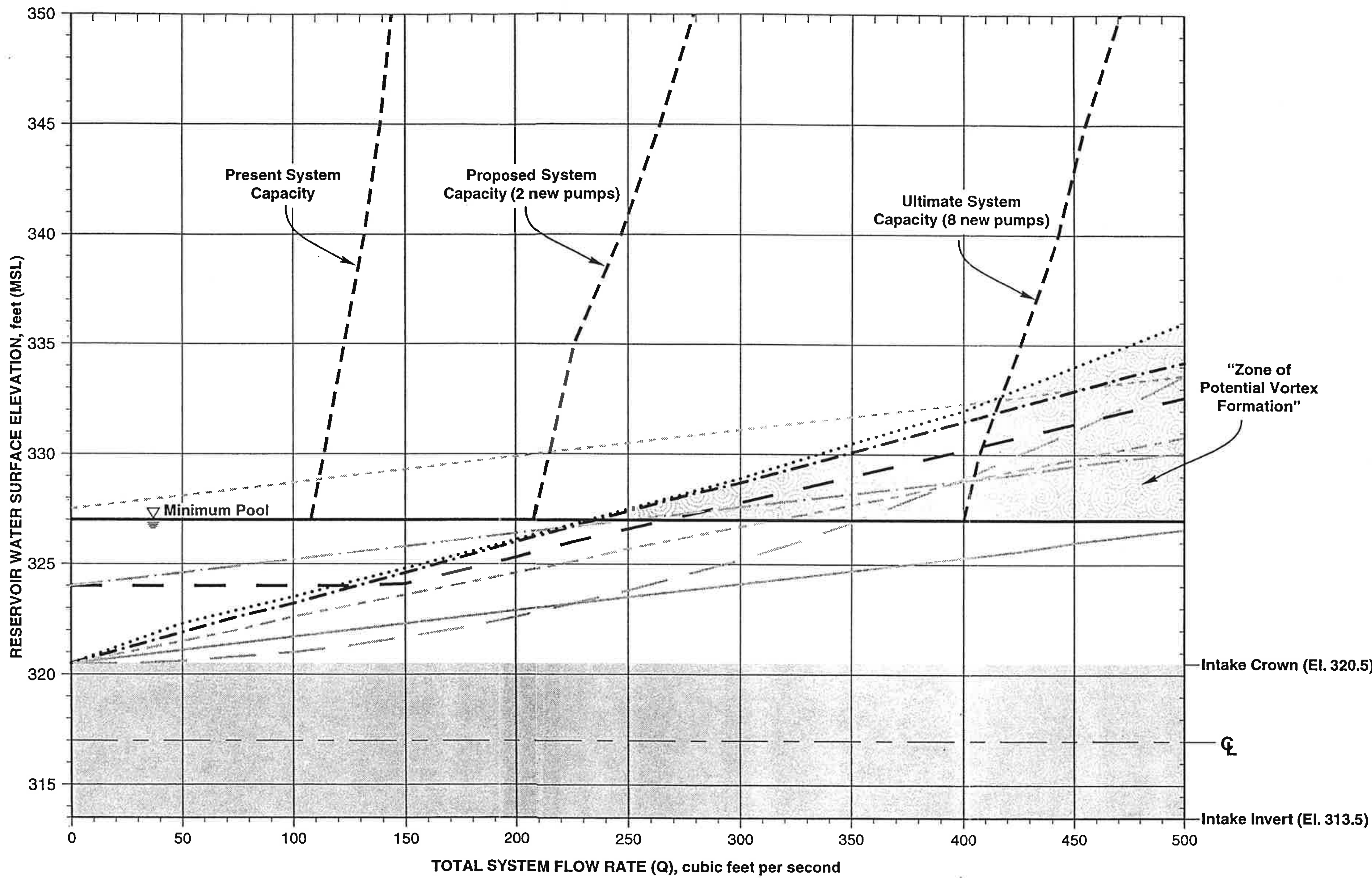
- Vortex formation is likely to occur if additional pumping capacity is added and delivery of 400 cfs is attempted at minimum pool. Indeed, critical (air entraining) vortex formation conditions should be expected to develop at approximately El. 332 when pumping at 400 cfs.

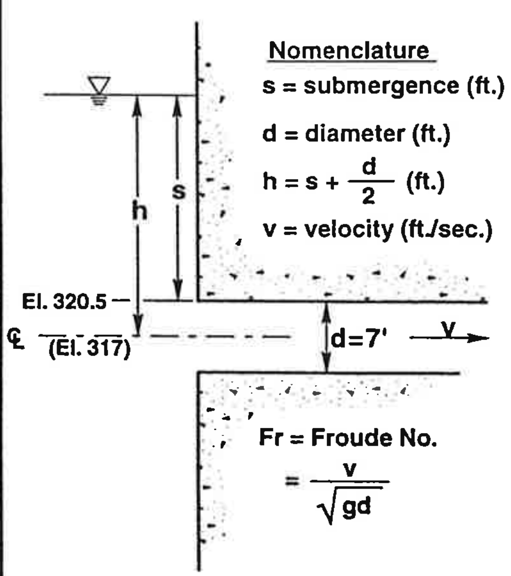
A zone of high vortex formation potential has been indicated for the Folsom Dam water supply intake based on the technical literature reviewed. This zone assumes no vortex defeating actions are taken, other than to limit pumping sufficiently to prevent formation of air entraining vortexes. The constraint that such an approach places on water supply deliveries is quite modest. In the final 5± feet of pool drawdown a gradual decrease of pumping rate from 400± cfs down to 235± cfs would be required. More severe restrictions might well be expected due to rationing programs.

The above pumping restrictions due to vortex formation might be considered unacceptable--e.g., in case of an emergency situation such as a large fire. If so, various actions could be considered to defeat the vortexes. A large floating (probably wooden) raft could be constructed over the intake area to resist the swirl and impede the vortex access to air. Guide vanes, air traps, air release valves and vacuum pumps could be installed between the intake and the pumping plant to combat detrimental vortex impacts. Many of these actions are relatively economical and could be implemented relatively quickly if necessary.

The USBR has indicated that a hydraulic model study could be conducted to better characterize vortex formation potential at the Folsom Dam water supply intake. The USBR would likely insist on such a study if water supply agencies wanted assurance of a full 400 cfs pumping capacity at minimum pool (El. 327). The USBR Denver hydraulic laboratory has estimated that such a study could be performed for approximately $63,000 (April, 1995).

Based on the modest likelihood of vortex formation at existing and proposed pumping capacities (with two additional pumps) it seems that such a modeling study can be postponed. Similarly any action to develop vortex defeating facilities would seem premature. The issue of vortex formation potential can and should be reconsidered when the next project to increase Folsom Project pumping capacity is initiated.





EXPLANATION

- Estimated upper boundary of vortex formation zone.
- $s/d = 1 + Fr$ (Ready and Pickford, 1972; most conservative).
- $s = 0.4\ vd^{0.5}$ (per Gordon, 1970, unsymmetric).
- $(h/d)_{critical} = 2Fr + 1/2$ (Knauss, 1987).
- $s = 5\frac{v^2}{2g}$ (Namikas, 1995).
- $s = 0.3\ vd^{0.5}$ (per Gordon, 1970, symmetric).
- $s/d = 0.5 + Fr$ (after Ready and Pickford).
- $s/d = Fr$ (Ready and Pickford, 1970).

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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
VORTEX FORMATION BASED ON WATER SURFACE ELEVATION AND FLOW

Checked By Peter V. Jack Date 1/26/96	Project No.	Figure No.
Approved By B Date 1/31/96	043.9501	8-1

9. PUMPING FLOOR LAYOUT

Based on the discussions of hydraulic factors in the previous sections, improvements to increase the Folsom Project pumping capacity can be limited to changes in the pumping plant. Accordingly, this section focuses on the physical arrangement of the hydraulic conduits and machinery on the pumping floor of the pumping plant.

USBR Drawing 485-208-980 was obtained from the Bureau as a CAD file and was modified to show the addition of Pumps 7 and 8 as presented in Figure 9-1. Pump dimensions were obtained from Ingersoll-Dresser for the 750-LNE-1050 and those dimensions result in the indicated layout.

The most important design/constructibility consideration is the indicated enlargement of the suction piping to 36" diameter (from the existing 30") and the discharge piping to 30" diameter (from the existing 24"). This involves cutting back the cones that provide transitions from the headers into the pumping plant. Around its circumference, the cone wall diverges from the center line of the pumping plant piping at an angle of 6 degrees. Thus, in order to gain 3" of piping radius (or 6" of diameter) the cones must be shortened by 2.38 feet. This is possible while still leaving sufficient working room between the headers themselves and the new weld required to install the larger diameter pipes. On the suction cone, 7.42" of clearance remains (less pipe thicknesses) at the tightest location and on the discharge cone, 10.52" of clearance remains (less pipe thicknesses).

Implementing the proposed cone shortenings will require:

- Removal of the concrete that surrounds the pipe/cone where it now penetrates the pump house wall.
- Removing the concrete embedment outside the wall, between the wall and the header, as necessary to establish acceptable working space.
- Draining the header.
- Precision cutting the cone to receive a new larger (36" or 30") diameter pipe.
- Precision welding the pipe to achieve the alignment needed to reach the pump.
- Renewal of the interior and exterior pipe coatings.
- Installation of the needed valve at the end of the new pipe.
- Refilling of the header.
- Replacement of the piping's concrete embedment and the concrete wall surrounding the pipe.

Since the headers must be drained, it is necessary to coordinate this operation with the system operating needs to maintain water deliveries. For the discharge piping, a period of gravity flow (usually a month or more) can be used to accomplish the needed modification. For the suction side (which is also the gravity bypass), the opportunities are more restricted. However, there may be a period during the winter when adequate gravity flow can be achieved through the Natoma gravity intake line and back flow to the pumping plant discharge header to feed the North Fork line. This could provide a several day period to accomplish the needed work. Also, the work might be scheduled in conjunction with some other need for draining the suction side of the system.

If the logistics for scheduling the suction side modification of the cones are simply unworkable, the installation can adopt an expansion to 36" diameter inside the pumping plant. It is noted however, that the suction side header will have to be drained for a short time to accomplish the needed piping modifications inside the plant, even if the cones are not cut back.

Other aspects of the layout are straightforward:

- The indicated valves will likely be AWWA C504 Class 150B butterfly valves. On the suction side a manual actuator will be sufficient. On the the discharge side a motorized actuator (AWWA C540) with sufficient torque capability to work during transitions in pump operation will be required. In checking conformance to AWWA C504, the water velocity at maximum pump discharge was found to be high. Therefore the discharge side valve was increased to 36" diameter to prevent valve actuation difficulties.

- The indicated flexible couplings will, at the least, conform to AWWA C219.

- The pump, motor base, and anchorage system will be designed in accordance with the manufacturer's recommendations, working (to the extent possible) with the dimensions of the removable pump floor slabs that are built into the existing structure.

Detailed design will need to address several additional issues such as the pump/motor/valve response to a power outage. The pump and motor will have to be capable of tolerating backflow or the valve system will have to be designed to prevent backflow.

Installation of the equipment presents an important constructibility issue relative to the capacity of the existing crane, which is rated at 7.5 tons. Both the pump and the 1500 hp motor will exceed this limit, so both will need to be disassembled and installed in portions. This will require supervision of manufacturer's representatives in order to protect warranties.

Table 9-1 presents the cost estimate (in 1995 dollars) for the hydraulic and mechanical components of the pumping plant improvements, including the needed concrete demolition and replacement for the cone work and pump base.

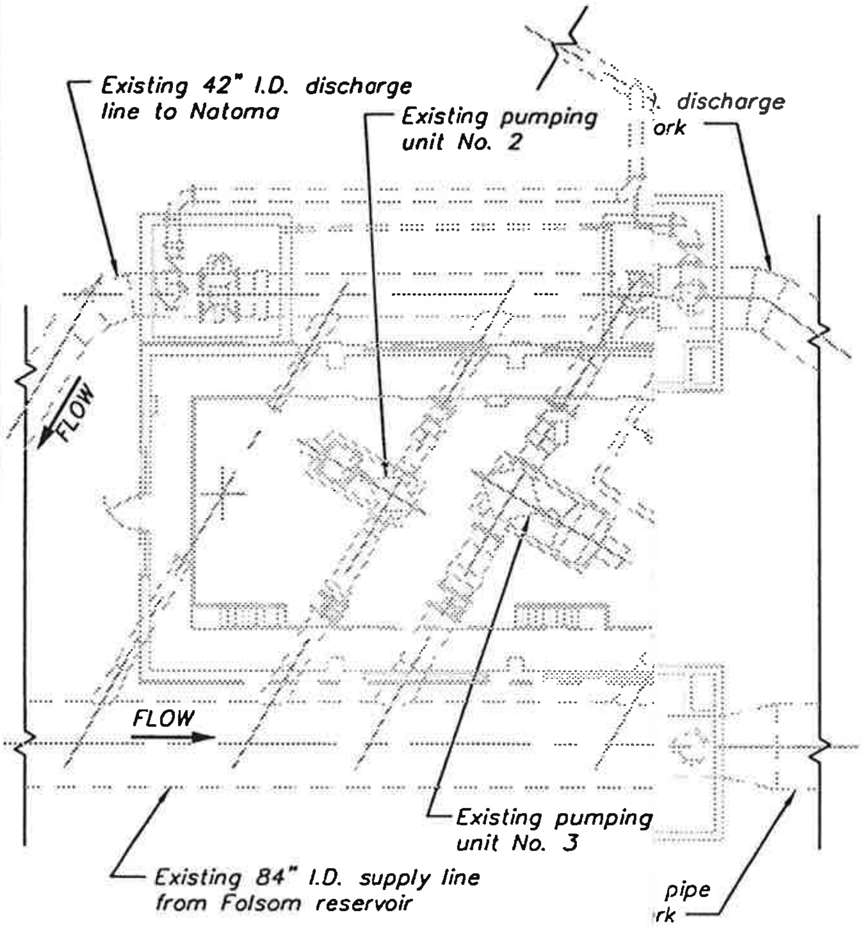
TABLE 9-1
COST ESTIMATE FOR
PUMPS, VALVES, PIPING & INSTALLATION*

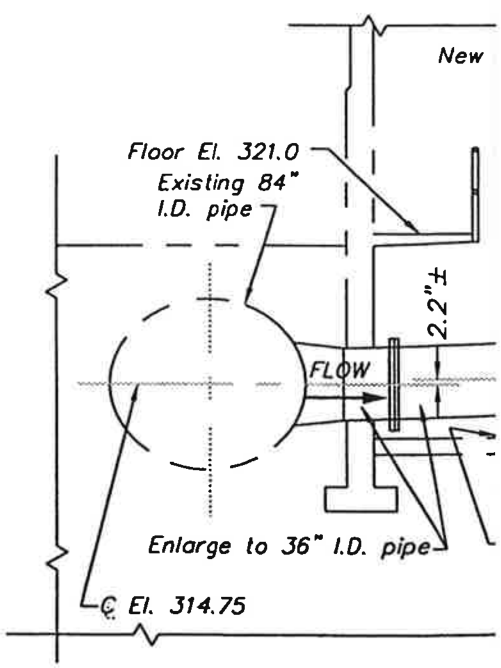
For each unit:

Pump (ID 750-LNE-1050)	$ 110,000
Valve (36"; 150B; Manual)	8,000
Valve (36"; 150B; Motor)**	13,000
Flexible couplings (2 @ 36"; $500 each)	1,000
Expander, reducer, and other piping	8,000
Subtotal materials	$ 140,000
Cutting back cones (labor & mat.; 2 @ $17,500)	35,000
Other installation (labor & mat., incl. pump and motor base)	60,000
Subtotal (for each unit)	$ 235,000
Taxes, mobilization, clean up, etc. (15%)	35,000
Total (for each unit)	$ 270,000

* Estimate is given at mid-1995 price levels. Note that the building modification costs for accommodating electrical equipment are included in the electrical estimates in Section 10.

** The motor-operated valve for the variable frequency drive alternative has been chosen based on the assumption that no long-term, high head throttling will be required.





REFERENCE BUREAU DRAWINGS

PLAN, ELEVATIONS AND DETAILS --	485-D-1415
REINFORCEMENT DETAILS --	485-D-1416
EQUIPMENT ARRANGEMENT --	485-D-1417
POWER CONDUIT PLAN --	485-D-1420
LIGHTING DIAGRAM AND CONDUIT PLAN --	485-D-1421
VALVE SUPPORT DETAIL --	40-D-5913

485-208-980

ESA CONSULTANTS INC.
MOUNTAIN VIEW, CALIFORNIA

FOLSOM DAM – WATER SUPPLY PUMPING CAPACITY

ADDITION OF UNITS 7 AND 8
GENERAL ARRANGEMENT

DRAWN BY DMO	DATE 1/31/96	PROJECT NO. 043.9501	DRAWING NO. 9-1
CHECKED BY B	DATE 1/31/96		

10. ELECTRICAL

10.1 Summary

The purpose of this electrical study is to analyze different types of motors and motor drives/controllers and recommend the most suitable and cost effective electrical system to operate the pumps. Discussions on the pumps and selection of their sizes and quantity are covered in the preceding sections of this report.

This study based on the pumping plant's operational requirements, considers three alternatives for selection of motors and motor drives/controllers; (1) variable speed motors with variable frequency drives (VFD's), (2) two speed motors with two speed controllers and, (3) single speed motors with single speed controllers.

Induction motors are more suitable for the pumping plant applications. Also, they are considerably less expensive and offer comparable efficiency and power factor as the synchronous motors.

The single speed and two speed motor alternatives would provide a variety of water delivery options and also would be less expensive. These two alternatives, however, would not provide the versatility and energy efficiency of a water delivery system that can be achieved with the variable speed system. Some flexibility in water delivery service, however, may be realized by selecting different pump combinations in response to the varying water demands.

The variable speed system would meet the pumping plant's water delivery service and operational requirements more closely than the single and two speed systems as discussed in the report. As such, the variable speed induction motors with VFD's using the pulse width modulated (PWM) technology are recommended.

10.2 Motors and Motor Drives/Controllers

Variable speed, two speed and single speed systems offer three alternatives to handle the varying requirements of water deliveries by the plant. The variable speed system can automatically control the water deliveries by change of the motor speeds in response to the preset water demands. The two speed and single speed systems in conjunction with the existing pumping plant motors could, also, provide a variety of water delivery schedules in response to the water demands by manually operating a pre-selected group of pumps for any given pumping conditions.

The state-of-the-art changes in motor designs have introduced newer induction motors which compare favorably with synchronous motors in regard to higher efficiency and power factor for pumping plant applications. The selection of induction motors results in significant cost savings.

Variable speed motors can be operated by magnetic drives or VFD's. Such drives would continuously control motor speeds based on the requirements of the water deliveries. Magnetic drives have been in use for many years. They provide satisfactory performance and are less expensive. However, the magnetic drives have significantly lower efficiencies at lower speeds. These magnetic drives are coupled together with the motor and pump and are installed as one unit at the pump location. This poses a major drawback in use of the drives due to the limited space at the pump location. VFD's on the other hand can be installed remotely from the pump and motor. As such, they do not cause similar space problems as the magnetic drives.

Modern VFD's use current source inverter (CSI) power structures and/or full pulse width modulated (PWM) switching pattern technologies. These technologies have provided more than one choice for solid state VFD selection. The PWM technology provides the best power quality output and efficiency at all speeds, and enormous diversity in operation with near perfect sinusoidal output waveform. Medium voltage (4160 V) VFD's with sophisticated modern technology (PWM) to control current and voltage harmonics at all load levels and speeds are more expensive and complex compared to the VFD's which only use the CSI technology and offer much less harmonics control and power quality.

The VFD's which use PWM technology are considered to be more suitable for the larger size motors such as those (1500HP) being considered for this pumping plant. The CSI technology which offers less harmonics control, less power quality and lower efficiencies at lower speeds could be a major concern in this application. Besides the low power quality and efficiency, the harmonics generated by this type of VFD's could have a serious impact on the utility grid system and on the operation of solid state (computer) loads.

Two speed (590 rpm and 505 rpm) motors with less than a factor of two difference in the speeds, as required for this pumping plant, would require two windings, one for each speed. This would result in a larger diameter and comparatively more expensive motor than the single winding motor. A two speed system would provide a better control of water deliveries compared to the single speed system by operating the pumps at different speeds and in different combinations with other pumps. Two speed motor controllers are compact in size compared to VFD's. VFD's require significantly larger foot print in the electrical control area than the single or two speed motor controllers.

Single speed motors and controllers would provide the simplest form of pumping plant system similar to the existing system. Also, this system would be less expensive in the initial installed costs compared to the other systems. However, the operating cost of the system considering the power consumption would outweigh the initial cost savings advantage. Also, this system would not provide the same degree of flexibility in water deliveries as the two and variable speed systems described above.

10.3 Power System Description and Arrangement

a. Description

The pumping plant switchgear is presently served by two redundant feeder lines from the main substation. The present cable capacity of each of the two feeders is 260 A (Amps;1-350 kcMil/ phase). These feeders are planned for replacement by the next larger size cables. The cable capacity of the new feeders after replacement by the new cables (500 kcMil/phase) will become 465 A.

Existing system loading is depicted in Table 10-1. This table shows that the total load on the existing switchgear busses and cables serving the existing switchgear is 257 A. The existing switchgear busses which are rated at 1000 A are adequately sized to serve the present loads. The cables serving the switchgear, however, are rated at 260 A (1-350 kcMil/ phase) and they are considered marginally sized to serve the present loads.

The new loading with the addition of the two new pumps, each rated at 1500 HP will become 617 A (see Table 10-2). This loading is significantly over the rating of the existing cables (1-350 kcMil/phase) and also about 25% over the rating of the new cables (465 A; 1-500 kcMil/phase).

In order to keep the new and existing loading of the pumping plant within the capacity of the new cables, only one of the new motors should be added to the existing switchgear. The second new motor should be served from a new switchgear which should be powered from one of the redundant (second) power feeders presently serving the existing switchgear. This arrangement of the new loads would result in a total loading of 437 A on one feeder and 180 A on the other feeder.

Some of the existing motor loads should also be shifted to the new switchgear to divide the total load between the two switchgear equally. This would make the system more reliable and flexible in operation. A separate load study to redistribute the existing and new loads on the two switchgear to provide improved system reliability should be considered during the design stage of the project.

b. Arrangement

The power supply and equipment arrangements covered in this section are for the recommended variable speed motor system (VFD's with PWM technology).

The power supply to the existing and new loads is shown on the Single Line Diagram, Figure 10-1. The arrangement of the existing and new switchgear is shown on the Electrical Equipment Plan Drawing, Figure 10-2.

The addition of the VFD switchgear for the new variable speed drives would require expansion and remodelling of the existing pumping plant building as shown in Figure 10-2. This arrangement should also be reviewed again at the design stage of the project if redistribution of the existing and new loads is considered for improved system reliability.

10.4 Electrical Cost Estimate

The electrical cost estimates for three alternatives (in mid-1995 dollars) are presented in Tables 10-3, 10- 4, 10- 5 and 10-6. The total costs for the electrical alternatives are as follows:

a. Variable Speed System:

(1) The total cost to install variable speed (CSI Technology) system for two new motors (Table 10-3) = $ 970,500

(2) The total cost to install variable speed (PWM Technology) system for two new motors (Table 10-4) = $ 1,120,500

b. Two Speed System:

The total cost to install two speed system for two new motors (Table 10-5) = $ 829,600

c. Single Speed System:

The total cost to install single speed system for two new motors (Table 10-6) = $ 462,100

TABLE 10-1
EXISITING LOADS

Pump No.	Speed (rpm)	Horsepower	Full Load Amps
2	1200	250	30
3	720	600	69
4	900	400	48
5	900	400	48
6	450	550	62
	Total	2,200	257

TABLE 10-2
EXISITING AND NEW LOADS

Pump No.	Speed (rpm)	Horsepower	Full Load Amps
2	1200	250	30
3	720	600	69
4	900	400	48
5	900	400	48
6	450	550	62
7 (new)	600	1500	180
8 (new)	600	1500	180
	Total	5,200	617

TABLE 10-3
ELECTRICAL COST ESTIMATE
VARIABLE SPEED MOTORS AND DRIVES (CSI TECHNOLOGY)

Description	Qty	Unit	Manhours /Unit	Total Manhours	Labor Cost/ Manhour	Material unit cost	Total Labor	Total Material	Total Cost
Variable Speed Motor	2	EA	180	360	$45	$155,000	$16,200	$310,000	$326,200
Variable Speed Drive	2	EA	80	160	$45	$165,000	$7,200	$330,000	$337,200
4 kV Cables, Cond. & Connect.	—	LS	—	—	—	—	—	—	$10,000
4 kV Switchgear Modifications	—	LS	—	—	—	—	—	—	$15,000
480 V Power Modifications	—	LS	—	—	—	—	—	—	$8,000
Building Modifications	—	LS	—	—	—	—	—	—	$80,000
								Total Direct Cost =	$776,400
								Bond, Insurance, Taxes, Profit (25%) =	$194,100
								TOTAL COST =	$970,500

TABLE 10-4
ELECTRICAL COST ESTIMATE
VARIABLE SPEED MOTORS AND DRIVES (PWM TECHNOLOGY)

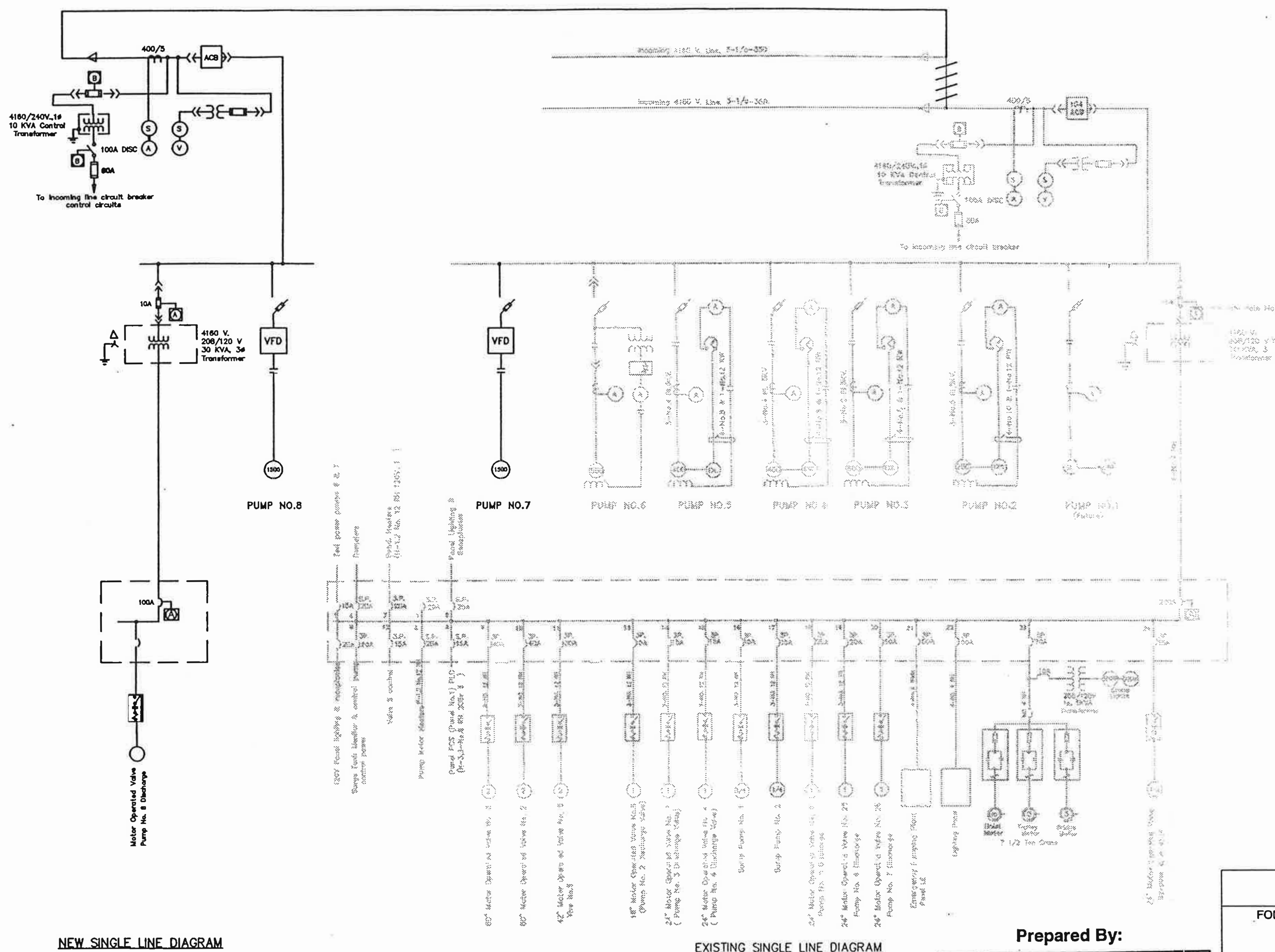
Description	Qty	Unit	Manhours /Unit	Total Manhours	Labor Cost/ Manhour	Material unit cost	Total Labor	Total Material	Total Cost
Variable Speed Motor	2	EA	180	360	$45	$155,000	$16,200	$310,000	$326,200
Variable Speed Drive	2	EA	80	160	$45	$225,000	$7,200	$450,000	$457,200
4 kV Cables, Cond. & Connect.	—	LS	—	—	—	—	—	—	$10,000
4 kV Switchgear Modifications	—	LS	—	—	—	—	—	—	$15,000
480 V Power Modifications	—	LS	—	—	—	—	—	—	$8,000
Building Modifications	—	LS	—	—	—	—	—	—	$80,000
								Total Direct Cost =	$896,400
								Bond, Insurance, Taxes, Profit (25%) =	$224,100
								TOTAL COST =	$1,120,500

TABLE 10-5
ELECTRICAL COST ESTIMATE
TWO SPEED MOTORS AND STARTERS

Description	Qty	Unit	Manhours /Unit	Total Manhours	Labor Cost/ Manhour	Material unit cost	Total Labor	Total Material	Total Cost
Two Speed Motor	2	EA	180	360	$45	$290,000	$16,200	$580,000	$596,200
Motor Starter	2	EA	50	100	$45	$15,000	$4,500	$30,000	$34,500
4 kV Cables, Cond. & Connect.	—	LS	—	—	—	—	—	—	$10,000
4 kV Switchgear Modifications	—	LS	—	—	—	—	—	—	$15,000
480 V Power Modifications	—	LS	—	—	—	—	—	—	$8,000
								Total Direct Cost =	$663,700
								Bond, Insurance, Taxes, Profit (25%) =	$165,900
								TOTAL COST =	$829,600

TABLE 10-6
ELECTRICAL COST ESTIMATE
SINGLE SPEED MOTORS AND STARTERS

Description	Qty	Unit	Manhours /Unit	Total Manhours	Labor Cost/ Manhour	Material unit cost	Total Labor	Total Material	Total Cost
Single Speed Motor	2	EA	180	360	$45	$150,000	$16,200	$300,000	$316,200
Motor Starter	2	EA	50	100	$45	$8,000	$4,500	$16,000	$20,500
4 kV Cables, Cond. & Connect.	—	LS	—	—	—	—	—	—	$10,000
4 kV Switchgear Modifications	—	LS	—	—	—	—	—	—	$15,000
480 V Power Modifications	—	LS	—	—	—	—	—	—	$8,000
								Total Direct Cost =	$369,700
								Bond, Insurance, Taxes, Profit (25%) =	$92,400
								TOTAL COST =	$462,100



LEGEND:

- Air circuit breaker, drawout type
- Air circuit breaker
- Combination motor starter with disconnect switch
- Rheostat
- Synchronous motor
- Squirrel cage motor, horsepower indicated
- Wound rotor motor, horsepower indicated
- Exciter
- Potential transformer
- Current transformer
- Ammeter and switch
- Voltmeter and switch
- Transformer
- Contactor, normally open
- Contactor, normally closed
- Fuse
- Disconnecting device
- Pothead
- Ground
- Key interlock (The lettered circle indicates the key)
- Static Exciter
- EXISTING CABLE TO BE REMOVED
- VFD VARIABLE FREQUENCY DRIVE
- ACB DRAWOUT AIR CIRCUIT BREAKER

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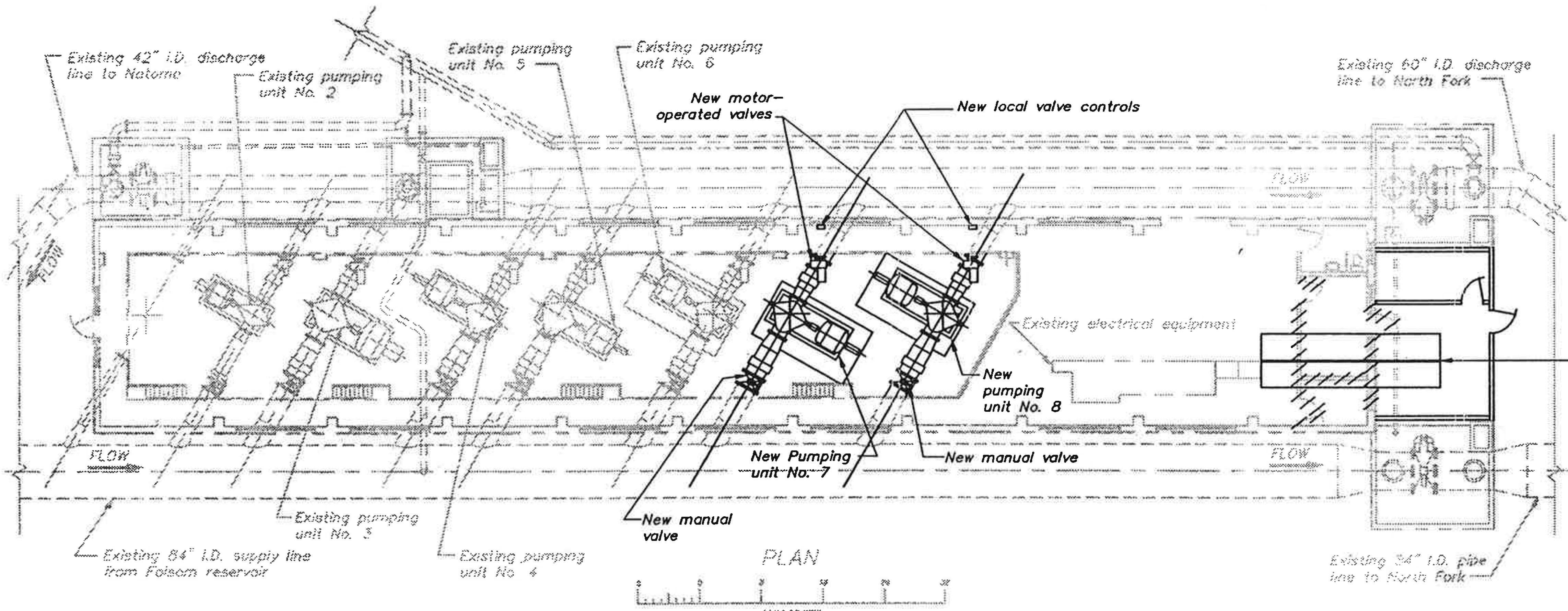
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
PUMPING PLANT EQUIPMENT MODIFIED SINGLE LINE DIAGRAM

Checked By	Date	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	10-1



REFERENCE BUREAU DRAWINGS

PLAN, ELEVATIONS AND DETAILS ---	485-D-1415
REINFORCEMENT DETAILS ---	485-D-1416
EQUIPMENT ARRANGEMENT ---	485-D-1417.
POWER CONDUIT PLAN ---	485-D-1420
LIGHTING DIAGRAM AND CONDUIT PLAN ---	485-D-1421
VALVE SUPPORT DETAIL ---	40-D-5913

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FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY

PUMPING PLANT EQUIPMENT
ELECTRICAL EQUIPMENT PLAN

Checked By	Date	Project No.	Figure No.
Approved By B	Date 1/31/96	043.9501	10-2

TABLE 11-1
OVERALL COST ESTIMATE FOR
TWO VARIABLE SPEED PUMPS
(PWM TECHNOLOGY)
(at mid-1995 price levels)

Hydraulic / Mechanical* (2 units @ $270,000)		$540,000
Electrical** (variable speed; PWM technology; 2 units)		1,120,000
	Subtotal	1,660,000
	Contingency (15%)	250,000
	Total Construction Cost	1,910,000
Engineering / Design (8%)		150,000
Bureau of Reclamation Design Review (2%)		40,000
	Subtotal	2,100,000
Construction Supervision (5%)		110,000
Bureau of Reclamation Supervision (3%)		60,000
	Total	$2,270,000
	Say	**$ 2.3 million**

* Includes civil work for pump, motor, and piping (see Section 9)

** Includes civil work for related building modification (see Section 10)

11. COST ESTIMATE

The overall cost estimate for the pumping capacity improvements are presented in Table 11-1 in mid-1995 dollars. This cost estimate is for two pumps with variable speed motors and the (more expensive) PWM variable frequency drive technology. The cost information is drawn from the more detailed estimates for the hydraulic/mechanical portion (Section 9) and the electrical portions (Section 10). Civil work costs for the respective portions of the project were included within those estimates. The subtotal of the aggregated estimate for two new pumping units is $1.66 million. Inclusion of a 15% contingency brings the total to $1,910,000. This is a construction cost estimate including equipment, materials and installation. The estimate of total project costs needs to include allowances for design, coordination with the USBR, construction management, and administration. Such allowances have been indicated in Table 11-1, resulting in a total project cost estimate of $2,270,00 which has been rounded upward to $2.3 million. It is noted that the intensity of USBR review is not predictable and the amount of effort required to coordinate with the Bureau and respond to their comments and concerns is likewise unknown. Thus, the allowances indicated are initial estimates.

12. REFERENCES

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APPENDIX A
FOLSOM DAM WATER SUPPLY PUMPING TEST
ON NOVEMBER 18, 1994

APPENDIX A
FOLSOM DAM WATER SUPPLY PUMPING TEST
ON NOVEMBER 18, 1994

A pumping test of the Folsom Dam water supply facilities was conducted on November 18, 1994. The primary purpose of the test was to confirm or refine the calculated delivery capacity and head loss findings reported in an earlier study (ESA Consultants, November 1994).

Preparatory work for the pump test included identification of measurement locations, installation of needed gages, development of data sheets and coordination with the affected water supply agencies to arrange for participation and establish appropriate operating conditions during the test. The test data are included as Attachment 1. Some clarifying questions and answers regarding test conditions are set forth in Attachment 2.

The test was performed in two distinct portions. The first portion of the test was performed while both Roseville and San Juan had their throttling valves fully open. The second portion was conducted while San Juan was fully open and Roseville was closed. Thus, Roseville head loss can be characterized only from the first portion of the test. The second portion gives an additional data point for San Juan.

There were numerous slight inconsistencies in the recorded data. These were resolved by using the results of both tests, the initial Corps (1951) head loss calculations, and considerable engineering judgment. The adjusted data that were adopted as an adequate, internally consistent representation of the test data are set forth in Table A-1. This table also provides the unadjusted field data for comparison. The following observations are provided:

- There is a flow rate discrepancy between the USBR North Fork venturi reading and the sum of the Roseville and San Juan treatment plant readings. The difference is approximately 4 percent and is likely due to slight miscalibration of one or more of the flow meter transducers.

- Two of the pressure gages appear to give slightly high results-- Point C (PC) appears high by 1 psi and the USBR stand pipe appears high by 1.5 feet (approximately 1 psi).

- The water surface elevations in the Roseville and San Juan rapid mix chambers are the ideal hydraulic grade measurement in each case, assuming that no throttling is occurring. Thus these elevations were inferred based on the plant hydraulic regimen and flow and they were used instead of PE and PF.

- Steady state conditions were not reached in the second test, but the inferred steady state numbers are not unreasonable compared to the readings available.

The indicated steady state readings translate into hydraulic grade lines for the system as plotted in Figure A-1 and A-2 and further tabulated in Table A-2.

Initial calculations of segment head losses using the measured pressures indicated substantial internal inconsistencies; i.e., one segment would have higher head losses than expected based on the Corps 1951 calculations and another would have lower head loss than expected. In some cases negative head losses were found and in others, seemingly significant discrepancies could be rationalized away based on the limited precision of the measurements.

Ultimately, by accepting the pressure measurements at the Hinkle "Y" (PD) and adopting the compromise system flow rates indicated in Table A-1, application of the Corps (1951) head loss factors gave reasonable results for all segments. This sequence of analyses is presented in Table A-3 and A-4 for the North Fork line. The calculations of head loss from PB to PD for the initial test using the Corps head loss factor showed agreement with measured pressures within 0.1 psi. It was primarily because of this result that PD was accepted, PB was slightly adjusted and the Corps head loss figures were then used everywhere possible.

From the Hinkle "Y" to San Juan and Roseville, no relevant Corps calculations were available; the piping systems were designed and constructed after 1951. A preliminary assessment of San Juan head loss was available from the initial ESA study but it required confirmation. Accordingly, head loss factors were calculated for San Juan and Roseville using the pressure measurement at Hinkle "Y" and the estimated water surface elevations in the first open tanks at each water treatment plant-- the rapid mix chambers. Those calculations are documented in Table A-5.

Finally, the head loss factors used in this study for each existing segment of the water supply pumping system are shown in Table A-6.

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TABLE A-1
FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST DATA

		Pressures							Flows					
FIRST TEST	Time	PA (psi)	PB (psi)	PC (psi)	PD (psi)	PE (ft. of H2O)	PF (psi)	USBR Stand Pipe (ft. elev.)	QN (cfs)	QS (cfs)	QR (cfs)	QT [a] (Sum N,S,R) (cfs)	USBR North Fork [a] (cfs)	QT [a] (Sum N,NF) (cfs)
	10:40	19	53.5	32	20	17.99	9	440	10	125	62.2	197.2	180	190
	10:45	19	53.5	32	20	17.86	9	440	10	125	63.3	198.3	180	190
	10:50	19	53.5	32	20	17.95	9	440	10	125	63.3	198.3	180	190
	10:55	19	53.5	32	20	17.90	9	440	10	125	63.3	198.3	180	190
	11:00	19	53.5	32	20	19.44	9	440	10	125	63.5	198.5	180	190
Steady State (b)	**10:45 to 11:00**	**18.6**	**53.6**	**30.9** [c]	**20.0**	**15.2** [d]	**8.5** [d]	**438.3** [e]	**10**	**120.6**	**61.2**	**191.8**	**181.8**	**191.8**
SECOND TEST														
	11:10	19	57.0		23	51.92			10	164	0	174	158	168
	11:15	19	57.0	35.4	23	59.28		445/448	10	164	0	174	158	168
Steady State (b,f)	**If Test Continued to 11:45 +/-**	**18.7**	**56.3**	**33.6** [c]	**23.0**	**55.94**	**8.6** [d]	**444.4**	**10**	**160**	**0**	**170**	**160**	**170**

Test Parameters:
Date: 11/18/94
Lake Level: 366.44
Pumps Running: 2, 3, 4, 5 & 6

Explanation:

QN = Flow to Natoma (City of Folsom & Prison)
QS = Flow to San Juan Water District
QR = Flow to City of Roseville
QT = Total Flow

PA: EL. 322.05 (Suction Header)
PB: EL. 314.52 (Jct. Grav. & Pump Disch.)
PC: EL. 365.95 (50 ft. downstream of the first Stand Pipe)
PD: EL. 388.36 (just upstream of Hinkle "Y")
PE: EL. 385.5 (Roseville)
PF: EL. 404.39 (San Juan)

Notes:

a There is a difference in flow reading between San Juan & Roseville versus USBR of around plus or minus 8.3 cfs. QT may be 190 cfs based on USBR reading of 180 cfs at North Fork Venturi during the first test. The discrepancy decreases to plus or minus 6 cfs during the second test.

b Steady state conditions adopted based on reconciling measurement inconsistencies.

c The pressure gauge at point C appears to read high by 1 psi.

d Since both Roseville and San Juan had their throttling valves wide open, the preferred data from the test is the water surface elevation in their rapid mix chambers (the initial, open-air tank in their treatment plants). These elevations were inferred (See Attachment 2) and used. The elevations used are consistent with some additional head loss from the point of pressure measurement to the rapid mix chambers.

e The USBR Stand Pipe readings appear to be high by approximately 1.5 feet.

f During the second test, it appears that points B, C, the USBR Stand Pipe, and Point E (Roseville) have not yet reached steady state. Inferred values represent an estimated ultimate steady state condition.

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TABLE A-2
FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST PRESSURES
CONVERTED TO ELEVATIONS

	Measured Pressure			Used Pressure		
	Pressure Reading		Head elevation	Head elevation	Adjusted Pressure	
First Test	(psi)	(ft of H2O)	(ft)	(ft)	(ft of H2O)	(psi)
PA (Suction Header)	19	43.85	365.90	364.98	42.93	18.6
PB (Jct. Gravity & Pump Disch.)	53.5	123.46	437.98	438.27	123.75	53.6
PC (50 ft. downstream of Stand Pipe)	32	73.85	439.80	437.27	71.32	30.9 [c]
PD (upstream of Hinkle "Y")	20	46.15	434.51	434.51	46.15	20.0
PE (Roseville)	N/A	17.90	403.40	400.70 [b]	15.20 [b]	N/A
PF (San Juan)	9	20.77	425.16	424.00 [b]	19.61	8.5 [b]
USBR Stand Pipe [a]	N/A	N/A	440	438.27 [c]	N/A	N/A
Second Test						
PA (Suction Header)	19	43.85	365.90	365.29	43.24	18.7
PB (Jct. Gravity & Pump Disch.)	57	131.54	446.06	444.35	129.83	56.3
PC (50 ft. downstream of Stand Pipe)	35.4	81.69	447.64	443.57	77.62	33.6 [c]
PD (upstream of Hinkle "Y")	23	53.08	441.44	441.44	53.08	23.0
PE (Roseville)	N/A	51.9/59.3	437.40/444.80	441.44	55.94	N/A
PF (San Juan)	-	-	-	424.35 [b]	19.96	8.6 [b]
USBR Stand Pipe [a]	-	-	445/448	444.35 [c]	N/A	N/A

a The USBR "Stand Pipe" reading is really located at PB, and reflects the hydraulic pressure at the junction of the gravity 84" line and the pumping discharge line when pumping operations are underway.

b The pressure measurements for Roseville and San Juan were not used. The estimated water surface elevation in the first open-air tanks were used instead. These changes to downstream measurement locations would show slightly lower pressures due to additional head losses.

c The adjusted pressure readings used are within the precision of the gage readings except for the following: (1) The pressure gage at PC appears to yield readings that are high by 1 psi; and (2) The USBR Stand Pipe transducer appears to yield readings that are high by approximately 1.5 feet.

TABLE A-3
NORTH FORK LINE
HEAD LOSS AND "k" VALUE

1. Corps of Engineers (1951) head loss calculation from junction of gravity feed and pumping plant discharge lines to Hinkle "Y":

   • Flow: 250 cfs

   • Head loss: 7.10 feet

   • Head loss factor: $k = \frac{\sqrt{\Delta h}}{Q}$

   k = 0.010658*

2. Pumping test measurements from junction of gravity feed and pumping plant discharge lines to Hinkle "Y":

   • First Test

	k from measurements		k from adjustments
Q (cfs)	PB - PD (Δh = 3.47 ft)	Stand Pipe - PD Δh = 5.49 ft	PBadj - PD (Δh = 3.76 ft)
180	0.010349	0.013017	0.010773
181.8	0.010246	0.012888	**0.010666***
188.3	0.009893	0.012443	0.010298

   • Second Test

	k from measurements		k from adjustments
Q (cfs)	PB - PD (Δh = 4.62 ft)	Stand Pipe - PD (Δh = 5.06 ft)	PBadj - PD (Δh = 2.91 ft)
158	0.013604	0.014237	0.010797
160	0.013434	0.014059	**0.010662***
164	0.013106	0.013716	0.010402

* Note that compromise flows and adjusted pressures yield "k" values that are essentially the same as the Corps' values.

TABLE A-4
NORTH FORK LINE
HEAD LOSS AND "k" VALUES USING POINT C (PC)

1. Corps of Engineers (1951) Head Loss Calculation:

A.
From junction of gravity feed and pumping plant discharge (PB) to PC

Flow 250 cfs
Head Loss 1.90 feet
Head Loss Factor: $k=(\Delta h)^{0.5} / Q=$ **0.005514***

B.
From PC to Hinkle "Y" (PD)

Flow 250 cfs
Head Loss: 7.10-1.90= 5.20 feet
Head Loss Factor: $k=(\Delta h)^{0.5} / Q=$ **0.009121***

2. Pumping Test Measurements

A.
From junction of gravity feed and pumping plant discharge (PB) to PC

First Test

	k From Measurements		k From Adjustments
	PB - PC	Stand Pipe - PC	PBadj. -PCadj.
Q (cfs)	(Δh=-1.82 ft)	(Δh= 2.02 ft)	(Δh= 1.00 ft)
180	calculation	0.007896	0.005556
181.8	is not	0.007818	**0.005501***
188.3	sensible	0.007548	0.005311

Second Test

	k From Measurements		k From Adjustments
	PB - PC	Stand Pipe - PC	PBadj. -PCadj.
Q (cfs)	(Δh=-1.58 ft)	(Δh=-1.14 ft)	(Δh= 0.78 ft)
158	calculation	calculation	0.00559
160	is not	is not	**0.005520***
164	sensible	sensible	0.005385

B.
From PC to Hinkle "Y" (PD)

First Test

	k From Measurements	k From Adjustments
	PC - PD	PCadj. - PD
Q (cfs)	(Δh= 5.29 ft)	(Δh= 2.76 ft)
180	0.0012778	0.009230
181.8	0.012657	**0.009138***
188.3	0.012215	0.008823

Second Test

	k From Measurements	k From Adjustments
	PC - PD	PCadj. - PD
Q (cfs)	(Δh= 6.20 ft)	(Δh= 2.13 ft)
158	0.015759	0.009273
160	0.015562	**0.009122***
164	0.015183	0.008899

* Note that compromise flows and adjusted pressures yield "k" values that are essentially the same as the Corps' values.

TABLE A-5
HEAD LOSSES FROM HINKLE "Y"
TO ROSEVILLE AND SAN JUAN

1. Roseville; First test

   - Flow: 61.2 cfs

   - Head loss: $PD + \frac{v^2}{2g}$ - Roseville Rapid Mix
     $= 434.51 + 0.35 - 400.70$
     $= 34.16$ ft

   - Head loss factor: $k = \frac{\sqrt{\Delta h}}{Q}$
     $= 0.0955$

2. San Juan

   a. First test

   - Flow: 120.6 cfs

   - Head loss: $PD + \frac{v^2}{2g}$ - San Juan Rapid Mix
     $= 434.51 + 0.35 - 424.00$
     $= 10.86$ ft.

   - Head loss factor: $k = \frac{\sqrt{\Delta h}}{Q}$
     $= 0.027325$

   b. Second test

   - Flow: 160 cfs

   - Head loss: $PD + \frac{v^2}{2g}$ - San Juan Rapid Mix
     $= 441.44 + 0.27 - 424.35$
     $= 17.36$ ft.

   - Head loss factor: $k = \frac{\sqrt{\Delta h}}{Q}$
     $= 0.026041$

   c. Use k = 0.0266

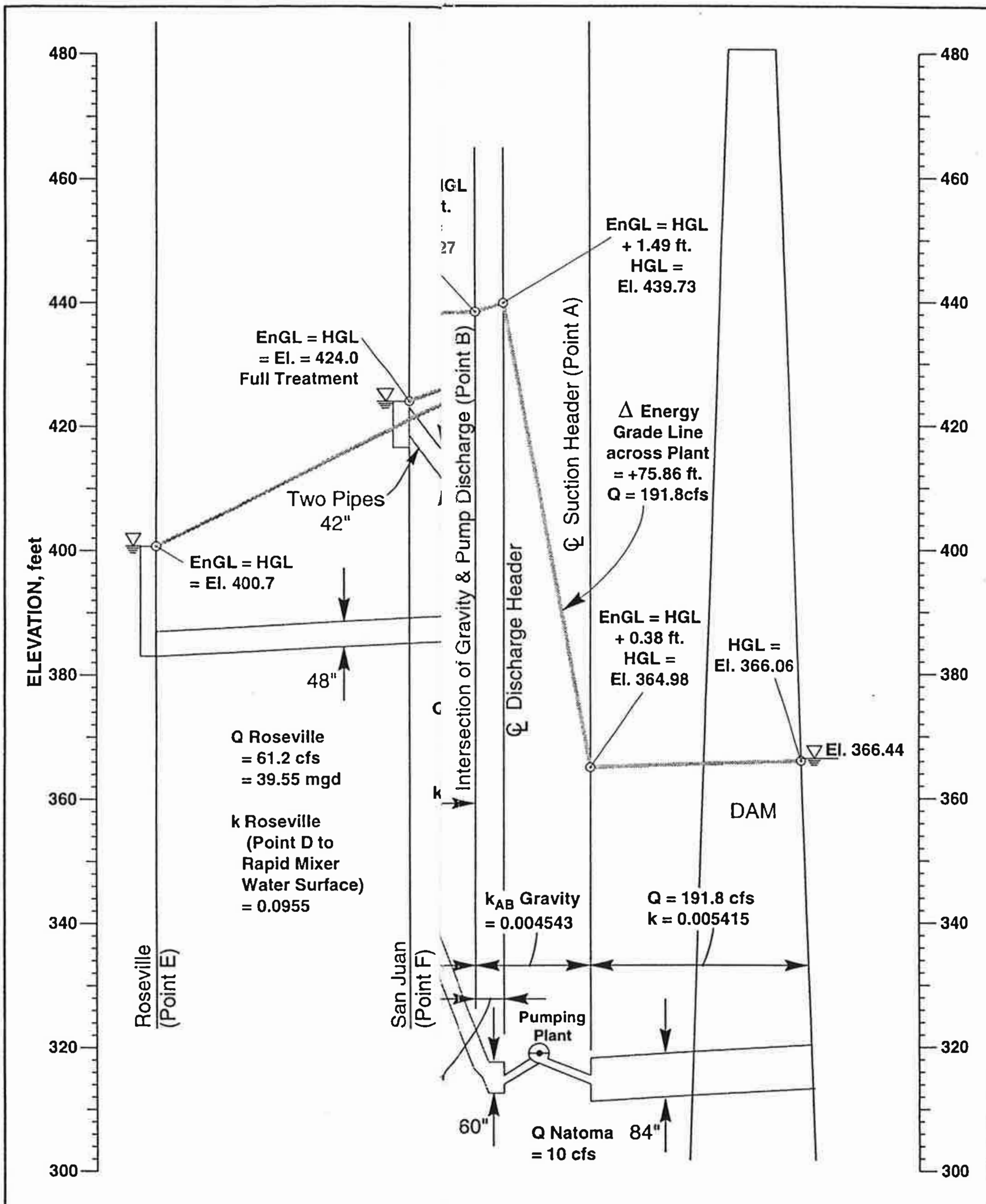
TABLE A-6
HEAD LOSS FACTORS USED

Reservoir to centerline of pumping plant suction header (PA)*:	k = 0.005415
Centerline of pumping plant discharge header to junction of pump discharge line and gravity feed line (PB)*:	k = 0.006657
Centerline of pumping plant suction header to junction of gravity feed line with pump discharge line*:	k = 0.004543
Junction of pump discharge line and gravity feed line (PB) to Hinkle "Y" (PD)*:	k = 0.010658
Junction of pump discharge line and gravity feed line (PB) to stand pipe (PC)*:	k = 0.005514
Hinkle "Y" (PD) to Roseville Rapid Mix**:	k = 0.0955
Hinkle "Y" (PD) to San Juan Rapid Mix**:	k = 0.0266

* Based on Corps 1951 calculations which use the following head loss assumptions:

- Mannings "n" = 0.013
- Gate Valve = $0.19v^2/2g$
- Contraction Loss = 0.1 to $0.5v^2/2g$
- Expansion Loss = 0.2 to $0.5v^2/2g$
- Venturi loss = $0.2(\Delta v^2/2g)$

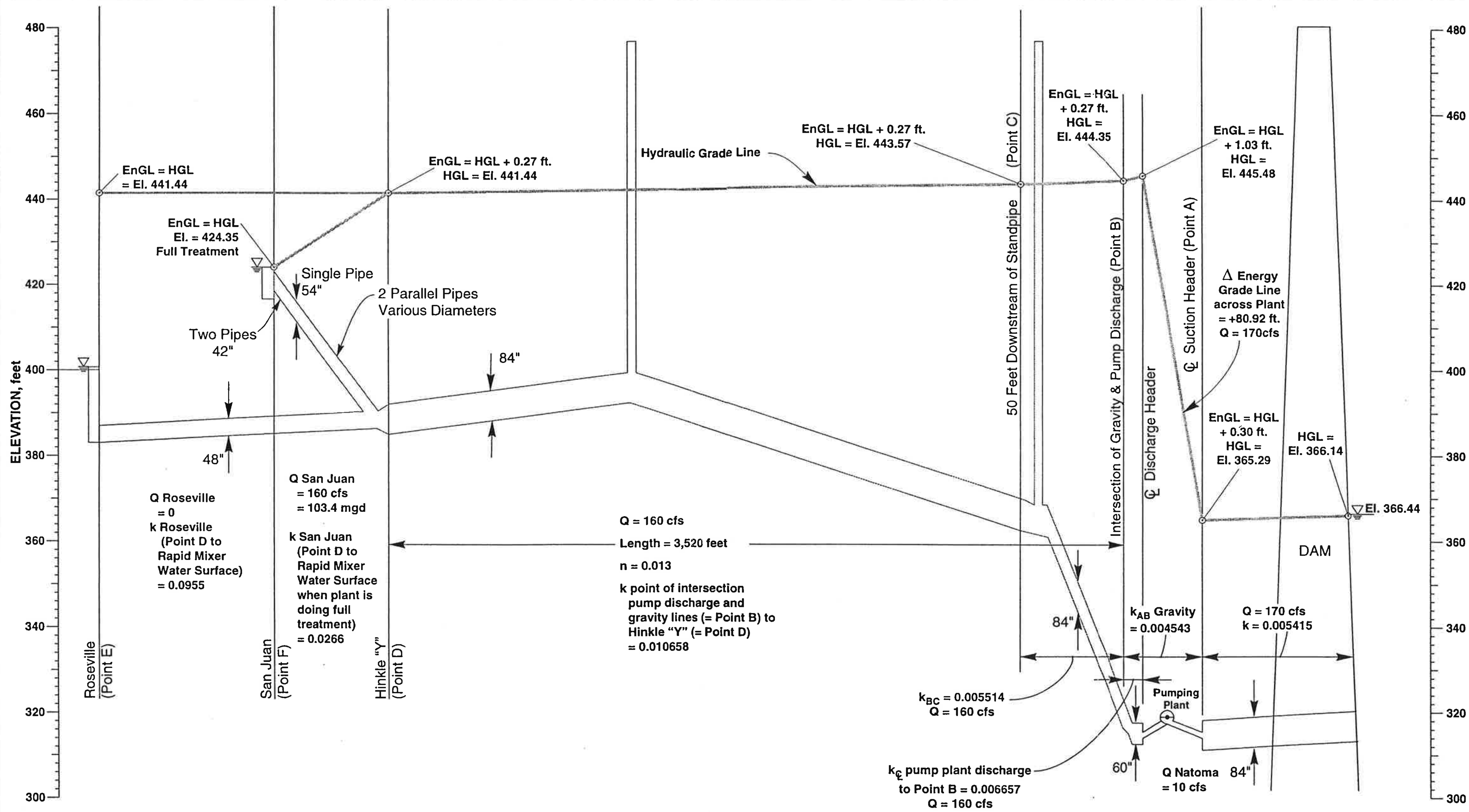
** Based on November 18, 1994 pumping test



ESA Consultants Inc.
Mountain View, California

FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY
NOVEMBER 1994 PUMPING TEST
FIRST TEST

		Project No.	Figure No.
Checked By Peter V. Jacks	Date 1/26/96	043.9501	A-1
Approved By B	Date 1/31/96		



Notes: 1) $\sqrt{\Delta h} = kQ$
2) HGL = Hydraulic Grade Line
3) EnGL = Energy Grade Line
4) Values of HGL Shown here were calculated using Q values from the pumping test and k values for the Corps' 1951 calculations

ESA Consultants Inc. Mountain View, California		
FOLSOM DAM - WATER SUPPLY PUMPING CAPACITY **NOVEMBER 1994 PUMPING TEST SECOND TEST**		
Checked By Peter V. Jache Date 1/26/96 Approved By B Date 1/31/96	Project No. 043.9501	Figure No. A-2

APPENDIX A
ATTACHMENT 1

PUMPING TEST DATA
AND PREPARATORY CORRESPONDENCE

ESA Consultants

File

MURRAY, BURNS AND KIENLEN
A Corporation
1616 29th Street, Suite 300
Sacramento, California 95816
Telephone (916) 456-4400
FAX (916) 456-0253

MEMORANDUM

TO: City of Roseville File — December 2, 1994

FROM: Mark Fortner

SUBJECT: Folsom Dam Water Supply Pump Test on November 18, 1994

Attached are the results of a pump test performed on November 18, 1994. The test was performed to verify the calculations for the report to the City of Roseville, Increasing Peak Water Supply Flows From Folsom Dam. The capacity curve developed in the report included pump #7. Pump #7 has been moved to the penstock tap and therefore the test did not include pump 7.

It should be noted that all the gages used in the test were calibrated with the exception of the Roseville gage. The accuracy of the gages is 1%±. Gage "B" appears to be reading low compared to the other gages and standpipe.

The results show that pump #6 does not provide a large benefit at high heads. The test verifies that the capacity curve developed for the Roseville report is reasonable. Should pump 7 be moved back to the pumphouse, another pump test is recommended.

Mark Fortner

MF:bl
Attachments

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

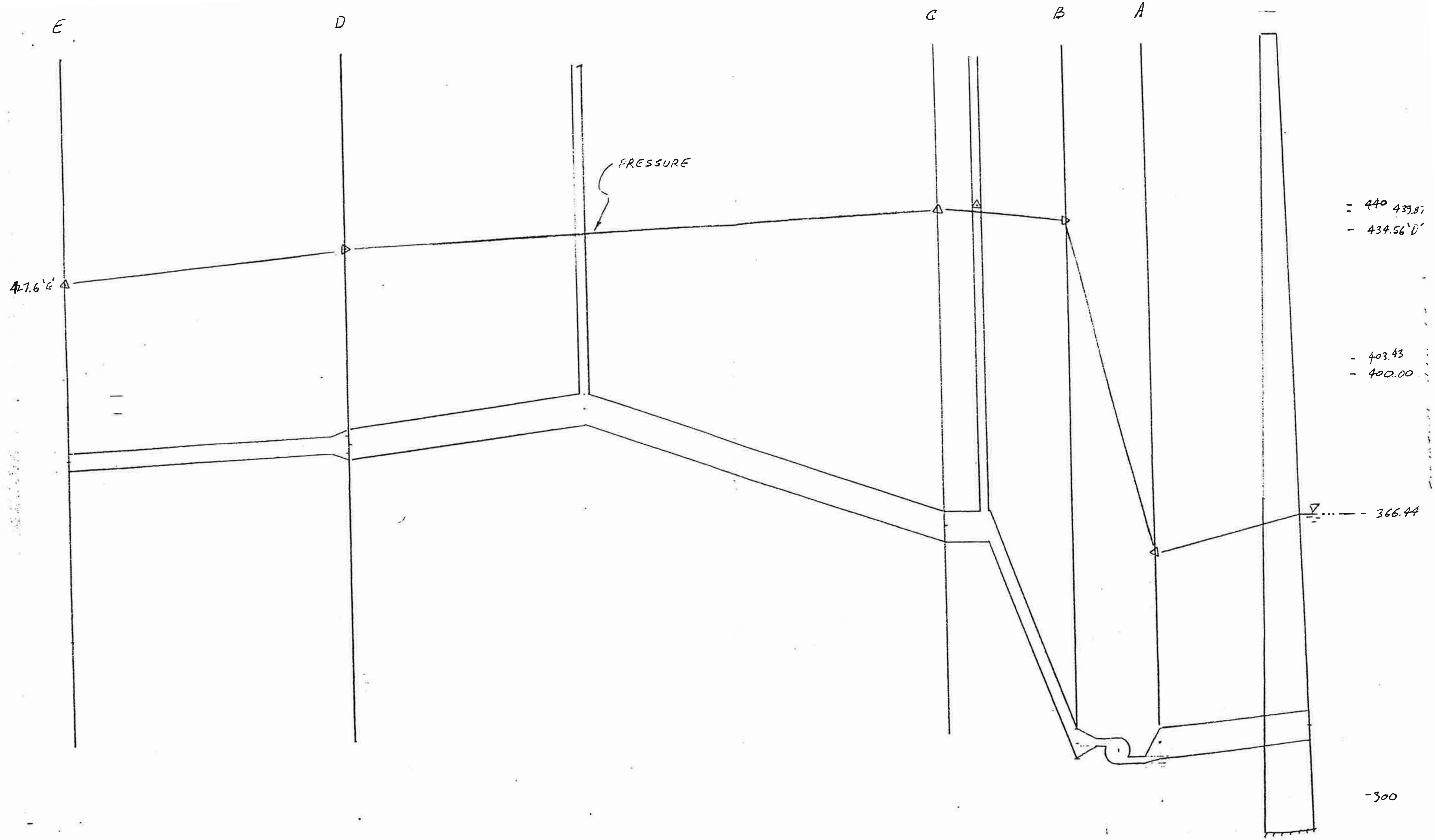
Date: 11/18/94
Lake Level: 366.44
Pumps Running: 2,3,4,5 & 6

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

Note: There appears to be a difference in flow reading between San Juan & USBR of around plus or minus 7 cfs. QT may be 190 cfs based on USBR reading of 180 cfs at North Fork ventur~~e~~i.

	Pressures(psi)						Flows(cfs)				
Time	PA	PB	PC	PD	PE (ft of H_2O)	PF	QN Natoma	QS	QR	QT	USBR Stand-pipe (ft ele
10:40	19	53.5	32	20	17.99	9	10	125	62.2	197.2	
10:45	19	53.5	32	20	17.86	9	10	125	63.3	197.3	8
10:50	19	53.5	32	20	17.95	9	10	125	63.3	197.3	440
10:55	19	53.5	32	20	17.90	9	10	125	63.3	197.3	
11:00	19	53.5	32	20	19.44	9	10	125	63.5	197.5	
-----ROSEVILLE CLOSED-----											
11:10	19	57.0		23	51.92		10	164*	--	174	445/
11:15	19	57.0	35.4	23	59.28		10	164*	--	174	448
*USBR reading of 158 cfs at North Fork Venturi											

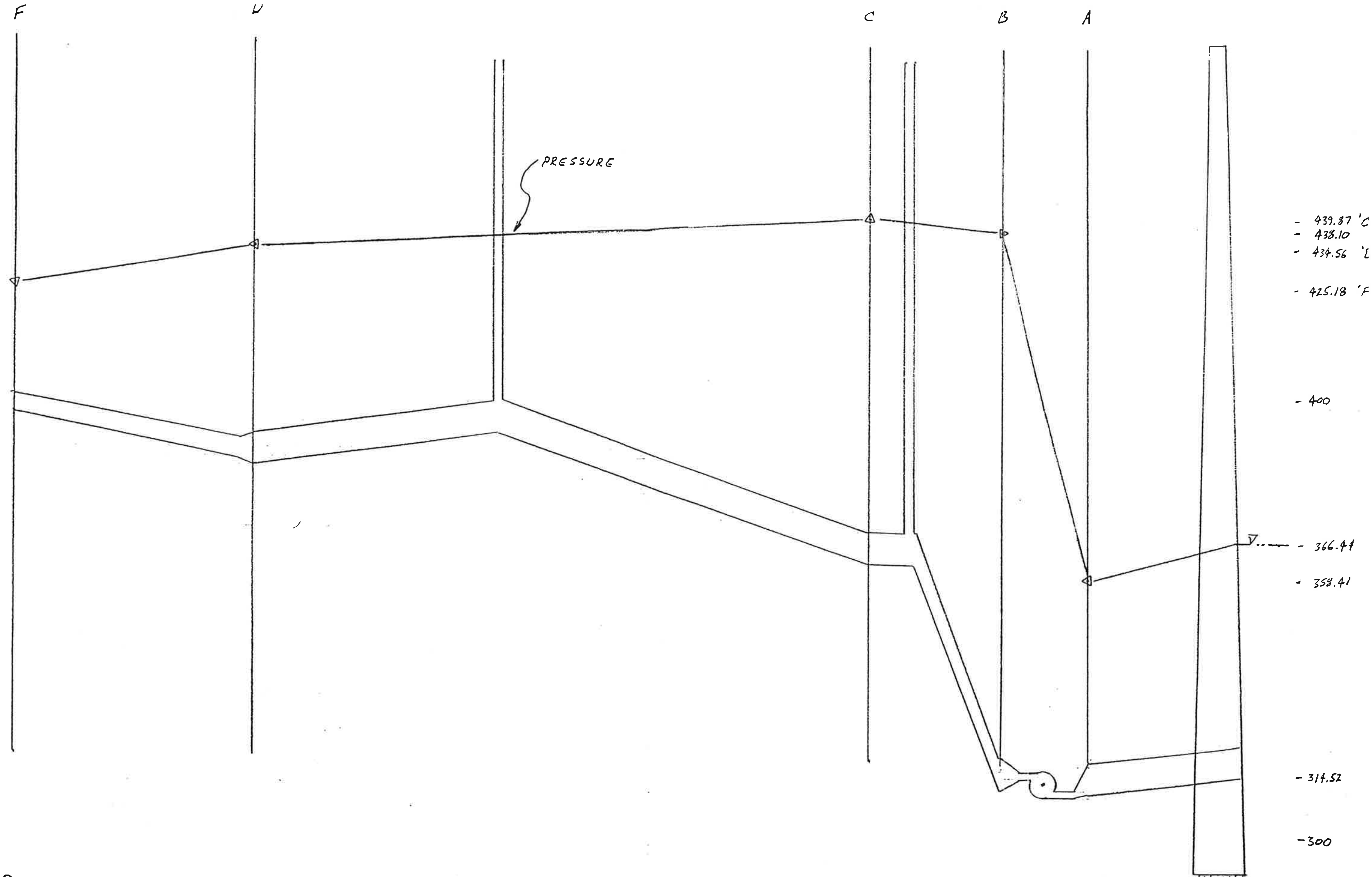
QN = Flow to ~~M~~Natomas (City of Folsom, Folsom Prison)
QS = Flow to San Juan SWD
QR = Flow to City of Roseville
QT = Total Flow



FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

V = 1" = 20'
H = No Scale

ROSEVILLE



SJSWD

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

V = 1" = 20'
H = No Scale

11/18/94
MF

Memo to City of Roseville, City of Folsom, San Juan Water District, U. S. Bureau of Reclamation — November 17, 1994
Re: Pump Test of Folsom Dam Water Supply system

City of Roseville

- Pressure at PE, upstream of throttling valve downstream of venturi. Measured in Roseville operation room.
- Flow to Roseville measured in Roseville operation room.
- Level of water in sedimentation basin.

San Juan Water District

- Pressure at PF on single feed line just upstream of treatment plant. This will be measured manually by SJWD personnel.
- Flow to SJWD, measured in SJWD operation room.
- Level of water in sedimentation basin.

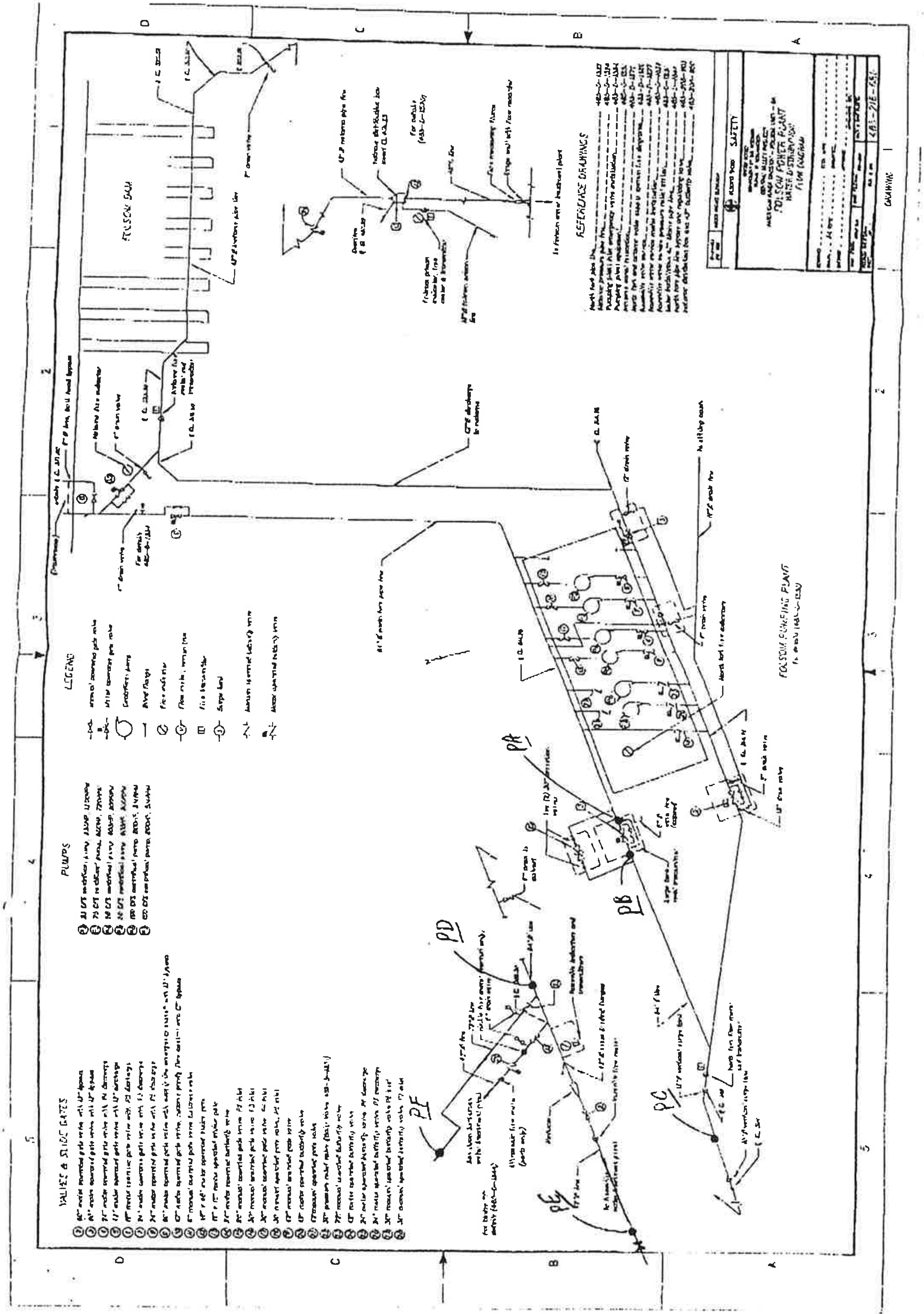
Gages will be in place by Thursday evening. Radios will be checked sometime Thursday. MBK and USBR personnel will meet at 9:30 a.m. on the day of the test to review any last minute items and call operators to synchronize watches.

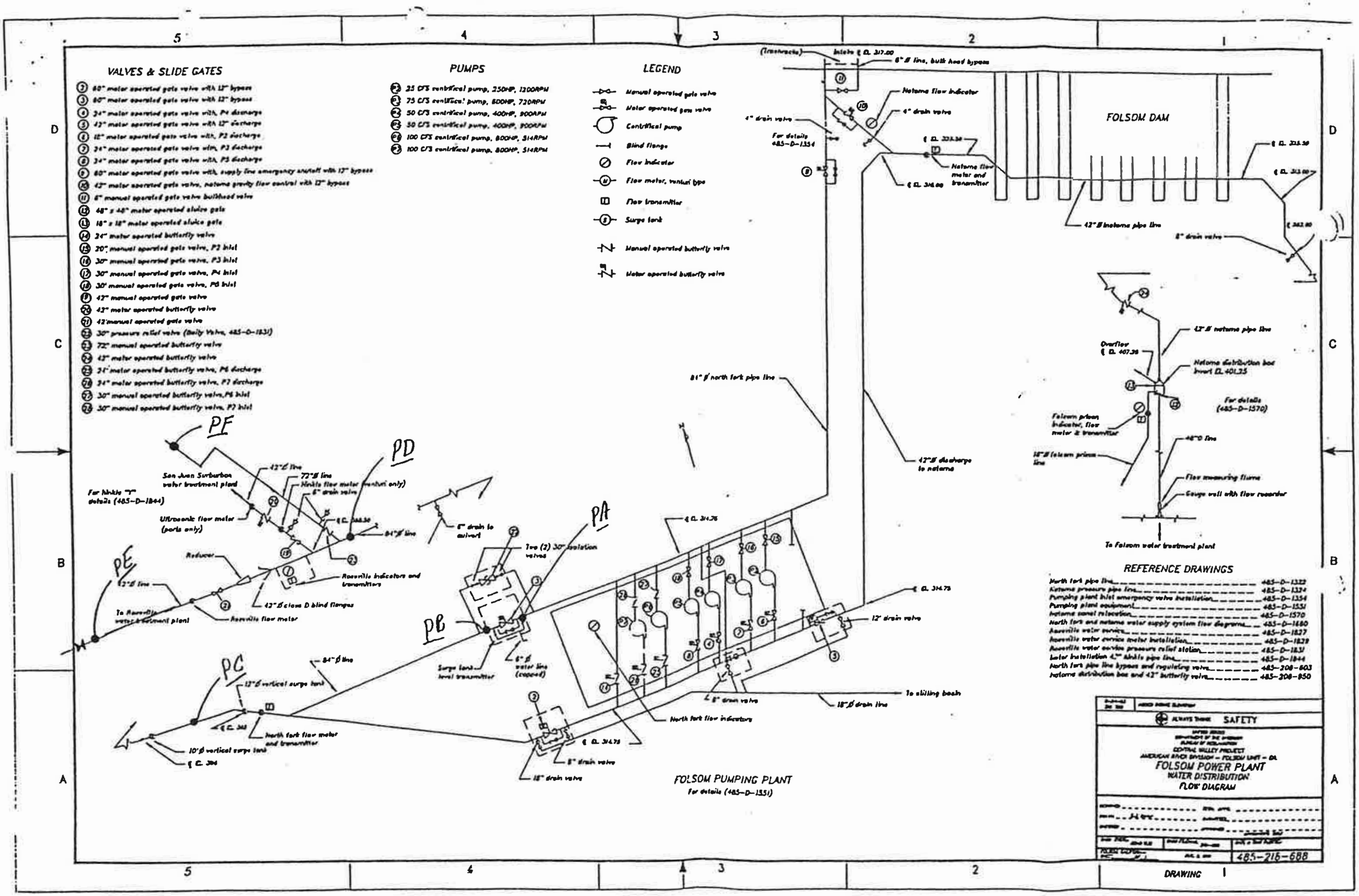
It is proposed that the USBR operation room will verify when a steady state condition has been reached by coordinating with the other operators by telephone. When the steady state condition has been reached, the USBR operator (probably Ed Dempsey) will call down to the pump plant and notify a manual gage reader, who will then relay to other gage readers, by radio, that at time X:XX we will begin reading. The readings will be made at every five minutes (i.e. 10:05, 10:10, 10:15, etc.) for the five readings. Ed will notify the pump plant when the test is complete or if problems arise. Attached is a data collection sheet, and a location map.

Please call if you have any questions or recommendations.

Mark Fortner

MF:bl
Attachments


FOLSOM DAM
REFERENCE DRAWINGS
SAFETY
FOLSOM POWER PLANT
WATER DISTRIBUTION
FLOW DIAGRAM
DRAWING
LEGEND
PUMPS
VALVES & SLIDE GATES
FOLSOM PUMPING PLANT
PA
PB
PC
PD
PE
PF


VALVES & SLIDE GATES
2 60" motor operated gate valve with 12" bypass
3 60" motor operated gate valve with 12" bypass
4 24" motor operated gate valve with, P4 discharge
5 42" motor operated gate valve with 12" discharge
6 12" motor operated gate valve with, P2 discharge
7 24" motor operated gate valve with, P3 discharge
8 24" motor operated gate valve with, P5 discharge
9 60" motor operated gate valve with, supply line emergency shutoff with 12" bypass
10 42" motor operated gate valve, natoma gravity flow control with 12" bypass
11 6" manual operated gate valve bulkhead valve
12 48" x 48" motor operated sluice gate
13 18" x 18" motor operated sluice gate
14 24" motor operated butterfly valve
15 20" manual operated gate valve, P2 inlet
16 30" manual operated gate valve, P3 inlet
17 30" manual operated gate valve, P4 inlet
18 30" manual operated gate valve, P5 inlet
19 42" manual operated gate valve
20 42" motor operated butterfly valve
21 42" manual operated gate valve
22 30" pressure relief valve (Daily Valve, 485-D-1831)
23 72" manual operated butterfly valve
24 42" motor operated butterfly valve
25 24" motor operated butterfly valve, P6 discharge
26 24" motor operated butterfly valve, P7 discharge
27 30" manual operated butterfly valve, P6 inlet
28 30" manual operated butterfly valve, P7 inlet
PUMPS
P2 25 CFS centrifical pump, 250HP, 1200RPM
P3 75 CFS centrifical pump, 600HP, 720RPM
P4 50 CFS centrifical pump, 400HP, 900RPM
P5 50 CFS centrifical pump, 400HP, 900RPM
P6 100 CFS centrifical pump, 800HP, 514RPM
P7 100 CFS centrifical pump, 800HP, 514RPM
LEGEND
Manual operated gate valve
Motor operated gate valve
Centrifical pump
Blind flange
Flow indicator
Flow meter, venturi type
Flow transmitter
Surge tank
Manual operated butterfly valve
Motor operated butterfly valve
FOLSOM DAM
PF
PD
PA
PE
PB
PC
San Juan Surburban water treatment plant
Ultrasonic flow meter (parts only)
Reducer
Roseville flow meter
To Roseville water treatment plant
Roseville indicators and transmitters
Surge tank level transmitter
12" drain valve
To stilling basin
North fork flow indicators
North fork flow meter and transmitter
10'Ø vertical surge tank
12"Ø vertical surge tank
84"Ø line
81" Ø north fork pipe line
42"Ø discharge to natoma
42" Ø natoma pipe line
Natoma flow indicator
Natoma flow meter and transmitter
Natoma distribution box
Overflow
Flow measuring flume
Gauge well with flow recorder
To Folsom water treatment plant
FOLSOM PUMPING PLANT
For details (485-D-1351)
REFERENCE DRAWINGS
North fork pipe line — 485-D-1322
Natoma pressure pipe line — 485-D-1324
Pumping plant inlet emergency valve installation — 485-D-1354
Pumping plant equipment — 485-D-1551
Natoma canal relocation — 485-D-1570
North fork and natoma water supply system flow diagrams — 485-D-1680
Roseville water service — 485-D-1827
Roseville water service meter installation — 485-D-1829
Roseville water service pressure relief station — 485-D-1831
Meter installation 42" Hinkle pipe line — 485-D-1844
North fork pipe line bypass and regulating valve — 485-208-603
Natoma distribution box and 42" butterfly valve — 485-208-850
ALWAYS THINK SAFETY
CENTRAL VALLEY PROJECT
FOLSOM POWER PLANT
WATER DISTRIBUTION
FLOW DIAGRAM
485-216-688
DRAWING

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11-18-94
Lake Level:
Pumps Running:

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

wille
ed valve

	Pressures(psi)						Flows(cfs)			
Time	PA psi	PB	PC	PD	PE	PF	QN	QS	QR	QT
~~10:[illegible]~~	~~20~~									
10:40	19									
10:45	19									
10:50	19									
10:55	19									
11:00	19									
11:05	19									
11:10	19									
11:15	19									

5

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11-18-94
Lake Level: ______
Pumps Running: ______
______

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

	Pressures(psi)						Flows(cfs)			
Time	PA	PB	PC	PD	PE	PF	QN	QS	QR	QT
1040		53.5								
1045		53.5								
1050		53.5								
1055		53.5								
1100		53.5								
1105		57.0								
1110		57.0								
1115		57.0								

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11-18-94
Lake Level:
Pumps Running:

ASHCROFT 4" LIQUID FILLED ~~GAGE~~ 0-100 PSI
CALIBRATED 12/17/91
S.N. PG003

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

Gary

		Pressures(psi)						Flows(cfs)			
	Time	PA	PB	PC	PD	PE	PF	QN	QS	QR	QT
	10:10:30			31.0							
	10:15:00			27.1							
	10:17:20			35.0							
	10:19:00			31.0							
	10:20:30			34.0							
	10:25:00			34.8							
	10:30:00			33.8							
	10:35:00			32.6							
	10:40:00										
BEGIN TEST	10:40:00			32.2							
MF 1st READ	41:20			32.0							
	45:00			32.0							
	46:20			32.0							
	50:00			32.0	Needle steady						
	51:20			32.0							
	55:00			32.0							
	56:20			32.0							
	11:00:00			32.0							
SVL OFF	01:20			32.2							
	05:00			34.6							
	06:20			35.2							
	10:00			35.5	Needle bouncing ±0.2 PSI						
	11:20			35.4							
	15:00			35.8-							
END TEST	16:20			35.8							
	20:00			27.0							

939-7263
Plant

791-1715 SJS

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11/18/98
Lake Level: ______
Pumps Running: ______

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

Bill Paul Gary Me Roseville SJS

	Time	Pressures(psi) PA	PB	PC	PD	PE	PF	Flows(cfs) QN	QS	QR	QT
1	10:40				20						
2	10:45				20						
3	10:50				20						
4	10:55				20						
5	11:00				20						
	11:02				21						
	11:04:30				22						
6	11:05				22						
	11:07				23						
7	11:10				23						
8	11:15				23						

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

San Juan Suburban

Date: 11/18/94
Lake Level: ______________
Pumps Running: ______________
____

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

	Pressures(psi)						Flows(cfs)			
Time	PA	PB	PC	PD	PE	PF	QN	QS	QR	QT
10:40						9				
10:45						9				
10:50						9				
10:55						9				
11:00						9				

366.44

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11-18-94
Lake Level: 366.44
Pumps Running: 2, 3, 4, 5, + 6

Q Natoma 10 cfs

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

Time	Pressures(psi) PA	PB	PC	PD	PE	PF	Flows(cfs) QN (North Fork)	QS	QR	QT	SP
1040							180	127	65		440
1045							180				440
1050							180				440
1055							180				440
1100							180				440
1110							158	164	0		448

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date: 11/18/94
Lake Level: ____________
Pumps Running: ____________
____

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

	Pressures(psi)						Flows(cfs)	San Juan		
Time	PA	PB	PC	PD	PE	PF	QN	QS	QR	QT
10:40 am								125		
10:45 am								125		
10:50 am								125		
10:55 am								125		
11:00 am								125		
11:10 AM	ROSEVILLE OFF LINE/SAN JUAN @ 100%							164		

CITY OF ROSEVILLE
WATER TREATMENT PLANT
9342 BARTON RD.
ROSEVILLE, CA 95746

TELEPHONE (916) 791-4586 • FAX (916) 791-4671

FAX TRANSMITTAL

DATE 11-21-94

TO COMPANY MURRY, BURNS & KIENLIN FAX NO. 456-0253

ATTENTION Mark Fortner

SUBJECT attached chart

FROM: NAME Jim Jessee

TOTAL NO. OF PAGES INCLUDING THIS PAGE

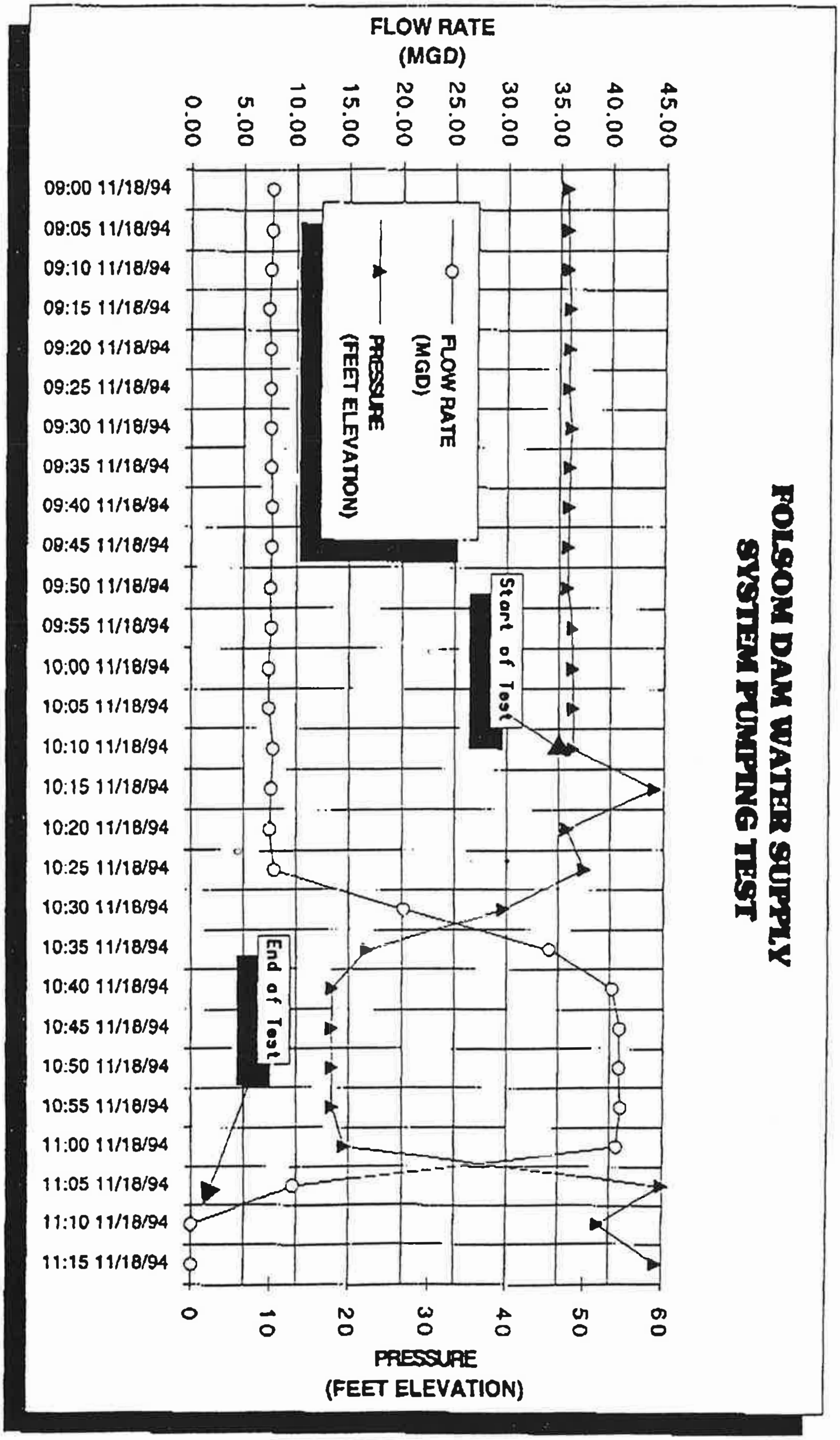
2

MESSAGE:

this chart replaces the one sent to you on Friday. The chart on Friday was labled wrong. throw it away.

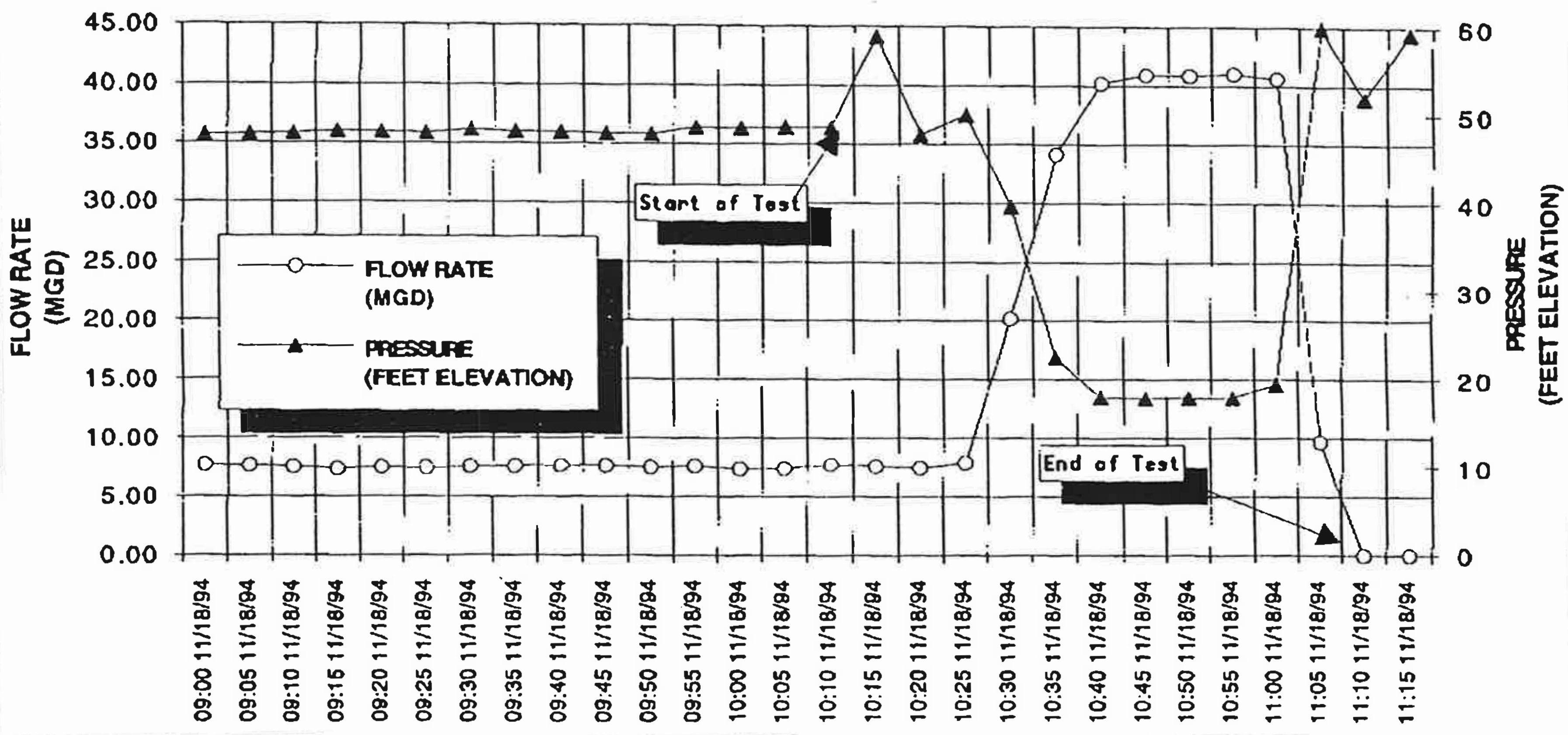
Jim

CITY OF ROSEVILLE WATER TREATMENT PLANT



CITY OF ROSEVILLE WATER TREATMENT PLANT

FOLSOM DAM WATER SUPPLY SYSTEM PUMPING TEST



FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

DATA FROM CITY OF ROSEVILLE
WATER TREATMENT PLANT

11/18/94

TIME AND DATE	FLOW RATE (MGD)	PRESSURE (Feet Elevation)
09:00 11/18/94	7.67	47.56
09:05 11/18/94	7.65	47.64
09:10 11/18/94	7.53	47.73
09:15 11/18/94	7.34	47.98
09:20 11/18/94	7.51	47.89
09:25 11/18/94	7.51	47.81
09:30 11/18/94	7.55	48.18
09:35 11/18/94	7.61	47.98
09:40 11/18/94	7.69	47.93
09:45 11/18/94	7.65	47.77
09:50 11/18/94	7.51	47.69
09:55 11/18/94	7.59	48.52
10:00 11/18/94	7.34	48.43
10:05 11/18/94	7.40	48.56
10:10 11/18/94	7.76	48.56
10:15 11/18/94	7.61	58.95
10:20 11/18/94	7.47	47.73
10:25 11/18/94	7.88	49.97
10:30 11/18/94	20.17	39.63
10:35 11/18/94	34.11	22.47
10:40 11/18/94	40.23	17.99 ✓
10:45 11/18/94	40.93	17.86 ✓
10:50 11/18/94	40.89	17.95 ✓
10:55 11/18/94	41.02	17.9 ✓
11:00 11/18/94	40.63	19.44
11:05 11/18/94	9.70	59.98
11:10 11/18/94	0.00	51.92
11:15 11/18/94	0.00	59.28

$\bar{x} = 17.93$

MURRAY, BURNS AND KIENLEN
A Corporation
1616 29th Street. Suite 300
Sacramento. California 95816
Telephone (916) 456-4400
FAX (916) 456-0253

MEMORANDUM

TO: City of Roseville, City of Folsom, San Juan Water District, U. S Bureau of Reclamation — November 17, 1994

FROM: Mark Fortner

SUBJECT: Pump Test of Folsom Dam Water Supply System

To clearly define the losses of the Folsom water supply system, a pump test is scheduled for Friday, November 18, 1994, between 10:00 and 10:30 a.m. This test will be with the system operating wide open.

The following data will be collected by the respective entity:

U. S. Bureau of Reclamation

- Pressure at PA upstream of pumping plant (upstream of 60" gate valve), on top of vault. This will be manually read by USBR personnel. See attached drawing.
- Pressure at PB downstream of pumping plant (downstream of 60" gate valve) in vault. This will be manually read by USBR personnel.
- Flow at North Fork flowmeter, measured in USBR operation room.
- Flow to Folsom, measured in USBR operation room.
- Folsom Lake level, measured in USBR operation room.
- Note which pumps are operating.

Murray, Burns and Kienlen

- Pressure at PC, downstream of venturi and surge tank. This will be manually read by MBK personnel.
- Pressure at PD, upstream of Hinkle Wye. This will be manually read by MBK personnel.

FOLSOM DAM WATER SUPPLY SYSTEM
PUMPING TEST

Date:____________________
Lake Level:________________
Pumps Running:____________

PA:El. 322.05
PB:El. 314.52
PC:EL. 365.95
PD:El. 388.36
PE:El. 385.5
PF:El. 404.39

	Pressures(psi)						Flows(cfs)			
Time	PA	PB	PC	PD	PE	PF	QN	QS	QR	QT

DRAFT

APPENDIX A
ATTACHMENT 2

QUESTIONS/ANSWERS REGARDING THE FOLSOM DAM PUMPING TEST DATA

ESA Consultants

APPENDIX A
ATTACHMENT 2

QUESTIONS / ANSWERS REGARDING THE FOLSOM DAM PUMPING TEST DATA

1. Regarding Roseville pressure readings, are they in psi or feet of water?
   Ans: Feet of water.

2. Was Roseville throttling during the first test?
   Ans: No, they were wide open.

3. What was the water surface elevation in Roseville's rapid mix chamber?
   Ans: Assume 400.7 based on plant hydraulic grade line for 41 mgd (63 cfs).

4. Regarding the San Juan pressure readings, where were they taken?
   Ans: In the chemical feed vault, above the pipeline.

5. Was San Juan throttling during the tests?
   Ans: No, they were wide open for both parts of the test.

6. What was the water surface elevation in the San Juan rapid mix chamber?
   Ans: For the first test, assume it was El. 424.0; for the second test assume it was El. 424.35. These numbers are inferred from operator observations of water surface versus Q and assumption of full treatment (including coagulation and sedimentation).

7. Where is Gage C relative to the first stand pipe?
   Ans: Approximately 50 feet downstream (toward Hinkle"Y").

APPENDIX B
COMMENTS RECEIVED ON
THE DRAFT OF THIS REPORT

- **U.S. Bureau of Reclamation**
- **Robert W. Miles for City of Folsom**

ESA Consultants

United States Department of the Interior

BUREAU OF RECLAMATION
North-Central California Area Office
7794 Folsom Dam Road
Folsom, California 95630

IN REPLY REFER TO:

CC-600
PRJ-22

DEC 0.7 1995

RECEIVED
DEC - 8 1995

Mr. Joseph D. Countryman, P.E.
Murray, Burns, and Kienlen
1616 29th Street, Suite 300
Sacramento, California 95816

Subject: Review of Draft Report - Folsom Pumping Plant and Pipeline Flow Enhancement, Central Valley Project

Dear Mr. Countryman: Joe

We have reviewed the draft report "Increasing Water Supply Pumping Capacity at Folsom Dam," dated October 20, 1995, and have the following comments:

1. The head-capacity curves with pump no.6 use the presently installed 450 RPM motor configuration. The 514 RPM motor can be installed to give added capacity at the higher head situations.

2. We agree with your assessment that the variable speed pumps will reduce the throttling and energy waste while providing the future pumping needs.

3. The use of PWM technology for the variable frequency drive (VFD) would be necessary because it would not impact the utility grid system and operation of solid state equipment; therefore, the CSI technology would not be acceptable.

4. The study recommends installing two new pumps which will raise the delivery capacity to 400 cfs at reservoir El. 392 and provide the 150 cfs peak flow necessary for Roseville. Since this is well above the minimum pool reservoir level of El. 327, we concur that the modeling study can be postponed. The intake water surface should be monitored if there are reservoir elevations that approach the minimum pool. If additional large pumps are installed then the modeling study will be required.

5. We concur that we should perform a full review of the emergency closure capability of the 60 inch and 42 inch intake gate valves located in Folsom Dam.

If you have any questions or concerns, contact Bill Joye of my staff at 988-1707 (TDD 989-7285).

Sincerely,

Tom

Thomas J. Aiken
Area Manager

ROBERT W. MILES
CONSULTING CIVIL ENGINEER
RCE 20595

November 9, 1995

Mr. Derrick H. Whitehead
Manager, Environmental Utilities
City of Roseville
1800 Booth Road
Roseville, CA 95747

Subject: Folsom Dam Conveyance Facilities File: 3.0110
City of Folsom Comments on Draft Report

Dear Mr. Whitehead:

This letter conveys the City of Folsom comments on the draft report entitled "Increasing Water Supply Pumping Capacity at Folsom Dam," dated September, 1995. This report has been distributed for review and comment by the project participants and Reclamation. We appreciate the efforts you, your staff, and your consultants have made to facilitate review of this work.

In general, we've found that the draft report has been well prepared, and we agree with the key finding that the pumping plant should be expanded by installation of two pumps with variable speed drivers. Beyond the selection of the pumps there are several issues that deserve some attention by the project team. We have itemized these points in the following paragraphs.

PUMPING CAPACITY

Table 4-1 of the draft report presents a summary of system flow rate and a distribution of the flows to the respective agencies. To review Table 4-1 we have assembled the information in the enclosed Table A.

Table A contains a summary of the various water contracts, amounts, and flows that the pumping plant may be expected to respond to now and in the future. Some of the information in the table has been estimated, such as the entries for "future" Roseville and Folsom water amounts and flows. The column entitled "Source/Priority" contains the three types of water to be conveyed; water rights water, Central Valley Project (CVP) water, and non-project water. These types of water are listed in our estimated order of priority, with water rights water being the highest priority. The last column contains estimates for the maximum

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flowrates necessary to convey the annual amounts. Table A shows that conveyance of the water rights water will require about 175 cfs of pumping capacity. Similarly, CVP water will require about 138 cfs, and non-project water will require an additional 173 cfs of pumping capacity.

Table B shows the pumping capacities required when the flowrates from Table A are tabulated and summed in order of priority. As the table shows, the water rights require 175 cfs of capacity. After the first contract for CVP water is added for San Juan WD, the pumping capacity becomes 206 cfs. Similarly, note that the required pumping capacity to implement Roseville's 1989 conveyance contract for non-project water is 438 cfs. For this reason, we believe that the pumping plant should be expanded to a capacity of 438 cfs, not 400 cfs as proposed in the draft report.

PUMPING CRITERIA

In the Summary, on page 1-1, it is proposed that the expanded pumping plant be able to pump 400 cfs at a reservoir elevation of 392 feet. We have reviewed this criterion and have an alternative to propose based upon the above information. Table B can be used to develop the following criteria.

1. The pumping plant should be able to pump the water rights water, 175 cfs, at a minimum pool elevation of 327.

2. The pumping plant should be able to pump the water rights plus CVP water, even during a critical dry year. If we assume that the CVP water is cut back on a flow basis to 75 percent of the contract amounts during a critical dry year, the total of water rights and CVP water would be 279 cfs. A rough estimate for the reservoir elevation during a critical dry year would be 340, which would occur during a repeat of August 1977, according to Table 5-5.

3. The pumping plant should be able to pump a combination of water rights, CVP, and non-project water of 438 cfs during a non-critical dry year at a reservoir pool elevation of about 395. The elevation of 395 would represent the reservoir level in August of a dry year, according to Table 5-5.

4. In the future, the pumping plant should be able to pump all three categories of water, 486 cfs, during a non-critical dry year, probably at a reservoir elevation of about 395, which would represent the reservoir level in August of a dry year.

A copy of Figure 1-1 from the draft report has been marked to show the above criteria. The proposed pumps are slightly undersized to meet the second and third criteria. However, it may not be necessary or desirable to provide complete pumping capacity to meet the above criteria demands immediately because it will take a considerable period of time before they actually develop. In general, pumping plants should be sized for requirements that will occur during a reasonable planning period. Pumping plants that have significant overcapacity tend to present operating problems or operate with less flexibility or efficiency than desired. It may be appropriate to cut back on the capacity of the two proposed pumps slightly and then install a third pump as the pumping requirements development over time.

The fourth criterion should be met with an expansion at some point in the future, as necessary.

STANDBY PUMPING CAPACITY

From Figure 5-12, if either Pump 7 or 8 is out of service the pumping plant cannot meet a criterion of 400 cfs at reservoir elevation 392. A standby pumping unit would be necessary to firm up the capacity.

SPACE FOR FUTURE ELECTRICAL SWITCHGEAR AND CONTROLS

Has space for future electrical equipment been designated? This should be done to avoid limitations for future expansions.

CONSTRUCTION PLAN

The sequence of construction activities should be evaluated to confirm that the pumping plant can be modified with reasonable lengths of downtime and disruption to the plant operations.

SCHEDULE

A schedule should be established for the project. It may be necessary to pre-order critical equipment.

COST ESTIMATE

Modification-type projects should have a contingency greater than 15 percent at this stage of project development. A more suitable value would be 25 percent. As the design develops in the next phase, the contingency can be reduced appropriately.

REVIEW AND DISCUSSION

Gordon Tornberg and I will be available to review these issues with you and the project team as required to promote a complete understanding of all the factors in this project.

Sincerely,

Robert W. Miles

Robert W. Miles

cc: Mr. Gordon F. Tornberg
Mr. Joseph D. Countryman

TABLE A
FOLSOM DAM CONVEYANCE FACILITIES
Water Contracts, Amounts, and Flows

SOURCE/ PRIORITY	AGENCY	YEAR OF CONTRACT	AMOUNT, acre-feet/year	FLOW RATE, cfs	CALCULATED FLOW RATE, cfs
Water Rights	Folsom	1971	22,000	--	61
	Folsom	1971	5,000	--	14
	San Juan WD	1954	33,000	75	91
	Prison	1958	4,000	9	9
Subtotals			59,000		175
CVP	San Juan WD	1962	11,200	--	31
	Roseville	1967	32,000	65/150	88
	Folsom (Fazio)	--	7,000	--	19
Subtotals			50,200		138
Non-Project	San Juan WD	1972	25,000	--	69
	Roseville	1989	20,000	--	56
	Roseville (Future)	--	10,000	--	28
	Folsom (Future)	--	7,200	--	20
Subtotals			62,200		173

TABLE B
FOLSOM DAM CONVEYANCE FACILITIES
Order of Priority for Pumping Capacity

SOURCE/ PRIORITY	PUMPING CAPACITY, cfs	San Juan WD, cfs	Roseville cfs	Folsom cfs	Prison cfs
Water Rights	175	91		75	9
CVP	206	31			
	294		88		
	313			19	
Non-Project	382	69			
	438		56		
	458			20	
	486		28		
Totals	486	191	172	114	9

KRFZ

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