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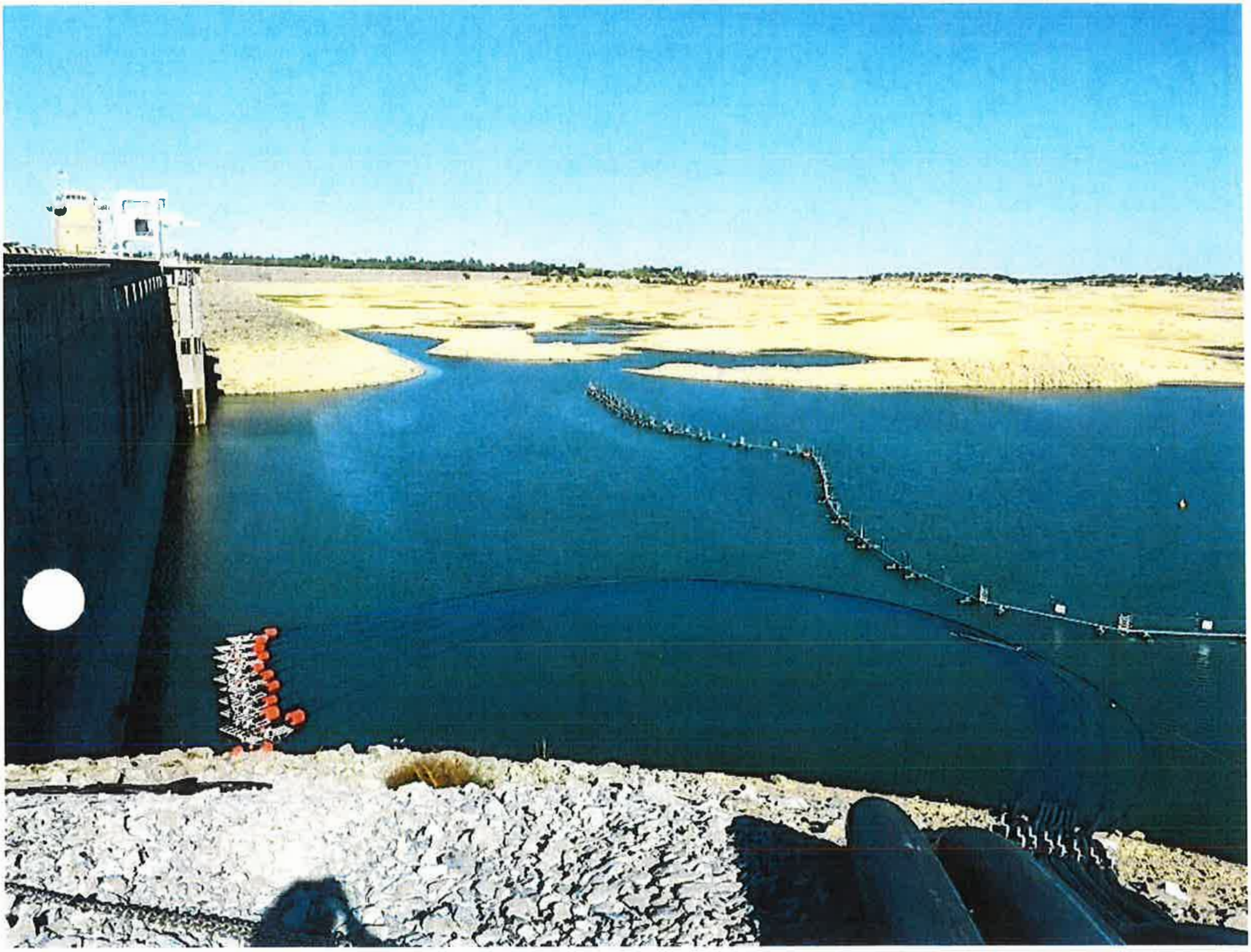
Folsom Drought Emergency Action Plan



View from the Left Wing showing ten 800' lengths of 12" HDPE pipe leading to 10 submersible pump systems upstream of Folsom Dam. The 30 CFS Temporary Drought Pumping System was installed, October, 2015.

EXHIBIT ROSEVILLE-16

Folsom Drought Emergency Action Plan (EAP)

Folsom Drought Emergency Action Plan (EAP)

BACKGROUND:

Northern California has incurred less than average precipitation the past four years which has resulted in drought conditions in many areas including very low reservoir water surface elevations in Folsom Dam. Folsom Dam normally provides raw water to the City of Folsom, Folsom Prison, San Juan Water District and the City of Roseville via Folsom's Pumping Plant and a water conveyance pipeline system when the reservoir elevation is below 425'. However, normal/direct use of Folsom's Pumping Plant will not be possible when the elevation reaches about 325'. At 325', the existing pumping plant will incur damaging vortices as exposure of the raw water intake to atmospheric conditions occurs at elevation 317'.

In providing some flexibility under drought conditions, a low lake level/emergency pump was installed in 1993 at a lower elevation than the existing pumping plant. The emergency pump (E-Pump) receives raw water via Folsom's power penstock #1 and can be operated at an elevation as low as 309'. The E-Pump is rated at 75 cfs and is designed to supply water to the existing pumping plant intake header, and operate in series with a pump or pumps within the existing pumping plant. In 2015, the Technical Service Center analyzed this arrangement considering the entire piping network, and determined that use of the E-Pump in series with the pumping plant can provide a <u>total</u> distribution of at least 70 cfs (as low as reservoir elevation 309') to the Natoma pipe line, the North Fork pipe line or both. While this series arrangement provides limited flow to the water purveyors, it may be utilized to provide flow to just San Juan Water District and the City of Roseville. A temporary 30 cfs submersible pump system was installed on the left wing of Folsom Dam, and commissioned in October, 2015 to supply water to the City of Folsom and Prison as conditions warrant.

DISCUSSION/COORDINATION WITH RECLAMATION PURVEYORS/CONTRACTORS:

The American River water purveyors are aware of Reclamation's reduced pumping capacity during severe drought conditions. The attached Table 1 shows the total reduced demands using the 2012 allocation year as the baseline, and Table 2 shows the total pumping capacities of a temporary 30 cfs plant, and utilization of the E-Pump in series with Folsom's Pumping Plant at different reservoir elevations. Typically, the purveyors' reduced demands during the summer exceed the temporary pumping plant and E-pump capacities. However, as long as the reservoir elevation remains above 340 ft during the summer (the existing main pumping plant can be utilized), and assuming similar demands in the future, the majority of the purveyors' water demands will be satisfied throughout the year.

EMERGENCY ACTIONS/STRATEGIES:

Considering the entire Central Valley Project, State Water Project, and operational strategies to maintain public health and safety, Folsom Dam can currently be operated in such a manner that the reservoir elevations should not reach 325' (which would result in non-use of Folsom's Pumping Plant).

However, should hydrologic conditions continue to worsen and/or dry conditions extend in the future, Reclamation needs to have a plan/strategy to deal with very dry conditions never encountered before. Therefore, the following actions/strategies will be implemented based on water demands and forecasts that predict Folsom reservoir elevation will reach 340' or below:

1. <u>Modes of Operation:</u> Implementation of the following operation modes are anticipated when the Folsom Pumping Plant cannot normally be used (at/below 325' reservoir elevation):
    a. E-Pump in series with Folsom Pumping Plant: This arrangement will be utilized to provide at least 70 cfs total flow split between the San Juan Water District and the City of Roseville. At

least 70 cfs will be provided continuously until vortices result at 309' due to exposure of the raw water intake to atmospheric conditions. The E-Pump and this series arrangement cannot be utilized below 309'

    i. Should conditions warrant, a 30 – 40 cfs submerged pump system could be procured/rented and installed on the right wing dam similar to the October, 2015 system installed on the left wing of Folsom Dam. Submersible pumps can be specified in the future to draw water as low as elevation 280'.

b. Procure/rent of 30 cfs system on left wing dam: This system was installed and operation in October, 2015 and is planned for utilization for the City of Folsom and Prison. The pumps specified for this system can pump water as low as elevation 309'. However, future systems could specify pumps to draw water as low as elevation

2. Contingency Operations and Repairs:

a. E-Pump Monitoring and Failure: The E-Pump's motor has protective devices to shutoff the motor should the high limit design temperature be reached. The pump and motor are operated on a regular basis (PMs) to ensure reliability of the system should it be needed in the future, and the system is in excellent condition as it has not seen much use over the years. An exact duplicate of the pump and motor (Pump #6) is located in Folsom's Pumping Plant. While Pump #6 has incurred use over the years, it is fully operational and in good condition. Therefore, parts from pump #6 could be utilized to effect repairs on the E-Pump if needed.

b. Procurement/Implementation Strategy: Reclamation has experience at all levels implementing a 30 cfs rental pumping system as indicated above in the minimal time possible. Reclamation contracting has the ability to execute contracts with contractors that have the specific expertise we need under emergency and/or compelling situations such as public health and safety with minimal paperwork required and delay. Forecast predictions, and the time to draw down Folsom reservoir should allow enough time to plan and execute any necessary actions to provide contingency flows to the water purveyors under extreme conditions. Future procurement actions in providing 30 -40 cfs pumping systems on the right and/or left wings of Folsom Dam will be tasked to perform any needed repairs on the E-Pump. This includes removing Pump #6 from its current location at Folsom Pumping Plant to the E-Pump location.

    i. **Key CCAO Commitment:** The CCAO will initiate implementation of this EAP, and critical to Reclamation's success is the hiring of a competent contractor with the experience and resources necessary to install a pumping system/systems as described above within a prescribed time frame. As such, contracting will be one of the first notifications after this EAP is initiated.

    The CCAO has and will continually evaluate forecasts and predictive data, and will initiate this EAP accordingly. Close monitoring of predictive data coupled with the time for the reservoir to draw down will facilitate full implementation of this EAP and the associated key actions that need to be performed to ensure the safety of the public.

    ii. **Key Contracting Commitment:** As indicated above, the CCAO will initiate this EAP and notify contracting regarding the basic scope anticipated (e.g. 40 cfs rental system on the right wing of Folsom Dam). The scope shall include standby services to repair the E-Pump including relocation of pump # 6 from Folsom Pumping Plant to the E-

Table of Contents

Folsom Drought Emergency Action Plan (EAP)

Tab A	Table 1 – American River Purveyor's Demands and Table 2 – Procure/Rent 30 CFS Pumping System and Utilize E-Pump (Stay above El=309')
Tab B	Drought EAP Contact List
Tab C	Drawing 485-218-688 - Folsom Pumping Plant Water Distribution Flow Diagram
Tab D	Technical Service Center Analysis Reports (4) – Utilize E-Pump in Series with Folsom Pumping Plant (Includes Pump Curve Data)
Tab E	Folsom Pumping Plant System Capacity Evaluation, WRE - July, 2011 (Includes Pump Curve Data)
Tab F	E-Pump and Pump #6 Pump and Motor Data Plate Photos
Tab G	Periodic Maintenance (PM) Inspections and Job Plans
Tab H	Designer's Operating Criteria and Standing Operating Procedure, Folsom Dam Emergency Pumping Plant (Original Document - Obsolete)
Tab I	CSG Proposal and Contract – 30 CFS System, Folsom Dam Left Wing
Tab J	Drought Related Work Orders

Pump location as necessary. While an urgent and compelling action could be requested, forecast data and reservoir draw down time should facilitate a more normalized procurement time horizon. However, once this EAP is initiated and contracting notified, the CCAO's expectation is that a CS/CO will be assigned immediately, and the individual's workload adjusted as required to accommodate a no notice priority procurement. The CCAO PM will be accountable to manage all aspects of the project, and will require the cooperation of many individuals/offices. The CCAO PM shall provide a scope of work, drawings, suggested contractors, and other timely data necessary to contracting in facilitating a request for proposal from one or more contractors. However, the assigned CS/CO shall proactively assist the CCAO PM in performing market research and other actions that might be performed by the PM in a routine procurement.

3. <u>Reclamation and Water Purveyor EAP Implementation Coordination and Communication:</u>
Normally, the CCAO Area Manager and water purveyors meet monthly to discuss various water related issues. However, this EAP will be intiated in the event CVO forecasts indicate the likely probability that the lake will draw down below 340'. As such, after EAP initiation, Reclamation's Operation Chief will initiate a meeting with the purveyor operations and management personnel per the EAP contact list, and conduct meetings on an as needed basis thereafter. The purpose of these meetings is to keep all concerned up to date, and discuss operational strategies under low lake level/emergency conditions.

Attachments:

A. Table 1 – American River Purveyor's Demands and Table 2 – Procure/Rent 30 CFS Pumping System and Utilize E-Pump (Stay above El=309')
B. Drought EAP Contact List
C. Drawing 485-218-688 - Folsom Pumping Plant Water Distribution Flow Diagram
D. Technical Service Center Analysis Reports (4) – Utilize E-Pump in Series with Folsom Pumping Plant (Includes Pump Curve Data)
E. Folsom Pumping Plant System Capacity Evaluation, WRE - July, 2011 (Includes Pump Curve Data)
F. E-Pump and Pump #6 Pump and Motor Data Plate Photos
G. Periodic Maintenance (PM) Inspections and Job Plans
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I. CSG Proposal and Contract – 30 CFS System, Folsom Dam Left Wing
J. Drought Related Work Orders

Table 1 - American River Purveyor's Demands*

	City of Folsom		City of Roseville		San Juan Water District		TOTAL	
Month	**MGD**	**CFS**	**MGD**	**CFS**	**MGD**	**CFS**	**MGD**	**CFS**
May 2012 (Reduced 20%)	23.9	37.0	12.1	18.7	33.0	51.1	69.0	**106.8**
June 2012 (Reduced 20%)	30.2	46.7	18.9	29.2	43.7	67.6	92.8	**143.6**
July 2012 (Reduced 20%)	32.4	50.1	21.4	33.1	49.8	77.1	103.6	**160.3**
August 2012 (Reduced 20%)	33.2	51.4	22.1	34.2	48.0	74.2	103.3	**159.8**
September 2012 (Reduced 20%)	28.8	44.6	15.1	23.4	46.6	72.1	90.5	**140.0**
October 2012 (Reduced 10%)	22.1	34.2	11.1	17.2	36.5	56.5	69.7	**107.9**
November 2012 (Reduced 10%)	13.6	21.0	11.1	17.2	24.2	37.5	37.9	**75.5**
December 2012	12	18.6	11.1	17.2	19.1	29.6	31.1	**65.1**
January 2013	11.3	17.5	11.1	17.2	19.1	29.6	30.4	**64.0**
February 2013	13.8	21.4	11.1	17.2	18	27.9	33.6	**66.2**

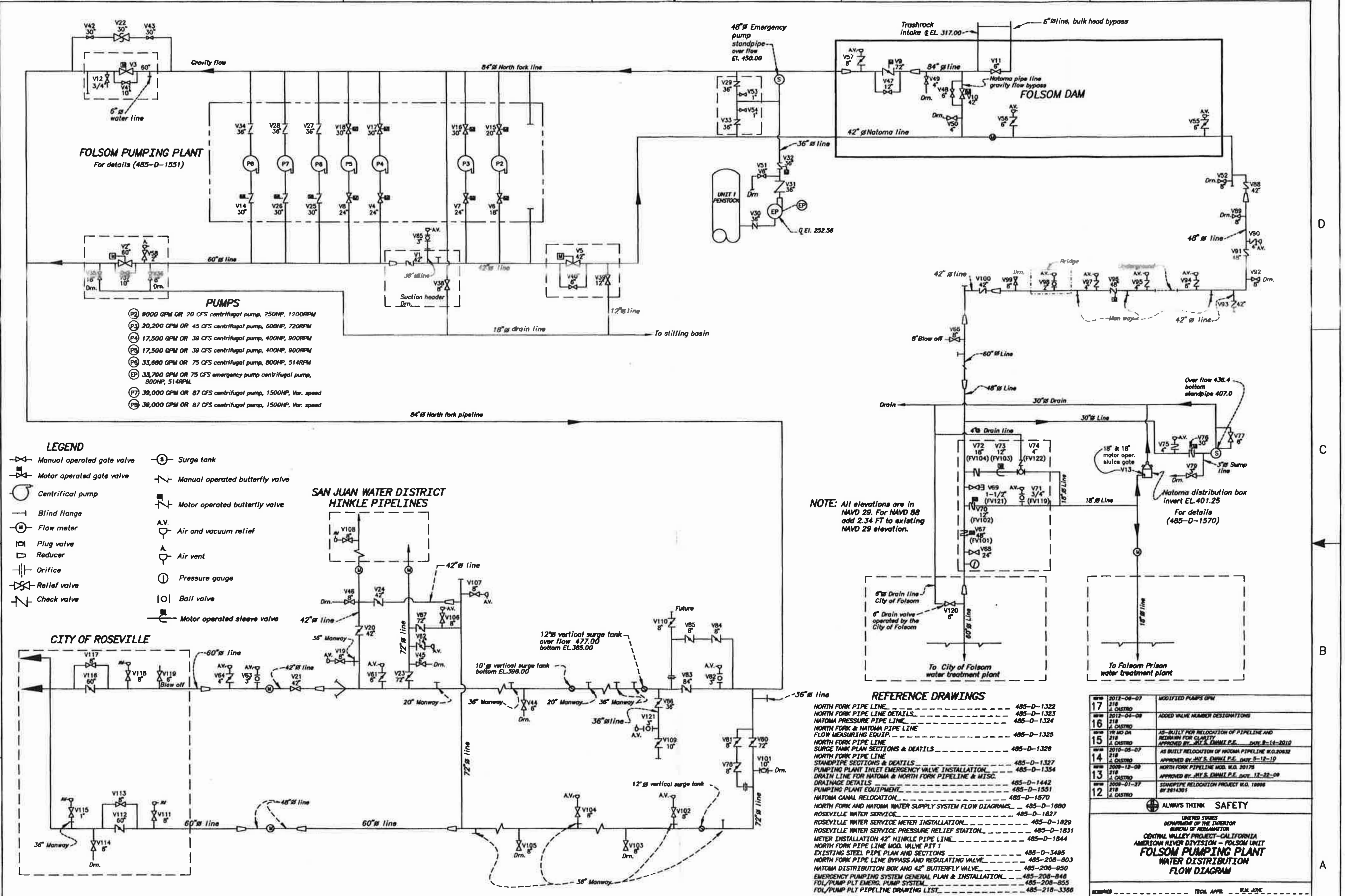
*These demand values were provided to Reclamation by the American River Purveyors to establish design criteria for the contingency operations and actions to procure pumps under drought conditions.

Table 2 – Procure/Rent 30 CFS Pumping System and Utilize E-Pump (Stay above El=309')

Storage (TAF)	**Elevation (FT)**	**Temporary/Rental System – Natoma Line (CFS)**	**E-Pump in series with Main Pumping Plant – North Fork Line (CFS)**	**Total Pumping (CFS)**
112	340	N/A	N/A	
89	330	N/A	NA	
70	320	30	70	100
62	315	30	70	100
55	310	30	70	100
	<309	30	0	30

Central California Area Office
EAP COMMUNICATIONS

CODE	AGENCY	WORK PHONE	CELL OR 24 HR PHONE
	Area Office Emergency Official	**(916) 402-4678**	
	Area Office Emergency Official Alt Numbers	(916) 989-7143	(916) 955-0445
CC-100	Area Manager	(916) 989-7180	(916) 293-2940
CC-105	Deputy Area Manager	(916) 989-7267	(916) 833-2791
	Folsom Control Operations	(916) 989-7251	(916) 221-8129
CC-600	Operations, Maintenance & Engineering Division	(916) 989-7143	(916) 955-0445
CC-160	Safety & Security Program Manager	(916) 989-7129	(916) 934-6253
CC-161	Physical Security Specialist	(916) 989-7171	(916) 799-3589
	SECURITY: Sacramento County Sheriff	(916) 989-7105	(916) 601-5882
CC-400	Resources Manager	(916) 989-7182	(707) 738-7615
	Central Valley Control Center (CVCC) **3310 El Camino Ave., Suite 300** **Sacramento, CA 95821**	**24-Hour Contact** **(916) 979-3002**	
MP-100	Regional Director	(916) 978-5000	
MP-105	Deputy Regional Director	(916) 978-5013	
MP-110	Assistant Regional Director for Business Services	(916) 978-5011	
MP-115	Assistant Regional Director for Technical Services	(916) 978-5012	
CVO-100	Operations Manager	(916) 979-2180	(916) 799-4896
MPCO-310	Mid-Pacific Region Construction Office	(530) 308-9852	
MP-3800	Regional Contracting Office	(916) 978-5141	(916) 978-5130
	City of Folsom	(916) 355-7200	916-948-8776
	City of Roseville Emergency Services Dispatch	(916) 786-6444	(916) 786-6444
	City of Roseville Water Treatment Plant	(916) 791-4586	916-746-1986
	Folsom Prison Water Treatment Plant		916-985-8610, x-7399
	San Juan Water District (Water Treatment Plant)	(916) 791-6917	916-971-1715



PUMPS

- (P2) 9000 GPM OR 20 CFS centrifugal pump, 250HP, 1200RPM
- (P3) 20,200 GPM OR 45 CFS centrifugal pump, 600HP, 720RPM
- (P4) 17,500 GPM OR 39 CFS centrifugal pump, 400HP, 900RPM
- (P5) 17,500 GPM OR 39 CFS centrifugal pump, 400HP, 900RPM
- (P6) 33,660 GPM OR 75 CFS centrifugal pump, 800HP, 514RPM
- (EP) 33,700 GPM OR 75 CFS emergency pump centrifugal pump, 800HP, 514RPM.
- (P7) 39,000 GPM OR 87 CFS centrifugal pump, 1500HP, Var. speed
- (P8) 39,000 GPM OR 87 CFS centrifugal pump, 1500HP, Var. speed

LEGEND

- Manual operated gate valve
- Motor operated gate valve
- Centrifugal pump
- Blind flange
- Flow meter
- Plug valve
- Reducer
- Orifice
- Relief valve
- Check valve
- Surge tank
- Manual operated butterfly valve
- Motor operated butterfly valve
- Air and vacuum relief
- Air vent
- Pressure gauge
- Ball valve
- Motor operated sleeve valve

REFERENCE DRAWINGS

NORTH FORK PIPE LINE	485-D-1322
NORTH FORK PIPE LINE DETAILS	485-D-1323
NATOMA PRESSURE PIPE LINE	485-D-1324
NORTH FORK & NATOMA PIPE LINE FLOW MEASURING EQUIP.	485-D-1325
NORTH FORK PIPE LINE SURGE TANK PLAN SECTIONS & DEATILS	485-D-1326
NORTH FORK PIPE LINE STANDPIPE SECTIONS & DEATILS	485-D-1327
PUMPING PLANT INLET EMERGENCY VALVE INSTALLATION	485-D-1354
DRAIN LINE FOR NATOMA & NORTH FORK PIPELINE & MISC. DRAINAGE DETAILS	485-D-1442
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 MOD. VALVE PIT 1 EXISTING STEEL PIPE PLAN AND SECTIONS	485-D-3495
NORTH FORK PIPE LINE BYPASS AND REGULATING VALVE	485-208-803
NATOMA DISTRIBUTION BOX AND 42" BUTTERFLY VALVE	485-208-950
EMERGENCY PUMPING SYSTEM GENERAL PLAN & INSTALLATION	485-208-848
FOL/PUMP PLT EMERG. PUMP SYSTEM	485-208-855
FOL/PUMP PLT PIPELINE DRAWING LIST	485-218-3366

18	2014-04-10 218 J. CASTRO	NORTH FORK PIPELINE REPAIR W.O. 1287638 CONTRACT NO. R12PC20104
17	2012-08-07 218 J. CASTRO	MODIFIED PUMPS GPM
16	2012-04-09 218 J. CASTRO	ADDED VALVE NUMBER DESIGNATIONS
15	YR MO DA 218 J. CASTRO	AS-BUILT PER RELOCATION OF PIPELINE AND REDRAWN FOR CLARITY APPROVED BY JAY S. DHAMI P.E. DATE 8-14-2010
14	2010-05-07 218 J. CASTRO	AS BUILT RELOCATION OF NATOMA PIPELINE W.O.20632 APPROVED BY JAY S. DHAMI P.E. DATE 5-12-10
13	2009-12-09 218 J. CASTRO	NORTH FORK PIPELINE MOD. W.O. 20175 APPROVED BY JAY S. DHAMI P.E. DATE 12-22-09
12	2009-01-27 218 J. CASTRO	STANDPIPE RELOCATION PROJECT W.O. 19996 BY 2814301

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
AMERICAN RIVER DIVISION - FOLSOM UNIT

FOLSOM PUMPING PLANT
WATER DISTRIBUTION
FLOW DIAGRAM

DESIGNED ____ TECH. APPR. W.M. JOYE
DRAWN TIM BURGESS SUBMITTED ____
CHECKED W.M. JOYE APPROVED D. MCCOMB
APPROVER'S TITLE
CADD SYSTEM ACAD V.10
CADD FILENAME
DATE & TIME PLOTTED
FOLSOM, CALIFORNIA SHEET 1 OF 1 1991-08-08
485-218-688

OFFICIAL USE ONLY

Project: Folsom Dam Emergency Pump Operation

Feature: Emergency Pump operated in Series with Pump 7 or Pump 8

Details: Delivery to City of Roseville and San Juan Water District for Folsom Reservoir elevations 325 feet to 309 feet

Author: Alan McCann

Date: 7/10/2015

Terminology:

High Reservoir: Reservoir WSEL 325 feet, utilization of Emergency Pump begins.
Low Reservoir: Reservoir WSEL 309 feet, utilization of Emergency Pump discontinues.

Background:

This investigation looked at utilizing the Emergency Pump in series with either Pump 7 or Pump 8 to supply water to the City of Roseville and San Juan Water District for Folsom Reservoir water surface elevations from 325 feet to 309 feet. The North Fork Pipeline supplies water from Folsom Reservoir Pump Station to the City of Roseville and San Juan Water District. Utilizing the drawings and figures in the Water Resources Engineering (WRE) Folsom Pumping Plant System Capacity Evaluation Final Report dated July 2011 system curves were developed for pumping water through the North Fork Pipeline. Two system curves were developed, one for Folsom Reservoir water surface elevation of 325 feet and the second curve for water surface elevation 309 feet. System curves assumed fully open valves to the San Juan Water District (no throttling) and partially closed valves (throttling) at Roseville to supply backpressure to match the head required to supply flow to San Juan Water District. Pumps 7 and 8 are VFD pumps Folsom personnel report operating at 40% to 65% of full speed (511 rpm).

Results:

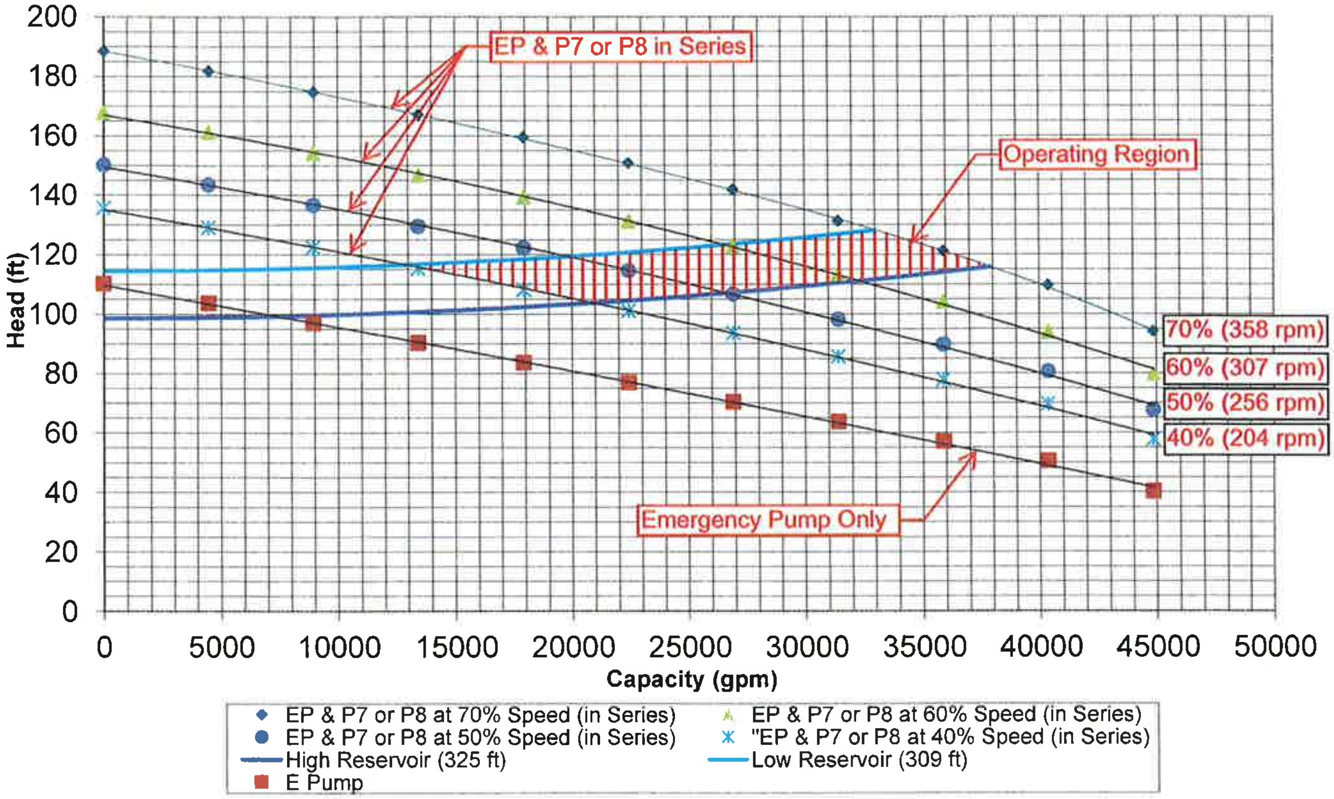
Attached are the pump curves for the Emergency Pump and Pump 7 or Pump 8 operated in series. Pump curves were developed utilizing curve number P-6191-P1 for the Emergency Pump and the full speed curve in figure 3-1 on page 3-6 of the WRE report for Pumps 7 and 8. Pumps will operate where the system curve intersects the pump curve. The following Table 1 is a summary of where the system curve intersects the pump curve. Values are approximations.

Table 1: Pump Flow Rates and Total Discharge Heads for North Fork Pipeline

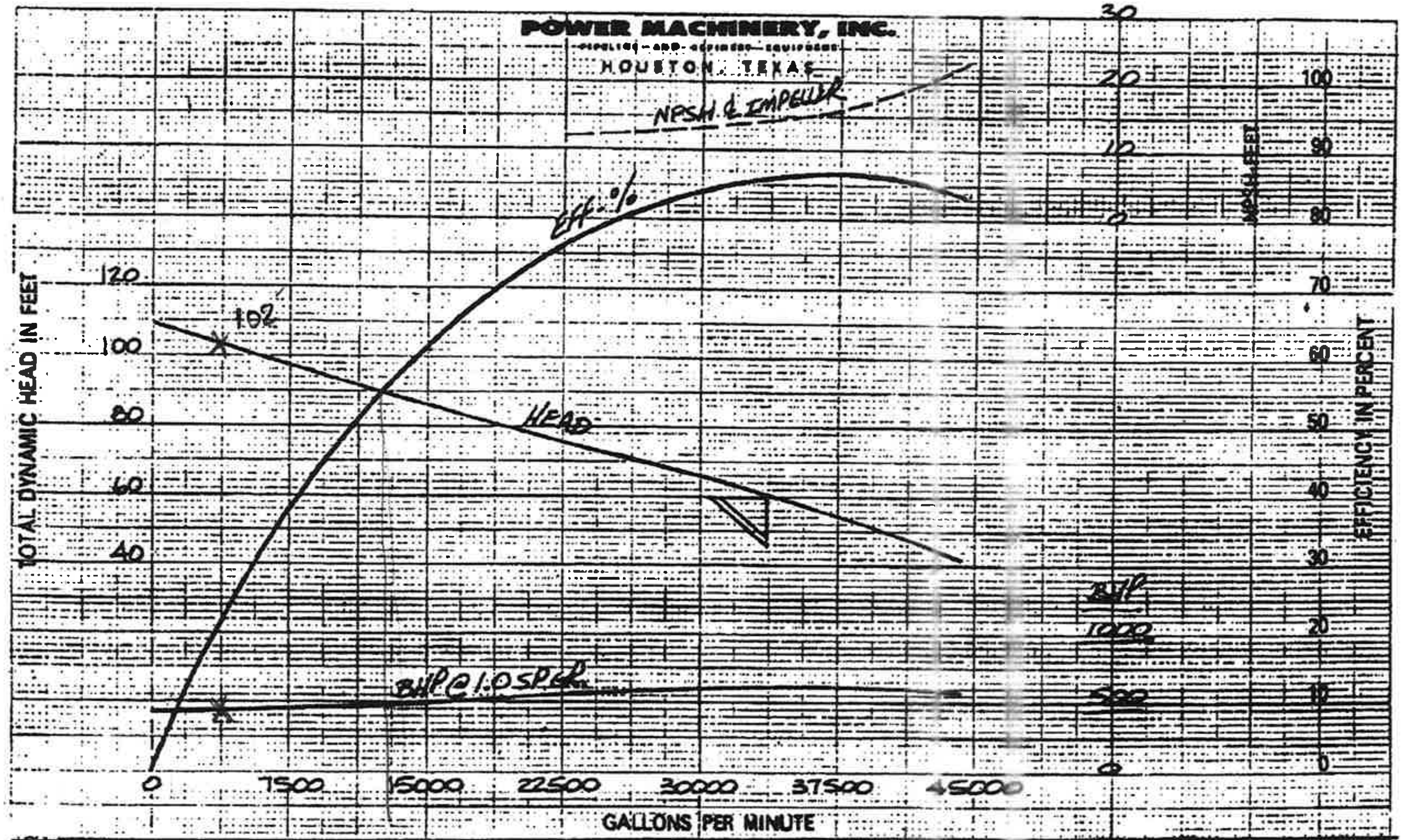
Rotational Speed of Pump 7 or 8 (Emergency Pump Full Speed)	Reservoir Condition	Flow Rate	Total Discharge Head
204 rpm (40% Full Speed)	High Reservoir (WSEL 325 feet)	20,197 gpm (45 cfs)	105 feet
	Low Reservoir (WSEL 309 feet)	12,118 gpm (27 cfs)	118.5 feet
256 rpm (50% Full Speed)	High Reservoir (WSEL 325 feet)	26,257 gpm (58.5 cfs)	108 feet
	Low Reservoir (WSEL 309 feet)	19,075 gpm (42.5 cfs)	120.5 feet
307 rpm (60% Full Speed)	High Reservoir (WSEL 325 feet)	32,316 gpm (72 cfs)	112 feet
	Low Reservoir (WSEL 309 feet)	26,032 gpm (58 cfs)	124 feet
358 rpm (70% Full Speed)	High Reservoir (WSEL 325 feet)	37,926 gpm (84.5 cfs)	115.5 feet
	Low Reservoir (WSEL 309 feet)	32,989 gpm (73.5 cfs)	128 feet

Curves for Emergency Pump and Pump 7 or Pump 8 in Series

North Fork Pipeline to Roseville and San Juan Water District
Emergency Pump & Pump 7 or Pump 8 (40-70% Speed)



Reference Curves



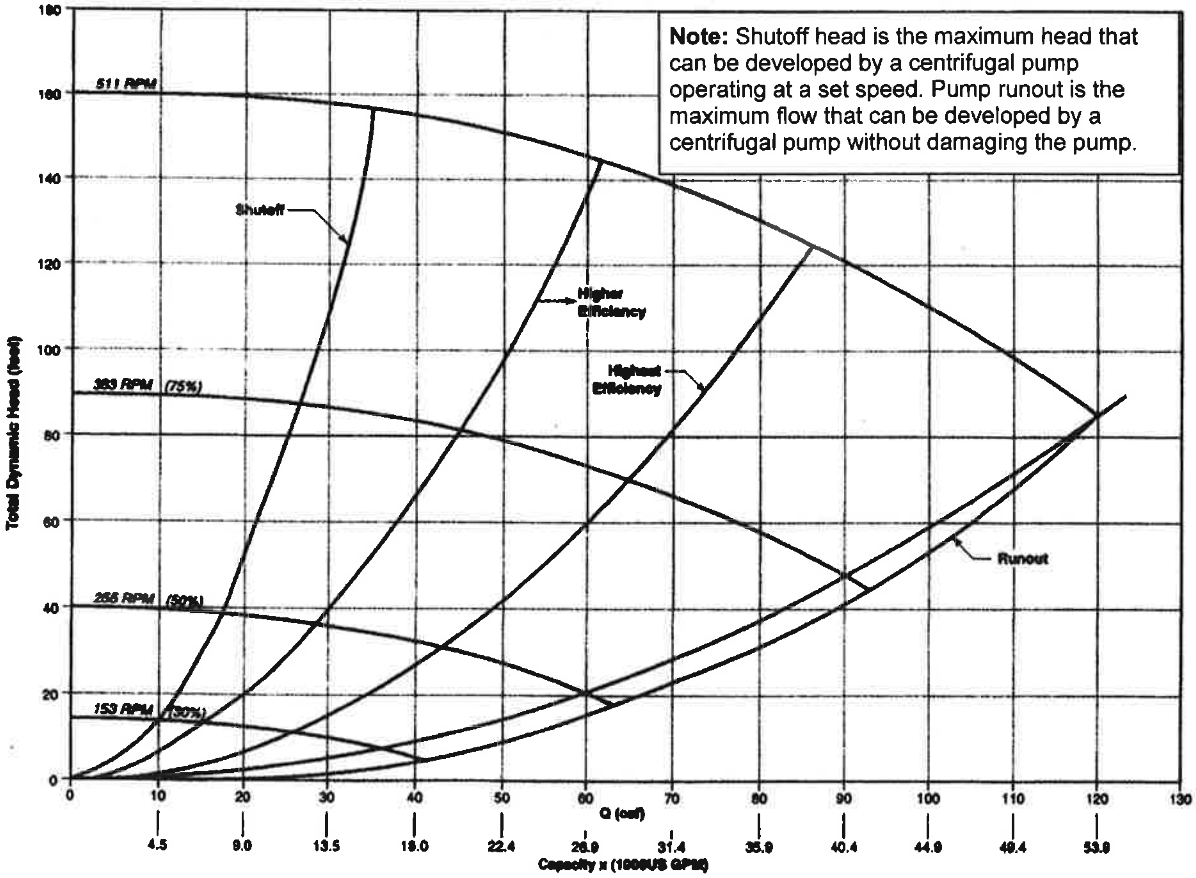
PUMP MFG'R. INGERSOLL-RAND	RPM 514	CASE MAT'L CAST IRON	IMP DIA. " 34 1/8	DRAWN BY SGR	CUSTOMER PUMP & MOTOR WORKS
SIZE AND TYPE 30" ALV		IMP MAT'L BRONZE	MAX 41" / MIN 34"	DATE 3-16-91	CURVE NO. P-6191-P1

Acceptable operating ranges for constant speed pumps, based on manufacturer's pump curves, are presented in Table 3-4. The actual pump curves are included in Appendix D.

Table 3-4 Acceptable Operating Ranges of Constant Speed Pumps at Folsom Pumping Plant

Pump	Flow Rate Range (cfs)	TDH Range (ft)	Min. Acceptable Efficiency
2	10 to 28	60 to 124	70%
3	22 to 69	64 to 114	72%
4 & 5	18 to 51	50 to 116	70%
6 & Emerg.	41 to 106	50 to 106	70%

Variable speed pumps generally operate over a wider range of flow rates and head than constant speed pumps. The nominal capacity of the variable speed pumps at different heads and speeds is illustrated in Figure 3-1.



Note: Shutoff head is the maximum head that can be developed by a centrifugal pump operating at a set speed. Pump runout is the maximum flow that can be developed by a centrifugal pump without damaging the pump.

Figure 3-1 Variable Speed Pump Performance Curves
Source: Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda, prepared by Will B. Betchart in March 2000.

Project: Folsom Dam Emergency Pump Operation

Feature: Emergency Pump operated in Series with Pump 7 or Pump 8

Details: Delivery to City of Folsom, Folsom Prison, City of Roseville, and San Juan Water District for Folsom Reservoir elevations 325 feet to 309 feet

Author: Alan McCann

Date: 7/15/2015

Background:

This investigation looked at utilizing the Emergency Pump in series with either Pump 7 or Pump 8 to supply water to the City of Folsom, Folsom Prison, City of Roseville and San Juan Water District for Folsom Reservoir water surface elevations from 325 feet to 309 feet. The Natoma Pipeline supplies water from Folsom Reservoir Pump Station to the City of Folsom and Folsom Prison. The North Fork Pipeline supplies water from Folsom Reservoir Pump Station to the City of Roseville and San Juan Water District. Utilizing the drawings and figures in the Water Resources Engineering (WRE) Folsom Pumping Plant System Capacity Evaluation Final Report dated July 2011, system curves were developed for pumping water through the Natoma and North Fork Pipelines. System curves were developed for Folsom reservoir elevations 309, 315, 320, and 325 feet.

The analysis assumed the delivery point in the system with the highest total discharge head will not be throttled which results in the following:

- For flows up to 71 cfs, a fully open valve at the San Juan Water District (no throttling) and partially closed valves (throttling) at the City of Roseville, City of Folsom, and Folsom Prison to supply backpressure matching the head required to supply flow to San Juan Water District.
- For flows above 71 cfs, a fully open valve at the City of Folsom (no throttling) and partially closed valves (throttling) at the City of Roseville, San Juan Water District, and Folsom Prison to supply backpressure to match the head required to supply flow to the City of Folsom.

All delivery point can be throttled, but throttling will result in higher head losses and a flow rate less than the maximum total flow rate attainable shown by the supplied system curves.

Results:

Attached are the pump curves for the Emergency Pump and Pump 7 or Pump 8 operated in series. Pump curves were developed utilizing curve number P-6191-P1 for the Emergency Pump and the full speed curve in figure 3-1 on page 3-6 of the WRE report for Pumps 7 and 8. The system curves represent the system at the reservoir elevation specified on each curve.

Each system curve shown represents the maximum flow rate for the identified Pump 7 and Pump 8 rotational speeds. If the delivery points are throttled, resulting in an increased system pressure, the pumps will operate in the regions highlighted in green and yellow. A unique system curve exists for each of these throttling conditions, but the pumps will always operate where the system curve intersects the pump curve.

Pumps have a minimum continuous stable flow (MCSF) which is typically depicted by a vertical line on the pump curves. This is a flow rate defined by the pump manufacture, but when unavailable can be estimated as the flow rate at 50 percent of the pumps best efficiency point. Since the manufactures pump curves do not have a MCSF shown on them, 50 percent of best efficiency was used. The actual MCSF for the pumps may be more or less than estimated. Operating below MCSF, hydraulic instabilities can become dramatic and cause pressure pulsations, vibrations, axial shuttling of the rotor and failures [1]. The estimate MCSF shown on the pump curves is for the Emergency pump, which has a higher MCSF than pumps 7 or 8.

Limitations of Pump Operation Analysis:

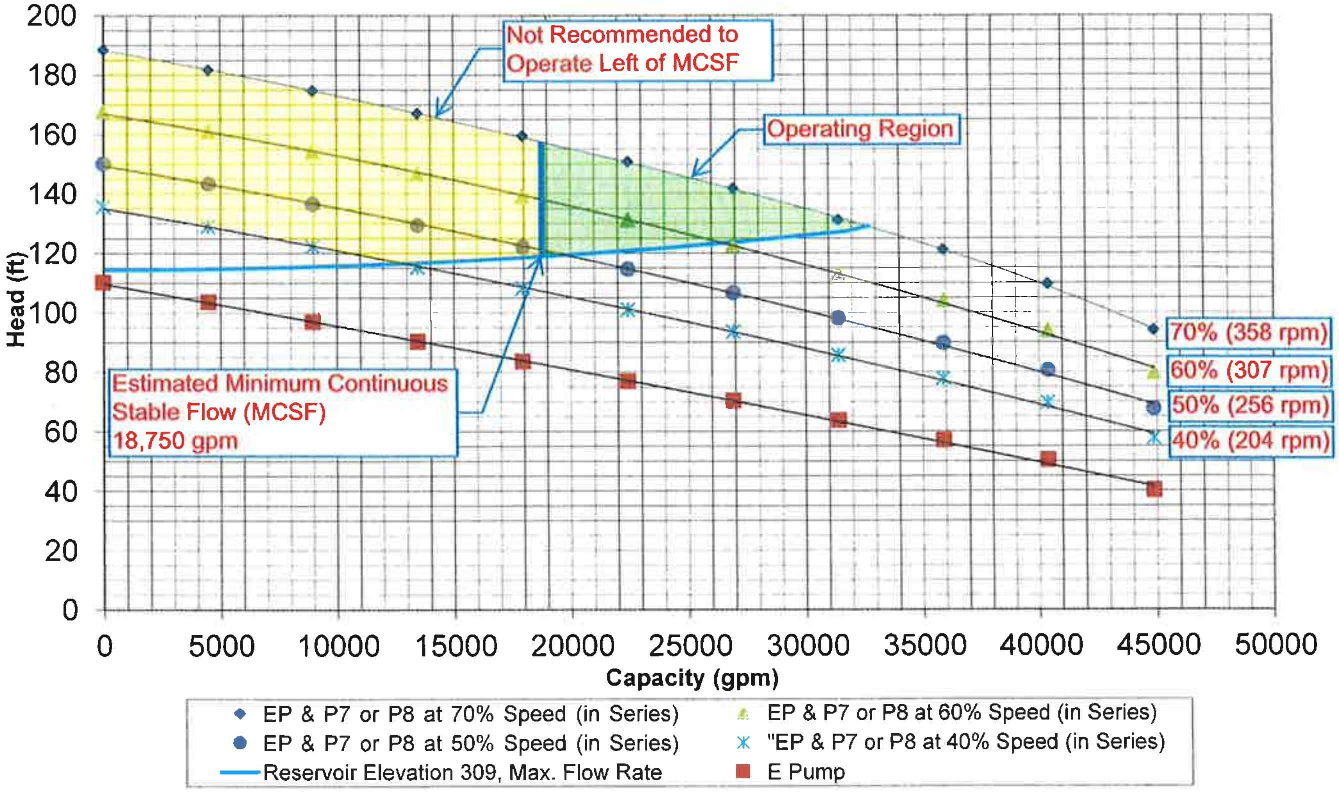
These operational pump curves developed for the Emergency Pump (EP) operated in series with Pump 7 (P7) or Pump 8 (P8) at the Folsom Pumping Plant cannot be guaranteed. They were based on original pump curves for the EP and P7/P8 when the pumps were new. The performance of the pumps will decline over time due to wear and possibly cavitation of the pump impellers. The headlosses calculated for the North Fork and Natoma pipeline systems are best estimates of the piping system losses. Lastly, the operation of the P7/P8 VFD pumps are at much lower speeds than we have experience with for VFD pumps.

We caution accepting these pump operational curves as a reliable and proven operational tool for providing pumped water to your water users from Folsom Reservoir at declining reservoir water surface elevations. The combined pump operational curves are an engineering estimation as to how two pumps-in-series will operate. Please note that this system is untested for the range of flows needed. The TSC cannot accurately predict what potential pump system operational issues may arise with the use of these calculated pump-in-series combined performance curves without operational tests.

[1] Nelik, Lev, "Stable Versus Thermal Minimum Continuous Flow for Centrifugal Pumps" Pumps and Systems Magazine, March 2014.

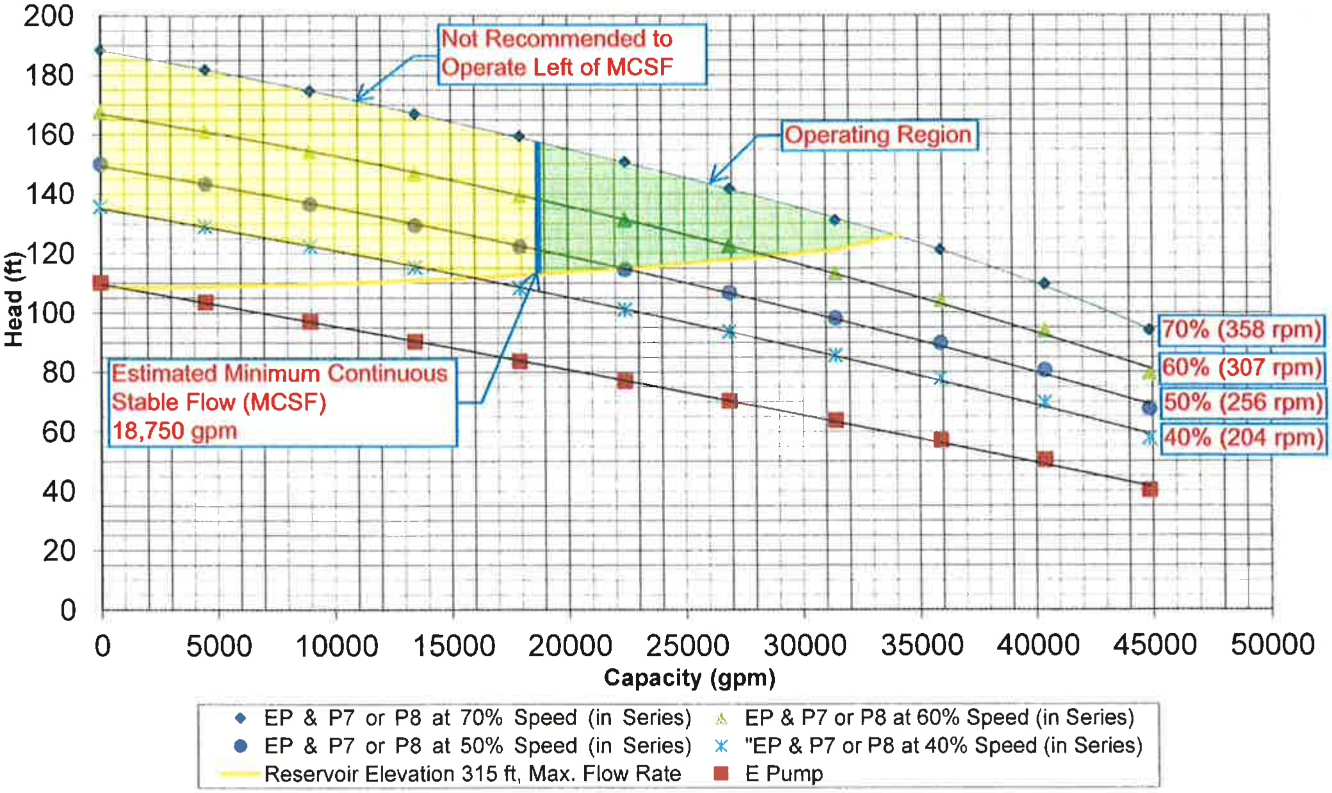
Curves for Emergency Pump and Pump 7 or Pump 8 in Series

North Fork and Natoma Pipeline Reservoir Elevation 309 feet
Emergency Pump & Pump 7 or Pump 8 (40-70% Speed)
Recommended Operating Region When Throttling at Delivery Points



7/15/2015

North Fork and Natoma Pipeline at Reservoir Elevation 315 feet
Emergency Pump & Pump 7 or Pump 8 (40-70% Speed)
Recommended Operating Region When Throttling at Delivery Points



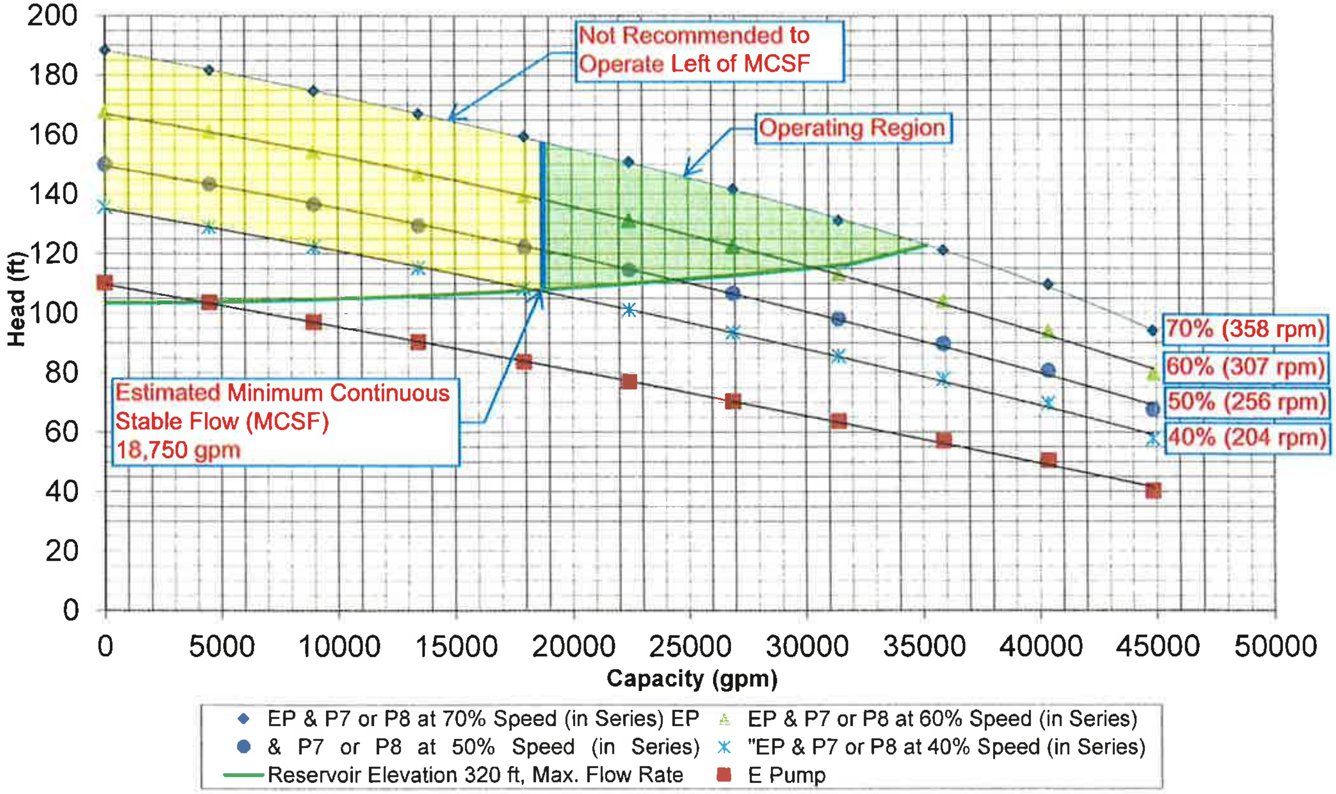
Not Recommended to Operate Left of MCSF

Operating Region

Estimated Minimum Continuous Stable Flow (MCSF) 18,750 gpm

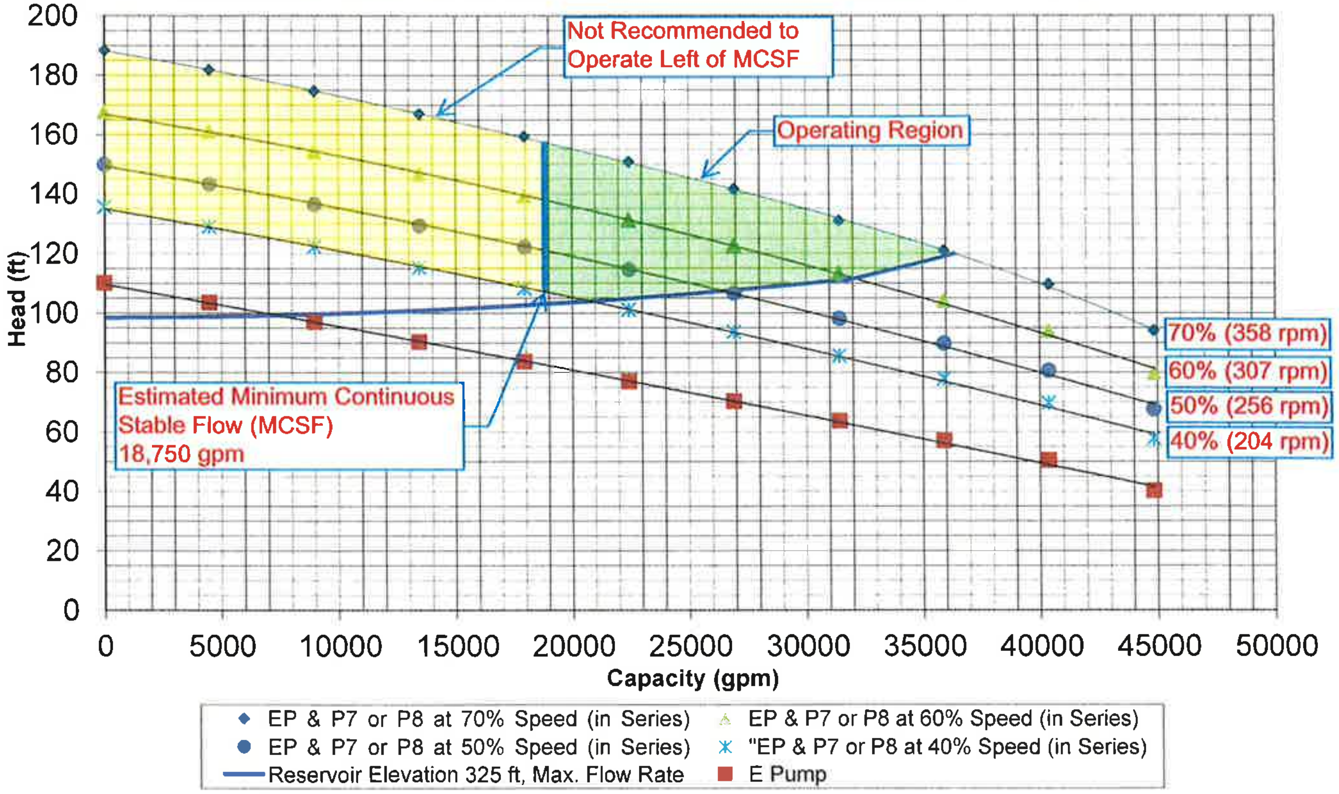
7/15/2015

North Fork and Natoma Pipeline at Reservoir Elevation 320 feet
Emergency Pump & Pump 7 or Pump 8 (40-70% Speed)
Recommended Operating Region When Throttling at Delivery Points



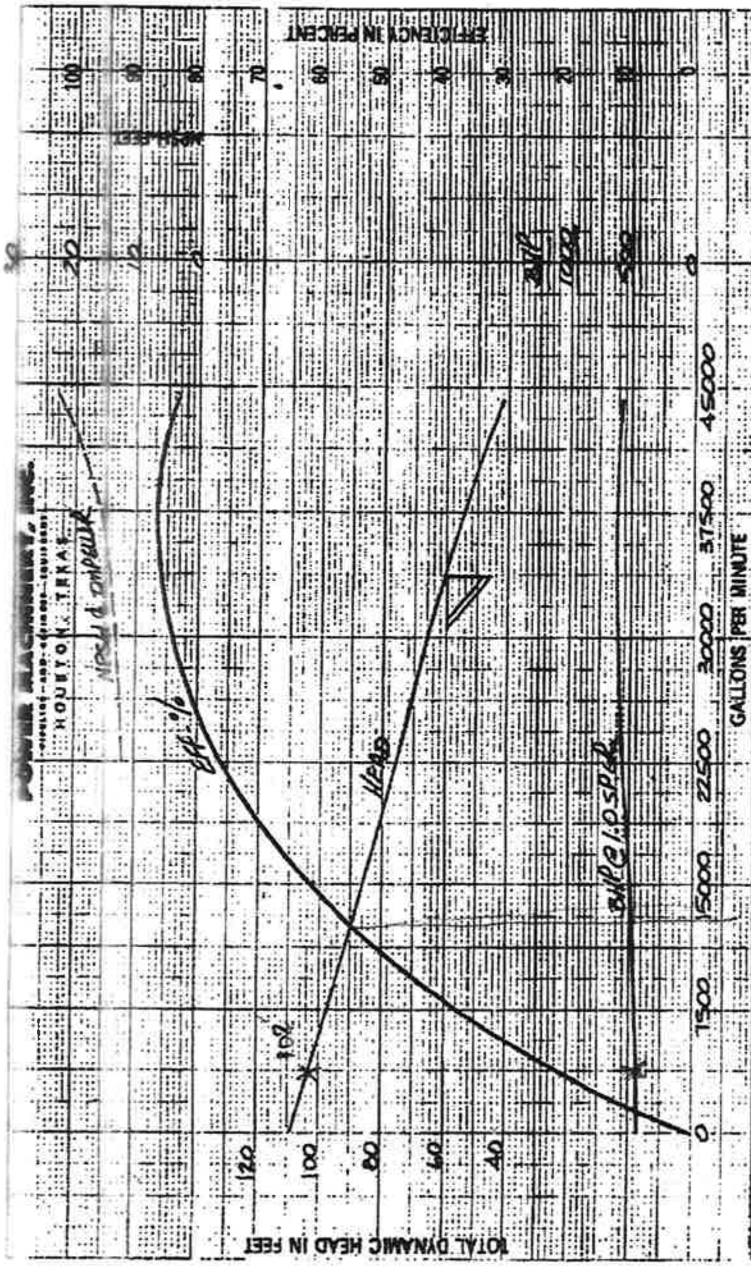
7/15/2015

North Fork and Natoma Pipeline at Reservoir Elevation 325 feet
Emergency Pump & Pump 7 or Pump 8 (40-70% Speed)
Recommended Operating Region When Throttling at Delivery Points



7/15/2015

Reference Curves



PUMP MFG'R. INGERSOLL-RAND	RPM	CASE MAT'L. CAST IRON	IMP DIA. " 34 1/8	DRAWN BY SGR	CUSTOMER PUMP & MOTOR WORKS
SIZE AND TYPE 30" ALV	514	IMP MAT'L. BRONZE	MAX 41" / MIN 34"	DATE 3-16-91	CURVE NO. P: 6191-P1

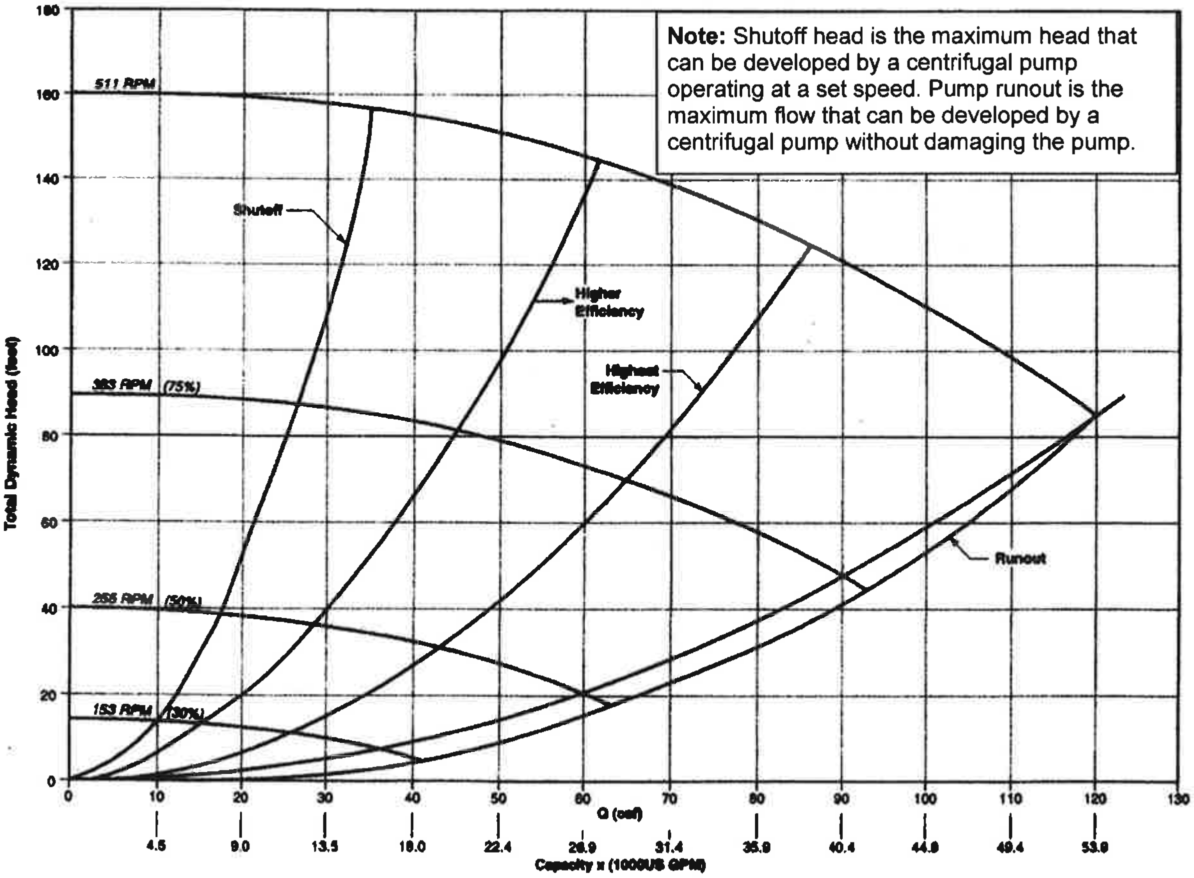
B– 2
Sheet 2 of 7

Acceptable operating ranges for constant speed pumps, based on manufacturer's pump curves, are presented in Table 3-4. The actual pump curves are included in Appendix D.

Table 3-4 Acceptable Operating Ranges of Constant Speed Pumps at Folsom Pumping Plant

Pump	Flow Rate Range (cfs)	TDH Range (ft)	Min. Acceptable Efficiency
2	10 to 28	60 to 124	70%
3	22 to 69	64 to 114	72%
4 & 5	18 to 51	50 to 116	70%
6 & Emerg.	41 to 106	50 to 106	70%

Variable speed pumps generally operate over a wider range of flow rates and head than constant speed pumps. The nominal capacity of the variable speed pumps at different heads and speeds is illustrated in Figure 3-1.



Note: Shutoff head is the maximum head that can be developed by a centrifugal pump operating at a set speed. Pump runout is the maximum flow that can be developed by a centrifugal pump without damaging the pump.

Figure 3-1 Variable Speed Pump Performance Curves
Source: Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda, prepared by Will B. Betchart in March 2000.

Project: Folsom Dam Emergency Pump Operation

Feature: Emergency Pump operated in Series with Pump 7 or Pump 8

Details: Delivery to Folsom Prison and City of Folsom for reservoir elevations 325 feet to 309 feet

Author: Alan McCann

Date: 7/1/2015

Terminology:

High Reservoir: Reservoir WSEL 325 feet, utilization of Emergency Pump begins.
Low Reservoir: Reservoir WSEL 309 feet, utilization of Emergency Pump discontinues.

Background:

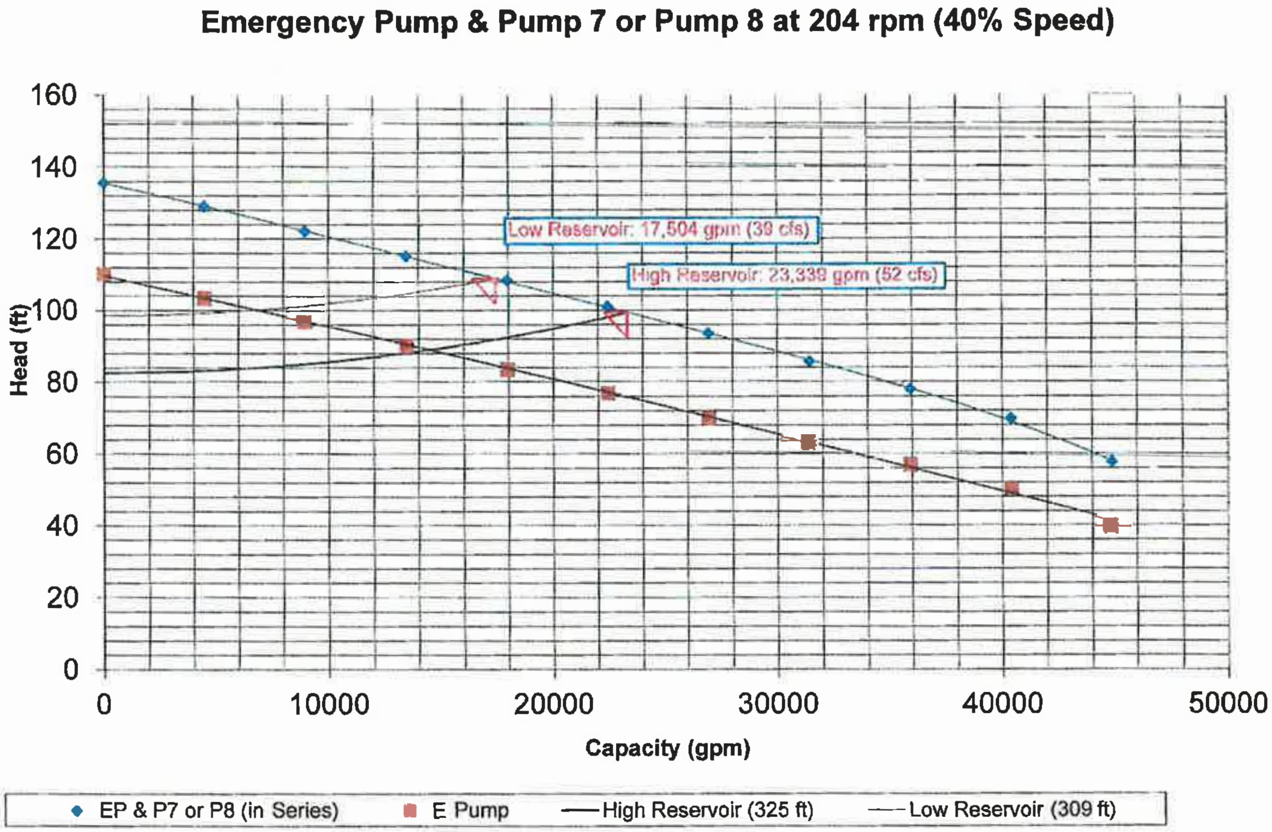
This investigation looked at utilizing the Emergency Pump in series with either Pump 7 or Pump 8 to supply water to the Folsom Prison and the City of Folsom for Folsom Reservoir water surface elevations from 325 feet to 309 feet. The Natoma Pipeline supplies water from Folsom Reservoir Pump Station to the Folsom Prison and City of Folsom. Utilizing the drawings and figures in the Water Resources Engineering (WRE) Folsom Pumping Plant System Capacity Evaluation Final Report dated July 2011 system curves were developed for pumping water through the Natoma Pipeline. Two system curves were developed, one for Folsom Reservoir water surface elevation of 325 feet and the second curve for water surface elevation 309 feet. System curves assumed fully open valves in the system (no throttling downstream of the pumps). Pumps 7 and 8 are VFD pumps which Folsom personnel report operating at 40% to 65% of full speed (511 rpm).

Results:

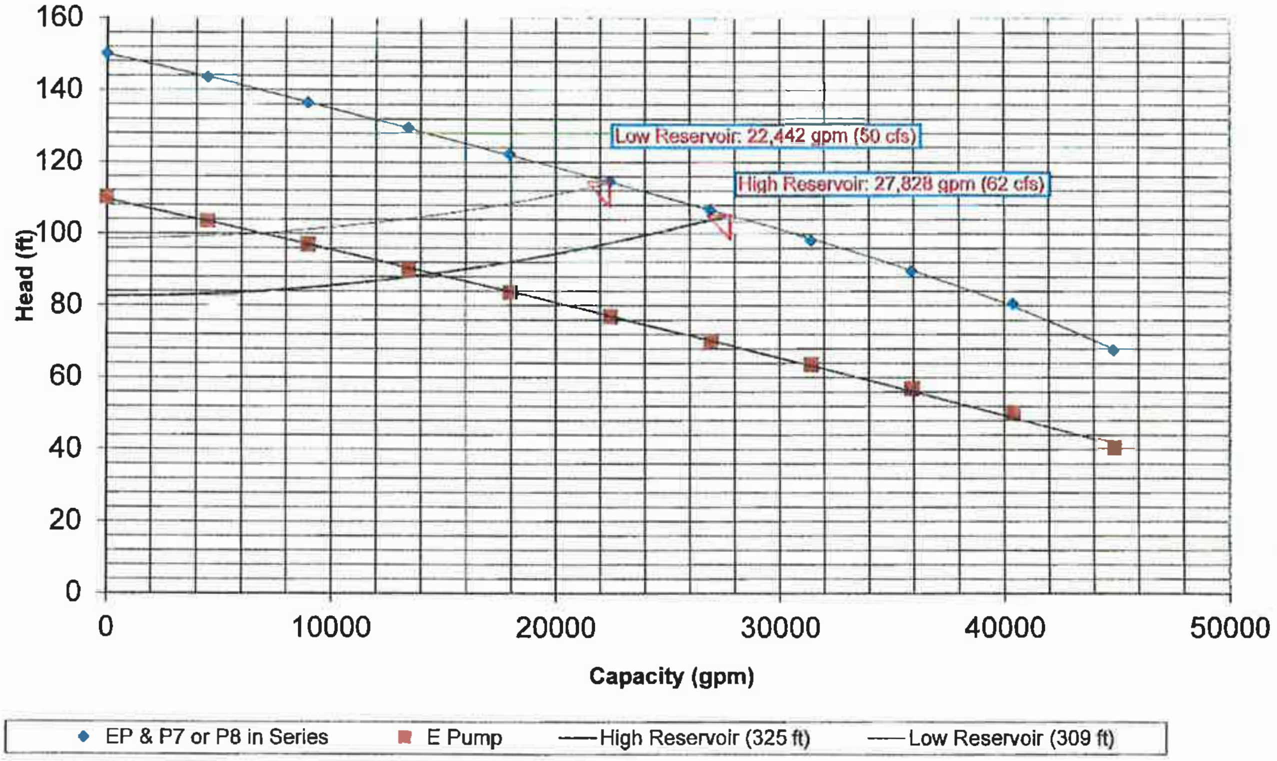
Attached are the pump curves for the Emergency Pump and Pump 7 or Pump 8 operated in series. Pump curves were developed utilizing curve number P-6191-P1 for the Emergency Pump and the full speed curve in figure 3-1 on page 3-6 of the WRE report for Pumps 7 and 8. Pumps will operate where the system curve intersects the pump curve. The following table is a summary of where the system curve intersects the pump curve. Values are approximations.

Rotational Speed of Pump 7 or 8 (Emergency Pump Full Speed)	Reservoir Condition	Flow Rate	Head
204 rpm (40% Full Speed)	High Reservoir (WSEL 325 feet)	23,339 gpm (52 cfs)	99.2 feet
	Low Reservoir (WSEL 309 feet)	17,504 gpm (39 cfs)	108.8 feet
256 rpm (50% Full Speed)	High Reservoir (WSEL 325 feet)	27,828 gpm (62 cfs)	105.3 feet
	Low Reservoir (WSEL 309 feet)	22,442 gpm (50 cfs)	114.1 feet
307 rpm (60% Full Speed)	High Reservoir (WSEL 325 feet)	32,316 gpm (72 cfs)	112.5 feet
	Low Reservoir (WSEL 309 feet)	27,828 gpm (62 cfs)	121.3 feet
358 rpm (70% Full Speed)	High Reservoir (WSEL 325 feet)	36,355 gpm (81 cfs)	119.8 feet
	Low Reservoir (WSEL 309 feet)	32,765 gpm (73 cfs)	129.2 feet

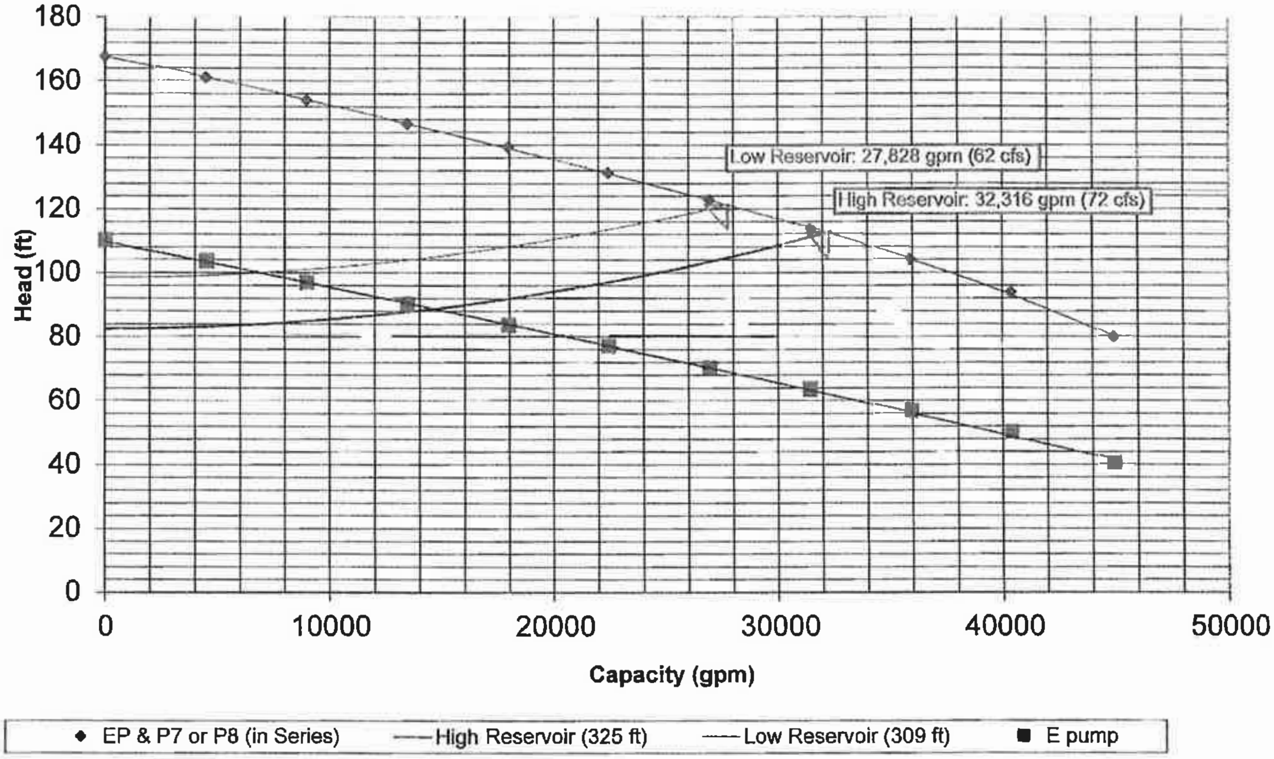
Curves for Emergency Pump and Pump 7 or Pump 8 in Series

Emergency Pump & Pump 7 or Pump 8 at 204 rpm (40% Speed)
Head (ft)
160
140
120
100
80
60
40
20
0
0
10000
20000
30000
40000
50000
Capacity (gpm)
Low Reservoir: 17,504 gpm (39 cfs)
High Reservoir: 23,339 gpm (52 cfs)
◆ EP & P7 or P8 (in Series)
■ E Pump
High Reservoir (325 ft)
Low Reservoir (309 ft)

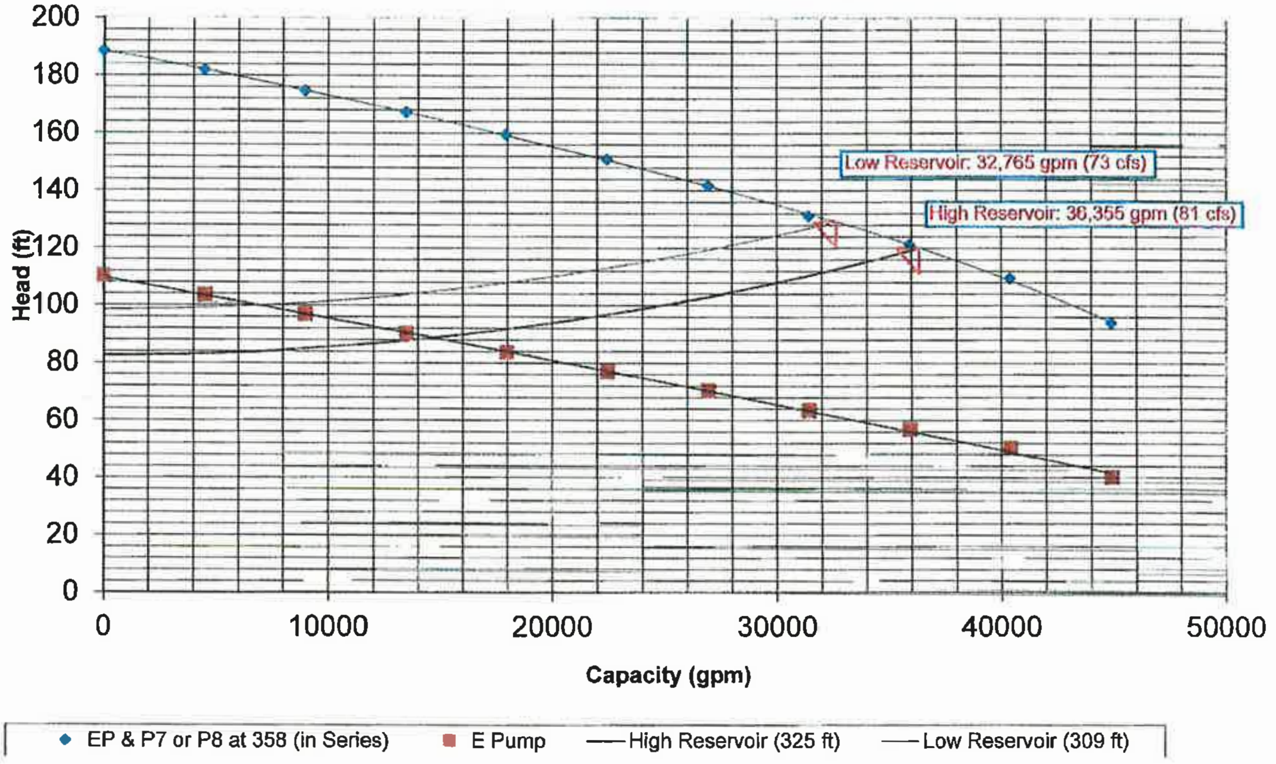
Emergency Pump & Pump 7 or Pump 8 at 256 rpm (50% Speed)



Emergency Pump & Pump 7 or Pump 8 at 307 rpm (60% Speed)



Emergency Pump & Pump 7 or Pump 8 at 358 rpm (70% Speed)



Reference Curves

Acceptable operating ranges for constant speed pumps, based on manufacturer's pump curves, are presented in Table 3-4. The actual pump curves are included in Appendix D.

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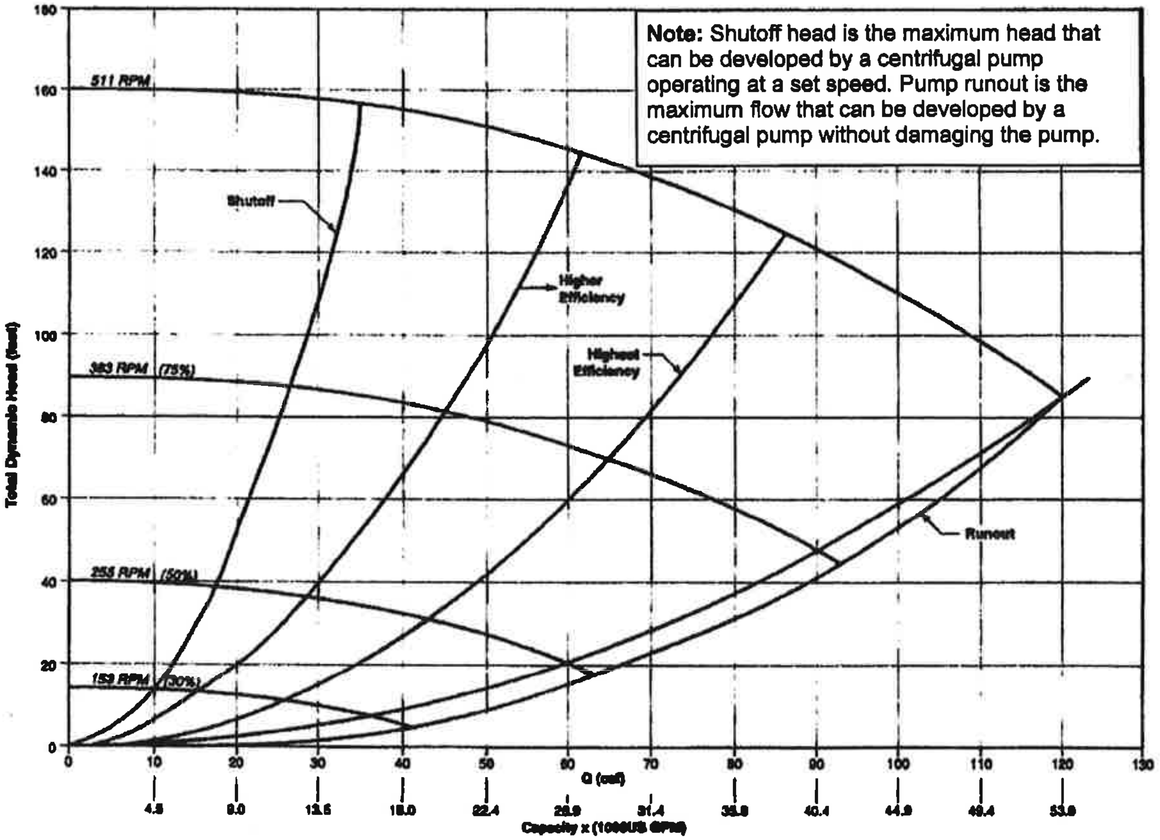
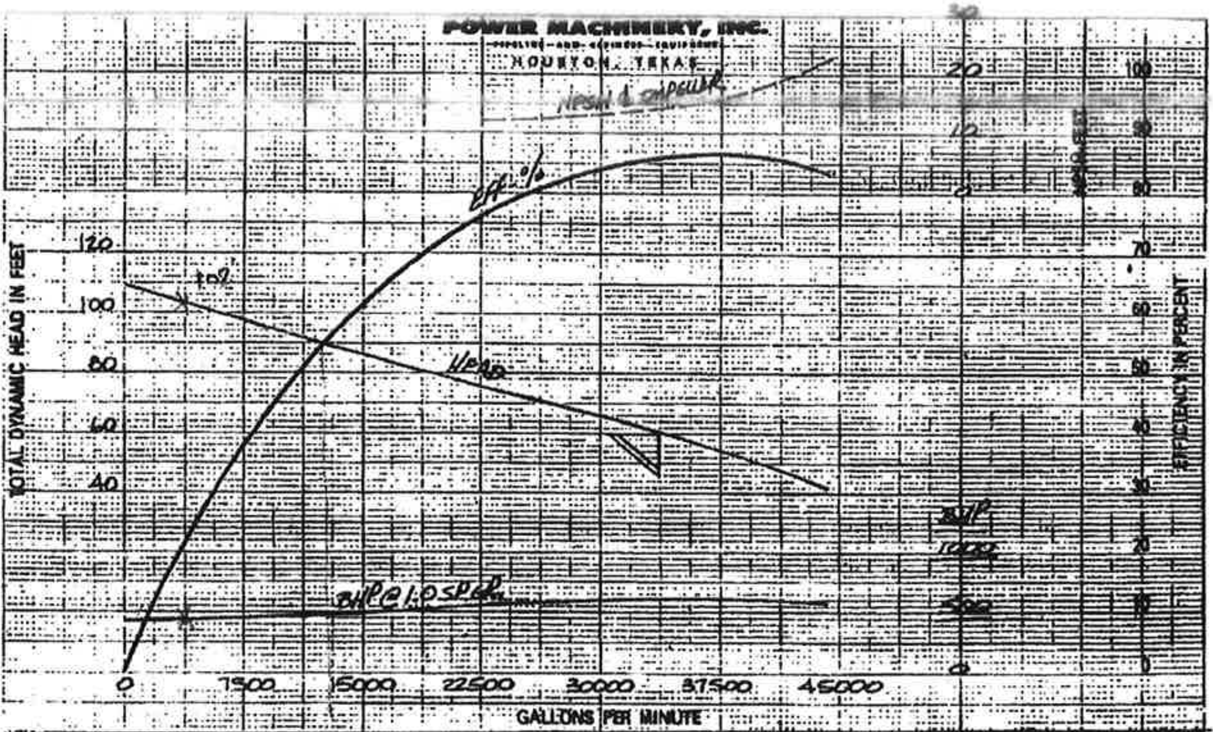
Variable speed pumps generally operate over a wider range of flow rates and head than constant speed pumps. The nominal capacity of the variable speed pumps at different heads and speeds is illustrated in Figure 3-1.



Note: Shutoff head is the maximum head that can be developed by a centrifugal pump operating at a set speed. Pump runout is the maximum flow that can be developed by a centrifugal pump without damaging the pump.

Figure 3-1 Variable Speed Pump Performance Curves
Source: Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda, prepared by Will B. Betchart in March 2000.



PUMP MFG'R.	RPM	CASE MAT'L	IMP. DIA.		DRAWN BY	CUSTOMER
INGERSOLL-RAND	514	CAST IRON	34 3/8"		SGR	PUMP & MOTOR WORKS
SIZE AND TYPE		IMP. MAT'L	MAX	MIN	DATE	CURVE NO.
30" ALV		BRONZE	41"	34"	8-16-97	P-6191-P1

SUMMARY - Folsom Emergency Pump Operation Analysis

June 25, 2015

An analysis was performed to be able to provide up to 75 cfs of water to the water treatment plants (WTP) for the City of Folsom and Folsom Prison operating the Emergency Pump, located near the toe of dam, in series with pumps at the Folsom Pumping Plant (PP). On inspection, identical pumps having the same design flow and rotational speed seem to be best suited for operation in series. Therefore, the analysis looked at operating the Emergency Pump (EP) in series with Folsom PP pump P6. Both pumps are of identical design Q (100 cfs) and rotational speed (514 rpm). The performance curves are additive for head at the same Q. Curve No. P-6191- P1 was used to depict the performance curve for these two pumps operating in series.

The static head for the combined pump (EP+P6) operating system was determined based on reservoir water surface elevation when EP+P6 would need to deliver water to the WTP reservoirs. High reservoir water surface elevation where operations would switch to the EP+P6 system was identified to be 325.00 feet and the Low reservoir water surface elevation where operations would cease was identified to be 309.00 feet. Folsom staff provided these reservoir water surface elevations in a 5/19/2015 conference call. Corresponding water surface elevations at the City of Folsom and Folsom Prison WTP reservoirs were determined to be approximately 408 feet at each. The Total Dynamic Head (TDH) for the EP+P6 pump system equals the static head for the EP+P6 system (difference in reservoir elevations) between the Folsom Reservoir High (325 feet) and Low (309 feet) operating levels required + friction headloss in the piping/valves through the system to the respective WTP reservoirs.

TDH for the EP+P6 system to the City of Folsom was calculated to be:

@ High Res. Water (325'): TDH = Static Head + Friction Headloss

TDH = (408' - 325') + friction headloss

TDH = 114.8 feet

@ Low Res. Water (309'): TDH = (408' – 309') + friction headloss

TDH = 125.5 feet

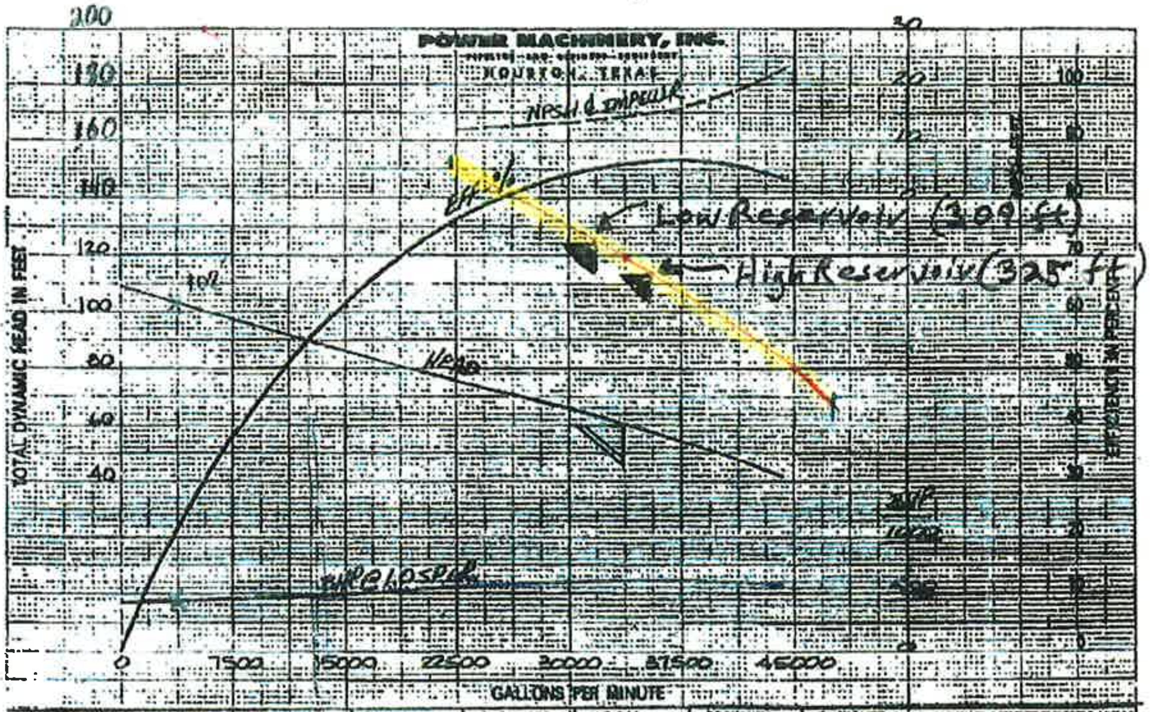
At these TDH values to the City of Folsom reservoir, the EP+P6 system performance curve estimates the flow is possible:

@ High Res. Water (325'): Q = 35,600 gpm (79.3 cfs)

@ Low Res. Water (309'): Q = 31,800 gpm (70.8 cfs)

The combined EP+P6 performance curve shows the flow (Q) values possible are within the best efficiency range of the pumps. Flows from pumps (EP+P6) between reservoir elevations 325 feet to 309 feet will be in recommended operating range for the pumps.

City of Folsom



PUMP MFG'R. INGERSOLL-RAND	RPM 514	CASE MAT'L. CAST IRON	IMP. DIA. 34 3/8"	DRAWN BY SGR	CUSTOMER PUMP & MOTOR WORKS
SIZE AND TYPE 30" ALV		IMP. MAT'L. BRONZE	MAX. 41" / MIN. 34"	DATE 8-16-91	CURVE NO. P 6191-P1

--- Emergency Pump and Pump #6

▬ 70% or higher efficiency range

FINAL REPORT

FOLSOM PUMPING PLANT
SYSTEM CAPACITY EVALUATION
(Task Order 06A1204097M, Contract 06CS204097M)

PREPARED FOR

US BUREAU OF RECLAMATION
CENTRAL CALIFORNIA AREA OFFICE
FOLSOM, CALIFORNIA

PREPARED BY

WRE Water Resources Engineering, Inc.

July 2011

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JULY 2011

FINAL REPORT

FOLSOM PUMPING PLANT - SYSTEM CAPACITY EVALUATION

PREPARED BY
WATER RESOURCES ENGINEERING, INC.
55 NEW MONTGOMERY STREET, SUITE 619
SAN FRANCISCO, CA 94105

Gustavo Arboleda

Gustavo Arboleda, PE
Principal Engineer, Water Resources Engineering, Inc.

Cynthia Cano

Cynthia Cano
Staff Engineer, Water Resources Engineering, Inc.

Water Resources Engineering, Inc.'s work on this report was performed by Principal Engineer Gustavo Arboleda, PE, and Staff Engineer Cynthia Cano. To the best of our knowledge, the data contained herein are true and accurate and satisfy the scope of work for the Task 5 deliverable under Task Order 06A1204097M. The data, findings, recommendations, specifications, or professional opinions were prepared solely for the use of our client in accordance with generally accepted professional engineering practice. We make no other warranty, either expressed or implied, and are not responsible for the interpretation by others of the contents herein.

FOLSOM PUMPING PLANT
SYSTEM CAPACITY EVALUATION

CONTENTS

APPENDICES

FIGURES

TABLES

EXECUTIVE SUMMARY

This report presents the results of studies performed to evaluate system capacity as well as operational and energy usage issues associated with the Folsom Pumping Plant raw water delivery system. Studies included:

- Evaluation of hydraulic performance
- Evaluation of the effects of higher demands on the water delivery system
- Evaluation of power and control systems
- Identification of possible corrective measures and their costs

Evaluation of Hydraulic Performance

The evaluation identified:

- *Physical deficiencies:*
    - ❖ The geometry of pump intakes at the Folsom Pumping Plant generates adverse approach flow conditions (swirl and skewed flow distributions) that result in a phenomenon known as "recirculation," characterized by loud crackling sounds around the pump suction and/or discharge. Suction and discharge recirculation can be very damaging to pump operation and should be avoided for continuous operation.[1]
    - ❖ Four of seven valves on pumping plant discharge piping (after pumps numbered 2, 3, 4, and 5) are gate valves not suitable for partially-open operation (i.e., throttling); the other three valves (after pumps numbered 6, 7, and 8) are of the butterfly type and can be safely used in a partially-open position. Valve throttling can be necessary at times to control pump head (i.e., lift) and keep pumps within the range of heads recommended by the manufacturer for safe and efficient operation.
    - ❖ Five of the seven pumps at the pumping plant (pumps numbered 2, 3, 4, 5, and 6) are of the constant-speed type; that is, the motors that drive the pumps maintain a steady rate of revolutions per minute (rpm) from no load to full load (the other two pumps, 7 and 8, have variable frequency drives that allow them to perform efficiently at different rpm). The constant speed pumps at the plant were designed to generate lifts ranging from 84 feet (pumps 4, 5, and 6) to 100 feet (pumps 2 and 3) when running at peak efficiency (as shown in Table 3-3 of this report). At the minimum operating efficiency recommended by manufacturers (as shown in Table 3-4 of this report), the pumps are designed to generate lifts ranging from 50 feet (pumps 4, 5, and 6) to about 60 feet (pumps 2 and 3). Available heads during periods of pump operation at the Folsom Pumping Plant are frequently under 50 feet; when constant speed pumps are operated continuously below the efficiency levels recommended by manufacturers, they are likely to develop

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[1] Karassik, I. J. et al, "Pump Handbook," Second Edition, McGraw-Hill, New York, 1986, pp. 2.267. The handbook indicates that the cavitation damage produced by discharge recirculation is generally invisible from the suction side, as it occurs on the underside of the impeller vanes; if discharge recirculation is occurring, this might explain why impeller damage has not been detected during pump impeller inspections at the Folsom Pumping Plant.

premature wear of the impeller vane tips, failure of the pump mechanical seal and bearings, and under extreme conditions breaking of the impeller shaft.

- *Operational deficiencies*:
    - ❖ Current operating procedures do not take into account the characteristics (i.e., "pump curves") of the constant speed pumps and their acceptable operating ranges, resulting in operation of the pumps well outside of manufacturer-recommended ranges. When operated outside manufacturer-recommended ranges, the pumps can suffer damage and may deliver less water than indicated by pump performance curves.
    - ❖ Discharge valves are slowly brought to full open position after pump startup without regard to operating pumps at the manufacturer-recommended total dynamic head (TDH). As previously indicated, operating pumps at lower-than-recommended heads can be detrimental to the pumps and generate less-than-expected flow rates.
    - ❖ The two pumps with variable frequency drives or "VFDs" (pumps numbered 7 and 8) are only operated between 50 and 75 percent of full speed; this constraint was imposed by operators based on observed deficient operation (noise and vibration) outside of this range of speeds. The VFD pumps are operated with the discharge valve fully open, although the pump operation training document prepared by Will Betchart in March 2000 indicates that valves should be throttled to control pump head. Valve throttling would likely allow operation of VFD pumps through their normal operating range, which is generally from about 30 to 100 percent of full speed.
- *Operational limits:*
    - ❖ Gravity flows - The raw water delivery system is capable of satisfying current and anticipated future demands by gravity when the reservoir water level is high enough. Based on raw water demand and reservoir level data provided by Reclamation for the years 2000 to 2007, the water level in the reservoir was high enough to allow deliveries by gravity to the North Fork Pipeline about 28 percent of the time.
    - ❖ Pumped flows - The 7 pumps in the Folsom Pumping Plant have a combined capacity of 404 cubic feet per second (cfs) when operated at peak efficiency. Current typical summer demands are approximately 309 cfs (see Table 2-1 of this report). Maximum current demands based on treatment capacities at the end points are about 361 cfs; maximum future demands based on anticipated treatment plant expansions would be 474 cfs (see Table 2-2 of this report). If the pumps were operated at peak efficiency, they would be able to meet current typical and maximum demands; they would not be able, however, to meet future maximum demands. Operation of the pumps at peak efficiency would generally require valve throttling: by partially closing the discharge valves, additional head would artificially be created that would bring the pumps to their most efficient operating level.

Effects of Higher Demands

Increased delivery volumes would:

- Raise the gravity flow threshold for both the North Fork and Natoma pipelines, thereby increasing the need to pump.

- Cause the pumping plant's constant speed pumps to be used more frequently, as demands would exceed the capacity of the variable speed pumps more often than now.
- Substantially increase power consumption; energy usage would more than double for a 25 percent increase in water demand.
- Require increased pump maintenance by accelerating the degradation of equipment that is already operating at low efficiencies under adverse hydraulic conditions.

Evaluation of Power and Control Systems

The plant's power supply could be upgraded as follows:

- Modernizing plant switchgear and using microprocessor-based, multi-functional relays would significantly improve the reliability of power supply to the pumping plant.
- New cable feeders from Switchgear UHA to pumping plant main switchgear would improve overall system reliability at a relatively moderate cost and with little disruption to plant operations.
- The configuration of the pumping plant's main switchgear 1 and switchgear 2 should be changed to provide redundancy and improve power supply reliability; under the existing system configuration, pumps would lose power upon failure of breakers or interconnecting cables.

The plant's controls appear to have adequate reliability. Since pump 7 and 8 share a control power supply, however, a malfunction or even a blown fuse can cause loss of control power to both pumps. To improve reliability, a separate power supply should be provided for each pump control circuit.

Corrective Measures and Their Cost

The following five corrective actions were identified that could be implemented individually or in various combinations:

- *Development and adoption of new Standard Operating Procedures (SOP):* The current SOP could be revised to operate pumps at their proper TDH; this would require throttling discharge valves on pumps 6, 7, and 8 as necessary, and operating constant speed pumps only when the TDH is within acceptable ranges, since existing gate valves would not allow throttling. If new valves and/or pumps are to be installed, development of a new SOP should be delayed to incorporate details of the operation of the new equipment.

  Costs: In-house preparation assumed, no external costs, and no equipment purchase involved.

- *Installation of butterfly valves on pump discharge pipes that lack them:* The new valves would include automated controls to operate pumps within acceptable TDH ranges. The existing SOP would have to be revised upon valve installation.

  Costs: Five new butterfly valves of appropriate sizes would cost approximately $315,000, including automated controls.

- *Power supply upgrades:* Could range from replacement of power cables to installation of new, modern switchgear with microprocessor-based, multi-functional relays. Improving the reliability of plant's main switchgear 1 and switchgear 2 is recommended to provide redundancy of power supply to the pumps.

  Costs: Cable replacement could be done for about $200,000; switchgear UHA could be upgraded for about $600,000. Refurbishing the plant's main switchgear would cost around $2M.

- *Installation of new variable speed pumps:* Options to install three, four, or five pumps were assessed. New valves are assumed with the new pumps. Power supply upgrades would be necessary as well, as the new pumps would increase the total power demand at the plant. A new SOP would be needed.

  Costs: New pumps, valves, and associated controls would cost from $5.1M dollars (for three pumps) to $8.4M dollars (for five pumps). A major overhaul of the power supply system would require an additional expenditure of about $2M dollars.

- *Pump intake reconfiguration:* A new intake configuration would improve the efficiency of the existing pumps only if they are operated within acceptable ranges; new discharge valves and a new SOP would be required along with the intake reconfiguration; pumps could remain as they are, and minor power supply upgrades would suffice.

  Costs: A physical model study (approximate cost $150,000 to $200,000) is recommended to design the reconfiguration of the pump intakes. Cost of the reconfiguration would depend on the design developed through the model tests. Minor modifications to the intake piping could cost under $1M. Major restructuring of the pumping plant intake, if required, could cost upwards of $5M.

1 INTRODUCTION

1.1 Background

The Bureau of Reclamation ("USBR" or "Reclamation") operates a pumping plant and several pipelines that supply water from Folsom Reservoir to the City of Folsom, Folsom Prison, the City of Roseville, and the San Juan Water District (SJWD). Projected increases in water demand will increase the burden on pumps, pipes, and power supplies, with possible adverse effects on system performance and maintenance needs.

The pumping plant and pipelines have experienced some operational problems at current delivery volumes. Standpipes have been overtopped a few times. Variable speed pumps are not operational through their full range. Constant speed pumps exhibit noises typically associated with cavitation (the rapid formation and collapse of bubbles), which can damage pumps and shorten their useful life.

The power supply to the pumping plant lacks redundancy, which could result in a halving of the pumping plant capacity if one of its two power sources were lost. In that case, only four of the eight pumps in the plant would remain operational until an alternate power source could be brought on line.

Energy usage is impacted by reservoir water levels and other factors: operation of pumps at low efficiencies, for example, increases power requirements; the settings in the programmable logic controller at the pumping plant affect pump performance and energy consumption; pump selection can also affect power consumption.

1.2 Scope

This report presents the results of studies performed to evaluate system capacity as well as operational and energy usage issues associated with the Folsom Pumping Plant and water delivery pipelines. The scope of the studies included:

- Collection and analysis of system configuration and operational data.
- Evaluation of the hydraulic performance of the pumping system (pumps, pipes, valves, fittings, surge tanks), including an assessment of variable frequency drive (VFD) operation.
- Evaluation of the potential impacts that sustained deliveries at higher-than-current volumes would have on system components.
- Evaluation of power supply and control systems.
- Development of recommended changes to the pumping plant and their estimated costs.

Technical memoranda were prepared at the end of each project phase to summarize results of evaluations of hydraulic performance, power/control systems reliability, and impacts of increased demands. This final report consolidates project findings, conclusions, and recommendations.

1.3 Objectives

The objectives of the tasks addressed in this report were to:

- Identify physical and operational deficiencies in the pumping system at current delivery volumes and recommend corrective measures.
- Assess the impacts of higher delivery volumes on system components and plant operations.
- Define current operational limits of pumping plant, pipelines, and electrical system.

1.4 Changes

There were two significant changes to the water delivery system since this project was started in September 2007:

- A new pipeline, along with a surge protection standpipe and associated valves, was added in 2010 as part of the Raw Water Bypass Pipeline Project.
- Parts of the Natoma Pipeline were reconfigured and re-aligned in 2010-2011.

The effects of these changes, if any, on hydraulic calculations and performance evaluations are noted where appropriate.

1.5 Report Organization

The remainder of this report is organized as follows:

- *Section 2 – System Configuration and Operational Data*
    - ❖ System description based on available drawings and field inspections
    - ❖ Operational data based on available documentation and interviews with operators and water customers
- *Section 3 - Hydraulic Performance Evaluation*
    - ❖ Basis of hydraulic performance evaluation
    - ❖ Ability to satisfy demands through gravity flows
    - ❖ Ability to satisfy demands through pumping
    - ❖ Conclusions about hydraulic performance
- *Section 4 – Evaluation of the Effects of Higher Demands*
    - ❖ Basis of evaluation
    - ❖ Impact of higher flow velocities
    - ❖ Raised gravity flow thresholds
    - ❖ Increased frequency of pump use
    - ❖ Increased power consumption
    - ❖ Conclusions about impacts of higher demands

- *Section 5 – Evaluation of Power and Control Systems*
  - ❖ Basis of electrical and control systems evaluation
  - ❖ Configuration of electrical and control systems
  - ❖ Reliability of electrical and control systems
  - ❖ Conclusions about power and control system reliability
- *Section 6 – Recommended Actions and Their Approximate Costs*
  - ❖ Development and adoption of new SOP
  - ❖ Discharge valve replacement
  - ❖ Upgrades of power supply
  - ❖ Pump replacement
  - ❖ Pump intake reconfiguration
  - ❖ Combinations of recommended actions
  - ❖ Impacts of recommended actions
- *Appendices*
  - ❖ References
  - ❖ Field tests
  - ❖ Hydraulic model
  - ❖ Pump curves
  - ❖ Referenced electrical/control drawings
  - ❖ Proposed pump selection schedule
  - ❖ Reclamation comments on first draft of report and WRE responses

1.6 Units and Datum

Flow rates and pressures can be reported in a variety of units. This report uses cubic feet per second (cfs) for flow rates and "feet of head" to indicate the height of the water column in pipelines or the lift provided by pumps. Commonly used conversions are listed below:

- 1 cfs = 448.8 gallons per minute (gpm) = 0.65 million gallons per day (MGD)
- 1 MGD = 1.55 cfs
- 1 foot of head = 0.43 pounds per square inch (psi)
- 1 psi = 2.31 feet of head

Elevations are reported in feet, and are referenced to the North American Vertical Datum of 1988 (NAVD88), unless otherwise noted. NAVD88 is the datum used by the California Data Exchange Center to report water surface elevations in reservoirs, including Folsom Reservoir. Some Reclamation drawings referenced in this document use the National Geodetic Vertical Datum of 1929 (NGVD29) which was used prior to the 1980s and is also referred to as the Mean Sea Level datum. NAVD88 and NGVD29 are related as follows at the Folsom Dam:

NGVD29 elevation + 2.34 feet = NAVD88 elevation

2 SYSTEM CONFIGURATION AND OPERATIONAL DATA

This section of the report describes the water delivery system associated with the Folsom Pumping Plant and outlines operations data. The water delivery system is broken down into the following components:

- Water source
- Water transmission pipelines
- Pumps
- Appurtenances
- Flow control valves
- Electrical power supply
- Control system

Operational data for the water delivery system include:

- Current and future water demands
- Water surface elevations that impact water deliveries
- VFD and constant speed pump operation

2.1 System Description

The water delivery system associated with the Folsom Pumping Plant is considered a "municipal and industrial" (M&I) system. That designation indicates that the system delivers untreated (raw) water to end users.

The conveyance of raw water from the Folsom Reservoir to four end users (SJWD, City of Roseville, Folsom Prison, and City of Folsom) requires a complex system of pipes, valves, flow meters, surge protection towers, and electric-motor-driven pumps. The approximate alignment of pipelines and locations of system end points are shown in Figure 2-1. A flow diagram for the raw water delivery system is presented in Figure 2-2. System components are described below.

2.1.1 Water Source

Folsom Reservoir is the water source for the raw water delivery system associated with the Folsom Pumping Plant. Folsom Dam regulates runoff from about 1,875 square miles of drainage area. The reservoir has a normal full-pool storage capacity of 975,000 acre-feet with a minimum seasonally designated flood control storage space of 400,000 acre-feet. Roughly 100,000 acre-feet of raw water are delivered annually to the larger customers, SJWD and the City of Roseville. About 40,000 acre-feet are delivered to the City of Folsom and Folsom Prison per year.

Figure 2-1 Raw Water Delivery System Layout

* North Fork Pipelines include an above-ground 84-inch diameter pipe and an underground 72-inch diameter pipe that extend in parallel from a point roughly 100 feet downstream of the Folsom Pumping Plant to the Hinkle Y

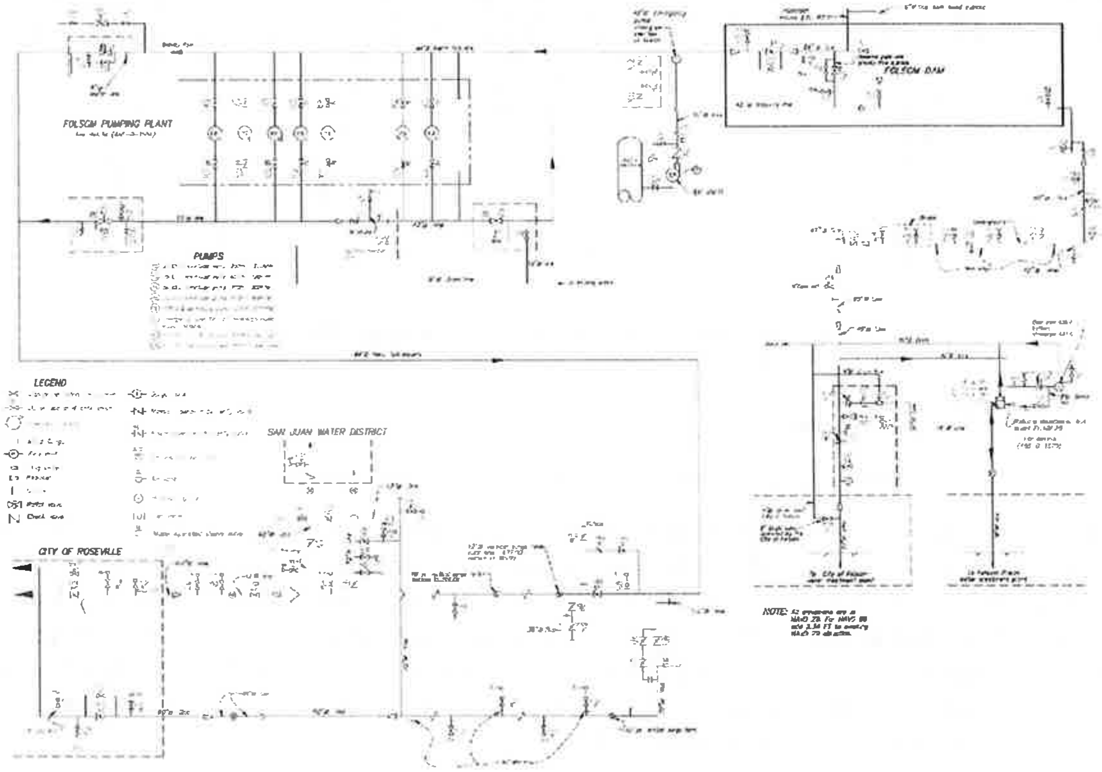

Figure 2-2 Folsom Pumping Plant Water Distribution Flow Diagram
Source: Drawing 485-218-688, Folsom Pumping Plant Water Distribution Flow Diagram, USBR, August 8, 1991, Last Revision November 4, 2010

Water surface elevation in the reservoir has fluctuated between 366.8 (winter 2008) and 465.4 (spring 2005) feet since 2001, as shown in Figure 2-3. When the reservoir water level is high, typically in the springtime, water can flow by gravity to the four end points. The threshold at which deliveries can be made by gravity depends on the total system demand (i.e., the higher the demand, the higher the reservoir water level needs to be).

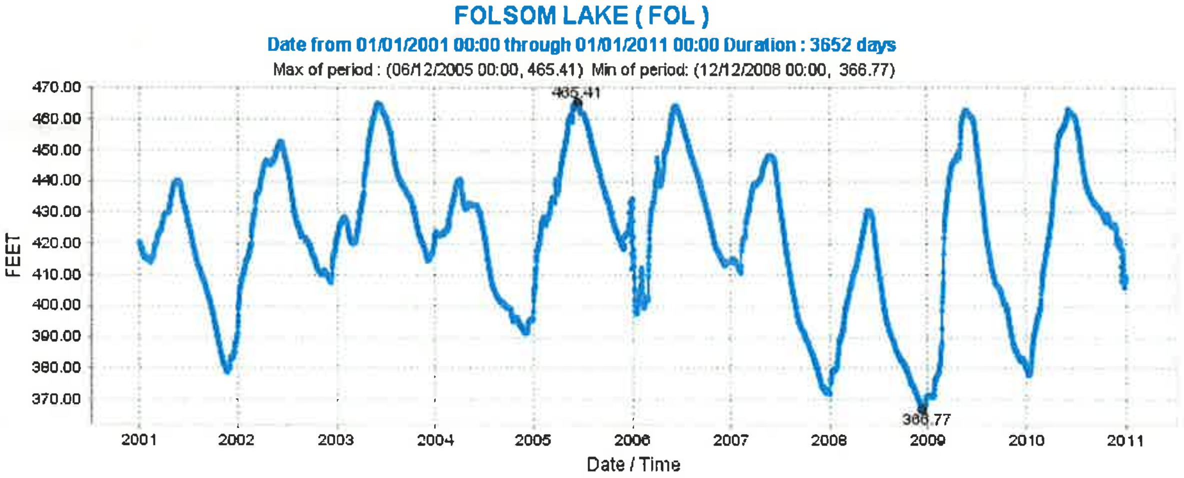

Figure 2-3 Folsom Reservoir Water Levels 2001-2010
Source: California Data Exchange Center

2.1.2 Water Transmission

Water is conveyed from Folsom Reservoir to four end users through four pipelines:

- *The North Fork Pipelines:* The original pipeline is an 84-inch-diameter above-ground steel pipe with two surge-protection standpipes (Figure 2-4). The pipeline originates at the Folsom Dam intake structure and extends about 4,000 feet above ground to the "Hinkle Y." A parallel 72-inch-diameter underground steel pipeline was added in 2010 (Figure 2-5) to provide redundancy in case the original pipeline failed or needed maintenance. The North Fork Pipelines can deliver gravity or pumped flows to the SJWD and City of Roseville pipelines, which originate at the Hinkle Y.
- *SJWD Pipelines:* Two above-ground parallel steel pipes, 42 and 72 inches in diameter, originate at the Hinkle Y. The respective diameters change to 54 and 66 inches about 850 feet downstream of the Hinkle Y, at the location of crossover valves that interconnect the two pipes. About 750 feet further downstream, the two pipes combine into a single 54-inch-diameter pipe that conveys gravity and pumped flows to the SJWD Water Treatment Plant
- *City of Roseville Pipelines:* Two underground pipelines, 48 and 60 inches in diameter, deliver Folsom Reservoir water to the City of Roseville's water treatment plant. The two pipelines originate from a 60-inch-diameter pipeline that extends 434 feet from Reclamation's metering facility at the Hinkle Y toward the Auburn Folsom Road. The 48- and 60-inch-diameter lines are roughly 9,000 feet long each.

Figure 2-4 North Fork Pipeline and Main Standpipe, Looking East (Picture on Left, with "Old" [2009] Natoma Pipeline in Background), and 84-inch North Fork Pipeline and 10-foot-diameter Standpipe, Looking West Toward Hinkle Y (Picture on Right)

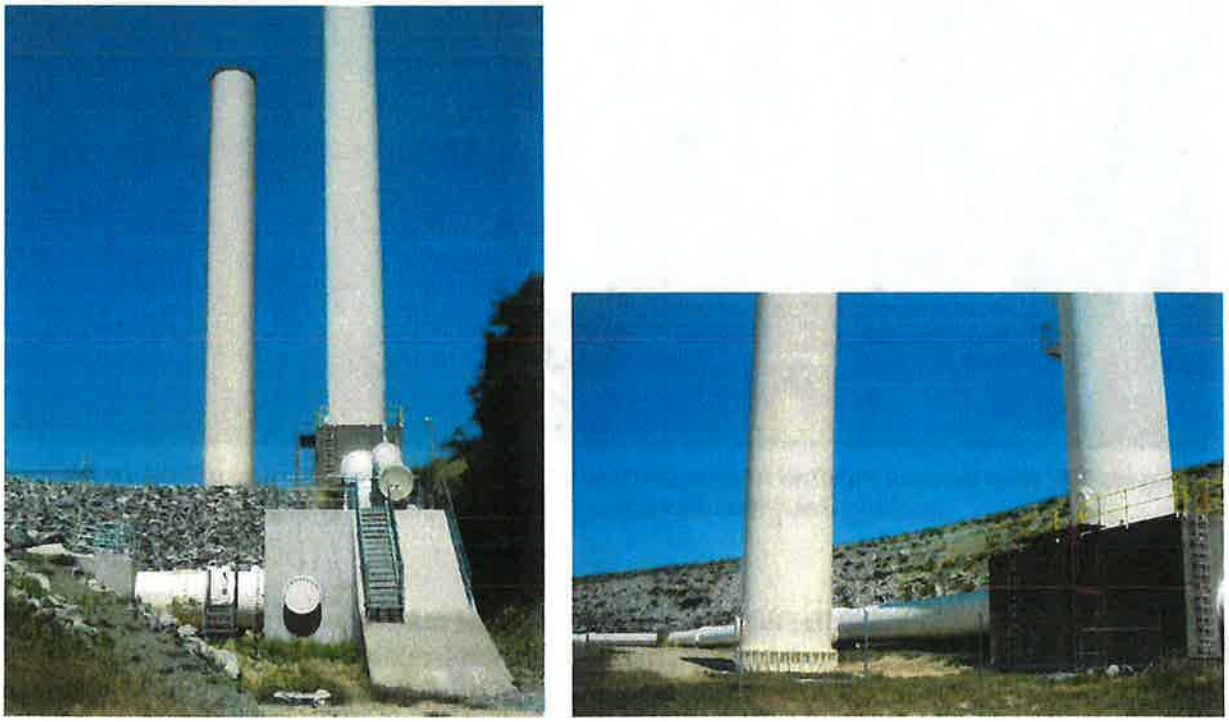

Figure 2-5 Connection to New 72-inch-diameter Pipe (Picture on Left); Standpipes on Above-ground and Underground Pipes (Picture on Right)

- *The Natoma Pipeline:* This 42-inch-diameter steel pipe branches off the North Fork Pipeline roughly 50 feet downstream of the Folsom Dam raw water intake. The pipeline is also connected to the Folsom Pumping Plant discharge manifold, which allows it to convey pumped flows to the City of Folsom and Folsom Prison water treatment plants. A construction project initiated by the City of Folsom replaced parts of the Natoma Pipeline with new 48- and 60-inch-diameter pipes (Figure 2-6). This project included the addition of a new 18-inch-diameter pipe originating at the Natoma Pipeline isolation valve structure and extending to Folsom Prison's water treatment plant; the project also included replacement of the pipeline's surge protection standpipe with a new 10-foot diameter standpipe with an overflow elevation of 436 feet.[2]

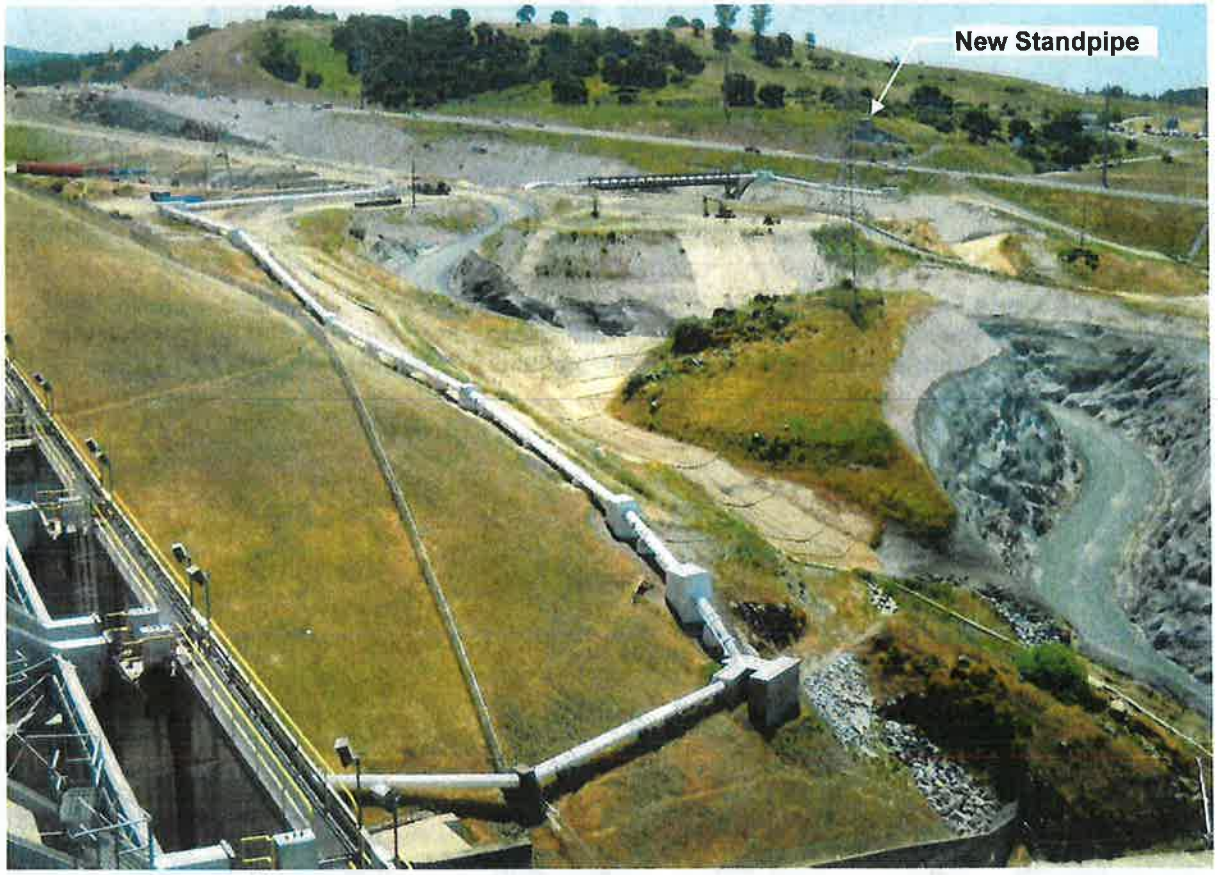

Figure 2-6 New Natoma Pipeline Alignment (May 2011), as Seen from the Top of Folsom Dam Looking East; New Standpipe in Upper Right of Picture

2.1.3 Pumps

Eight pumps are available to raise the hydraulic grade line of reservoir water to satisfy downstream demands. Seven of the pumps, five with constant velocity and two with variable frequency drives, are within the Folsom Pumping Plant (Figure 2-7); pump suction piping is connected to the 84-inch-diameter North Fork Pipeline (centerline elevation of 317.1 feet). The

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[2] Per Sheet C-10, "Standpipe Plans, Section, and Details," City of Folsom "Natoma Standpipe Relocation" drawings, March 2007.

eighth pump, designated the "emergency pump," is located in a separate enclosure adjacent to Penstock No. 1 (Figure 2-8); the pump's 36-inch diameter suction line taps the penstock at elevation 261.34 feet. Pump capacities[3] range from roughly 20 to 90 cfs for lifts ranging from 84 to 126 feet. Motor horsepower range is from 250 to 1,500.

Figure 2-7 Folsom Pumping Plant Pumps, Looking South from Entrance Nearest Dam

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[3] At points of maximum efficiency on pump curves.

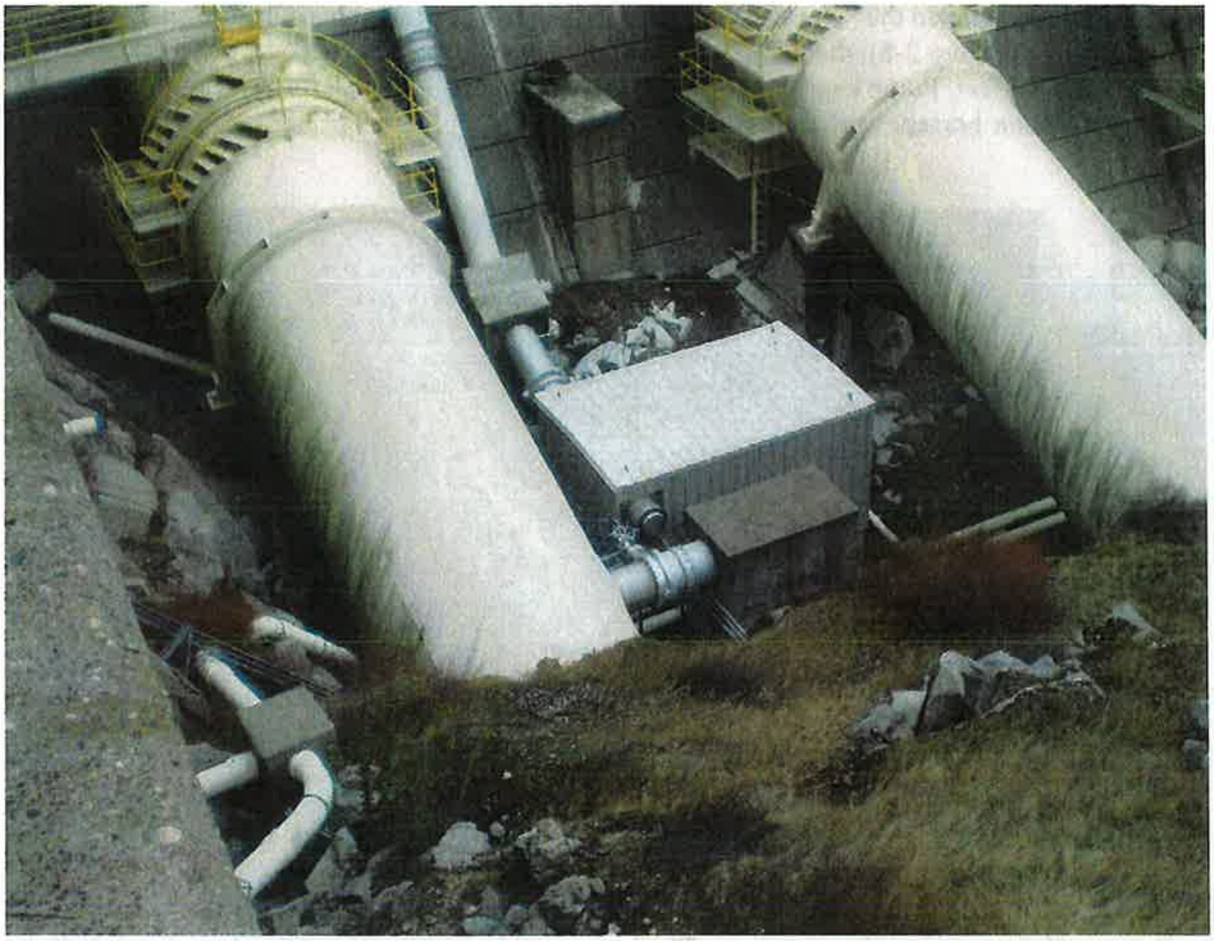

Figure 2-8 Emergency Pump Enclosure Adjacent to Penstock No. 1

2.1.4 Appurtenances

Appurtenances include surge protection towers, valves, and flow meters. Additional appurtenances include air relief and drain valves, overflow piping, and instrumentation and controls.

Surge Protection

The North Fork Pipelines have three surge protection towers:

- Two towers are located about 200 feet downstream of the pumping plant: a 12-foot diameter tower on the 84-inch-diameter pipe and a 10-foot-diameter tower on the 72-inch-diameter pipe. The towers overflow at elevation 479.34 feet.[4]
- A 10-foot-diameter standpipe on the 84-inch-diameter pipe, with overflow at elevation 479.34 feet, is located about 2,200 feet downstream of the pumping plant.

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[4] As previously indicated, elevations are consistently referenced to NAVD88 datum.

The Natoma Pipeline has a 10-foot diameter standpipe with roof at elevation 440 feet (overflow at elevation 436 feet and maximum operating level at 434 feet). A 30-inch diameter pipe connects the pipeline to the standpipe.[5]

The 36-inch-diameter emergency pump discharge line has a 48-inch-diameter standpipe that rises along the outside face of Folsom Dam. The standpipe overflows at elevation 452.34 feet.

Valves

The system includes over 80 valves of various types and sizes, both manual- and motor-operated (see Figure 2-2). Most of the valves are of either the gate or butterfly type.

Flow Meters

There are flow meters on the North Fork, Natoma, SJWD, and City of Roseville pipelines, as indicated in Figure 2-2.

2.1.5 Flow Control

Flow rates are controlled by throttling valves at three of the system's four end points. Operators at the water treatment plants at SJWD, City of Roseville, and City of Folsom set a target flow rate and their automated valves open or close as needed to maintain the target flow rate. The flow rate to Folsom Prison is partially controlled by an overflow weir in a distribution box. The box is located a short distance upstream of the prison's pump station wet well, which is the raw water delivery point.

Current practice is not to throttle any of the valves in the pumping plant. Valves on the pumps' discharge pipes are programmed to open slowly as the pumps are turned on and operate fully open. Pumps 6, 7, and 8 have butterfly valves, which would allow throttling. The other pumps have gate valves, which are not designed for and could be damaged if continuously operated partially open.

2.1.6 Electrical Power Supply

A double-ended substation supplies electrical power to the pumping plant's 4.16kV switchgear (labeled "UHA"). Switchgear UHA receives power from two transformers, designated KZ4A and KV9A. Switchgear UHA has two main breakers, 52-A and 52-B; the first connects to transformer KV9A and the second to both transformer KZ4A and a tie breaker designated UHA5. The main breakers and the tie breaker are electrically interlocked.

Switchgear UHA is connected to the pumping plant's switchgears 1 and 2. Switchgear 1 provides power to 208/120V panel CPC through transformer KPA. Switchgear 2 provides power to 208/120V panel CPB through transformer KPB. Both transformers KPA and KPB provide power to 208/120V panels CPA and CPD through an automatic transfer switch.

The electrical supply to the pumping plant is discussed in greater detail in Section 5 of this document.

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[5] According to Sheet C-10, "Standpipe Plans, Section, and Details," City of Folsom "Natoma Standpipe Relocation" drawings, March 2007.

2.1.7 Control System

Information about the configuration of the control system was derived from two drawings. Pumping Plant Expansion Project drawing E-3 shows that the VFD pumps (7 and 8) and their motor-operated discharge valves (V14 and V26) are hard-wired for start/stop or open/close control, interlock, and remote monitoring. The VFD pumps share an 115VAC-24VDC control power supply. The VFD control and the PLC in remote panel 1101 are mentioned in the drawing, but no details are provided.

Reclamation drawing No. 485-218-1461 is a partial representation of the Pumping Plant Central Start/Stop Control Schematic. The drawing indicates that a loss of 24V control power device 27CPC was installed (the device, however, is not shown on the drawing). How the Central Start/Stop Control is connected to each pump's start/stop control circuit is likewise not shown. The physical protection of these control circuits from central control to local pump could not be determined from available information.

2.2 Operational Data

The raw water delivery system is expected to convey water continuously to SJWD, City of Roseville, City of Folsom, and Folsom Prison water treatment plants, at the rates they individually require. Water deliveries are preferably made by gravity, when the water level in Folsom Reservoir allows it. When the water level in the reservoir is too low to satisfy demands by gravity, pumps are turned on to provide the necessary lift. VFD pumps are used before constant speed pumps. Information about water demand, water surface elevations that impact water deliveries, and VFD and constant speed operation is presented below.

2.2.1 Current and Future Water Demands[6]

Typical winter and summer demands from the four water purveyors supplied through the Folsom Pumping Plant are presented in Table 2-1. Seasonal fluctuations are illustrated in Figures 2-9 and 2-10.

Table 2-1 Typical Winter and Summer Demands

	Flow Rates (cfs)				
Demand Condition	**SJWD**	**City of Roseville**	**City of Folsom**	**Folsom Prison**	**Total**
Typical winter demands	40	32	25	3	**100**
Typical summer demands	170	77	57	5	**309**

Raw water demands are limited by treatment capacities. The Folsom Reservoir water goes directly into the treatment trains at the SJWD, City of Roseville, City of Folsom, and Folsom Prison treatment plants. The maximum flow rate each of these purveyors can request at any one time, therefore, is the maximum flow rate that their plants can treat. Current and future treatment capacities (i.e., maximum demands) are summarized in Table 2-2.

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[6] Based on information provided in 2009 by Bill Sadler (SJWD), Shawn Barnes (City of Roseville), Todd Eising (City of Folsom), and Pedro Reyes (Folsom Prison).

Table 2-2 Current and Future* Maximum Demands

	Flow Rates (cfs)				
Purveyor	SJWD	City of Roseville	City of Folsom	Folsom Prison	Total
2009 Treatment Capacity	186	93	77	5	**361**
Planned Future Capacity	232	155	77	10	**474**

* San Juan Water District: Timing of future treatment plant upgrades is uncertain, as they depend on development within their service area and consequent demand increases.

City of Roseville: Already increased its treatment capacity from 93 cfs to what it considers the "ultimate" treatment capacity of 155 cfs, but demand will likely stay under the 93 cfs range for the next several years.

City of Folsom: No treatment planned upgrades currently planned.

Folsom Prison: Changes to increase capacity are under way in 2011.

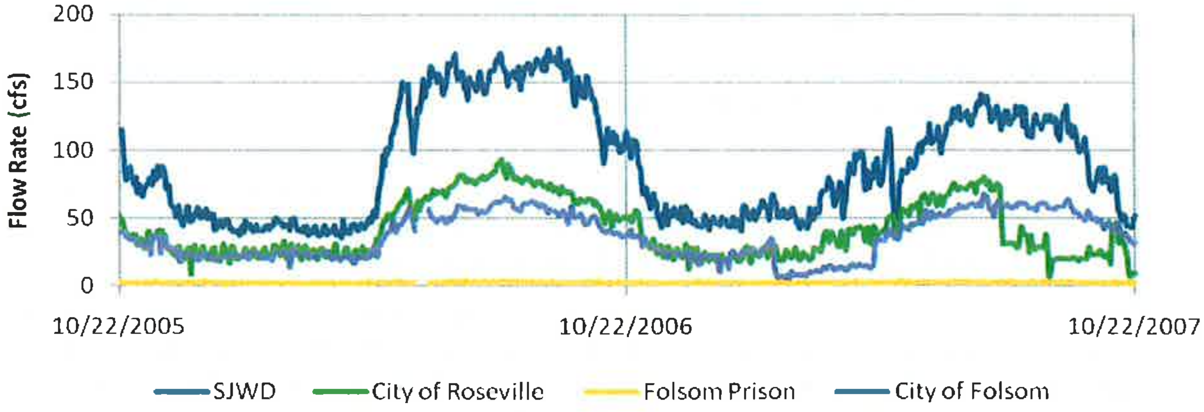

Figure 2-9 Average Daily Flows to Each of Four Purveyors, 2005-2007

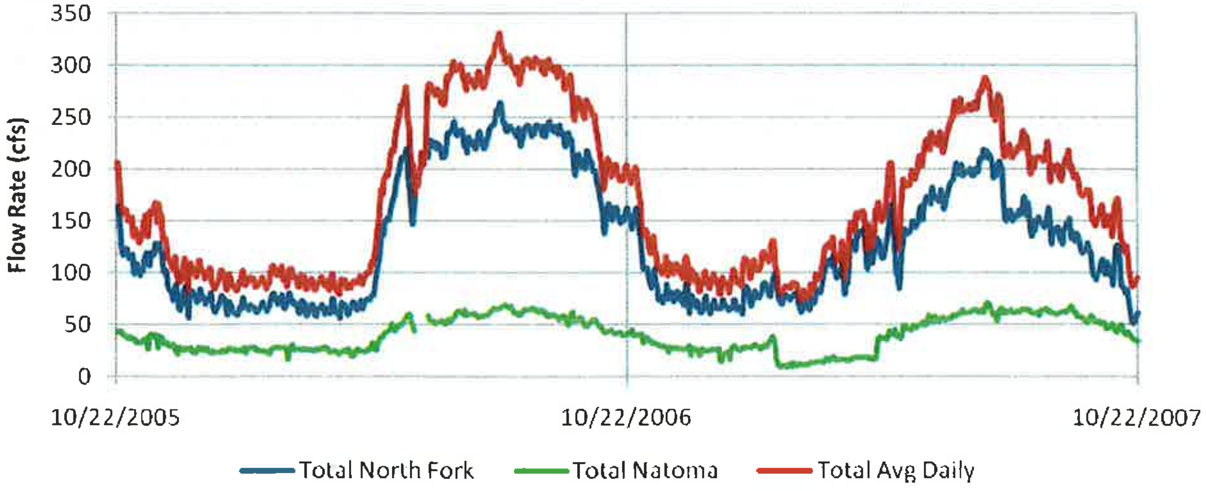

Figure 2-10 Total Average Daily Flows from 2005 to 2007

2.2.2 Elevations Relevant to Water Deliveries

Elevations relevant to water deliveries from the Folsom Pumping Plant system are listed below; most are illustrated graphically in Figure 2-11

- *Folsom Reservoir water level:* The water level in the reservoir changes continuously throughout the year, as shown in Figure 2-3. Gravity flows to the North Fork Pipelines are possible when the reservoir level is above 425 feet; summer demands would require higher reservoir levels, typically above 430 feet. Gravity flows to the Natoma Pipeline are possible when the reservoir level is above 410 feet.
- *End point water levels:* Water levels at the end points, shown graphically in Figure 2-11, remain largely unchanged over time, as they depend on process elevations in each water treatment plant.
- *Elevations of raw water intakes:* Very low water levels in the reservoir, at or below elevation 332 feet, render the intake to the pumping plant unusable.[7] The intake to the emergency pump would remain usable for reservoir water levels as low as 310 feet; the emergency pump draws water from one of the power penstocks, located roughly 20 feet lower than the raw water intake. The actual intake point from the penstock to the pump suction pipe is at elevation 261.34 feet.
- *Overflow level in North Fork Pipelines standpipes:* The overflow level in the standpipes is higher than the maximum lake level and would therefore not be reached under gravity flow conditions; it could be exceeded, however, during pumping operations.
- *Overflow level in Natoma Pipeline standpipe:* The overflow level in the new standpipe is at elevation 436 feet; the water level in the reservoir goes above that elevation almost every year (see Figure 2-3); selected valves on the Natoma Pipeline are closed or throttled to prevent overflows at reservoir levels above 436 feet.
- *Overflow level in emergency pump standpipe:* The emergency pump standpipe overflows above elevation 452.34 feet. Water levels need to be monitored and the 36-inch butterfly valve on the discharge line possibly throttled to prevent standpipes from overflowing when the emergency pump is activated. If the emergency pump is operated in accordance with its Standard Operating Procedure no valve throttling would be required, as the pump would not be operated for reservoir levels above 330 feet; the pump has a 100-foot lift and would therefore not be able to reach the overflow level when operated at reservoir levels of 330 feet and lower.

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[7] At least 10 feet of water depth above the crown of the intake are needed to prevent air entrainment, which could lock the pumps and/or result in cavitation.

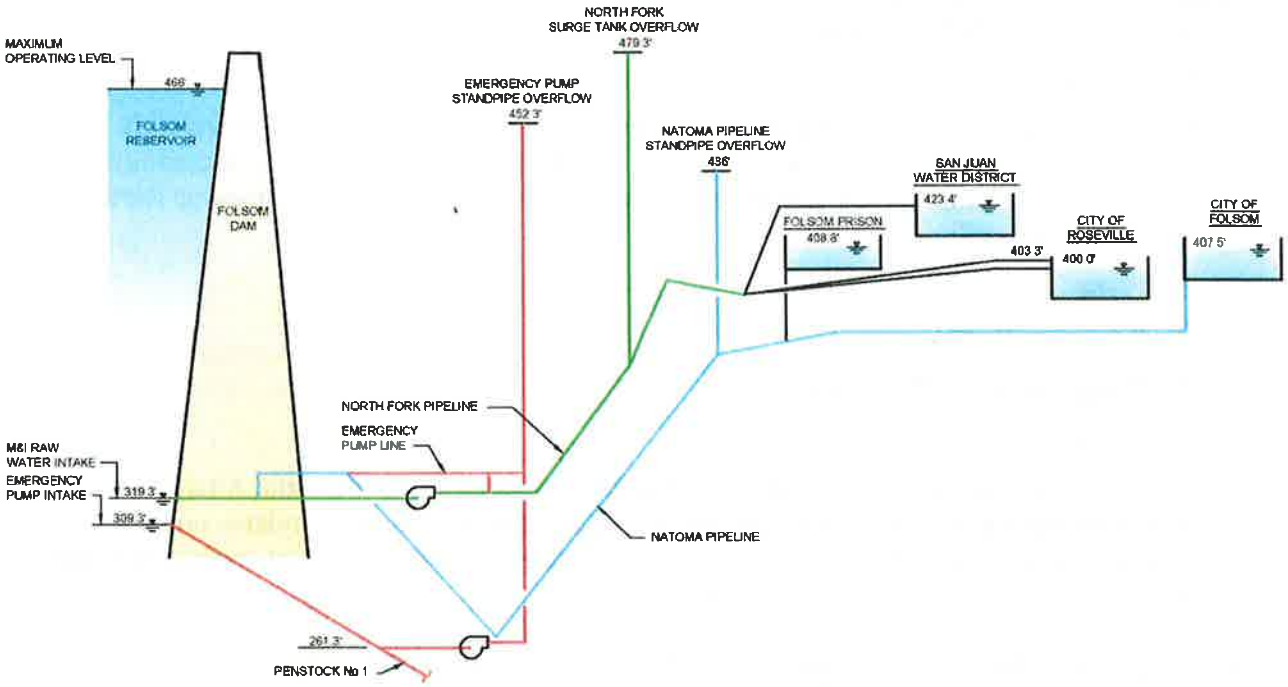


Figure 2-11 Water Surface Elevations that Impact Water Deliveries

2.2.3 Pump Operation

Pumps can be operated from the Folsom Power Plant control room or from the pumping plant. On and off controls are available at both the control room and the pumping plant. Operators prefer to operate pumps from the pumping plant in order to visually confirm proper operation. Standpipe set points for variable speed pump operation can be changed only at the pumping plant.

Variable speed pumps are generally turned on before constant speed pumps. Operators limit operation of the VFDs to speeds between 50 and 75 percent of full speed and pump controls are locked to prevent operation above 75 percent speed. Operators also avoid running the two VFDs together for reasons explained in Section 3 of this document. Under current operating procedures, pumps are activated as follows:

1. Operators assess demand based on requests from four purveyors.
2. Operators select pumps to satisfy total demand. Either Pump 7 or Pump 8 (pumps with VFDs) is selected to satisfy demands up to 85 cfs; if demand exceeds 85 cfs, one or more constant speed pumps are turned on along with one VFD, based on labels on pump startup buttons which read:
    - Pump 2 = 25 cfs
    - Pump 3 = 75 cfs
    - Pump 4 and 5 = 50 cfs each
    - Pump 6 = 100 cfs
3. Operators activate pumps, generally from the controls in the pumping plant. A target North Fork Pipeline surge tank level is selected by looking it up in a table that relates surge tank levels to SJWD demand. A setting for the VFD is determined by looking it up on a table that relates surge tank level to VFD set point.

Pump operation and pump capacities are discussed in detail in Section 3 of this document.

3 HYDRAULIC PERFORMANCE EVALUATION

The hydraulic performance of the raw water delivery system was evaluated to identify physical and operational deficiencies in the pumping system at current delivery volumes and recommend corrective measures. The evaluation also helped define current operational limits of the pumping plant and pipelines. This section of the report presents:

- Basis of hydraulic performance evaluation
- Ability to satisfy demands through gravity flows
- Ability to satisfy demands through pumping
- Conclusions about hydraulic performance

3.1 Basis of Hydraulic Performance Evaluation

The hydraulic performance of the raw water delivery system associated with the Folsom Pumping Plant was evaluated on the basis of:

- Available data
    - ❖ Document review
    - ❖ Inspections
    - ❖ Interviews
- Field tests to measure actual head losses
- Computer simulations

3.1.1 Available Data

Document Review
A variety of drawings and documents were reviewed, including (see Appendix A for a full list):

- Pumping plant expansion drawings prepared by SAI Engineers for USBR in 1997.
- Roseville 60" Raw Water Pipeline Project drawings prepared by Boyle Engineering in 2001.
- Natoma Standpipe Relocation drawings prepared by Robert W. Miles for the City of Folsom in 1997.
- Construction of Natoma Pipeline Phase A drawings prepared by Robert W. Miles for the City of Folsom in 1998.
- Natoma Raw Water Pipeline Phase B drawings prepared by CDM for the City of Folsom in 2000.
- Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda, prepared by Will B. Betchart in March 2000.
- Folsom Pumping Plant Capacity Evaluation, Attachment B-1: Maximum Bypass Capacity through the Discharge Header Assuming Maximum Flood Control Water Surface, prepared by Will B. Betchart in December 2004.

- Folsom Pumping Plant Emergency Pump Test, prepared by Will B. Betchart in December 2004.
- Designer's Operating Criteria and Standard Operating Procedure, Folsom Dam Emergency Pumping Plant, prepared by USBR.
- Pump Test Data from Ingersoll-Dresser Pump Company, May 1998.
- Daily Flow Data for 2004-2006 provided by SJWD and City of Roseville.
- Daily Flow and Pump Operation Data for 2004-2006 provided by USBR.

Inspections

Above-ground system components were visually inspected several times over the course of the project. The inspections served to confirm and supplement information on drawings and other documents.

Interviews

Interviews were conducted with:

- Reclamation's mechanical and electrical engineering staff at the Folsom office, to discuss system design and operating criteria.
- Folsom Pumping Plant operators, to review current operating practices and discuss system limitations.
- Treatment plant operators at SJWD, City of Roseville, City of Folsom, and Folsom Prison, to discuss raw water demands, flow controls, future expansions, and raw water delivery details.

3.1.2 Field Tests to Measure Actual Head Losses

Field test were conducted to measure actual energy losses during system operation. Tests were performed on April 29, 2009, following a previously devised and approved test plan. Data inconsistencies prompted a topographic survey to verify key pipeline elevations; WRE conducted a simple survey to verify North Fork Pipeline elevations from the pumping plant to the Hinkle Y. Once the data inconsistencies were resolved, a memorandum presenting the results of the head loss tests was prepared (attached in Appendix B). Test results were used to calibrate the computer model that was developed to evaluate hydraulic performance.

3.1.3 Computer Simulations

A hydraulic model of the system was developed to simulate current and future operating conditions. InfoWater, a geospatial water distribution system modeling tool, was used to model the raw water delivery system. The attributes of system components (elevations of junctions and valves, lengths and diameters of pipes, pump characteristics, reservoir water levels) were coded into the InfoWater model.

The computer model was initially calibrated using calculated head losses and later re-calibrated using data from field tests conducted in April and September, 2009. The calibrated version of the model closely reproduces head losses measured during field tests.

Additional details of model development and a listing of the system characteristics entered into the model are included in Appendix C.

3.2 Ability to Satisfy Demands through Gravity Flows

The ability of the system to satisfy demands through gravity flows was assessed by evaluating:

- North Fork Pipeline gravity flows.
- Natoma Pipeline gravity flows.
- Frequency of gravity flows.

3.2.1 North Fork Pipeline Gravity Flows

The threshold water levels at which typical and maximum water deliveries become possible via gravity flow were calculated using the hydraulic model. Computer simulations were performed assuming simultaneous delivery to four end users. Valves at each end point were throttled as needed to achieve the combination of demands under consideration. Typical demands were derived from historical data; current and future treatment plant capacities were provided by Chief Operators at each site.

The reservoir water levels at which deliveries can be made through the North Fork Pipeline are controlled by SJWD. The target water level at the SJWD treatment plant is 425.4 feet. The target water level at the City of Roseville treatment plant is 400 feet. Reservoir water levels higher than 400 feet would make possible gravity flows to the City of Roseville, but only water levels higher than 425.4 would make possible gravity flow to SJWD. In order to deliver to the two purveyors simultaneously, the higher reservoir water levels must be used, hence the intake valves at the City of Roseville treatment plant must be throttled accordingly.

The computed threshold water levels are listed in Table 3-1. The simulations assumed all flow through the (original) 84-inch-diameter pipeline. If the 72-inch pipeline alone were used, the threshold levels would be higher. If the two pipelines were used together, the threshold levels would be slightly lower than those presented in Table 3-1.

Table 3-1 Reservoir Water Levels Required to Meet North Fork Pipeline Demands by Gravity

Demand Condition	Flow Rates (cfs) SJWD	Flow Rates (cfs) Roseville	Flow Rates (cfs) Total	Min. Water Level in Folsom Reservoir (ft)
Typical winter demands	40	32	72	426
Typical summer demands	170	77	247	439
Current maximum demands (Existing capacity of treatment plants)	186	93	279	441
Future maximum demands (Projected treatment plant capacities)	232	155	387	455

3.2.2 Natoma Pipeline Gravity Flows

The threshold water levels for typical and maximum demands were similarly computed for the Natoma Pipeline. Since it is possible to deliver water by gravity to Natoma Pipeline end users while pumping to North Fork Pipeline end users (closing valve V5 while V10 is open), the target levels for SJWD do not control threshold levels for Natoma Pipeline flows.

The reservoir water levels at which deliveries can be made through the Natoma Pipeline are controlled by target water levels at the City of Folsom treatment plant (elevation 407.5 feet as shown in Figure 2-11) and Folsom Prison (elevation 408.8 feet). Reservoir water levels above elevation 436 feet require valve throttling to prevent overflows at the standpipe.

The computed threshold water levels are listed in Table 3-2. The simulations assumed the pipe lengths and diameters corresponding to the new Natoma Pipeline, as reflected in *Construction of Natoma Pipeline Phase A* drawings.

Table 3-2 Reservoir Water Levels Required to Meet Natoma Pipeline Demands by Gravity

	Flow Rates (cfs)			
Demand Condition	**City of Folsom**	**Folsom Prison**	**Total**	**Min. Water Level in Folsom Reservoir (ft)**
Typical winter demands	25	3	28	413
Typical summer demands	57	5	62	424
Current maximum demands (Existing capacity of treatment plants)	77	5	82	435
Future maximum demands (Projected treatment plant capacities)	77	10	87	436

3.2.3 Frequency of Gravity Flows

The raw water delivery system cannot satisfy demands year-round by gravity alone. Between January 1, 2000 and November 30, 2007 gravity flows were possible between 28 and 55 percent of the time:

- *North Fork Pipeline:* 698 days or 28 percent of the total number of days.
- *Natoma Pipeline:* 1,412 days or 55 percent of the total number of days.

These frequencies are based on actual reservoir water levels, actual water demands, and calculated threshold levels generated by the computer model. The frequencies do not necessarily reflect actual system operation during that period.

Future reservoir water levels are difficult to predict. If they remain at approximately the same levels observed in the past decade, demand increases will shorten the amount of time that raw water deliveries can be made with gravity flows.

3.3 Ability to Satisfy Demands through Pumping

The ability to satisfy demands through pumping was assessed by evaluating:

- Pump capacities
- Pump operating ranges
- Operational constraints
- System's pumping capacity

3.3.1 Pump Capacities

Pump curves - graphical representations of the relation between flow rate, total dynamic head (TDH), pump efficiency, and brake horsepower - are available for all pumps in the Folsom Pumping Plant as well as for the emergency pump. Pump curves are typically based on flow tests conducted at the manufacturer's site before pump delivery. The curves are generally verified after the pumps are installed before an owner accepts the pumps and puts them into operation.

Pump characteristics at their highest efficiency point are summarized in Table 3-3. The actual pump curves are included in Appendix D. The emergency pump (not listed in Table 3-3) has the same characteristics as pump 6.

Table 3-3 Pump Characteristics at Peak Efficiency

Pump	Flow Rate (cfs)	TDH (ft)	Peak Efficiency	Brake Horsepower
2	20	100	88%	260
3	50	98	90%	610
4 & 5	40	84	88%	410
6	80	86	87%	560
7 & 8*	87	125	90%	1,370
Total	**404**	-	-	**4,990**

* Variable speed pumps; characteristics shown are for maximum pump speed of 511 rpm.

3.3.2 Pump Operating Ranges

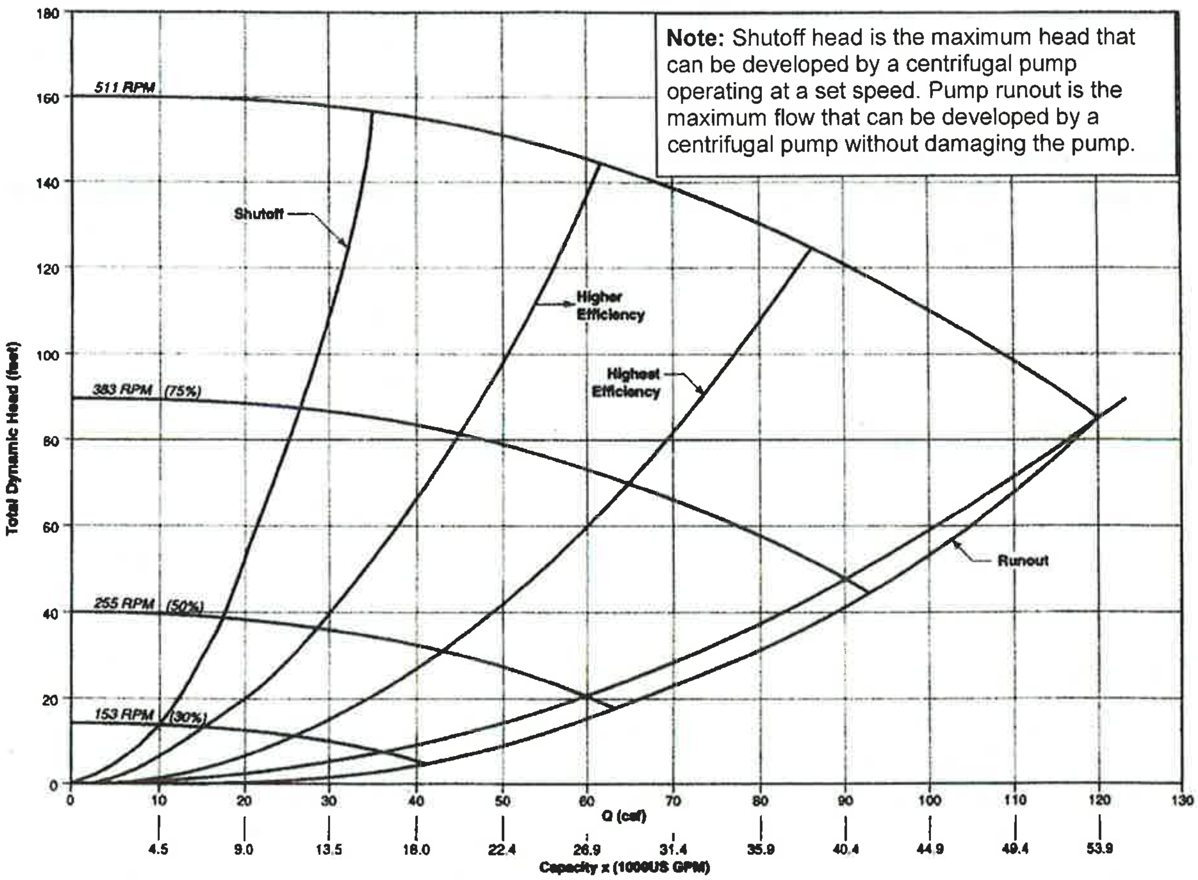
Operating ranges for the constant speed pumps were verified by Flowserve Corporation, owners of Worthington Pumps, the manufacturer of the Folsom Pumping Plant's constant speed pumps. Application Engineer Stephen Thorwart of the Flowserve facility in Rancho Dominguez, California, indicated that their pumps can generally be expected to operate satisfactorily when run at no less than 80 percent of their peak efficiency (i.e., 0.8 x Peak Efficiency). Below that level of efficiency, the pumps do not necessarily follow the pump curve and are subject to cavitation, recirculation, and uneven loading of moving parts that will significantly shorten pump life.

Acceptable operating ranges for constant speed pumps, based on manufacturer's pump curves, are presented in Table 3-4. The actual pump curves are included in Appendix D.

Table 3-4 Acceptable Operating Ranges of Constant Speed Pumps at Folsom Pumping Plant

Pump	Flow Rate Range (cfs)	TDH Range (ft)	Min. Acceptable Efficiency
2	10 to 28	60 to 124	70%
3	22 to 69	64 to 114	72%
4 & 5	18 to 51	50 to 116	70%
6 & Emerg.	41 to 106	50 to 106	70%

Variable speed pumps generally operate over a wider range of flow rates and head than constant speed pumps. The nominal capacity of the variable speed pumps at different heads and speeds is illustrated in Figure 3-1.



Note: Shutoff head is the maximum head that can be developed by a centrifugal pump operating at a set speed. Pump runout is the maximum flow that can be developed by a centrifugal pump without damaging the pump.

Figure 3-1 Variable Speed Pump Performance Curves

Source: Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda, prepared by Will B. Betchart in March 2000.

3.3.3 Operational Constraints

Reported by Operators

Operators indicated that the following constraints, developed through operational experience, are applied to pumping plant operation:

- Pumps 7 and 8 are not operated together.
- Pumps 7 and 8 are operated individually only at 50 to 75 percent of maximum speed.
- Discharge valves on constant and variable speed pumps are kept fully open during pump operation.

Pumps 7 and 8 are normally operated individually in automatic mode. Pump controls are locked to prevent pump speed from increasing above 75 percent of full speed.

Confirmed by Field Tests

Pump operation tests were conducted on September 25, 2009 (see Appendix B for memorandum summarizing pump tests). Pumps were operated without valve throttling. Test observations showed that:

- Pumps 7 and 8 do not perform well when operated together at 75 percent speed; pumps operated acceptably well, however, at 65 percent speed.
- Pumps 7 or 8 do not perform well above 75 percent of full speed.
- Reported poor performance of the variable speed pumps at speeds lower than 50 percent speed was not observed during tests with speeds as low as 40 percent.

Pump power consumption tests were conducted on October 26, 2009 (see Appendix B for test summary). These tests showed that pumps 2 through 5 were operated outside manufacturer-recommended efficiency ranges. The lowest measured efficiency was 26 percent (Pump 5).

Performance Problems Observed

A phenomenon known as "discharge recirculation" occurred when the VFD pumps were operated individually at greater than 75 percent speed or together at greater than 65 percent speed. This phenomenon is characterized by random crackling noises and intermittent knocking sounds in the suction and discharge piping. Discharge recirculation causes cavitation pitting of the impeller resulting in poor pump performance (off the pump curve) and eventual mechanical failure.[8]

Discharge recirculation was also evident at the constant speed pumps operated during the field tests. The recirculation could be the result of operating the pumps well outside their prescribed efficiency range, unfavorable approach flow conditions, or a combination of both. When the discharge valve on Pump 3 was throttled to increase pump TDH (going outside of normal operation protocol for a limited time), the noises that characterize discharge recirculation dissipated at about the half-closed position.

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[8] A more detailed description of discharge recirculation can be found at http://www.lawrencepumps.com/Newsletter/news_v04_i4_Apr07.html

Likely Cause of Discharge Recirculation

Approach flow conditions are a possible cause of discharge recirculation. Impellers are designed with the assumption that incoming flow is evenly distributed throughout the approach section. A number of approach flow conditions have been identified in laboratory tests to be detrimental to impeller performance:

- *Uneven flow distribution*: flow tends to favor one side over the other.
- *Pre-rotation*: flow approaches the impeller in a circulatory pattern that may or may not be in the same direction that the impeller rotates.
- *Vorticity*: a tight flow spiral forms immediately upstream of the impeller.

These conditions are generally a function of the geometry of the approach section. The approach geometry for all pumps at the Folsom Pumping Plant is likely to cause approach flow problems, even when pumps operate within acceptable efficiency ranges.

3.3.4 System's Pumping Capacity

Ideal Conditions

If pumps within the pumping plant (i.e., not including the emergency pump) were to operate at the peak efficiencies shown in Table 3-3, the total system capacity would be 404 cfs, sufficient to meet maximum (2009) demands, which are estimated at 361 cfs (Table 2-2).

Constraints

It is impossible to operate all pumps at maximum efficiency under current conditions for the following reasons:

- *Pumps have different TDHs and there is no valve throttling:* Since valves on the suction and discharge sides of the pumps are operated fully open, pumps in operation are subject to the same head (i.e., the pressure differential between the suction side and the discharge side would be about the same, other than for minor losses which could be slightly different for each pump). Without individual throttling of discharge valves, there is no way to set the head for each pump at its optimum level.
- *Variable speed pumps are operated at 50 to 75 percent of full speed:* The range at which variable speed pumps are operated is illustrated in Figure 3-2.

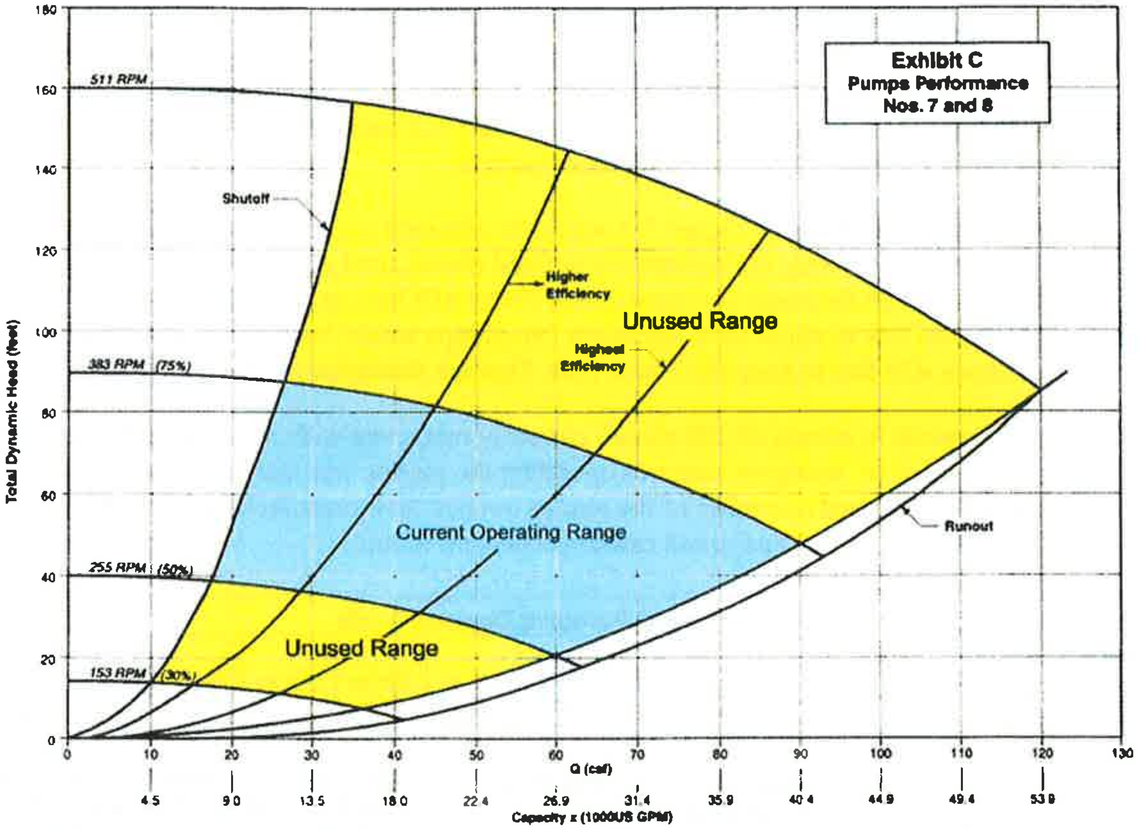


Figure 3-2 Range at which Variable Speed Pumps Are Operated

- *Unfavorable intake geometry:* The geometry of the pump intakes, which consist of different diameter pipes branching off an 84-inch diameter manifold, is likely to cause uneven flow distributions and vorticity that lower pump efficiency. Even if operated within the ranges prescribed by the manufacturer, the pumps are likely to operate at reduced efficiency.

Theoretical Capacity

A system capacity was calculated for a theoretical scenario in which:

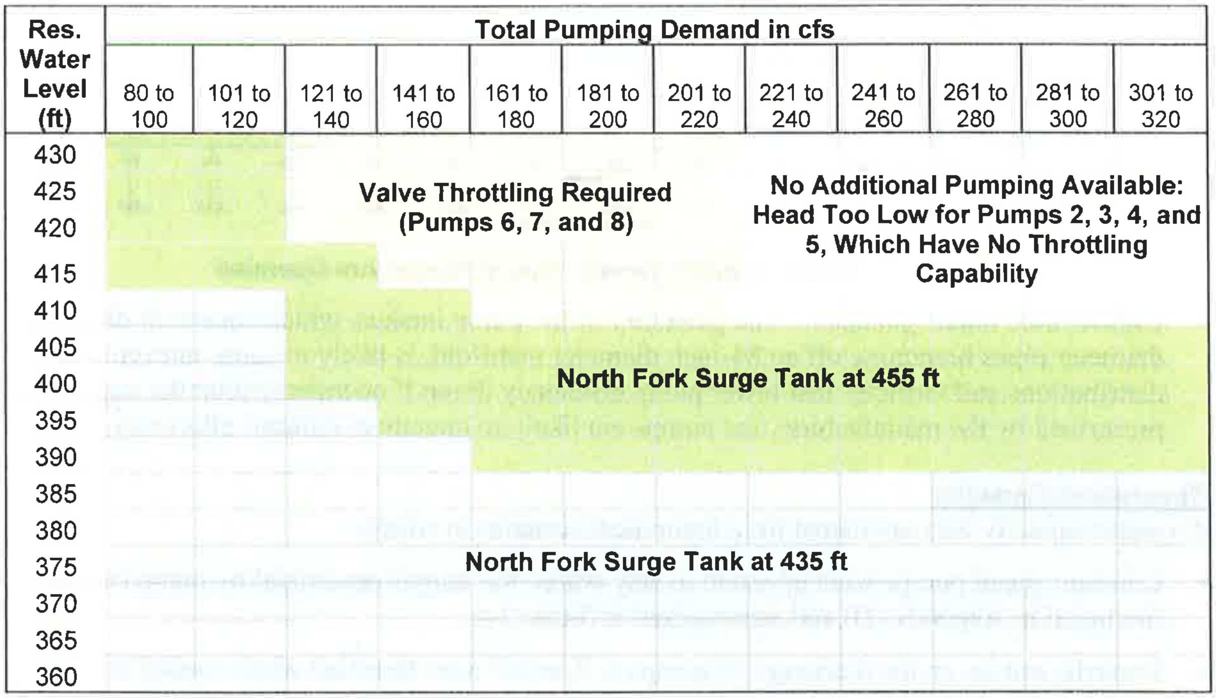
- Constant speed pumps were operated to stay within the ranges prescribed by pump curves (included in Appendix D) and summarized in Table 3-4.
- Butterfly valves on the discharge of pumps 6, 7, and 8 were throttled when needed to keep the pumps within acceptable operating ranges.
- Surge tank water levels on the North Fork Pipeline were kept below the overflow elevation of 479.3 feet, with the target generally set at elevation 455 feet.
- Pumps 7 and 8 were operated between 50 and 75 percent speed.
- When needed to meet demands, pumps 7 and 8 were operated together at speeds not exceeding 65 percent, one manually and the other one in automatic mode.

A pump selection schedule using the parameters described above is presented in Appendix F.

The theoretical scenario described above is achievable with the system that is now in place. Operating constraints would not be altered, with the exception of introducing throttling for valves on the discharge pipes for pumps 6, 7, and 8, for which throttling is feasible. The operating instructions for pumps 7 and 8 actually indicate that valve throttling should be part of standard operating practices for the variable speed pumps.

The system capacity illustrated in Figure 3-3 would be obtained under the theoretical operating scenario. When operating using the constraints defined above, total system demands in excess of 220 cfs could not be met for reservoir water levels above 410 feet, as the TDH for constant speed pumps would be too low to allow their operation. No pumps would be operated for reservoir water levels above 430 feet to keep the North Fork Pipeline standpipes from overflowing.

Total system demands in excess of 220 cfs are currently met, even with reservoir water levels above 410 feet. Doing so, however, requires operating the pumps well outside their normal operating ranges. Continued operation of the pumps outside their manufacturer-recommended ranges will damage the pumps and could cause mechanical failure.



Res. Water Level (ft)	Total Pumping Demand in cfs											
	80 to 100	101 to 120	121 to 140	141 to 160	161 to 180	181 to 200	201 to 220	221 to 240	241 to 260	261 to 280	281 to 300	301 to 320
430												
425					Valve Throttling Required (Pumps 6, 7, and 8)					No Additional Pumping Available: Head Too Low for Pumps 2, 3, 4, and 5, Which Have No Throttling Capability		
420												
415												
410												
405												
400								North Fork Surge Tank at 455 ft				
395												
390												
385												
380												
375							North Fork Surge Tank at 435 ft					
370												
365												
360												

Figure 3-3 System Capacity When Operating All Pumps within Acceptable Ranges

3.4 Conclusions about Hydraulic Performance

The hydraulic performance evaluation identified:

- Physical deficiencies
- Operational deficiencies
- Operational limits
- Potential corrective measures

3.4.1 Physical Deficiencies

Pumping Plant Intake Geometry

The geometrical design of pump intakes at the Folsom Pumping Plant generates adverse approach flow conditions that affect pump performance. Suction pipes come off the 84-inch-diameter pipeline at a 30-degree angle. The intake to Pump 2 is first, followed by intakes to pumps 3 through 8 (Figure 3-4). The streamlines into each suction pipe change depending on the pumps that are operating; due to the geometrical arrangement, streamlines generate a skewed flow distribution at pump impellers. The skewed flow distribution causes uneven loading of moving parts and can result in vorticity and pre-rotation. These phenomena lower pump efficiency and can eventually damage the pump.

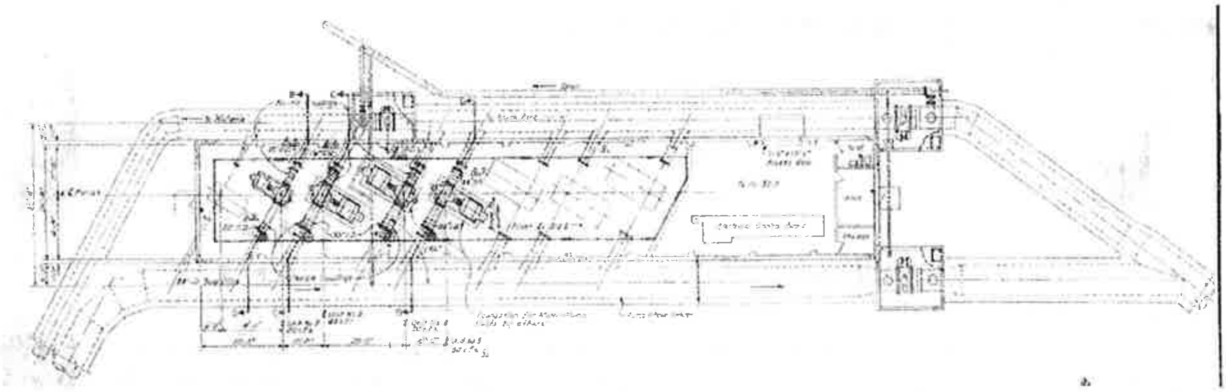


Figure 3-4 Plan View of Pump Arrangement

Source: "Pumping Plant Equipment, Mechanical – Pump Installation" drawing, Folsom Reservoir Project, US Army Corps of Engineers, September 1951

Valving Arrangement on New North Fork Pipeline

The current valving arrangement conveys water from Folsom Reservoir to both the SJWD and the City of Roseville through the North Fork Pipeline. Both gravity and pumped flows have the same path.

The thresholds for gravity flow are quite different for SJWD and the City of Roseville. The end point water surface elevation at SJWD is 423.4 feet, while at the City of Roseville it is 400 feet. Demands from the City of Roseville could be met by gravity with reservoir levels of 405 feet and higher. Demands from SJWD, however, can only be met with reservoir levels above 426 feet.

If the pipes and valves were re-arranged to separate deliveries to the City of Roseville from deliveries to SJWD, the number of days in which gravity flows to Roseville were possible would increase (and therefore the number of days in which pumping was required would decrease). Between 2001 and 2007, Folsom Reservoir had water levels between 405 and 426 feet about 13 percent of the time. Those 326 days (an average of 47 days per year), the City of Roseville could have been served through gravity flows had the piping arrangement been suitable.

Separating Roseville and SJWD flows would require a connecting pipe from the pumping plant's suction manifold to the new 72-inch diameter North Fork Pipeline. Several additional valves would also be required to allow both gravity and pumped flows into the new pipeline.

3.4.2 Operational Deficiencies

Pump Selection
Current operating procedures do not take into account the characteristics of the constant speed pumps (i.e., "pump curves") and their operating ranges. The constant speed pumps are selected for operation based on their rated flow capacity only. The variable speed pumps are operated at 50 to 75 percent of the total speed, without regard to total dynamic head (TDH). To deliver its rated capacity, however, a pump requires a particular TDH. At the appropriate TDH, a pump operates at peak efficiency and delivers its rated flow.

Valve Throttling
To reach the appropriate TDH, discharge valves would have to be throttled. Only Pumps 6, 7, and 8 are equipped with discharge valves suited for throttling.

Throttling of the valves on pumps 7 and 8 is likely to increase their range of operation. The training manual on the operation of the variable speed pumps indicates the appropriate valve angle required to achieve the proper TDH. Adherence to these guidelines would improve pump performance.

3.4.3 Operational Limits

Gravity Flows
The raw water delivery system is capable of satisfying current and anticipated future demands by gravity, when the reservoir water level is high enough to allow it. From 2000 to 2007, the water level in the reservoir was high enough to allow deliveries by gravity to the North Fork Pipeline about 28 percent of the time. Pumping was required the remaining 72 percent of the time. If reservoir water levels were to remain in the same range in the future, demand increases will shorten the time periods in which raw water deliveries can be made with gravity flows.

Pumped Flows
The 7 pumps in the Folsom Pumping Plant have a combined rated capacity of 404 cubic feet per second (cfs) when operated at peak efficiency. Current typical summer demands are approximately 309 cfs (Table 2-1). Maximum current demands based on treatment capacities at the end points are about 361 cfs; maximum future demands based on anticipated treatment plant expansions would be 474 cfs (Table 2-2). If the pumps were operated at peak efficiency, they would be able to meet current typical and maximum demands; they would not be able to meet future maximum demands. Operation of the pumps at peak efficiency would generally require valve throttling: by partially closing the discharge valves, additional head would artificially be created that would bring the pumps to their most efficient operating level.

3.4.4 Potential Corrective Measures

New Pump Intake Structure
A more efficient pump intake would improve pump performance. Design of an appropriate structure would require physical modeling.

Revised Operating Procedures
Operating procedures must consider each pump's TDH and its acceptable operating range. Operation outside manufacturer-recommended ranges should be avoided.

New Discharge Valves/Controls

The only way to operate the pumps at peak efficiency given the prevailing lake levels is by throttling discharge valves. Three of the seven pumps in the pumping plant have butterfly valves suited for throttling. The other four pumps should have discharge valves that allow throttling. The discharge valves should be automated to open only to the point where the differential head across the pump matches the ideal TDH.

Pump Replacement

The implementation of valve throttling would allow existing pumps to operate efficiently at any reservoir water level. If future reservoir water levels are similar to the levels of the past 10 years, significant valve throttling would be required: constant speed pumps have rated heads of 84 to 100 feet, but the vast majority of the time they would be pumping against lower heads. Pumping to meet a TDH of 100 feet when the water level differential is much lower wastes power. Replacement of the constant speed pumps with variable speed pumps would reduce power consumption.

4 EVALUATION OF THE EFFECTS OF HIGHER DEMANDS

The conveyance of higher-than-current flow rates through the raw water delivery system was evaluated to assess the effects on system components and plant operations. This section of the report presents:

- Basis of evaluation
- Impact of higher flow velocities
- Raised gravity flow thresholds
- Increased frequency of pump use
- Increased power consumption
- Conclusions about impacts of higher demands

4.1 Basis of Evaluation

The effects of conveying higher-than-current flow rates through the Folsom Pumping Plant raw water delivery system were evaluated on the basis of:

- Hydraulic calculations of flow velocities through system components.
- Computer simulations of gravity flows assuming simultaneous deliveries to four purveyors, to calculate gravity flow thresholds for future demand conditions.
- Review of flow and reservoir level data provided by Reclamation for the period between January 1, 2001 and November 29, 2007, to assess increased frequency of pump use for the future demands outlined in Section 2 of this document.
- Power consumption calculations for increased demands, assuming pumps are operated within manufacturer-specified ranges.

4.2 Impact of Higher Flow Velocities

A comparison of flow velocities in the system's pipelines, for current and future maximum demands, is presented in Table 4-1. Estimated energy losses due to friction for every 1,000 feet of pipeline are included in the table.

The increase in flow velocities would have the most significant effect on the North Fork Pipeline. At a future maximum delivery rate of 387 cfs, velocity in the 84-inch-diameter pipe would reach 10.0 feet per second (ft/s). Although the pipe should be able to sustain a velocity of this magnitude without detrimental abrasion or scouring, energy losses due to friction would almost double from 1.5 to 2.7 ft/thousand feet of pipe. Energy losses could be reduced by splitting the total flow between the 84- and 72-inch-diameter pipelines.

Table 4-1 Comparison of Flow Velocities for Maximum Delivery Rates, Current and Future

Condition	Pipeline	Max Flow Rate (cfs)	Max Flow Velocity (ft/s)	Friction Loss per 1,000 ft of Pipe (ft)
Current	84-inch North Fork	279	7.2	1.5
Future	84-inch North Fork	387	10.0	2.7
Current	42-inch Natoma	82	8.5	4.5
Future	42-inch Natoma	87	9.0	5.0
Current	48-inch Natoma	82	6.5	2.3
Future	48-inch Natoma	87	6.9	2.6
Current	60-inch Natoma	82	4.2	0.8
Future	60-inch Natoma	87	4.4	0.9

4.3 Raised Gravity Flow Thresholds

4.3.1 North Fork Pipeline

A comparison of reservoir water levels required for gravity flow deliveries, for current and future demands, is presented in Table 4-2. The "current" capacity of the City of Roseville water treatment plant was assumed to be 93 cfs, its capacity before recent improvements. Summer demands were assumed to range from 90 to 100 percent of treatment capacity. Future winter demands were assumed at 25 percent above current levels.

Table 4-2 North Fork Pipeline: Comparison of Threshold Reservoir Levels for Gravity Flow*

		Flow Rates (cfs)			
Condition	Demand	Roseville	SJWD	Total	Min. Water Level in Folsom Reservoir (ft)
Current	Winter Avg. Daily	26	54	80	426
Future	Winter Avg. Daily	34	68	102	427
Current	90% Capacity	84	167	251	438
Future	90% Capacity	140	209	349	449
Current	100% Capacity	93	186	279	441
Future	100% Capacity	155	232	387	455

* Based on computer simulations that assumed simultaneous deliveries to four end users.

As indicated in Table 4-2, to deliver maximum future demands by gravity, the water level in the reservoir would have to be at least 455 feet. The model simulations assumed that the Natoma

Pipeline surge tank (overflow elevation at 436 feet) would be isolated to prevent overflows. SJWD valves were assumed fully open, and the valves at the City of Roseville water treatment plant were throttled to divide flow evenly between the 48- and 60-inch-diameter Roseville pipelines. Conveying most of the flow to the City of Roseville through the 60-inch-diameter pipe would reduce head losses (i.e., lower the reservoir level); current practice, however, is to split flow about evenly between the two pipelines.[9]

4.3.2 Natoma Pipeline

A comparison of reservoir water levels required for gravity flow deliveries for current and future demands is presented in Table 4-3. The current maximum delivery to the Folsom Prison Water Treatment Plant was limited to 5 cfs, based on the constraint imposed by the overflow weir in the distribution box upstream of the delivery point. The future maximum of 10 cfs assumed that improvements would be made to the overflow weir. Summer demands were assumed to range from 90 to 100 percent of treatment/delivery capacity. Future winter demands were assumed at 25 percent above current levels.

Table 4-3 Natoma Pipeline: Comparison of Gravity Flow Threshold Reservoir Levels*

		Flow Rates (cfs)			Min. Water Level in Folsom
Condition	**Demand**	**Folsom Prison**	**City of Folsom**	**Total**	**Reservoir (ft)**
Current	Winter Avg. Daily	3	23	26	411
Future	Winter Avg. Daily	4	29	33	413
Current	90% Capacity	4.5	69	74	430
Future	90% Capacity	9	69	78	433
Current	100% Capacity	5	77	82	435
Future	100% Capacity	10	77	87	437

* Based on computer simulations that assumed simultaneous deliveries to four end users.

As indicated in Table 4-3, to deliver maximum future demands by gravity the water level in the reservoir would have to be at least 437 feet. The water level at the Natoma Pipeline surge tank did not reach its overflow level (elevation 436 feet) during the gravity flow simulations summarized in Table 4-3.

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[9] Based on flow data for 2005 and 2006 provided by the City of Roseville.

4.4 Higher Frequency of Pump Use

The frequency of pump use was analyzed on the basis of flow and reservoir level data provided by Reclamation for the period between January 1, 2001 and November 29, 2007. Flow and reservoir level data for these 2,524 days were examined to determine the percentage of days in which pumps would have been required to deliver raw water to the various purveyors. This determination was made on a theoretical basis (i.e., based on threshold levels for gravity flow determined by the hydraulic model) and does not necessarily reflect actual pumping plant operation during that time period.[10]

The future frequency of pump use was calculated by assuming increased daily deliveries and the same reservoir levels recorded between 2001 and 2007. The daily delivery data for the 2,524 days of record were multiplied by a factor that accounts for the anticipated delivery increase.

The higher frequency of pump use calculated as described above assumes that the reservoir levels between 2001 and 2007 are representative of future conditions.

4.4.1 North Fork Pipeline

Increased deliveries to North Fork Pipeline purveyors are limited by the capacities of the treatment plants at the end points. The maximum increase for SJWD would be 25 percent, from the current capacity of 186 cfs to a future capacity of 232 cfs. The maximum increase for the City of Roseville would be 67 percent, from 93 to 155 cfs.

Increased frequency of pump use is illustrated in Table 4-4, which is based on flow and reservoir level data for the 2,524 days between January 1, 2001 and November 29, 2007. At current delivery conditions, pumps would have to be used, on average, 70 percent of the time. Increasing deliveries would raise the frequency of pump use to as much as 87 percent of the year.

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[10] Theoretical rather than actual operation was used in the analysis to provide a valid before-and-after comparison; actual operation was not consistent in gravity flow threshold levels and pump selection.

Table 4-4 North Fork Pipeline: Frequency of Pump Use*

Condition	Reservoir Level and Flow	No. of Days	Percent
Current	Reservoir level above 441 ft (no pumping)	591	24
	Reservoir level between 426 and 441 ft, flows under 80 cfs (no pumping)	154	6
	Reservoir level between 426 and 441 ft, flows over 80 cfs (pumping required)	540	21
	Reservoir level under 426 ft (pumping required)	1,239	49
Future: SJWD and Roseville Demands Up 25%	Reservoir level above 455 ft (no pumping)	222	9
	Reservoir level between 427 and 455 ft, flows under 102 cfs (no pumping)	149	6
	Reservoir level between 427 and 455 ft, flows over 102 cfs (pumping required)	867	34
	Reservoir level under 427 ft (pumping required)	1,286	51
Future: SJWD Demand Up 25% and Roseville Demand Up 67%	Reservoir level above 455 ft (no pumping)	222	9
	Reservoir level between 427 and 455 ft, flows under 102 cfs (no pumping)	100	4
	Reservoir level between 427 and 455 ft, flows over 102 cfs (pumping required)	916	36
	Reservoir level under 427 ft (pumping required)	1,286	51

* Based on flow and reservoir level data for the 2,524 days between 01/01/2001 and 11/29/2007

4.4.2 Natoma Pipeline

Increased deliveries to Natoma Pipeline purveyors were limited to the doubling of the delivery capacity to Folsom Prison, from 5 to 10 cfs. Deliveries to the City of Folsom were assumed to remain at a maximum of 77 cfs based on information from treatment plant management.

Frequency of pump use is illustrated in Table 4-5. The number of days when pumping to the Natoma Pipeline is necessary would actually decrease slightly, from 46 percent to an estimated 42 percent, if deliveries to Folsom Prison increased to 10 cfs.

Table 4-5 Natoma Pipeline: Frequency of Pump Use*

Condition	Reservoir Level and Flow	No. of Days	Percent
Current	Reservoir level above 435 ft (no pumping)	863	34
	Reservoir level between 411 and 435 ft, flows under 26 cfs (no pumping)	504	20
	Reservoir level between 411 and 435 ft, flows over 26 cfs (pumping required)	627	25
	Reservoir level under 411 ft (pumping required)	530	21
Future: Folsom Prison Delivery Capacity Up to 10 cfs	Reservoir level above 437 ft (no pumping)	779	31
	Reservoir level between 413 and 437 ft, flows under 33 cfs (no pumping)	673	27
	Reservoir level between 413 and 437 ft, flows over 33 cfs (pumping required)	482	19
	Reservoir level under 413 ft (pumping required)	590	23

* Based on flow and reservoir level data for the 2,524 days between 01/01/2001 and 11/29/2007

4.5 Increased Power Consumption

Increases in power consumption were analyzed using the 2001-2007 flow and reservoir level data provided by Reclamation. Since the analysis in Section 4.4.2 above indicates that anticipated future demands are not likely to increase the number of days when pumping is required to satisfy Natoma Pipeline demands, the power consumption analysis was limited to North Fork Pipeline requirements.

The following assumptions were made when estimating current and future power use:

- For each "pumping required" day (1,779 days out of 2,524 days of record for "current conditions" in the North Fork pipeline), the power used by the pumps in operation was calculated assuming that the average daily flow was maintained for 24 hours:

  Power in kW-hours = 24 hours x (Flow Rate) x (Head) / (Efficiency x 11.81)

- For future conditions, demand up 25 percent, the average daily flow rates recorded between January 1, 2001 and November 29, 2007 were increased by 25 percent; reservoir levels remained the same. This increased the number of "pumping required" days from the 1,779 days in the "current" column to 2,153 out of 2,524 days, as shown in Table 4-4.
- For future conditions, SJWD demand up 25 percent, Roseville demand up 67 percent, the average daily flow rates recorded for the 2001-2007 period were increased by the appropriate percentages; reservoir levels remained the same. This increased the number of "pumping required" days from the 1,779 days in the "current" column to 2,202 days out of 2,524 days of record, as shown in Table 4-4.
- Pump efficiencies of 0.80 for variable speed pumps and 0.75 for constant speed pumps were assumed. These efficiencies are easily attainable when pumps are operated within their normal operating ranges.

- The selection of pumps to be operated for a given combination of demand and reservoir water level was based on the assumptions that: pumps would operate within acceptable ranges specified in Table 3-4; valves on pumps 6, 7, and 8 would be throttled as needed; and pumps 7 and 8 would be operated together. See Appendix F for full pump selection schedule.

Results of the power consumption analysis are summarized in Table 4-6.

Table 4-6 Calculated Current and Future Power Usage for Deliveries to the North Fork Pipeline*

	Current (2001-2007)	Deliveries up 25%	Deliveries up 25% for SJWD, 67% for Roseville
Number of Days Operating:			
2 Variable Speed Pumps	781	343	337
2 Variable Speed Pumps + Pump 6	469	333	353
1 Variable Speed Pump + Constant Speed Pumps	529	1,477	1,512
Total	1,779	2,153	2,202
Average Annual Power Consumption in MW-hours (based on daily power calculations for 6.9 years)	5,670	12,872	14,477
Future Power Use as Percent of Current	100%	227%	255%

* Based on flow and reservoir level data for the 2,524 days between 01/01/2001 and 11/29/2007

A 25 percent demand increase would more than double power consumption. This would occur because at higher demands, the less efficient constant speed pumps would be used more frequently and the more efficient variable speed pumps would be used less frequently (see Appendix F to better understand how moving to a higher demand affects pump selection).

4.6 Conclusions about Impacts of Higher Demands

Increased delivery volumes would:

- Increase flow velocities, resulting in higher energy losses due to friction.
- Raise the gravity flow threshold for both the North Fork and the Natoma pipelines.
- Increase the number of days on which pumping is required to meet raw water demands.
- Cause the less efficient constant speed pumps to be used more frequently, and the more efficient variable speed pumps to be used less frequently.
- Substantially increase power consumption.
- Result in increased pump maintenance by accelerating the degradation of equipment that is already operating at low efficiencies under adverse hydraulic conditions.

5 EVALUATION OF POWER AND CONTROL SYSTEMS

Power and control systems were evaluated to assess their condition and operational limits. This section of the report presents:

- Basis of electrical and control systems evaluation
- Configuration of electrical and control systems
- Reliability of electrical and control systems
- Conclusions about power and control system reliability

5.1 Basis of Electrical and Control Systems Evaluation

The assessment of electrical power supply and control system reliability is based on observations made during a site visit on October 16, 2007,[11] and review of the drawings listed in Table 5-1 (included in Appendix E).

Table 5-1 Electrical and Control Drawings Reviewed

Drawing No.	Title	Author	Date
485-218-1093	Folsom Power Plant & Switchyard UHA Panel 2 Breaker 52-3 (312) Pumping Plant Feeder No. 1 Wiring Diagram	USBR	2/5/2007
485-218-1094	Folsom Power Plant & Switchyard UHA-Feeder 52-6 (612) Wiring Diagram	USBR	2/5/2007
485-218-1461	Folsom Pumping Plant Stand Pipe High Level – Pump Trip Control Schematic Diagram	USBR	3/14/2002
485-218-1470	Folsom Dam Pumping Plant Expansion Single Line Diagram	USBR	9/22/2005
485-218-1784	Folsom Switchyard Electrical Installation Switching Diagram	USBR	6/8/2007
485-218-1859	Folsom Pumping Plant Electrical Installation 208/120C Power Distribution System Single Line Diagram	USBR	10/22/2005
Pumping Plant Expansion E-1	Single line diagram	SAI Engineers	3/7/1997
Pumping Plant Expansion E-3	Pump 7 & 8 and Mov-14 & 26 Control Schematics	SAI Engineers	3/13/1997

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[11] The site visit and review of drawings were conducted by Lawrence Lam, P.E. of YEI Engineers, Inc., a member of the consulting team responsible for this study.

5.2 Configuration of Electrical and Control Systems

5.2.1 Electrical System

Power Source

As indicated in Section 2 of this document, a double-ended substation supplies electrical power to the pumping plant's 4.16kV switchgear (designated "UHA"). In the double ended substation, switchgear UHA receives power from transformers KZ4A and KV9A. Switchgear UHA has two main breakers, 52-A connecting to transformer KV9A, and 52-B connecting to transformer KZ4A and a tie breaker, UHA5. The main breakers and tie breaker are electrically interlocked (see drawing number 485-218-1784). Switchgear UHA is connected to the pumping plant's switchgears 1 and 2. Switchgear 1 through transformer KPA provides power to 208/120V panel CPC. Switchgear 2 through transformer KPB provides power to 208/120V panel CPB. Both transformers KPA and KPB provide power to 208/120V panels CPA and CPD through an automatic transfer switch.

Transformers

There are two main transformers serving the pumping plant:

- Transformer KZ4A is three phase, 10/12.5MVA, 13.8(Y)-4.16(Y) kV; its primary voltage is 13.8kV, derived from a 220kV substation.
- Transformer KV9A is three phase 10/12.5MVA, 115(delta)-4.16(Y) kV; its primary voltage is 115kV.

There are two secondary transformers serving the internal loads in the pumping plant:

- Transformer KPA is three-phase, 75kVA, 4.16kV (delta)-208/120V; its primary voltage is 4.16kV, derived from a switchgear 1.
- Transformer KPB is three-phase, 75kVA, 4.16kV (delta)-208/120V; its primary voltage is 4.16kV, derived from a switchgear 2.

Switchgear UHA and Breakers

The primary voltages of transformers KZ4A and KV9A are different, and their power is supplied from different substations. By the electrical interlock of the main breakers 52-A, 52-B and tie breaker UHA5, switchgear UHA can supply power to its loads from either or both of its power sources.

Connecting Cables

Switchgear UHA is connected to the pumping plant's switchgear 1 and 2 through individual sets of three 1/C 500 kcmil cables. For switchgear 1, the total connected potential maximum load of pumps 2, 3, 4 and 8 appears to be 2,750 horsepower (HP) or about 382 Amps. For switchgear 2, the total connected load of pumps 5, 6 and 7 is 2,800 HP or about 389 Amps. Determination of the actual loading on the switchgears would require load testing; no load testing was performed for this evaluation.

Main Switchgear 1 and Switchgear 2
Main switchgear 1 receives power from breaker 312 of switchgear UHA. Main switchgear 2 receives power from breaker 612 of switchgear UHA. Switchgear 1 connects to pumps 2, 3, 4 and 7. Switchgear 2 connects to pumps 5, 6, 8 and the emergency pump (see drawing number 485-218-1784).[12] While switchgear 2 is connected to pumps 5, 6, 8, and the emergency pump, it does not provide power to all simultaneously: the emergency pump is designed to be used only when the Folsom Reservoir water level is too low to allow operation of the other pumps; the switchgear, therefore, is set up to provide power to either pumps 5, 6, and 8 (individually or together) or to the emergency pump alone.

5.2.2 Control System

Information about control system configuration was derived from two drawings. Pumping Plant Expansion Project drawing E-3 shows that VFD pumps (7 and 8) and motor operated valves (V26 and V14) are hard wired for start/stop or open/close control, interlock and remote monitoring. The VFD pumps share an 115VAC-24VDC control power supply. The VFD control and the PLC in the remote panel 1101 are mentioned in the drawing but no details are provided.

Drawing 485-218-1461 is a partial representation of a Pumping Plant Central Start Stop Control Schematic. The drawing indicates that a loss of 24V control power device 27CPC was installed (the device, however, is not shown on the drawing). How the Central Start Stop Control is connected to each pump start-stop control circuit is likewise not shown. The physical protection of these control circuits from central control to local pump could not be determined from information available.

5.3 Reliability of Electrical and Control Systems

5.3.1 Electrical System Reliability

Power Sources
From a system configuration standpoint, a setup with double-ended substations and independent power sources, such as the Folsom Dam Pumping Plant setup, is considered to be highly reliable. Simultaneous failure of both independent power sources is very unlikely. According to the Institute of Electrical and Electronics Engineers' *Survey of Reliability of Electric Utility Power Supplies to Industrial Plants*, if the two power sources from adjacent substations are considered utility circuits, the probability of losing both circuits is 0.312 per year (probabilities are generally expressed as a number between 0 and 1, with 0 representing no possible occurrence and 1 representing certain occurrence). The estimated downtime is 0.52 hours per failure, which equates to 0.1622 probable hours of downtime in a year (8,760 hours) and power availability 99.998 percent of the time.

Transformers
The two main transformers (located in the switchyard area), KZ4A and KV9A, are rated 10MVA each. Each of the transformers is capable of serving the whole plant with ample capacity. The

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[12] Drawing 485-218-1470 shows a different power supply arrangement, with switchgear 2 connected to pumps 5, 6, 7 (instead of 8), and emergency pump. For purposes of this memorandum the more recent drawing number 485-218-1784 was assumed correct.

physical condition of the transformers is not known; if they were installed at the same time as switchgear UHA, the transformers would have been in service for 25 years. Since transformers generally have longer life expectancies than switchgear, their reliability can still be considered high.

Switchgear UHA and Breakers

Switchgear UHA is connected to two redundant power sources. It receives power from two separate transformers, which in turn derive their primary power from separate substations. Switchgear UHA provides the flexibility of supplying power to its loads by either or both of its power sources. For a UHA bus serving one group of pumps (pumps 2, 3, 4, 7 or pumps 5, 6, and 8/or emergency pump) to lose power, one of the following would have to happen:

- Both power sources lost, a highly unlikely occurrence, as indicated above.
- Failure of one transformer (KZ4A or KV9A) and simultaneous failure of tie breaker UHA5, a highly improbable occurrence.
- Failure of one main breaker (52-A or 52-B) and simultaneous failure of tie breaker UHA5, which is also highly unlikely.
- Failure of the bus section, the probability of which is also low.

The reliability of switchgear UHA, therefore, is high based on its configuration. On visual inspection, however, the switchgear UHA looked aged and rusted, presumably due to its outdoor location and extended exposure to the elements. It appeared to be in its late stages of useful life. This was confirmed by a subsequent check of UHA nameplates, which show a manufacturing date of April 1983. The likelihood of failure of 25-year-old equipment under normal operations or under fault conditions depends on the frequency and quality of maintenance, but can generally be expected to be high.

UHA feeder breakers are protected by over-current relay only (see drawings 485-218-1093 and 485-218-1094). This type of protection was typical for switchgear in the 1980's, but current standards would include a micro-processor-based multi-function relay. The multi-function relay can provide various protections and more information under fault. More information about a fault assists operation and maintenance personnel in identifying problems so that the system can be put back on line faster, thereby improving its reliability.

Connecting Cables

Age and condition of the cables and terminations are not known. Since failure of a cable can affect the availability of an entire section of the pumping plant, cables that are old and/or in poor condition would adversely impact the reliability of the pumping plant's power supply.

The reliability of cables is different for the two switchgears, as the total connected load of switchgear 1 is about 381 Amps and total connected load of Switchgear 2 is 389 Amps. Each is served by a set of 500 kcmil cable, which is rated for 380 Amps. Both sets of cable are marginally able to serve the full load .Unless there is some load diversity, i.e. not all the loads running at the same time, no more loads can be added to switchgear 1 or switchgear 2 through existing cables.

Main Switchgear 1 and Switchgear 2

Since main switchgear 1 is connected to UHA via breaker 312, failure of this breaker or the interconnecting cable D-D will cause main switchgear 1 and its associated pumps to lose power. Similarly, failure of breaker 612 or interconnecting cable E-E will cause main Switchgear 2 and its associated pumps to lose power. Under the existing system configuration, therefore, pumps would lose power upon failure of breakers or interconnecting cables. This switchgear configuration offers a low level of power supply reliability.

Detailed shop drawings of switchgears 1 and 2 were not available for review. The bus ratings for both switchgears are unknown. From field observation, however, switchgear 1 and switchgear 2 appear to be in fair condition (see Figures 5-1 and 5-2).

In the 1999 Pumping Plant Expansion Project, field modifications were made to change the switchgear bus from one section to two sections. Modifications of this kind are likely to adversely impact equipment reliability. Drawing E-1 of the Pumping Plant Expansion project indicates that main switchgears 1 and 2 were originally a single switchgear. The main breaker was removed and bypassed by bus bar jumpers. A section of bus bars was removed to create separation of switchgear 1 and switchgear 2. There is no connection that can tie switchgear 1 and switchgear 2 together. To provide redundancy and therefore increase reliability, a new tie (breaker) would be required so that the busses and associated loads of switchgears 1 and 2 can have access to power via either set of cables (assuming the switchgear busses are adequately rated, say for 800 Amps or above). Each set of cables would need to be upgraded to carry switchgear 1 and switchgear 2 loads, as well as the total load of the entire pumping plant.

Drawings indicate that switchgear 1 has a spare position for another pump starter. The position can be used to support pump additions (with appropriate cable upgrades).

Depending upon the load addition required to support increases in pumping capacity, switchgear 1 and switchgear 2 should be re-evaluated for further modification or replacement.

The reliability of the 208/120V power distribution system is somewhat better than the 4160V distribution system for the pumping loads. By using automatic transfer switch 2802, the 208/120V power panels CPA and CPD have access to power from both switchgear 1 and switchgear 2 (refer to Drawing 485-218-1859). The power service to the 208/120V loads, mainly HVAC blowers, large pump heaters, pump discharge valves, and control panels, is reliable.

5.3.2 Control System Reliability

The hard wire schematics for start/stop or open/close control, interlock and remote monitoring appear to have adequate reliability.

Since Pump 7 and Pump 8 share a control power supply, a malfunction or even a blown fuse can cause control power loss to both pumps. To improve reliability, a separate power supply should be provided to each pump control circuit.

Figure 5-1 Switchgear 1 and Switchgear 2 Front View

Figure 5-2 Switchgear 1 and Switchgear 2 Back View

5.4 Conclusions about Power and Control System Reliability

Switchgear UHA should be replaced with new, modern switchgear to significantly improve the reliability of power supply to the pumping plant. To maintain 100 percent redundancy and thereby achieve high reliability, the new breakers replacing the existing breakers 312 and 612 should have adequate rating to handle the total existing pumping plant loads (Pumps 2 to 8) plus any new pump motor loads. Microprocessor-based multi-functional relays are recommended for the new switchgear.

New cable feeders from Switchgear UHA to pumping plant main switchgear should be further evaluated. Replacement of cable and termination would improve overall system reliability at relatively moderate cost and little disruption to plant operations.

The configuration of the pumping plant's main switchgear 1 and switchgear 2 should be changed to provide redundancy and improve power supply reliability. Under the existing system configuration, pumps would lose power upon failure of breakers or interconnecting cables.

6 RECOMMENDED ACTIONS AND THEIR APPROXIMATE COSTS

Improvements suggested in the hydraulic performance and power/control system evaluation sections of this document are summarized in this section. Approximate implementation costs are presented. Improvements are described in order of increasing cost, followed by an assessment of their impacts on system reliability, ability to meet increased demands, and energy usage. The following improvements and their impacts are discussed:

- Development and adoption of new SOP
- Replacement of discharge valves
- Upgrades of power supply
- Pump replacement
- Reconfiguration of pump intake
- Combinations of recommended actions
- Impact of recommended actions

6.1 Development and Adoption of New SOP

Standard operating procedures for the Folsom Pumping Plant could be revised to utilize pumps more efficiently. More efficient utilization (i.e., operation of pumps within manufacturer-recommended ranges) would reduce maintenance requirements and prevent further pump damage.

Adoption of a new SOP without changing valves or pumps is "recommended" only to the extent that it would help prevent further pump damage caused by operating them outside prescribed ranges. Adoption of such an SOP clearly does not resolve capacity issues, use power efficiently, or remedy the hydraulic deficiencies inherent in the configuration of the suction piping.

6.1.1 Basics of New SOP

A pump-selection schedule was developed (see Appendix F) that can form the basis for a new SOP. The schedule tries to retain current pump operating practices to the extent possible:

- Select pumps based on reservoir level and total pumping demand.
- Operate variable speed pumps only within 50 and 75 percent of total speed.
- When two variable speed pumps are operated together, operate one manually and place the other one in automatic mode; do not operate either pump above 65 percent of total speed when operated together.
- Start pumps against closed valves and allow discharge valves to open fully (except as noted below).

The proposed procedures differ from current practices in two important ways:

- Pumps would be operated only within the range of total dynamic heads (TDH) suggested by the manufacturer. At the Folsom Pumping Plant the TDH is approximately equivalent to the elevation difference between the reservoir and the North Fork Pipeline surge tank.
- Limited valve-throttling is proposed, to keep pumps within proper TDH ranges when the required lift is low (i.e., when the reservoir water level is above 405 feet). Throttling is proposed only for pumps 6, 7, and 8, which are equipped with butterfly valves suitable for operation in a partially open position.

The proposed pump selection schedule (Appendix F) would maintain the pressure in the North Fork Pipeline under the maximum operating level of its main surge tank (which has an overflow elevation of 479.3 feet). The target water level in the surge tank would be set at:

- Elevation 435 feet for reservoir water levels of 405 feet and lower.
- Elevation 455 feet for reservoir levels between 405 and 430 feet.

The pump selection schedule does not consider pumping at reservoir levels above 430 feet. In order to keep pumps within their operating ranges at such high reservoir water surface elevations, surge tank levels would have to be set close to the overflow point, creating a high potential for spills.

The new Natoma Pipeline surge tank has a maximum operating level of 434 feet and overflows at 436 feet. If the North Fork surge tank is operated with a water level at 455 feet while pumps are used to deliver water to the City of Folsom and the Folsom Prison, the Natoma Pipeline surge tank would have to be isolated to prevent overflows. Alternatively, various valves could be throttled to keep levels in the Natoma surge tank below the maximum operating level.

The proposed pump selection schedule consists of a simple set of spreadsheets (included in Appendix F). An operator would locate the total demand and the reservoir level, and the best pump combination for that set of conditions would be listed.

Deviation from the pump selection schedule would be necessary for demands higher than 220 cfs with reservoir levels at 410 feet or higher (see Figure 3-3 or spreadsheets in Appendix F). The only way to meet demands under those conditions would be to use the constant speed pumps well outside their normal operating ranges.

6.1.2 Costs Associated with New SOP

If the new SOP is implemented in-house (based on the pump selection schedule in Appendix F) and the training of operators is done by the SOP developers, there would be no external costs. No equipment purchases are proposed under this action.

6.2 Replacement of Discharge Valves

Five of the existing eight pumps have gate valves on their discharge lines. Butterfly valves on the discharge lines would allow throttling.

As established in Section 3 of this document, current practice at the pumping plant is to operate with discharge valves fully open, regardless of the most efficient operating range of each pump. The only way to keep pumps within their efficient, manufacturer-recommended operating ranges is through valve throttling.

6.2.1 Description of Valve Improvements

Changing over to butterfly valves on discharge lines would require:

1. Removal and disposal of existing valves.
2. Modification of discharge piping; the extent of the modifications would depend on the size difference between old and new valves.
3. Installation of new butterfly valves with electric actuators.
4. Installation of pressure sensors on suction and discharge piping.
5. Purchase and installation of a new programmable logic controller (PLC), set to operate valves to open as far as necessary to keep the differential pressure at the pump's optimum head.
6. Incorporation of new controls into overall pumping plant controls.

Valve replacement work can be performed during periods when gravity flows are possible. There would be no disruptions of water deliveries.

6.2.2 Costs Associated with New Valves

Approximate costs of purchasing and installing new valves are presented in Table 6-1. Soft costs (engineering, financing, pre- and post-construction costs) and internal Reclamation costs are not included.

Table 6-1 Valve Replacement Costs

Description	Unit	Quantity	Unit Cost	Total Cost
Removal and disposal of existing valves	LS	1	$3,500	$3,500
Discharge pipe modifications	EA	4	$3,000	$12,000
18-inch butterfly valve w/ elec. motor actuator	EA	1	$17,000	$17,000
24-inch butterfly valve w/ elec. motor actuator	EA	3	$26,000	$78,000
Pressure sensors	EA	8	$2,000	$16,000
New valve controls	LS	1	$50,000	$50,000
Reconfiguring plant controls	LS	1	$5,000	$5,000
Subtotal Direct Construction Cost				**$181,500**
Mobilization/demobilization 5% of Subtotal				$9,100
Subtotal				$190,600
General Contractor's General Conditions, OH&P @ 10%				$19,100
Subtotal				$209,700
Design development & estimating contingencies (20%)				$41,900
Estimated construction cost				$251,600
Construction contingency (25%)				62,900
Estimated Field Cost (FC), in 2011 Dollars				**$314,500**

6.3 Upgrades of Power Supply

The improvements described in this section are independent of changes to controls associated with new valves and/or new pumps. The power supply improvements can be implemented individually or together. Implementation of all improvements at the same time would minimize plant disruption and reduce costs.

6.3.1 Description of Power Supply Upgrades

Three upgrades are suggested:

- Replacement of switchgear UHA with new, modern switchgear with microprocessor-based, multi-functional relays; new switchgear would be designed to accommodate new pumps as required.
- Replacement of feeder cable and termination at switchgear UHA.
- Improve reliability of plant's main switchgear 1 and switchgear 2: add a new tie (breaker) so that the busses and associated loads of switchgears 1 and 2 can have access to power via either set of cables (assuming the switchgear busses are adequately rated, say for 800 Amps or above). Upgrade each set of cables to carry switchgear 1 and switchgear 2 loads, as well as the total load of the entire pumping plant.

6.3.2 Costs Associated with Power Supply Upgrades

Approximate costs are presented in Table 6-2. Upgrades can be implemented individually or together. Soft costs (engineering, financing, pre- and post-construction costs) and internal Reclamation costs are not included.

Table 6-2 Cost of Power Supply Upgrades

Item	Estimated Cost	Assumptions/Comments
Replacement of switchgear UHA	$600,000	Implementation of all changes together would reduce total costs an estimated 20%
Cable and termination replacement	$200,000	
Improvement of plant's main switchgear	$2M	

6.4 Pump Replacement

Replacement of constant speed pumps with variable speed pumps would reduce power consumption and allow efficient pump operation at all times. Different combinations of pump replacement are possible. Only combinations that would be capable of satisfying the maximum future demands were considered.

6.4.1 Description of Pump Replacement Alternatives

Many combinations of pump replacement are possible. The following are suggested for further consideration:

- Replace pumps 2, 3, 4, and 5 (four pumps) with three variable speed pumps rated for 75 cfs each. Pumps 6, 7, and 8 to remain in place. Although Pump 6 is a constant speed pump, its butterfly discharge valve allows operation at the appropriate TDH.
- Replace pumps 2, 3, 4, 5, and 6 (five pumps) with four variable speed pumps rated for 75 cfs each. Pumps 7, and 8 to remain in place.
- Replace pumps 2, 3, 4, 5, and 6 (five pumps) with five variable speed pumps rated for 60 cfs each. Pumps 7, and 8 to remain in place.

Total pumping plant capacities for existing pumps and suggested replacement alternatives are presented in Table 6-3.

Pump replacement work can be performed during periods when gravity flows are possible. There would be no disruptions in water deliveries.

Table 6-3 Pumping Plant Capacity for Various Pump Replacement Scenarios

Pump	Rated* Pump Capacities (cfs) Existing	Three New Pumps	Four New pumps	Five New Pumps
2	20	-	-	60
3	50	75	75	60
4	40	75	75	60
5	40	75	75	60
6	80	80	75	60
7	87	87	87	87
8	87	87	87	87
Total	**404**	**479**	**474**	**474**

* "Rated" pump capacities represent flow rates at maximum operating efficiency.

6.4.2 Costs Associated with Pump Replacement

Approximate pump replacement costs are presented in Table 6-4 for the "Four New Pumps" alternative. Unit costs are provided to facilitate estimating the costs of the three-pump and five-pump alternatives. Soft costs (engineering, financing, pre- and post-construction costs) and internal Reclamation costs are not included.

Table 6-4 Pump Replacement Costs (Four New Variable Speed Pumps)

Description	Unit	Quantity	Unit Cost	Total Cost
Removal and disposal of (4) existing pumps	LS	1	$7,000	$7,000
New pumps/drivers	EA	4	$600,000	$2,400,000
New VFDs	EA	4	$300,000	$1,200,000
New suction valves	EA	4	$24,500	$98,000
New butterfly discharge valves	EA	4	$24,500	$98,000
Sensors and piping modifications	EA	4	$5,000	$20,000
New pump/valve controls	LS	1	$50,000	$50,000
Reconfiguring plant controls	LS	1	$5,000	$5,000
Subtotal Direct Construction Cost				**$3,878,000**
Mobilization/Demobilization 5% of Subtotal				$193,900
Subtotal				$4,071,900
General Contractor's General Conditions, OH&P @ 10%				$407,200
Subtotal				$4,479,100
Design Development & Estimating Contingencies (20%)				$895,800
Estimated Construction Cost				$5,374,900
Construction Contingency (25%)				1,343,700
Estimated Field Cost (FC), in 2011 Dollars				**$6,718,600**

The approximate costs for the 3- and 5-pump alternatives would be:

- Three new 75 cfs variable speed pumps: $5.1M
- Five new 60 cfs variable speed pumps: $8.4M

6.5 Reconfiguration of Pump Intake

The cost of reconfiguring the pump intakes is impossible to determine until a new configuration is selected. The three-dimensional flow patterns from suction manifold to pumps are very complex and make analytical design methods unsuitable. A physical model of the pump intakes would be required to properly analyze approach flow patterns and arrive at a satisfactory design.

The cost of physical model tests would vary depending on the extent of the model, its scale, and the complexity of the testing program. Modeling costs are likely to be in the range of $150,000 to $200,000.

The reconfigured intake could take many shapes. One would be a modified manifold with strategically placed metal guide vanes on the approaches to each suction pipe and inside of each suction pipe. Another possibility would be a pressurized sump that provides evenly distributed flow to each pump intake. In either case, a temporary pumping plant bypass would have to be provided and the work scheduled for one gravity-flow period; opening valves V1, V2, V5, and V10 and closing V3 would allow use of the discharge piping as a bypass with limited capacity.

The physical model study would identify hydraulic deficiencies and might also identify a "quick fix." In that case construction costs might be in the hundreds of thousands of dollars. If the model study could only identify complex redesigns, construction costs could run above $5M.

6.6 Combinations of Recommended Actions

The actions described above must be evaluated individually, although implementation of several or all of them together is also feasible:

- *Development and adoption of a new SOP:* The current SOP could be revised while keeping the same equipment. If new valves and/or pumps are to be installed, development of the new SOP should be delayed to incorporate details of the operation of the new equipment.
- *Installation of new butterfly valves:* The new valves would include automated controls to keep existing pumps within acceptable operating ranges. The existing SOP would have to be revised upon valve installation.
- *Power supply upgrades:* The upgrades could be implemented while keeping the existing equipment. Their implementation would make more sense, however, as part of a pumping plant refurbishing that included new pumps, valves, and controls.
- *Installation of new variable speed pumps:* New valves are assumed with the new pumps. Power supply upgrades would be necessary as well, as the new pumps would increase the total power demand at the plant. A new SOP would be needed.
- *Pump intake reconfiguration:* A new intake configuration would improve the efficiency of the existing pumps only if they are operated within acceptable ranges; new discharge valves

and a new SOP would be required along with the intake reconfiguration; pumps could remain as they are, and minor power supply upgrades would suffice.

6.7 Impacts of Recommended Actions

The effects of the recommended actions are summarized in Table 6-5.

Table 6-5 Impacts of Recommended Actions

Action	Impacts
Develop new SOP	For existing equipment: • Would reduce maintenance needs, prevent undue pump/valve wear • Would NOT reduce power consumption • Would NOT increase capacity or system reliability For new valves and pumps with power system upgrades: • Would reduce maintenance needs, prevent undue pump/valve wear • Would reduce power consumption • Would improve system reliability
New discharge valves	• Would stop cavitation damage of constant speed pumps • Would reduce maintenance needs, prevent undue pump/valve wear • Would NOT reduce power consumption but rather increase it • Would make 404 cfs capacity attainable without pump damage • Would increase system reliability by operating at best pump efficiency
Power supply upgrades	• Would improve reliability of power supply to the pumping plant • Would maintain one hundred percent redundancy • Would modernize plant
New pumps	• Would reduce power consumption • Would increase pumping capacity • Would increase system reliability • Would reduce long term maintenance needs
Reconfigured intake	• Would improve pump efficiency • Would reduce maintenance needs, prevent undue pump/valve wear

APPENDIX A

References

DRAWINGS

Pumping Plant Expansion Drawings

Drawing No.	Title	Author	Date
T-1	Title Sheet, Vicinity and Location Map and Drawing List	SAI Engineers	3/7/1997
A-1	Building floor and roof	SAI Engineers	3/11/1997
A-2	Building elevations	SAI Engineers	3/7/1997
S-1	Civil/structural demolition plan	SAI Engineers	2/26/1997
S-2	Foundation plan	SAI Engineers	2/26/1997
S-3	Building addition, roof framing plan	SAI Engineers	2/26/1997
S-4	Building sections	SAI Engineers	2/26/1997
S-5	Pump foundation plan	SAI Engineers	2/26/1997
S-6	Miscellaneous details	SAI Engineers	2/25/1997
E-0	Legend, abbreviations and general notes	SAI Engineers	3/7/1997
E-1	Single line diagram	SAI Engineers	3/7/1997
E-2	Three line diagram	SAI Engineers	3/7/1997
E-3	Pump 7 & 8 and Mov-14 & 26 Control Schematics	SAI Engineers	3/13/1997
E-5	Electrical demolition plan	SAI Engineers	3/7/1997
E-6	New electrical equipment and grounding plans	SAI Engineers	3/7/1997
E-7	Switchgear 1 and 2 Sections and Details	SAI Engineers	3/13/1997
E-8	Raceway plan and Switchgear 1 and 2 elevation	SAI Engineers	3/7/1997
E-9	Lighting and power plans and panel schedule	SAI Engineers	3/7/1997
M-1	Mechanical demolition plan and sections	SAI Engineers	2/21/1997
M-4	VFD room AC plan	SAI Engineers	2/21/1997
M-5	Pump area sections	SAI Engineers	2/21/1997

Miscellaneous Drawings

Drawing No.	Title	Author	Date
	Natoma Raw-Water Pipeline Phase B	Camp Dresser & McKee Inc.	April 2000
	S.N.T.W.P.T. San Juan Suburban Water Treatment District - Raw Water Pipeline	Clendenen Engineers	9/30/1986
	Pipelines for Sidney N. Peterson Water Treatment Plant	Clendenen & Associates	1976
	Construction of Natoma Pipeline - Phase A - Vol 2 - Drawings	Robert Miles	8/7/1998
	Construction of Natoma Standpipe Relocation – Vol 2 - Drawings (Conformed to Addendum No. 1)	Robert Miles	March 2007
C-1	Construction of Natoma Standpipe Relocation – Sheet C-1	Robert Miles	8/21/2007
C-4	Construction of Natoma Standpipe Relocation – Sheet C-4	Robert Miles	8/21/2007
C-4	Construction of Natoma Standpipe Relocation – Sheet C-8	Robert Miles	8/21/2007
485-208-603	North fork pipe line by-pass and regulating valve	USBR	Unknown
485-208-846	Emergency pumping system general plan and installation	USBR	July 1992
485-208-852	Emergency pumping plan electrical installation	USBR	July 1992
485-208-854	Emergency pumping system 36 inch pipe installation in valve unit	USBR	6/7/1992
485-208-855	Emergency pumping system standpipe	USBR	6/4/1992
485-208-942	San Juan and Roseville pipeline plan and profile	USBR	9/1/1987
485-208-950	Natoma distribution box and 42" butterfly valve profile, details and sections	USBR	11/1/1988
485-208-951	Natoma regulating system and 42" butterfly valve schematic	USBR	11/1/1988
485-208-953	Natoma waterline remote control electrical installation	USBR	11/1/1988
485-208-980	Folsom Dam Pumping Plant Pumping Unit No. 6	USBR	10/16/1989
485-208-1147	General plan and tap installation	USBR	2/13/1992
485-208-1149	Emergency pumping system 84" pipe tap installation	USBR	3/4/1992
485-218-688	Folsom Pumping Plant Water Distribution Flow Diagram	USBR	8/8/1991

Drawing No.	Title	Author	Date
485-218-1093	Folsom Power Plant & Switchyard UHA Panel 2 Breaker 52-3 (312) Pumping Plant Feeder No. 1 Wiring Diagram	USBR	2/5/2007
485-218-1094	Folsom Power Plant & Switchyard UHA-Feeder 52-6 (612) Wiring Diagram	USBR	2/5/2007
485-218-1461	Folsom Pumping Plant Stand Pipe High Level - Pump Trip Control Schematic Diagram	USBR	3/14/2002
485-218-1470	Folsom Dam Pumping Plant Expansion Single Line Diagram	USBR	9/22/2005
485-218-1479	Bypass Pipe and Valve at Sta 10+90 Details	USBR	6/17/2000
485-218-1480	Bypass Pipe and Valve at Sta 10+90 Details	USBR	6/17/2000
485-218-1719	Folsom Dan Natoma Pipeline Phase A Plan & Profile Station 0+82 to 13+00	USBR	August 1998
485-218-1720	Natoma Pipeline Phase A Plan & Profile Station 13+00 to 25+00	USBR	August 1998
485-218-1721	Natoma Pipeline Phase A Plan & Profile, Station 25+0 to 37+00	USBR	August 1998
485-218-1722	Natoma Pipeline Phase A Plan & Profile Station 37+00 to 49+56	USBR	August 1998
485-218-1753	Roseville 60" raw water pipeline project cover sheet	USBR	6/30/2001
485-218-1754	Roseville 60" raw water pipeline project layout and notes	USBR	6/30/2001
485-218-1755	Roseville 60" raw water pipeline project abbreviations, symbols and general notes	USBR	6/30/2001
485-218-1756	Roseville 60" raw water pipeline project horizontal/vertical control and hydraulic profile	USBR	6/30/2001
485-218-1757	Roseville 60" raw water pipeline project Barton Road plan and profile	USBR	6/30/2001
485-218-1758	Roseville 60" raw water pipeline project Barton Road plan and profile	USBR	6/30/2001
485-218-1759	Roseville 60" raw water pipeline project Barton Road plan and profile	USBR	6/30/2001
485-218-1760	Roseville 60" raw water pipeline project Barton Road plan and profile	USBR	6/30/2001
485-218-1761	Roseville 60" raw water pipeline project Baldwin Reservoir plan and profile	USBR	6/30/2001
485-218-1762	Roseville 60" raw water pipeline project Baldwin Reservoir plan and profile	USBR	6/30/2001

Drawing No.	Title	Author	Date
485-218-1763	Roseville 60" raw water pipeline project Baldwin Reservoir plan and profile	USBR	6/30/2001
485-218-1764	Roseville 60" raw water pipeline project Auburn-Folsom road plan and profile	USBR	6/30/2001
485-218-1765	Roseville 60" raw water pipeline project Auburn-Folsom road plan and profile	USBR	6/30/2001
485-218-1766	Roseville 60" raw water pipeline project Facility tie-in details	USBR	6/30/2001
485-218-1767	Roseville 60" raw water pipeline project appurtenance details	USBR	6/30/2001
485-218-1768	Roseville 60" raw water pipeline project trench details	USBR	6/30/2001
485-218-1769	Roseville 60" raw water pipeline project pipeline details	USBR	6/30/2001
485-218-1770	Roseville 60" raw water pipeline project miscellaneous details	USBR	6/30/2001
485-218-1771	Roseville 60" raw water pipeline project Barton Road Tree Removal Plan	USBR	6/30/2001
485-218-1772	Roseville 60" raw water pipeline project Baldwin Reservoir tree removal plan	USBR	6/30/2001
485-218-1773	Roseville 60" raw water pipeline project Auburn-Folsom road tree removal plan	USBR	6/30/2001
485-218-1774	Roseville 60" raw water pipeline project tree information sheet	USBR	6/30/2001
485-218-1775	Roseville 60" raw water pipeline project test station installation	USBR	6/30/2001
485-218-1776	Roseville 60" raw water pipeline project test station & cable connection	USBR	6/30/2001
485-218-1777	Roseville 60" raw water pipeline project test station & cable connection	USBR	6/30/2001
485-218-1778	Roseville 60" raw water pipeline project traffic control plan	USBR	6/30/2001
485-218-1784	Folsom Switchyard Electrical Installation Switching Diagram	USBR	6/8/2007
485-218-1859	Folsom Pumping Plant Electrical Installation 208/120C Power Distribution System Single Line Diagram	USBR	10/22/2005
485-D-65	Steel penstocks plan and profiles	USBR	4/16/1951
485-D-1293	Main concrete dam typical sections	USCOE	6/1/1951
485-D-1294	Main concrete dam	USCOE	Unknown

Drawing No.	Title	Author	Date
485-D-1322	Folsom Dam North Fork Pipe Line Plan, Profile & Sections	USCOE	3/18/1954
485-D-1324	Folsom Dam Natoma Pressure Pipe Line Plan, Profile and Details	USCOE	6/25/1951
485-D-1354	Folsom Dam Pumping Plant Inlet Emergency Valve Installation	USCOE	8/15/1956
485-D-1551	Pumping Plant Equipment Mechanical Pump Installation	USCOE	9/11/1951
485-D-1570	Mechanical flow control & measuring equipment	USCOE	11/28/1952
485-D-1680	North fork Natoma water supply system flow diagrams	USCOE	4/25/1973
485-D-1826	Electrical installation surge tank	USBR	4/2/1969
485-D-1827	Roseville Water Service General Arrangement	USBR	9/25/1969
485-D-1828	Roseville Water Service Surge Tank and Standpipe Modifications	USBR	4/16/1969
485-D-1829	Roseville Water Service Meter Installation Plan & Section	USBR	7/24/2000
485-D-1831	Roseville Water Service Pressure Relief Station Plan and Sections	USBR	3/12/1973
485-D-1844	Meter Installation 42" Hinkle Pipe Line General Arrangement Location	USBR	2/5/1973
485-D-1847	Roseville/ San Juan flow control equipment schematic and wiring diagrams	USBR	6/17/1991
G-7	General Process Flow Schematic, Roseville Water Treatment Plant Phase III Expansion	City of Roseville Env. Utilities Department	Feb 2006
G-9	General Hydraulic Profile, Roseville Water Treatment Plant Phase III Expansion	City of Roseville Env. Utilities Department	Feb 2006
Sheets 40 to 51 of 57	Raw Water Pipeline, Contract II, Schedule C, City of Roseville Water Supply Facilities	Brown & Caldwell	Feb 1969
G-5	Schematic Flow Diagram and Hydraulic Profile, Sidney N. Peterson Water Treatment Plant	Clendenen & Associates	June 1977

DOCUMENTS

Title	Author	Date
Folsom Pumping Plant Training for Pumps 7 & 8 Operation, Preliminary Session, March 13, 2000 Agenda	Will B. Betchart	3/11/2000
Folsom Pumping Plant Capacity Evaluation, Attachment B-1: Maximum Bypass Capacity Through the Discharge Header Assuming Maximum Flood Control Water Surface	Will B. Betchart	12/31/2004
Folsom Pumping Plant Emergency Pump Test	Will B. Betchart	12/31/2004
Flow Data 2004	City of Roseville Water Treatment Plant	2004
Flow Data 2005	City of Roseville Water Treatment Plant	2005
Flow Data 2006	City of Roseville Water Treatment Plant	2006
Designer's Operating Criteria and Standard Operating Procedure, Folsom Dam Emergency Pumping Plant	Folsom Dam, American River Division, Central Valley Project, California	Unknown
Standpipe & Isolation Valve Structure, Natoma Pipeline	Folsom Water Treatment Plant	11/23/1999
Pump Test Data	Ingersoll-Dresser Pump Company	5/18/1998
San Juan Water District Water Treatment Plant Flows	San Juan Water District	January 2004 - October 2007
Folsom Dam Flow Data	USBR	January 2001 - November 2007
Folsom Pumping Plant Flows 2006-2007	USBR	2006 - 2007
Folsom Pumping Plant Delivery and Efficiency Data	Unknown, Provided by USBR	7/1/1994

APPENDIX B

Field Tests

B1. Head Loss Test Memorandum

B2. Pump Operation Memorandum

B3. Pump Power Consumption Tests

B1. Head Loss Tests Memorandum

WRE Water Resources Engineering, Inc.

MEMORANDUM

DATE: December 21, 2009

TO: Brian Zewe, US Bureau of Reclamation

FROM: Gustavo Arboleda, WRE

RE: Folsom Pumping Plant Capacity Evaluation
Field Testing on Raw Water Distribution System – Test Results

Background

Water Resources Engineering, Inc. (WRE) was retained by Bureau of Reclamation (Reclamation) to conduct an evaluation of the capacity of the Folsom Pumping Plant and associated water transmission pipelines. As part of the hydraulic evaluation of the system, WRE developed a computer model that replicates the hydraulic performance of pumps, valves, and pipes. The computer model uses one of the more advanced software packages available (Info Water by MWH Soft); its accuracy, however, depends on assumptions regarding energy losses.

Field test were conducted to measure actual energy losses during system operation. Tests were performed on April 29, 2009, following the previously devised and approved test plan attached as Appendix B1-1. This memorandum presents the results of the field tests.

Summary of Test Results

Head loss data are summarized in Figures 1 to 3. In addition to the test data points, Figures 1 to 3 include best-fit curves representing the head loss versus flow rate relationship for various segments of the piping system. These relationships were used to calibrate the computer model.

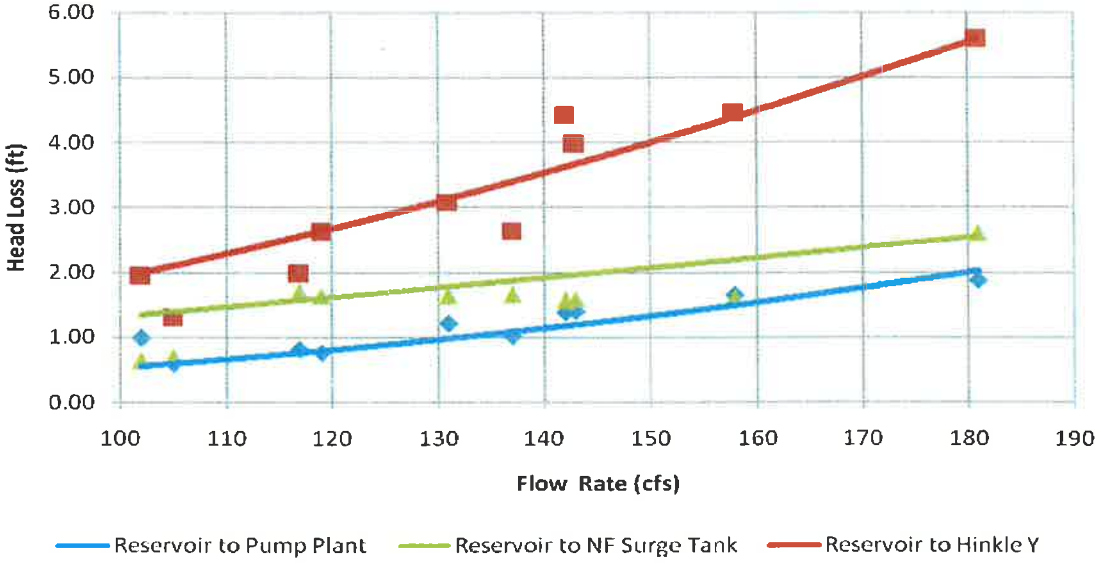


Figure 1. Head Losses in North Fork Pipeline

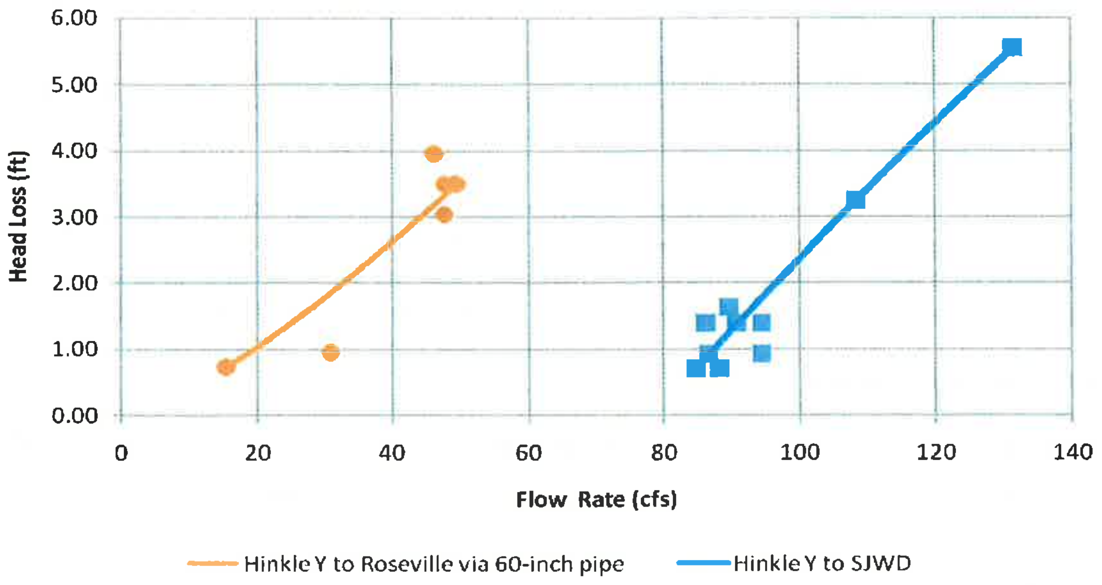


Figure 2. Head Losses in SWJD and City of Roseville Pipes

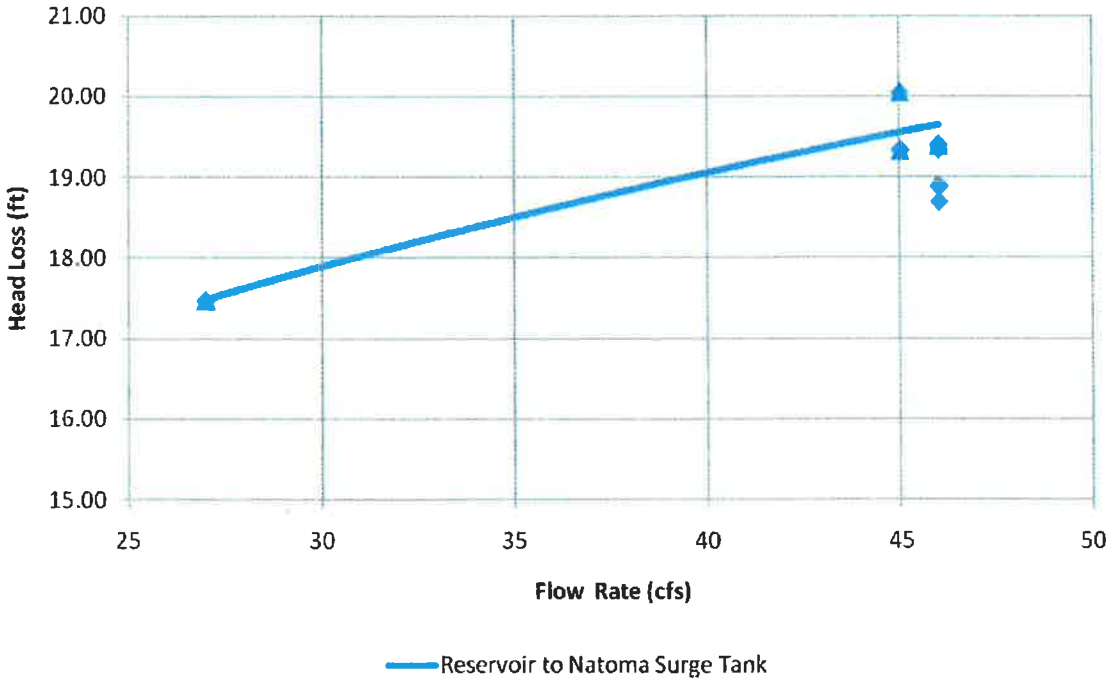


Figure 3. Head Losses in Natoma Pipeline

Field Test Procedures

Field tests were conducted by Reclamation's pumping plant operators with support from Reclamation and WRE engineers and with the collaboration of treatment plant operators at the San Juan Water District (SJWD), City of Roseville, City of Folsom, and Folsom Prison.

Tests consisted of setting flow rates at pre-determined levels, waiting for the system to stabilize, and then collecting 14 measurements: 6 flow meter readings and 8 pressure readings. Of the 8 pressure readings 5 were collected from the gages installed for the tests, and the other 3 from digital readouts at Reclamation's central controls. Table 1 summarizes measurement locations.

Table 1. Measuring Stations

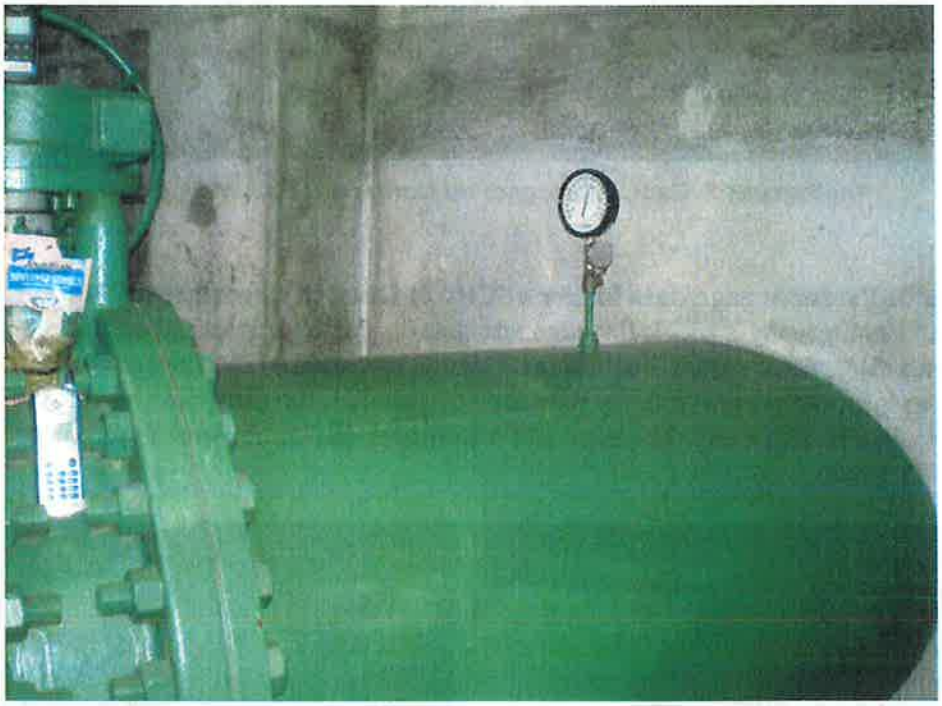
Station No.	Location	Parameter	Units*
1	Control room	Reservoir water surface elevation	Feet
2	Pumping plant, Pump 6 suction line	Pressure	psi
3	Control room	Water level on North Fork Pipeline surge tank	Feet
4	North Fork Pipeline at Hinkle Y, Pipeline Sta. 49+60	Pressure on North Fork Pipeline	psi
5	City of Roseville Treatment Plant	Pressure upstream of flow control valve	psi
6	SJWD Treatment Plant	Pressure upstream of flow control valve	psi
7	Control room	Water level on Natoma Pipeline surge tank	Feet
8	City of Folsom Treatment Plant	Pressure upstream of flow control valve	psi
9	Control room	Flow rate on Reclamation's North Fork Pipeline flow meter	cfs
10	Control room	Flow rate on Reclamation's Natoma Pipeline flow meter	cfs
11	City of Roseville Treatment Plant	Flow rate on City of Roseville's flow meter	MGD
12	SJWD Treatment Plant	Flow rate on SJWD's flow meter	MGD
13	Control room	Flow rate on Reclamation's flow meter on pipe to Folsom Prison	cfs
14	City of Folsom Treatment Plant	Flow rate on City of Folsom's flow meter	MGD

* psi: Pounds per square inch; 1 psi = 2.307 feet of head
cfs: cubic feet per second; 1 cfs = 448.8 gallons per minute = 7.48 gallons per second
MGD: million gallons per day; 1 MGD = 1.547 cfs

Pressure gages provided readings in terms of "psi" at the point of measurement. In order to calculate head losses, the psi were converted to feet of water above the gage. Adding the feet of water to the gage elevation provided a water surface elevation that could be compared to the reservoir water level and to readings from other gages. Gage elevations were determined as indicated below.

Station No. 2: Pressure gage/data logger on suction line to Pump 6
As shown in Photograph 1, the gage was installed approximately 10 inches above the Pump 6 suction pipe. Folsom Pumping Plant Drawing 485-208-980 (see Appendix B1-2) shows a pipeline centerline elevation of 314.75 feet and a 30-inch pipe diameter. The gage, therefore, was approximately at elevation 314.75 + ½(30/12) + (10/12) = 316.8 feet.

A data logger was also installed at this location and 4 others. This electronic device continuously recorded pressures and stored readings every 10 seconds. The data logger at the Pump 6 suction line was 3.5 inches below the gage centerline, at an elevation of approximately 316.5 feet.



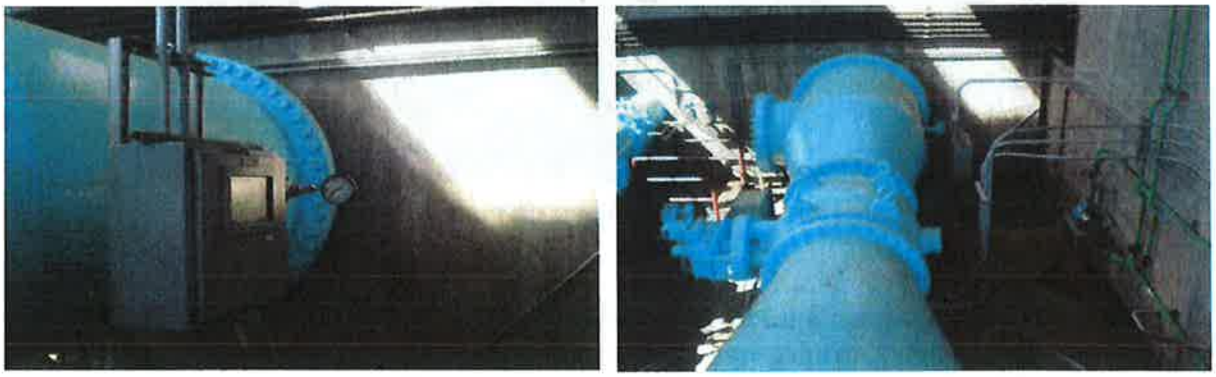
Photograph 1. Gage/data logger on Pump 6 suction pipe

Station No. 4: Pressure gage/data logger at Hinkle Y
As shown in Photograph 2, the gage was installed on the center of the North Fork Pipeline. The gage was roughly 40 feet upstream of the "Y" connection to SJWD pipelines. According to Reclamation Drawing 485D-1322 (see Appendix B1-2), the pipe centerline at the "Y" is at elevation 388.5 feet, and the pipe slopes up to the Y at 0.0052 feet/foot. The gage, therefore, was approximately at elevation 388.5 - (40 x 0.0052) = 388.3 feet. The data logger was approximately at 388.0 feet.

Photograph 2. Gage/data logger on North Fork Pipeline at Hinkle Y

Station No. 5: Pressure gage/data logger at City of Roseville Treatment Plant

As shown in Photographs 3 and 4, the gage and data logger were installed on the center of the City of Roseville's water supply line a short distance upstream of the flow control valve. According to information provided by the City of Roseville, the centerline elevation for the water supply line is 385.5 feet. The gage and data logger, therefore, were approximately at elevation 385.5 feet.



Photographs 3 & 4. Gage/data logger on City of Roseville's water supply line

Station No. 6: Pressure gage/data logger at SJWD Treatment Plant

The gage and data logger were installed over the 54-inch diameter influent pipe at the chemical feed vault (Photograph 5). SJWD measured the distance from the floor of the vault (elevation

402 feet) to the gage at 34.5 inches. The gage, therefore, was approximately at elevation 402.0 + (34.5/12) = 404.9 feet. The data logger was approximately at 404.6 feet.

Photograph 5. Gage/data logger in SJWD chemical feed vault

Station No. 8: Pressure gage at City of Folsom Treatment Plant
According to information provided by the City of Folsom, the gage was approximately at elevation 388.0 feet.

Test Conditions

Tests were initiated at 7 a.m. on April 29, 2009. The water level in the Folsom Reservoir was 448.2 feet at the beginning of the tests and at 448.1 feet at the end. No pumps were used; all deliveries were made by gravity. Due to unanticipated delays in a SJWD valve installation project, only one of the two lines from the Hinkle Y to SJWD was used (72-inch pipe, which reduces to 66-inch and then to 54-inch).

A total of 10 tests were performed, as follows:

1. City of Roseville operating at about 10 MGD with all flow through 48-inch pipeline (valve on 60-inch pipeline closed); other purveyors operating normally.
2. City of Roseville operating at about 20 MGD with all flow through 48-inch pipeline (valve on 60-inch pipeline closed); other purveyors operating normally.
3. City of Roseville operating at 30 MGD with all flow through 48-inch pipeline (valve on 60-inch pipeline closed); other purveyors operating normally.

4. City of Roseville operating at about 10 MGD with all flow through 60-inch pipeline (valve on 48-inch pipeline closed); other purveyors operating normally.
5. City of Roseville operating at about 20 MGD with all flow through 60-inch pipeline (valve on 48-inch pipeline closed); other purveyors operating normally.
6. City of Roseville operating at 30 MGD with all flow through 60-inch pipeline (valve on 48-inch pipeline closed); other purveyors operating normally.
7. SJWD operating at 70 MGD; other purveyors operating at normal capacities; the City of Roseville using only its 60-inch pipeline.
8. SJWD operating at 85 MGD; other purveyors operating at normal capacities; the City of Roseville using only its 60-inch pipeline.
9. All purveyors operating at normal capacities; the City of Roseville using only its 60-inch pipeline.
10. City of Folsom operating at a reduced capacity, other purveyors at normal capacities; the City of Roseville using only its 60-inch pipeline.

Test Data

The first set of readings was collected at approximately 7:15 a.m. and subsequent readings were collected at roughly half-hour intervals. A full set of readings was collected within a 10-minute span. The readings collected through visual inspection of the gages and digital readouts are presented in Appendix B1-3 and summarized in Figures 1 to 3.

The data loggers recorded readings every 10 seconds and captured pressure spikes produced during valve adjustments as well as small fluctuations. The data logger readings were analyzed for each test. Averaging data logger readings after the system stabilized resulted in the measurements presented in Appendix B1-3.

Test data were analyzed for accuracy and consistency. Adjustments were made where visual readings did not coincide with data logger output. The data logger readings were given preference over visual readings because of their higher accuracy. Since the data logger readings changed over time, the visual readings in some instances helped determine the time interval to be selected from the data logger readings.

Flow Rate Measurements

Flow rates were measured two different ways: on the North Fork Pipeline, separate readings were obtained from Reclamation's meter and from the meters at SJWD and City of Roseville treatment plants. On the Natoma Pipeline readings were obtained from Reclamation's meter and from the meters at the City of Folsom treatment plant and the pipe to Folsom Prison.

As would be expected given the timing of the readings and the accuracy of flow metering devices, there were some differences in the readings from separate sources. The differences, presented in Tables 2 and 3, ranged from less than one percent to close to seven percent.

Table 2. Flow Rate Differences in North Fork Pipeline

	Flow Rates in "cfs"				North Fork Pipeline Flow Meter Readings Greater than Sum of Purveyors' Readings by
Test	SJWD	Roseville	SJWD + Roseville	North Fork Pipeline	
1	83.5	15.3	98.8	105	6.30%
2	83.5	31.1	114.6	117	2.10%
3	83.5	46.4	129.9	137	5.50%
4	83.5	16.2	99.7	102	2.30%
5	83.5	30.9	114.4	119	4.00%
6	83.5	46.4	129.9	131	0.80%
7	108.3	46.1	154.4	158	2.30%
8	131.5	45.8	177.3	181	2.10%
9	92.8	46.7	139.5	143	2.50%
10	92.8	46.6	139.4	142	1.90%

Table 3. Flow Rate Differences in Natoma Pipeline

	Flow Rates in "cfs"				Natoma Pipeline Flow Meter Readings Less than Sum of Individual Readings by
Test	Folsom Prison	City of Folsom	Prison + City of Folsom	Natoma Pipeline	
1	2.9	44.9	47.8	46	3.70%
2	3.2	43.9	47.1	46	2.40%
3	3	43.6	48.2	45	6.60%
4	2.9	44.9	47.8	46	3.70%
5	3.2	45	48.2	45	6.70%
6	2.9	44.9	47.8	45	5.80%
7	3.2	44.9	48.1	46	4.30%
8	3.2	44.9	48.1	46	4.30%
9	3.1	43.5	46.6	45	3.40%
10	3.3	25.2	28.5	27	5.30%

Flow rates measured by Reclamation's meter on the North Fork Pipeline were consistently higher than the sum of the flow rates measured by the meters at SJWD and City of Roseville treatment plants, as shown in Figure 3.

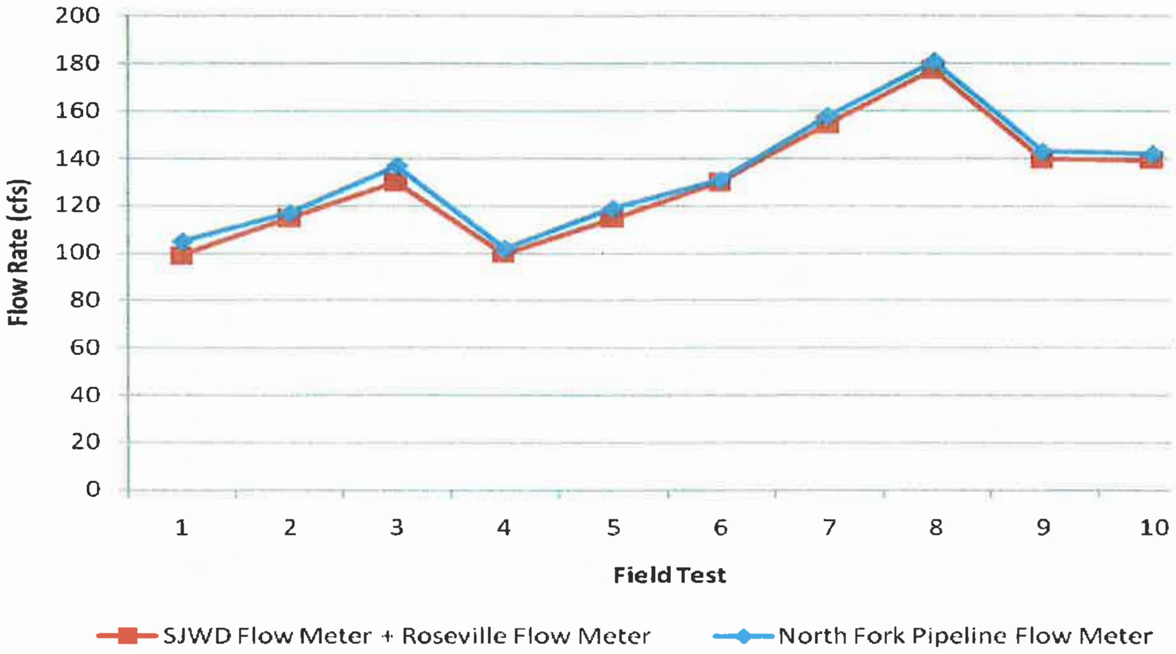


Figure 3. Flow Rate Measurements in North Fork Pipeline

Flow rates measured by Reclamation's meter on the Natoma Pipeline were consistently lower than the sum of the flow rates measured by the meters at the City of Folsom treatment plant and the pipe to Folsom Prison, as shown in Figure 4.

The test data presented in this memorandum used the flow rates measured by the water purveyors, for consistency. As indicated above, the differences between these readings and Reclamation's meters were relatively small. Use of either set of readings would not alter test findings.

WRE Water Resources Engineering, Inc.

DRAFT TEST PLAN - REVISED

DATE: April 1, 2009

TO: Brian Zewe, US Bureau of Reclamation

FROM: Gustavo Arboleda, WRE

RE: Folsom Pumping Plant Capacity Evaluation
Field Testing on Raw Water Distribution System

Background

Water Resources Engineering, Inc. (WRE) was retained by Reclamation to conduct an evaluation of the capacity of the Folsom Pumping Plant and associated water transmission pipelines. As part of the hydraulic evaluation of the system, WRE developed a computer model that replicates the hydraulic performance of pumps, valves, and pipes. The computer model uses one of the more advanced software packages available (InfoWater by MWH Soft); its accuracy, however, depends on assumptions regarding energy losses.

Field testing is the only reliable way of determining energy losses through the pumps, valves, and pipes of the distribution system. WRE, under its contract with Reclamation, was tasked to prepare a plan for a series of field activities that would allow the direct measurement of energy losses. The plan was initially submitted on January 15, for tests to be performed in February, when the Folsom Reservoir water level was low enough to require use of the pumping plant for raw water deliveries. The plan was revised on March 11 to delete tests on the Natoma Pipeline due to a pipeline collapse in late February.

Tests are now anticipated to be performed on April 29, 2009. A revised plan is required, as the Folsom Reservoir water level is currently at 442 feet and rising, precluding the use of pumps for raw water delivery. This document presents the newly revised plan.

Objective

The objective of the field testing is to collect data on energy losses between the reservoir and four end users: San Juan Water District (SJWD), the City of Roseville, Folsom Prison, and the City of Folsom. Specifically, the field testing will consist of recording pressures along the North Fork and Natoma pipelines for various rates of flow. Field measurements of energy losses will be used to refine the hydraulic model and verify its predictive abilities.

Preparatory Activities

Field tests will require a collaborative effort between Reclamation and raw water purveyors. The water treatment plants that receive Folsom Reservoir water will have to deviate from their normal operating procedures for the duration of the tests. A list of preparatory activities is presented below.

- **Set Test Date.** Reclamation has set a tentative test date of April 29, 2009.

- **Instrument Check.** The following pressure gages (or water level indicators) and flow meters will be used for the tests:
    - Folsom Reservoir water level indicator, reading water surface elevation in feet.
    - Pressure gage on suction side of pumping plant piping; piping is at a centerline elevation of 314.75 feet (see Figure 1, *Folsom Dam Raw Water Delivery System Schematic,* attached to this document); for a reservoir water level of 444 feet, the gage would read close to 129.25 feet (444 – 314.75 = 129.25) or 56 psi. Installing a digital gage such as the one illustrated in Figure 2 would greatly facilitate data collection.
    - Water level indicator on North Fork Pipeline surge tank, reading water surface elevation in feet.
    - Pressure gage on North Fork Pipeline at the Hinkle Y (at the location shown in Figure 3, attached, which is a short distance from the end of the North Fork Pipeline. The pipeline centerline elevation at the gage will need to be determined; the *Folsom Dam Raw Water Delivery System Schematic* shows a centerline elevation of 388.5 feet at the Y with the 42-inch pipe to SJWD, so the gage will be at an elevation slightly lower. For a reservoir water level of 444 feet, the static (no-flow) reading on the gage would be close to 55.5 feet (444 – 388.5 = 55.5) or 24 psi, depending on location. Installing a digital gage such as the one illustrated in Figure 2 would greatly facilitate data collection.
    - Pressure gages immediately upstream of the City of Roseville's end valves on their 48- and 60-inch pipelines. Shawn Barnes of the City of Roseville indicated on March 30 that readings from these gages were readily available from their electronic data acquisition system. Their datum (centerline pipe elevation at gage) will be provided by the City of Roseville.
    - Pressure gage immediately upstream of the San Juan Water District flow control valve. Bill Sadler of SJWD indicated on March 31 that readings from this gage are readily available from their electronic data acquisition system. Its datum (centerline pipe elevation at gage) will be provided by SJWD.
    - Water level indicator on new Natoma Pipeline surge tank, reading water surface elevation in feet.
    - Pressure gage immediately upstream of the City of Folsom flow control valve. Jim Bridges of the City of Folsom indicated on March 31 that the gage has not been calibrated recently but believes it can be checked by the April 29 tentative test date. Its datum (centerline pipe elevation at gage) will be provided by the City of Folsom.
    - Reclamation's flow meter on North Fork Pipeline, reading flow rate in cfs.
    - Reclamation's flow meter on Natoma Pipeline, reading flow rate in cfs.
    - City of Roseville's flow meters, reading flow rate in MGD.
    - SJWD's flow meter, reading flow rate in MGD.
    - Folsom Prison flow meter, reading flow rate in cfs.
    - City of Folsom flow meter, reading flow rate in MGD.
- **Prepare Data Sheets.** WRE will prepare the data sheets that will be used to record test data, and submit them to Reclamation for review and approval.

- **Test Procedure Review.** Reclamation pumping plant operators and SJWD, City of Roseville, City of Folsom, and Folsom Prison chief water treatment plant operators will review test procedures and confirm they are prepared to operate the system in accordance with these procedures on the scheduled test date.
- **Test Notification.** WRE will remind Reclamation pumping plant operators and SJWD, City of Roseville, City of Folsom, and Folsom Prison chief water treatment plant operators of impending tests 48 and 24 hours prior to testing.

Test Procedures

Tests will be directed by the test coordinator, either a Reclamation engineer or chief pumping plant operator, with support from WRE engineers. Reclamation valves referenced in the test procedures are shown in the system schematic attached at the end of this document. Purveyor valves and instrumentation are located in each water treatment plant and the respective plant operators will be responsible for their operation. Communication between the test coordinator and the treatment plant operators will be via cell phone.

The procedures outlined below assume that the reservoir water level will be at or above 444 feet and therefore the normal mode of delivering raw water will be by gravity flow. Based on data from previous years, anticipated normal rates of delivery at the end of April are in the order of 100 MGD to SJWD, 30 MGD to the City of Roseville, 35MGD to the City of Folsom and about 3 MGD to Folsom Prison. Test flow rates will stay within (i.e., will not exceed) the normal delivery rates.

Test procedures assume that:

- Reclamation valves will remain at their normal settings throughout the tests. Valve throttling to regulate flow rates will be done at the four end points by personnel from the respective water treatment plants.
- The raw water delivery system will be operating normally at the start of the testing, delivering water to the 4 purveyors via gravity flows.
- Pressure readings along the system will be made at indicated locations at the same time, or as close to it as practical (i.e., readings taken within 15 minutes of each other will be acceptable).

Tests will consist of the sequential steps listed below. WRE engineers will check each set of readings collected during a test step for "reasonableness" (falling within expected values) before proceeding to next test step.

Step	Approximate Time	Procedure
1	7:00 to 7:30 AM	Ask City of Roseville operators to set their flow rate to 10 MGD, all through the 48-inch pipeline (i.e., they should make sure the valve on the 60-inch pipeline is totally closed). Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters, listed below to facilitate referencing. • Folsom Reservoir water surface elevation • Pressure on gage on pumping plant suction header • Water level on North Fork Pipeline surge tank • Pressure on gage at Hinkle Y • Pressure immediately upstream of Roseville's flow control valve • Pressure immediately upstream of SJWD's flow control valve • Water level on Natoma Pipeline surge tank • Pressure immediately upstream of the City of Folsom flow control valve. • Flow rate on Reclamation's North Fork Pipeline flow meter. • Flow rate on Reclamation's Natoma Pipeline flow meter. • Flow rate on City of Roseville's flow meter. • Flow rate on SJWD's flow meter. • Flow rate on Folsom Prison's flow meter. • Flow rate on City of Folsom's flow meter.
2	7:30 to 8:00 AM	Ask City of Roseville operators to set their flow rate to 20 MGD, all through the 48-inch pipeline. Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters.
3	8:00 to 8:30 AM	Ask City of Roseville operators to set their flow rate to 30 MGD, all through the 48-inch pipeline. Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters.
4	8:30 to 9:00 AM	Ask City of Roseville operators to set their flow rate to 10 MGD, all through the 60-inch pipeline (i.e., they should make sure the valve on the 48-inch pipeline is totally closed). Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters

5	9:00 to 9:30 AM	Ask City of Roseville operators to set their flow rate to 20 MGD, all through the 60-inch pipeline. Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters.
6	9:30 to 10:00 AM	Ask City of Roseville operators to set their flow rate to 30 MGD, all through the 60-inch pipeline. Other water purveyors can maintain their normal settings. When flow stabilizes on Roseville's flow meter, record data from pressure gages and flow meters.
7	10:00 to 10:30 AM	Ask City of Roseville operators to resume normal operations. Ask SJWD operators to set their flow rate at 70 MGD. Other water purveyors can maintain their normal settings. When flow stabilizes on SJWD's flow meter, record data from pressure gages and flow meters.
8	10:30 to 11:00 AM	Ask SJWD operators to set their flow rate at 85 MGD. Other water purveyors can maintain their normal settings. When flow stabilizes on SJWD's flow meter, record data from pressure gages and flow meters.
9	11:00 to 11:30 AM	Ask SJWD operators to resume normal operations. Other water purveyors can maintain their normal settings. When flow stabilizes on SJWD's flow meter, record data from pressure gages and flow meters.
10	11:30 AM to 12:30 PM	Lunch Break
11	12:30 to 1:00 PM	Ask City of Folsom operators to set flow rate to about half of the "normal operations" flow rate. When flow stabilizes on City of Folsom's flow meter, record data from pressure gages and flow meters.
12	1:00 to 1:30 PM	Resume normal operations system-wide.

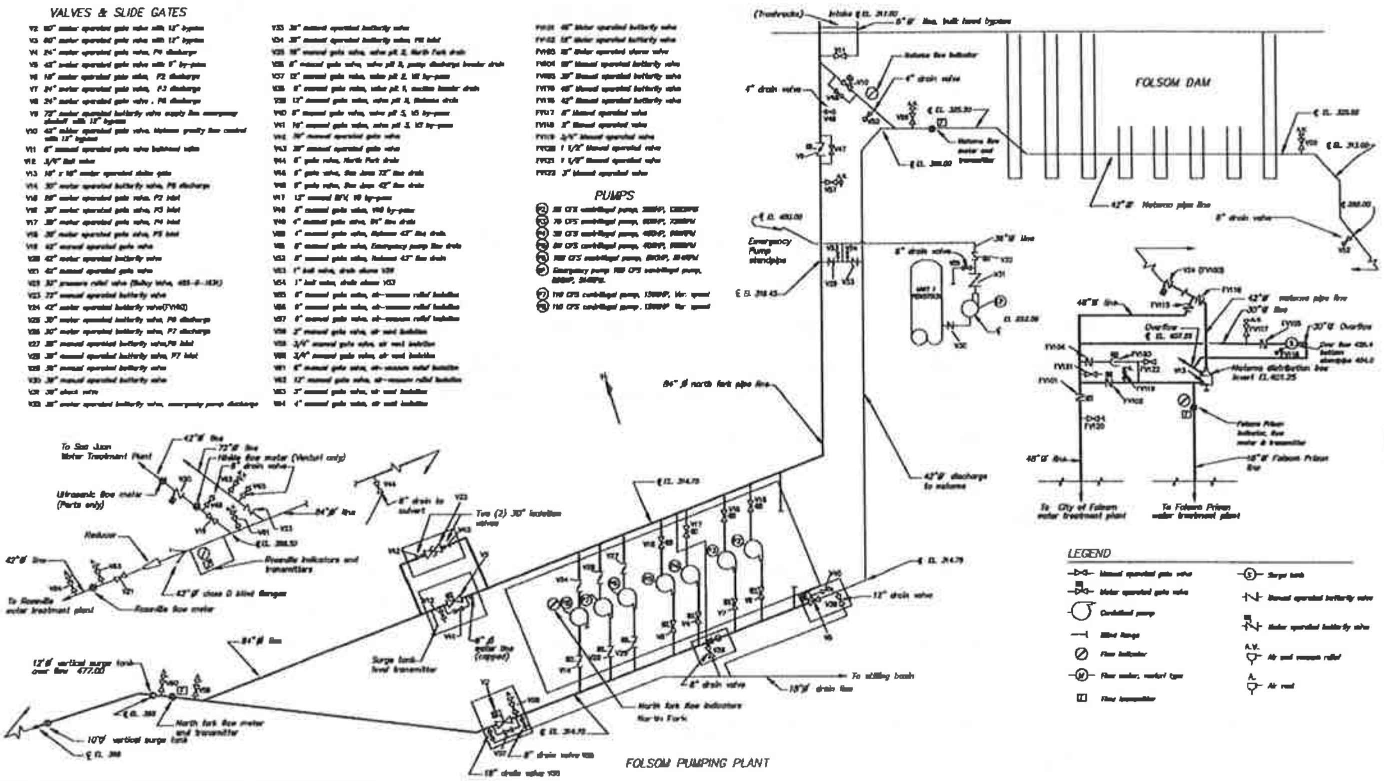
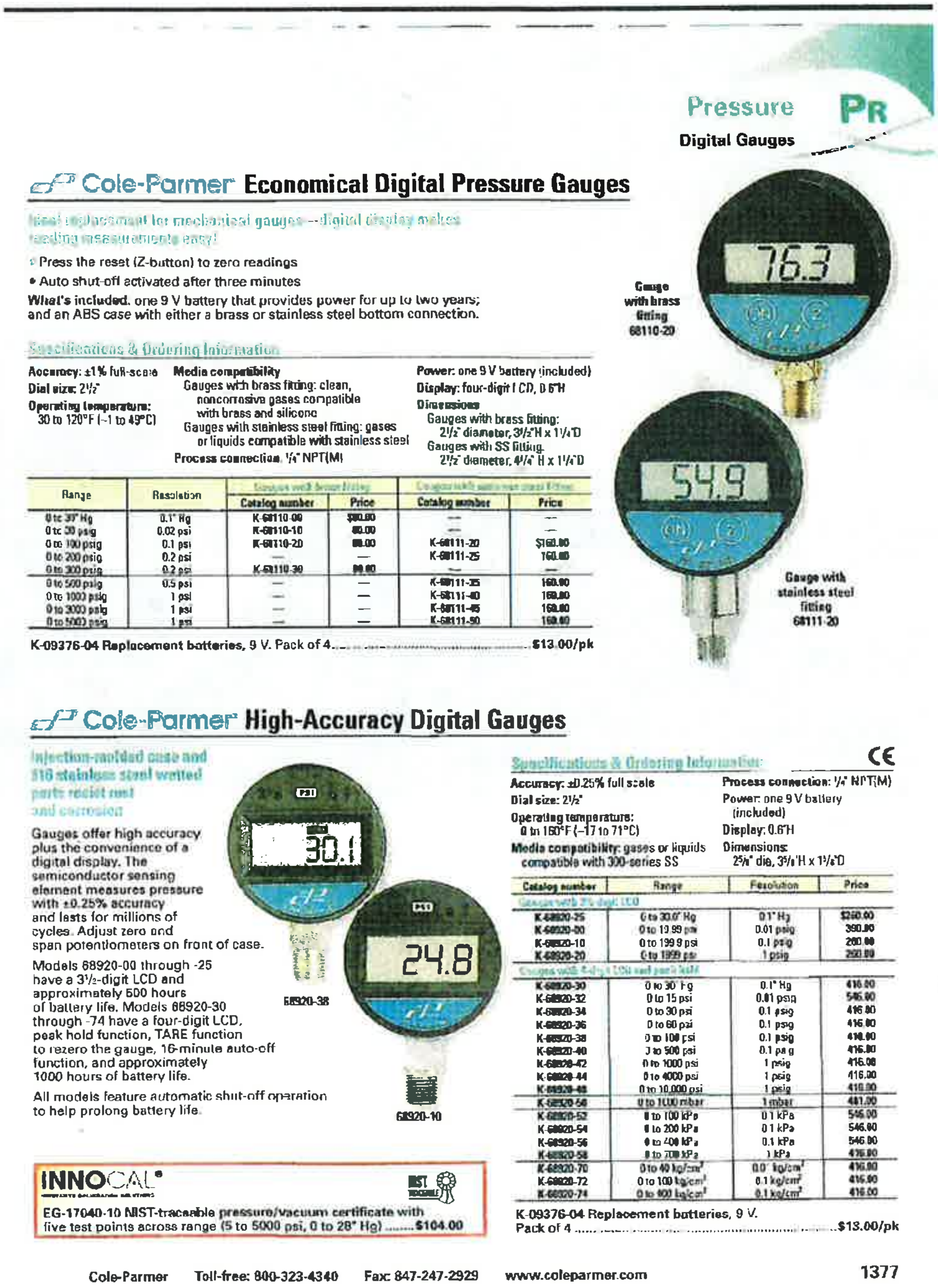


Figure 1. Folsom Dam Raw Water Delivery System Schematic

Source Drawing 485-218-688, Folsom Pumping Plant Water Distribution Flow Diagram, USBR, August 8, 1991



Pressure PR
Digital Gauges

Cole-Parmer Economical Digital Pressure Gauges

Ideal replacement for mechanical gauges—digital display makes reading measurements easy!

- Press the reset (Z-button) to zero readings
- Auto shut-off activated after three minutes

What's included. one 9 V battery that provides power for up to two years; and an ABS case with either a brass or stainless steel bottom connection.

Gauge with brass fitting 68110-20

Gauge with stainless steel fitting 68111-20

Specifications & Ordering Information

Accuracy: ±1% full-scale
Dial size: 2½"
Operating temperature: 30 to 120°F (–1 to 49°C)

Media compatibility
Gauges with brass fitting: clean, noncorrosive gases compatible with brass and silicone
Gauges with stainless steel fitting: gases or liquids compatible with stainless steel
Process connection. ¼" NPT(M)

Power: one 9 V battery (included)
Display: four-digit LCD, 0.6"H
Dimensions
Gauges with brass fitting: 2½" diameter, 3½"H x 1¼"D
Gauges with SS fitting. 2½" diameter, 4¼" H x 1¼"D

Range	Resolution	Gauges with brass fitting		Gauges with stainless steel fitting	
		Catalog number	Price	Catalog number	Price
0 to 30" Hg	0.1" Hg	K-68110-00	[illegible]	—	—
0 to 30 psig	0.02 psi	K-68110-10	[illegible]	—	—
0 to 100 psig	0.1 psi	K-68110-20	[illegible]	K-68111-20	$160.00
0 to 200 psig	0.2 psi	—	—	K-68111-25	160.00
0 to 300 psig	0.2 psi	K-68110-30	[illegible]	—	—
0 to 500 psig	0.5 psi	—	—	K-68111-35	160.00
0 to 1000 psig	1 psi	—	—	K-68111-40	160.00
0 to 3000 psig	1 psi	—	—	K-68111-45	160.00
0 to 5000 psig	1 psi	—	—	K-68111-50	160.00

K-09376-04 Replacement batteries, 9 V. Pack of 4 .... $13.00/pk

Cole-Parmer High-Accuracy Digital Gauges

Injection-molded case and 316 stainless steel wetted parts resist rust and corrosion

Gauges offer high accuracy plus the convenience of a digital display. The semiconductor sensing element measures pressure with ±0.25% accuracy and lasts for millions of cycles. Adjust zero and span potentiometers on front of case.

Models 68920-00 through -25 have a 3½-digit LCD and approximately 500 hours of battery life. Models 68920-30 through -74 have a four-digit LCD, peak hold function, TARE function to rezero the gauge, 16-minute auto-off function, and approximately 1000 hours of battery life.

All models feature automatic shut-off operation to help prolong battery life.

68920-38

68920-10

INNOCAL®

EG-17040-10 NIST-traceable pressure/vacuum certificate with five test points across range (5 to 5000 psi, 0 to 28" Hg) $104.00

Specifications & Ordering Information

CE

Accuracy: ±0.25% full scale
Dial size: 2½"
Operating temperature: 0 to 160°F (–17 to 71°C)
Media compatibility: gases or liquids compatible with 300-series SS

Process connection: ¼" NPT(M)
Power: one 9 V battery (included)
Display: 0.6"H
Dimensions: 2⅝" dia, 3⁵⁄₈"H x 1⁵⁄₈"D

Catalog number	Range	Resolution	Price
Gauges with 3½-digit LCD			
K-68920-25	0 to 30.0" Hg	0.1" Hg	$260.00
K-68920-00	0 to 19.99 psi	0.01 psig	390.00
K-68920-10	0 to 199.9 psi	0.1 psig	280.00
K-68920-20	0 to 1999 psi	1 psig	280.00
Gauges with 4-digit LCD and peak hold			
K-68920-30	0 to 30" Hg	0.1" Hg	416.00
K-68920-32	0 to 15 psi	0.01 psig	546.00
K-68920-34	0 to 30 psi	0.1 psig	416.00
K-68920-36	0 to 60 psi	0.1 psig	416.00
K-68920-38	0 to 100 psi	0.1 psig	416.00
K-68920-40	0 to 500 psi	0.1 psig	416.00
K-68920-42	0 to 1000 psi	1 psig	416.00
K-68920-44	0 to 4000 psi	1 psig	416.00
K-68920-48	0 to 10,000 psi	1 psig	416.00
K-68920-50	0 to 1000 mbar	1 mbar	481.00
K-68920-52	0 to 100 kPa	0.1 kPa	546.00
K-68920-54	0 to 200 kPa	0.1 kPa	546.00
K-68920-56	0 to 400 kPa	0.1 kPa	546.00
K-68920-58	0 to 700 kPa	1 kPa	416.00
K-68920-70	0 to 40 kg/cm^2	0.01 kg/cm^2	416.00
K-68920-72	0 to 100 kg/cm^2	0.1 kg/cm^2	416.00
K-68920-74	0 to 400 kg/cm^2	0.1 kg/cm^2	416.00

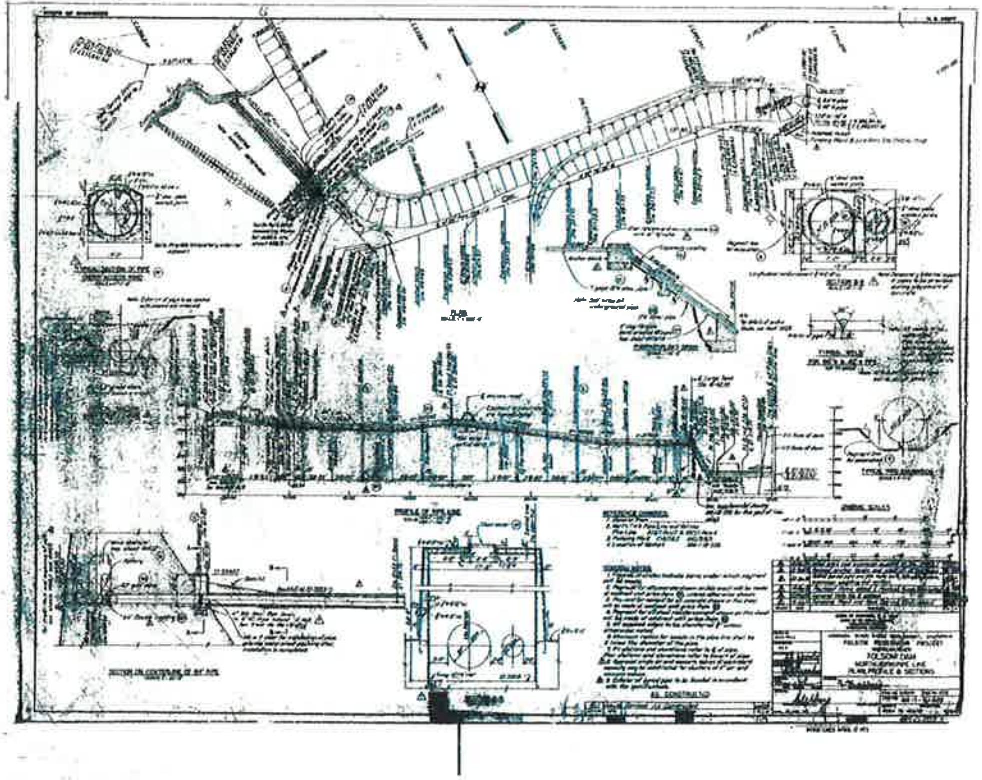
K-09376-04 Replacement batteries, 9 V.
Pack of 4 .... $13.00/pk

Cole-Parmer Toll-free: 800-323-4340 Fax: 847-247-2929 www.coleparmer.com 1377

Figure 2. Sample Digital Pressure Gages

Figure 3. Pressure Gage Location at Hinkle Y

APPENDIX B1-2
Reference Drawings


AS CONSTRUCTED
FOLSOM DAM
PLAN, PROFILE & SECTIONS

DATA SHEET

Folsom Pumping Plant Capacity Evaluation
Field Testing on Raw Water Distribution System
April 29, 2009

Station	Unit	7:00-7:30 AM	7:30-8:00 AM	8:00-8:30 AM	8:30-9:00 AM	9:00-9:30 AM
1	ft	448.19	448.18	448.15	448.14	448.14
2	psi	57	57	57	57	57
3	ft	448	447	447	448	447
4	psi	26	25.5	25	26	25.5
5	psi	26.25	26	25.28	26	25
6	psi	16.5	15.5	16	16.1	16.1
7	ft	429.3	429.1	428.1	428.8	428.8
8	psi	8.5	8.5	8.5	8.5	8.5
9	cfs	105	117	137	102	119
10	cfs	46	46	45	46	45
11	MGD	9.9	20.1	30	10.51	20
12	MGD	54	54	54	54	54
13	cfs	2.9	3.2	3.0	2.9	3.2
14	MGD	29	28.4	28.2	29	29.1

KEY

1	Folsom Reservoir water surface elevation
2	Pressure on gage on pumping plant suction header
3	Water level on North Fork Pipeline surge tank
4	Pressure on gage at Hinkle Y
5	Pressure immediately upstream of Roseville's flow control valve
6	Pressure immediately upstream of SJWD's flow control valve
7	Water level on Natoma Pipeline surge tank
8	Pressure immediately upstream of the City of Folsom flow control valve
9	Flow rate on Reclamation's North Fork Pipeline flow meter.
10	Flow rate on Reclamation's Natoma Pipeline flow meter.
11	Flow rate on City of Roseville's flow meter.
12	Flow rate on SJWD's flow meter.
13	Flow rate on Folsom Prison's flow meter.
14	Flow rate on City of Folsom's flow meter.

DATA SHEET

Folsom Pumping Plant Capacity Evaluation
Field Testing on Raw Water Distribution System
April 29, 2009

Station	Unit	9:30-10:00 AM	10:00-10:30 AM	10:30-11:00 AM	11:00-11:30 AM	12:30-1:00 PM
1	ft	448.13	448.1	448.1	448.09	448.07
2	psi	57	57	57	57	57
3	ft	447	447	446	447	447
4	psi	25	25	24	25	25
5	psi	24	23.5	22.75	23.75	23.75
6	psi	16	14.1	12.5	16.1	15.5
7	ft	428.8	429.4	428.7	428.7	430.6
8	psi	8.5	8.5	8.5	8.5	7.9
9	cfs	131	158	181	143	142
10	cfs	45	46	46	45	27
11	MGD	30	29.8	29.6	30.2	30.1
12	MGD	54	70	85	60	60
13	cfs	2.9	3.2	3.2	3.1	3.3
14	MGD	29	29	29	28.1	16.3

KEY

1	Folsom Reservoir water surface elevation
2	Pressure on gage on pumping plant suction header
3	Water level on North Fork Pipeline surge tank
4	Pressure on gage at Hinkle Y
5	Pressure immediately upstream of Roseville's flow control valve
6	Pressure immediately upstream of SJWD's flow control valve
7	Water level on Natoma Pipeline surge tank
8	Pressure immediately upstream of the City of Folsom flow control valve
9	Flow rate on Reclamation's North Fork Pipeline flow meter.
10	Flow rate on Reclamation's Natoma Pipeline flow meter.
11	Flow rate on City of Roseville's flow meter.
12	Flow rate on SJWD's flow meter.
13	Flow rate on Folsom Prison's flow meter.
14	Flow rate on City of Folsom's flow meter.

APPENDIX B1-3
Field Test Data

Data Logger Summary Sheet

Folsom Pumping Plant Capacity Evaluation
Field Test on Raw Water Distribution System
April 29, 2009

		Average Pressure Readings (psi)			
		Pumping Plant Suction Header	North Fork Pipeline at Hinkle Y	Uptream Side of Roseville Valve	Upstream Side of SJWD Valve
Test	Time Range	Sta. No 2	Sta. No. 4	Sta No. 5	Sta. No. 6
1	7:15 - 7:20 A.M.	56.7	27.9	28.3	17.5
2	7:35 - 7:45 A.M.	56.6	27.6	28.0	17.3
3	8:10 - 8:20 A.M.	56.5	27.3	27.6	17.0
4	8:50 - 9:00 A.M.	56.5	27.6	27.5	17.5
5	9:15 - 9:25 A.M.	56.5	27.3	27.1	17.3
6	9:35 - 9:45 A.M.	56.4	27.1	25.6	17.1
7	10:00 - 10:10 A.M.	56.2	26.5	25.2	15.4
8	10:30 - 10:40 A.M.	56.1	26.0	24.7	13.9
9	11:10 - 11:20 A.M.	56.3	26.7	25.4	16.5
10	12:40 - 12:50 A.M.	56.2	26.5	26.5	16.4

Key

Test	Descriptions
1	Roseville operating at 10 MGD (15.5 cfs) with flows thru 48-inch pipeline
2	Roseville operating at 20 MGD (30.9 cfs) with flows thru 48-inch pipeline
3	Roseville operating at 30 MGD (46.4 cfs) with flows thru 48-inch pipeline
4	Roseville operating at 10 MGD (15.5 cfs) with flows thru 60-inch pipeline
5	Roseville operating at 20 MGD (30.9 cfs) with flows thru 60-inch pipeline
6	Roseville operating at 30 MGD (46.4 cfs) with flows thru 60-inch pipeline
7	SJWD operating at 70 MGD (108.3 cfs); Roseville using 60-inch pipeline
8	SJWD operating at 85 MGD (131.5 cfs); Roseville using 60-inch pipeline
9	All purveyors operating at normal; Roseville using 60-inch pipeline
10	Folsom operating at reduced capacity; Roseville using 60-inch pipeline

B2. Pump Operation Memorandum

WRE Water Resources Engineering, Inc.

MEMORANDUM

DATE: September 25, 2009

TO: Brian Zewe, US Bureau of Reclamation

FROM: Gustavo Arboleda, WRE

RE: Folsom Pumping Plant Capacity Evaluation
Field Tests – Variable and Constant Speed Pumps

Background

Task 3C of the Folsom Pumping Plant Capacity Evaluation, Field Monitoring and Investigation, calls for:

- Interviewing pumping plant operators regarding current operating practices;
- Investigating operational constraints on VFD pumps;
- Inspecting and observing pumps in operation, including constant speed pumps (#2, 3, 4, 5, 6) and pumps equipped with variable frequency drives, or VFDs (#7 and 8);
- Developing a pumping plant Standard Operating Procedure (SOP) for existing equipment.

This memorandum addresses the first three bullet points. The Standard Operating Procedure will be presented as a separate document.

Current operating practices, operational constraints, and field observations are summarized below. Conclusions are presented at the end of the document.

Current Operating Practices

Current operating practices were provided by Reclamation Senior Relief Operator Art Pakao and Control Operator Kenneth Zellner on Monday, September 21, 2009. Conversations with Kenneth Zellner regarding operating practices continued at the pumping plant through Wednesday morning, September 23. Current pumping plant operating practices are summarized below.

Assessing Demand: Operators get water demand information from four purveyors.

- Total demand = North Fork Pipeline demand + Natoma Pipeline demand*
- North Fork Pipeline demand = San Juan Water District (SJWD) demand + City of Roseville demand
- Natoma Pipeline demand = City of Folsom demand + Folsom Prison demand

* If Natoma Pipeline is supplied by gravity, pumping demand for Natoma Pipeline is 0.

Selecting Pumps: One of the VFD pumps (#7 or 8) is generally operated, along with one or more constant speed pumps, to meet total demand. One VFD pump is expected to deliver up to 85 cubic feet per second (cfs). Constant speed pumps are selected based on flow rate. Operators have labels on pump startup buttons, which read:
Pump 2 = 25 cfs
Pump 3 = 75 cfs
Pump 4 = 50 cfs
Pump 5 = 50 cfs
Pump 6 = 100 cfs

Activating Pumps: Pumps can be activated from the power plant control room. Current SOP, however, is to activate pumps from the controls in the pumping plant. A target North Fork Pipeline surge tank level is determined by looking it up on a table that relates surge tank levels to SJWD demand. A setting for the VFD is determined by looking it up on a table that relates surge tank level to VFD setpoint. All pumps start against a closed discharge valve and the valves are programmed to open slowly until fully open.

Operational Constraints

Operators indicated that the following constraints were applied to pumping plant operation:

- Pumps 7 and 8 not to be operated together.
- Pumps 7 and 8 to be operated only from 50 to 75 percent of maximum speed.
- Discharge valves on constant and variable speed pumps to be kept fully open during pump operation

Pumps 7 and 8 are normally operated individually in automatic mode. Pump controls are locked to prevent pump speed from increasing above 75 percent of full speed.

Field Observations

Monday September 21

Engineers Brian Zewe and John Robinson of Reclamation witnessed Monday's tests. Total demand on Monday morning, September 21, was about 210 cfs:

SJWD	94 cfs
City of Roseville	70 cfs
City of Folsom	43 cfs
Folsom Prison	3 cfs
Total	210 cfs

Operators used pumps 3, 4, and 7 to meet total demand.

Instruments at the pumping plant read as follows:

Reservoir level:	406.4 feet
Surge tank level:	443 feet
North Fork flow rate:	157 cfs

Pump 7 was at 67 percent of full speed. Discharge valves on pumps 3, 4, and 7 were fully open. No unusual noise or vibration were observed from pump 7 or its motor. Random crackling noises and intermittent knocking sounds were clearly audible on the discharge side of pumps 3 and 4.

Pump 3 was shut off and Pump 6 started. With pumps 4, 6, and 7 in operation, random crackling noises and intermittent knocking sounds were clearly audible on the discharge side of pumps 4 and 6.

Tests of Pump 7 at Low Speed: Pump 7 speed was manually lowered to 45 percent of maximum speed. Pumps 4 and 6 remained in operation. Discharge valves remained fully open. The water level in the surge tank came down to 436.1 ft and the total North Fork flow rate changed to 138 cfs. No unusual noise or vibration were observed from pump 7 or its motor. Random crackling noises and intermittent knocking sounds were clearly audible on the discharge side of pumps 4 and 6.

The speed of pump 7 was lowered to 40 percent of maximum speed. Pumps 4 and 6 remained in operation. Discharge valves remained fully open. The water level in the surge tank came down to 431.5 ft and the total North Fork flow rate changed to 130 cfs. No unusual noise or vibration were observed from pump 7 or its motor. Random crackling noises and intermittent knocking sounds were clearly audible on the discharge side of pumps 4 and 6.

Tuesday, September 22

Test on Pump 3 with Partially Closed Discharge Valve: The discharge valve on Pump 3 was closed slowly after the pump had been in operation for several hours. When the valve was about 50 percent closed, the discharge pressure went up about 10 psi (approximately 23 ft) and the random crackling noises and intermittent knocking sounds started to dissipate. When the valve was about 55 percent closed, the discharge pressure went up about 15 psi (35 ft) above the open-valve pressure and the noises were no longer discernible.

Wednesday, September 23

Tests scheduled for Tuesday were cancelled and later re-scheduled for Wednesday morning. Engineers Jay Emami and Brian Zewe of Reclamation witnessed the tests. Control Operator Kenneth Zellner operated the pumps. The water levels in the reservoir and surge tank were initially 406.17 ft and 442.9 ft, respectively. Pumps 2, 3, 4 and 7 were in operation with pump 7 set to automatic mode.

Tests of Pump 7 at High Speed: Technicians modified the lock on VFD controls to allow pumps to operate up to 80 percent of full speed. As the speed of Pump 7 was manually raised to 75 percent of maximum speed, the surge tank level went over 450 ft; the operator shut off Pump 4 and the surge tank level dropped to 443 ft.

With pumps 2 and 3 in operation and Pump 7 at 75 percent of maximum speed, random crackling noises and intermittent knocking sounds became apparent on the discharge side of the pump. The noises grew louder in intensity as the speed on Pump 7 was raised to 80 percent for a few seconds. The speed was then lowered to 65 percent and the noises disappeared.

Tests of Pump 8 at High Speed: Pump 7 was shut off and Pump 8 started. Pumps 2 and 3 remained in operation. Manually raising the speed of Pump 8 above 75 percent of maximum speed had the same results observed for Pump 7: random crackling noises and intermittent knocking sounds became apparent on the discharge side of the pump. The noises grew louder in intensity as the speed on Pump 8 was raised to 80 percent for a few seconds. The speed was then lowered to 65 percent and the noises disappeared.

Tests of Pumps 7 and 8 Operating Together: With pumps 2, 3, and 8 in operation, Pump 7 was started on manual operation. The speed on pumps 7 and 8 were raised and lowered to observe the effect of these changes:

- With one VFD pump at 65 percent speed or lower, raising the other VFD pump to 75 percent speed brought about the crackling noises on the discharge side of the pump operating at the higher speed.
- With both VFD pumps operating at 65 percent speed or slower, there were no unusual noises or vibration.
- The conditions above remained the same for the VFD pumps when pumps 2 and 3 were shut off, one at a time.

Conclusions

Current Operating Practices

Current operating procedures do not take into account the characteristics of the constant speed pumps (i.e., "pump curves") and their operating ranges. The constant speed pumps are selected for operation based on their rated flow capacity. To deliver its rated capacity, however, a pump requires a particular total dynamic head (TDH). At the appropriate TDH the pump would operate at peak efficiency and deliver the rated flow.

The TDH required for the constant speed pumps to operate at peak efficiency, based on pump performance curves provided by Reclamation, are presented in Table 1, below.

Table 1. Pump Flow Rates and Heads at Peak Efficiency

Pump	Peak Efficiency Flow Rate (cfs)	TDH (ft)	Peak Efficiency
2	20	100	88%
3	50	98	90%
4	40	84	88%
5	40	84	88%
6	80	86	87%

The pumps at the Folsom Pumping Plant were manufactured by Worthington Pumps. Worthington became part of Flowserve Corporation several years ago. Flowserve engineers responsible for Worthington Pumps were contacted to verify acceptable operating ranges for the Folsom Pumping Plant pumps. Application Engineer Stephen Phorwart (Flowserve facility in Rancho Dominguez, CA) indicated that their pumps can generally be expected to operate satisfactorily when run within 80 percent of their peak efficiency. Below that level of efficiency the pumps do not necessarily follow the pump curve and are subject to cavitation, recirculation, and uneven loading on moving parts that will significantly shorten pump life.

The acceptable operating ranges for the constant speed pumps, based on pump performance curves provided by Reclamation, are presented in Table 2, below.

Table 2. Operating Range for Constant Speed Pumps

Pump	Flow Rate (cfs) Range	TDH (ft) Range	Lowest Acceptable Operating Efficiency
2	10-28	60-124	70%
3	22-69	64-114	72%
4	18-51	50-116	70%
5	18-51	50-116	70%
6	41-106	50-106	70%

The TDH for Folsom Pumping Plant pumps is roughly represented by the difference in water level between the surge tank on the North Fork Pipeline and the reservoir. The tables used to set a surge tank level do not take into account the head requirements of the constant speed pumps. On Monday September 21, for example, the target surge tank level resulted in a TDH under 40 feet. This TDH allowed the VFD pumps to operate satisfactorily, but was well below the acceptable operating range for any of the constant speed pumps.

Had the reservoir level been around 370 feet, setting the surge tank at 443 feet, as it was on Monday September 21, would have resulted in a TDH of 73 feet. Pumps 2, 3, 4, 5 and 6 would have been able to operate within their acceptable range. VFD pumps would operate near their limiting 75 percent of full speed for that TDH.

Operators should consider TDH (rather than simply a target surge tank level) and the pumps' operating ranges. Prolonged operation outside of acceptable operating ranges damages the pumps and shortens their useful life.

Operational Constraints and Field Observations

Two of three operational constraints were proven by field tests to be justified:

- Pumps 7 or 8 should not be operated at speeds greater than 75 percent of full speed.
- Pumps 7 and 8 do not perform well when operated together.

A phenomenon known as "discharge recirculation" occurs when the VFD pumps are operated individually at greater than 75 percent speed or together at greater than 65 percent speed. Discharge recirculation causes cavitation pitting of the impeller resulting in poor pump performance (off the pump curve) and eventual mechanical failure. A more detailed description of discharge recirculation can be found at:

http://www.lawrencepumps.com/Newsletter/news_v04_i4_Apr07.html

The third constraint postulated initially, that VFD pumps should not be operated below 50 percent speed, was not confirmed by the field tests performed. Pump 7 was operated as low as 40 percent speed with no sign of discharge recirculation. It is very probable, however, that discharge recirculation will occur at lower-than-50 percent speeds if the VFD pumps are operated out of their efficient operating range.

Discharge recirculation was evident at the constant speed pumps operated during the field tests. The recirculation could be the result of operating the pumps well outside their prescribed efficiency range. It is possible, however, that the discharge recirculation would occur even when the pumps are operated within their prescribed operating range, as one of the contributing factors are the approach flow conditions, as explained below.

Likely Cause of Discharge Recirculation

Approach flow conditions are a major determinant of pump performance. Impellers are designed with the assumption that incoming flow will be evenly distributed throughout the approach section. A number of approach flow conditions have been determined through laboratory tests to be detrimental to impeller performance:

- Uneven flow distribution, where flow tends to favor one side over the other.
- Pre-rotation, where flow approaches the impeller with a circulatory pattern which may or may not be in the same direction that the impeller rotates.
- Vorticity, where a tight flow spiral forms immediately upstream of the impeller.

These conditions are generally a function of the geometry of the approach section. The approach geometry for all pumps at the Folsom Pumping Plant is likely to cause approach flow problems, even when pumps operate within acceptable efficiency ranges.

Possible Remedies

The only way to improve approach flow conditions is by changing the suction header configuration. And the only fail-safe way to develop an approach geometry that will provide acceptable flow conditions is through physical model tests.

“Base” tests on a physical model that replicates the current pumping plant configuration would confirm the causes of poor pump performance. Structural modifications can then be tested in the model until a configuration is arrived at that provides satisfactory flow conditions for all combinations of pumps in operation. Major changes to the configuration of the pumping plant intake are likely to be needed.

Even with a favorable approach flow, pumps will not perform well if operated at low efficiencies. A different set of operating procedures needs to be adopted to reduce the potential for pump damage.

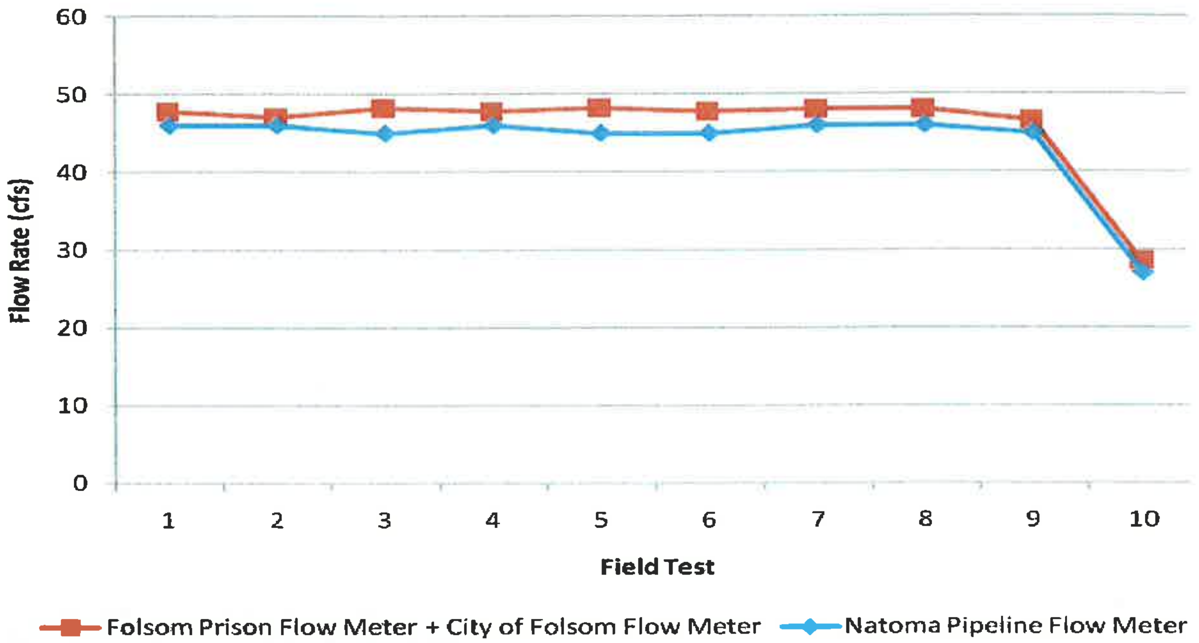


Figure 4. Flow Rate Measurements in Natoma Pipeline

APPENDIX B1-1
Test Plan

B3. Pump Power Consumption Tests

PUMP POWER ANALYSIS

Field measurements were conducted on October 26, 2009 by Reclamation to estimate pump power consumption at the Folsom Pumping Plant. Power Quality Analyzers measured power applied to the constant speed pumps. For the variable frequency drive pumps (VFDs), operators recorded and averaged the power readings from the control panel.

Measurements

Power input was measured for each pump in the pumping plant. The Power Quality Analyzer provided continuous readings of voltage and current for several minutes, as illustrated in Figure A-1. A peaking factor was applied to the median voltage and current to derive power usage from:

Power (kW) = Median Voltage (volts) * Median Current (amps) * Peaking Factor / 1,000

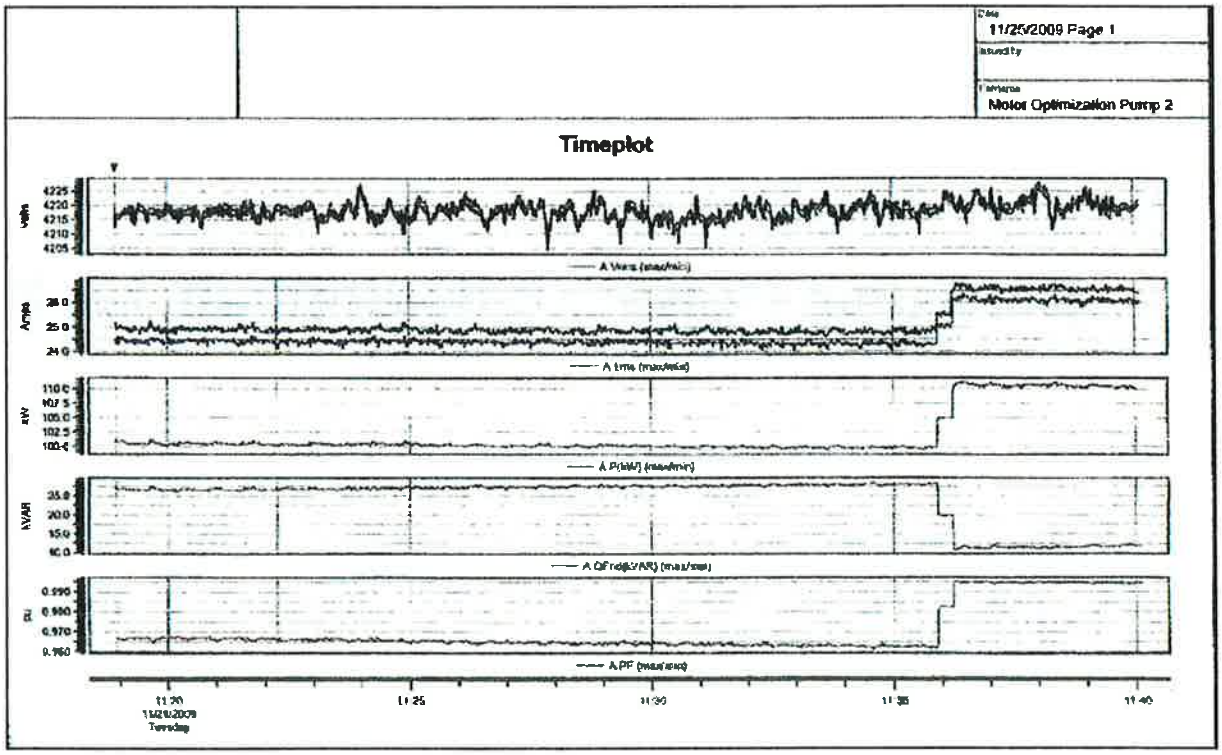


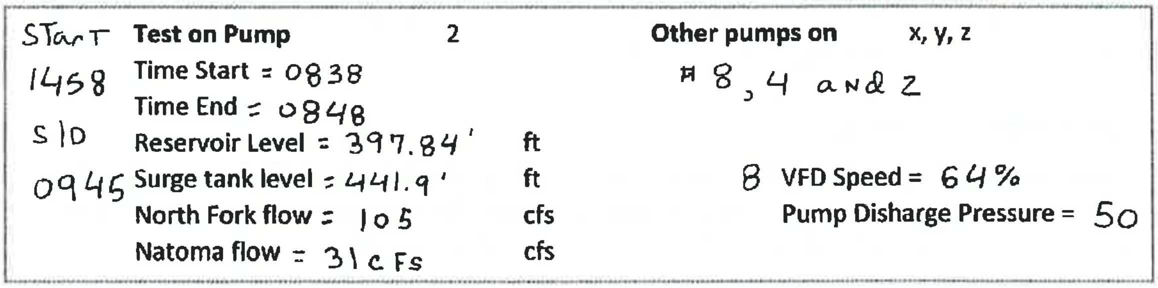
Figure A-1. Power Quality Analyzer Readings for Pump 2

Computed power usage derived from the pump tests are listed in Table A-1. The peaking factors were supplied by Reclamation.

Table A-1. Calculated Power Input from Pump Tests

Pump	Voltage (v)	Current (Amps)	Peaking Factor	Power (kW)	Power (HP)
2	4216.0	25.4	0.978	105	141
3	4195.0	69.4	0.963	281	377
4	4200.0	47.6	0.983	196	263
5	4219.0	47.2	0.949	190	255
6	4196.0	90.0	0.80	301	404
7				257	345
8				228	306

Other data related to pump operation were collected as well, as illustrated in Figure A-2 and summarized in Table A-2. The data for other pumps are shown on pages A-7 and A-8.



START **Test on Pump** 2 **Other pumps on** x, y, z
1458 **Time Start** = 0838 # 8, 4 and 2
Time End = 0848
S/D **Reservoir Level** = 397.84' ft
0945 **Surge tank level** = 441.9' ft 8 **VFD Speed** = 64%
North Fork flow = 105 cfs **Pump Disharge Pressure** = 50
Natoma flow = 31 cFs cfs

Figure A-2. Sample Record of Pump Test

Table A-2. Pump Operation Data during Power Tests

	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
Reservoir level (ft)	397.84	397.74	397.84	397.75	397.68	397.63	397.63
Surge tank level (ft)	441.9	441.8	442.1	441.8	441.8	442.7	441.8
North Fork flow rate (cfs)	105	116	103	110	111	90	92
Natoma flow rate (cfs)	31	31	33	30	37	37	34
Total flow rate (cfs)	136	147	136	140	148	127	126
Pumps in operation	8, 4, 2	8, 6, 3	8, 4, 2	8, 5, 3	8, 6	7, 3	8
VFD speed (% of max)	64	46	64	54	60	62	60
Pump outlet pressure (to nearest psi)	50	55	50	42	50	55	54
Pump Inlet pressure (to nearest psi)	35	35	35	35	35	35	35

Analysis

Each of the measurements made during the power tests is analyzed below for validity and accuracy. Pump efficiency is approximated based on power input measurements and flow and pump lift data.

Measured Inlet Pressures

Pressures measured by the gage upstream of the pump should reflect the water level in Folsom Reservoir less the energy losses in the suction piping, which should be small.

Measured inlet pressure (all tests) = 35 psi

Equivalent Head = 35 psi x 2.302 ft/psi = 80.6 ft

Hydraulic Grade = Gage elevation (approximately 317.8 ft) + 80.6 ft = 398.4 ft

This head is generally within a foot of reported reservoir water levels. Considering that gage readings were accurate only to about 0.5 psi or 1.15 feet, the pressure readings appear correct. They are not accurate enough, however, to assess pressure losses between the reservoir and the pump. For purposes of this analysis, those pressure losses can be neglected and the reservoir level assumed as the head upstream of the pump.

Measured Outlet Pressures

Pressures measured by the gage downstream of the pump should reflect the head gain or lift provided by the pump. These pressures should be slightly higher than the water levels in the surge tank, to account for head losses between pump and surge tank.

Table A-3. Comparison of Measured Outlet Pressures and Surge Tank Levels

	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
Surge tank level (ft)	441.9	441.8	442.1	441.8	441.8	442.7	441.8
Pump outlet pressure (to nearest psi)	50	55	50	42	50	55	54
Equivalent head in ft (psi x 2.302)	115.1	126.6	115.1	96.7	115.1	126.6	124.3
Hydraulic grade in ft (317.8 + Head)	432.9	444.4	432.9	414.5	432.9	444.4	442.1
Head loss (ft) between pump and surge tank	-9.0	2.6	-9.2	-27.3	-8.9	1.7	0.3

Table A-3 shows that measured outlet pressures in 4 out of 7 tests were lower than surge tank levels, which is physically impossible. This indicates that either the gage readings or the surge tank levels were recorded incorrectly. Pump efficiency calculations (discussed in "Pump Efficiency" section below) indicate that gage readings are more likely to be correct. For purposes of this analysis, the gage readings will be considered representative of the head downstream of the pump.

Measured Flow Rates

The flow rates recorded during the tests correspond to readings from flow meters on the North Fork and Natoma pipelines. There is no way to measure individual pump discharges at the pumping plant when there is more than one pump in operation.

Pump discharges can be approximated from pump performance curves provided by the pump manufacturer. These curves provide a relationship between total head or lift and pump discharge. For constant speed pumps there is a single performance curve. For pumps with VFDs, there is a separate performance curve for each pump speed.

The pump lifts measured during the power tests (Table A-4) are outside the normal range of operation of the constant speed pumps (Pumps 2, 3, 4, 5, and 6). These pumps are rated for lifts (i.e., total dynamic heads) from 84 to 100 feet; lifts during tests were all less than 50 feet.

Table A-4. Measured Pump Lifts and Pump Ratings

	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
Pump inlet pressure (to nearest psi)	35	35	35	35	35	35	35
Pump outlet pressure (to nearest psi)	50	55	50	42	50	55	54
Measured pump lift (psi)	15	20	15	7	15	20	19
Measured pump lift in ft (psi x 2.302)	35	46	35	16	35	46	44
Pump rated head (ft)	100	98	84	84	86	20-85	20-85
Pump rated flow (cfs)	20	50	40	40	80	18-90	18-90

Since pumps with VFDs (Pumps 7 and 8) were operated within acceptable ranges, pump curves (Figure A-3) were used to approximate the flow rate through these pumps. The remainder of the flow rate indicated by flow meters was assumed to be provided by the other pump(s) in operation. Where there was more than one constant speed pump in operation, they were assumed to contribute to the total flow rate in the same ratio as their rated capacities. For example, where pumps 2 and 4 were operating together, the flow rate for pump 4 was assumed to be twice that of pump 2. Estimated test flow rates are presented in Table A-5.

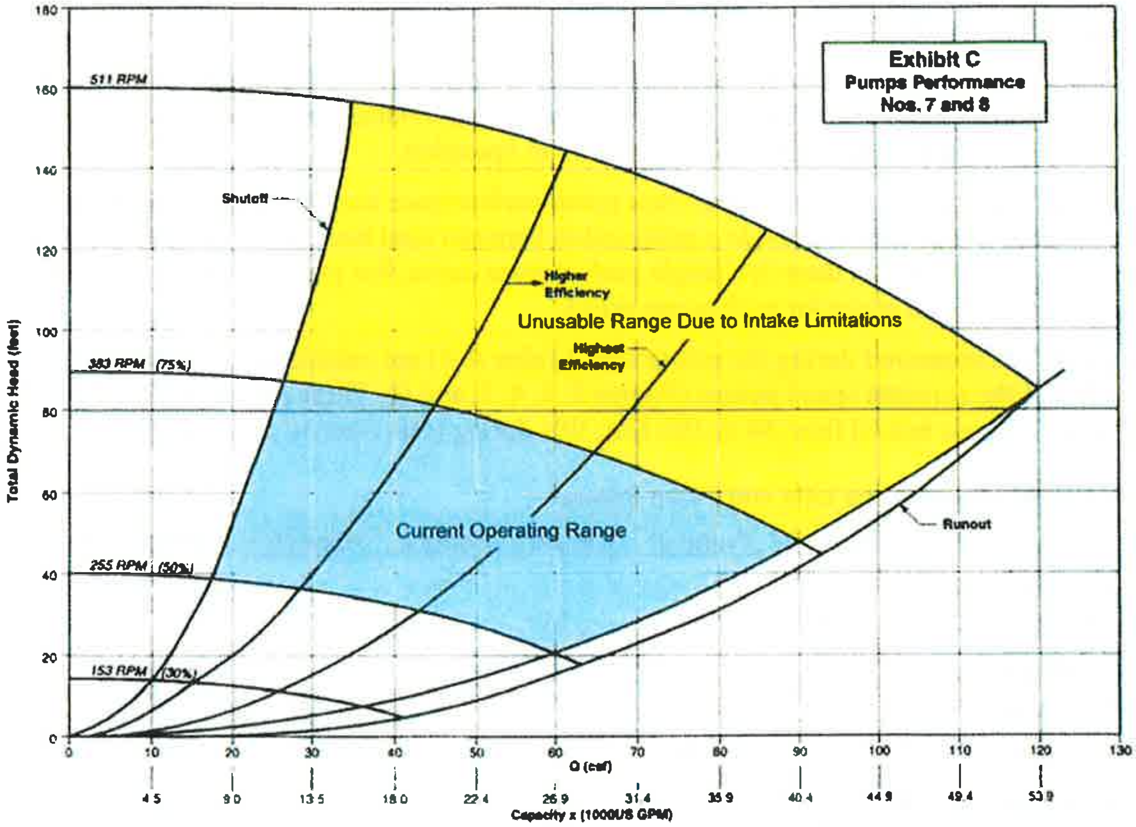


Figure A-3. Pump Performance Curves for Pumps 7 and 8

Table A-5. Estimated Test Flow Rates

Pumps Operating	Total Q (cfs)	Measured Lift (ft)	VFD Speed (% of Max)	VFD Pump Flow Rate (cfs)	Constant Speed Pump Flow Rates (cfs)	
2, 4, 8	136	35	64	P8= 75	P2= 20	P4= 41
3, 6, 8	147	46	64*	P8= 60	P3= 33	P6= 54
3, 5, 8	140	16	54	P8= 60	P3= 44	P5= 36
6, 8	148	35	60	P8= 70	P6= 78	
3, 7	127	46	62	P7= 55	P3= 72	
3, 8**	126	44	60	P8= 50	P3= 76	

* Test data sheet showed a speed of 46%. Pump curves indicate, however, that the measured lift is not possible at that speed. The most likely speed based on pump curves is 64%.

**Test data sheet showed pump 8 operating alone. Pump 8, however, does not have the capacity to deliver 126 cfs. The pump that was operating during the previous test (pump 3) was assumed to be still in operation.

Pump Efficiency

Pump efficiency is defined as the ratio of the water power to the power provided from a power source. The "water power" is the power added to the flowing water through the pump's rotating element; this power does not account for mechanical energy losses. The power provided from a power source is the measured power input; this power includes losses in the pump as well as mechanical losses from the bearings and seals and leakage.

Efficiency = Water Power / Measured Power Input

Water Power in hp = (pump lift in feet) * (flow rate in cfs) / 8.82

Note that 1 kW = 1.341 hp

Computed pump efficiencies based on power input measurements are listed in Table A-6.

Table A-6. Pump Efficiencies Based on Power Tests

Pump	Flow Rate (cfs)	Head (ft)	Water Power (HP)	Measured Power Input (HP)	Pump Efficiency
2	20	35	79	141	56%
3	33	46	172	377	46%
4	41	35	163	263	62%
5	36	16	65	255	26%
6	78	35	310	404	77%
7	55	46	287	345	83%
8	50	44	249	306	82%

The computed pump efficiencies indicate:

- Pumps 2, 3, and 4 show very low efficiencies; this is consistent with the fact that these pumps were operating outside their normal range (pumps are rated for lifts ranging from 84 to 100 feet; they were operated at lifts ranging from 35 to 46 feet).
- Pump 5 shows a very low efficiency; this is consistent with irregularities observed during the tests (the power measurements would not stabilize) and could be related to the very low lift (16 ft), well below the pump's normal operating range (pump 5 is rated for 84 ft).
- Pump 6 was operated close to its rated flow rate of 80 cfs but did not show its peak efficiency due to the low lift (operated at 36 feet, rated for 86 feet).
- Pumps 7 and 8 were operating at a reasonable efficiency, as the pump lifts were within their normal operating range.

Pump Power Analysis Field Record

10/26/09

Scan to him

Measuring Power Input at Folsom Pumping Plant

StarT **Test on Pump** 2
1458 Time Start = 0838
Time End = 0848
S/O Reservoir Level = 397.84' ft
0945 Surge tank level = 441.9' ft
North Fork flow = 105 cfs
Natoma flow = 31 cFs cfs

Other pumps on x, y, z
8, 4 and 2
8 VFD Speed = 64%
Pump Disharge Pressure = 50

StarT **Test on Pump** 3
0944 Time Start = 1347
Time End = 1357
S/O Reservoir Level = 397.74 ft
1358 Surge tank level = 441.8 ft
North Fork flow = 116 cfs
Natoma flow = 31 cfs

Other pumps on x, y, z
8, 6 and 3
8 VFD Speed = 46%
Pump Disharge Pressure = 55 PSi

StarT **Test on Pump** 4
1500 Time Start 0902
Time End 0940
S/O Reservoir Level = 397.84 ft
0942 Surge tank level = 442.1 ft
North Fork flow = 103 cfs
Natoma flow = 33 cfs

Other pumps on x, y, z
8, 4 and 2
8 VFD Speed = 64%
Pump Disharge Pressure = 50

StarT **Test on Pump** 5
0941 Time Start : 1322
Time End : 1333
S/O Reservoir Level = 397.75 ft
1335 Surge tank level = 441.8 ft
North Fork flow = 110 cfs
Natoma flow = 30 cfs

Other pumps on x, y, z
8, 5 and 3
8 VFD Speed = 54%
Pump Disharge Pressure = 42

StarT **Test on Pump** 6
1334 Time Start = 1448
Time End
S/O Reservoir Level = ~~441.8~~ 397.68 ft
1459 Surge tank level = 441.8 ft
North Fork flow = 111 cfs
Natoma flow = ~~37~~ 42 (37) CFS cfs

Other pumps on x, y, z
#8, 6 ~~and 3~~
8 and 6
8 VFD Speed = 60%
Pump Disharge Pressure = 50 psi

Test on Pump 7
Time Start
Time End

Other pumps on x, y, z

other pmp 3

Reservoir Level	397.63	ft		
Surge tank level	442.7	ft	**VFD Speed =**	
North Fork flow	90	cfs	**Pump Disharge Pressure =**	55
Natoma flow	37	cfs		

Test on Pump 8

Other pumps on x, y, z 0

Time Start				
Time End				
Reservoir Level	397.63	ft		
Surge tank level	441.8	ft	VFD Speed =	
North Fork flow	92	cfs	Pump Disharge Pressure =	54
Natoma flow	34	cfs		

		PUMP # 8		
		KW	I	%N
1505	1	232	127	60
	2	233	126	60
	3	219	122	59
	4	241	127	61
	5	235	127	60
	6	220	122	59
	7	215	123	59
	8	214	122	59
	9	237	127	60
	10	234	126	60
1515	11	230	125	60

		pump # 7		
		KW	I	%N
1558	1	253	128	62
	2	253	129	62
	3	246	129	62
	4	271	134	63
	5	260	130	63
	6	244	128	62
	7	258	129	62
	8	250	129	62
	9	258	127	62
	10	268	131	63
1608	11	269	133	63

APPENDIX C

Hydraulic Model

Hydraulic Model Development

Pertinent reports, drawings, and operational data provided by Reclamation were compiled and reviewed. A listing of the documentation collected and analyzed is included in Appendix A. Information from these sources was used to establish the configuration of the physical system to be modeled.

A number of individuals provided or confirmed data related to the physical configuration and operation of the raw water delivery system at their respective ends. Information was provided by:

- Reclamation engineers Brian Zewe, Jesse Castro, and John Robinson.
- Reclamation Folsom Dam Operators Robert Skordas, Butch Branec, Art Pakao and Kenneth Zellner.
- Shawn Barnes, City of Roseville Water Treatment Plant
- Bill Sadler and Greg Turner, SJWD Water Treatment Plant
- Jim Bridges and Phil Carter, City of Folsom
- Mike Sundby and Pedro Reyes, Folsom Prison Water Treatment Plant

The raw water delivery system was modeled using InfoWater, a geospatial water distribution system modeling tool. The attributes of system components (elevations of junctions and valves, lengths and diameters of pipes, pump characteristics, reservoir water levels) were determined and coded into the InfoWater model.

Model Calibration

The computer model was initially calibrated using hand calculations and later re-calibrated using data from field test conducted in April and September, 2009. In its calibrated version, the model closely reproduces head losses measured during field tests, as illustrated in Figures C-1 to C-3.

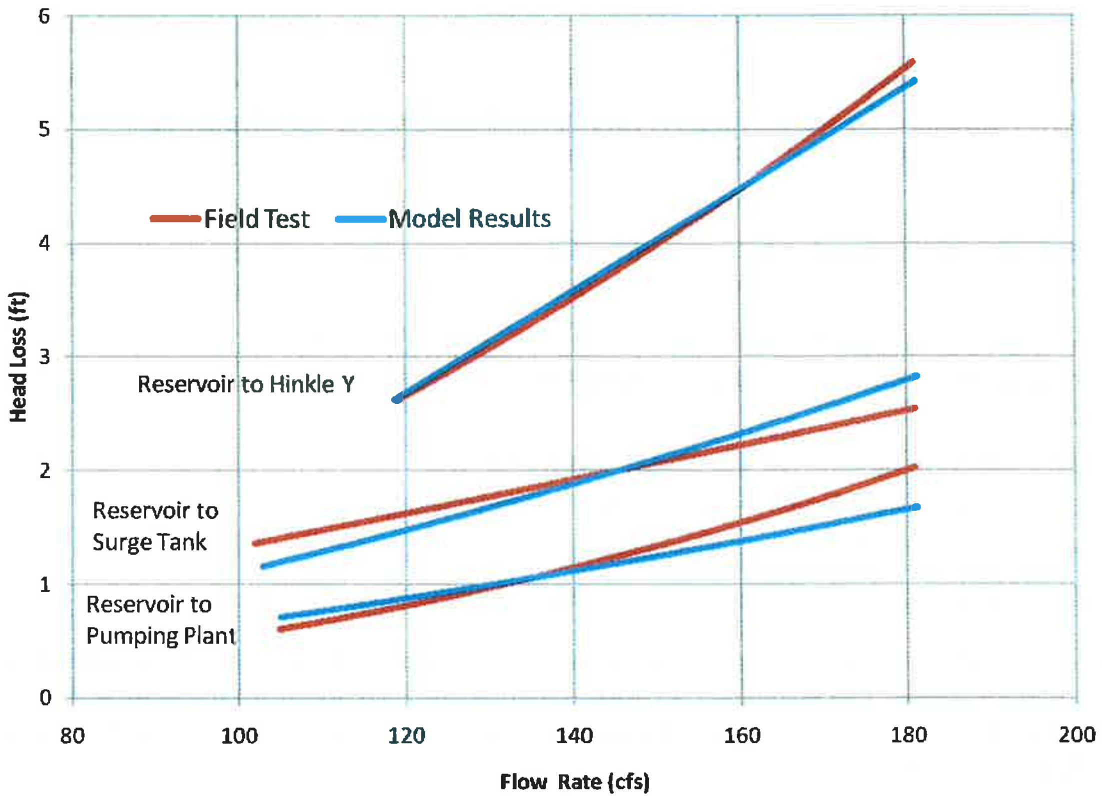


Figure C-1. Comparison of Head Losses – North Fork Pipeline

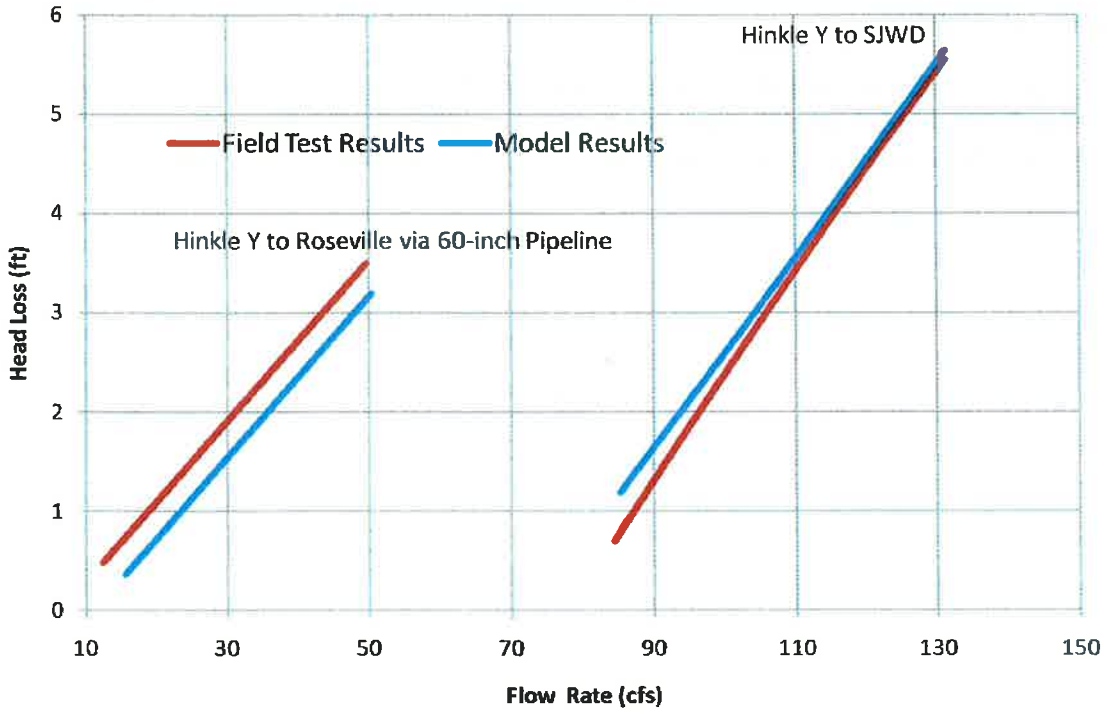


Figure C-2. Comparison of Head Losses – City of Roseville and SJWD Pipes

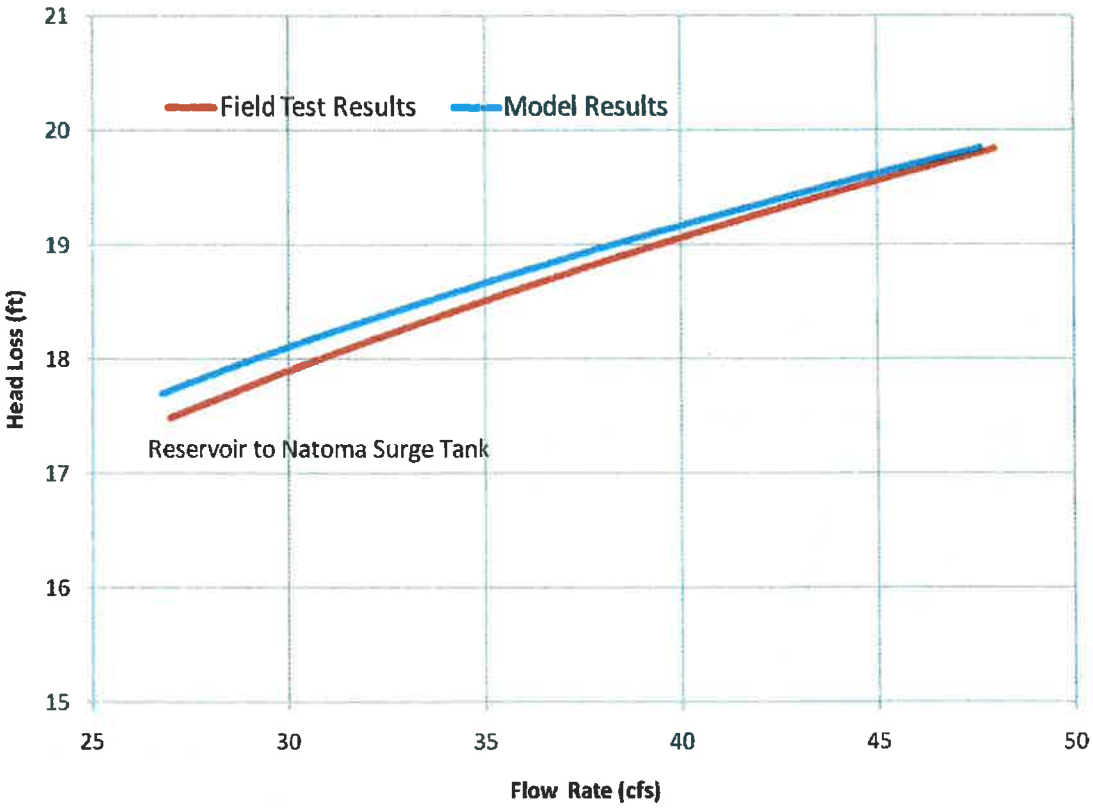


Figure C-3. Comparison of Head Losses – Natoma Pipeline

Attributes of Hydraulic Model Components

Figure C-4 illustrates the extent of the hydraulic model. Relevant elevations, diameters, lengths, and pump characteristics are listed below, Tables C-1 to C-12.

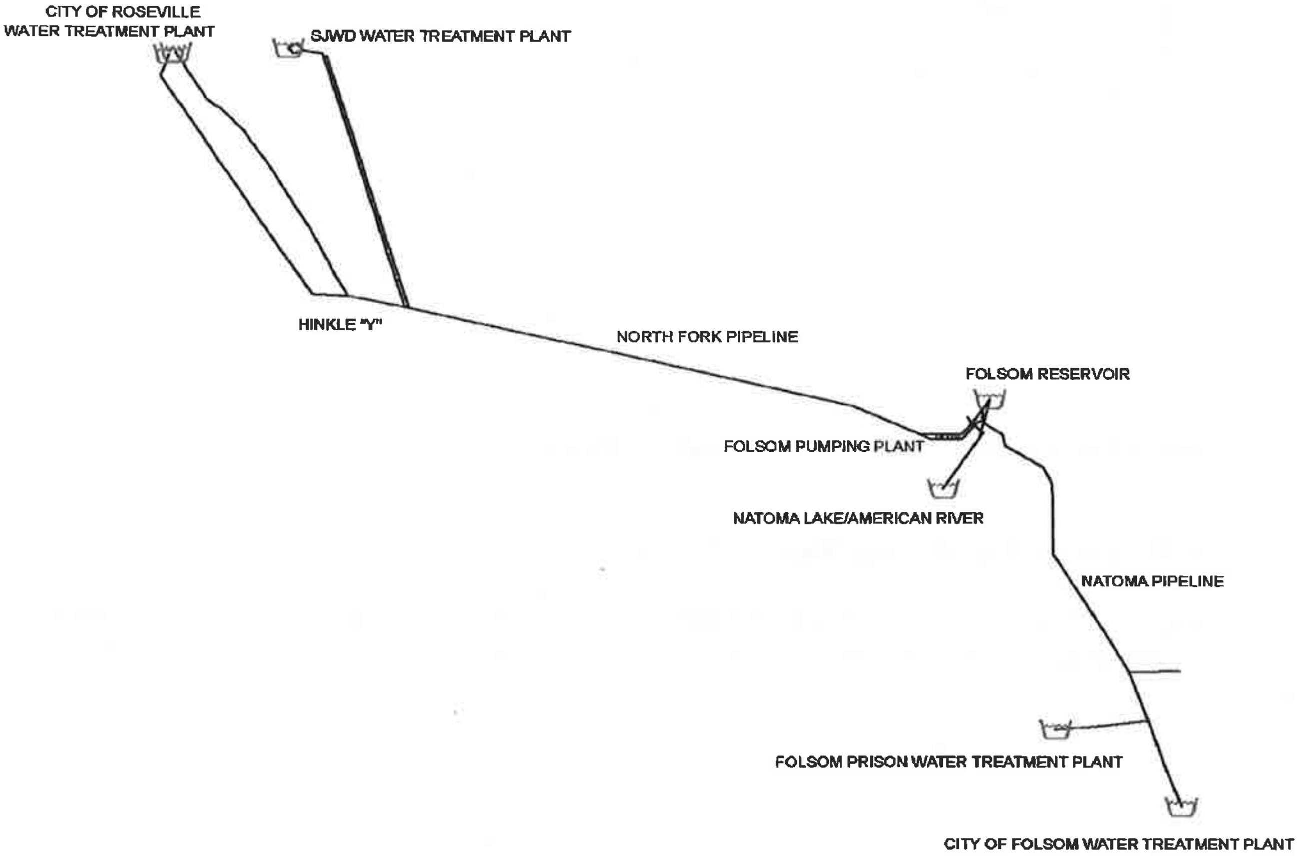


Figure C-4. Extent of Hydraulic Model - Folsom Dam Raw Water Delivery System

Table C-1. Junctions

ID	ELEVATION	ID	ELEVATION	ID	ELEVATION
J10	314.75	J72	314.75	J148	381.20
J12	314.75	J74	388.50	J150	396.34
J14	314.75	J76	367.70	J152	388.33
J16	314.75	J78	394.31	J154	403.37
J18	314.75	J80	386.50	J156	350.33
J20	314.75	J82	383.80	J158	407.84
J22	314.75	J90	388.50	J160	398.37
J24	314.75	J92	389.50	J162	344.95
J26	314.75	J94	389.50	J164	381.81
J28	314.75	J96	394.31	J166	372.74
J30	314.75	J98	394.31	J168	390.88
J32	314.75	J100	313.00	J170	388.62
J34	314.75	J102	328.30	J182	382.69
J36	314.75	J106	282.00	J184	372.00
J40	314.75	J108	447.00	J186	390.49
J44	314.75	J110	394.31	J188	373.71
J46	316.45	J112	368.50	J190	400.32
J48	317.00	J122	365.00	J192	357.12
J50	317.00	J124	396.00	J194	359.33
J52	319.00	J128	368.50	J196	401.23
J54	342.30	J130	368.50	J198	344.65
J56	318.65	J132	404.00	J200	317.00
J58	342.00	J134	387.75	J202	376.88
J60	258.00	J136	394.00	J204	373.55
J62	316.17	J138	392.51	J206	391.11
J64	316.17	J140	367.69	J208	369.95
J66	325.50	J142	383.10	J210	384.00
J68	325.50	J144	390.90		
J70	315.75	J146	378.73		

Table C-2. Reservoirs

ID	Water Level (ft)
FOLSOM	307 - 466
SAN_JUAN	423.4
AMRIVER	150.0
ROSEVILLE (60-inch)	400.0
ROSEVILLE (48-inch)	403.26
CITY_OF_FOLSOM	407.5
PRISON	408.8

Table C-3. Valves (K=0.2)

ID	Elevation (ft)	Diameter (In)
V2	314.75	60
V3	314.75	60
V4	314.75	24
V5	314.75	42
V6	314.75	18
V7	314.75	24
V8	314.75	24
V9	316.08	60
V10	316.20	42
V14	314.75	30
V15	314.75	20
V16	314.75	30
V17	314.75	30
V18	314.75	30
V24	360.00	42
V25	314.75	30
V26	314.75	30
V27	314.75	36
V28	314.75	36
V29	323.00	36
V30	256.00	36
V32	256.00	36
V33	319.00	36
V34	314.75	36
V101	368.50	48
V102	368.50	12
V8030	394.31	42
V8046	388.60	42

Table C-3. Valves (K=0.2)

ID	Elevation (ft)	Diameter (in)
V8048	394.00	42
V8064	388.60	72
V8068	386.50	60
V8070	394.31	42
V8072	389.50	48
V8074	389.50	48
V8076	383.80	36
V9000	394.00	48
V9002	385.00	24
VENTURI_METER	340.00	60

Table C-4. Pipes

ID	LENGTH	MATERIAL	DIAMETER	FROM NODE	TO NODE
P10	7	Steel	30	J10	V34
P12	10	Steel	84	J10	J14
P14	10	Steel	84	J14	J16
P16	20	Steel	84	J16	J18
P18	10	Steel	84	J18	J20
P20	20	Steel	84	J20	J22
P22	10	Steel	84	J22	J24
P24	10	Steel	60	J12	J26
P26	7	Steel	30	J14	V28
P28	7	Steel	30	J16	V27
P30	10	Steel	60	J26	J28
P32	20	Steel	60	J28	J30
P34	7	Steel	30	J18	V18
P36	10	Steel	60	J30	J32
P38	7	Steel	30	J20	V17
P40	20	Steel	42	J32	J34
P42	7	Steel	30	J22	V16
P44	10	Steel	42	J34	J36
P46	7	Steel	20	J24	V15
P48	7	Steel	30	V34	PUMP_8_VFD
P50	8	Steel	24	PUMP_8_VFD	V14

Table C-4. Pipes

ID	LENGTH	MATERIAL	DIAMETER	FROM NODE	TO NODE
P52	8	Steel	24	V14	J12
P54	7	Steel	30	V28	PUMP_7_VFD
P56	8	Steel	24	PUMP_7_VFD	V26
P58	8	Steel	24	V26	J26
P60	7	Steel	30	V27	PUMP_6
P62	8	Steel	24	PUMP_6	V25
P64	8	Steel	24	V25	J28
P66	7	Steel	30	V18	PUMP_5
P68	8	Steel	24	PUMP_5	V8
P70	8	Steel	24	V8	J30
P72	7	Steel	30	V17	PUMP_4
P74	8	Steel	24	PUMP_4	V4
P76	8	Steel	24	V4	J32
P78	7	Steel	30	V16	PUMP_3
P80	8	Steel	24	PUMP_3	V7
P82	8	Steel	24	V7	J34
P84	7	Steel	20	V15	PUMP_2
P86	8	Steel	18	PUMP_2	V6
P88	8	Steel	18	V6	J36
P90	10	Steel	42	J36	V5
P96	10	Steel	42	V5	J40
P98	20	Steel	84	J24	J44
P100	50	Steel	84	J44	J46
P102	50	Steel	84	J48	J46
P104	50	Steel	84	V9	J48
P106	5	Steel	36	J46	V29
P108	5	Steel	36	J52	V33
P110	10	Steel	36	J54	J52
P112	207	Steel	42	J40	J56
P114	50	Steel	36	J54	J58
P116	10	Steel	36	V32	J58
P118	50	Steel	84	J50	V9
P120	5	Steel	36	V29	J52
P122	5	Steel	36	V33	J56
P124	72	Steel	42	J56	J62
P126	22	Steel	42	J62	J64
P128	24	Steel	42	J64	J66

Table C-4. Pipes

ID	LENGTH	MATERIAL	DIAMETER	FROM NODE	TO NODE
P130	610	Steel	42	J66	J68
P132	50	Steel	42	J50	V10
P134	50	Steel	42	V10	J66
P136	30	Steel	60	J12	V2
P138	59	Steel	60	J72	J70
P140	29	Steel	84	J10	V3
P142	75	Steel	84	J70	VENTURI_METER
P144	1,279	Steel	84	J76	J124
P146	10	Steel	42	J74	V8046
P148	5	Steel	60	V2	J72
P150	30	Steel	84	V3	J70
P152	400	Steel	60	J74	J80
P154	25	Steel	60	J80	V8068
P156	100	Steel	60	J82	V8076
P158	20	Steel	60	V8076	ROSEVILLE
P162	26	Steel	84	J90	J74
P164	855	Steel	54	J78	J110
P166	100	Steel	60	J92	J94
P168	10	Steel	72	J90	V8064
P170	855	Steel	66	J98	J96
P172	78	Steel	42	J68	J100
P174	415	Steel	42	J100	J106
P176	1,087	Steel	42	J102	V24
P178	53	Steel	84	J200	J50
P180	81	Steel	42	J106	J102
P182	5	Steel	36	EMERGENCY_PUMP	V32
P184	5	Steel	36	V30	EMERGENCY_PUMP
P186	200	Steel	48	J54	J108
P188	50	Steel	54	J110	J92
P190	5	Steel	42	J96	V8070
P192	750	Steel	42	V8046	V8048
P194	15	Steel	42	J98	V8030
P196	10	Steel	42	V8048	J78
P198	5	Steel	42	V8030	J78
P200	38	Steel	48	J112	J128
P202	3,000	Steel	48	J134	J136
P204	5	Steel	48	J136	V9000

Table C-4. Pipes

ID	LENGTH	MATERIAL	DIAMETER	FROM NODE	TO NODE
P206	103	Steel	48	J128	J130
P208	1	Steel	48	V9000	CITY_OF_FOLSOM
P210	378	Steel	60	J138	J82
P212	500	Steel	60	J140	J138
P214	307	Steel	60	J142	J144
P216	251	Steel	60	J144	J146
P218	768	Steel	60	J146	J148
P220	1,227	Steel	60	J148	J150
P222	951	Steel	60	J150	J152
P224	103	Steel	60	J152	J154
P226	707	Steel	84	J122	J76
P228	1,354	Steel	84	J124	J90
P230	503	Steel	60	J154	J156
P232	0.1	Steel	84	FOLSOM	J200
P234	761	Steel	72	V8064	J98
P236	100	Steel	48	J94	V8072
P238	1,057	Steel	60	J156	J158
P240	5	Steel	36	J60	V30
P242	9,400	Steel	60	V8068	J82
P244	20	Steel	42	V8070	J110
P246	200	Steel	186	FOLSOM	J60
P248	400	Steel	186	AMRIVER	J60
P250	82	Steel	42	V24	J112
P252	4	Steel	48	J130	V101
P254	4,480	Steel	60	V101	J134
P256	4	Steel	18	J130	V102
P258	1,000	Steel	18	V102	PRISON
P260	100	Steel	48	J94	V8074
P262	10	Steel	48	V8072	SAN_JUAN
P264	10	Steel	48	V8074	SAN_JUAN
P266	200	Steel	30	J128	J132
P268	67	Steel	84	VENTURI_METER	J122
P270	96	Steel	60	J158	J160
P272	551	Steel	60	J160	J162
P274	1,077	Steel	60	J162	J164
P276	437	Steel	60	J164	J166

Table C-4. Pipes

ID	LENGTH	MATERIAL	DIAMETER	FROM NODE	TO NODE
P280	565	Steel	60	J168	J140
P282	456	Steel	60	J170	J80
P292	40	Steel	60	J80	J182
P294	1,181	Steel	48	J182	J184
P296	970	Steel	48	J184	J186
P298	460	Steel	48	J186	J188
P300	750	Steel	48	J188	J190
P302	300	Steel	48	J190	J192
P304	270	Steel	48	J192	J194
P306	665	Steel	48	J194	J196
P308	785	Steel	48	J196	J198
P310	1,480	Steel	48	J198	J202
P312	200	Steel	48	J202	J204
P314	380	Steel	48	J204	J206
P316	700	Steel	48	J206	J208
P318	569	Steel	48	J208	J210
P324	50	Steel	48	J210	V9002
P330	50	Steel	48	V9002	RES9010

Table C-5. Pump IDs

ID	ELEVATION
Pump_8_VFD	314.75
Pump_7_VFD	314.75
Pump_6	314.75
Pump_5	314.75
Pump_4	314.75
Pump_3	314.75
Pump_2	314.75
Emergency_Pump	252.56

Pump Characteristics

Table C-6. Pump 2

Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	137	0	120
10	123	67	220
15	118	83	240
20	100	88	260
25	78	84	260
28	60	72	250

Table C-7. Pump 3

Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	122	0	300
10	118	43	360
20	117	65	440
30	110	80	480
40	106	88	540
50	98	90	610
60	93	88	620
70	63	78	620

Table C-8. Pumps 4 and 5

Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	130	0	290
10	124	50	340
20	115	73	370
30	102	85	400
40	84	88	410
50	50	70	390
53	29	45	370

Table C-9. Pumps 6 and Emergency

Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	120	0	450
20	114	43	475
40	106	67	500
50	104	76	530
60	98	82	550
70	94	85	555
80	86	87	560
90	80	86	550
100	65	83	530
108	54	80	500

Table C-10. Pumps 7 and 8 at 511 RPM (Full Speed)

Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	162	0	885
23	155	37	1069
45	154	71	1112
68	140	86	1263
87	126	91	1371
91	122	90	1403
111	78	67	1468

Table C-11. Pumps 7 and 8 at 358 RPM

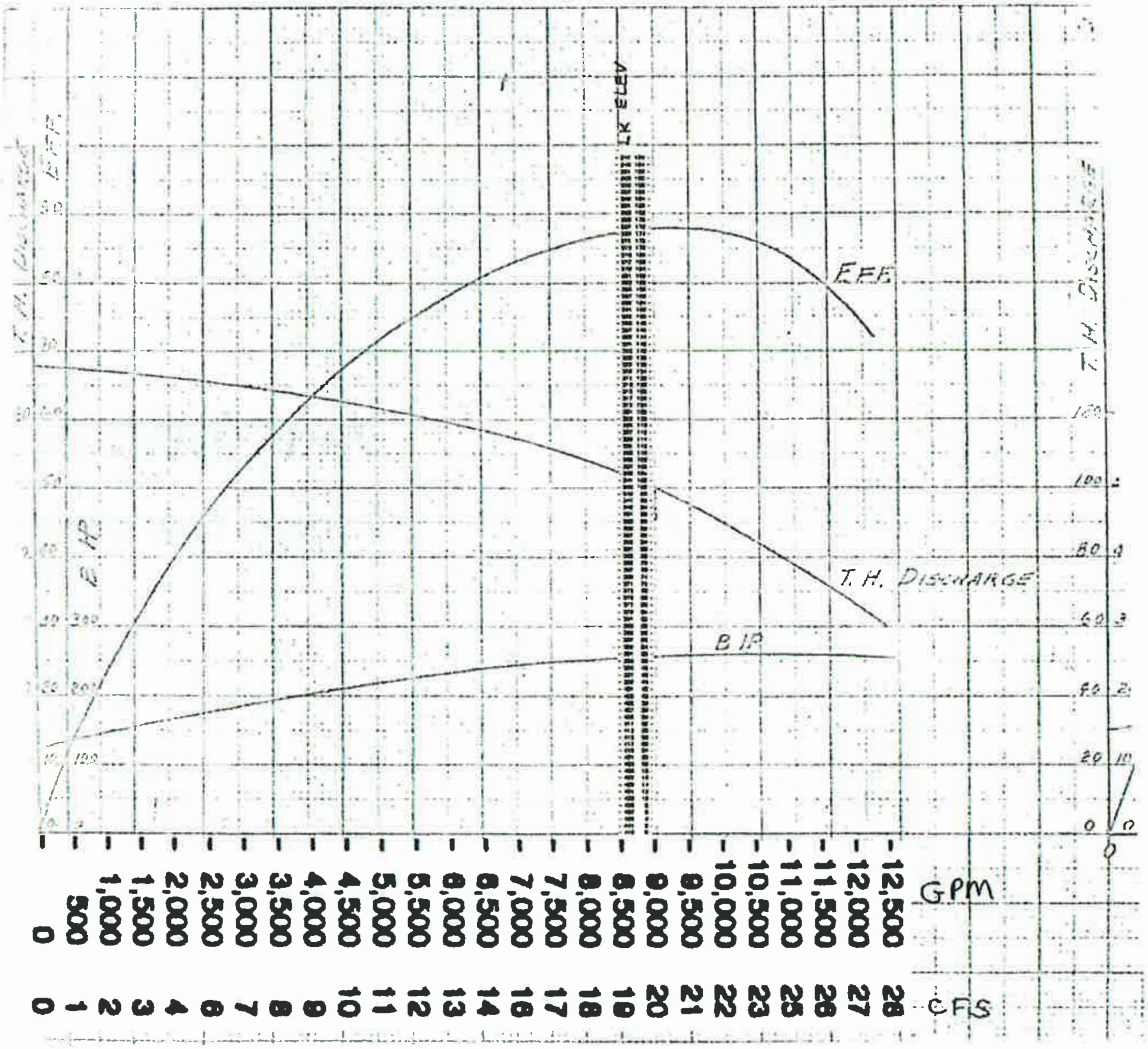
Q (cfs)	Head (ft)	Efficiency (%)	BHP
0	81	0	307
15	77	37	339
32	74	68	387
47	69	86	430
61	63	91	472
63	61	91	483
79	49	85	515
88	41	78	520

Table C-12. Pumps 7 and 8 at 255 RPM

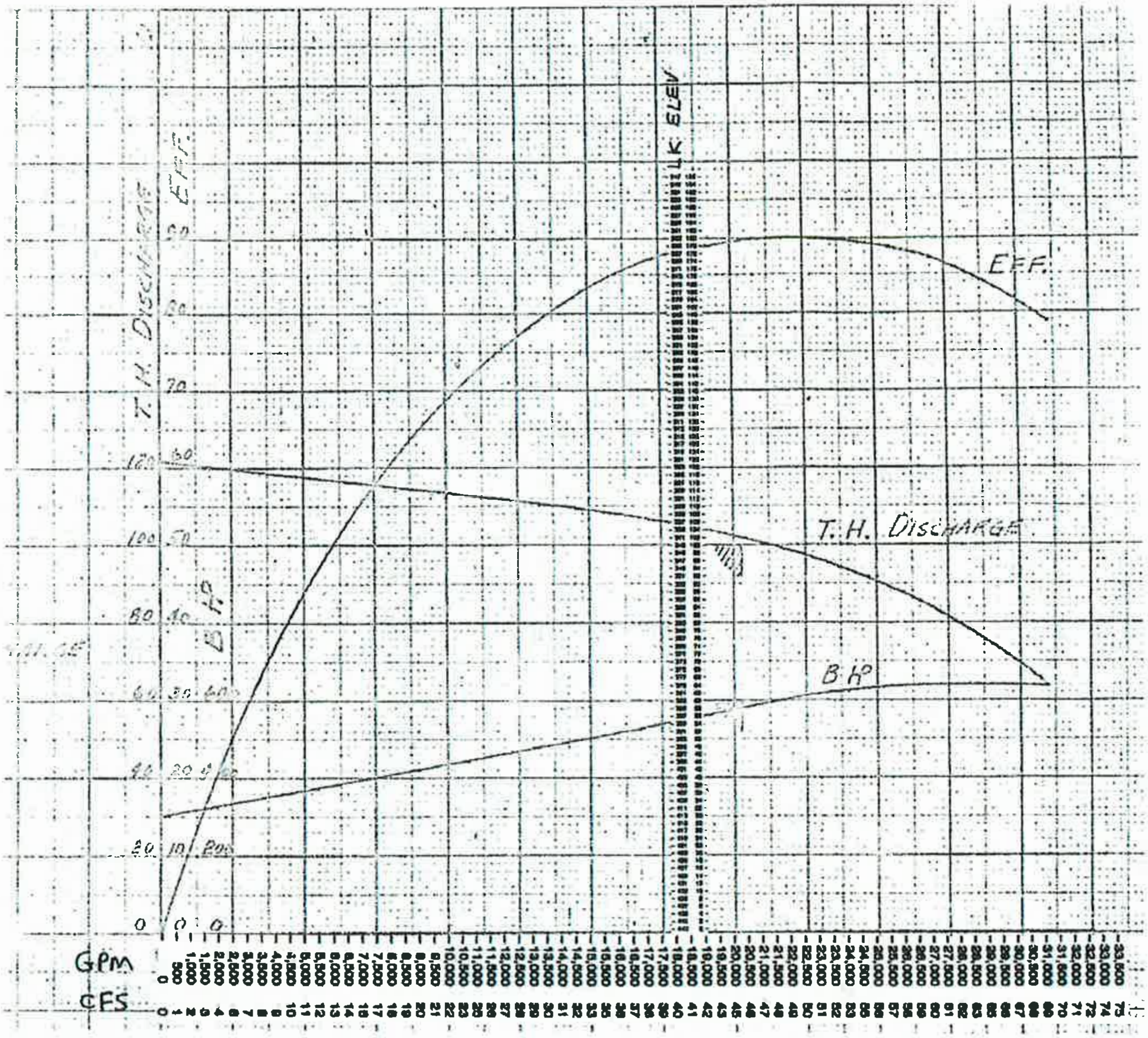
Q (cfs)	Head (ft)	Efficiency (%)	BHP
22	38	70	
28	36	86	
43	31	91	
50	28	86	

APPENDIX D

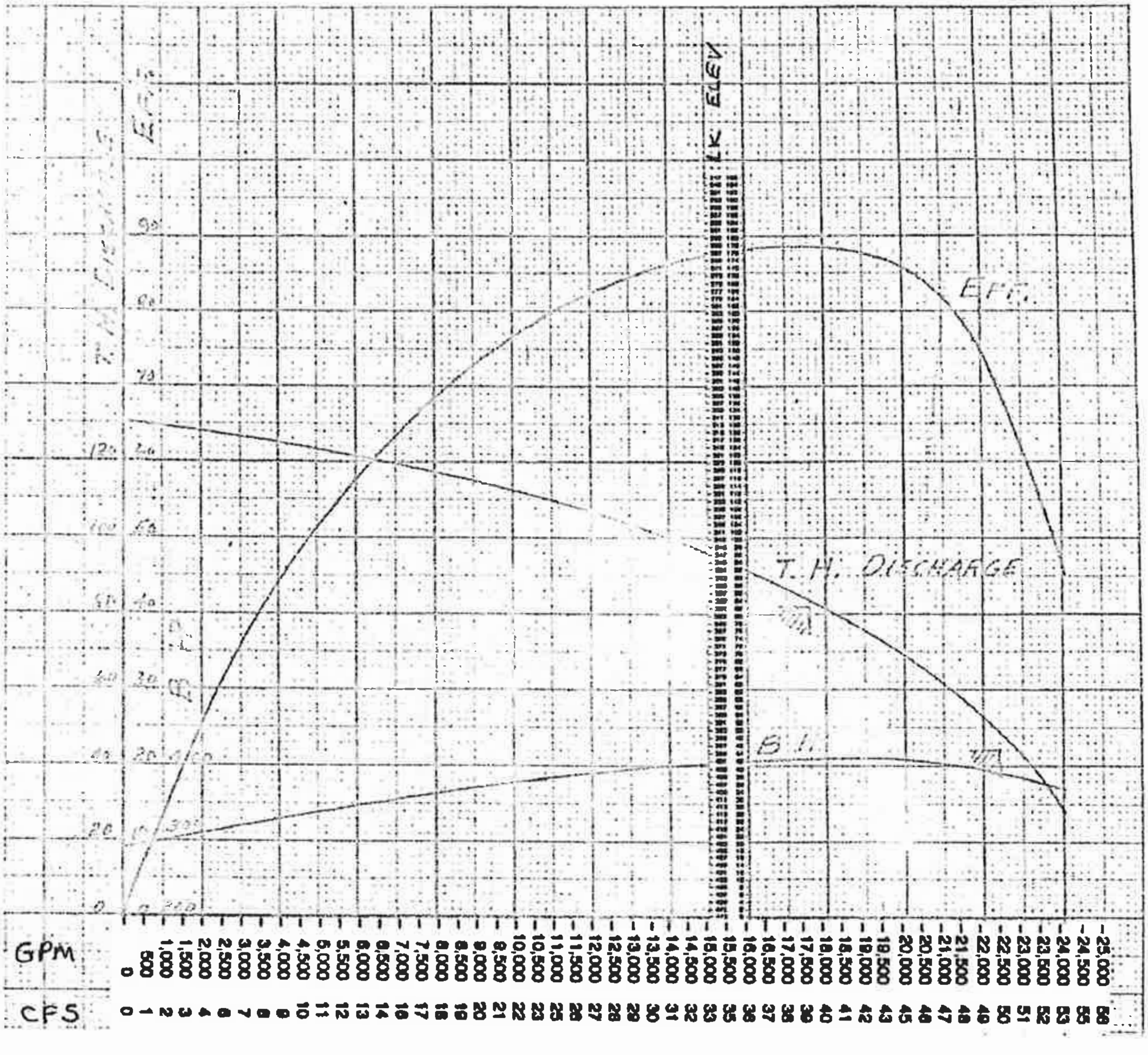
Pump Curves



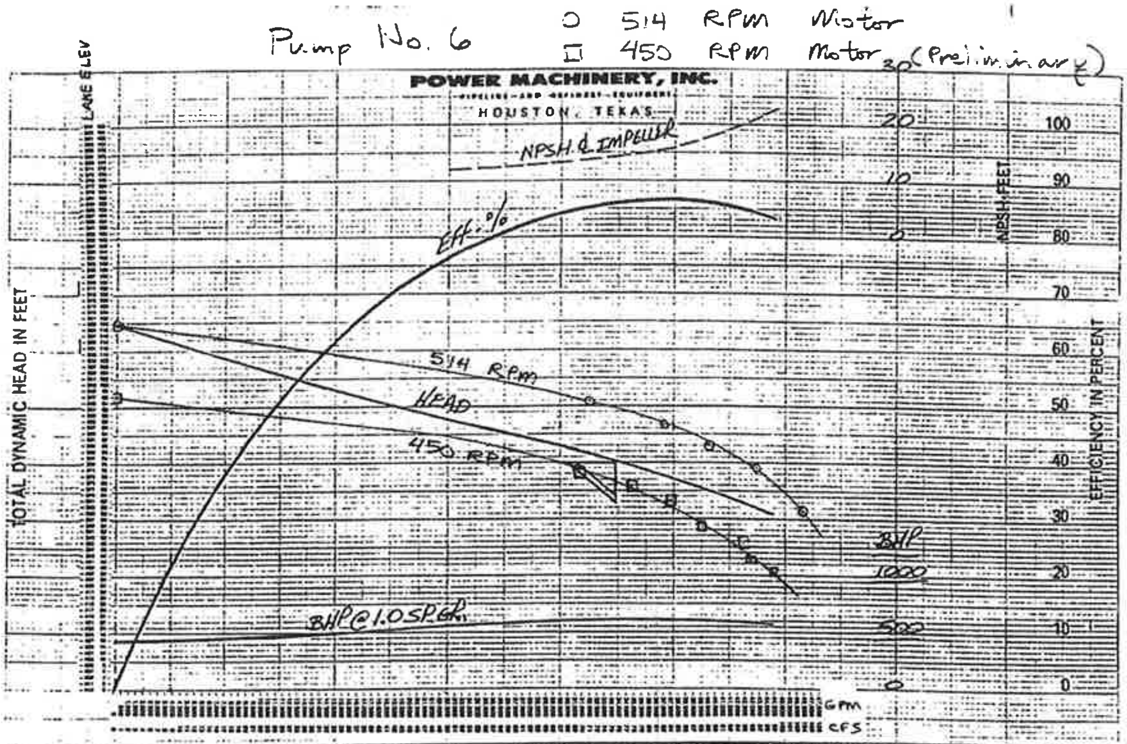
Operating Range for Pump #2



Operating Range for Pump #3



Operating Range for Pumps #4 and #5



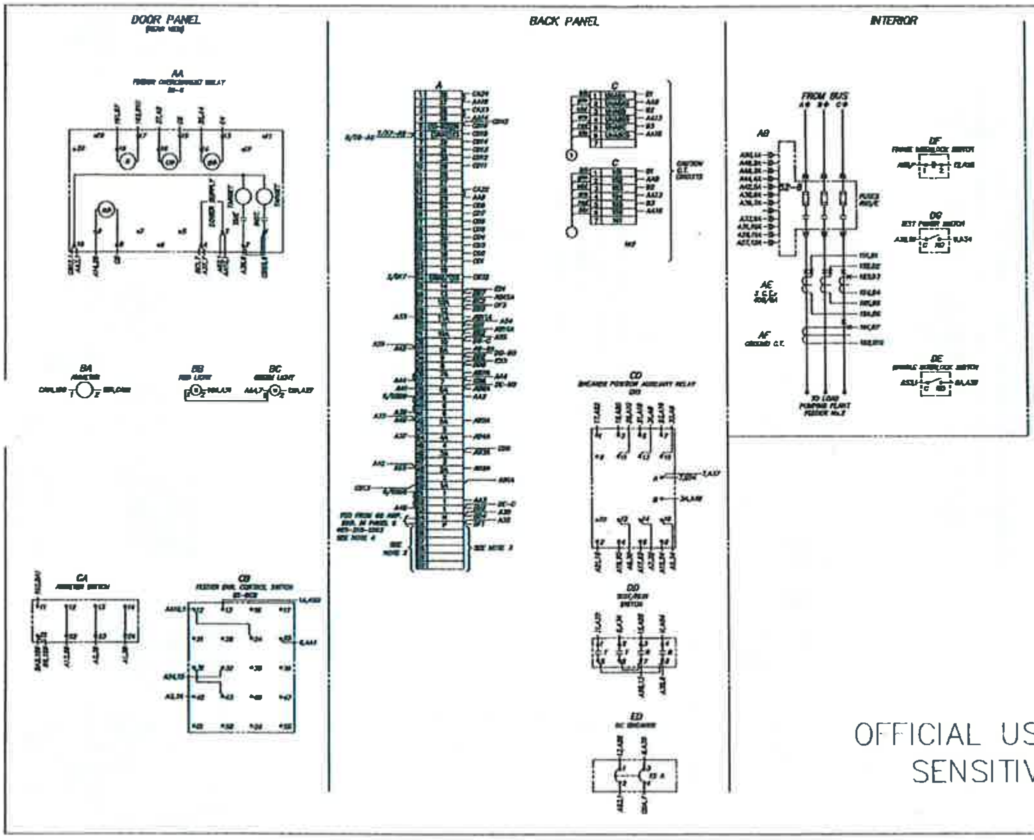
PUMP MFG'R. INGERSOLL-RAND	RPM 514	CASE MAT'L CAST IRON	IMP DIA. 34 7/8		DRAWN BY SGR	CUSTOMER PUMP & MOTOR WORKS
SIZE AND TYPE 30" ALV		IMP MAT'L BRONZE	MAX 41"	MIN 34"	DATE 3-16-91	CURVE NO. P-6191-P1

Operating Range for Pump #6 and Emergency Pump

APPENDIX E

Referenced Electrical/Control Drawings

COMPUTER DRAFTING



CABLE LIST

CABLE No.	CABLE DESIGNATION	REFERENCE DRAWING	CABLE SIZE
①	[illegible]	[illegible]	[illegible]

NOTES

1. Manufacturer's wire numbers are shown on the wires and on terminal block A. Bureau standard designations are also used, ie, 17,A33 is wire number 17 that goes to terminal A33.

2. Wires going to other panels have the panel number followed by a dash in front of the destination, if it goes to a feeder panel it is marked with an F and the feeder number, ie, 1/C3-A6 goes to panel 1, feeder 3, terminal A6.

3. No AC circuits for heating and lighting are shown on this drawing, see drawing [illegible].

4. DC Power to feeders are interconnected and fed from a [illegible] Amp. breaker in panel [illegible] see drawing [illegible].

REFERENCE DRAWINGS

UNA FEEDERS-SCHEMATICS ———— [illegible]
UNA 52A, 52B, AND 2N-SCHEMATICS ———— [illegible]
UNA C.T. & P.T.-SCHEMATICS ———— [illegible]
UNA PANEL 3-WIRING ———— [illegible]
UNA PANEL 4-WIRING ———— [illegible]
UNA PANEL 5-WIRING ———— [illegible]
UNA PANEL 6-WIRING ———— [illegible]
UNA AC DISTRIBUTION ———— [illegible]
UNA FEEDERS 52-1 THRU 52-11
EXCEPT 52-3 & 52-4 ———— [illegible]
UNA FEEDER 52-3 ———— [illegible]

2	[illegible]	[illegible]
1	[illegible]	[illegible]

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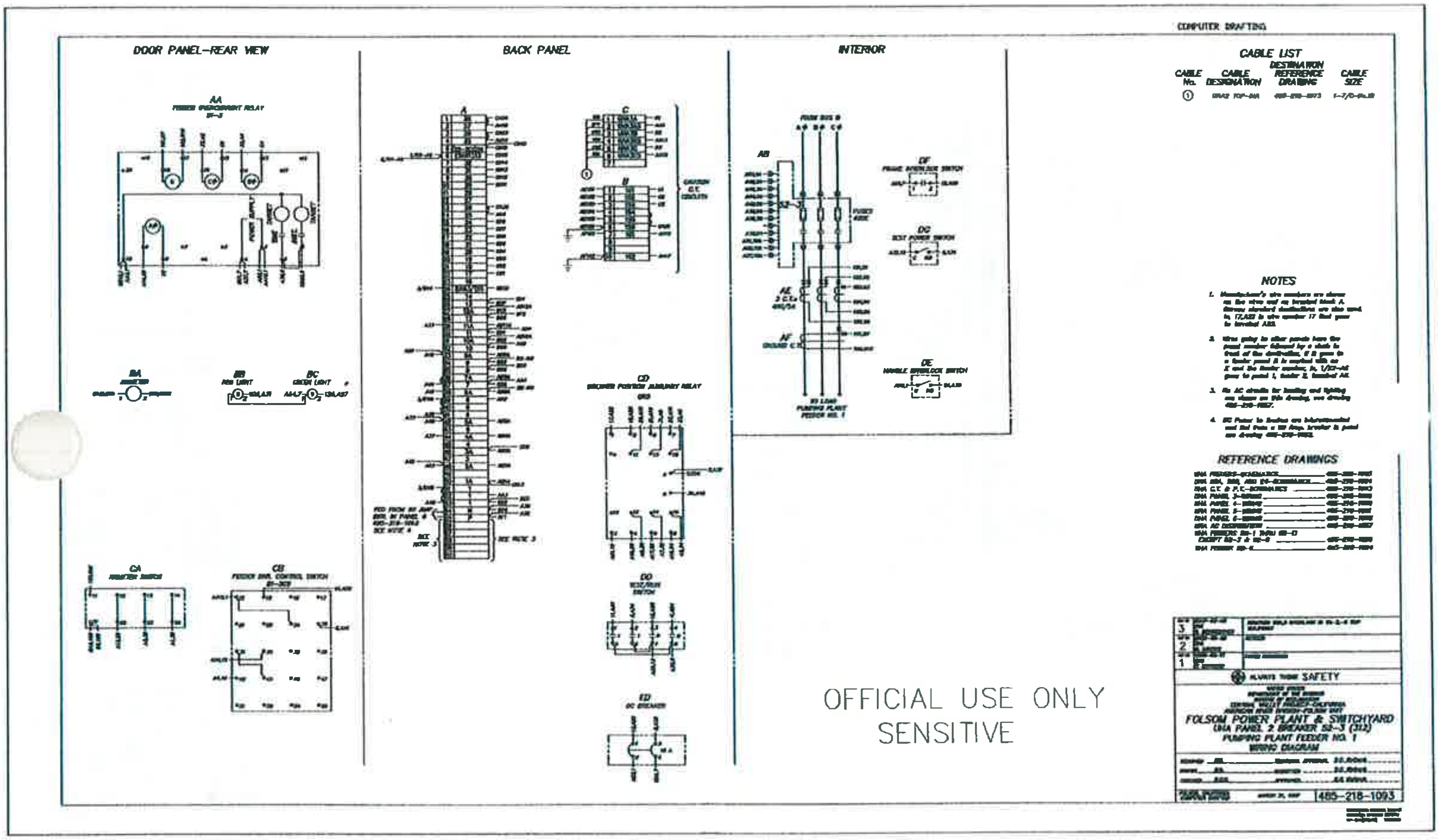
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
AMERICAN RIVER DIVISION-FOLSOM UNIT

FOLSOM POWER PLANT AND SWITCHYARD
UNA-FEEDER 52-6 (612)
WIRING DIAGRAM

485-218-1094



FOLSOM POWER PLANT & SWITCHYARD
UNA PANEL 2 BREAKER 52-3 (312)
PUMPING PLANT FEEDER NO. 1
WIRING DIAGRAM

485-218-1093

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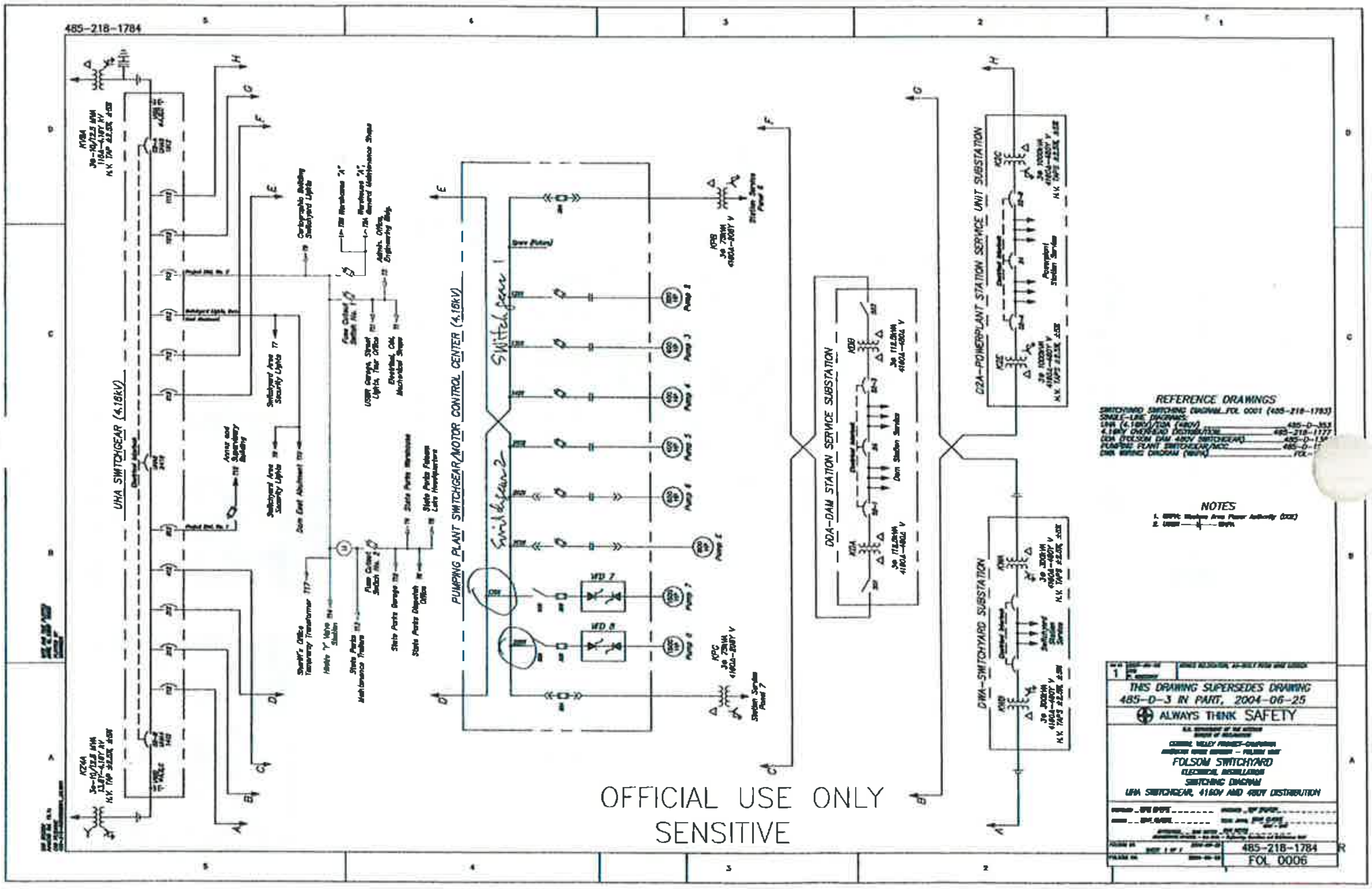
SENSITIVE

485-218-1784



REFERENCE DRAWINGS

SWITCHYARD SWITCHING DIAGRAM FOL 0001 (485-218-1783)
SINGLE-LINE DIAGRAMS:
UHA (4.16kV)/G2A (480V) ______ 485-D-353
4.16KV OVERHEAD DISTRIBUTION ______ 485-218-1777
DDA (FOLSOM DAM 480V SWITCHGEAR) ______ 485-D-13
PUMPING PLANT SWITCHGEAR/MCC ______ 485-D-1
DWA WIRING DIAGRAM (WAPA) ______ FOL-

NOTES

1. WAPA: Western Area Power Authority (DOE)
2. USBR ——|—— WAPA

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SENSITIVE

1

THIS DRAWING SUPERSEDES DRAWING
485-D-3 IN PART, 2004-06-25

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BUREAU OF RECLAMATION

CENTRAL VALLEY PROJECT—CALIFORNIA
AMERICAN RIVER DIVISION — FOLSOM UNIT
FOLSOM SWITCHYARD
ELECTRICAL INSTALLATION
SWITCHING DIAGRAM
UHA SWITCHGEAR, 4160V AND 480V DISTRIBUTION

SHEET 1 OF 1

485-218-1784 R

FOL 0006

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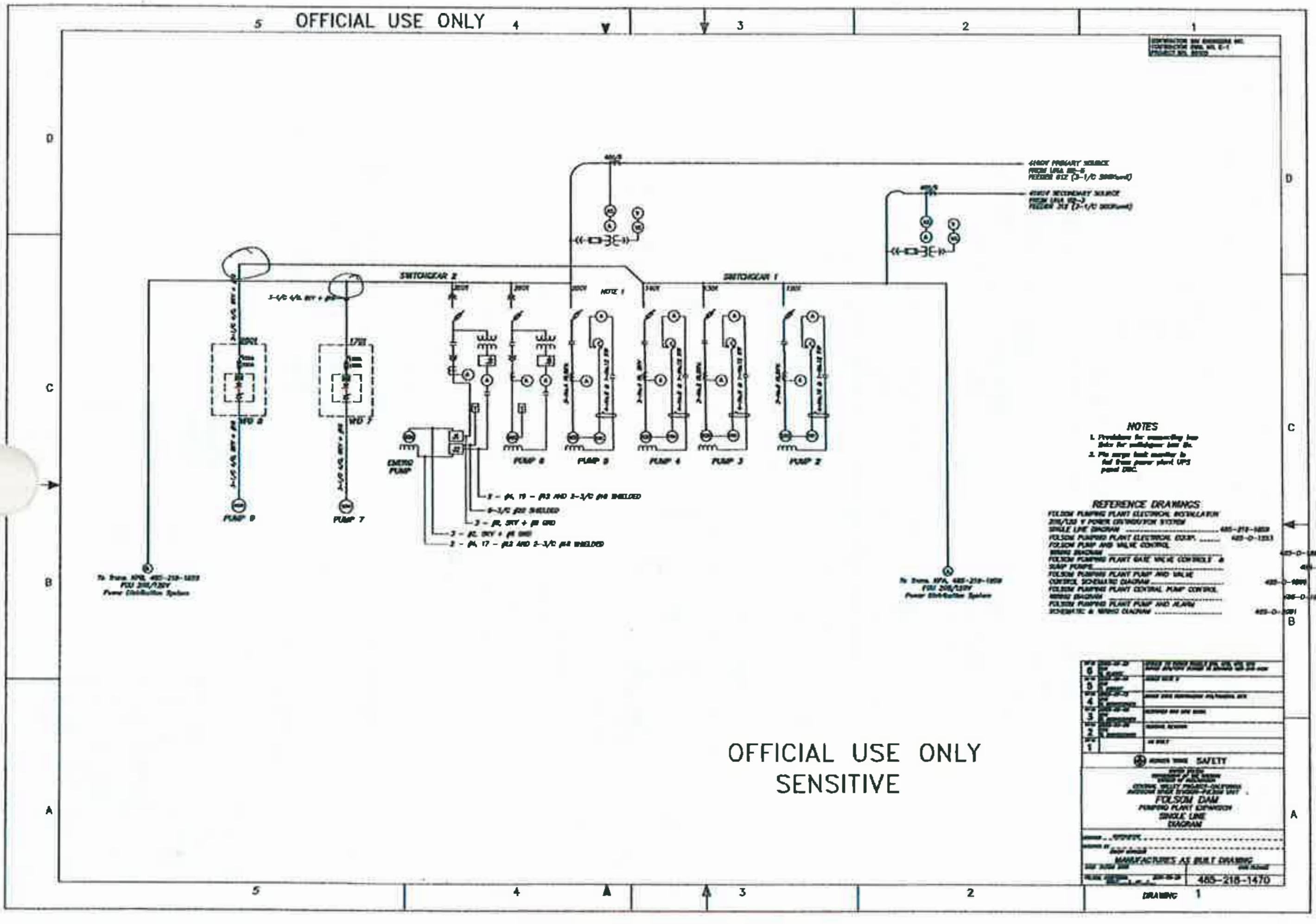

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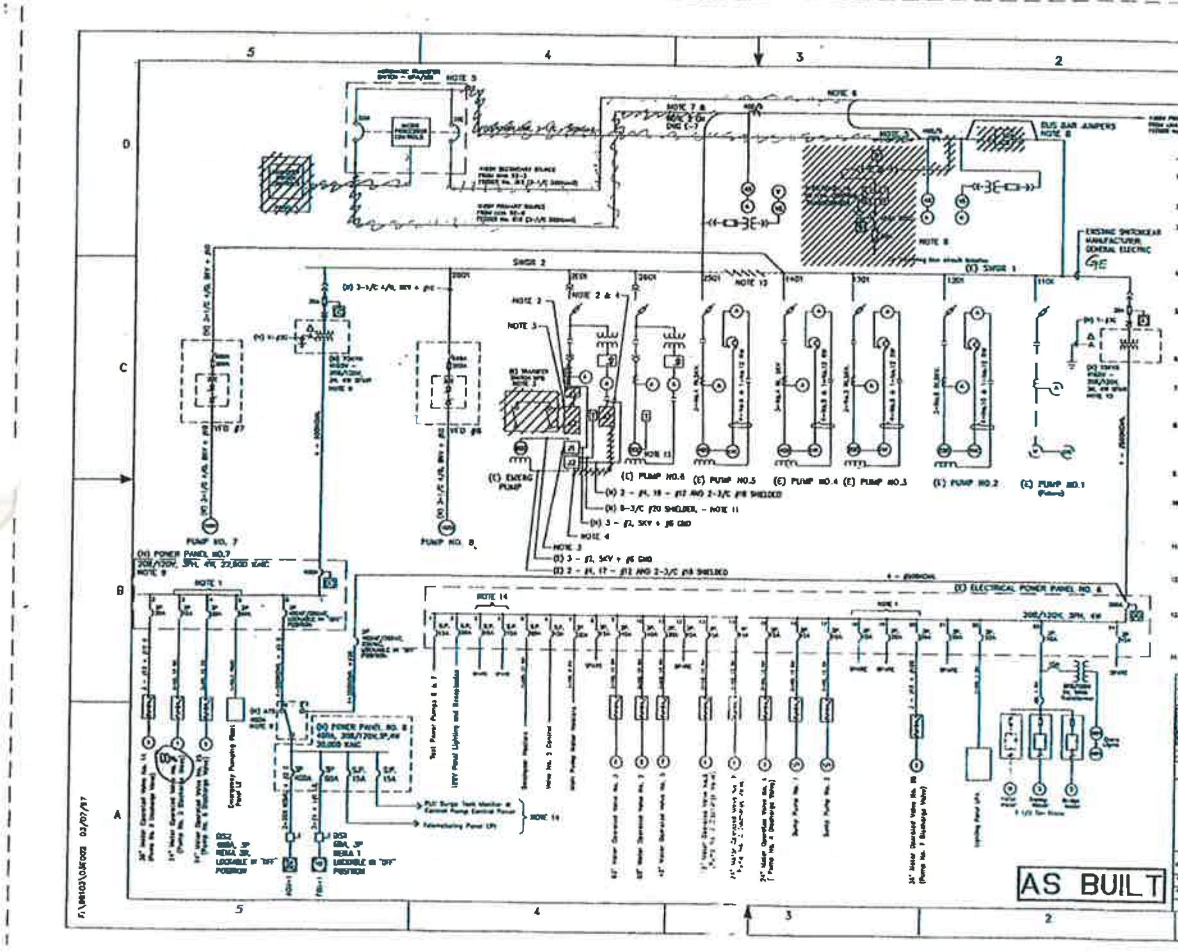


F:\98103\03E002 02/07/97

NOTES:

1. DISCONNECT AND EXTEND (E) CABLES, AS REQUIRED, FOR PUMPS NO. 3 & 8 DISCHARGE VALVES AND THE EMERGENCY PUMPING PLANT PANEL TO (N) DISTRIBUTION PANEL BOARD AS SHOWN.
2. DISCONNECT AND REMOVE (E) CABLES AND CONDUITS CONNECTED TO (E) J-BOXES J1 & J3 AND REMOVE THE J-BOXES.
3. DISCONNECT AND REMOVE (E) TRANSFER SWITCH, J-BOX J2 AND CONNECTED CONDUITS AND CABLES. THE OUTGOING POWER CABLES/CONDUIT FROM (E) J-BOX J2 SHALL BE CUT AND CONNECTED TO (N) INCOMING POWER CABLES/CONDUIT THRU (N) J-BOX J4 INSTALLED ON THE COLUMN.
4. DISCONNECT AND CUT (E) CONTROL CABLES & CONDUIT CONNECTED TO (E) J-BOX J2 UPTO THE COLUMN AND CONNECT REMAINING CABLES/CONDUIT TO (N) J-BOX J5 ABOVE (N) J-BOX J4. CONNECT (N) CONTROL CABLES/CONDUIT TO (N) J-BOX J5.
5. DISCONNECT (E) AUTOMATIC TRANSFER SWITCH CONNECTIONS FROM (E) BREAKERS 52E AND 52N. KEEP THE TRANSFER SWITCH & THE TWO BREAKERS AS SPARE. REMOVE (E) FOUR OUTGOING 3-1/C 300kcmil CABLES FROM AUTOMATIC TRANSFER SWITCH TO BREAKER ACB CT'S TERMINALS.
6. CONNECT (E) INCOMING FEEDER No. 212 FROM UNIT 32-3 AT THE CT'S TERMINALS WHERE THE (E) INCOMING TO BREAKER ACB HAVE BEEN DISCONNECTED FOR NOTE 5.
7. CONNECT (E) INCOMING FEEDER No. 612 FROM UNIT 32-6 TO THE (N) CT/PT CABINET. DISCONNECT AND REMOVE ALL UNUSED CABLE AND CONTROL WIRING BETWEEN THE TRANSFER SWITCH AND THE PUMPING PLANT. SEAL THE ENDS OF ALL CONDUITS.
8. REMOVE (E) ACB PM, ASSOCIATED CONTROL TRANSFORMER, PRIMARY & SECONDARY DISCONNECT SWITCHES AND 50/51 RELAYS. PROVIDE AND INSTALL (N) BUS BARS TO BUS THRU THE BREAKER CONNECTIONS. THE 50/51 RELAYS SHALL BE DELIVERED TO THE RECLAMATION REPRESENTATIVE.
9. THE 400A PANEL, [illegible], 75KVA XFMR AND 400A ATS SHALL BE PROVIDED IN ONE FREE STANDING VERTICAL DISTRIBUTION SWITCHBOARD TYPE SECTION.
10. THE (E) 30KVA XFMR SHALL BE REPLACED WITH (N) 75KVA, 3φ, 4W, 480V – 208/120V XFMR OF THE TYPE AND RATING TO MATCH THE EXISTING XFMR. THE (N) 400A CIRCUIT BREAKER SHALL BE MOUNTED ABOVE THE TRANSFORMER WITH BREAKER HANDLE AND TRIP SETTING ACCESSIBLE FROM THE OUTSIDE.
11. TERMINATE SHIELDED CABLE CONDUCTORS FROM TEMPERATURE RELAY "T" IN J-BOX J2 FOR FUTURE USE BY RECLAMATION FOR WATER [illegible].
12. REMOVE (E) 4160V BUS BETWEEN SWITCHGEAR 1, SECTION 1401 (PUMP #1) AND SWITCHGEAR 2, SECTION 2501 (PUMP #5). FURNISH NEW BUS LINKS FOR FUTURE USE BY RECLAMATION.
13. REPLACE (E) MOTOR ON PUMP No. 8 WITH THE [illegible] MOTOR FURNISHED BY RECLAMATION, RECONNECT AND TEST THE MOTOR FOR PROPER OPERATION IN COORDINATION WITH RECLAMATION AFTER INSTALLATION.
14. DISCONNECT & EXTEND (E) CABLES, AS REQUIRED, FOR LOADS IN POINTS 3 & 4 TO (N) POWER PANEL NO. 8 AS SHOWN.

1	[illegible]	AS BUILT	[illegible]	[illegible]
REV.	DATE	DESCRIPTION	DRAWN	APPROVAL

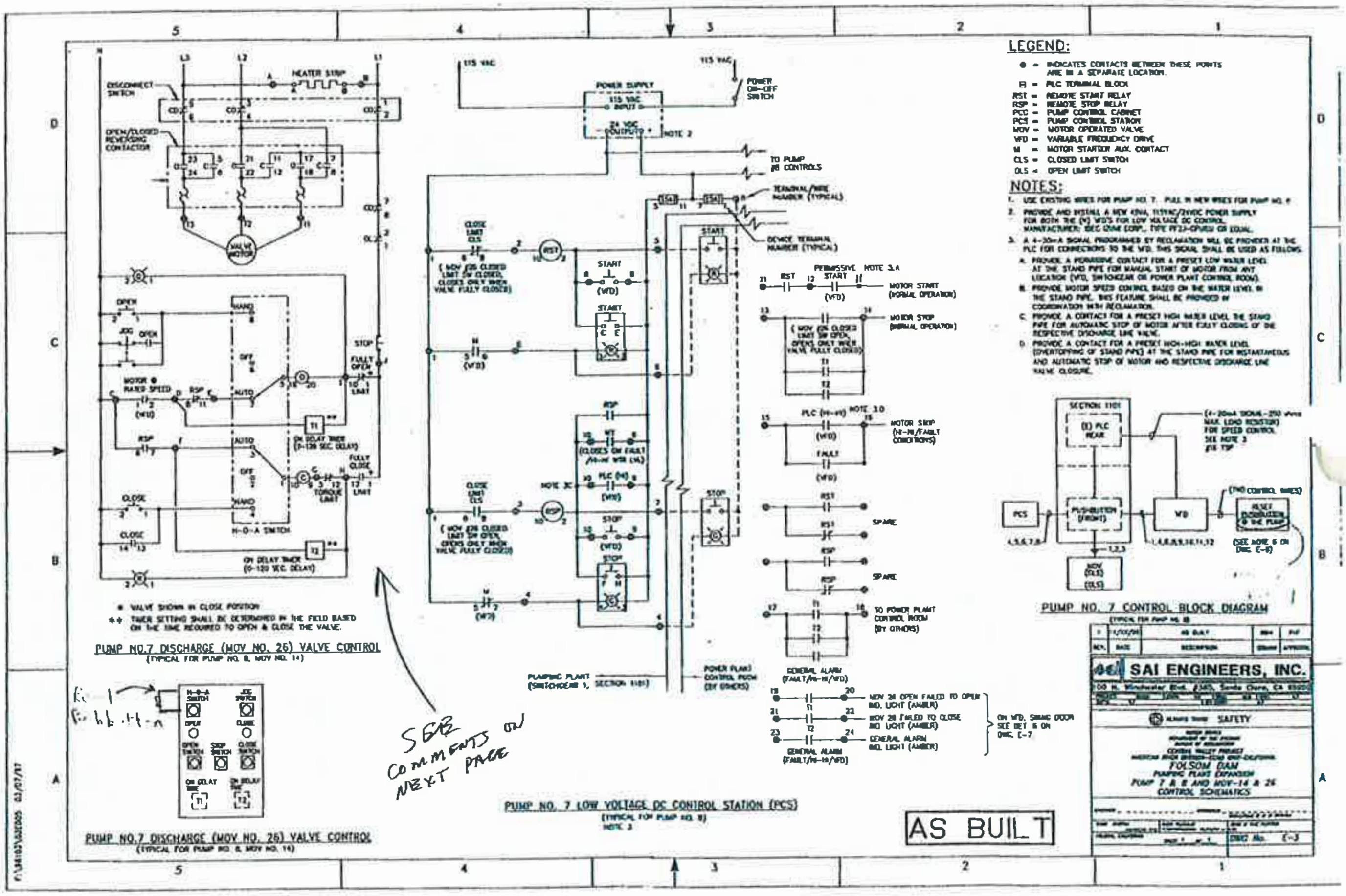
SAI ENGINEERS, INC.
[illegible] N. Winchester Blvd. #265, Santa Clara, CA 95050

SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
AMERICAN RIVER DIVISION–CCAO MPE–CALIFORNIA
FOLSOM DAM
PUMPING PLANT EXPANSION
SINGLE LINE
DIAGRAM

DWG No. E-1

AS BUILT



LEGEND:

● = INDICATES CONTACTS BETWEEN THESE POINTS ARE IN A SEPARATE LOCATION.
⊟ = PLC TERMINAL BLOCK
RST = REMOTE START RELAY
RSP = REMOTE STOP RELAY
PCC = PUMP CONTROL CABINET
PCS = PUMP CONTROL STATION
MOV = MOTOR OPERATED VALVE
VFD = VARIABLE FREQUENCY DRIVE
M = MOTOR STARTER AUX. CONTACT
CLS = CLOSED LIMIT SWITCH
OLS = OPEN LIMIT SWITCH

NOTES:

1. USE EXISTING WIRES FOR PUMP NO. 7. PULL IN NEW WIRES FOR PUMP NO. 8
2. PROVIDE AND INSTALL A NEW KVA, 115VAC/24VDC POWER SUPPLY FOR BOTH THE (N) VFD'S FOR LOW VOLTAGE DC CONTROL. MANUFACTURER: IDEC IZUMI CORP., TYPE PF2J-OPU[illegible] OR EQUAL.
3. A 4-20mA SIGNAL PROGRAMMED BY RECLAMATION WILL BE PROVIDED AT THE PLC FOR CONNECTIONS TO THE VFD. THIS SIGNAL SHALL BE USED AS FOLLOWS:
   - A. PROVIDE A PERMISSIVE CONTACT FOR A PRESET LOW WATER LEVEL AT THE STAND PIPE FOR MANUAL START OF MOTOR FROM ANY LOCATION (VFD, SWITCHGEAR OR POWER PLANT CONTROL ROOM).
   - B. PROVIDE MOTOR SPEED CONTROL BASED ON THE WATER LEVEL IN THE STAND PIPE. THIS FEATURE SHALL BE PROVIDED IN COORDINATION WITH RECLAMATION.
   - C. PROVIDE A CONTACT FOR A PRESET HIGH WATER LEVEL THE STAND PIPE FOR AUTOMATIC STOP OF MOTOR AFTER FULLY CLOSING OF THE RESPECTIVE DISCHARGE LINE VALVE.
   - D. PROVIDE A CONTACT FOR A PRESET HIGH-HIGH WATER LEVEL (OVERTOPPING OF STAND PIPE) AT THE STAND PIPE FOR INSTANTANEOUS AND AUTOMATIC STOP OF MOTOR AND RESPECTIVE DISCHARGE LINE VALVE CLOSURE.

* VALVE SHOWN IN CLOSE POSITION

** TIMER SETTING SHALL BE DETERMINED IN THE FIELD BASED ON THE TIME REQUIRED TO OPEN & CLOSE THE VALVE.

PUMP NO.7 DISCHARGE (MOV NO. 26) VALVE CONTROL
(TYPICAL FOR PUMP NO. 8, MOV NO. 14)

PUMP NO. 7 LOW VOLTAGE DC CONTROL STATION (PCS)
(TYPICAL FOR PUMP NO. 8)
NOTE 3

PUMP NO.7 DISCHARGE (MOV NO. 26) VALVE CONTROL
(TYPICAL FOR PUMP NO. 8, MOV NO. 14)

PUMP NO. 7 CONTROL BLOCK DIAGRAM
(TYPICAL FOR PUMP NO. 8)

Fi 1
Fi hb.1-1-A

SEE COMMENTS ON NEXT PAGE

AS BUILT

1	1/03/08	AS BUILT		
REV.	DATE	DESCRIPTION	DRAWN	APPROVED

SAI ENGINEERS, INC.
100 N. Winchester Blvd. #305, Santa Clara, CA 95050

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WATER SERVICE
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
AMERICAN RIVER DIVISION-FOLSOM UNIT-CALIFORNIA
FOLSOM DAM
PUMPING PLANT EXPANSION
PUMP 7 & 8 AND MOV-14 & 26
CONTROL SCHEMATICS

DWG. No. C-3

F:\SAI03\SE005 03/07/17

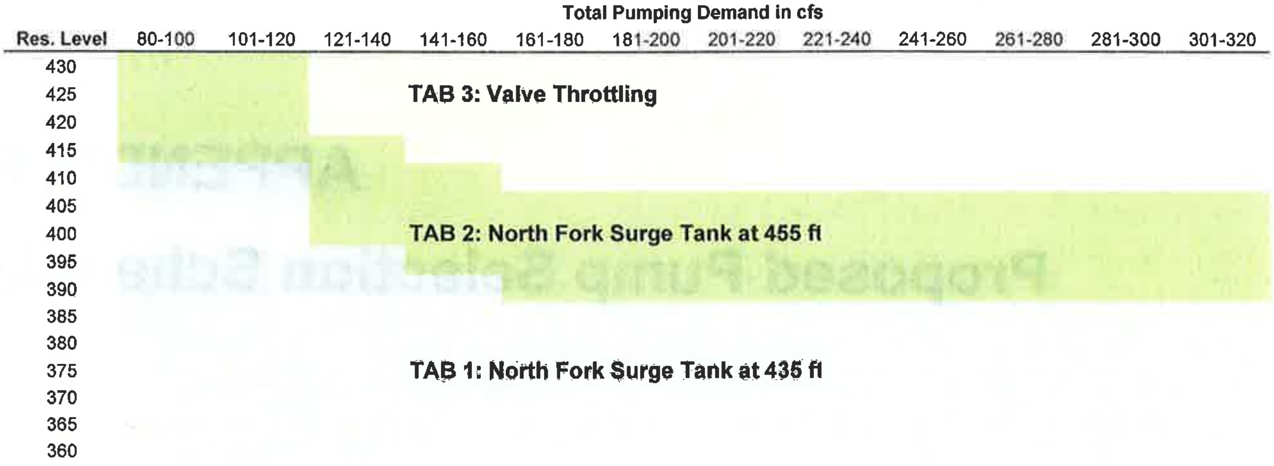
APPENDIX F

Proposed Pump Selection Schedule

Folsom Pumping Plant

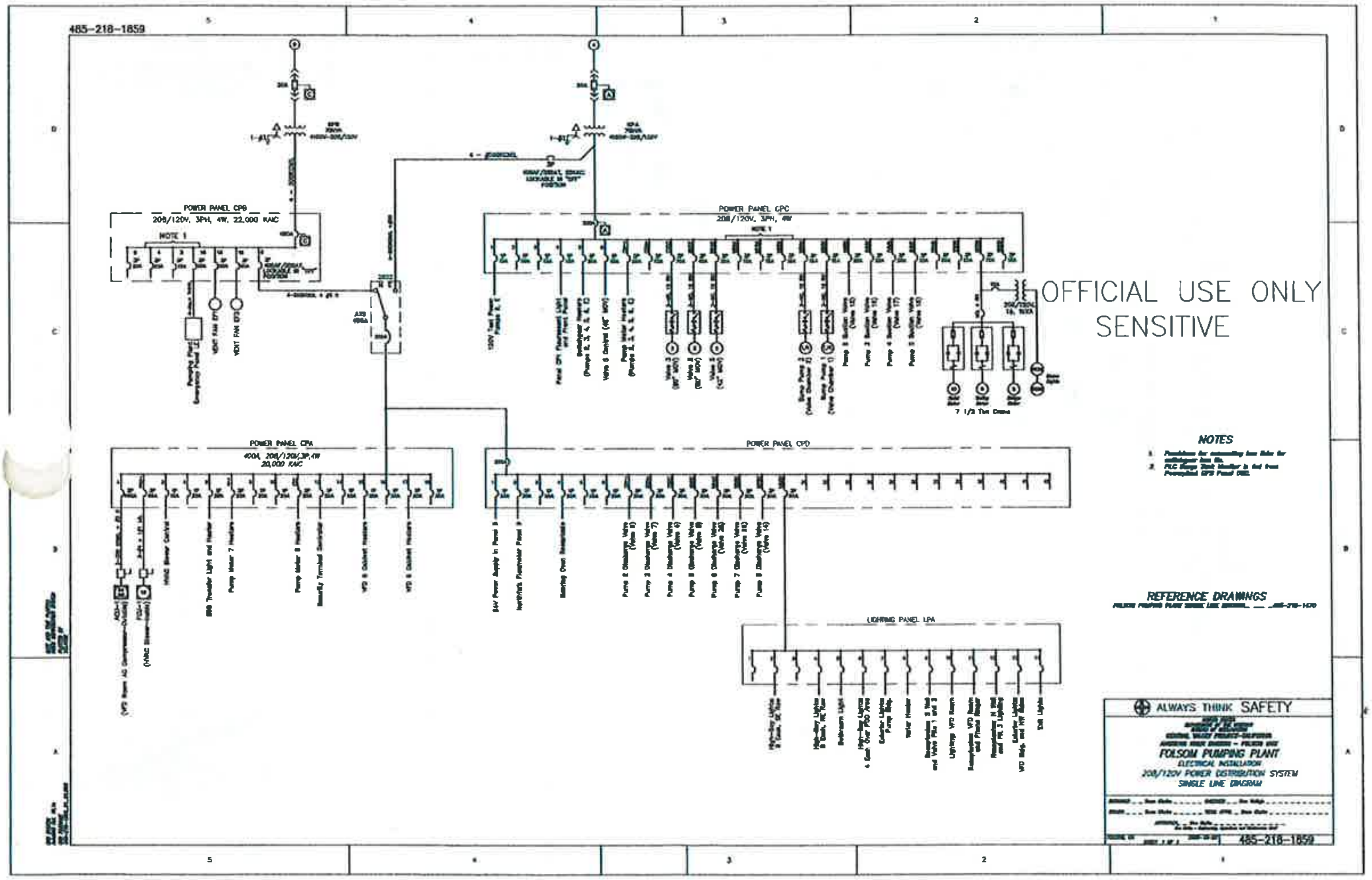
Proposed Pump Operation Schedule for Pumped Raw Water Deliveries

1. Determine Folsom Reservoir water level (ft elevation)
2. Determine total pumping demand (cfs)
3. Select spreadsheet tab from graph below:



4. Select pumps and settings from appropriate tab

Notes:	Pumping not feasible for combinations of reservoir level and total demand that fall outside the "tab" areas
	Pumps 7 and 8 can be used interchangeably (i.e., using pump 7 where it says 8 and visceversa will not affect operations)
	Pumps 4 and 5 can be used interchangeably (i.e., using pump 4 where it says 5 and visceversa will not affect operations)



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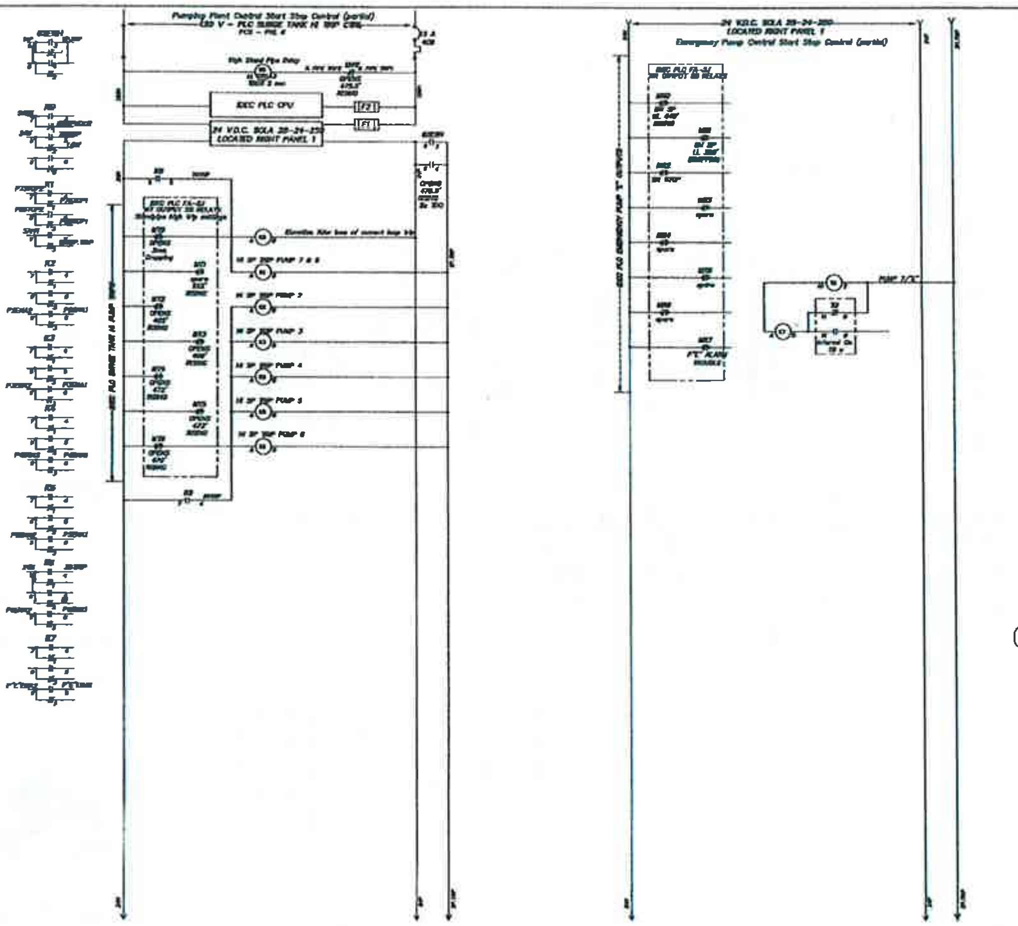
FOLSOM PUMPING PLANT
ELECTRICAL INSTALLATION
208/120V POWER DISTRIBUTION SYSTEM
SINGLE LINE DIAGRAM

485-218-1859



EXPLANATION

DEVICE	LOCATION	DESCRIPTION
[illegible]	PNL 1	[illegible]
[illegible]	PNL 1	[illegible]
[illegible]	PNL 1	[illegible]
[illegible]	PNL 1	[illegible]
[illegible]	PNL 1	[illegible]
K7	PNL 1	[illegible]

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FOLSOM PUMPING PLANT
STAND PIPE HIGH LEVEL—— PUMP TRIP CONTROL
SCHEMATIC DIAGRAM

465-218-1461

Folsom Pumping Plant

Proposed Pump Operation Schedule for Pumped Raw Water Deliveries

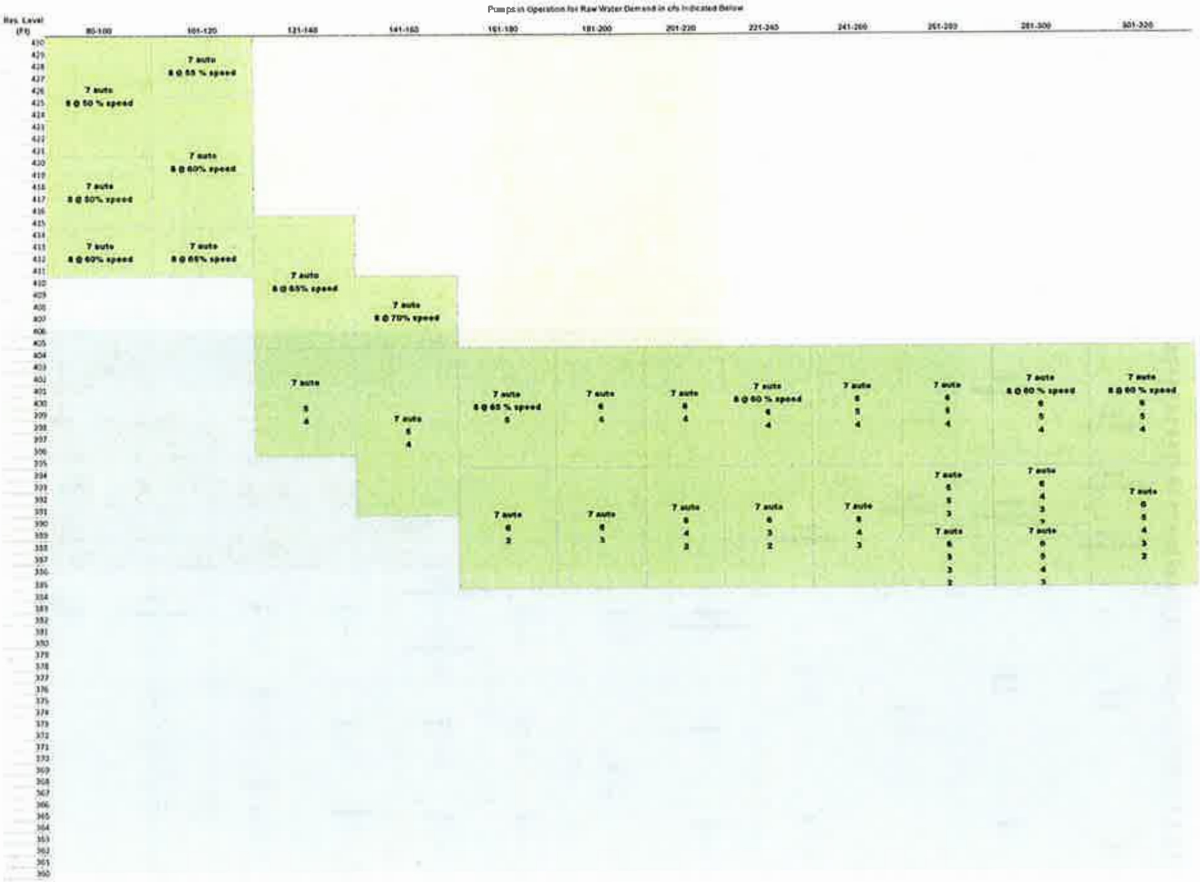
TAB 1: North Fork Surge Tank at 435 Feet (VFD Setpoint 0.65)

Res. Level (Ft)	Pumps in Operation for Raw Water Demand in cfs Indicated Below											
	80-100	101-120	121-140	141-160	161-180	181-200	201-220	221-240	241-260	261-280	281-300	301-320
430	🟩	🟩										
429	🟩	🟩										
428	🟩	🟩										
427	🟩	🟩										
426	🟩	🟩										
425	🟩	🟩										
424	🟩	🟩										
423	🟩	🟩										
422	🟩	🟩										
421	🟩	🟩										
420	🟩	🟩										
419	🟩	🟩										
418	🟩	🟩										
417	🟩	🟩										
416	🟩	🟩										
415	🟩	🟩	🟩									
414	🟩	🟩	🟩									
413	🟩	🟩	🟩									
412	🟩	🟩	🟩									
411	🟩	🟩	🟩									
410	7 auto 8 @ 50 % speed	7 auto 8 @ 55 % speed	🟩	🟩								
409			🟩	🟩								
408			🟩	🟩								
407			🟩	🟩								
406			🟩	🟩								
405		7 auto 8 @ 60% speed	🟩	🟩								
404			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
403			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
402			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
401			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
400			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
399	7 auto 8 @ 55% speed		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
398			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
397			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
396			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
395			7 auto 8 @ 65% speed	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
394	7 auto 8 @ 60% speed	7 auto 8 @ 65% speed		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
393				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
392				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
391				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
390				7 auto 8 @ 70% speed	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
389	7 auto 8 @ 65% speed				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
388					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
387					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
386					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
385					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
384	7 auto 4 or 5	7 auto 4 or 5	7 auto 5 4	7 auto 5 4	7 auto 8 @ 65 % speed 6	7 auto 5 4	7 auto 6 4	7 auto 8 @ 60 % speed 6 4	7 auto 6 5 4	7 auto 6 5 4	7 auto 8 @ 60 % speed 6 5 4	7 auto 8 @ 60 % speed 6 5 4
383												
382												
381												
380												
379								7 auto 8 @ 65% speed 6 4				
378												
377												
376												
375												
374					7 auto 6 2	7 auto 6 3	7 auto 6 4 2	7 auto 6 3 2	7 auto 6 4 3	7 auto 6 5 3	7 auto 6 4 3	7 auto 6 5 4 3 2
373												
372												
371												
370												
369										7 auto 6 5 3 2	7 auto 6 5 4	
368												
367												
366												
365												
364		7 auto 4 2		7 auto 5 4 2	7 auto 6 4		7 auto 6 3 2	7 auto 6 4 3	7 auto 6 4 3 2		7 auto 6 5 4 3 2	
363												
362	7 auto 8											
361												
360												

Folsom Pumping Plant

Proposed Pump Operation Schedule for Pumped Raw Water Deliveries

TAB 2: North Fork Surge Tank at 455 Feet (VFD Setpoint 0.76)



Pumps in Operation for Raw Water Demand in cfs Indicated Below

Res. Level (Ft)	80-100	101-120	121-140	141-160	161-180	181-200	201-220	221-240	241-260	261-280	281-300	301-320
430												
429		7 auto 8 @ 55 % speed										
428												
427												
426	7 auto 8 @ 50 % speed											
425												
424												
423												
422												
421												
420		7 auto 8 @ 60% speed										
419												
418	7 auto 8 @ 50% speed											
417												
416												
415												
414												
413	7 auto 8 @ 60% speed	7 auto 8 @ 65% speed										
412												
411												
410			7 auto 8 @ 65% speed									
409												
408				7 auto 8 @ 70% speed								
407												
406												
405												
404												
403												
402			7 auto 5 4								7 auto 8 @ 60 % speed 6 5 4	7 auto 8 @ 60 % speed 6 5 4
401								7 auto 8 @ 60 % speed 6 4	7 auto 6 5 4	7 auto 6 5 4		
400					7 auto 8 @ 65 % speed 5	7 auto 6 4	7 auto 6 4					
399												
398				7 auto 5 4								
397												
396												
395												
394										7 auto 6 5 3	7 auto 6 4 3 2	
393												
392												7 auto 6 5 4 3 2
391							7 auto 6 4 2	7 auto 6 3 2	7 auto 6 4 3			
390					7 auto 6 2	7 auto 6 3						
389										7 auto 6 5 3 2	7 auto 6 5 4 3	
388												
387												
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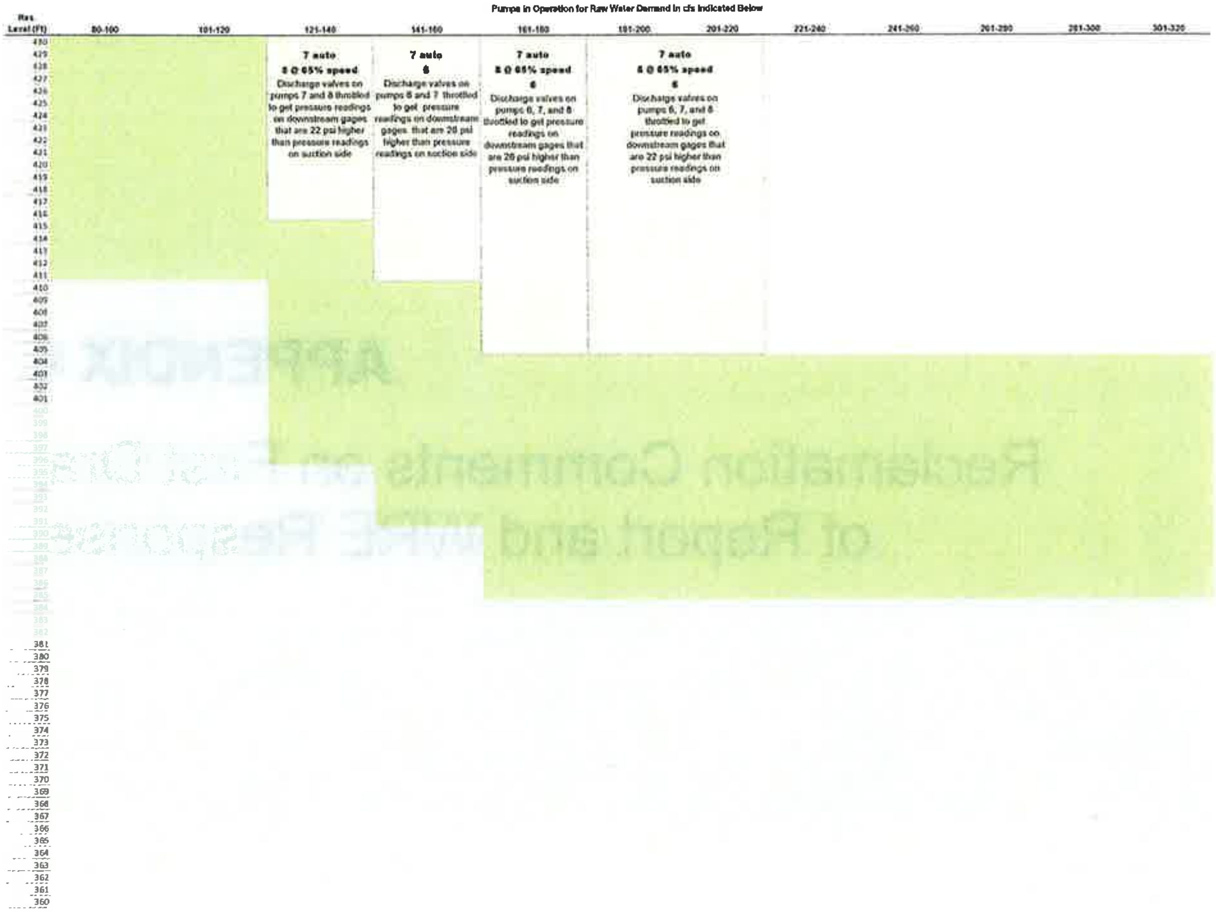
361												
360												

Folsom Pumping Plant

Proposed Pump Operation Schedule for Pumped Raw Water Deliveries

TAB 3: Valve Throttling (North Fork Surge Tank at 455 Feet, VFD Setpoint 0.76)



Pumps in Operation for Raw Water Demand in cfs Indicated Below

Res. Level (Ft)	80-100	101-120	121-140	141-160	161-180	191-200	201-220	221-240	241-260	261-280	281-300	301-320
430–411			**7 auto** **8 @ 65% speed** Discharge valves on pumps 7 and 8 throttled to get pressure readings on downstream gages that are 22 psi higher than pressure readings on suction side	**7 auto** **8** Discharge valves on pumps 8 and 7 throttled to get pressure readings on downstream gages that are 20 psi higher than pressure readings on suction side	**7 auto** **8 @ 65% speed** **6** Discharge valves on pumps 6, 7, and 8 throttled to get pressure readings on downstream gages that are 20 psi higher than pressure readings on suction side	**7 auto** **8 @ 65% speed** **6** Discharge valves on pumps 6, 7, and 8 throttled to get pressure readings on downstream gages that are 22 psi higher than pressure readings on suction side						

430 429 428 427 426 425 424 423 422 421 420 419 418 417 416 415 414 413 412 411 410 409 408 407 406 405 404 403 402 401 400 399 398 397 396 395 394 393 392 391 390 389 388 387 386 385 384 383 382 381 380 379 378 377 376 375 374 373 372 371 370 369 368 367 366 365 364 363 362 361 360

APPENDIX G

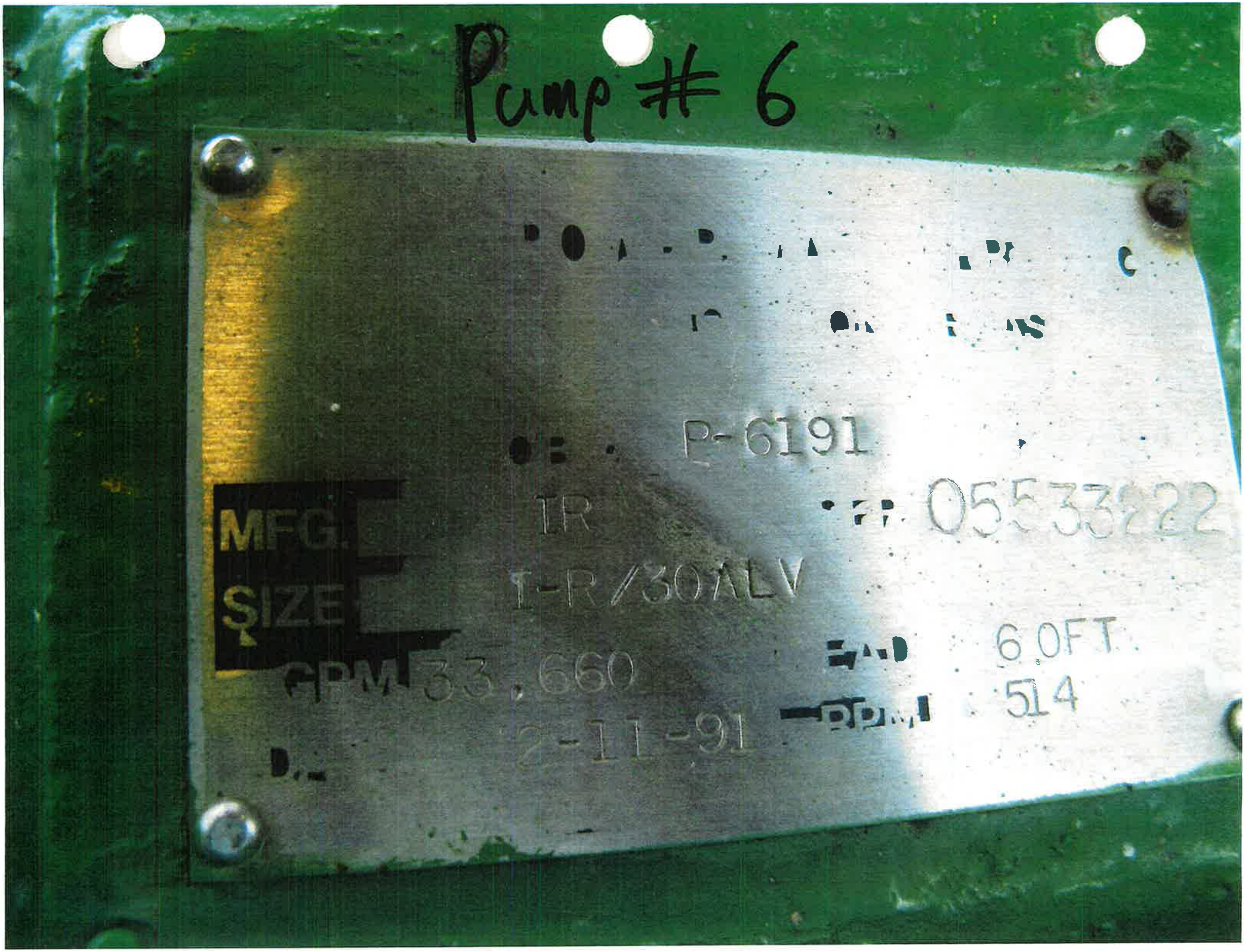
Reclamation Comments on First Draft of Report and WRE Responses

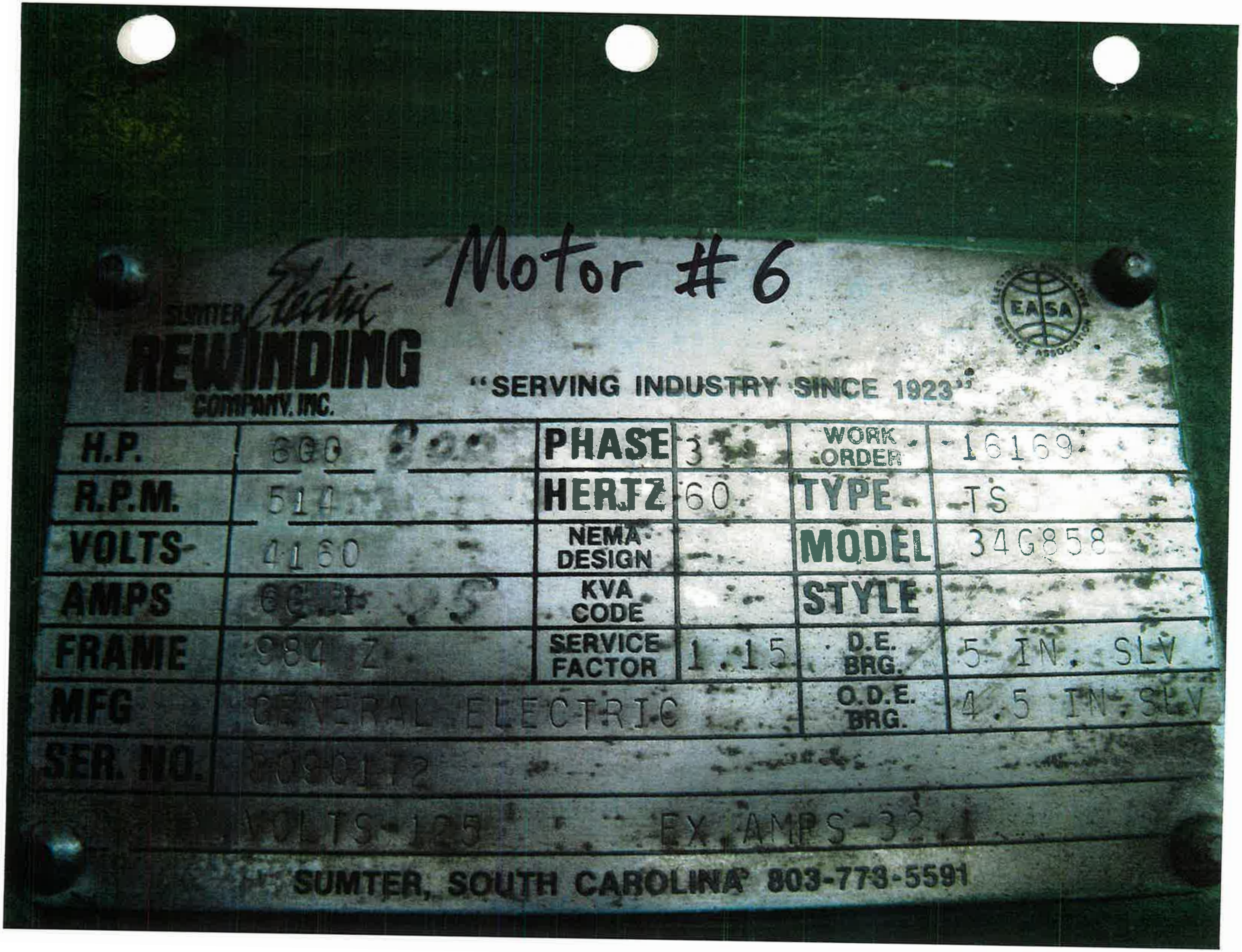
Folsom Pumping Plant System Capacity Evaluation

Comments on First Draft - Final Report

Ref. No.	Document	Section	Page	Full Comment Text	Comment Author	Source	Response	Response Author
1		Corrective Measures	ES-2	The report recommends installing butterfly valves on the discharge of pumps for purposes of throttling Reclamation typically does not recommend throttling pump discharges Attempts to regulate above 50-foot of differential head using butterfly valves has resulted in severe cavitation	Melavic	Reclamation	We understand Reclamation prefers not to throttle discharge valves, and it is a good practice when possible. But in this case it results in highly inefficient likely damaging, pump operation Cavitation is a real problem (it is occurring now and that is one of our major concerns), and if throttling valves are installed they should be selected carefully. You might refer to http://www.valmatic com/pdfs/Cavitation_in_Valves_7-22-08 pdf for a good treatise on valve cavitation As indicated there, manufacturers typically recommend that no throttling be done if the cavitation index is under 2 5 The cavitation index for pumps 2 to 6 would be above 5 if operated at peak efficiency Note that when operated at very low heads, with the discharge head set by the VFDs, the cavitation index falls <0	Gustavo Arboleda, WRE
2		3 3 2	3-5	Second sentence doesn't make sense The author most likely intends to state that Flowserve recommends operations within 20% of peak efficiency, but not 80% Within 20% is also consistent with Table 3-4	Melavic	Reclamation	We avoided saying "within 20% of peak efficiency" because that would imply that if peak efficiency was 80% then it would be acceptable to operate from 60% to 100% efficiency (or plus or minus 20 percentage points) But what we intend to convey is that the pumps should be operated at "no less than 80% of their peak efficiency, or "no less than 0 8 * Peak Efficiency " Therefore, if peak efficiency is 80%, then the pump should not be operated at less than 0 8 * 80% = 64% efficiency We will clarify wording in the report	Gustavo Arboleda, WRE
3		3 3 4	3 8	States that the pump will not operate at peak efficiency unless valve throttling is introduced. Throttling introduces a head loss and is energy inefficient because the pump will work against a higher head. The pump may run smoother by adjusting the system curve closer to the pump curve, but it is not more efficient from the perspective of energy efficiency Was impeller diameter considered?	Melavic	Reclamation	Absolutely right. We say so in the report You might note that the summary table (Table 6-5) has it in capital letters • Would NOT reduce power consumption but rather increase it Changing impellers was considered We discussed it with Brian Zewe during our most recent trip to the plant. It was concluded that changing impellers repeatedly would be impractical	Gustavo Arboleda, WRE
		Appendix C	all	Appendix C does not include the pump curve for the E-Pump which is fairly identical to Pump #6	Melavic	Reclamation	Pump curve data on Page C-13 of Appendix C does indicate that the data applies to both Pump #6 and the Emergency Pump The actual pump curves are presented in Appendix D and there is no curve for the emergency pump We will change the caption under the Pump #6 curve to indicate that it applies to the emergency pump as well	Gustavo Arboleda, WRE

Pump #6


P-6191
MFG.
TR
05533222
SIZE
T-R/30ALV
6.0FT
GPM
33,660
RPM
514
2-11-91



Motor #6

SUMTER Electric REWINDING COMPANY, INC.

"SERVING INDUSTRY SINCE 1923"

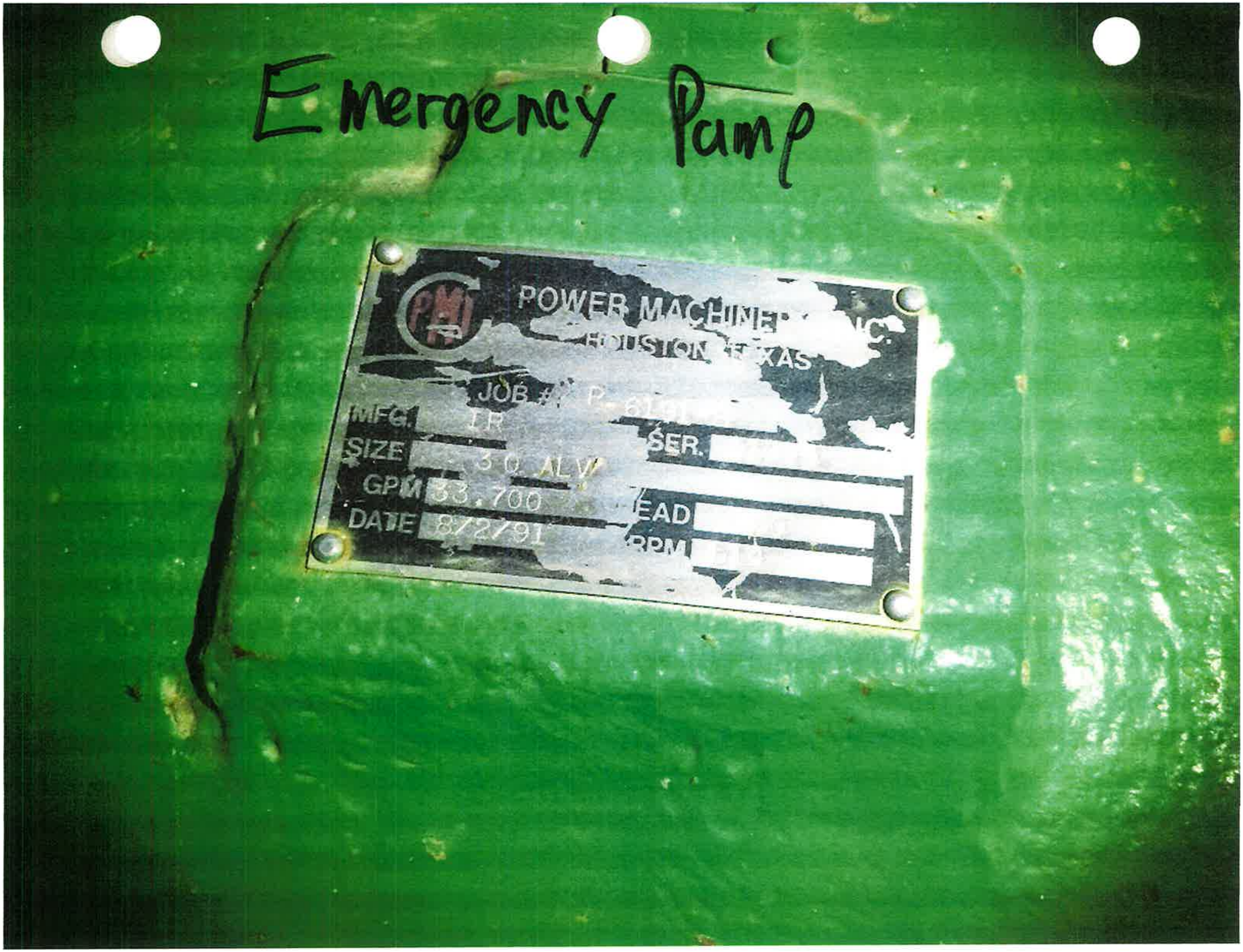
EASA

H.P.	600	**PHASE**	3	**WORK ORDER**	16169
R.P.M.	514	**HERTZ**	60	**TYPE**	TS
VOLTS	4160	**NEMA DESIGN**		**MODEL**	34G858
AMPS	66.1	**KVA CODE**		**STYLE**	
FRAME	984 Z	**SERVICE FACTOR**	1.15	**D.E. BRG.**	5 IN. SLV
MFG	GENERAL ELECTRIC			**O.D.E. BRG.**	4.5 IN. SLV
SER. NO.	8030172				

VOLTS-125 EX. AMPS-32.1

SUMTER, SOUTH CAROLINA 803-773-5591

Emergency Pump




Emergency
Motor

RECLAMATION
Managing Water in the West

PM Details Report

PM: 12260 - FOU EMERGENCY LOW LEVEL PUMP INSPECTION_PM

Parent:					
Asset:				**Interruptible?**	No
Location:	FO-PMPPLT-PMP-EMER, PUMPING PLANT, EMERGENCY PUMP			**Outage Required?**	No
Routes:					
Reference:	FIST Vol. 4-1A Sec. 2.11-15 thru 2.11-19				
Frequency:		**FIST Frequency:**		**Variance?**	No
Last Start Date:	5/28/15	**Estimated Next Due Date:**	5/28/16	**Last Completion Date:**	8/7/15
Lead Craft:	CC-MECH	**FBMS Work Order:**			
Work Type:	PM	**Sub Work Type:**	O&M	**Current Counter:**	8
Supervisor:	CASTRO, JESSE			**Priority:**	3
Lead Person:				**Crew:**	
Next Job Plan:	25192				
PM Master:					

Job Plan: 25192, FOU PUMPING PLANT LOW LEVEL PUMP INSPECTION - MINOR (O&M)

Op	Op Description	Task Duration
10	JHA/HECP	0:30

Energy Source Determination: ***WARNING*** CLEARANCE REQUIRED- 4160v pump disconnect (72 hr. notice required for outage request) Clearance Points: 1. 4160 VAC Disconnect Switch #2E01, (Ref. Drawing 485-218-1470) 2. Discharge Valve #31, Closed (Ref. Drawing 485-218-688 3. Suction Valve #30, Closed; (Ref. Drawing 485-218-688) Energy Source: Water pressure: pump suction Valve / discharge valve. Rotating Shaft: Motor/Pump Coupling Lockout: CLEARANCE- Required for pump/motor coupling maintenance Additional comments: ***CAUTION*** Execise Extreme CAUTION accessing the Low Level Pump Building- -Steps and Ladders may be wet and/or slippery -Grating Deck is HEADBANGER when using ladders past penstock *NOTIFY OPERATIONS UPON ARRIVAL AND DEPARTURE AT LOW LEVEL PUMP* -BEWARE of SNAKES or OTHER DANGEROUS WILDLIFE beneath penstocks - Watch for wasps during summer, bring spray Completed By ____________________ Reviewed By ____________________

Qty	Craft	Hours	Item #	Store-room	Qty	Service Item	Qty	Tool #	Qty	Tool Hours
1	CC-MECH	5	0		0		0		0	0

RECLAMATION
Managing Water in the West

Job Plan Details Report // **25192 - FOU PUMPING PLANT LOW LEVEL PUMP INSPECTION - MINOR (O&M)**

Status:	ACTIVE	**Interruptible?**	No	**Lead Craft:**	CC-MECH
Duration:	5.00			**Crew:**	
Planned By:				**Lead Person:**	

Job Plan Tasks

Sequence	Task ID	Description	Duration	Meter Name
	10	JHA/HECP	0.50	
		Energy Source Determination: ***WARNING*** CLEARANCE REQUIRED- 4160v pump disconnect (72 hr. notice required for outage request) Clearance Points: 1. 4160 VAC Disconnect Switch #2E01, (Ref. Drawing 485-218-1470) 2. Discharge Valve #31, Closed (Ref. Drawing 485-218-688 3. Suction Valve #30, Closed; (Ref. Drawing 485-218-688) Energy Source: Water pressure: pump suction Valve / discharge valve. Rotating Shaft: Motor/Pump Coupling Lockout: CLEARANCE- Required for pump/motor coupling maintenance Additional comments: ***CAUTION*** Execise Extreme CAUTION accessing the Low Level Pump Building- -Steps and Ladders may be wet and/or slippery -Grating Deck is HEADBANGER when using ladders past penstock *NOTIFY OPERATIONS UPON ARRIVAL AND DEPARTURE AT LOW LEVEL PUMP* -BEWARE of SNAKES or OTHER DANGEROUS WILDLIFE beneath penstocks - Watch for wasps during summer, bring spray Completed By ______________________________ Reviewed By ______________________________		

Sequence	Task ID	Description	Duration	Meter Name
	20	Drawings, Instructions and Tools	0.50	
		Drawings or Instructions: 485-D- 551 485M-208-1966-1969 485M-218-392L 485M-218-748-L 485-208-(853-855) 485-218-(1478-1480) 485-218-688 *****NOTICE***** LOW LEVEL PUMP COUPLING is METRIC Materials: Chevron Ultra-Duty "O" Grade Grease with small button head. (Pump Bearings and Couplings) Rags Lectra clean solvent		

Sequence	Task ID	Description	Duration	Meter Name
	30	Inspect/Clean/Lubricate	2.00	
		____1. Operational check of bearings before lubricating (SEE OP 40, 1, a.) ____2. Lubricate pump bearings (Chevron Ultra-Duty "O" Grade) COUPLING: ***WARNING*--Rotating Shaft--CLEARANCE REQUIRED ON PUMP ____1. Inspect coupling for general condition, and hardware security ____2. Lubricate pump and motor coupling (Chevron Ultra-Duty "O") (5/16" Allen wrench and 7/16" NF long neck zirk fitting) (Grease adapter is METRIC THREAD- 16mm x 1.5 lead) DRAIN LINES: ____1. Clean out all pump drain lines		

Sequence	Task ID	Description	Duration	Meter Name
	40	Inspect FOU Emergency Pipeline	3.00	

Job Plan Tasks

Sequence	Task ID	Description	Duration	Meter Name
		OPERATIONAL CHECK OF EQUIPMENT (Accomplish during pump ops test) ____1. Check Pump for Proper Operation ___a. Check pump bearings for noise / heat / vibration. Annotate any abnormalities ___b. Check pump /motor coupling for noise / vibration. Annotate any abnormalities ____2. Check pump packing for cooling water flow rate. ____3. 36" BFV (V30) and flex coupling ___ a. Operate valve open and closed ___ b. Inspect flex coupling for leakage and hardware security ____4. 36" Check Valve (V31) and flex coupling _ _ a. inspect and adjust flapper shaft packings ___ b. Inspect flex coupling for leakage and hardware security ____5. 36" Motor operated BFV (V32) ___a. Operate valve open and closed INSPECT AND SERVICE: VALVES, COUPLINGS, AND FLANGED CONNECTIONS ____1. 6" drain V51 ___ a. Operate valve open and closed ____2. 36" BFV (V29) and flex coupling ___ a. Operate valve open and closed ___ b. Inspect flex coupling for leakage and hardware security ____3. 36" BFV (V33) and flex coupling ___ a. Operate valve open and closed ___ b. Inspect flex coupling for leakage and hardware security ____4. 1" gate valve _ _ a. Operate valve V53 open and closed ___ b. Operate valve V54 open and closed ____5. Inspect reinforcement nozzle ____6. 24" manway at base of emergency standpipe ____7. 24" manway at top of emergency standpipe		

Work Assets

Location	Asset	Item	Descripton	Work Type
FO-PMPPLT-PMP-8			PUMPING PLANT, PUMP #8	
FO-PMPPLT-PMP-7			PUMPING PLANT, PUMP #7	
FO-PMPPLT-PMP-6			PUMPING PLANT, PUMP #6	
FO-PMPPLT-PMP-5			PUMPING PLANT, PUMP #5	
FO-PMPPLT-PMP-4			PUMPING PLANT, PUMP #4	
FO-PMPPLT-PMP-3			PUMPING PLANT, PUMP #3	
FO-PMPPLT-PMP-2			PUMPING PLANT, PUMP #2	
FO-PMPPLT-PMP-EMER			PUMPING PLANT, EMERGENCY PUMP	

Planned Labor

Task ID	Craft	Skill Level	Vendor	Contract	Labor	Qty	Hours	Rate	Line Cost
	CC-MECH					1	5.00	114.36	571.80
								Total Planned Labor Cost:	571.80

Grand Total for all Costs: **$571.80**

RECLAMATION
Managing Water in the West

PM Details Report

PM: 11881 - FOU PUMP E MOTOR INSPECTION _EL

Parent:					
Asset:				**Interruptible?**	No
Location:	FO-PMPPLT-PMP-EMER	PUMPING PLANT, EMERGENCY PUMP		**Outage Required?**	No
Routes:					
Reference:	FIST Vol. 3-4 Sec.2.2				
Frequency:		**FIST Frequency:**		**Variance?**	No
Last Start Date:	5/1/15	**Estimated Next Due Date:**	5/1/16	**Last Completion Date:**	10/8/15
Lead Craft:	CC-ELECT	**FBMS Work Order:**			
Work Type:	PM	**Sub Work Type:**	O&M	**Current Counter:**	8
Supervisor:	SEMONEIT, KARL			**Priority:**	3
Lead Person:				**Crew:**	
Next Job Plan:	15647				
PM Master:					

Job Plan: 15647, FOU - PUMPING PLANT PUMP EMERGENCY MOTOR INSPECTION - MINOR (O&M)

Op	Op Description	Task Duration
10	JHA/HECP	0:00

Energy Source Determination
Electrical Energy / Lockout Points:
4160 VAC Fused Contactor Disconnect Switch #2E01, Racked Out And Removed From PCCE Cabinet, Locked Out Under Clearance;
208 VAC Motor Heaters / Panel Le Brkr. #8/10;
208 VAC/ V32 Discharge Valve / Panel LE Brkr. #2/4/6;
120 VAC Control Power And Cabinet Heaters;
120 VAC Test Power / Panel CPC Brkr. #1;
24 VDC Remote Control Power/ Panel 1 Rear, Fuse DB7;
64 VDC Alarm Power / Switch In PCCE Cabinet, Left Side;

Hydraulic Energy:
Water: V32 Discharge Valve, Locked Out Under Clearance;
Water: V30 Suction Valve, Locked Out Under Clearance;

Clearance Points:
1. Locking Device Placed In Position To Block High Voltage Shutters In Closed Position, PCCE Cabinet;
2. V32 Discharge Valve Disconnect Switch / Ervcs Panel;
3. V32 Discharge Valve Manual Valve Operator;
4. V30 Suction Valve (Optional);

Qty	Craft	Hours	Item #	Store-room	Qty	Service Item	Qty	Tool #	Qty	Tool Hours
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0

Job Plan: 15647, FOU - PUMPING PLANT PUMP EMERGENCY MOTOR INSPECTION - MINOR (O&M)

Op	Op Description	Task Duration
10	JHA/HECP	0:00

Energy Source Determination
Electrical Energy / Lockout Points:
4160 VAC Fused Contactor Disconnect Switch #2E01, Racked Out And Removed From PCCE Cabinet, Locked Out Under Clearance;
208 VAC Motor Heaters / Panel Le Brkr. #8/10;
208 VAC/ V32 Discharge Valve / Panel LE Brkr. #2/4/6;
120 VAC Control Power And Cabinet Heaters;
120 VAC Test Power / Panel CPC Brkr. #1;
24 VDC Remote Control Power/ Panel 1 Rear, Fuse DB7;
64 VDC Alarm Power / Switch In PCCE Cabinet, Left Side;

Hydraulic Energy:
Water: V32 Discharge Valve, Locked Out Under Clearance;
Water: V30 Suction Valve, Locked Out Under Clearance;

Clearance Points:
1. Locking Device Placed In Position To Block High Voltage Shutters In Closed Position, PCCE Cabinet;
2. V32 Discharge Valve Disconnect Switch / Ervcs Panel;
3. V32 Discharge Valve Manual Valve Operator;
4. V30 Suction Valve (Optional);

Qty	Craft	Hours	Item #	Store-room	Qty	Service Item	Qty	Tool #	Qty	Tool Hours
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0
1	CC-ELECT	2	0		0		0		0	0

RECLAMATION
Managing Water in the West

Job Plan Details Report // 15647 - FOU - PUMPING PLANT PUMP EMERGENCY MOTOR INSPECTION - MINOR (O&M)

Status:	ACTIVE	**Interruptible?**	No	**Lead Craft:**	CC-ELECT
Duration:	2.00			**Crew:**	
Planned By:				**Lead Person:**	

Job Plan Tasks

Sequence	Task ID	Description	Duration	Meter Name
	10	JHA/HECP	0.00	

Energy Source Determination
Electrical Energy Lockout Points:
4160 VAC Fused Contactor Disconnect Switch #2E01, Racked Out And Removed From PCCE Cabinet, Locked Out Under Clearance;
208 VAC Motor Heaters / Panel Le Brkr. #8/10;
208 VAC/ V32 Discharge Valve / Panel LE Brkr. #2/4/6;
120 VAC Control Power And Cabinet Heaters;
120 VAC Test Power / Panel CPC Brkr. #1;
24 VDC Remote Control Power/ Panel 1 Rear, Fuse DB7;
64 VDC Alarm Power / Switch In PCCE Cabinet, Left Side;

Hydraulic Energy
Water: V32 Discharge Valve, Locked Out Under Clearance;
Water: V30 Suction Valve Locked Out Under Clearance;

Clearance Points:
1. Locking Device Placed In Position To Block High Voltage Shutters In Closed Position, PCCE Cabinet;
2. V32 Discharge Valve Disconnect Switch / Ervcs Panel;
3. V32 Discharge Valve Manual Valve Operator;
4. V30 Suction Valve (Optional);

Sequence	Task ID	Description	Duration	Meter Name
	20	Drawings, Instructions & Tools	0.00	

Job Plan Tasks

Sequence	Task ID	Description	Duration	Meter Name
		Single line: 485-218-1470 Schematics: 485-218-1296; Wiring: 485-D-1867, 1868 485-218-1557 485-218-1466 Piping: 485-218-688 Manual: GEH-3102D Spare Parts: Motor Contactor Coil; Item No.: 1D300G102 Catalog Title: Coil, Motor Contactor Closing Location: 22A07D01 Field Contactor Coil; Catalog Title: Coil, Electrical, GE 15D22G2 Location: Vidmar Cabinet In VFD Room; Item No.: W5950008957483 Also At Nim. Location: 55A04B01 Bearing Oil: Catalog Title: Chevron GST ISO 46 OIL Location: Oil Shed Item No.: GSTISO46 Carbon Brushes, Slip Ring (4): Catalog Title: Brush, Carbon, For Pump 6 And E Slip Rings Item No.: 1010517260201 Location: 15C01B01;		

Sequence	Task ID	Description	Duration	Meter Name
	30	Inspect Slip Rings and Brushes	0.00	

Job Plan Tasks

Sequence	Task ID	Description	Duration	Meter Name

INSPECT SLIP RING AND BRUSHES

_____ 1. Check condition of the slip ring for grooving and excessive wear. Clean, polish or resurface as needed.
_____ 2. Inspect the brushes for wear, freedom of movement, and for proper spring tension. Replace as necessary.
_____ 3. Inspect the brush pigtail connection for tightness and any damage
_____ 4. Inspect the slip ring area for signs of excess carbon, clean as needed.
_____ 5. Inspect for the presence of oil on the slip ring or brushes.
_____ 6. Check motor bearing oil level.

Sequence	Task ID	Description	Duration	Meter Name
	40	Inspect Motor Bearings and Heaters	0.00	

_____ 1. Check outboard bearing oil level.
_____ 2. Check inboard bearing oil level.
_____ 3. Verify motor heaters are hot while motor is shut down
_____ 4. Run motor and check bearing noise
_____ 5. Log current run hour meter reading ___________ HRS.

Sequence	Task ID	Description	Duration	Meter Name
	50	Megger HV Cables Motor Windings	0.00	

MEGGER HV CABLE AND MOTOR WINDINGS @ 5000 V
PERFORM 10 MIN. TEST FOR P. I.
_____ 1. Record and download megger readings. TEST #______
_____ 2. Final megger reading: __________ ____OHMS

Work Assets

Location	Asset	Item	Descripton	Work Type
	13048		PUMP #5 MOTOR	
	13067		PUMP #6 MOTOR	
	13039		PUMP #4 MOTOR	
	13030		PUMP #3 MOTOR	
	13096		EMERGENCY PUMP MOTOR	
	13021		PUMP #2 MOTOR	

Planned Labor

Task ID	Craft	Skill Level	Vendor	Contract	Labor	Qty	Hours	Rate	Line Cost
	CC-ELECT					1	2.00	116.42	232.84
								Total Planned Labor Cost:	232.84

Grand Total for all Costs: **$232.84**

—Obsolete—

DESIGNER'S OPERATING CRITERIA

AND STANDING OPERATING PROCEDURE

FOLSOM DAM EMERGENCY PUMPING PLANT

FOLSOM DAM
AMERICAN RIVER DIVISION
CENTRAL VALLEY PROJECT
CALIFORNIA

CONTENTS

Page

CHAPTER III REFERENCE MATERIAL

FOREWORD

Of primary concern to the Bureau of Reclamation is the safety of the general public and of the operating and maintenance personnel. Careful consideration also should be given to the conservation and protection of the Bureau of Reclamation's facilities. Therefore, safety, conservation, and protection should be the theme of the operating instructions.

The Reclamation Safety and Health Standards, Design Standards No. 1, Chapter 3, and OSHA Safety and Health Standards (29CFR 1910) are standards for safety. Please READ them and FOLLOW their instructions and recommendations.

The Avoidance of Accidents
is an Essential Requirement
of Every Operation.

DO NOT TAKE CHANCES

DESIGNERS' OPERATING CRITERIA
AND STANDING OPERATING PROCEDURE
FOLSOM DAM EMERGENCY PUMPING PLANT

FOLSOM DAM
AMERICAN RIVER DIVISION
CENTRAL VALLEY PROJECT
CALIFORNIA

CHAPTER I GENERAL

A. Location.

Folsom Dam and its appurtenant facilities are located approximately 2 miles north of Folsom in Sacramento County, California. The dam and its facilities are on the American River about 2 miles upstream of Folsom, California, as shown on the Location Map, Drawing No. 1 (485-208-949).

B. Purpose.

These operating criteria are confined to the operation of the emergency pumping plant. Folsom Dam was constructed by the Army Corps of Engineers for flood control and power generation as authorized by the American River Basin Development Act of 1949. The Folsom Powerplant was constructed by the Bureau of Reclamation for power generation. The Folsom Dam Pumping Plant (pumping plant) was constructed by the Army Corps of Engineers for irrigation uses on both sides of the American River and a water supply for Folsom Prison. Later, project water was delivered for domestic, municipal, and industrial uses for the city of Folsom, San Juan Suburban Water District, and the city of Roseville.

The Folsom Dam Emergency Pumping Plant (emergency pumping plant) was constructed to provide water to the cities of Roseville and Folsom, San Juan Suburban Water District, and Folsom Prison during drought years when Folsom Reservoir levels do not allow the delivery of water from the reservoir by gravity through the existing 84-inch pipeline to the pumping plant or by use of the primary pumping plant for water deliveries down to approximately 330 foot reservoir elevation.

CHAPTER II EMERGENCY PUMPING PLANT

A. Prefabricated Metal Building

1. Purpose - The purpose of the metal building is to protect the pumping unit from the elements while the pumping unit is installed in the emergency pumping plant at the toe of Folsom Dam. The pumping unit is not weatherproof.

2. Description - The building is a prefabricated rigid frame metal building manufactured by "United Structures of America, Inc." of Houston, Texas. The building was designed for 20 lb/ft^2 live roof load and 80 mph wind load in accordance with the Uniform Building Code. The building was furnished with the manufacturer's standard paint system, one access door and wall vents as specified.

3. Operation - The roof is equipped with four lifting lugs, one near each corner of the roof. The hole diameter in each lifting lug is 2 inches. When the pumping unit is to be moved in or out of the building, the roof rafters are to be unbolted from the columns and the roof lifted as a single unit, using all four lifting eyes concurrently. There are four bolted rafter-column connections, each consisting of six 1/2-inch diameter by 1-1/4-inch long ASTM Designation: A325 high-strength bolts.

When the roof is placed back on top of the building after being removed, the 24 attachment bolts shall be reinstalled and tightened in accordance with the instructions of the building manufacturer.

4. Maintenance - All metalwork should be inspected, cleaned, and repainted as necessary.

B. Emergency Pumping Plant.

1. Purpose - The emergency pumping plant conveys water from Penstock No. 1 to the 84-inch pipeline which feeds the pumping plant.

2. Description - The emergency pumping plant consists of a pumping unit, 36-inch diameter pipeline, and a 48-inch diameter standpipe. The pumping unit is Unit No. 7 of the pumping plant relocated within the emergency pumping plant. The pumping unit is shown on Drawing Nos. 485-208-846, 847, 848, and 853. The pipeline is a 36-inch-diameter steel pipe extending from Penstock No. 1 to the existing 84-inch-diameter pipeline and the new 48-inch-diameter standpipe. The top of the standpipe is at elevation 447.25. Manual 36-inch butterfly valves are located on each end of the pipeline to isolate the 36-inch pipeline from Penstock No. 1 and the 84-inch pipeline when the emergency pumping plant is not in use. There is a 36-inch swing check valve in the 36-inch pipeline and a 6-inch drainline downstream of the pumping unit. An electric motor-operated butterfly valve is located on the 36-inch pipeline downstream of the swing check valve. The pipeline is shown on Drawing Nos. 485-208-846, -853, -854 and -855.

3. Operation - The emergency pumping plant shall not be operated with the reservoir elevation above 330.00 or below 307.00. The initial design criteria were for operation of the emergency pumping plant between Elevation 340.00 and 325.00. The lower limit may be adjusted to as low as Elevation 307.00 depending on actual field conditions. The upper limit should be adjusted to Elevation 330.00 unless field conditions do not allow delivery through the existing system at this low an elevation. Unit No. 7 of the pumping plant shall be relocated to the emergency pumping plant. The pipe jig in the emergency pumping plant shall be removed to allow the installation of the pumping unit. All electrical and control connections shall be made as described in Section II.C.2. The butterfly valves shall be opened to allow water to fill the pipeline when the pumping unit is in the operating position. The butterfly valve at the Penstock No. 1 tap and the motor operated butterfly valve shall be opened to equalize the water level in the pipeline and standpipe with the reservoir water level. After the water level has equalized, open the 84-inch pipeline tap manual butterfly valve and close the motor operated butterfly valve. The pumping unit can be energized. After the pumping unit has reached full speed, the butterfly valve near the swing check valve will open automatically. The gate valve in the 84-inch pipeline upstream of the 36-inch pipeline connection then shall be closed.

After the reservoir has risen to El. 330.00 and the emergency pump is no longer needed, the gate valve in the 84-inch pipeline shall be opened and the pump shall be deenergized. The manual butterfly valves shall be closed and the motor operated butterfly valve opened. The 6-inch drainline shall be opened to drain the pipeline. After the pipeline is drained, the 6-inch gate valve and the motor-operated butterfly valve shall remain open to drain possible valve leakage. The pumping unit shall be removed from the emergency pumping plant and reinstalled within the pumping plant. All electrical and control connections shall be made. The pipe jig shall be reinstalled in the emergency pumping plant.

4. Maintenance - The pipeline shall be inspected for leakage when the pipe is filled with water. The valves shall be checked and operated annually. When the valves are operated, the reservoir elevation shall not be above 440.00. After the butterfly valves have been operated, the pipeline shall be drained. All maintenance of the valves shall be as recommended by the particular valve manufacturer. Every five years the tell tale ports at the taps for the manual butterfly valves at Penstock No. 1 and the 84-inch pipeline shall be checked for seepage.

C. Electrical System

1. Purpose - The purpose of the electrical system is to provide control of and electrical power for the pumping unit in the emergency pumping plant.

2. Description - The electrical system consists of one motor-pump unit, one motor-operated butterfly valve, one butterfly valve remote control panel, one sectionalizing switch, lighting panelboard, light fixtures, outlet receptacles and wiring, conduit and grounding systems.

The motor for the Emergency Pumping Plant pumping unit is an existing motor from Unit 7 of the pumping plant.

PUMPING PLANT

A 5kV, 200-amp, 3-phase, SF6 puffer-type switch, designated switch No. 1703 (UPB), is installed at Unit 7 in the pumping plant. The switch is to provide power to either Unit 7 in the pumping plant or the unit in the emergency pumping plant. New wires and conduits have been installed between this switch and the unit in the emergency pumping plant.

The existing excitation/control circuits for Unit 7 in the pumping plant will be connected to either Unit 7 in the pumping plant or the pumping unit in the emergency pumping plant. A new terminal strip at Unit 7 and new wires and conduit between the terminal strip and the pumping unit in the emergency pumping plant has been installed.

"A selector switch, designated "SS5", controls which valve (NORMAL or EMERGENCY) and valve controls are actuated, and controls whether the emergency standpipe level protection is activated through the PLC (Programmable Logic Controller) for pump shutdown. The switch is located within the No. 7 motor control cabinet.

MOTOR OPERATED BUTTERFLY VALVE

The butterfly valve with electric motor operator is installed in the 36-inch discharge line downstream of the swing check valve. The operator, designated "E-VCS", includes an electric motor, reduction gears, limit switch mechanism, torque limit switch mechanism, handwheel with declutching mechanism, position indicator, and reversing motor starter with motor overload relays, and a "LOCAL-REMOTE" selector switch, which must remain in the REMOTE position for automatic control.

EMERGENCY PIPELINE STANDPIPE

The 36-inch diameter pipeline is equipped with a standpipe. The standpipe has a pressure transducer connected to the PLC. The PLC is currently programmed to shut down the emergency pumping unit if the water level in the standpipe goes above Elevation 440.00 or below Elevation 325.00.

EMERGENCY PUMPING PLANT

The butterfly valve remote control panel, designated "E-RVCS", includes a disconnect switch, "AUTO-OFF-HAND" selector switch, "OPEN," "STOP," and "CLOSE" pushbuttons, indicator lamps, and an "EMERGENCY STOP" pushbutton which will shut down all running pumps when the SS5 switch is in the EMERGENCY position. The panel is installed within the emergency pumping plant."

A 120/208-volt, 100-amp, 3-phase, 4-wire panelboard with a 50-amp main breaker, designated panel "LE", is installed inside the emergency pumping plant, which provides power to the motor-operated butterfly valve and the motor space heaters. Supply for this panelboard comes from the pumping plant 120/208-volt AC distribution panel. Four 80-watt fluorescent light fixtures are installed inside the building. One 50-watt high pressure sodium light fixture, with a 120-volt high power factor ballast, controlled by a photocell is installed on the wall above the entrance door.

3. Operation - The Unit 7 motor and pump shall be removed from the pumping plant and installed on the pump frame in the emergency pumping plant. Electrical conductors shall be connected to the motor. The excitation/control circuits shall be disconnected from Unit 7 in the pumping plant and connected to the pumping unit in the emergency pumping plant. The sectionalizing switch shall be switched such that electrical power will be conducted to the pumping unit in the emergency pumping plant.

4. Maintenance - Maintenance of the electrical equipment shall be as recommended by the manufacturers of the equipment.

D. Sequence Of Operation

Note: See drawing 485-218-688 for valve designations.

1. Start Sequence

a. Remove the weather proofing from valve no. 31 (36-inch swing check valve located downstream of the emergency pump discharge). Ensure that the counter weights will clear the valve body, the cushion chamber small check valve and orifice on the bottom of the chamber are clear, the inside of the cylinder is lubricated with light oil, and that the valve mechanism is free to operate.

b. Close the 6-inch drain valve located downstream of the 36-inch swing check valve.

c. Open valve no. 32 (36-inch motor operated butterfly valve).

d. Open valve no. 30 (36-inch manual butterfly valve at FU-1 penstock tap).

e. The water level in the system will equalize with the reservoir level. Examine the system visually for leaks or movement.

f. Open valve no. 29 (36-inch manual butterfly valve located in the valve pit where the 36-inch emergency pump pipeline connects to the 84-inch pipeline).

g. After the emergency pump pipeline is watered up, close valve no. 32, verify the motor operated butterfly valve local selector is in the REMOTE position, and the E-RVCS valve control panel is in the AUTO position.

h. Verify that the emergency pump standpipe water level gage reads properly.

i. Verify disconnect 1703 (pump no. 7 motor feeder disconnect adjacent to the normal motor location) and switch SS5 (valve control switch in the pump no. 7 motor starter cabinet) are in the EMERGENCY pump position.

j. Close pump no. 7 motor starter disconnect 1701 and bump start pump and check that motor rotation is proper.

k. Start and operate the emergency pump and verify that valve no. 32 has opened.

l. Close valve no. 9 (60-inch gate valve at the 84-inch outlet from Folsom Dam).

2. Stop Sequence

a. Open valve no. 9.

b. If the system is to be shut down for a short time, the only requirement is to stop the pump. If the system is to be secured for the season or longer, continue with the following steps.

c. Close valve no. 29.

d. Close valve no. 30.

e. Open valve no. 32.

f. Open the 6-inch drain valve located downstream of valve no. 31.

g. After the system is drained the 6-inch drain valve and valve no. 32 shall remain open to drain possible valve leakage.

h. Clean, lubricate, and weather proof valve no. 31 (36-inch swing check valve).

3. Test Operation With The Reservoir Water Level Above 330.00 And Below 440.00

Same as Start Sequence above except keep valve no. 9 open (step 1).

CHAPTER III REFERENCE MATERIAL

A. Bureau of Reclamation Specifications

The following specifications are available for reference purposes in the Regional and Project Offices:

Number	Title
20-C0338	Emergency Pumping Plant - Phase I Folsom Dam Pumping Plant, American River Division, Central Valley Project, California
20-C0404	Emergency Pumping Plant - Phase III Folsom Dam Pumping Plant, American River Division, Central Valley Project, California

B. Bureau of Reclamation Publications

Paint Manual, Third Edition, 1976

Reclamation Safety and Health Standards

Design Standards No. 1, Chapter 3

OSHA Safety and Health Standards (29 CFR 1910), revised January 1976

Irrigation O&M Bulletin No. 60, "Pumping Plant Maintenance Schedules and Records," Revised 1970.

C. Manufacturers' Data

"DeZurik Installation, Operation & Maintenance Manual," DeZurik, A Unit of General Signal, Sartell, Minnesota.

"Operation Instructions," GA Industries Inc., Mars, Pennsylvania.

"Operating and Maintenance Manual," Joslyn Power Products Corporation, Alsip, Illinois.

D. Bureau of Reclamation Drawings

Latest revised prints of all Bureau of Reclamation drawings mentioned in the text have been included as part of these criteria.

NO. DRAWING NO. TITLE

GENERAL

1.
(a)485-208-949-- Location Map
(b)485-208-744-- Right Abutment Surface Treatment--Plan, Section and Detail (location map only)

PUMPING PLANT

2.
(a)485-208-846 -- General Plan and Installation
(b)485-208-847 -- Grading Plan
(c)485-208-848 -- Tap Thrust Block and Pump Slab
(d)485-208-849 -- Tap Valve Access Stairway
(e)485-208-853 -- Pumping Unit Installation

PIPELINE

3.
(a)485-208-1147 -- General Plan and Tap Installation
(b)485-208-1148 -- Penstock Tap Installation
(c)485-208-1149 -- 84-Inch Pipe Tap Installation
(d)485-208-850 -- Pipe Anchorage Details
(e)485-208-854 -- 36-Inch Pipe Installation in Valve Vault

STANDPIPE

4.
(a)485-208-851 -- Standpipe Support Details
(b)485-208-855 -- Standpipe

ELECTRICAL

5.
(a)485-208-852 -- Electrical Installation

REFERENCE

6.
(a)485-D-65 -- Steel Penstocks--Plan and Profiles
(b)485-D-1293 -- Main Concrete Dam--Plan
(c)485-D-1294 -- Main Concrete Dam--Elevations
(d)485-D-1295 -- Main Concrete Dam--Typical Sections
(e)485-D-1324 -- Natoma Pressure Pipe Line--Plan, Profile and Details
(f)485-D-1415 -- Pumping Plant--Plan, Elevations and Details
(g)485-D-1416 -- Pumping Plant--Reinforcement Details
(h)485-D-1417 -- Pumping Plant--Equipment Arrangement
(i)485-D-1420 -- Pumping Plant--Power Conduit Plan

(j)485-D-1551 -- Pumping Plant Equipment--Mechanical--Pump Installation
(k)485-D-1552 -- Pumping Plant Equipment--Electrical Installation --Power Single Line Diagram
(l)485-D-1553 -- Pumping Plant Equipment--Electrical--Switchboard & Power Panel--Sheet 1
(m)485-D-1553 -- Pumping Plant Equipment--Electrical--Switchboard & Power Panel--Sheet 2
(n)485-D-1866 -- Folsom Pumping Plant--Electrical Installation--Pump and Valve Controls--Schematic Diagram
(o)485-D-1868 -- Folsom Pumping Plant--Electrical Installation--Electrical Power Panel
(p)485-D-2061 -- Folsom Pumping Plant--Bristol Recorder and Control Circuits--Schematic and Wiring Diagram
(q)485-208-562 -- Penstock Access--Stairway and Walkway--General Plan and Elevations
(r) 485-218-688 -- Folsom Pumping Plant -- Water Distribution -- Flow Diagram

STANDARD DRAWINGS

7.

(a)40-D-5913 -- Valve Support
(b)40-D-6003 -- 18" Steel Ladder
(c)40-D-6022 -- 42" Two Rail Handrail--Details
(d)40-D-6248 -- Flange Support
(e)104-D-254 -- Equipment Enclosures
(f)104-D-286 -- Metal Conduit Bends

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Work Order: 3815978

3815978

CC (CENTRAL CALIFORNIA AREA OFFICE)

WO Description: FOU EMERGENCY PUMP MOTOR WINDING TEMP PROTECTION

Long Description: This work order is created to engineer pump motor winding over-temperature protection for Emergency Pump.

Location:	FO-PMPPLT-PMP-EMER (PUMPING PLANT, EMERGENCY PUMP)			**WO Priority:**	3
Asset:	-			**Asset Priority:**	4
FBMS Work Order:	R2358630	**Crew:**		**Calc Priority:**	7
WBS Element:	RX.03538841.3220000	**Reported Date:**	10/28/2015	**Work Type:**	MOD
Fund:	15XR0680A4	**Target Start:**	10/27/2015	**Sub Work Type:**	NONE
Reported By:	BRIZUELA, LEONARDO	**Target Finish:**		**Status:**	APPR
On Behalf Of:		**Scheduled Start:**		**Outage Required?:**	N
Supervisor:	LAWSON, DAVID	**Scheduled Finish:**		**PM:**	
Lead:	LY, HUE	**Actual Start:**	10/27/2015	**PM Compliance Range:**	
Lead Craft:	CC-EENG	**Actual Finish**			
Reference:	-				
Classification:	-				

Child Work Orders

No Child Work Orders

Safety Plan Information

No Safety Plan

Job Plan

No Job Plan

Tasks

Task ID	Description	Completed?
10	ESTIMATE JOB HAZARDS AND DEVELOPE JHA	☐
20	ENGINEER WIRING SCHEMATICS	☐
30	PROCURE MATERIALS	☐
40	INSTALL WIRING	☐
50	PROGRAM, TEST, AND COMMISSION OVER TEMP RELAY	☐
60	COMPLETE WORK ORDER, UPDATE FILE PRINTS	☐

Labor

Task	Craft	Labor	Qty	Hours
	CC-C&I		2.00	0.00
	CC-CCOPER		1.00	0.00
	CC-EENG		1.00	0.00
	CC-ELECT		2.00	0.00

Materials

No Material Records

Tools

No Tool Records

Work Log

No Work Log Records

Remarks

Lead Signature: ____________________ **Date:** ____________________

Lead Print Name: ____________________

Supervisor Signature: ____________________ **Date:** ____________________

Supervisor Print Name: ____________________

Total Time Charged: ____________________

Work Order: 2844691

2844691

CC (CENTRAL CALIFORNIA AREA OFFICE)

WO Description: FOU DROUGHT TEMPORARY PUMP STATION

Long Description: This WO is for all work associated with a temporary pump station that will be floated in the lake and connected to our current raw water system to feed the water customers.

Location:	FO-PMPPLT (PUMPING PLANT)			**WO Priority:**	3
Asset:	-			**Asset Priority:**	4
FBMS Work Order:	R3786519	**Crew:**		**Calc Priority:**	7
WBS Element:	RX.03538842.3221000	**Reported Date:**	01/23/2014	**Work Type:**	MOD
Fund:	16XR0680A4	**Target Start:**		**Sub Work Type:**	NONE
Reported By:	CASTRO, JESSE	**Target Finish:**		**Status:**	APPR
On Behalf Of:		**Scheduled Start:**		**Outage Required?:**	N
Supervisor:	KINSEY. ANDERS	**Scheduled Finish:**		**PM:**	
Lead:	SANTANA, JOSE	**Actual Start:**	10/30/2015	**PM Compliance Range:**	
Lead Craft:		**Actual Finish**			
Reference:	-				
Classification:	-				

Child Work Orders

No Child Work Orders

Safety Plan Information

No Safety Plan

Job Plan

No Job Plan

Tasks

No Planned Tasks

Labor

No Labor Records

Materials

No Material Records

Tools

No Tool Records

Work Log

No Work Log Records

Remarks

Work Order: 2844691

CC (CENTRAL CALIFORNIA AREA OFFICE)

2844691

Lead Signature: ____________ **Date:** ____________

Lead Print Name: ____________

Supervisor Signature: ____________ **Date:** ____________

Supervisor Print Name: ____________

Total Time Charged: ____________

Work Order: 3718893

3718893

CC (CENTRAL CALIFORNIA AREA OFFICE)

WO Description: FOU AUXILIARY PUMPING SYSTEM

Long Description:

The purpose of this project [Auxiliary Pumping System (APS)] is to provide a target total flow of 80 cfs split between Folsom Prison, City of Folsom, San Juan Water District and the City of Roseville under drought/low lake elevations. This is planned as a permanently installed project. The project is phased as follows:

Phase I	Initiation
Phase II	Planning
Phase III	Design and Development
Phase IV	Procurement
Phase V	Execution
Phase VI	Closeout

The project needs to be operational by 5/2/2016, and closeout by 9/30/2016.

Location:	FO-PMPPLT (PUMPING PLANT)			**WO Priority:**	3
Asset:	-			**Asset Priority:**	4
FBMS Work Order:	R3786519	**Crew:**		**Calc Priority:**	7
WBS Element:	RX.03538842.3221000	**Reported Date:**	08/24/2015	**Work Type:**	ENG
Fund:	16XR0680A4	**Target Start:**	07/31/2015	**Sub Work Type:**	MAJ MOD
Reported By:	ZEWE, BRIAN	**Target Finish:**	09/30/2016	**Status:**	APPR
On Behalf Of:		**Scheduled Start:**		**Outage Required?:**	N
Supervisor:	KINSEY, ANDERS	**Scheduled Finish:**		**PM:**	
Lead:	ZEWE, BRIAN	**Actual Start:**	07/31/2015	**PM Compliance Range:**	
Lead Craft:		**Actual Finish**			
Reference:	-				
Classification:	-				

Child Work Orders

No Child Work Orders

Safety Plan Information

No Safety Plan

Job Plan

No Job Plan

Tasks

No Planned Tasks

Labor

No Labor Records

Materials

No Material Records

Tools

No Tool Records

Work Log

No Work Log Records

Remarks

Lead Signature: ____________________ **Date:** ____________________

Lead Print Name: ____________________

Supervisor Signature: ____________________ **Date:** ____________________

Supervisor Print Name: ____________________

Total Time Charged: ____________________