BUREAU OF RECLAMATION

Feasibility Report
Appendix C – Engineering Designs and Costs

Los Vaqueros Reservoir Expansion Investigation
Final Feasibility Report

U.S. Department of the Interior

February 2020

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Feasibility Report
Appendix C – Engineering Designs and Costs

Los Vaqueros Reservoir Expansion Investigation, California
Interior Region 10 • California-Great Basin

prepared for Reclamation by Stantec under Contract No. R12PC20255, GS-00F-0040L

Cover Photo: A full Los Vaqueros Reservoir in the spring (Contra Costa Water District)

Contents

Page

Figures

Tables

Attachments

Attachment 1 – Geotechnical and Seismic Evaluations (Conveyance Facilities)

- Attachment 1A – Geotechnical and Seismic Evaluations TM (March 2007)
- Attachment 1B – Geotechnical Considerations Addendum (October 2015)

Abbreviations and Acronyms

ºC	degrees Celsius
°F	degrees Fahrenheit
2012 IBC	2012 International Building Code
AC	alternating current
ADA	American's with Disabilities Act
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWG	American Wire Gage
AWWA	American Water Works Association
BAWSCA	Bay Area Water Supply and Conservation Agency
Bay Area	San Francisco Bay Area
BBID	Byron-Bethany Irrigation District
CALFED	CALFED Bay-Delta Program
CARV	combination air release and air/vacuum valve
CBC	California Building Code
CCWD	Contra Costa Water District
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CLSM	controlled low-strength material
CPU	central processing unit
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DC	direct current
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
ECCID	East Contra Costa Irrigation District
ECCID Intertie	East Contra Costa Irrigation District's existing Bixler Intake
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EL	elevation
ETPS	Expanded Transfer Pump Station
FS	factor of safety
ft/sec	feet per second
GFCI	ground-fault circuit interrupter
HGL	hydraulic grade line
HI	Hydraulic Institute
HMI	human machine interface

hp	horsepower
I&C	Instrumentation and Control
I/O	input/output
IEEE	Institute of Electrical and Electronics Engineers
Investigation	Los Vaqueros Reservoir Expansion Investigation
ISA	The Instrumentation, Systems, and Automation Society
kPa	kiloPascal
ksi	kips per square inch
kV	kilovolt
kVA	thousand volt amps
LED	light-emitting diode
LiDAR	Light Detection and Ranging
Local Agency Partners	Prospective Bay Area partner water agencies include CCWD; Alameda County Water District; Alameda County Flood Control and Water Conservation District, Zone 7; BAWSCA; BBID; City of Brentwood; Del Puerto Water District; EBMUD; ECCID; San Francisco Public Utilities Commission; San Luis Water District; San Luis & Delta-Mendota Water Authority; Santa Clara Valley Water District; and Westlands Water District.
LOR	Local/Off/Remote
mA	milliamp
MCC	Motor Control Center
MG	million gallons
MG1	Motors and Generators - 1
mm	millimeter
msl	mean sea level
MV	medium voltage
MVA	thousand volt amps
NAD 27	North American Datum 1927
NEC	National Electrical Code
NECA	National Electrical Contractor Association
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NOD	North of Delta
OCPD	Overcurrent Protection Device
OIU	Operator Interface Unit
OM&R	operations, maintenance, and replacement
OPCC	opinion of probable construction cost
P&ID	Piping and Instrumentation Diagrams
PG&E	Pacific Gas and Electric Company
PID	Proportional-Integral-Derivative
PLC	programmable logic controller

psf	pounds per square foot
psi	pounds per square inch
PVC	polyvinyl chloride
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
Refuges	SOD CVPIA-designated wildlife refuges
RT	radiographic test
RVSS	reduced-voltage-solid-state
SCADA	Supervisory Control and Data Acquisition
SOD	South of Delta
TAF	thousand acre-feet
TBD	to be determined
TCC	Time Current Coordination
TCE	temporary construction easement
TCP/IP	Transmission Control Protocol/Internet Protocol
TDH	Total Dynamic Head
TM	Technical Memorandum
UL	Underwriters Laboratories
UPS	uninterruptable power supplies
USACE	U.S. Army Corps of Engineers
V	volt
VFD	variable frequency drive
WAN	Wide Area Network
WAPA	Western Area Power Administration
WSEL	water surface elevation
XHHW	cross-linked high heat water resistant insulated wire

This page left blank intentionally.

Chapter 1 Introduction

This technical appendix to the Feasibility Report for the Los Vaqueros Reservoir Expansion Investigation (Investigation) documents the engineering and cost estimate analyses to support federal plan formulation and evaluation. The Investigation is a feasibility study evaluating alternatives to develop environmental water supplies and improve the reliability and quality of San Francisco Bay Area (Bay Area) water supplies, primarily through the expansion of Los Vaqueros Reservoir in Contra Costa County, California.

Background

Los Vaqueros Reservoir is located in the coastal foothills west of the Sacramento-San Joaquin Delta (Delta) in the eastern Bay Area. Contra Costa Water District (CCWD), owner and operator of the reservoir, provides water for 500,000 customers throughout central and eastern Contra Costa County as one of the largest urban water districts in California (CCWD 2017). CCWD completed construction of the original 100-thousand-acre-foot (TAF) Los Vaqueros Project in 1997. CCWD stores water in Los Vaqueros Reservoir that is diverted from the Delta when water quality is favorable, for later release and blending when Delta water quality is degraded. An initial expansion, Phase 1, to 160 TAF was completed in 2012. The primary purpose of both phases of the project is to address seasonal water quality degradation associated with CCWD's Delta water supplies, and CCWD's dry year reliability. The 160 TAF reservoir also provides important emergency water supply storage and, as secondary benefits, recreation and flood management.

Expansion of the Los Vaqueros Reservoir was one of five potential surface water storage projects identified by the CALFED Bay-Delta Program (CALFED) as warranting further study. In 2001, the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), and CCWD began appraisal-level studies of the potential to expand Los Vaqueros Reservoir to address regional water quality and supply reliability needs. The appraisal-level studies indicated that expanding the reservoir to as much as 500 TAF capacity was technically feasible and could provide water quality and supply reliability to agencies in the region, as well as providing potential benefits to fisheries sensitive to water management operations in the Delta.

Subsequently, Reclamation was directed in Public Law 108-7 (Omnibus Appropriations Act of 2003) to conduct a feasibility-level investigation of the potential expansion of Los Vaqueros Reservoir. In 2004, voters in CCWD's service area were asked to vote on whether CCWD should consider expanding the reservoir. The advisory ballot measure won approval, and as a result, the proposed expansion project was further developed and refined through preparation of environmental documentation in accordance with the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA), and extensive public outreach.

After the Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR) was published in 2009 by Reclamation and CCWD, a two-step approach was implemented for expanding Los Vaqueros Reservoir. This was done in order for CCWD to move forward with addressing urgent water supply and quality needs, particularly during dry years, while the feasibility-level investigation was still in process. The initial expansion was completed as a local action by CCWD, without financial assistance from the Federal government. Because it was done without State or Federal assistance, this feasibility-level investigation was put on hold until after completion of the initial expansion. To implement this initial expansion, the CCWD Board of Directors certified the EIS/EIR (Reclamation 2010) and approved an expansion from 100 TAF to 160 TAF on March 31, 2010. Reclamation issued a Record of Decision in February 2011 to enter into an Integrated Operations Agreement with CCWD based on the 2010 EIS/EIR. Construction on the initial expansion began in early 2011 and was completed in 2012.

Reclamation, DWR, and CCWD continue to investigate the feasibility of larger expansion alternatives, as documented in this appendix, because the earlier appraisal-level studies indicated that an additional expansion of Los Vaqueros Reservoir beyond the initial 60 TAF would provide additional regional water supply reliability and statewide environmental benefits. This feasibility-level investigation includes updates to the project plans and studies previously performed to account for significant changes to existing conditions that have occurred since the 2010 EIS/EIR was released, as well as to account for changes that are anticipated to take place within the coming years. These changes include CCWD's initial expansion of Los Vaqueros Reservoir to 160 TAF and the operation of this expanded storage space, other local infrastructure changes (e.g., Contra Costa Canal Replacement Project), likely water management constraints resulting from regulatory actions in the Delta and large programs such as Bay Delta Conservation Plan, and new project beneficiaries to participate in the Investigation.

Study Location

Los Vaqueros Reservoir is located in the Kellogg Creek watershed of Contra Costa County, California in the central and south Delta. The reservoir lies in the foothills west of the Delta and east of the Bay Area. The study area for the Investigation includes the Los Vaqueros Reservoir watershed and associated facilities, central and south Delta, and service areas of potential local partner water agencies. The central and south Delta is roughly bound by the San Joaquin River on the north and the boundaries of the legal Delta to the south (as established in Section 12220 of the California Water Code). Prospective Bay Area partner water agencies include CCWD; Alameda County Water District; Alameda County Flood Control and Water Conservation District, Zone 7; Bay Area Water Supply and Conservation Agency; Byron-Bethany Irrigation District; City of Brentwood; Del Puerto Water District; East Bay Municipal Utility District; East Contra Costa Irrigation District; San Francisco

Public Utilities Commission; San Luis Water District; San Luis & Delta-Mendota Water Authority[1]; Santa Clara Valley Water District; and Westlands Water District. These are collectively referred to herein as Local Agency Partners.

Other potential partners include the managing agencies of South-of-Delta (SOD) Central Valley Project Improvement Act (CVPIA)-designated wildlife refuges (Refuges): California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, and Grassland Water District, in cooperation with Reclamation.

Due to the potential influence on other programs and projects, an extended study area was identified for the Investigation. The extended study area includes the Refuges, operational areas of the Central Valley Project (CVP) and State Water Project (SWP), and the service areas of other Bay Area water agencies that may be indirectly affected by project operations.

Project Objectives

The Investigation focuses on using an expanded Los Vaqueros Project to accomplish the following primary and secondary planning objectives:

Primary Planning Objectives

- Develop water supplies for environmental water management that supports fish protection, habitat management, and other environmental water needs.

- Increase water supply reliability for water providers within the Bay Area to help meet municipal and industrial water demands during drought periods and emergencies or to address shortages due to regulatory and environmental restrictions.

Secondary Planning Objective

- Improve the quality of water deliveries to municipal and industrial customers in the Bay Area, without impairing the project's ability to meet the environmental and water supply reliability objectives stated above.

[1] The SLDMWA includes Banta-Carbona Irrigation District, Broadview Irrigation District, Byron-Bethany Irrigation District, Central California Irrigation District, the City of Tracy, Columbia Cana Company, Del Puerto Water District, Eagle Field Water District, Firebaugh Canal Water District, Fresno Slough Water District, Grassland Water District, Henry Miller Reclamation District #2131, James Irrigation District, Laguna Water District, Mercy Springs Water District, Oro Loma Water District, Pacheco Water District, Panoche Water District, Patterson Water District, Pleasant Valley Water District, Reclamation District #1606, San Benito County Water District, San Luis Water District, Santa Clara Valley Water District, Tranquility Water District, Turner Island Water District, West Side Irrigation District, West Stanislaus Irrigation District, and Westlands Water District.

Final Alternatives Considered in the Feasibility Report

The No Action Alternative and four Action Alternatives are evaluated in this Feasibility Report. The physical features of the alternatives are summarized in Table 1-1. The Action Alternatives are refined versions of the alternatives evaluated in the 2010 Final EIS/EIR with the exception of Alternative 3, which was rejected in the 2010 Final EIS/EIR and was not further refined or evaluated herein. These alternatives account for changes to existing conditions that have occurred since the 2010 EIS/EIR was released (e.g., expansion of Los Vaqueros Reservoir to 160 TAF, completion of other local projects). These alternatives are operated to provide varying levels of emphasis to the above project objectives.

Physical Features

Alternatives 1A, 1B, and 2A would expand Los Vaqueros Reservoir storage from 160 TAF to 275 TAF, build a new Delta-Transfer Pipeline, and relocate the existing Marina Complex and Los Vaqueros Watershed trails and access roads that would be inundated by the reservoir expansion. None of these would occur under Alternative 4A. All the action alternatives would upgrade the existing Transfer Facility, build a new Transfer-Bethany Pipeline, increase Pumping Plant #1 capacity, and add facilities to deliver water to the Transfer Facility from the Rock Slough Intake, which entails building a new Neroly High Lift Pump Station.

A list of the major components for all the alternatives is provided in Table 1-1 below. Alternatives 1A, 1B, and 2A differ from one another only in the proposed operational priorities of the facilities. Figure 1-1 shows the facilities associated with alternatives 1A, 1B, and 2A. Figure 1-2 shows the facilities associated with alternative 4A.

Table 1-1. Summary of Facilities for the Final Alternatives

	No Action	Alternatives 1A, 1B, 2A[1]	Alternative 4A
Existing Facilities (no change)			
Old River Intake	250 cfs	250 cfs	250 cfs
Middle River Intake	250 cfs	250 cfs	250 cfs
Old River Pipeline	320 cfs	320 cfs	320 cfs
Los Vaqueros Pipeline	400 cfs	400 cfs	400 cfs
Transfer Pipeline (Fill/Release)	200/400 cfs	200/400 cfs	200/400 cfs
EBMUD-CCWD Intertie	155 cfs	155 cfs	155 cfs
Transfer Reservoir	4 million gallons	4 million gallons	4 million gallons
Proposed Modifications to Existing Facilities			
Los Vaqueros Reservoir Capacity	160 TAF	275 TAF	160 TAF
Los Vaqueros Reservoir Maximum Water Surface Elevation	507 feet	560 feet	507 feet
Transfer Facility Pump Station Capacity	150 cfs	200 cfs	200 cfs

Table 1-1. Summary of Facilities for the Final Alternatives (contd.)

	No Action	Alternatives 1A, 1B, 2A[1]	Alternative 4A
Proposed New Facilities			
Transfer-Bethany Pipeline Capacity	None	300 cfs	300 cfs
Delta-Transfer Pipeline Capacity	None	180 cfs	None
Expanded Transfer Facility Pump Station Capacity	None	300 cfs	300 cfs
Expanded Transfer Facility Storage Reservoir Capacity	None	5 million gallons	5 million gallons
Neroly High Lift Pump Station Capacity	None	350 cfs	350 cfs
Pumping Plant #1 Capacity	200 cfs	350 cfs[2]	350 cfs[2]
Los Vaqueros Watershed Facilities			
Los Vaqueros Marina Complex	No change	Relocated upslope	No change
Los Vaqueros Watershed Trails	None	Expanded	None
Los Vaqueros Interpretive Center	No change	Improved	Improved
Los Vaqueros Watershed Office Barn	No change	Seismically upgraded and improved	Seismically upgraded and improved

Notes:

General: Local Agency Partners plan on constructing several projects related to the proposed Los Vaqueros Reservoir expansion. These include the Brentwood Pipeline, the EBMUD-CCWD Intertie Pump Station, the EBMUD Walnut Creek Pumping Plant Variable Frequency Drives, the EBMUD Mokelumne Aqueduct Relining, and the East Contra Costa Irrigation District Intertie. These associated local projects are not part of the Federal feasibility study but are important related improvements to Local Agency Partners' infrastructure that would be constructed in conjunction with this project.

[1] Alternatives 1A, 1B, and 2A differ from one another only in the proposed operational priorities of the facilities. Alternatives evaluated in the Investigation are refined versions of the alternatives evaluated in the 2010 Final EIS/EIR. Alternative 3 was rejected in the 2010 Final EIS/EIR and was not evaluated further in Phase 2 of the Investigation.

[2] Permitted capacity is 350 cfs as defined in the Supplement to the Final EIS/EIR. 300 cfs is the capacity modeled and designed under the Feasibility Study to reflect the current operation requirements. Capacity requires improvements to the existing Rock Slough Fish Screen's rake cleaning system, included under Pumping Plant #1 improvements in this Feasibility Report.

Key:
CCWD = Contra Costa Water District
cfs = cubic feet per second
EBMUD = East Bay Municipal Utility District
EIS = Environmental Impact Statement
EIR = Environmental Impact Report
TAF = thousand acre-feet

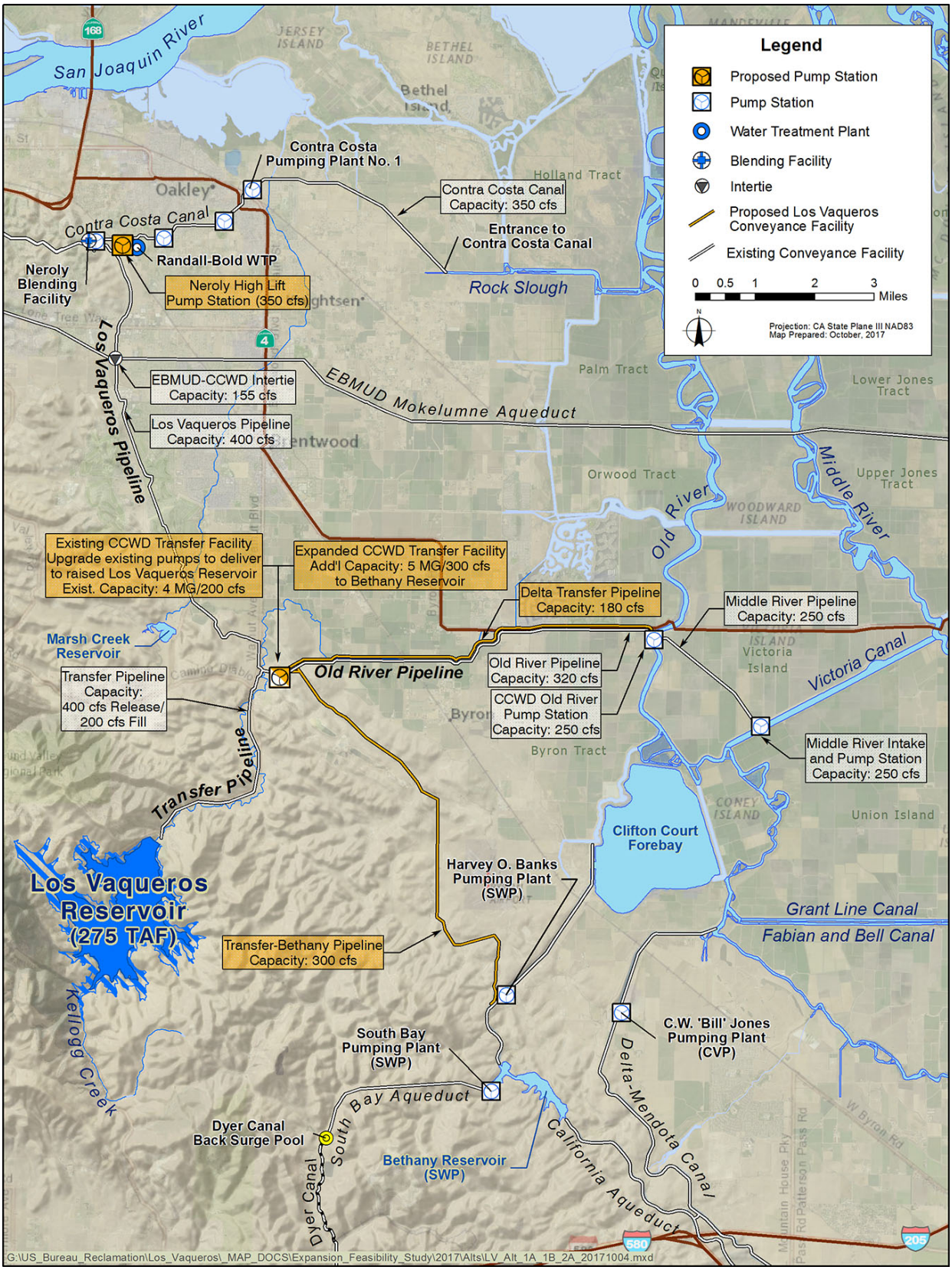


Figure 1-1. Major Components of Alternatives 1A, 1B, and 2A

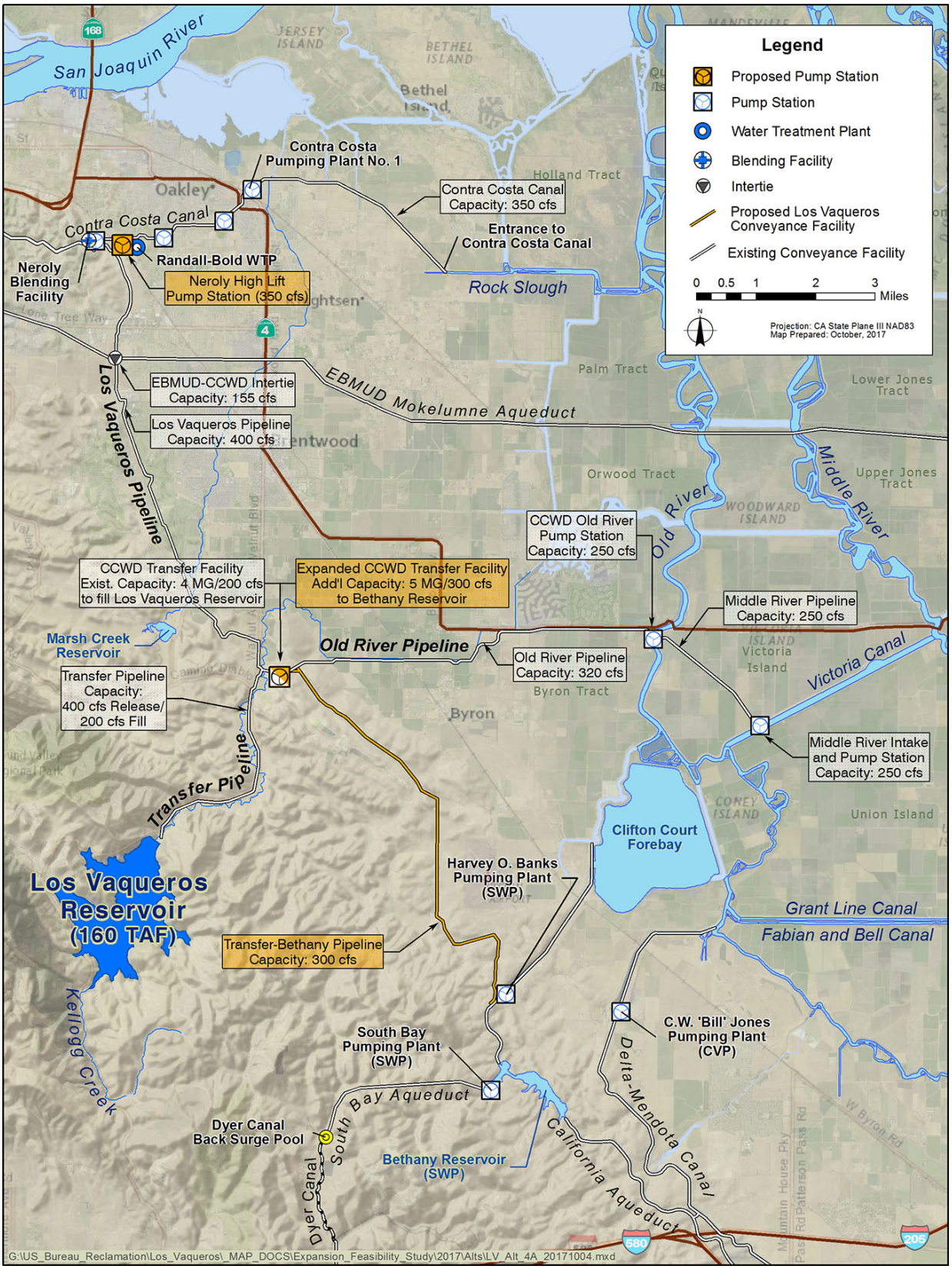


Figure 1-2. Major Components of Alternative 4A

Operational Priorities

All alternative plans would utilize CCWD's existing Delta intakes at Old River, Middle River, and Rock Slough to divert water from the Delta. In addition, CCWD, Local Agency Partners, and the Refuge Water Supply Program might (subject to obtaining the appropriate water rights modifications and other approvals) receive water diverted from the Freeport Intake on the Sacramento River via the EBMUD-CCWD Intertie. Water diverted at these four locations could be directly delivered to beneficiaries or stored in Los Vaqueros Reservoir for later use.

The Refuges would receive water delivered through the Transfer-Bethany Pipeline to the California Aqueduct. The delivered water would be either direct diversions or rediversions from the Delta, or releases from Los Vaqueros Reservoir storage, depending on the alternative plan. The water would be Delta Surplus Water[2] or water otherwise made available from CCWD or a Local Agency Partner or the Refuge Water Supply Program. The alternatives would not change the manner in which water is conveyed by the Refuge Water Supply Program to the various Refuges.

Similarly, water delivered to Local Agency Partners would be direct diversions or rediversions from the Delta, or releases from Los Vaqueros Reservoir storage. The water would be Delta Surplus Water or water available from Local Agency Partner water rights and contracts. In addition, some alternatives include dedicated storage space in Los Vaqueros Reservoir for Local Agency Partner storage and withdrawal, including reserved drought and/or non-drought emergency storage.

All operations were formulated to meet the project objectives while minimizing impacts and avoiding harm to other water users. The operational differences and priorities for the Action Alternatives is summarized below.

- Alternative 1A is operated to maximize deliveries for water supply reliability to the Local Agency Partners, including drought and emergency supply reliability. The operations first seek to deliver Delta surplus and/or Local Agency Partner's water rights and contract supplies to meet current demands. Any available supplies above current demands are stored in Los Vaquero Reservoir for later use, including dry years. If additional system capacity is available after these operations, CVPIA Level 2 Refuge water is wheeled through CCWD facilities instead of C.W. Jones Pumping Plant, freeing up capacity to increase CVP SOD deliveries at C.W. Jones Pumping Plant. Last, remaining CCWD system capacity is then used to deliver water supplies south of the Delta to help meet Incremental Level 4 Refuge contract allocations. These operational priorities result in the highest water deliveries to Local Agency Partners and CVP contractors (via wheeling), and the lowest deliveries to Refuges, compared with the other alternative plans.

- Alternative 1B includes the same physical facilities as Alternative 1A but is operated to provide roughly equal water deliveries (long-term) to both Local Agency Partners and Refuges, thereby balancing the Investigation's two primary objectives. Level 2 Refuge supplies (which result in increased CVP operational flexibility) are only wheeled through

[2] "Delta Surplus Water" is water diverted when the Delta is in excess conditions as defined in the SWRCB's Decision 1641.

CCWD facilities once the operational priorities for Local Agency Partners and Refuges are met. In addition, SOD CVP contractor deliveries that would otherwise by limited by Delta conveyance constraints are rescheduled using Los Vaqueros Reservoir expanded storage, resulting in additional CVP operational flexibility. These operational priorities result in higher benefits to Local Agency Partners (M&I and agricultural water supplies), Refuges, and CVP contractors, compared with the other alternative plans.

- Alternative 2A includes the same facilities as Alternatives 1A and 1B but is operated to maximize potential Incremental Level 4 deliveries to the Refuges. Benefits to Refuges occur from both direct deliveries conveyed via CCWD facilities, as well as water supplies stored in Los Vaqueros Reservoir. These operational priorities result in the highest benefits to Refuges, compared with the other alternative plans.

- Alternative 4A uses similar operational priorities as Alternative 1B. Alternative 4A is formulated to maximize potential project deliveries to both the Local Agency Partners and Refuges, but without the benefit of expanded storage in Los Vaqueros Reservoir. These operations result in relatively low benefits to Local Agency Partners, Refuges, and CVP contractors, compared with the other alternative plans.

Organization of This Appendix

This appendix is organized as follows:

Chapter 1, **Introduction**, provides an overview of the Investigation.

Chapter 2, Engineering Setting, summarizes the existing Los Vaqueros Project and related facilities, and the geotechnical analyses.

Chapter 3, Design Criteria, describes the design criteria for the new facilities.

Chapter 4, Dam and Reservoir Elements, documents dam and related designs for expansion of Los Vaqueros Reservoir from 160 TAF to 275 TAF. Design drawings for the dam raise are included in Attachment 2. The major relocations associated with the expanded reservoir are also described.

Chapter 5, Conveyance and Pumping Facilities, documents design activities related to the conveyance, and pumping facilities considered in the alternatives, and includes facility layouts, hydraulic review, and other conceptual designs. Detailed drawings (10 percent level of design) for the conveyance elements are included in Attachment 3.

Chapter 6, Construction Schedule and Field Cost Estimates, documents the "Class 4" estimates of probable cost and construction schedules prepared for each of the alternatives.

Chapter 7, Project Capital and Operations, Maintenance, and Replacement (OM&R) Costs, documents the project cost components that are used to calculate a total project cost from the field cost estimates for each of the alternatives.

Chapter 8, References, lists the sources used in preparing this technical appendix.

This appendix also includes design drawings and supporting technical reports, included as attachments. These attachments, referenced throughout this document, include the following:

- **Attachment 1– Geotechnical and Seismic Evaluations (Conveyance Facilities)** documents existing and available geotechnical information used to support design of conveyance and pumping facilities.

- **Attachment 2 – 275 TAF Dam Design and Cost Estimates** documents the design of the 275 TAF dam raise and appurtenant facilities, including the stability and seismic analysis, embankment materials, design drawings, and cost estimates.

- **Attachment 3 – Conveyance & Pumping Design Drawings** includes drawings for the conveyance and pumping elements of each of the alternatives under consideration by the Investigation.

Attachment 4 – Construction Schedule and Cost Estimate documents the construction schedule and cost estimates for each of the alternatives.

Chapter 2 Engineering Setting

This chapter describes major existing facilities, available geotechnical data, and established engineering design criteria for the expansion project. The engineering design criteria provide the engineering parameters necessary for the feasibility-level engineering design work presented in this appendix.

Existing Facilities

The existing Los Vaqueros Project provides 160 TAF of offstream water storage to improve water quality and provide emergency water supplies for CCWD customers. Water is diverted from the Delta at the Old River Intake and Pump Station, and Middle River Intake and Pump Station, and pumped to Los Vaqueros for storage. Water can be delivered by gravity to the Contra Costa Canal or can be pumped directly from the Old or Middle rivers to the Contra Costa Canal, for blending with other CCWD water supplies to meet CCWD water quality targets.

The existing Los Vaqueros Project comprises the primary facilities described in this section. These facilities, in conjunction with proposed new facilities, are included in the various action alternatives described in Chapter 1.

Old River Intake and Pump Station

The Old River Intake and Pump Station are located on a 16.8-acre site adjacent to the Old River, immediately south of the Highway 4 crossing. The facility diverts water from the Old River through a positive barrier fish screen with an area of 1,250 square feet. The pumping plant includes five fixed speed 50 cubic feet per second (cfs) pumps with a total capacity of 250 cfs. The intake was configured to accommodate an additional 70 cfs of intake capacity with additional fish screens.

Old River Pipeline

The Old River Pipeline is a 78-inch-diameter (American Water Works Association (AWWA) C300) reinforced concrete cylinder pipe that conveys water from the Old River Pumping Plant to the Transfer Reservoir and Pump Station and to the Los Vaqueros Pipeline. The Old River Pipeline has a capacity of 320 cfs, is 34,700 feet long, and lies within an 85-foot-wide right-of-way.

Middle River Intake and Pump Station

The Middle River Intake and Pump Station was constructed in 2010 to provide more pumping capacity to the Transfer Facility and onward to other associated CCWD infrastructure. This facility lifts water from Victoria Canal (roughly southeast of the existing Old River Intake and Pump Station) to the Transfer Facility for delivery to Los Vaqueros Reservoir or the Contra Costa Canal. The current configuration includes five pumps, three fixed speed 50 cfs pumps and two with variable frequency drives, with a total capacity of 250 cfs.

Middle River Pipeline

The Middle River Pipeline conveys the Middle River Pump Station discharge approximately 30,000 feet across Victoria Island before tunneling beneath the Old River and connecting to the Old River Pipeline. The pipeline is constructed of 72-inch diameter steel pipe with cement mortar lining and coating and has a capacity of 250 cfs. Three butterfly isolation valves are installed in the pipeline, one valve is located on the Middle River Pump Station site and two valves are located on either side of the Old River tunnel crossing. The pipeline includes an impressed current cathodic protection system; the cathodic protection system has two deep bed anodes installed at the Middle and Old River Pump Stations.

Transfer Reservoir

The Transfer Reservoir serves as the hydraulic grade line control for the conveyance system. The 4-million-gallon (MG) reservoir provides a stable pumping head for the Old River Pump Station and Transfer Pump Station (and would serve similar functions for proposed facilities). It also provides hydraulic control for operation of Flow Control Stations 1 and 2, and necessary storage for operation of the system. The Transfer Reservoir includes an emergency overflow, which prevents pressure buildup in the Los Vaqueros and Old River pipelines if Flow Control Station 1 is not functioning properly. This existing overflow is sized to convey gravity flows of up to 500 cfs, based on uncontrolled flow, in the Transfer Pipeline from Los Vaqueros Reservoir.

Transfer Pumping Plant

The Transfer Pumping Plant is currently used to lift water from the Old River Pipeline to Los Vaqueros Reservoir. The design capacity of the existing pumping plant is 200 cfs, provided by four fixed speed pumps rated at 50 cfs each. The Old River Pumping Plant operates at a flow rate equal to or greater than the flow rate at the Transfer Pumping Plant to deliver water to Los Vaqueros Reservoir. When Old River Pumping Plant flow exceeds flow from the Transfer Pumping Plant, the excess flow is delivered to the Contra Costa Canal through the Los Vaqueros Pipeline.

Flow Control Station 1

The existing Flow Control Station 1 controls the rate of flow from Los Vaqueros Reservoir to the Contra Costa Canal. This station dissipates excess energy (head) in the Transfer Pipeline when water is released from Los Vaqueros Reservoir.

Flow Control Station 2

The existing Flow Control Station 2 controls the water surface level in the Transfer Reservoir as well as the maximum downstream water surface elevation in the Contra Costa Canal. This station dissipates excess energy (head) in the Los Vaqueros Pipeline to help maintain a stable water level in the Transfer Reservoir.

Transfer Pipeline

The existing Transfer Pipeline is a 72-inch-diameter steel pipe, mortar-lined and mortar-coated (AWWA C200), which conveys water to and from Los Vaqueros Reservoir. The Transfer Pumping Plant pumps water through this pipeline into Los Vaqueros Reservoir, and deliveries from the reservoir flow by gravity to the junction with the inlet to Flow Control Station 1. The pressure rating

of the pipe varies along the pipeline from 100 pounds of pressure per square inch (psi) to 200 psi. The Transfer Pipeline is 19,600 feet long and can convey up to 200 cfs from the Transfer Facility to the reservoir, and 400 cfs from the reservoir to the Transfer Facility.

Los Vaqueros Pipeline

The existing Los Vaqueros Pipeline conveys water by gravity from the discharge of Flow Control Station 1 (junction of the Transfer Pipeline and Old River Pipeline) to the delivery point at within an 85-foot right-of-way, the pipeline consists of two continuous segments: the first is 18,000 feet long with 96-inch-diameter pipe, and the second is 29,000 feet long with 90-inch-diameter pipe. The pipeline has a capacity of 400 cfs.

Los Vaqueros Dam and Reservoir

Los Vaqueros Dam is a zoned earthfill embankment dam located on Kellogg Creek. The crest of the dam, at an elevation of 523 feet, is about 230 feet above the downstream toe. The dam comprises an embankment volume of approximately 3.8 million cubic yards and has a crest width of 30 feet and a length of 1,300 feet. Releases are made via a variable-elevation outlet gallery. The reservoir formed by the dam has a capacity of 160 TAF at gross pool.

Mokelumne Aqueduct Intertie

A 52 cfs intertie between EBMUD's Mokelumne Aqueduct and CCWD's Los Vaqueros Pipeline was completed in 2007. The intertie is being used to fill Los Vaqueros Reservoir or for direct delivery to CCWD. Water delivered from the Mokelumne Aqueduct is of very high quality (averaging 7 to 8 milligrams per liter chloride) compared with CCWD's Delta supplies and has a recognizable positive impact on Los Vaqueros operations. Operation standards/requirements related to the intertie include the following:

- Deliveries will be made preferentially to Los Vaqueros Reservoir, with deliveries made directly to the Contra Costa Canal only when the reservoir was full or if water was needed to meet an immediate CCWD water quality target.

- Deliveries will be made from the intertie to the Transfer Facility via gravity (pressure in the Mokelumne Aqueduct is sufficient to deliver water through reverse flow to the Transfer Facility, from which it would be pumped to Los Vaqueros Reservoir).

- Reservoir releases and/or Old River Pipeline deliveries to CCWD cannot be made while Mokelumne Intertie deliveries are being made to Los Vaqueros Reservoir (a single pipeline is available for both actions).

Surveying and Mapping Information

Surveying and mapping information to support the feasibility level design were obtained from the original Los Vaqueros Project information, as well as from information obtained specifically for this Investigation.

Survey Datum and Benchmarks

Survey horizontal datum was based on the California State Plane System, Zone 3 for North American Datum 1927 (NAD 27) Survey vertical datum was based on the National Geodetic Vertical Datum (NGVD 1929) in U.S. survey feet. The horizontals and vertical datums are selected to maintain consistency with the original Los Vaqueros Project technical documents.

The Record drawings for the original Los Vaqueros Project provided a listing of the horizontal coordinate locations (in the NAD 27–based California Coordinate Systems) for pumping plant facilities property lines. The pipelines rights-of-way and temporary construction easements are also identified, primarily by dimensioned offsets from the pipeline centerline, with identified horizontal coordination locations.

Aerial Imagery

2014 aerial images were purchased from Contra Costa County. The 2014 images were based on the survey horizontal datum of California State Plane System, Zone 3 for North American Datum 1983. The 2014 images were converted to the NAD 27 to fit the horizontal control used for the original Los Vaqueros System Project. The 2014 images reflect a near-current depiction of surface visible facilities and are sufficient to support and conduct the feasibility-level designs.

Topographic Information

Available survey and mapping for the original Los Vaqueros Project were conducted in December 1991 covered a mapping area of approximately 101,000 linear feet by 1,250 feet, and included the Los Vaqueros, Transfer and Old River Pipeline alignments and Old River Intake and Transfer Facility sites. Digital topographic mapping was produced for mapping accuracy standards for 2-foot and 1-foot contour interval mapping, respectively for the pipelines and pumping plant facilities. Spot elevations were shown in appropriate locations and at a minimum of 50-foot intervals through flat areas.

Light Detection and Ranging (LiDAR) mapping produced in 2007 for mapping accuracy standards for 2-foot contour interval mapping was obtained. The 2007 LiDAR mapping is considered a useful tool to readily assess changes in the topography that have occurred in the years since 1991, particularly along long stretches of the pipeline alignments.

The original Los Vaqueros Project topography will be used for the majority of the feasibility-level pipeline designs, given the availability of detailed information on the existing pipelines. At some locations, such as the expanded transfer facility and reservoir, the 2007 LiDAR mapping will supplement the 1991 mapping information due to limited 1991 mapping coverage.

Geotechnical Analysis

Geotechnical characteristics and potential design and construction issues for the conveyance and pumping facilities is included in Attachment 1 and summarized in Table 2-1. Attachment 1A contains a March 2007 feasibility-level geotechnical and seismic evaluation based on existing data and considering project facilities proposed at that time. Attachment 1B contains an October 2015

addendum to the Attachment 1A evaluation with consideration of the currently proposed project facilities. The Mokelumne-Transfer Pipeline and Expanded Old River Intake and Pump Station, discussed in Attachment 1B, have since been removed from the proposed project. The Neroly High Lift Pump Station has since undergone additional design due to CCWD's preference for an alternative site. Additional information has been developed for the Transfer-Bethany Pipeline to address independent 2018 Design, Cost Estimating, and Construction Review comments received and additional geotechnical evaluations, recommended as part of this review, will occur post-authorization. Project risk and uncertainty are discussed in the main body of the feasibility report.

The new and modified conveyance and pumping facilities are grouped in three areas as functions of general site subsurface conditions and anticipated performances, as follows:

- **Area 1** – Delta-Transfer Pipeline (Station 0+00 to Station 100+00) and Expanded Old River Intake and Pump Station;
- **Area 2** – Delta-Transfer Pipeline (Station 100+00 to Station 250+00); and
- **Area 3** – Delta-Transfer Pipeline (Station 250+00 to Station 375+00), Transfer Pipeline, Mokelumne-Transfer Pipeline, Expanded Transfer Pump Station and Transfer Pump Station.

Surface faulting is not a hazard at the new and modified facilities because no active faults that would rupture the surface are identified in the project area (DWR 2009).

It is assumed that the new and modified facilities could not be struck by a tsunami because the project area is located within the Delta at least 50 miles from the Pacific Ocean. Although no maps of tsunami hazards in the Delta were found in the publications reviewed, potential risks of catastrophic inundation are assumed to be small. This is because the tsunami hazards map west of the Delta area indicates a maximum inundation of 3 feet above mean sea level and tsunami effects would be attenuated in Suisun and Grizzly bays before reaching the Delta area (DWR 2016).

Table 2-1. Geotechnical Characteristics and Potential Design and Construction Issues

Subject	Area 1	Area 2	Area 3
Predominant Geotechnical Characteristics	Saturated medium stiff silty clay / clayey silt, loose silty sand / sandy silt, and muck	Partially saturated medium stiff to stiff silty clay / clayey silt, and loose silty sand / sandy silt	Dry stiff to hard silty clay / clayey silt, and dense silty sand / sandy silt
Design and Construction Issues:			
Pipe Buoyancy	Yes	No	No
Delta Subsidence	Yes	No	No
Bearing Capacity	Yes	Possible [1]	No [4]
Settlement	Yes	Possible [1, 2]	Yes [5, 6]
Trenching and Temporary Excavation – Excavation Stability	Yes	Yes [2]	Yes, localized [5, 6]
Seismic Shaking	Yes	Yes [2]	Yes [5, 6]
Irrigation and Drainage Crossings	Yes	Yes [2]	No
Road Crossings	No	Yes	Yes
Creek Crossings	No	Yes [2]	Yes [2]
Canal Crossings	No	Yes [2]	No
Available Borrow Sources	Yes	Possible [3]	No
Corrosion Potential	Yes	Yes [2]	Yes
Expansive Soils	Yes	Yes [2]	Yes [2]
Levee Failure and Response to Potential Flooding	Yes	No	No
Scour Damage from Adjacent Kellogg Creek	No	No	Possible [3]
Rock Excavation	No	No	Possible [3]

Notes:

Yes = issues are expected; No = issues are not expected; Possible = potential issues to be confirmed in next design phase.

[1] Possible issues for structures that might be built in Area 2; no issues are expected for the pipeline.

[2] Issues similar to those described in Area 1 (see Area 1 for descriptions of issues)

[3] Possible issues that cannot be currently confirmed due to insufficient information.

[4] No bearing capacity issues are expected at Expanded Transfer Pump Station and Transfer Pump Station, but allowable bearing pressure is provided in Area 3.

[5] Issues are expected to be localized adjacent to Kellogg Creek where the soils could be soft / loose and saturated.

[6] Localized issues adjacent to Kellogg Creek similar to those described in Area 1 (see Area 1 for descriptions of issues).

A geotechnical evaluation was performed for the Los Vaqueros Dam raise element and is included in Attachment 2.

Chapter 3 Design Criteria

Engineering criteria were developed for the feasibility study based on previously accepted criteria identified for the Los Vaqueros Project, industry practice, codes and standards, and professional judgment. These criteria are appropriate for defining project elements and developing feasibility-level construction estimates for use in comparing and screening alternatives. The design criteria should be reviewed and updated prior to beginning a detailed design effort.

Design criteria for conveyance and pumping facilities are presented below. Neroly High Lift Pump Station and Transfer-Bethany Pipeline are not specifically addressed but the fundamental criteria would also apply to these facilities, which are further described in Chapter 5 of this document. Los Vaqueros Dam and Reservoir elements are described in Chapter 4 of this document.

General

Project facilities covered by the design criteria presented in this section include new pipelines, pump stations, and associated appurtenant facilities.

The 66-inch diameter Delta-Transfer Pipeline will be routed parallel to the existing 78-inch diameter Old River Pipeline to convey water from Old River and Middle River Intake Pump Stations to the raw water storage and distribution system. The pipeline will tie into existing piping at the Old River Intake facility and at the Transfer facility. The pipeline will include isolation valves and a flow meter.

The Expanded Transfer Pump Station will be located adjacent to the existing Transfer Pump Station and will have the capability to pump water from both the Old River and Delta-Transfer pipelines to Bethany Reservoir. The pump station will include six – 50 cfs capacity vertical turbine pumps, a new electrical substation, and a Motor Control Center (MCC). A new 5 MG reservoir will be located adjacent to the pump station and will provide hydraulic grade line (HGL) control for the Old River and Middle River pump stations, among other hydraulic functions.

All elevations used on the Project are referenced to the National Geodetic Vertical Datum of 1929.

Civil

This section provides civil discipline design criteria.

Conveyance Pipeline Design Criteria

Key conveyance pipeline design considerations and design criteria for the Delta-Transfer Pipeline addressed herein include hydraulic capacity, pipe material selection, pipe design pressures, flow velocity, pipe structural design, fittings and specials, and pipe joints. The proposed Delta-Transfer Pipeline would begin at a connection to the 78-inch Old River Pipeline vertical riser section on the

Old River Pump Station site and extend to the 96-inch Los Vaqueros Pipeline connection on the Transfer Facility site.

Hydraulic Criteria

The hydraulic design criteria are presented in the Operational, Hydraulic, and Mechanical section of this chapter. A principal goal of the hydraulic analysis is to establish a recommended diameter for the Delta-Transfer Pipeline. The design flow capacity and recommended diameter for the Delta-Transfer Pipeline is shown in Table 3-1.

Table 3-1. Summary of Proposed Pipeline Size and Flow Rate

Pipeline	Design Flow Rate (cfs)	Pipeline Diameter (inches)	Approximate Length (feet)
Delta-Transfer	180[1]	66	37,320[2]

Notes:

[1]Assumes that the existing 78-inch diameter Old River Pipe delivers approximately 320cfs to the Transfer Facility

[2]The pipe length extends from the connection to the 78-inch Old River Pipeline vertical riser section on the Old River Pump Station site and extends to the 96-inch Los Vaqueros Pipeline connection on the transfer Facility site.

Key:

cfs= cubic feet per second

The hydraulic evaluations also provide input to development of design criteria related to working pressures, transient pressures and flow velocity as described in paragraphs below.

Pipe Material

A pipeline material evaluation was performed during the original Los Vaqueros Project. The evaluation identified two suitable pipe material options: welded steel pipe per AWWA C200 and reinforced concrete cylinder pipe per AWWA C300. These materials were judged to be suitable for installation based on the rugged nature of construction, ability to meet the project's pressure requirements, flexibility with fittings and connections, ability to resist thrust, and performance during seismic events. Both pipe types are considered potentially viable for the currently planned facilities, and in the past a minimum of two pipe materials were included in the design to encourage increased competition among pipe suppliers of different pipe materials. However, steel pipe with welded joints provides a more seismically resilient pipe system which is considered to provide superior performance under design seismic conditions. Therefore, the design criteria, plans, and cost estimates are based on the use of welded steel pipe. Further analysis should be conducted during design development to evaluate the market conditions and the number of manufacturers capable of delivering each pipe type before a final decision is made on inclusion of reinforced concrete cylinder pipe in the final design.

Lining Steel Pipe with a diameter of 66 inches and under shall have a factory spun cement mortar lining per AWWA C205. This is consistent with the lining for the adjacent Old River Pipeline.

Coatings The buried AWWA C200 steel pipe for the Old River Pipeline has a 1-inch minimum thick cement mortar coating per AWWA C205 with a 25-mil overcoat of 100 percent solids coal tar epoxy. Coal tar epoxy is not usually specified due to manufacturing application limitations associated

with its use, and concerns about potential carcinogenic effects. For this reason, a flexible coating is recommended for the steel pipe in lieu of the cement mortar coating. Flexible coatings may be either be a polyethylene tape wrapped coating per AWWA C214 or a polyurethane coating per AWWA C222. Heat shrink sleeves are recommended for coating all pipe joints in the field per AWWA C216.

Pipe specials, fittings, and flanges shall be field coated with cold-applied petrolatum and petroleum wax tape, in accordance with AWWA C217. The exterior protection of all irregular-shaped fittings will require filler approved by the wax tape manufacturer. Wax tapes are subject to mechanical and soil stress and must be protected with an outer wrap of fiberglass mat or suitable tape. Total applied thickness to be specified will depend on both soil and service conditions; however, at no time shall the thickness of the tape be less than 40 mils.

Design Pressures

Key pipeline design pressures are discussed in the following paragraphs.

Working Pressure The working pressure is defined as the maximum operating pressure at various points along the pipeline based on the maximum pumped HGL while flow is delivered through the Delta-Transfer Pipeline to the terminal reservoirs located at the Transfer Pump Station site. Since the pipeline may be fed from either the Middle River or Old River Pump Station or both, several operating conditions must be considered. The working pressure at any point along the alignment is equal to the difference between the maximum HGL and the pipe centerline elevation. This maximum working pressure is presented under the Operational, Hydraulic, and Mechanical section.

Pipe pressure classes will be developed starting at 50 psi and increasing in 25 psi increments up to the maximum pressure class required. For the Delta-Transfer Pipeline, the pressure class starts at 200 psi at the lower elevations near the Old River pump station and decreases to a 50-psi pressure class at the high elevations near the Transfer Facility. The pipe extending past the terminal reservoirs to the connection point with the 96-inch Los Vaqueros Pipeline will be 50-psi pressure class. Stationing corresponding to the beginning and ending limits of each pressure class will be developed during the design development stage.

Transient Pressures Hydraulic transient pressures result from sudden velocity changes in the water flowing through a pipeline. These transient (or surge) pressures can propagate from closing a valve too rapidly or may result from an electrical power failure at a pump station that causes a sudden pump shut down. Other causes may include modulating a regulating valve too quickly or a sudden release of entrapped air from the pipeline. The most common cause of a pipeline surge condition for a pumped water transmission main is electric power failure at the pump station.

Pipelines will be provided with appurtenant features, as required, to assure that maximum transient pressures do not exceed 133 percent of the steady state design pressure. Appurtenant features may include hydrodynamic surge tanks.

Pump Shutoff Pressure There are mainline isolation valves on the Delta-Transfer Pipeline just downstream of the meter vault on the Old River Pump Station site and just prior to the terminal reservoir turnout connection at the Transfer Facility site. If the isolation valve near the reservoir

turnout should be closed, and either pump station is on line, the pumps would be pumping against a closed valve and the pressure in the pipeline would rise to the full pump shutoff pressure. Based on preliminary pump selections, the pump shutoff HGL is approximately 655 feet. The resulting pump shutoff pressures must also be considered in the design of the pipe. Based on an assumed 655-foot HGL, the maximum shutoff pressure in the pipe near the Old River Pump Station (where the pipe centerline is at approximately -20 feet elevation) is approximately 293 psi.

Test Pressures Test pressure is the pressure in the pipeline during pressure testing. The test pressure should be limited to 1.33 times the working pressure.

Flow Velocity

The velocity of the flow will control the amount of headloss in the pipeline for any given pipe diameter. As the pipe diameter decreases and the velocity increases, the headloss in the pipeline increases. If the headloss is too high, the pipeline is not efficiently sized for the required flow. There is a trade-off between increased pipe cost for a larger pipe diameter and increased pumping energy costs. Also, higher velocities increase the potential for more severe hydraulic transient conditions.

Typically, the most efficient pipeline sizing for a pumped water transmission line coincides with a maximum velocity in the range of 7 to 8 feet per second (ft/sec). The design velocity for the 66-inch-diameter Delta-Transfer Pipeline is approximately 7.5 ft/sec. Typically, the maximum desired velocity for cement mortar lined pipe in continuous service is approximately 10 ft/sec. However, pipelines and valving systems can occasionally accommodate much higher velocities without damage, including velocities as high as 15 ft/sec through flow valves. Velocities through valves are usually limited to prevent damage to valve seats.

Pipe Structural Design

The water transmission pipe design must be integrated with the design of all the system elements including the upstream pump stations to ensure that the pipelines will be capable of withstanding all design pressure and operating conditions. The system hydraulics evaluation is the overarching information that must be used to correctly design the pipe. Pipes shall be capable of withstanding the maximum internal pressures (working/test/shutoff/surge) and the maximum external loading configuration acting independently on the pipe. No reduction of external loads due to internal pressure will be allowed.

Steel pipe is considered a flexible pipe system and will be designed using the flexible pipeline design methods noted in AWWA M-11, "Steel Pipe – A Guide for Design and Installation" and also ASCE Manual of Practice 79 – "Steel Penstocks", where applicable. All steel pipe will be consistent with the requirements of AWWA C200 and other AWWA standards as referenced elsewhere in this design criteria document, except where project specific criteria are more stringent.

There are three main parts to steel pipe design:

1. Hoop stress and handling requirements.

2. Deflection limitation.

3. Buckling avoidance.

Design criteria for each of these topics is discussed in the following sub-sections.

Hoop Stress and Handling Requirements

Hoop Stress Requirements Waterlines are subject to hydraulic pressures within the pipeline and must have adequate pipe wall strength to resist the induced stresses with a suitable factor of safety. The greater wall thickness for the pipe, defined by internal hydrostatic pressures from the working, test, surge, or shutoff head conditions, will control the hoop stress design. Dynamic forces (thrust stresses) are included in the pipeline design only if their additive stress to internal pressure, Poisson's ratio, temperature stresses, and other applied stresses (total stress condition) would exceed the allowable stress for the selected steel.

Hoop stress is calculated based on applied hydraulic pressures within the pipeline and the allowable stress in the steel must be factored to provide a suitable factor of safety (FS) for design. Typically, the design must consider both maximum working pressure and pump shutoff pressure for pumped systems. Design hoop stress calculations must also consider test pressures and transient (surge) pressures. The following Table 3-2 summarizes the various design pressures, and factors of safety established for use in hoop stress calculations. Note, in some cases these factors of safety are more conservative than AWWA M-11 Guidelines.

Table 3-2. Pipeline Design Pressures and Factors of Safety

Design Pressure Condition	Factor of Safety	Allowable Stress (psi) [2]	Percent of Yield	Comment
Working Pressure[1]	2.0	21,000	50.0%	
Test Pressure	1.5	28,000	66.7%	Test Pressure is established at 1.33 times working pressure
Transient Pressure	1.5	28,000	66.7%	Transient Pressure limited to 1.33 times working pressure
Pump Shutoff Pressure	1.5	28,000	66.7%	Based on actual pump shutoff

Notes:
[1] Maximum operating pressure for pumped pipelines and maximum static pressure for gravity pipelines
[2] Assumes 42,000 psi Minimum Yield Steel
Key:
psi = pounds per square inch
% = percent

The hoop stress calculation is based on the Barlow (AWWA M-11 § 4.1) formula:

$$P = \frac{2tS}{D}$$

Where: S = the allowable hoop stress (psi).

	t	=	pipe wall thickness (inches).
	D	=	Pipe OD (inches) –outside diameter of the steel can.
	P	=	Design Pressure (psi)
and	S	=	Ys/FS.
	Y_s	=	Yield stress (psi).
	FS	=	Factor of Safety.

Allowable stress and factors of safety for different design pressure conditions are taken from the above table. Allowable hoop stress from working pressure is the lesser of the following: 50 percent of yield stress (FS=2), but with a limiting value (maximum allowable hoop stress) of 21 kips per square inch (ksi) for mortar lined pipe and 16.5 ksi for mortar coated pipe.

Handling Requirements The minimum wall thickness for handling should be based on the following formula, for mortar lined pipe:

$$t \geq \frac{D}{240}$$

Where:	t	=	minimum wall thickness, inches.
	D	=	outside pipe diameter (pipe can OD), inches.

Minimum Wall Thickness The minimum wall thickness for the pressure and handling condition is the greater wall thickness of the requirements listed above.

Deflection Limits of Flexible Pipe Deflection limits of flexible pipe are based on load calculations similar to that used for rigid conduits. However, due to pipe flexibility and its effect on differential settlement of the soil column over the pipe, computation of the dead load is simplified.

Loads on Flexible Pipe Two conditions for external loads shall be considered:

Live load plus dead load with full depth of cover. Note that the effect of live loads diminishes with depth of cover.

Live load plus dead load with minimal cover. The minimal cover used in the calculation should be coordinated with the specifications. The specifications should state the amount of cover required prior to operating heavy equipment above the pipe. The live load should represent the heaviest equipment anticipated for use in compaction or hauling material above the pipe.

Live Loads Live loads are generally categorized into distributed and impact loads, the distributed traffic loads are as defined in Table 3-3, below. At a depth greater than 8 feet, the effect of the wheel load becomes insignificant.

Table 3-3. Pipeline Design – Live Load Effect

Highway HS-20 Loading		Railroad E-80 Loading	
Soil Cover (feet)	Load (psf)	Soil Cover (feet)	Load (psf)
1	1,800	2	3,800
2	800	5	2,400
3	600	8	1,600
4	400	10	1,100
5	250	12	800
6	200	15	600
7	176	20	300
8	100	30	100

Note: Neglect live load when less than 100 psf, use dead load only. Table from AWWA M-11 Design Manual.

Key:
AWWA = American Water Works Association
psf = pounds per square foot

Concentrated Loads If large concentrated loads are anticipated over the pipeline they should also be considered in the design on an item by item basis.

Earth Loads Common conservative design practice, for buried steel pipelines, is to calculate dead loads on flexible pipes for the positive projecting embankment condition (i.e., at transition width). This is called the prism load. The unit weight of soil should be developed by the project geotechnical engineer based on the geotechnical exploration and testing program documented in the geotechnical reports. Backfill height and trench conditions will be provided in the project drawings.

The earth load varies with soil characteristics. More importantly, it varies with installation conditions. Following AWWA M-11, when a flexible pipe is buried in an embankment or wide trench, the settlement ratio for the soil is assumed to be zero. As such, the prism of soil over the pipe is used in the AWWA calculation as a resultant earth load (Prism Load) and is used for the pipeline installation condition.

The Prism Load will be calculated using the following equation:

$$W_c = HwB_c$$

Where: W_c = Dead load on conduit, pound per linear foot.

H = Height of fill above pipe, feet.

w	=	Unit weight of backfill material, pound per cubic foot.
B_c	=	Outside diameter of the pipe, feet.

Pipe Deflection Minimum wall thickness for external loads shall be determined using the Modified Iowa formula, as presented in AWWA M-11:

$$\Delta D_v = D_L[\frac{KWr^3}{(EI + 0.061E' * r^3)}]$$

Where:	ΔD_v	=	Pipe vertical deflection in inches.
	D_L	=	Deflection lag factor.
	K	=	Bedding constant (0.1).
	W	=	Load per unit of pipe length, pound per linear inch.
	r	=	Pipe radius, inch.
	EI	=	Pipe wall stiffness, pound-inch.
	E'	=	Modulus of soil reaction, psi.
Where:	E	=	Modulus of elasticity (30,000,000 psi for steel and 4,000,000 psi for cement mortar).
	I	=	Transverse moment of inertia per unit of length of individual pipe wall components, inch^3.

The limiting value of allowable deflection will normally be the maximum deflection that does not impact the integrity of the lining or coating system on the pipe. Limit deflection for pipelines to the limits noted below in Table 3-4.

Table 3-4. Pipeline Deflection Limits

Pipe Type	Deflection Limit
Steel Pipe, dielectrically (i.e., Polyurethane) lined and coated	3.75%[1]
Steel pipe, mortar lined and dielectrically coated (i.e., tape wrap or polyurethane)	2.25%[1]
Steel pipe, mortar lined and coated	1.5%[1]

Note:
[1] Limits are 75% of AWWA allowable limits.
Key:
% = percent
AWWA = American Water Works Association

The following Table 3-5, Deflection Lag Factor, should be considered and applied as appropriate for selection of the deflection lag factor.

Table 3-5. Pipeline Deflection Lag Factor

	Granular Soils/CLSM		Cohesive Soils	
Pressure	Cover <2D	Cover >2D	Cover <2D	Cover >2D
>30 psi	1.0 to 1.15	1.1 to 1.2	1.15 to 1.25	1.2 to 1.352
<30 psi	1.1 to 1.2	1.15 to 1.25	1.2 to 1.35	1.25 to 1.5

Key:
CLSM= controlled low strength material
D= diameter of pipe
PSI = pounds per square inch

The bedding constant should be 0.1 (approximately 60-degree bedding angle). Modulus of soil reaction (composite E') should be as recommended by the future project geotechnical report. Composite E' is the combination of E'_n, (modulus of soil reaction for the native surrounding soils) and E'_b (modulus of soil reaction for the pipe zone material).

The pipe wall thickness required to meeting deflection requirements is the second design wall thickness calculated. If either calculated thickness is greater than the normal maximum plate thickness that can be used in pipe manufacture by spiral weld machines, then improvement of the bedding and backfill around the pipe may be required to strengthen the pipe/soil interaction, reduce deflection, and reduce the minimum wall thickness.

Pipe Buckling The third calculation set for pipe wall thickness is the buckling equation. The first step in this process includes defining the allowable buckling pressure using the allowable buckling pressure equation in AWWA M-11 (Equation 6-7).

$$q\_a = (1/FS)(32R\_\omega\ B'E'EI/D\text{^}3\ )\ \text{^}(1/2)$$

Where: q_a = Allowable buckling pressure in psi (kiloPascal (kPa)).

FS = 2.0 (factor of safety).

D = Diameter of pipe, in. (millimeter (mm)).

R_w = Water buoyancy factor.

= $1 - 0.33\ (h_w/h),\ 0 \leq h_w \leq h$

h_w = Height of water surface above top of pipe, in. (mm).

h = Height of ground surface above top of pipe, in. (mm).

B' = Empirical coefficient of elastic support (dimensionless).

= $1/[1 + 4e^{-0.065H}]$

= $1/[1 + 4e^{-0.213H}]$ (equivalent metric equation)

Where: H = Height of fill above pipe, feet (meter).

E' = modulus of soil reaction.

EI = Pipe wall stiffness.

This equation defines the limit of collapse (radial hoop) pressure that the pipe can sustain with an appropriate factor of safety.

For normal pipe installations, there are two additional calculations required to determine if applied loads (pressures) exceed the allowable pressure, from the calculation above. The first of these equations calculates the applied pressure from groundwater, soil and vacuum pressures, as given by AWWA M-11 (Equation 6-8). This pressure must be lower than the allowable pressure. If not, the pipe wall thickness must be increased to resist buckling.

$$\gamma_\omega h_\omega + R_\omega \frac{W_c}{D} + P_v \leq q_a$$

Where: h_ω = Height of water above pipe, in. (mm).

γ_ω = Specific weight of water = 0.0361 pounds per cubic inch (0.0098 kPa/cubic mm).

P_v = Internal pressure in psi (kPa); atmospheric pressure less absolute pressure inside the pipe, in psi (kPa).

W_c = Vertical soil load on pipe per unit length, in pounds per inch. (kPa/mm).

At certain points along the pipeline (e.g., at right-of-way crossings), it is appropriate to consider live loads as a component of the external buckling load. However, the simultaneous application of live-load and internal vacuum transient is not normally required. Where live loads are considered, the buckling requirement is satisfied by AWWA M-11 (Equation 6-9). Thus, the second buckling pressure equation deals with groundwater, soil and live load pressures on the pipe and is calculated using the equation that follows. This pressure must also be lower than the allowable pressure. If not, the pipe wall thickness must be increased to resist buckling.

$$\gamma_\omega h_\omega + R_\omega \frac{W_c}{D} + \frac{W_L}{D} \leq q_a$$

Where: W_L = Live load on the pipe per unit length, in pounds per inch. (kPa/mm).

Additional pipe load (stress) conditions

Additional pipe load (stress) conditions include the following:

Poisson's ratio.

Temperature change (thermal stresses).

Thrust forces.

Each of these design conditions create additional stresses in the pipe wall that must be accounted for in the design to provide adequate pipe life and avoid overstressing the pipe material.

Poisson's Ratio Poisson's ratio is the force applied to the pipe as a result of internal pressure and acts uniformly around the pipe in a longitudinal direction. As the pipe expands due to the hoop stress (internal pressure), it also shrinks in length due to Poisson's effect.

Poisson's ratio for steel is usually given as 0.30 and mortar is given as 0.25. Therefore, the longitudinal stress created by internal pressure would be 30 percent of the applied hoop stress.

Thermal Stresses Temperature-induced thermal stresses are created in the pipe as a result of temperature fluctuations over the daily operation of the facility. The stress induced into the pipe wall due to temperature changes is:

$$\sigma_P = P \times t \times \alpha$$

Where: σ_P = Induced pipe stress.

t = Temperature change (degrees Fahrenheit (°F)).

α = Thermal expansion coefficient for steel, 6.5×10^{-6} inch/°F

The specifications must state the maximum allowable temperature of the steel when the closure joints are welded. If controlled low-strength material (CLSM) is used to backfill the pipe zone, the maximum temperature of the CLSM must also be stated in the specifications. The force due to a drop in temperature, between the time the joints are welded and the pipe is placed in service, will always create tension in the pipe wall. Temperature stresses must be considered in the combined stress analysis described in this sub-section.

Thrust Forces Waterlines are subject to hydraulic thrust forces at the locations of change in direction or diameter, wyes, tees, or termination at a plug or valve. Thrust is generated by internal hydrostatic pressure and dynamic (momentum) forces. Dynamic forces are usually not significant in pipelines unless velocity head is large in comparison with hydrostatic pressure.

In high velocity pipelines, however, dynamic thrust may be sizeable. Hydrostatic pressure will usually be the greatest long-term pressure the pipeline is subjected to and governs the design of thrust anchorage. Thrust design pressure is the larger of working pressure, test pressure, or pump shutoff pressure.

Transient pressures (surge), however, may also be considered as thrust-generating forces if potential exists for greatly exceeding the test pressure or shutoff pressure. The Design Engineer should estimate the magnitude of hydrostatic thrust force at the bends, dead ends, branches, and closed valves, and shall ensure that anchorage of pipelines to withstand the applied thrust forces is accomplished through the use of restrained joints. Restrained joints rely on the transfer of thrust to the soil by friction between the pipe surface and the soil. Thrust blocks will not be allowed.

Design of restrained joint systems is not covered by this Design Criteria summary; however, most pipe manufacturers provide literature on the subject for use with their pipe materials. It is important to understand each thrust restraint design method as they differ widely between manufacturers. These methods vary in the way the thrust loading is applied to the pipe, and in some cases, the side soil adjacent to the pipe. Therefore, the adjacent soil properties could also be required depending on the method chosen for design.

In addition, several soil factors used in the design vary by manufacturer method. It is important to identify this information in the future project geotechnical report, including safe bearing load of undisturbed in situ soil, soil cohesion, angle of internal friction, and soil unit weight.

The most conservative method is the one presented in AWWA M-11 (shown in Figure 13-16 and Equation 13-6) and will be the recommended method for thrust restraint length calculations for the projects (Note, be sure to apply the correct formula per the July 2004 Errata issued for equation 13-16 for the Fourth Edition of AWWA M-11).

The thrust loads must be capable of being carried by the pipeline and joint system used. The design of fillet welds at the pipe joints will be required to verify that the load transfer can take place across the welded joint. Circumferential fillet weld design is covered in AWWA M-11 on pages 220 through 222 of the Fourth Edition. The following longitudinal joint efficiencies are to be used in joint design:

e = 0.45 (single-welded lap).

e = 0.55 (double-welded lap).

e = 0.70 (butt weld, no radiographic test (RT).

e = 0.85 (butt weld, partial RT).

e = 1.00 (butt weld, full RT).

See AWWA C206 for guidance on welding procedures.

Check to verify that the combined applied stresses do not exceed the allowable weld stress. The axial stresses can never exceed half of the hoop stresses caused by internal pressure. Also, the tension and the thermal tension stress is not additive since tension can only exist if it is not restrained and the thermal stress can only exist if the pipe is restrained.

Fittings and Specials

Fittings should have standard dimensions in accordance with AWWA C208. In general, large radius bends (R = 2.5D) should be used to minimize head losses and reduce stress levels in the fittings.

Joints

All pipe shall use lap welded slip joints. An inside lap weld will be used for pipes 48 inches and larger. Internal and external lap welds may be used when thrust design requirements exceed capability of internal single weld. Pipes 42 inches and smaller shall be welded from the outside. During design the pipeline Engineer shall verify the pipe, fittings, and field welds are suitable to handle resist thrust forces. Joints welded inside and outside may be required for high thrust areas. Thrust restraint requirements will be shown on the Design Drawings.

Butt straps will be allowed for applications requiring field adjustment or closures. Butt straps shall be welded from the inside and outside and incorporate threaded holes to allow testing by an air and soap test.

Appurtenances

Pipeline appurtenances (including air release valves, combination air release and air/vacuum valves (CARV), blowoff valves, isolation valves, manways, and pipeline markers) will be provided along the pipeline where needed to support pipeline function and operation. Exact appurtenance locations will consider conflicts with other structures, vehicular traffic, existing utilities, and will avoid those locations most vulnerable to damage or vandalism. The appurtenances will be co-located in vaults where possible to reduce costs and space requirements. Where the Delta-Transfer Pipeline runs parallel to the existing Old River Pipeline, it is anticipated that appurtenances will be located in approximately the same location (stationing) as the existing appurtenances for ease of access and operation. The purpose of each appurtenance and key design criteria are described below:

Air Valves

Descriptions and design criteria associated with air release valves, air and vacuum valves, and CARVs are summarized below.

Air Release Valves The purpose of air release valves is to vent relatively small quantities of air that accumulate at the high points in the pipeline during normal system operations. Valves are typically located at all high points, although they may also be located along long flat or descending slopes, or descending grade breaks at significant vertical bends where velocities may be insufficient to keep air pockets moving forward to the next high point. Air vales are typically sized based on the maximum differential pressure at each valve location based on an air flow rate equal to 2 percent of the maximum water flow rate, using manufacturer design recommendations for orifice diameter and valve size. For the purposes of this conceptual design air release valves have been sized and located to match air valves on the existing parallel Old River Pipeline. Final air valve sizing and locations will be determined during final design.

Air and Vacuum Valves The purpose of air and vacuum valves is to exhaust or admit large volumes of air during filling or draining of the pipeline. They are located at high points or significant changes in grade. Valves are sized for the worst case of filling or draining the pipeline. The worst

case for draining typically occurs during a pipeline failure. Large steel pipe may collapse under significant negative pressures, so the collapse pressure must be checked based on the appropriate AWWA M-11 formula. Valves are then sized using the maximum filling rate, maximum draining rate, pipe collapse pressure, and manufacturer performance graphs. Straight air and vacuum valves are not proposed for this project but this function will instead be provided through the use of combination air release and air/vacuum valves described below.

Combination Air and Vacuum Valves CARVs incorporate operating features of both air release valves and air and vacuum valves. These valves will be provided at all pipeline high points along the alignment, and at significant downward grade breaks, and potentially along long continuous slopes at a spacing of 2,500 feet. The air discharge/inlet pipe from the valve will terminate with a stainless-steel mesh bug screen. Sizing is based on the criteria described in the two paragraphs above. For the purposes of this conceptual design, CARVs have been assumed to be sized and located to match CARVs on the existing parallel Old River Pipeline. Final air valve sizing and locations will be determined during final design.

CARVs and air release valves must be inspected and serviced regularly. To facilitate inspection and preserve valve function, the valves are placed in individual access vaults that can be accessed at grade in an accessible location. A typical air valve detail is used for air release and CARV valves as shown on the conceptual design drawings, based on the detail used for the existing Old River Pipeline. The installation is shown to be combined with a manway, which is typical for these installations.

Blowoff Valves and Pipeline Draining

Blowoffs are valved pipeline outlets located at low points located between adjacent high points in the pipeline profile to allow the pipeline to be drained. Blowoffs are used to drain and flush the pipeline prior to internal pipeline inspection or repairs. A typical blowoff detail is proposed as shown on the conceptual design drawings, based on the detail used for the existing Old River Pipeline. They consist of a 24-inch manway outlet with a reducing flange, an 18-inch gate valve, an 18-inch riser pipe extending to the top of the vault and above grade, with a 12-inch flanged outlet. Use of a portable pump is required to drain the pipeline completely.

The operational approach for draining the Delta-Transfer Pipeline should be similar to the current plan for draining the Old River Pipeline. That is, the pipeline should first be drained back to the Old River to reduce the head at other blowoff locations, thereby reducing the volume and velocity of discharges from blowoffs to canals, creeks, and other water courses along the pipeline alignment. The procedure to dewater the Delta River Pipeline would be as follows:

1. The Old River Pump Station would be shut down.

2. At the Transfer Facility site, the Delta-Transfer Pipeline Isolation valve leading to the Expanded Transfer Facility Reservoir and other facilities at the site would be closed, and two valves at the Old River Pump Station site connecting to the Old River pipeline would be closed to isolate the Delta-Transfer Pipeline.

3. The Middle River pump station and the Old River Pipeline would remain on line and continue to deliver water to the Transfer Facility.

4. The 24-inch drain valve at the Old River Pumping Plant would be opened to drain the majority of the Delta-Transfer Pipeline water back to the pump station wetwell.

5. Remaining water in the Delta-Transfer Pipeline would be then be drained through blowoffs at the Reclamation District 800 irrigation canal, Kellogg Creek, and other individual pipeline low points via other blowoffs.

Generally, blowoffs are sized so that a given pipeline reach can drain within 12 to 24 hours. However, in this case, all blowoff are proposed at 12-inch diameter to match blowoff facilities provided on the existing Old River Pipeline. Actual drain rates may need to be throttled to a lower flow rate to avoid overloading local ditches and waterways with runoff.

Isolation Valves

A mainline isolation and flow trimming valve will be provided for the Delta-Transfer Pipeline at the Old River Pump Station site for isolation and flow control purposes. This valve will be located downstream of the new meter vault. The planned configuration uses a reduced diameter ball valve for flow trimming and a bypass with another ball valve. The bypass piping is used for pipeline filling and flow control at low flows and includes a fixed orifice sleeve to produce back pressure on the bypass valve to avoid cavitation on the bypass valve. This isolation and flow trimming valve configuration matches the approach used for the existing 78-inch Old River Pipeline but is scaled down to accommodate the smaller flow through the 66-inch-diameter pipeline.

Other mainline isolation valves are planned to allow isolation of the Delta-Transfer Pipeline from the Old River Pipeline, as shown on the drawings at the Old River Pump Station Site and the Expanded Transfer Facility. There will be no main line isolation valves along the length of the Delta-Transfer Pipeline, which is consistent with the approach for the Old River Pipeline. The mainline isolation valves will be full diameter butterfly valves either located in vaults or above grade when associated with above grade piping as shown.

Additional smaller isolation valves will be required at blowoffs, air valves, and any other connections to the pipeline. Butterfly valves are used on the air valve connections and gate valves are used on the blowoff connections to match existing details. These valves are located with vaults as shown in the details.

Access Manways

The pipeline interior is entered through access manways consisting of 24-inch-diameter flanged outlets, located inside vaults. The manways allow worker entry during construction for welding, cleaning, coating and inspection activities. The manways may also be used periodically during the pipeline's active life for inspection and minor repairs. Based on the Old River Pipeline design, manways will be provided at all air valve and blowoff locations and no other intermediate locations; this provides access typically at about 3,000 feet or less spacing, except for two reaches where the distance between manways extends from about 3,000 to 4,500 feet.

Pipeline Markers

Right-of-way signs exist at ingress/egress points and pipeline station markers along the existing Old River Pipeline at 1,000-foot intervals centered on the pipe. There are also existing markers placed

close to valves and other appurtenances. New pipeline markers will be provided using the existing marker detail to locate the Delta-Transfer Pipeline centerline location, stationing, and appurtenances.

Siting and Land Requirements

The Delta-Transfer Pipeline alignment has been designed with the intention of staying on one side of the existing Old River Pipeline and within the existing permanent easement of the Old River Pipeline. The existing permanent easement is 85 feet wide and the existing Old River Pipeline is situated off center of the easement (i.e., 50 feet available on one side of the Old River Pipeline centerline and 35 feet is available on the opposite side). Typically, the side in which there is a 50-foot-wide corridor allows for the most optimal space for construction and later maintenance. The proposed Delta-Transfer Pipeline alignment will be placed between 15 and 25 feet offset from the centerline of the Old River Pipeline and installed within the existing easement along the north side of the Old River Pipeline. The north side is typically the wider side of available easement. However, there are some relatively short sections where the north side of the alignment falls within the narrow side of the existing permanent easement.

To provide sufficient space for construction, in a cost-effective manner, it is recommended that additional temporary construction easements be acquired along the length of the proposed alignment. Locations and lengths of additional temporary construction easements (TCE) vary along the pipeline due to available space within and outside the easement. The additional TCE is shown on the plan and profile of the conceptual drawings where available, recognizing that there are some areas where it is not feasible to acquire additional easements due to existing development.

Along with the TCE needed for construction it is suggested that additional permanent easements be acquired for future maintenance along lengths of the pipeline. In these areas the pipeline is being constructed in the narrow side of the available easement which leads to limited space on the north side for future maintenance. By acquiring this additional easement, similar trench slopes can be used to excavate and access the pipe in the future if needed.

Geotechnical Considerations

Based on previous geotechnical investigations, the soils around the existing Old River Pipeline can be generally divided into three distinct strata, the levee fill, the peaty or topsoil materials, and the alluvial soils.

Levee fill is found around the Old River Pump Station. The peaty soils were found in many areas of the alignment but were contained within approximately15 feet below the surface. Below the top soil and peaty layers, alluvial soils composed of silty clay or clayey silt with intermittent thin layers of silty or clayey sand were encountered.

The majority of the Delta-Transfer Pipeline is located in alluvial soils that are relatively weak and with a shallow ground water table. This is especially true for areas closest to the Old River Pump Station, where the ground elevation is below 0 feet, therefore dewatering may be needed during construction. These soils also have high liquefaction potential which needs to be taken into design consideration for the pipeline. Soils throughout the area may have moderate to high expansion

potential and are not suitable for structure backfill or structure support. The project area is also located in a seismically active area with several faults nearby.

Trenches and Shoring

Open cut trenches are allowed for areas where there is adequate space for stable trench slopes. This method will be used for a majority of the alignment, but for areas where there is little room for safe trenches, shoring can be used to support the trench walls where appropriate for the soil conditions. It will be the contractor's responsibility to provide temporary shoring that is compliant with California Occupational Safety and Health Administration. Trench sections have been developed for the conceptual design and can be found on drawing GC-1 of the Los Vaqueros Conceptual Drawing package.

Pipeline Crossings

The Delta-Transfer Pipeline will cross the following types of facilities and waterways:

- Roads
- Railroads
- Pipelines
- Underground telephone and Fiber Optic Cables
- Agricultural Drainage channels
- Creeks

This section describes general conceptual design approaches and design criteria for these crossings, as shown on the design drawings. These criteria will need to be further developed and reviewed with owners or agencies responsible for approving or permitting the crossing designs during later design development stages.

This section does not address the following types of crossings which may require agreements with owners or agencies but do not specifically impact the pipeline design:

- Overhead powerline crossings
- Overhead telephone line crossings
- Privately owned drainage and irrigation channels

This section does not address specific cathodic protection and test station connections that may be required at utility crossings. Specific criteria for these features should be developed during the later design development phase.

Road Crossings

Open Cut Bixler Road and Hoffman Lane are existing paved roads under Contra Costa County Public Works Department jurisdiction. The current conceptual design is based on an assumed open cut road crossing approach at these locations using similar design details as those developed for the previous Old River Pipeline. The County will require traffic control, detour plans, compaction requirements, and surface restoration conforming to Caltrans requirements.

Bore and Jack Trenchless crossings are proposed at the Byron Highway and Vasco Road. The crossings would be constructed by slipping the pipeline inside a steel casing (minimum 78 inches in diameter) installed via the bore and jack construction method. Casing spacers and installation details will be similar to the casing installations provided for the Old River Pipeline at these locations.

Railroad Crossing

The Southern Pacific Railroad crossing will be constructed by slipping the pipeline inside a steel casing (minimum 78 inches in diameter) installed under the railroad tracks via the bore and jack construction method. The design will be done in accordance with Southern Pacific Transportation Company design and construction requirements as outlined in the Southern Pacific Lines Common Standards. This includes a minimum 5.5 feet of cover from the top of the casing to the base of the rail. However, because of the vertical location of other utilities at the crossing it is likely the depth of cover will be closer to approximately 10 feet or more. The design should consider potential settlement and provide appropriate settlement monitoring during construction.

Pipeline Crossings

Petroleum and Natural Gas Pipeline Crossings The Delta-Transfer Pipeline will cross several petroleum and natural gas pipelines. Preliminary information regarding the approximate location diameter, owner, and minimum clearance requirements for these crossings based on data from the previous Old River Pipeline design is shown in Table 3-6. Facility Owners should be contacted to identify specific additional crossing criteria and requirements. In addition, further investigation is required to determine if there are additional petroleum or natural gas pipelines along the current alignment.

Table 3-6. Minimum Utility Clearances for the Old River Pipeline

Station	Diameter	Owner	Product	Minimum Vertical Clearance (inches)
127+85	42	PG&E	Natural Gas	12
210+60	4	PG&E	Natural Gas	12
239+25	12	Santa Fe Pacific	Refined Products	24
240+30	8	Chevron	Refined Products	12
240+65	12	Unocol	Natural Gas	24
348+10	26	PG&E	Natural Gas	12
348+20	18	Chevron	Crude Oil	12

Key:
PG&E = Pacific Gas and Electric Company

Water Transmission and Irrigation Pipelines The Delta-Transfer Pipeline will cross numerous water transmission and irrigation pipelines. Typically, there is a 12-inch minimum vertical clearance required for these pipeline crossings. The utilities and agencies that own and operate these pipelines have specific criteria governing the crossing of their pipelines. These additional requirements should be identified during design development.

Telephone and Fiber Optic Cable Crossings The pipeline alignment crosses both Verizon and US Sprint communication cables. The conceptual design is based on a 12-inch minimum vertical clearance required for these crossings. The companies that own and operate these communication cable crossings have specific criteria governing the crossing of their facilities. These additional requirements should be identified during design development.

Drainage Channel Crossings

The Delta-Transfer Pipeline crosses the Reclamation District 800 drainage channel near stations 34+50, and 100+40 and another relatively large earthen drainage canal at station 80+70. Reclamation District 800 requires a minimum vertical clearance of 8 feet between invert of the ditch and the top of the pipeline. Lean concrete or CLSM placed in the pipe zone is also required at these three crossings to protect the pipeline during channel cleaning operations. The total flow of the channel must be diverted during construction. The crossing details will use details similar to the corresponding Old River Pipeline crossings. . No thrust blocks would be required at these crossings since the pipe has all welded joints and thrust would be resisted through the pipeline and soil friction along the pipe. Other minor earthen drainage canals or ditches will be crossed without concrete or CLSM trench backfill, similar to the corresponding Old River Pipeline crossings.

Creek Crossings

The Delta-Transfer Pipeline crosses Frisk Creek near station 113+70. The conceptual design is based on the approach used for the Old River Pipeline Crossing of Frisk Creek and requires concrete encasement to protect the pipe from potential damage during high flow scour events. The top of the pipe must be placed below a maximum scour depth or 5 feet below the invert of the stream whichever is greater. The crossing shown in the conceptual design drawings corresponds to the open cut construction design approach used for the Old River Pipeline crossing. However, ultimately the final design crossing criteria must be based on the current requirements of the appropriate regulatory agencies. The open cut construction method may not be possible any more if the permitting requirements have changed significantly and trenchless methods may ultimately be required.

Cathodic Protection

Assuming steel pipe is to be used for the construction of the new pipelines, cathodic protection will be necessary due to the corrosive properties of the soil indicated in previous reports. Although no new soil corrosivity testing has been done at this time it is assumed that the corrosion control and cathodic protection criteria used for the original Los Vaqueros Project are appropriate for the new pipelines as well. Soil resistivity surveys for sizing cathodic protection systems will be completed during the next phase of design.

Based on the previous criteria for the Los Vaqueros Project there will need to be an impressed current cathodic protection system using deep well anodes and test stations located at approximately every 1,000 feet, at foreign pipeline crossings, and at pipe casings for the Delta-Transfer Pipeline, the Transfer-Bethany Pipeline, and for pipelines at the new Expanded Transfer facility and at the new Neroly High Lift Pump Station Facility. These criteria are assumed as requirements at this stage of design development.

Other General Civil Design Criteria

This section describes other general civil design requirements and design criteria associated with work along the pipeline alignment, at the Expanded Transfer Facility, and at the Old River Pump Station facility.

Access and Grading Requirements

Access to pipeline facilities and appurtenances is necessary for future maintenance. Since the Delta-Transfer Pipeline will run parallel to the existing Old River Pipeline and appurtenances for the new pipeline have been clustered near the existing appurtenances, the existing access roads can be used for access to most new appurtenances. However, there will likely be some locations where slight modifications are needed. This may require the construction of extensions to existing gravel roads.

New paved access roads will be provided at the Expanded Transfer Facility including the area around the reservoir tank, the surge tanks, the pumping plant, and the MCC building. These areas will be paved with 2½-inch asphalt concrete pavement over 12 inches of aggregate base. A 16-foot-wide paved access road will be provided around the circumference of the reservoir tank. Paved areas should be graded to a minimum 2-percent slope with curbs and gutters for drainage.

Permanent cut slopes around the Expanded Transfer Facility reservoir shall be a maximum 2H:1V for stability and ease of maintenance. Permanent fill slopes will vary depending on location around the site but shall be a maximum of 2H:1V. Maximum temporary cut and fill slopes will be determined by the contractor based on geotechnical recommendations.

Stormwater Control

For stormwater drainage, storm drain pipes will be provided around the Expanded Transfer Facility where new impervious surfaces have been installed. Currently there are several drains around the existing Transfer Facility site which drain to a catch basin and then are released to a ditch offsite. The new facility's drainage system may tie into the existing system and discharge to the same location if pipe capacity is adequate. New catch basins and storm drain piping will be needed as well as curb and gutters around the Expanded Transfer Site to properly drain storm water. At the top of the cut slope for the new facility a concrete lined v-ditch will be provided to intercept runoff and guide the flow to drains which will then outfall offsite, similar to the existing facility. Stormwater concerns will be evaluated during design to determine if a new outfall is needed to accommodate the increased runoff flow from the site.

Valve Vaults

Main line isolation valve vaults will be designed with removable concrete panels for the installation of the valves and possible future maintenance requirements. The design of the vault lids and

removable panels will be traffic rated to accommodate vehicle loads as indicated in the Structural Design Criteria section of this chapter. Two 30-inch-by-26-inch access hatches will be provided so that maintenance staff can access either side of the pipe within the vault. Ladders will be provided as well as an elevated walkway to access the valve for maintenance and manual operation if necessary. A sump and sump pump is to be provided in the bottom of the vault for drainage. Inlet and outlet ventilation pipes and ventilation fan are also provided.

Restoration

During pipeline construction, the top 2 feet of soil will be stockpiled and used as final trench backfill. In grazing lands and in grassy open fields, grass will be planted to reduce the potential for erosion and weed growth. Where row crops exist, the surface will be returned to original grade, but rows will not be reproduced.

Restoration of the rights-of-way/easements after construction will be part of the construction contract. Final backfill under paved areas will meet design standards of the appropriate agency. Road surfaces, curbs, gutters and other surface improvements, disturbed during construction, will be replaced.

Design Criteria Summary

Table 3-7 presents a brief general summary of the key pipeline and civil design criteria described in this section.

Table 3-7. General Pipeline Design Criteria Summary

Description	Criteria
Pipeline Material	Welded steel pipe (AWWA C200) has been assumed at this stage of the design. Reinforced concrete cylinder pipe (AWWA C300) may also be suitable and could be considered later during design as well.
Maximum Pipeline Velocity	10 feet/second
Standard Joint	Steel spigot and bell rings with welded joints for welded steel pipe (AWWA C200), or a rubber gasket joint for reinforced concrete cylinder pipe (AWWA C300).
Pressure Class of Pipe	Varies – 200 psi maximum working pressure
Lining	Cement mortar lining per AWWA C205.
Coating	Polyethylene tape wrapped coating per AWWA C214 or a polyurethane coating per AWWA C222.
Working Pressure	2.0 factor of safety
Transient Pressure	Less than 133% of the working pressure with a 1.5 factor of safety
Pump Shutoff Pressure	Based on actual pump shutoff with a 1.5 factor of safety
Test Pressures	Limited to 1.33 times the working pressure with a 1.5 factor of safety
Deflection Limits	Limit of 2.25% for mortar lined and dielectrically coated (i.e., tape wrap or polyurethane) steel pipe. Bedding constant factor should be 0.1 (approximately 60-degree bedding angle)
Fittings and Specials	Fittings will be designed in accordance with AWWA C208 and large radius bends (R=2.5) should be used where possible.

Table 3-7. General Pipeline Design Criteria Summary (contd.)

Description	Criteria
Air Release Valves	Size based on the maximum water flow rate using manufacturer design recommendations. Valves shall be compliant with AWWA C512 Located to match air valves on the existing parallel Old River Pipeline.
Combination Air and Vacuum Valves (CARVs)	Provided at all pipeline high points and at significant downward grade breaks. Valves shall be compliant with AWWA C512 Located to match CARVs on the existing parallel Old River Pipeline.
Blowoff Valves	Provided at all low points. A typical blowoff consists of a 24-inch manway outlet, an 18-inch gate valve, an 18-inch riser, and a 12-inch flanged outlet. All blowoffs are proposed at 12-inch diameter to match blowoff facilities on the existing Old River Pipeline.
Isolation Valves	Mainline isolation valves allow isolation of the Delta-Transfer Pipeline from the Old River Pipeline and the Expanded Transfer Facility. No mainline isolation valves are located along the length of the Delta-Transfer Pipeline.
Access Manways	24-inch diameter flanged outlets will be provided at all air valve and blowoff locations with no other intermediate locations.
Pipeline Markers	At every 1,000 feet centered on the new pipeline
Bore and Jack	A steel casing (minimum 18-inch diameter larger than carrier pipe OD) will be provided at trenchless crossings
Railroad Crossing	A steel casing (minimum 18-inch diameter larger than carrier pipe OD) will be provided at trenchless crossings. Installations will comply with railroad agency requirements.
Utility Crossings	For water transmission and irrigation pipelines a 12-inch minimum vertical clearance will be required along with additional clearances and criteria per agency requirements. For telephone and fiber optic cable crossings a 12-inch minimum vertical clearance will be required along with additional clearances and criteria per agency requirements.
Drainage Channel Crossings	Lean concrete or CLSM placed in the pipe zone for all three major channel crossings. For crossing the Reclamation District 800 channel a minimum vertical clearance of 8 feet between the invert of the ditch and top of pipe. Other minor earthen drainage canals or ditches will not require concrete or CLSM backfill.
Creek Crossing	Concrete encasement required for the Frisk Creek crossing. Top of pipe must be placed below a maximum scour depth or 5 feet below the invert of the stream, whichever is greater.
Cathodic Protection	Impressed current cathodic protection using deep well anodes and test stations located at approximately every 1,000 feet, at foreign pipeline crossings, and at pipe casings.
Access and Grading	Paved access will be 2 ½-inch AC pavement over 12 inches of aggregate base and graded to a 2% slope. Permanent cut slopes will be maximum 2H:1V Permanent fill slopes will be maximum 2H:1V
Isolation Valve Vaults	Removable concrete panels for installation and maintenance of valves Lid and panels will be traffic rated Two 30-inch by 26-inch access, with ladders, on either side of the pipe A sump and sump pump Inlet and outlet ventilation pipes with a fan

Table 3-7. General Pipeline Design Criteria Summary (contd.)

Description	Criteria
Restoration	Hydroseed grassy fields and slopes for stability. Replace landscaping and surface improvements in kind. Row crops will not be replaced.

Key:
% = percent
AC = Asphalt Concrete
AWWA = American Water Works Association
CARV = combination air release and air/vacuum valve
CLSM = controlled low strength material
H : V = horizontal : vertical
OD = outside diameter
psi = pounds per square inch

Operational, Hydraulic, and Mechanical

This section covers design criteria used for operational, hydraulic, and mechanical design of project facilities.

Operational Design Criteria

The following is a list of operational flow design criteria:

- The maximum combined pipeline flow capacity from the Old River and Middle River Pump Stations (both nominal 250 cfs capacity) to the Transfer Pump Station and new Expanded Transfer Pump Station (ETPS) shall be 500 cfs.
- The total flow from the Middle River Pump Station may be directed to both the existing Old River Pipeline and the new Delta-Transfer Pipeline. Alternatively, flow may be directed exclusively to either one or the other pipeline, up to the pipeline's design capacity.
- The total flow from the Old River Pump Station may be directed to both the existing Old River Pipeline and the new Delta-Transfer Pipeline. Alternatively, flow may be directed exclusively to either one or the other pipeline, up to the pipeline's design capacity.
- At the ETPS/Transfer site flow from the Delta-Transfer Pipeline may be:
  - Comingled with the flow from the Old River Pipeline and routed to the Contra Costa Canal via the Los Vaqueros Pipeline.
  - Comingled with the flow from the Old River Pipeline and pumped to either Bethany Reservoir via the Expanded Transfer Pump Station or to Los Vaqueros Reservoir via the Transfer Pump Station.
  - Isolated from the flow from the Old River Pipeline and routed to the Contra Costa Canal via the Los Vaqueros Pipeline.
  - Isolated from the flow from the Old River Pipeline and pumped to Bethany Reservoir via the Expanded Transfer Pump Station.

- At the ETPS/Transfer site flow from the Old River Pipeline may be:
  - Comingled with the flow from the Delta-Transfer Pipeline and routed to the Contra Costa Canal via the Los Vaqueros Pipeline.
  - Comingled with the flow from the Delta-Transfer Pipeline and pumped to either Bethany Reservoir via the Expanded Transfer Pump Station or to Los Vaqueros Reservoir via the Transfer Pump Station.
  - Isolated from the flow from the Delta-Transfer Pipeline and routed to the Contra Costa Canal via the Los Vaqueros Pipeline.
  - Isolated from the flow from the Delta-Transfer Pipeline and pumped to Los Vaqueros Reservoir via the Transfer Pump Station.
  - Isolated from the Delta-Transfer Pipeline, with the Delta-Transfer Pipeline isolation valve closed, and used to feed the ETPS Station to pump to Bethany Reservoir.

Hydraulic Design Criteria

Pipelines will be sized to provide a maximum velocity of less than 10 ft/sec. As identified in the Civil Design Criteria, a 66-inch diameter was selected for the Delta-Transfer Pipeline and provides a velocity of approximately 7.5 ft/sec at the design flow (180 cfs). The Bethany Pipeline was assumed to be an 84-inch diameter providing a velocity of approximately 7.8 ft/sec at 300 cfs.

A system head curve for the Expanded Transfer Pump Station will be developed using the Hazen Williams Equation. A Hazen Williams C-Factor of 113 was determined for the Middle River Pipeline as part of the existing system hydraulic model development (refer to Existing System Hydraulic Model Technical Memorandum (TM), MWH, December 2015) and was applied to both the Delta-Transfer and Bethany Pipelines.

A surge analysis will be performed to evaluate and recommend surge mitigation measures. It is anticipated that surge mitigation devices will include hydro pneumatic surge tanks manifolded and connected to the pump station discharge header.

Mechanical

This section includes a listing of codes, standards and recommended practices that will be used on the project, mechanical design criteria for yard valving and appurtenances for the Delta-Transfer Pipeline at both the Old River Pump Station and the Expanded Transfer Pump Station sites, the equipment at the Expanded Transfer Pump Station, and the Expanded Transfer Reservoir. Note that no modifications to the Old River and Middle River Pump Stations are anticipated in the proposed project.

Codes, Standards & Recommended Practices

The following standards and references will be used for the sizing and design of the pump station, mechanical equipment, and appurtenances:

- American National Standards Institute (ANSI)/Hydraulic Institute (HI) Pump Intake Design Standard 9.8
- ANSI/HI Rotodynamic Pump for Pump Piping Design Standard 9.6.6
- EM 110-2-3105 Mechanical and Electrical Design of Pumping Stations by U.S. Army Corps of Engineers (USACE)
- Pumping Station Design by Garr M. Jones
- AWWA M-11 Steel Pipe – A Guide for Design and Installation
- AWWA C512 – Air Release, Air/Vacuum, and Combination Air Valves for Water and Wastewater Service
- ANSI/HI 2.1-2.2 – Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions
- ANSI/HI 2.3 – Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Design and Application
- ANSI/HI 9.1-95 – Pumps – General Guidelines
- ANSI/HI 9.6.1 – Rotodynamic Pumps Guideline for NPSH Margin
- ANSI/HI 9.6.2 – Rotodynamic Pumps for Assessment of Applied Nozzle Loads
- ANSI/HI 9.6.3 – Rotodynamic (Centrifugal and Vertical) Pumps – Guideline for Allowable Operating Region
- ANSI/HI 9.6.5 – Rotodynamic Pumps Guideline for Condition Monitoring
- ANSI/HI 9.6.8 – Rotodynamic Pumps – Guideline for Dynamics of Pumping Machinery

Yard Valving and Appurtenances Design Criteria

Design criteria for yard valving and appurtenances are provided in Table 3-8 below. Yard piping design criteria will be as stated in the Civil discipline design criteria section of this chapter.

Table 3-8. Yard Valving and Appurtenances Design Criteria

Item	Design Criteria
Delta-Transfer Pipeline Isolation Valve Station at Old River Facility Site	Motorized ball valve, AWWA C-507, with modulating ball valve bypass for pipeline filling and low flow trimming. Locate in buried concrete vault.
Delta-Transfer and Old River Pipeline Flow Routing Valves at Old River Facility Site	Motorized Butterfly valves, resilient seated AWWA C-504, 3 – new located in buried concrete vaults, 1 – existing
Delta-Transfer Pipeline Isolation Valve at Expanded Transfer Site	Motorized Butterfly valve, resilient seated AWWA C-504, located in buried concrete vault
Delta-Transfer and Old River Pipeline Downstream Isolation Valves at tie-in near Flow Control Station 1	Motorized Butterfly valves, resilient seated AWWA C-504, located in buried concrete vaults
Air Release Valves, Air and Vacuum Valves, and CARVs	To be provided along the piping at local high points where required for air release and/or vacuum relief. Standard detail will be provided. Refer to Civil discipline design criteria.
Blowoff Assemblies	To be provided at local low points where pipeline draining for inspection or repair is required. Standard detail will be provided. Refer to Civil discipline design criteria.

Key:
AWWA = American Water Works Association
CARV = combination air release and air/vacuum valve

Expanded Transfer Pump Station Design Criteria

Pump systems will be designed in accordance with guidelines established by the Hydraulic Institute Standards. Pumps will be selected to operate within their Preferred Operating Region during continuous operation, or within its Allowable Operating Region for intermittent operation. Pumps' best efficiency point will be optimized as close as possible to the operating point where the pumps are anticipated to operate most of the time to save energy consumption.

The pump station suction configuration will be designed to the latest Hydraulic Institute Standards ANSI/HI 9.8 - Pump Intake Standards. Computational fluid dynamic model of the pump intake configuration may be required to verify flow approach of the pump meets the recommended criteria by HI. In addition, physical modeling of the pump station is anticipated.

Pumps will be vertical, multi-stage turbine pumps similar in design and construction as the existing pump station. The ETPS will take suction from the Delta-Transfer Pipeline through a suction piping manifold. Each pump will be installed inside a fabricated steel, mortar lined and coated "can" or "barrel." The motor and discharge head will be founded on finished grade and the pump discharge valves will be located above ground. The header pipe will be located below ground and will be routed to connect to the Transfer-Bethany Pipeline.

It is anticipated that surge tanks will be used for hydraulic surge protection similar to the existing pump stations with air and vacuum valves strategically located where identified in the hydraulic transient analysis. Pump station piping and valve design criteria will essentially follow the same

criteria as the existing Transfer pump station. Design criteria for the Expanded Transfer Pump Station is summarized in Table 3.9.

Table 3-9. Expanded Transfer Pump Station Design Criteria

Item	Design Criteria
Type of Pumps	Vertical turbine pumps in barrels
Number of Pumps	6 (all duty)
Design Flow	50 cfs each
Total Pump Station Design Flow	300 cfs
Design TDH at Design Flow	126 feet
Pump Check and Flow Control	Ball Valve, AWWA C-507, with check and flow control actuation on each pump discharge
Pump Isolation	Motorized Butterfly Valve, resilient seated AWWA C-504
Air Evacuation and Vacuum Relief	CARVs at two locations on each pump discharge. Valves shall be compliant with AWWA C512.
Minimum Pump Efficiency at Best Efficiency Point	80 percent
Pump Materials of Construction:	
All materials in contact with water	NSF 61 and Lead Reduction Act Compliant
Impeller	316 stainless steel
Bowl	Ductile iron, epoxy lined and coated
Wear Rings	Hard stainless steel
Bowl Bearing	Lead free bismuth bronze
Intermediate Bearings	Neoprene with non-metallic backing
Pump Shaft	Open line shaft, product lubricated
Pump Column	Fabricated steel, epoxy lined and coated
Coupling	Adjustable spacer type coupling
Motor (also refer to Electrical discipline design criteria presented in this document)	Constant Speed, Induction type
Motor Horsepower	1,250 hp each
Expanded Transfer Pump Station Flow Meter Isolation Valve	Motorized Butterfly valve, resilient seated AWWA C-504, located in buried concrete vault
Process Piping Velocity	Pump Suction Piping: < 8 ft/sec Pump Discharge Piping: <10 ft/sec
Hydropneumatic surge tanks	Sized to mitigate surge pressures due to loss of power at the pump station

Key:
AWWA = American Water Works Association
CARV = combination air release and air/vacuum valve
cfs = cubic feet per second
ft/sec = feet per second
hp = horsepower
NSF = National Sanitation Foundation
TDH = Total Dynamic Head

Expanded Transfer Reservoir

The following design criteria apply to the new reservoir associated with the Expanded Transfer Pump Station:

- The primary Expanded Transfer Reservoir functions are similar to those described for the existing Transfer Reservoir in the original Los Vaqueros Reservoir design and summarized as follows:
  - Provide a stable water surface elevation for operation of the pumps at the Old River and Middle River Pump Stations.
  - Provide hydraulic level control for the flow control valves at Flow Control Stations 1 and 2.
  - Provide a stable suction pressure for operation of the Expanded Transfer pumps.
  - Provide storage volume required for the controlled shutdown of the Old River/Middle River pumps or the Transfer/Expanded Transfer pumps.
  - Provide a controlled emergency overflow to prevent pressure buildup in the Los Vaqueros, Old River, or Delta-Transfer Pipelines.
- It is assumed that the reservoir will be a coated steel above ground reservoir similar to the existing reservoir. As noted in the original design, the steel tank has a lower capital cost than alternative materials and allows better access for maintenance and sediment removal.
- Reservoir capacity requirements determined as follows:
  - Normal tank operating water surface elevation (WSEL) = 213 feet, same as existing 4 MG Transfer reservoir tank. The tanks are interconnected.
  - Normal operating WSEL band is calculated based on 20 minutes of flow from 2 pumps (all new and existing project pumps are nominal 50 cfs capacity). The calculated volume is split between the existing and the new reservoir tanks and added above and below the normal operating WSEL.
  - Required storage above the normal operating WSEL band is calculated from the volume pumped during the orderly shutdown of the Old River and Middle River Pump Stations, which each include five pumps. The shutdown sequence includes 5 minutes to verify Transfer or Expanded Transfer pump failure and begin the shutdown sequence at the Old River and Middle River Intakes, 2 minutes for controlled closure of each pump control butterfly valve, and a 1-minute stagger between complete shutdown of one pump and initiation of the shutdown sequence for the next pump. The total time for the controlled shutdown is assumed to be 19 minutes (with the first pump shutting down after 7 minutes on each successive pump shut down in 3-minute increments). The calculated volume is split between the existing and the new reservoir tanks and added above the upper WSEL band.

  - Required storage below the normal operating WSEL band is calculated from the volume pumped during the orderly shutdown of the Transfer (four pumps) and Expanded Transfer Pump Stations (six pumps). The shutdown sequence includes 5 minutes to verify Old River or Middle River pump failure and begin the shutdown sequence at the Transfer and Expanded Transfer Pump Stations, 1 minute for controlled closure of each pump control butterfly valve, and a 2-minute stagger between complete shutdown of one pump and initiation of the shutdown sequence for the next pump. The total time for the controlled shutdown is assumed to be 22 minutes (with the first pump shutting down after 7 minutes on each successive pump shut down in 3-minute increments). The calculated volume is split between the existing and the new reservoir tanks and added below the upper WSEL band.

  - The grand total storage required was calculated at approximately 9 million gallons. With the existing 4-million-gallon Transfer Reservoir the required volume of the new Expanded Transfer Reservoir is 5 million gallons.

- New reservoir height will match the existing reservoir height at 26 feet tall to the overflow. Required radius will be 90 feet, as compared to the existing reservoir radius of 81 feet. It should be noted that the forces developed by seismic sloshing, which will be evaluated in the next phase of design, may necessitate either an increase in tank height or additional reinforcement of the tank roof.

- Inlet/Outlet pipe designed for maximum 8 ft/sec velocity at 300 cfs flow rate.

- Internal tank overflow piping will be provided and will be set at the same elevation as the existing Transfer reservoir tank. Tank overflow will be routed to tie into the existing transfer reservoir overflow pipe and directed to Kellogg Creek. Confirmation of the appropriate sizing of the combined overflow pipe will need to be evaluated in the next phase of design. The pipe may require enlargement to carry the combined flow.

HVAC

Ventilation will be provided for the new electrical MCC building serving the new Expanded Transfer Pump Station. The ventilation system will be similar to the existing Transfer Pump Station MCC building and will include louvered access doors and two exhaust fans with output ducted to louvered roof dormers. The ventilation system will be sized for sufficient air flow to maintain interior air temperature at no greater than ten degrees above exterior air temperature.

Plumbing

Plumbing facilities will include small diameter potable and non-potable piping. As the existing nearby Transfer MCC building has a bathroom, no bathroom will be provided in the new Expanded Transfer MCC building.

Plumbing Codes, Standards and Regulations Plumbing system design will conform to the following codes and standards and any supplementary requirements of regulatory authorities having jurisdiction:

- Latest applicable version of California Building Code and Ordinances and Amendments

- Latest applicable version of International Plumbing Code
- Latest applicable version of International Fire Code
- Latest applicable version of National Fire Protection Association (NFPA)

Design Criteria

- Where available, water pressure from potable water system to buildings should be a minimum of 50 pounds per square inch gauge.
- Light duty hose valves for building exterior wash-down will be 3/4-inch globe valves with hose thread adapters.
- Medium-duty hose valves for exterior wash-down will be 1-inch globe valves with hose thread adapters.
- Pipe 3-inch and smaller shall be Type K copper tube with silver soldered fittings

Electrical

This section discusses the criteria to be used for electrical design. The governing standards, codes and practices are included.

Codes, Standards, and Recommended Practices

The work will be specified in accordance with the current applicable provisions of codes, standards, and recommended practices published by the following organizations:

- ANSI
- American Society for Testing and Materials (ASTM)
- Electrical Testing Laboratories
- Illuminating Engineering Society of North America
- Insulated Cable Engineers Association
- Institute of Electrical and Electronics Engineers (IEEE)
- The Instrumentation, Systems, and Automation Society (ISA)
- International Electrical Testing Association
- National Electrical Manufacturers Association (NEMA)
- National Electrical Installation Standards

- National Electrical Contractor Association (NECA)
- National Fire Protection Agency (NFPA)
- Underwriters Laboratories (UL)
- Occupational Safety and Health Administration (OSHA)

Specific Codes, Standards & Recommended Practices

The work will be specified in accordance with specific codes, standards and recommended practices. The latest edition in effect at final design will be used. Performance will be specified to follow applicable requirements of:

- 2014 NFPA 70 – National Electrical Code (NEC))
- 2016 California Electrical Code (based on the 2014 NEC) – California Code of Regulations Title 24 Part 3
- 2015 International Building Code (2015 IBC)
- 2016 California Building Code Part 1 and 2 (based on the 2015 IBC) – California Code of Regulations Title 24 Part 2 Volume 1 of 2 and Volume 2 of 2
- 2016 California Energy Code – California Code of Regulations Title 24 Part 6
- 2015 International Fire Code
- 2016 California Fire Code (based on the 2015 International Fire Code) – California Code of Regulations Title 24 Part 9
- 2016 California Administrative Code – California Code of Regulations Title 24 Part 1 including Chapter 10 Administrative Regulations for the California Energy Commission
- 2016 California Mechanical Code (based on the 2015 Uniform Mechanical Code) – California Code of Regulations Title 24 Part 4
- 2003 (R2010) ANSI/NEMA C37.57 Std for Switchgear Testing
- 2016 ANSI/NEMA C84.1 American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)
- 2016 NEMA Motors and Generators – 1 (MG1) Motors and Generators
- 2010 American Society of Civil Engineers (ASCE)/SEI 7-10 Minimum Design Loads for Buildings and Other Structures: including Chapter 13, "Seismic Design Requirements for Nonstructural Components," and Appendix 11A.1.3.10, "Quality Assurance Provisions" – "Special Inspection and Testing" – "Mechanical and Electrical Components"

- 1993 IEEE 141 (R 1999) IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Red Color Book)
- 2001 IEEE 242 IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Color Book)
- 1997 IEEE 399 IEEE Recommended Practice for Industrial and Commercial Power System Analysis (Brown Color Book)
- 2014 IEEE 519 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- 2006 IEEE 551 IEEE Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems (Violet Color Book)
- 2006 IEEE 1015 IEEE Recommended Practice for Applying Low Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Color Book)
- 2002 IEEE 1584 IEEE Guide for Performing Arc-Flash Hazard Calculations
- 2011 IEEE 1584b Amendment to IEEE Guide for Performing Arc-Flash Hazard Calculations IEEE Std 1584-2002
- 2013 IEEE 1584.1 IEEE Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584™
- 2015 IEEE Std C37.20.2™ Standard for Metal-Clad Switchgear
- 2013 IEEE Std C37.20.3™ Standard for Metal-Enclosed Interrupter Switchgear (1 kilovolt (kV)- 38 kV)
- 2013 IEEE Std C37.20.4™ Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear
- NECA 1 Standard for Good Workmanship in Electrical Construction (ANSI)
- NECA 101 Standard for Installing Steel Conduits (Rigid, intermediate metal conduit, and steel electrical metal tubing) (ANSI)
- NECA/NEMA 605 Installing Underground Nonmetallic Utility Duct (ANSI)
- 2017 International Electrical Testing Association ATS (ANSI) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems
- 2018 NFPA 101 Life Safety Code

- 2017 NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- 2016 NFPA 820 Standard for Fire Protection in Wastewater Treatment and Collection Facilities
- 2017 NESC C2 National Electrical Safety Code
- UL 508A-2018 Standard for Industrial Control Panels
- 2018 NFPA 70E Standard for Electrical Safety in the Workplace
- 2018 NFPA 79 Electrical Standard for Industrial Machinery

NFPA 70E Standard for the Electrical Safety in the Workplace

Based on interpretations of the NFPA 70E, segregation of electrical rooms, locked and accessible to qualified and trained electrical staff to house indoor electrical equipment (480 volts (V) and above) is suggested. Low Voltage cabinets (120V panel boards, programmable logic controller (PLC) cabinets) will be installed in adjacent rooms. This minimizes the risks of arc flash exposure to maintenance staff that may not be trained in arc flash safety and allow them to access the cabinets wearing non arc flash rated work clothes.

Energy Efficiency Guidelines

Work will be specified to comply with the National Energy Efficiency requirements as applicable, including the Energy Independence and Security Act of 2007. In particular, Title 10 Code of Federal Regulations, Part 431, Energy Efficiency Program for Certain Commercial and Industrial Equipment, including Subpart B, Paragraph 431.25 for Electric Motors; Subpart K, Paragraph 431.196 for Distribution Transformers; and Subpart L, Paragraph 431.206 for Exit Signs.

Work and materials will be specified to comply with the 2013 California Energy Code (Title 24 Part 6).

NEMA premium efficiency motors will be specified, per NEMA MG1, where general purpose and inverter-duty motors are applied, with the size and speed range listed for premium efficiency motors in 2016 NEMA MG1.

The lighting and lighting control will comply with requirements of 2016 California Energy Code (Title 24 Part 6).

The power monitoring will comply with requirements of 2016 California Energy Code (Title 24 Part 6).

The voltage drop will comply with requirements of 2016 California Energy Code (Title 24 Part 6).

Inspection Authority
The Authority Having Jurisdiction for electrical work will be Contra Costa County.

Equipment Load Estimates

4000 V Vertical Pump Load Estimate for Expanded Transfer Pump Station
The approximate load of 6 1,250 hp is 6 x 1,250 thousand volt amps (kVA) = 7,500 kVA. This will constitute most of the Expanded Transfer Pump Station load. This will be refined during the next stage of design when the specific pump sizes and speeds are selected from the pump universe of potential vendors.

Auxiliary Equipment Load Estimate for Expanded Transfer Pump Station
The approximate load of the auxiliary and facility equipment is estimated at 225 kVA. This will be refined during the next stage of design when the specific equipment is identified and sized for the project. The 120 volt 3-phase load is estimated at 45 kVA. The 120 volt 1-phase load is estimated at 25 kVA.

Old River Pump Station Vault Load Estimate
The increase in the 480-volt auxiliary transformer load is estimated to be 75 kVA so the auxiliary transformer size will increase from 150 kVA to 225 kVA.

Power Distribution
The expected power for the new Expanded Transfer Pump Station facilities is to be supplied by the utility Pacific Gas and Electric Company (PG&E). The same PG&E substation, distribution poles and rights of way that feed the existing Transfer Pump Station facilities are expected to be used to feed the new Expanded Transfer Pump Station facilities. PG&E will need to engineer and design their distribution to support the total load at this location.

Main Power Feed
The utility PG&E delivers 21 kV power via distribution poles from their substation to the end overhead pole on the hill adjacent to the existing Transfer Pump Station facilities overlooking the 21 kV to 4.16 kV existing outdoor substation and adjacent MCC building housing the existing medium voltage motor controls. The existing PG&E feed then goes into underground ductbank to the facility existing substation at the end overhead pole on top of the hill. The new 21 kV power feed to the new Expanded Transfer Pump Station facilities is expected to go underground in conduit ductbank from this same pole and feed the new facility 21 kV to 4.16 kV substation.

20.78 kV Site Distribution
The new underground ductbank carrying 21 kV power to the new substation for the new Expanded Transfer Pump Station facilities will follow the hill top ridge to a transition point to go down the hill to the new facility location. This will be laid out in more detail when final siting of the new facilities is available including the new 20.78 kV/4.16 kV substation.

20.78 kV / 480 Volt Substation

Due to voltage drop and motor starting issues the new substation shall match the existing substation in rating and footprint at a nominal base 15 kVA size. This may be reduced after the PG&E requirements and Utility impedances are determined for this project and motor starting and voltage drop calculations are performed to show that a smaller substation will meet the various requirements.

Switchboard

Switchboard(s) shall distribute 480V 3-phase 3-wire power in the MCC building to the various loads.

Motor Control Centers

Motor control centers shall house collections of motor controllers including smaller 6-pulse variable frequency drives, reduced voltage solid state starters for large constant speed motors, and contactor starters for smaller constant speed motors.

Miscellaneous Electrical Distribution

Stand-alone 480//208/120V 3-phase 4-wire lighting transformer with matching lighting panelboards shall be provided for indoor and outdoor lighting. Stand-alone 480//240/120V 1-phase 3-wire power transformers with matching power panelboards may be provided for auxiliary equipment

Utilization Voltages

Power equipment shall use 480-volt distribution power in general. Specialized power equipment such as battery chargers and other auxiliaries may use 240V single phase distribution. Indoor lighting and receptacles shall use 120V distribution power in general. Nearby outdoor lighting and receptacles shall use 120V distribution power. Distant outdoor lighting may use 208 or 240 or 480V distribution power depending on distance and power requirements. The large vertical turbine pump motors shall use the nominal 4,160V power similar to the existing pumps.

Existing Utility 21 kV Feed

The existing 21 kV feed to the existing facilities are expected to remain as they currently exist.

Equipment

The electrical distribution equipment will be designed to support the selected equipment for this facility. This includes compliance with current PG&E requirements and applicable codes and standards of the day.

Distribution System Equipment – General

The distribution system equipment will be similar to what was installed in the existing Transfer Pump Station facility, existing Old River Intake facility and existing Middle River Intake facility. Power factor correction equipment will be used to comply with the utility PG&E voltage drop requirements and support the delivered voltage during motor starting by lowering the required Utility system current draw during a starting event. A switched power factor correction capacitor will be provided to each motor starter to correct the power factor to 0.95 when running at speed. A large solid state switched power factor correction capacitor bank shall provide the large reactive motor

starting current during a motor start to support the system voltage and continuously adjust the reactive kVA provided as the motor come up to speed to keep a slightly lagging power factor.

20.78 kV/4.16 kV Substation and 4.16 kV Switchgear

The proposed 20.78 kV/4.16 kV substation and 4.16 kV switchgear is proposed to match the existing Transfer Pump Station facility substation and switchgear. This was done to accommodate voltage drop restrictions that are expected from the utility PG&E and accommodate motor starting issues related to large premium efficiency induction motors. After motor starting and load flow studies are conducted with proposed vendors and their equipment, Utility impedance data is made available, and Utility voltage drop limitation are identified specifically for this facility lower rated equipment may be considered.

Transformers

Transformers will be new equipment for the new facilities. All applicable new transformers shall comply with the Department of Energy increased efficiency requirements effective January 1, 2016 for low and medium voltage transformers per 10 CFR 431.

Switchboards

Indoor, front-accessible, fixed mounted circuit breaker switchboards, in NEMA 1-gasketed enclosures will be provided. Specification section 26 22 00, Low-Voltage Switchboards will contain additional requirements.

Motor Control Centers

Reduced-voltage-solid-state (RVSS), full-voltage-non-reversing, full-voltage-reversing, two-speed-two winding and two-speed-single-winding, other non-variable-frequency starters, and smaller variable frequency drives (VFD) powering motors less than 60 horsepower (hp) will be located within the MCCs.

Panelboards

Panelboard schedules showing panelboard description and equipment numbers, bus ratings (short-circuit interrupting and withstand, voltage, current and phase), mounting type, main and branch circuit breaker ampere ratings and number of poles, circuit numbers, load descriptions and equipment tag numbers, connected volt-amperes per phase, connected volt-ampere subtotals per phase, total connected load in volt-amperes, and a demand load estimate will be prepared.

Panelboards will be sized to accommodate expected loads in accordance with the NEC. In addition, the following requirements will be adhered to:

1. Each panelboard will be sized to accommodate 25 percent spare capacity, with at least 25 percent spare circuit breakers and will be fully bussed.

2. Panelboards will be in NEMA 1 enclosures as a minimum when in ventilated Electrical rooms. For outdoor installation and damp indoor locations NEMA 4X stainless steel enclosures will be used.

3. Machine-printed directories, with circuit descriptions complying with the 2011 NEC will be provided within each panelboard.

Specification section 26 12 16, panelboards and general purpose dry type transformers, will contain additional requirements.

Variable Frequency Drives

VFDs will be the most current model (no end-of-production) made by Eaton, ABB, Siemens, Rockwell/Allen Bradley, Schneider or Toshiba and using the latest technology and fabrication. VFDs powering motors smaller than 60 hp will be group mounted in motor control centers.

For mitigating the effects of carrier frequency problems between VFDs and their respective motors, all VFDs will, at a minimum, be provided with load-side rate of change of voltage with respect to time or similar output filters. All VFDs will have input line reactors. Additional filtering equipment as required to comply with specified harmonic limitations shall be provided.

Bypass contactors are not anticipated for any VFDs. Specification section 26 29 23, Variable Frequency Drive Units, will contain additional requirements.

Motors

Where applicable, electric motors will comply with NEMA MG1. Also, premium efficient motors will be provided, as defined in NEMA MG1, for all new motor-driven equipment complying with California Title 24 Part 6 – California Energy Code. Motors used with VFDs will comply with NEMA MG1, Part 31. Motors will be suitable for the indicated or required starting method and the environments in which they are installed. Motors will be equipped with space heaters, thermostats/thermistors, or both, will be provided with shaft bearing grounding rings, insulated bearings and properly and adequately circuited to their respective controllers with VFD lead cables. Specification section 26 05 10 – Electric Motors, will contain additional requirements.

Motors larger than 25 hp will be suitable for RVSS starters.

Medium voltage motors will be suitable for RVSS starter starting, have weatherproof II enclosures, have one resistance temperature detector bearing temperature detectors per bearing, have two resistance temperature detectors per phase for a total of six, have a space heater to prevent condensation, and have vibration sensing equipment.

Uninterruptable Power Supply Units

Battery-type uninterruptable power supplies (UPS) will be provided to supply power to critical instrumentation and control loads (e.g., PLC) and analytical instruments such as flow meters and analyzers. Each of these UPS(s) for these critical systems will provide battery backup for at least 30 minutes and will have both automatic internal static-switch bypass and manual external maintenance bypass (furnished as an integral part of the UPS package and fabricated by the same manufacturer, as the UPS). A UPS in the new Electrical Building sized for PLC, instrumentation, and controls to match the instrumentation work will be provided. Specification section 26 33 53, Uninterruptible Power, Single Phase, will contain additional requirements.

Disconnect Switches

Local disconnect switches at all motors that are remote (greater than 50 feet), out-of-sight, or both, from their respective controllers will be provided. This requirement applies to motors at all utilization voltages less than 600V. Additional requirements:

1. All motor disconnect switches will be equipped with an auxiliary contact (or an additional pole if auxiliary contacts are not available, e.g., 120V toggle switches), which will be wired to the applicable PLC controlling the motor circuit, to provide "Switch Closed" position indication to the Supervisory Control and Data Acquisition (SCADA) system.

2. All disconnect switches sized larger than 15 ampere and rated for 600V or less will be fusible and be equipped with time-delay current-limiting fuses appropriate for the branch circuit providing a minimum interrupting rating of 100 kiloampere symmetrical.

3. Where used at motors fed from VFDs or for motors with integral space heaters, or both, switches with auxiliary contacts (early-break/late-make), wired into VFD and motor controls, to disable controllers if the switches are open, will be provided.

4. An informational sign on each 480V motor disconnect switch, rated 30A and larger, that states "AVOID OPENING/CLOSING SWITCH IF MOTOR CIRCUIT IS ENERGIZED" will be provided.

5. Enclosed safety switches, rated 600V and 30A and larger, will be provided in NEMA 4X, Type 316 stainless steel, enclosures. Outlet boxes with matching conduit types and with weatherproof covers, for all motor-rated toggle-type switches will be provided;

6. The above requirements will not apply to motor installations where installing a local disconnect switch at the motor is impractical (e.g., submersible pump) or would create a more hazardous condition.

Overload Protection

Each motor will have thermal overload protection in all ungrounded phases per the NEC. Controller-mounted relays will have an external manual reset.

Ground Fault Protection for Vault Equipment

All electrical equipment installed in an underground vault will have the line side of the feeder protected by a ground-fault circuit interrupter (GFCI) rated overcurrent protective device in the panelboard or MCC, control panel, or other power supply mounted above ground. The following will have GFCI protection in or as a part of the overcurrent protective device:

1. Lighting.

2. Convenience outlets.

3. Ventilation fans.

4. Sump pump(s).

Convenience Receptacles

The following receptacle requirements will be adhered to:

1. Duplex receptacles for general service will be installed on walls or columns and no more than 25 feet apart in all process areas and in Electrical rooms. There will be at least four duplex receptacles in each room, on each exterior equipment pad, and where required by the NEC for heating, air-conditioning, and refrigeration equipment. In NEMA 1 dry areas, receptacles will be industrial-spec grade NEMA 5-20R. Receptacles will be spaced such that from any location in a room or space two receptacles can be reached with a 25-foot extension cord in all accessible areas of the facilities.

2. Heavy duty, corrosion-resistant GFCI receptacles, in weatherproof/in-use enclosures, will be installed in outdoor damp and wet areas and in indoor areas subject to wash down or corrosive environments, and as required by code. Feed-through GFCI receptacles will not be used to serve downstream receptacles requiring GFCI protection.

3. GFCI circuit breakers in panelboards, in lieu of GFCI receptacles, will not be used.

4. Weatherproof GFCI outlets will be installed on the exterior of new buildings and at outdoor equipment pads. Outlets will be mounted no more than 50 feet apart. Roofs having any mechanical equipment using electric power will have a minimum of two weatherproof GFCI outlets that are within 10 feet of the mechanical equipment.

Specification section 26 05 36, Wiring Devices, will contain additional requirements.

Conduit and Raceway Systems

The following conduit and raceway requirements will be adhered to:

1. Separate raceway systems will be provided for each of the following:

    a. 24V direct current (DC) digital control and analog signal circuits

    b. 120V alternating current (AC) digital control circuits

    c. 120/208V and 120/240V AC power circuits

    d. 480V AC power circuits (conduits/ducts for 480V AC circuits will be combined within the same ductbanks as conduits/ducts for 120/208V and 120/240V AC power circuits)

    e. 20.78 kV AC power circuits, with separate conduits/raceways for each unit substation current and future.

    f. Fiber optic cables (2-inch minimum conduit size for all installations)

2. Minimum sizes of conduits will be 3/4-inch for exposed work and 1-inch when encased in floor slabs or when otherwise concealed. Conduit sizes that will be used for all above ground circuits are 1-inch, 2-inch and 4-inch, for all above-ground (i.e., not in ductbanks) circuits. Conduit-fill calculations will be based on conductors with cross-linked high heat water resistant insulated wire (XHHW) insulation.

3. At least three pipe-outside-diameters, center-to-center spacing, between adjacent conduits placed in concrete slabs or walls will be provided. If conduits of different sizes are run adjacent to each other, the average outside diameter for the calculation will be used.

4. For circuits below 600V, the number of conduit bends to a total of 270 degrees will be limited, at which point pull or junction boxes will be provided. For circuits above 600V, conduit bends to 180 degrees between manholes or pull boxes will be limited.

5. The maximum cable length between manholes will be less than 400 feet for an essentially straight run and reduced by 50 feet for each bend of 45 degrees; and by 100 feet for each bend of 90 degrees. Bends will be made with the largest radius possible.

6. For exterior areas (even if covered) and interior areas classified as damp/wet or "corrosive," rigid, (polyvinyl chloride (PVC))-coated galvanized rigid steel conduit that is resistant to direct sunlight will be used.

7. For exterior, underground, concrete-encased ductbanks, PVC Schedule 40 conduit will be used; however, for all elbows and bends, factory-fabricated, PVC-coated, rigid galvanized steel, with the largest available radii will be used. Field bends will not be used. The only conduit sizes that will be used in ductbanks are 2-inch, 4-inch, 5-inch and 6-inch; 1-inch conduits will only be used when included for a dedicated circuit, such as street lighting circuits.

8. For direct-buried conduits not encased in concrete, PVC Schedule 80 conduit will be used.

9. PVC-coated steel elbows and riser conduits for all below-grade/below-slab conduits that extend through slabs will be used. All through-slab conduits will be terminated flush with finished slabs with embedded PVC-coated steel conduit couplings, with factory plugs.

10. For analog process instrumentation wiring, for interior (exposed and concealed) and exterior areas, rigid galvanized steel in noncorrosive, non-damp/wet environments and PVC-coated galvanized-steel conduit in any situation that may be corrosive or damp/wet will be used.

11. For low-level process instrumentation wiring for underground installations, PVC-coated galvanized-steel conduit will be used.

12. All power, control, and instrumentation circuits will be routed in separate conduits.

13. Underground conduit runs of two or more conduits will be installed with interlocking spacers every five feet.

Specification sections 26 05 33, Electrical Raceway Systems, and Section 26 05 43, Underground Raceway Systems, will contain additional requirements.

Conductor and Raceway Schedules

Each circuit will be identified with a unique tag, usually consisting of alphanumeric characters based on Piping and Instrumentation Diagrams (P&ID) designations for control wiring and equipment designations for power wiring. Other power wiring will also require panelboard circuit designations for identification. Raceway schedules will be provided for all distribution circuits and

control/instrumentation circuits. All circuits and associated raceways on site and within a building will be shown on the site and building plans. Exceptions to this are conduits used for interior and exterior lighting and receptacle branch circuit runs.

Wire and Cable

The following wire and cable requirements will be adhered to:

1. All power wire sizes will be increased to accommodate harmonic currents when feeding, or being fed from, equipment that generates harmonic currents.

2. Conductors will be De-rated, per NEC correction factors, for all power circuits installed in non-air-conditioned interior spaces and all exterior locations, for use in an environment with a maximum ambient temperature of 45 degrees Celsius (ºC).

3. All power wiring shall be copper stranded conductors. All power conductors shall have type XHHW-2 insulation. All control wiring shall be stranded and have type XHHW-2 insulation.

4. Cross-linked polyethylene (XHHW-2) insulation will be used for all power and control wiring rated for 600V and applied to all 480V and lower voltage AC and DC systems.

5. Specialty VFD-rated, 1,000V, multi-conductor, shielded cables, with individual conductors insulated with XHHW-2, such as manufactured by Belden Cable, will be used for the output leads between VFDs and their respective motors, especially for lead lengths exceeding 100 feet. Shielded cables will be used, with PVC jacket, for installations in conduit and shielded, jacketed cables, with armor casing, for installations in cable trays.

6. Low-voltage wiring systems will be sized, rated 1,000V or less, based on 75ºC temperature rating of wire insulation.

7. All power wiring will be color coded and solid colors will be used through the entire length of the conductor using the color coding specified in Table 3-10 below.

Table 3-10. Power Wiring Color Code Summary

Wire Tape Color or Wire Insulation Color Table for Wire Identification		Color for Voltage	
	208/120	480/277	12470
Phase A	BLACK	BROWN	BLACK
Phase B	RED	ORANGE	RED
Phase C	BLUE	YELLOW	BLUE
Neutral	WHITE	GRAY	N/A
Switch Traveler Leg	PURPLE		
Ground	GREEN	GREEN	GREEN

Key: N/A = Not Applicable

8. To reduce electrical noise in instrument circuits, twisted-shielded-pair or triad instrumentation/signal cable for all 24V DC analog circuits will be used. The shield will be grounded at only one end, i.e., where the input signal arrives. Instrumentation/signal cable will comply with Insulated Cable Engineers Association S-73-532/NEMA WC 57 Standard for Control, Thermocouple Extension, and Instrumentation Cables.

9. Each control wire and twisted-shielded-pair/triad instrument/signal cable with a unique wire and cable number will be tagged. Each control wire, pair/triad, with the separate and unique numbers at the field end and at the final point of termination, as well as all accessible terminal junction box in-between will be tagged. The same wire numbers will be used for identifying terminals on terminal blocks whenever wires are landed on them.

10. Grounding cable will be insulated copper with XHHW-2 600V insulation, or uninsulated copper conductor, sized as required to comply with the NEC, at a minimum. All power cable and conduit/raceway and all control cable and conduit/raceway will contain a code complying grounding cable.

11. Special cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular manufacturer. Special cable will be installed in accordance with the manufacturer's recommendations.

12. Individual wires of control or instrument/signal cables will not be spliced. Where distances preclude use of uninterrupted lengths of wires or cables, circuits using interim terminal junction boxes will be extended, with each incoming and outgoing wire terminated on a separate, tagged terminal of terminal blocks mounted inside the terminal junction box.

13. NEMA 1 enclosures will be provided for terminal junction boxes located in indoor dry and conditioned spaces; all other terminal junction boxes will be provided with NEMA 4X, Type 316 stainless steel, enclosures. Terminal junction boxes will be provided with hinged covers, and with a terminal for each active wire and each spare wire, and with additional 20-percent spare terminals (with a minimum of five).

14. If other types and constructions of cable are required as design and construction of the project progresses, those will be designated and routed as required.

15. No. 12 American Wire Gage (AWG) copper will be used for lighting and convenience outlets as a starting minimum size. Full size neutral will be used as a minimum. Lighting and receptacle loads will not be combined on the same circuit.

16. A neutral conductor will be provided for each individual power circuit. Combined neutrals will not be used.

17. All equipment will have its wire and cables in separate conduits for power, control, and monitoring (communications and signal/instrumentation). There will not be more than three power conductors per conduit run.

18. All medium-voltage cable will be stranded copper, shielded, insulated for a minimum of 133 percent of the standard nominal system voltage being used. The insulation will be Ethylene-Propylene-Rubber. The wire stranding will have a semiconducting conductor shield. The

insulation will have a semiconducting insulation shield. The shield conductor will be copper. The cable will have a PVC jacket. The cable will be rated medium voltage (MV)-105. All medium-voltage cable will comply with ICE S-93-639/NEMA WC742006 5-46kV, Shielded Power Cable for Use in the Transmission and Distribution of Electrical Energy. The minimum size of medium-voltage cables, for distribution circuits from the service entrance 20.78 kV switchgear to the new unit substation will be No. 4/0 AWG copper, with a No. 1/0, 600V, XHHW-2 equipment grounding conductor, regardless of load and overcurrent protection device ratings.

Based on control and signal circuits designated in P&IDs, the following number of spare control/signal wires or cables will be provided:

1. 20-percent spare control wires (minimum of two No. 14 wires) from each defined field device to its respective local control panel or interim telephone junction box that interfaces with an exterior ductbank.

2. 20-percent spare signal cables (minimum of one shielded pair or triad) from each defined field device to its respective local control panel or interim telephone junction box that interfaces with an exterior ductbank.

3. 20-percent spare control wires (minimum of four #14 wires) within each multi-conductor (Tray Cable type) control cable routed through an exterior ductbank between telephone junction boxes within separate buildings and extended through building interiors to PLC or control cabinets or other final circuit-termination points.

4. 20-percent spare signal cables (minimum of two shielded pair or triad) within each multiconductor (Tray Cable type) signal cable routed through an exterior ductbank between terminal junction boxes within separate buildings and extended through building interiors to PLC cabinets.

5. All spare wires will be landed onto individual spare terminal points within telephone junction boxes, control/PLC cabinets, or other final circuit-termination.

During detailed design technical specifications will contain additional requirements.

Electrical Equipment Identification

1. All electrical equipment will be identified and tagged with a unique numbering system.

2. Laminated-plastic engraved nameplates will only be used for electrical equipment installed indoors in electrical rooms/buildings in dry non-corrosive areas. All other nameplates will be embossed/engraved Type 316 stainless steel suitable for use outdoors, in corrosive areas with exposure to sun and high-ambient temperature.

Power Distribution System Analyses

1. A short circuit and coordination study will be performed during construction by the contractor or by a selected manufacturer of the major electrical equipment, for the actual equipment being installed, to ensure proper short-circuit equipment rating of the equipment based on the short-circuit fault current availability from the point of service. This study will

build on the requirements of previous short-circuit study evaluations available from the owner and will include the existing Transfer Pump Station electrical facilities. The study will be specified to be prepared by a professional engineer, registered in the State of California. The report will be required to show the single-line diagrams for the new electrical system, including the 20.78 kV metal enclosed service entrance facility main circuit breaker and related feeder fused switches and the 20.78 kV – 4.16 kV substations' 15 MVA transformer power source and secondary 4.16 kV overcurrent protection device (OCPD); 4.16 kV – 480 V transformer power source; 480V power panelboards, switchboards, MCCs, and 480 motors, with corresponding short-circuit data. The fault current available (both maximum and minimum values and X/R ratios) from the utility company (PG&E) will be obtained by the study provider and will be confirmed by the local utility with a signed letter confirming the data. The report will be specified to show a tabulation of protective devices, time-current characteristic curves of each device and their settings. The same studies shall be provided for standby engine generator set.

2. A summary report of all the studies performed, including load flow and voltage drop study, short-circuit study, protective device coordination and evaluation study, arc-flash study, and harmonic analysis will be specified to be provided. SKM software or equal will require to be used to help generate the report, organize the information, and perform the calculations. All electronic data input to the software and output from the software will be submitted to the owner along with the software identification and version to allow future engineers to perform future studies. The report will be specified to use the design names and identification, so that the design and the report are tied together and can be related.

3. The objective of the load flow, motor starting, and voltage drop studies is to document wire and transformer sizes and taps are adequate and set to deliver power at maximum future load with a delivery voltage that does not fall below the minimum equipment utilization voltage per the voltage standards with minimum allowable utility voltage being provided. At the same time, for minimum load and maximum utility voltage, and the transformer taps set for maximum load, the voltage drop study will document that equipment utilization voltages do not exceed the maximum allowable standard value for one running piece of equipment and all others turned off. The report will also be used to verify compliance with maximum voltage-drop limits per local energy code requirements.

4. The objective of the short-circuit study is to document adequate short-circuit interrupting ratings of OCPDs (including circuit breakers and fuses), and withstand ratings for equipment, for the complete project. Additional short-circuit studies will be performed to support the arc-flash calculations where minimum fault values may be required to obtain worst-case arc-flash energies.

5. The objective of the protective device coordination and evaluation study is to provide the settings for the adjustable OCPDs and document coordination and selectivity for all the protective devices. Also, the protective device coordination and evaluations study will document protection of equipment in accordance with current codes and standards.

6. The objective of the arc-flash study is to provide arc-flash energy calculations for documenting the required personal protective equipment requirements for owner's staff, contractors, maintenance, and operation personnel working in or around the related

electrical equipment. The contractor will furnish and install the arc-flash warning labels on all equipment to comply with NFPA 70E and NEC requirements.

7. The objective of the harmonic analysis is to ensure compliance with IEEE 519-2014 and to verify that excessive harmonic voltages and currents do not occur with respect to resonant systems in particular when reduced voltage solid state starting large motors where the applied voltage waveform is chopped up to the load to reduce the applied voltage.

During detailed design technical specifications will contain additional requirements.

Load Flow, Voltage Drop, and Motor Starting Study

1. A complete load flow and voltage drop study of the new electrical system from the 20.78 kV utility supply at the substations supplying power down to each and every significant load will be specified to be provided.

2. Three steady state studies will be specified for three cases using Utility current impedance data as follows:

   – The existing Transfer Pump Station and the new Expanded Transfer Pump Station all at maximum rated load.

   – The new Expanded Transfer Pump Station at maximum rated load and Transfer Pump Station pumps are not running.

   – The existing Transfer Pump Station at maximum rated load and the new Expanded Transfer Pump Station pumps are not running.

3. The study will be specified to document design compliance with ANSI/NEMA C84.1 2016 American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz) minimum and maximum voltages.

4. Each power source will be specified to have calculations showing the maximum voltage is not exceeded at each load with no equipment running and the minimum voltage is not reached at each load with maximum running load. The calculation will be done with a computer program, such as SKM or equal.

5. For the low-voltage part of the system (600V or less) the voltage drop shall comply with California Title 24 Part 6 – California Energy Code requirements for voltage drop.

6. The Load Flow and Voltage Drop Study will be specified to be performed in accordance with IEEE 399-1997 IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis.

7. Two motor starting studies will be provided to document the voltages on the various busses stay within the ANSI/NEMA C84.1 limits during the last motor start as follows:

   – The existing Transfer Pump Station will have all pumps running at rated load and the new Expanded Transfer Pump Station will have all pumps running except the last pump

being started. The study shall document the buss voltages while starting the last pump motor with all other pumps running at full load.

- The new Expanded Transfer Pump Station will have all pumps running at rated load and the existing Transfer Pump Station will have all pumps running except the last pump being started. The study shall document the buss voltages while starting the last pump motor with all other pumps running at full load.

Short-Circuit Study

1. A complete worst-case short-circuit study of the new electrical system from the 20.78 kV Utility supply at the substation supplying power down to each and every load will be specified to be provided. Some trial and error studies will need to be performed to get the worst case with the highest fault current.

2. The study will be specified to cover the Utility source maximum available fault level and the current Utility source available fault level as two separate studies.

3. The study will document design compliance with protective device and equipment short circuit interrupting and withstand ratings having a minimum margin of at least 20 percent over the future build-out installation. The short-circuit studies will be in accordance with IEEE Standards 141, 242, 399, 551, and 1051.

4. The calculations will be done with a computer program, such as SKM or equal.

5. Complete studies will be performed for line to ground faults for the two cases named above – Utility maximum available fault level and current Utility fault level.

Protective Device Coordination and Evaluation Study

1. A complete Protective Device Coordination and Evaluation study of the project's new electrical system from the 20.78 kV utility supply at the substations supplying power down to each and every load will be specified to be provided.

2. The study will be specified to provide the settings for each and every adjustable protective device. Time Current Coordination (TCC) plots will be specified to be drawn to show proper selectivity and coordination for all protective devices.

3. The TCC plots will be specified to be drawn and generated from a computer program, such as SKM or equal.

4. A summary table of settings and devices will be specified to be generated and published for use by the OWNER and CONTRACTOR.

5. Each TCC plot will be specified to have a partial single line showing the arrangement and identification of the protective devices in the TCC plot.

6. A full set of ground fault TCC plots, coordination documentation and settings will be specified to be provided similar to the phase TCC plots with related partial single lines having the arrangement and identification information shown.

7. The results of the protective device evaluation study will be specified to be presented in tabular form with device names listed in the first column, the equipment ratings in the next columns, and the fault exposure in the next columns that can be compared to the equipment ratings and the final columns will be pass or fail and associated remarks.

8. The plotting and presentation will be specified to be performed with a computer program, such as SKM or equal.

9. The Protective Device Coordination and Evaluation Study will be specified to comply with IEEE 399-1997 IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis.

ARC-Flash Study

1. A complete arc-flash study will be specified to be provided for the project's new electrical system from the 20.78 kV utility supply at the substation supplying power down to each and every load as recommended in NFPA 70E for the two short-circuit studies noted above.

2. Arc-flash calculation will be specified to be performed per IEEE 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations, and NFPA 70E-2018, Standard for Electrical Safety in the Workplace.

3. The calculation will be specified to be performed using a computer program, such as SKM or equal.

These calculations will be repeated after an 85 percent reduction in fault available from the utility for the two cases above. The worst-case results for the four cases shall be tabulated and submitted.

Harmonic Analysis for Application of Capacitor Power Factor Correction

1. A complete Harmonic Analysis will be specified to be provided for the project's new electrical system from the 20.78 kV utility supply at the substation supplying power down to each and every load for the facility operating at full rated capacity. The analysis and calculations will present system impedance graphs versus frequency to show the electrical system natural resonances. The analysis and calculations will present expected Total Harmonic Distortion for voltage and current at each voltage level at each power transformer primary and secondary with a breakdown for each frequency component listed in the IEEE 519-2014 tables, including Table 1 for Voltage Distortion Limits and Table 2 for Current Distortion Limits. The studies will be conducted for the maximum peak load at the facilities during a motor start using a reduced voltage solid state motor starter that provides typical RVSS harmonic voltages and currents while reducing the applied voltage to the motor load using solid state switching during the initial start.

2. Harmonic calculations and analysis will be specified to be performed per IEEE 519-2014, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, and IEEE 399-1997, IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis.

3. The calculations will be specified to be performed using a computer program, such as SKM or equal.

4. Harmonic measurements of current and voltage will be specified to be recorded during actual system operation during a motor RVSS start and then compared to the calculated results to verify that the calculations are reasonable, to demonstrate no severe harmonic distortion or resonance is present in the system and to show that compliance with IEEE 519-2014 recommendations has been achieved. These measurements will be specified to be made a part of the complete Harmonic Analysis study report.

Electrical Equipment Control

The Instrumentation and Control section in this document contains the "Control System Philosophy" for electrical equipment. The following requirements will be adhered to as well as coordinated with "Instrumentation and Controls Design Criteria on Performance Requirements" section:

1. Ladder-type control diagrams will be prepared for each motor (excluding motors that are provided as part of a packaged system where the control diagrams will be provided by the manufacturer), showing all control wiring, pilot devices, auxiliary contacts, inputs and outputs between the starter and Instrumentation and Control (I&C) I/O boards, and external connections.

2. Each motor starter will be wired to receive LOCAL, OFF, REMOTE, and PLC RUN or remote equipment control panel command contacts, to accomplish the control discussed above.

3. Controls and safety shutdown interlocks (e.g., pressure switches, no flow switches, and low-low-level switches) will be directly wired to the motor control circuit. A reset pushbutton and control relay will be provided to reset the pump or motor or equipment after a shutdown.

All motor control circuits will be designed for 120V. All motor starters will have individual control power transformers with 120V secondary and with primary and secondary overload and short circuit protection.

Grounding

A complete grounding and bonding system will be provided for the new facilities according to the NEC, California Title 24 Part 3 – California Electrical Code, and as will be specified in Specifications Section 26 05 26, Grounding. Where any of these conflict, the most stringent requirements will be used.

Grounding System Electrodes

The grounding electrode system will consist of recognized building steel, reinforcing steel, approved water and process pipes, driven electrodes, buried/encased ground mats, concrete encased Ufer electrodes, and buried cables (ground rings). The grounding electrode system installed for this project will have a maximum resistance to ground of 5 ohms. If more than one rod is required, rods will be installed at least one rod length apart. At a minimum, two rods, at opposing corners of facilities, will be accessible for inspection via test wells. At a minimum, 4/0 AWG bare copper conductors will be used to interconnect the ground rods and other electrodes. In addition to other

NEC-required grounding electrodes, a concrete-encased Ufer grounding electrode will be provided for each building and structure.

All underground duct banks will be encased in reinforced concrete and will have a continuous 4/0 bare copper grounding conductor placed throughout the length of each duct bank. This grounding conductor will then be thermos-welded to the rebar, encased in the concrete and thermos-welded to the 4/0 grounding grid conductor at each end of all electrical equipment, enclosures, and electrical equipment stands, for a continuous grounding system.

Equipment Grounding

At a minimum, the following requirements will be adhered to:

1. The non-current-carrying metal parts of all electrical equipment, devices, panelboards, metallic raceways and metallic supports/structures of electric items will be connected to the equipment grounding/bonding conductors.

2. Main bonding jumpers will be connected between the service equipment ground bus, the neutral bus, and the grounding electrode system.

3. A separate equipment grounding conductor, sized in accordance with the NEC, will be provided in raceways for all feeder and branch circuit raceways and integral with all power and 120V control cables.

4. The equipment grounding conductor for feeder and branch circuits will be bonded to its respective panelboard, MCC, Substation, or switchgear at each termination.

5. Junction boxes will be connected to the equipment grounding system with grounding clips mounted directly on the box or with 3/8-inch machine screws or equal.

6. The metal sheeting and any exposed vertical metal structural elements of each building will be grounded.

7. Metal fences enclosing electrical equipment will be grounded.

8. Metal equipment platforms, poles or other metal structures, which support electrical equipment, will be grounded.

9. All conduits entering and leaving metal enclosures or cabinets will be bonded to such via conduit ground bushings. Any conduit penetrations in the top or sides of metal enclosures or cabinets will be done via threaded type hubs such as Meyer's and ground bushing style lock rings made for such hubs. Sealing lock rings are not allowed.

Good electrical connections between the grounding system and metal frames and railing that support pushbutton stations, receptacles, instrument cabinets, etc., and metallic raceway containing the circuits to these devices will be provided.

Lighting

Light-emitting diode (LED) lighting will be used for both indoor and outdoor lighting. The lighting will be designed to comply with California Title 24 Part 6 – the California Energy Code that regulates to minimize energy use.

Electric Equipment Seismic/Wind Anchorage and Miscellaneous Requirements

1. Seismic anchorage calculations will be provided for all electrical equipment over 400 pounds in weight. In addition, seismic functionality will be required for all electrical equipment that can be provided with a manufacturer's certification that the equipment will not undergo a loss of its intended function after application of specified earthquake motions. Compliance with California Title 24 Part 2, the 2015 IBC and ASCE/SEI 7-10, Chapter 13, Seismic Design Requirements for Non-Structural Components, is required for seismic loads and associated anchoring and foundations.

2. Wind anchorage calculations will be required for all exterior electrical equipment over 100 pounds in weight and all luminaire poles over 10 feet high. Compliance with the 2015 IBC and Southern Nevada Building Officials Amendments for the 2015 IBC will be required for wind loads and associated anchoring and foundations.

Equipment Finish

Electrical materials and equipment will be provided with the manufacturer's standard finish system. Enclosures for equipment located outdoors, and subject to direct sun exposure, will be suitable for a high semi-arid solar energy/high ultraviolet light energy environment. The following paragraphs contain additional equipment enclosure requirements, especially for corrosive locations unsuitable for stainless steel materials.

Altitude

Materials and equipment will be provided suitable for installation and operation under rated conditions at an elevation of 200 feet above sea level in a semi-arid environment rich in solar ultraviolet energy.

Outdoor Equipment

Equipment and devices to be installed outdoors, or in unheated or non-air-conditioned indoor spaces, will be capable of continuous operation within an ambient temperature range of -8°C to 48°C (18 to 117°F); outdoor equipment that is only rated for 40°C will be de-rated for the environment. Additional equipment such as sunshades, heating equipment, or cooling equipment will be provided so that this performance requirement can be met.

Hazardous and Corrosive Areas

The limits of corrosive areas will be specifically defined on the electrical drawings. To the greatest extent possible, electrical equipment will be located outside of these areas.

Electrical Enclosures

The following requirements will be adhered to:

1. MCCs, panelboards, and switch boards in Electrical Rooms will be NEMA 1 gasketed enclosures for indoor, dry, air-conditioned locations; NEMA 4X (Type 316 stainless steel) enclosures will be provided for indoor non-air-conditioned spaces, and all outdoor locations; NEMA 4X (Type 316 stainless steel) will be provided for corrosive environments where type 316 stainless steel holds up. Fiber-reinforced plastic will be used for enclosures only for corrosive locations unsuitable for stainless steel enclosures. Regardless of the location, the enclosure material will be compatible with the chemicals being used in the area where the equipment is being installed.

2. All enclosures will be UL listed; all assembled control panels will be UL listed as a complete assembly.

3. Custom-made control panels, comprised of a UL-listed enclosure and UL 508 listed system components, will be UL 508A listed as a complete assembly, with a labeled integrated short-circuit current withstand rating, and will comply with Article 409 of the NEC.

Instrumentation

This section describes and identifies the Instrumentation and Control equipment, networks and processes required to implement control and monitoring of the project's facility with minimal attention to its daily routine operation. The design philosophy, design criteria, materials of construction, instrumentation equipment manufacturers and related control and monitoring philosophy to meet the intent of the project are discussed.

To document the following I&C items that will be used to provide a final Facilities design:

- Preferred I&C equipment including PLCs, operator interfaces, communication devices and field instruments.

- Design criteria standards that include tag numbering conventions, Local/remote control parameters and color usage conventions.

- Intelligent P&IDs for the Facilities and associated facilities.

- Control strategies, using MWH's Control Loop Description format that describes both the main pumping system and the auxiliary systems incorporating both local and operator interface controls and how these are used to control each piece of equipment or process.

- SCADA interface description that includes how the new information generated by the new Facilities will be integrated into the existing SCADA system.

Table 3.11. Glossary of Instrumentation and Control Terms

Term	Definition
A/M	Auto-Manual
ATS	Automatic Transfer Switch
DCS	Distributed Control System
GUI	Graphic User Interface
H/O/A	Hand-Off-Auto
H/O/R	Hand-Off Remote
HMI	Human Machine Interface
L/O/R	Local-Off-Remote
L/R	Local-Remote
LAN	Local Area Network
LCP	Local Control Panel
LCS	Local Control Station
LOS	Lockable Off Switch
MCC	Motor Control Center
O/A/C	Open-Auto-Close
O/S/C	Open-Stop-Close
OIU	Operator Interface Unit
PCIS	Process Control and Instrumentation System
PID	Proportional-Integral-Derivative
PLC	Programmable Logic Controller
S/S	Start-Stop
SCADA	Supervisory Control and Data Acquisition
SCADA	Supervisory Control and Data Acquisition
VCP	Vendor Control Panel (Supplied by Equipment Vendor)
VSD	Variable Speed Drive
WAN	Wide Area Network

Codes, Standards and References

- UL – 508, Standard for Industrial Control Equipment.
- ANSI.
- ASTM International
- DIN – VDE 0611, Terminal Blocks for Connecting Copper Conductors; Distribution Terminal Blocks up to 6mm.
- ISA standards including:
  - S5.1 - 2009, Instrumentation Symbols and Identification
  - S5.4 - 1991, Instrument Loop Diagrams

  - S50.00.01-1975 (R2012), Compatibility of analog signals for electronic industrial process instruments
  - TR20.00.01-2007, Specification forms for process measurement and control instruments, Part 1: General Considerations
- NEC
- NFPA
- IEEE – C62.41, recommended practice on surge voltages in low-voltage AC power circuits.
- NEMA, including:
  - 250, Enclosures for Electrical Equipment (1,000V maximum)
  - ICS 1, Industrial Control and Systems General Requirements

Design Criteria

The overall control system design should be one which highlights ease of use, resiliency to component failure, modular construction/maintenance, and regional parts and support availability. The process control system will be designed in accordance with typical commercial production facilities standards. Design criteria intended to support this philosophical approach are bulleted below:

- The system installation approach will be geared toward location of electronic components within secured facilities to the greatest extent possible. Where electronic components must be installed outdoors, enclosures will be secured.
- Use of air conditioning units in remote panels will be avoided, if possible: panels components will be designed for extreme conditions and outdoor panels will be designed to reflect/radiate heat away from the panel.
- The selected control system equipment will be required to have regional repair, and configuration support and readily available spare parts.
- Centralized control of the new expansion facilities will be added to the existing CCWD Bollman Control Center, thereby concentrating key components within secure areas.
- The use of redundant components will allow the process to continue uninterrupted and maintenance tasks to be planned/scheduled:
  - Redundant Wide Area Network fiber optic cabling
  - Use of redundant controllers when appropriate

  - Use of redundant online power supplies for panels, communication hubs and key network components.

- Mechanical, hydraulic and reserve battery power solutions for protection against power failure or cycling.

Wiring of Field Sensors

Field sensors, process control equipment, and final control elements will be directly wired to PLCs. Control logic will reside in the PLCs. Control logic will not be distributed outside the individual facility control system, except in the case of vendor furnished packages. PLC and remote I/O cabinets will be strategically located throughout the facilities. Considerations in selecting locations will be the process area, reducing conduit and wiring lengths, non-hazardous locations, and non-corrosive locations.

Communications

Communications to valve actuators, instruments, power monitoring and motor controllers will be by network communications when cost effective. For other interfaces and instruments, hard wiring or owner preferred equipment will be used.

Local Control

Local control will typically be performed via control panels and pushbutton control stations. Lock-out stop pushbuttons will be provided at each piece of equipment. Where system control panels or area control panels are required, local monitoring and control of equipment will be provided via an electronic Operator Interface Terminals will be used. These touch screen panels may be used to display complex local controls at the field panel. The Operator Interface Terminals will communicate with the local PLC and will be configured to display specific data for the process area and will allow control of local equipment.

Programmable Logic Controllers

The PLCs will have the appropriate processing and memory capacity. PLCs will have redundant power supplies. The inputs and outputs for the PLC will be 24V of direct current for the discrete points, and 4-20 milliampere DC points for the analog signal inputs and outputs. Network compatible cards may be used for power management and protection devices, variable speed drive units and the like using standardized interface protocols.

Design for Future Considerations

In general, all site control systems and local networks will be designed in anticipation of connection and integration into a centrally managed and administered control network while minimizing installed cost. To this end, the site design will seek to employ common hardware, software, data transfer methodologies, communication medium type and communication protocols.

Control System Architecture

Control System Philosophy

The general control philosophy for the new expansion facilities is to provide a high level of automation with the minimal use of selector switches and pushbutton controls. Manual control will typically be performed from the computer-based control system and not via control panels and pushbutton control stations. Lock-out stop pushbuttons will be provided at each piece of equipment. Control logic will not be distributed outside of the individual facilities remote terminal unit system, except in the case of vendor furnished packages.

A remote terminal unit cabinet will be located in the Expanded Transfer Pump Station MCC room. The main process equipment packages will each be supplied with a main hot standby redundant PLC processors, along with I/O cabinets or additional PLC cabinets which will accommodate all I/O points for the new facility. Each PLC and I/O cabinet will be supplied power from an uninterruptible power supply.

A licensed multiple address radio system and a spread spectrum radio system will communicate from the Expanded Transfer Pump Station PLC to the Bollman Control Center. The PLC cabinet includes a local Human Machine Interface (HMI) which allows operators to control on-site equipment and monitor off-site facility conditions. The Ethernet switch in the PLC cabinet will provide connection capability for additional PLCs and workstations that are anticipated in future phases of the expansion of the project. Existing workstations at the Bollman Control Center Control Room will serve as the operation staff's primary "window" into the new facilities and will be configured to display all process information. HMI terminals at the PLC cabinets will serve as the secondary "window" into the process for the operations staff but are intended primarily for use by operators during testing and startup. The touch screen HMI terminals will allow the operations staff to locally monitor the individual equipment processes for the facility systems.

PLC Requirements

The PLCs will match with the Owner's current PLC manufacturer and will be Schneider Electric Modicon Quantum. PLCs will have redundant hot standby processors and redundant 24V DC power supplies. The inputs and outputs for the PLC will be 24V DC for the discrete points, and 4-20 milliamps (mA) DC points for the analog signal inputs and outputs. Network compatible cards will be used for power management and protection devices, variable speed drive units and the like using standardized interface protocols.

Process Requirements and Design Criteria

Instrumentation Design Criteria

- "Smart" instruments will be used where cost effective, with hardwired instruments in all other cases.
- Outdoor instruments will be designed with appropriate environmental considerations.
- Analyzers will be reagent-less type and equipped with smart sensors.

- Ultrasonic measurement will be the preferred level measurement technology for balance tanks, wet wells, reservoirs and chemical storage tanks.
- Hydrostatic level sensors will be employed where applicable.
- Ultrasonic flow meters will be the preferred flow measurement instrument in primary process.
- 24V DC or loop-power will be the preferred scheme with quick-connections for signal (and power where applicable).

Communications to valve actuators, instruments, and motor controllers will be by network communications when cost effective. For other interfaces and instruments, hard wiring or owner preferred equipment will be used. The inter-site communication medium multiple address radio system licensed radio. All controllers and control panels will be furnished with monitored, redundant power supplies and all area equipment groupings will be supported by smart UPS units (with relay-card interface), monitored by the control system via hardwire connection. Links to the portable emergency generator systems will also be established for system and fuel status monitoring.

I/O depicted on the P&ID drawings for each process area will be displayed on the HMI control screens and all analog data (as well as alarms and status points) will be historically collected, recorded and trended. Generated control screens will be consistent in presentation, quality, color usage, symbol usage, and navigation options will be developed through meetings with Contra Costa Water District.

Piping and Instrumentation Diagrams

P&IDs will be developed to approximately 50 percent complete as part of the Feasibility Report. Overview P&ID drawing GI-01 is attached to this memorandum. The P&IDs will be drawn in compliance with ISA Standard S5.1. Diagram format including symbols and abbreviations will be shown.

Level Measurement

Reservoir or tank level measurements will be made using a differential pressure actuated transducer or an ultrasonic level transducer and transmitter. The analog signal will be taken back to the Expanded Transfer Pump Station PLC.

Level Switch

A reservoir or tank high- and/or low-level switch will be provided to increase reliability of detecting a level alarm before the reservoir or tank overflows or the pumps associated with the low level in the reservoir or tank shut down.

Depending upon the final configuration of a process area, an area flood monitoring switch will be provided to detect accumulation of water resulting from a high level in a sump or flooded floor.

Level switch digital signals will be taken back to the Expanded Transfer Pump Station PLC.

Pressure Measurement
Selected pressure measurements of process lines will be monitored by the process area PLC.

Pressure Switch
A Low suction pressure switch will be hardwired into the pump control circuit to provide pump protection. An auxiliary contact on the pressure switch will be taken to the pump PLC for monitoring and alarming purposes.

Temperature Measurement
Process temperature measurements will be made using a resistance temperature detector and temperature transmitter. The analog signal will be taken back to the Expanded Transfer Pump Station PLC.

Flow Measurement
Most process flow rate measurements will be measured using an ultrasonic flowmeter. Some measurements will be measured by propeller type flow meters where the flow ranges will be limited to about a 6:1 turndown. Air flow measurements will be measured by a mass thermal flow type flowmeter. The flow rate signals will be transmitted to the Expanded Transfer Pump Station PLC and totalized.

Analytical Measurement
The process will be measured for water quality with the respective analyzers. The analyzers will generally measure turbidity, pH, conductivity, oxidation reduction potential, chlorine residual, ammonia, and other parameters. All analytical measured signals will be transmitted to the Expanded Transfer Pump Station PLC.

Instrument List Table of Manufacturers
As a minimum, all work and equipment will conform to the instrumentation design criteria defined in Table 3-12.

Table 3-12. Instrumentation Design Criteria

Measurement	Sensor Type	Preferred Manufacturer	Applications
Measurement Devices			
Flow Measurements	Ultrasonic	Accusonics	Raw water
Level Measurements	Ultrasonic	Endress Hauser or Pulsar	Reservoir, Tank, Basin or Wet well level, Chemical Tanks
	Pressure	Endress Hauser	Chemical Tanks, Pressurized Tanks
Pressure Measurements	Gage Pressure	Endress Hauser	Process pipelines, pressure vessels

Table 3-12. Instrumentation Design Criteria (contd.)

Measurement	Sensor Type	Preferred Manufacturer	Applications
DP Measurements	Differential Press.	Endress Hauser or Rosemount	Loss of Head, Filter Differential Pressure, Pressurized Tanks
Temperature Measurements	Resistance Temperature Detector	Interface Devices	Process Temperature, Ambient Temperature, motor and pump bearings
Analyzers			
Turbidity	Low Turbidity	Hach-GLI	Filtered water, finished water
	High Turbidity	Hach	Raw water
Chlorine Residual		Rosemount	All process water
Ozone Concentration	Gas	IN USA	Ozone generation
	Dissolved	IN USA	Contact basin
Suspended Solids			
Dissolved Oxygen	Optical	Hach/Insite	
Ambient Oxygen			
Analyzers			
Vibration Measurements	Vibration	Bentley Nevada	Large pump and motor monitoring
Weight Measurements	Strain Gage		Bulk chemical tanks
	Hydraulic		Bulk chemical tanks
Switches			
Flow Switches	Thermal	Fluid Components, Inc.	Process lines, seal water, chemical flows
	Vane	W.E. Anderson	Air duct ventilation
	Paddle	McDonnell & Miller	Emergency shower lines
Level Switches	Electrode Probe	Warrick, BW Vibrating Fork, Endress Hauser	Chemical day tanks
	Float	Flygt, Kari, Consolidated Electric	Dirty water levels, sludge, adhesive processes
	Magnetic	Magtech	Side mounted level gauges
Pressure Switches	Pressure	Ashcroft, SOR, United Electric	Process lines
Flood Switches	Float	Flygt, Kari, Consolidated Electric	Vaults, sumps, potential flood areas
Temperature Switches	Capillary	Ashcroft	Motor and pump bearings
Alarm Indicators			
Beacon Alarms	Strobe/Rotating	Federal Signal	Confined spaces
Panel Alarms	Incandescent	Panalarm, Rochester	Local control panels, usually vendor package systems

Table 3-12. Instrumentation Design Criteria (contd.)

Measurement	Sensor Type	Preferred Manufacturer	Applications
Indicators			
Side Mounted Level Gage	Magnetic Follower	Magtech	Chemical Tanks, Pressure Tanks
Flow Indicator	Rotating Wheel	Gems	Chemical flow lines, low flow rate applications
	Rotameter (water)	Brooks, Pennwalt	Seal water lines, analyzer sample lines, transport water
	Rotameter (air)	Headland, Universal	Bubbler panels, air supply lines
Pressure Gages	Bourdon	Ashcroft, Ametek	Pump suction/discharge lines, pressurized process lines

Major Controller Hardware and Software Components

Communication Media/Networks

The communication media for the PLC wide area network is via radio network that will communicate via Kregor Peak to the Bollman Control Center. New Ethernet switches located in PLC and remote I/O cabinets will be 1,000 megabits per second, managed industrial grade switches from Cisco. These switches will provide 100-Base-T ports for CAT-6e Ethernet cable.

Signal Levels

- Analog Inputs – Conventional Two Wire and Intelligent Transmitters:
  - Signal level to the PLC will be an isolated 4-20mA DC.
  - All instrument shields will be terminated at the PLC control panels.
  - For instruments wired directly to the PLC, the 24V DC loop power will be from the PLC control panel.
- Analog Inputs – Four Wire Transmitters:
  - Signal level to the PLC will be an isolated 4-20mA DC.
  - Signal power supply will be from the transmitter.
- Analog Outputs:
  - Signal from the PLC will be isolated 4-20mA DC at 24V.
  - Signal power supply will be from the PLC.

Control Methods

Each piece of equipment, such as a pump or valve, etc., will be controlled from the Bollman Control Center. Local manual control will be through the use of hardwired selector switches and

pushbuttons at the equipment. Remote manual control, via the computer control system, will be from the SCADA System HMIs. All automatic functions will be provided through the local PLC, with a supervisory interface through the central computer control system. Local monitoring of individual equipment packages will be available at the PLC panel mounted HMI terminals.

Control panels supplied with vendor-supplied package type equipment, such as sump pumps, will locally control the equipment in an automatic mode with monitoring performed through the Expanded Transfer Pump Station SCADA control system.

PLC Hardware Requirements

Each redundant PLC central processing unit (CPU) will be of solid-state design. All CPU operating logic will be contained on plug-in modules for quick replacement. The controller will be capable of operating in a hostile industrial environment (i.e., subject to heat, electrical transients, radio frequency interference, and vibration) without fans, air conditioning, or electrical filtering.

Each PLC will have all of the capabilities required to implement the control schemes and database. PLCs will have floating point math and Proportional-Integral-Derivative (PID) controller modulating capability. Each CPU will provide internal fault analysis with a fail-safe mode and an output for remote alarming.

Each central processor will contain all the relays, timers, counters, number storage registers, shift registers, sequences, arithmetic capability, and comparators necessary to perform the control functions. It will be capable of interfacing sufficient discrete inputs, analog inputs, discrete outputs, and analog outputs to meet the requirements and have at least 100 percent excess capacity. All PLCs will be provided to support and implement closed loop floating and PID control which will be directly integrated into the PLC control program. The power supply will contain capacitors to provide for orderly shutdown if incoming power fails. If this occurs, the processor will cease operation, forcing all outputs off. The processor will have a key type memory protect switch to prevent unauthorized program changes.

Each programmable controller will be equipped with nonvolatile flash memory of sufficient capacity to store the control program, tag data, and unit operating system with room for 50 percent growth. An indicator will show the status of the batteries and a reference will be available through the discrete outputs, to alert the Operator that the batteries need to be changed. Each controller will be supplied with an internal lithium battery which will retain the program during power outages for up to one year.

Each programmable controller will be capable of being programmed with an IEC61131-3 compliant software using simple "ladder diagram" language, and Sequential Functional Blocks. It will be capable to be reprogrammed locally with a portable laptop computer or from a remote location via a control system network. Where indicated, the controller will support hot-standby CPU redundancy. Controls will be able to switch from the primary to the secondary processor (and vice versa), automatically or manually, without interruption of plant control processes.

Each programmable logic controller will be equipped, or will have access via a linked backplane, to the following communication options as required on the Control Network Block Diagrams:

- One industrial standard, IEEE 802.3, 10 Base-T Ethernet communication port (RJ45)
- One RS-232-C serial programming port
- One Modbus TCP/IP communication port
- Remote I/O Adapter module (where applicable).

The 32-bit CPU will support floating-point math and PID functions. Processors will be web-enabled and will support all onboard memory.

Discrete Input Modules: All contact closure inputs from devices external to the programmable controller module will be optically isolated from foreign power sources and wiring or other I/O Modules. The modules will have LEDs to indicate status of each discrete input. The input modules will have a maximum of 16 points each. The PLC system will support discrete input hardware consisting of the following types:

- Powered DC inputs for devices which operate at 24V DC.

Discrete Output Modules: All contact closure outputs for ON/OFF operation of devices external to the programmable controller module will be optically isolated from inductively generated, normal mode and low energy, common mode transients. All output modules will have LEDs to indicate status of each output point. Each output point will be individually isolated, fused and connected to interposing relays as required. The PLC system will also offer discrete output hardware consisting of the following types:

- Outputs for equipment which operate on 24V DC.

Analog Input Modules: Analog inputs of 4 to 20mA DC signals with an analog to digital conversion performed with a minimum of 16-bit precision. The analog to digital conversion will be updated with each scan of the processor. Analog input modules will have a minimum of eight inputs each. Input modules will be source or sink to handle 2-wire or 4-wire transmitters respectively.

Analog Output Modules: Analog outputs of 4 to 20mA DC output signals where each output circuit will perform a digital to analog conversion (minimum 12-bit precision) with each scan of the processor. Each analog output module will have a minimum of four isolated output points which will be rated for loads of up to 1200 ohms.

Enclosure Requirements/Area Classifications

The following NEMA ratings for enclosure panels will be specified for the classified areas within the project:

- General Purpose: Enclosures will be NEMA 12.

- Outdoor Locations: Instruments and control panels will have NEMA 4X 316 stainless steel enclosures and be mounted ¼" from walls unless otherwise noted.

- Damp locations: Locations indoor and 2 feet below grade or classified as damp locations will conform to outdoor location requirements. An exception is that the space from walls may be less than ¼."

- Splash Locations: Areas that are designated as splash proof will have the same requirements as outdoor locations except that the enclosures will be NEMA 4.

- Corrosive Locations: Enclosures will be stainless steel NEMA 4X and all electrical hardware will be PVC coated.

- Hazardous Locations: Areas designated as hazardous will have all electrical installations suitable for Class 1, Division 1 or 2, Group C or D locations as required by NFPA 820.

Backup Power Supplies (Uninterruptable Power Supply)

UPS will be provided for each of the new facilities. The UPS will maintain conditioned power to all associated loads under normal conditions (line power available) and also under battery-powered conditions (for a specified time period). UPS units mounted within panels will be secured to a shelf attached to the panel backplane. Floor mounted UPS units will follow NEC code clearance requirements.

Human Machine Interface

Local monitoring and control of equipment will be provided via an HMI. The HMI will communicate with the local PLC and will be configured to display specific data for the Expanded Transfer Pump Station.

The HMI configuration will include requirements that all command outputs to equipment and set point adjustments require verification of action.

The operator display panel will meet the following requirements:

- An HMI which allows the operator to select objects on the screen, with a minimum of 120 touch cells.

- Display will be pixel-based and will support a minimum of 256 colors.

- A library of graphic symbols to use for display generation.

- Security features will require a password to control any equipment.

- An ability to communicate over Modbus or TCP/IP to the facility PLC.

Hardwired Safety Interlocks

All interlocks deemed critical to the protection of personnel and major equipment will be hardwired to the MCC with isolated inputs to the PLC. Interlocks and control devices not deemed critical for the protection of personnel and major equipment will be wired to the PLC.

All interlocks will be in affect when equipment is operated via the PLC. The critical interlocks only will be in affect when equipment is operated from the HOA station.

Software Programming

The following terms are used in the software programming of PLC/SCADA functions:

- Operator Settings: Operator set or entered values will be constants that are adjustable or set from operator displays. Examples of operator set or entered values are controller set points, batch set points, etc. Specific values that are required to be operator set will be noted in the process control strategy descriptions.

- Tunable Values: Tunable values will be constants that are adjustable at engineer level displays without requiring any software reconfiguration. These values will not generally be adjustable from operator level displays.

The following general PLC functions will be specified to be provided:

- All analog and discrete inputs to the PLC will be displayed. Both RUNNING and OFF input states will be displayed.

- All analog inputs will have instrument failure alarms when the input is below 0 percent or above 100 percent for a tunable time initially set at 10 seconds.

- All discrete FAIL inputs will be alarmed. Other discrete inputs will be alarmed as noted in the control strategy descriptions.

- When alarms are specified in the control strategy descriptions, alarms will be initiated from the applicable inputs. If discrete inputs are not available, the specified alarms will be initiated from the applicable analog input.

- All analog inputs will be trended.

- All flow inputs and equipment run times will be totalized and recorded. All totalized values will be displayed.

- Displays will be grouped functionally for ease of operation. Both analog and discrete functions associated with an item of equipment or a group of equipment will be provided on the same display.

- All discrete outputs will generally be maintained outputs. For START/STOP PLC functions, the PLC will issue a maintained START command until a RUNNING state is no longer

detected or when a STOP command is issued. When a momentary command is required, the PLC will issue the command for 2 seconds, and then remove the signal.

- For equipment that is controllable from the PLC, a control mode status signal will be sent to the PLC to indicate when the PLC is allowed to control the equipment. The PLC will monitor the control mode status (LOCAL/REMOTE) and attempt to control only equipment that is in the REMOTE mode.

- For equipment that the PLC is allowed to control, the PLC will provide a FAIL alarm if the equipment fails to comply with a PLC command signal (START, STOP, OPEN, CLOSE) that has been present for more than a tunable time period. In this event, the command will be removed subsequent to the expiration of the tunable time period.

- All PID control functions (Proportional, Proportional + Integral, and Proportional + Integral +Derivative) will be provided with standard analog controller functions and operator interfaces including the following:

  - AUTO/MANUAL mode selection: In AUTO, the output of the controller will be based on the PID control calculation. In MANUAL, the output of the controller will be operator adjustable. Transfer between operational modes will be smooth.

  - LOCAL/REMOTE set point selection: In LOCAL, the set point will be operator adjustable. In REMOTE, the set point will be adjustable from a REMOTE set point input.

  - Set point, process variable, and controller output will be displayed.

  - Provisions will be included to prevent reset windup on the controllers.

When equipment is tagged "OUT OF SERVICE" by the operator, all associated equipment will have their alarms inhibited until the tagged equipment is re-tagged IN SERVICE.

Design Philosophy

The Expanded Transfer Pump Station facility will be designed for unattended operation using a PLC based control system with remote monitoring and control. The control system will be automated to achieve maximum efficiency without providing undue complexity to the operations or maintenance personnel. Four levels of control will be provided (where appropriate):

- Local Manual Control

- Local Automatic Control

- Remote Manual Control

- Remote Automatic Control

A single Local/Off/Remote (LOR) selector switch will be provided to implement this functionality. Remote manual or auto control is selectable from either the local HMI or from the HMI at the Bollman control center.

Each of the above control methods is described as follows:

Local Manual Control

Local manual control will be provided from either a Field Control Station conveniently located on or near to the equipment, or, as in the case of a pump, from the MCC. Local manual control is engaged when the LOR switch is selected to Local. With the switches in these positions all control from the PLC is inhibited.

Selection of local manual control implies that the operator has accepted full responsibility for the operation of that equipment and is providing due diligence. In the case of taking local manual control of one of the Distribution Pumps, protecting the pump from running dry will be provided by a Low Suction Pressure Switch, "hard wired" into the pump control circuit. Thus, irrespective of the LOR switch position, low suction protection will always be provided.

Local Automatic Control

Local automatic control is implemented when the LOR switch is selected to Local. Local automatic control will only activate when all devices required are also selected to local automatic control (e.g., local automatic control) of a distribution pump can only be achieved when the associated discharge valve is also selected to local automatic control.

Remote Manual Control

Remote control is engaged when the LOR switch is selected to Remote. Remote manual is then selected from either the local OIU or from the HMI at the SCADA control center.

Remote manual control allows the operator to assume full responsibility for starting and stopping the piece of equipment. Except for the instance of manual remote control, a distribution pump, where the low suction pressure switch will automatically stop the pump, all other equipment will remain in the same state until issued some alternative remote manual command.

When the LOR switch on a device operating in remote manual control is moved from the Remote position the device immediately changes state as the switch goes to the off position.

Remote Automatic Control

Remote control is engaged when the LOR switch is selected to Remote. Remote auto control is then selected from either the local OIU or from the HMI at the SCADA control center.

Remote automatic control will be managed by the main facility PLC, which will continue operating in remote automatic control even if "off-site" communication is lost. Control parameters in the main PLC may be changed from either the local HMI or the Bollman Control Center HMI providing the operator has the appropriate authorization.

Emergency Shutdown

One emergency shutdown button will be located on a field control panel. The emergency stop pushbutton will shut down all pumps. The field control panel will also contain an emergency stop reset button that can only be operated locally. The pumps will only become available once the reset has been operated.

Control Mode Design Considerations

The Instrumentation and Control system will be designed to implement the control modes as efficiently and as effectively as possible while complying with all appropriate standards and guidelines. Design choices will be made that provide potential minimum long-term cost of ownership both in terms of energy use and equipment maintenance.

Control Monitoring Requirements

The control and monitoring objective is to provide efficient and effective control of the pump station. This will be accomplished by ensuring adequate and sufficient information is available to both the automatic control system and the supervisory system.

Tagging and Naming Conventions

All instrument tag letters will follow ISA S5.1 standard

All tagging, wire and equipment numbering, and naming will comply with CCWD standards.

All instrument tag numbers will comply with the following standards:

Example: 152-LAH-01A

152 – Facility Number

LAH – ISA abbreviation

01 – Loop Number

A- Suffix used if a redundant instrument is used for the same measurement or digital reference (example: redundant pressure transmitters)

Security and Telecommunication

The primary security facilities include a perimeter laser security system, a keycard entry system, and live Ethernet based "IP Address" security cameras.

A new telephone and data communication system will be installed at the Expanded Transfer Pump Station. The telephone and data system will include the following;

- A digital telephone line
- An analog burglar alarm line
- An analog fire alarm line

- A backup analog burglar/fire alarm line
- Ethernet based "IP Address" security cameras

Analog telephone service will be provided by extending the analog lines of an existing AT&T trunk line that feeds the existing Transfer Pump Station facility. Digital telephone service and Ethernet based security cameras service will be provided through a connection to the District's Wide Area Network via a series of microwave towers connecting to the District's main campus.

Telephone and data service at the Expanded Transfer Pump Station will be connected to Old River Pump Station and Middle River Pump Station through a fiber optic line running along the new 66-inch pipeline connecting the new Transfer Pump Station and Old River Pump Station. Old River Pump Station are connected to Middle River Pump Station via an overhead fiber optic line that uses the same route as the existing Western Area Power Authority 69 kV line. Backup telephone and data service at Expanded Transfer Pump Station will be established by extending the existing service at the existing Transfer Pump Station.

The Expanded Transfer Pump Station Electrical Building includes an intrusion limit at each exterior door, the intrusion switches will be monitored by the SCADA system.

Conclusions and Recommendations

The PLC programming should be standardized. This includes the following areas of programming:

- Logic Address – Identification of address symbols.
- Descriptions – Address descriptions to indicate function.
- Use of Rung Comments
- Use of Page Titles
- Use of sub-routines and program files
- Use and provision of data files for plant SCADA interface use.
- Use of calculations and conversion standards for use in reporting data acquisition
- Structure of data files for Plant Use.
- Provision of fully configured input/output (I/O) database and mapping.

The following PLC architecture approach is recommended:

- Use of individual PLC's at each new facility.

- Each motor controller will communicate with the network via Modbus Transmission Control Protocol/Internet Protocol (TCP/IP).

- Each of the motor controllers would also communicate with a small, dedicated operator interface unit (OIU), located on the front of each motor controller.

- The OIU would be used to indicate individual motor controller parameters including alarms and set points.

- Hardwired switches will be provided for local control operations, including a LOR selector switch with Start and Stop pushbuttons for pump start/stop control and a speed controller or potentiometer for local pump speed control in the local mode only.

This approach would allow the individual motor controller, local switches and associated motor controller OIU to operate independently from the CCWD PLC/SCADA system. This approach would be beneficial if a failure of either the area PLC or the communication network should occur. The hardware cost for each would be very similar, as the Remote I/O units would instead become part of the motor controller. The software configuration cost would be less with this approach as the programming responsibility for the motor controller operation would be transferred to the motor controller manufacturer from the PLC programmer reducing the probable coordination costs.

Structural

All structures, including nonstructural components and nonbuilding structures, identified within the project scope shall be designed in accordance with the structural design criteria provided in this section.

Governing Codes and Standards

- 2016 California Building Code (CBC), based on 2015 IBC.

- Minimum Design Loads for Buildings and Other Structures 7-10 – American Society of Civil Engineers.

- Where the design references listed below are used, the 2016 CBC modifications to those standards shall apply. Additionally, the ASCE 7-10 modifications to the standards shall apply, unless specifically stated otherwise in the 2016 CBC.

Reference Specifications, Codes, and Standards

2016 CBC California Building Code

2015 IBC International Building Code

AASHTO AASTHO LRFD Bridge Design Specifications – Seventh Edition (2014 edition)

California Amendments to the AASHTO LRFD Bridge Design Specification – Six Edition

ACI 318 Building Code Requirements for Structural Concrete and Commentary (2014 edition)

ACI 350 Code Requirements for Environmental Engineering Concrete Structures and Commentary (2006 edition)

ACI 350.1 Tightness Testing of Environmental Engineering Concrete Structures (2010 edition)

ACI 350.3 Seismic Design of Liquid Containing Concrete Structures and Commentary (2006 edition)

ACI 350.4R Design Considerations for Environmental Engineering Concrete Structures (2004 edition)

ADM Aluminum Design Manual (2015 edition)

AISC American Institute of Steel Construction:

AISC 303 – Code of Standard Practice for Steel Buildings and Bridges (2010 edition)

AISC 325 – Steel Construction Manual, 15th Edition (2010 edition)

AISC 341 – Seismic Provisions for Structural Steel Buildings (2010 edition)

AISC 358 – Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications

AISC 360 – Specifications for Structural Steel Buildings (2010 edition)

ASCE 7 American Society of Civil Engineers Standard 7-10 Minimum Design Loads for Buildings and Other Structures (20160 edition)

AWS D1.1 Structural Welding Code – Steel (2015 edition)

AWS D1.2 Structural Welding Code – Aluminum (2014 edition)

AWS D1.3 Structural Welding Code – Sheet Steel (2014 edition)

AWS D1.4 Structural Welding Code - Reinforcing Steel (2014 edition)

AWS D1.6 Structural Welding Code – Stainless Steel (2014 edition)

AWS D1.8 Structural Welding Code – Seismic Supplement (2014 edition)

EM 1110-2-2100 Stability Analysis of Concrete Structures, USACE

EM 1110-2-2504	Design of Sheet Pile Retaining Walls, USACE
EM 1110-2-2906	Design of Pile Foundations, USACE
Moody EM No. 27	A Water Resources Technical Publication, Engineering Monograph No. 27: Moments and Reactions for Rectangular Plates by W.T. Moody / United States Department of Interior Bureau of Reclamation – reprinted 1986
Stantec	Stantec Design Quality Procedures
TMS 402	Building Code Requirements for Masonry Structures (2016 edition)
TMS 602	Specifications for Masonry Structures (2016 edition)

Structural Systems, Design Methods, and Assumptions

Hydraulic Structures:

1. Hydraulic structures shall be designed and constructed of cast-in-pace reinforced concrete in accordance with ACI 350-06.

2. Hydrodynamic forces shall be determined in accordance with ACI 350.3-06.

3. The following hydraulic structures have been identified within the project scope:

    a. Pump Station (Expanded Transfer Facility).

    b. Vertical Turbine Pump – Wet Well (Expanded Transfer Facility)

    c. Transfer Pipeline Isolation Valve Vault (Expanded Transfer Facility).

    d. Delta-Transfer Pipeline Isolation Valve Vault (Expanded Transfer Facility).

    e. Delta-Transfer Pipeline Meter Station Vault (Old River Facility).

    f. Delta-Transfer Pipeline Isolation Valve Station Vault (Old River Facility).

    g. Appurtenant Facilities (Los Vaqueros Reservoir)

Non-Hydraulic Structures – Buildings:

1. Buildings shall be designed and constructed of reinforced concrete masonry units and a reinforced concrete foundation.

2. Each above ground roof system will consist of a light-gauge pre-engineered truss steel joist or structural steel beams with metal roof decking.

3. For non-hydraulic structures with top slabs, each floor level shall be designed and constructed of cast-in-place concrete slabs system with reinforced concrete beams (where applicable).

4. The following buildings (non-hydraulic structures) have been identified within the project scope:

    a. MCC Electrical Building (Expanded Transfer Facility).

Nonstructural Components:

1. Unless otherwise indicated, all nonstructural components shall be designed in accordance with Chapter 13 of ASCE 7.

2. Nonstructural component structures that are contained inside liquid-containing structures shall be designed to resist hydrodynamic forces in accordance with Chapter 15 of ASCE 7.

3. Nonstructural components and their anchorage subjected to vibrations shall be designed in accordance with ACI 350.4R.

4. The following nonstructural components have been identified within the project scope:

    a. Pipe supports (Expanded Transfer Facility and Old River Facility) – as applicable.

    b. Elevated structural steel platforms with galvanized steel grating inside the reinforced concrete vaults (Expanded Transfer Facility and Old River Facility).

    c. Vertical turbine pump anchorage (Expanded Transfer Facility).

Nonbuilding Structures:

1. Unless otherwise indicated, all nonbuilding structures shall be designed in accordance with Chapter 15 of ASCE 7.

2. Nonbuilding structures and nonstructural component structures that are contained inside liquid-containing structures shall be designed to resist hydrodynamic forces in accordance with Chapter 15 of ASCE 7.

3. Nonbuilding structures and their anchorage subjected to vibrations shall be designed in accordance with ACI 350.4R.

4. The following nonbuilding structures have been identified within the project scope:

    a. 5-million-gallon steel tank foundation of reinforced concrete (Expanded Transfer Facility).

    b. 21 kV substation foundation of reinforced concrete, including aluminum platform grating (Expanded Transfer Facility).

    c. Surge control tank reinforced concrete foundation (Expanded Transfer Facility).

    d. Vertical Turbine Pump Foundation / Wet Well Top Slab (Expanded Transfer Facility).

    e. Pipe Bridge of reinforced concrete (Old River Facility).

Structural Design Criteria

General Criteria

Unless otherwise indicated by the Lead Structural Engineer, all the structures covered by this section shall be designed to meet the requirements for the risk category and environmental exposure herein:

a. Risk Category: III

b. Environmental Exposure: Normal

Live Loads

All structures within the project scope shall be designed for the live loads as shown in Table 3-13 and in accordance with the 2016 CBC

Table 3-13. Structural Live Loads

Area	Uniform Load	Concentrated Load
1. Elevated Slabs	100 psf	1,000 lb
2. Roof Live Load	20 psf	300 lb
3. Floor Live Load		
Process Area	250 psf	3,000 lb
Electrical Rooms	300 psf	3,000 lb
Stairs and Landings	100 psf	300 lb
Platforms	100 psf	300 lb
4. Traffic Areas		HS20 (vehicle load)

Key:
HS20 = Highway Semi-Trailer Truck 20 tons
lb = pound
psf = pounds per square foot

Snow Design Criteria

Snow load criteria shall be developed in accordance with Chapter 7 of ASCE 7 and the local authority having jurisdiction. All structures within the project scope shall be designed for the following:

1. Ground Snow Load, P_g: 0 pounds per square foot (psf) ($\leq$ 1,500 feet)

2. Snow Exposure Factor, C_e: 1.0

3. Snow Load Importance Factor, I_s: 1.1

4. Thermal Factor, C_f: 1.0

Flood Design Criteria

All structures within the project scope shall be designed to resist loads and buoyant forces associated with the following flood criteria:

1. 100 Year Flood Elevation — To be determined (TBD, preliminarily estimated from FEMA 2010 Flood Insurance Rate Map)

Hydraulic Design Criteria

All hydraulic structure designs shall consider fluid levels at static and seismic conditions. Hydrodynamic forces shall be determined in accordance with ACI 350.3-06 and shall consider unbalanced fluid loads wherever they occur.

Hydrostatic (non-seismic load cases): Maximum overflow condition TBD

Hydrodynamic forces: Normal high-water operating level TBD

Wind Design Criteria

For developing the required wind loading associated with the main wind force resisting systems and components and cladding, the following wind design parameters shall be developed in accordance with Chapters 26 through 31 of ASCE 7 and the local authority having jurisdiction:

1. Ultimate Design Wind Speed: 110 miles per hour.
2. Exposure Category: C
3. Internal Pressure Coefficient: +/- 0.18 , +/- 0.55
4. Components and Cladding: Per ASCE 7-10
5. Topographic Factor, Kzt: 1.0

Seismic Design Criteria

For developing the required seismic loading associated with the seismic force resisting systems, nonstructural components, and nonbuilding structures, the following seismic design parameters shall be developed in accordance with ASCE 7, and the local authority having jurisdiction:

Expanded Transfer Facility:

Seismic Importance Factor, I: 1.25

Mapped spectral response acceleration parameters at short periods: $S_S = 1.50$ g

Mapped spectral response acceleration parameters at 1-second periods: $S_1 = 0.568$ g

Site Class (pending Geotechnical investigation): D

Long-Period Transition Period, TL: 8 seconds

Design Spectral Response Acceleration at Short Period: $S_{DS} = 1.00$ g

Design Spectral Response Acceleration at 1-Second Period: $S_{D1} = 0.568$ g

Seismic Design Category: D

Old River Facility:

The Old River Facility has been categorized as Site Class F which will require a site-specific analysis. However, since the structures that will be constructed on site (Meter Vault, Isolation Valve Vault, and the Pipe Bridge) appear to have structure periods less than 0.5 seconds, then map-based ground motions for Site Class D may be used per ASCE 7-10, Chapter 20, however liquefaction mitigation must still be addressed. This will need to be confirmed by the Geotechnical Engineer prior to final design.

Seismic Importance Factor, I: 1.25

Mapped spectral response acceleration parameters at short periods: S_S = 1.239g

Mapped spectral response acceleration parameters at 1-second periods: S_1 = 0.424g

Site Class (pending Geotechnical): D

Long-Period Transition Period, TL: 8 seconds

Design Spectral Response Acceleration at Short Period: S_{DS} = 0.830g

Design Spectral Response Acceleration at 1-Second Period: S_{D1} = 0.446g

Seismic Design Category: D

Soil Design Criteria:

All structures shall be designed to resist static and dynamic earth pressures in accordance with the project geotechnical report, ASCE 7, the CBC:

a. Buried structures and other structures resisting vertical and lateral earth pressures shall be designed to resist soil earth pressures outlined in the project geotechnical report.

b. The effects of groundwater shall be considered during the design of buried structures and recommendations outlined in the project geotechnical report.

c. Dynamic lateral earth pressures associated with seismic events shall be based on the recommendations outlined in the project geotechnical report.

Geotechnical Assumptions and Foundation Systems

A complete, final geotechnical investigation and report will be required prior to the design of the structures outlined in the project scope. For the basis of this report, the following documents were referenced: "*Draft Addendum to Technical Memorandum: Geotechnical Considerations"* by MWH dated October 2015 (Attachment 1B). The following preliminary geotechnical parameters have been assumed for preliminary design for the anticipated range of soil bearing capacities:

Expanded Transfer Facility – High Soil Bearing Capacity Areas:

1. Minimum Foundation Design Criteria:
    a. Foundation Type: Spread footings, continuous footings, and mat foundations.
    b. Minimum footing depth: 18 inches
    c. Minimum footing width: Varies / as required.
    d. Coefficient of Friction (to be confirmed during the final report): 0.35
    e. Active Pressure (to be confirmed during the final report): 35 psf per foot of depth
    f. At-Rest Pressure (to be confirmed during the final report): 60 psf per foot of depth
    g. Passive Pressure (to be confirmed during the final report): 166 psf per foot of depth
    h. Allowable bearing pressure (to be confirmed during the final report):
        i. Static (DL+LL): 3,000 psf
        ii. Short Term Loading (wind and seismic): 4,000 psf

Expanded Transfer Facility – Lower Soil Bearing Capacity Areas:

1. Minimum Foundation Design Criteria:
    a. Foundation Type: mat foundations and piles.
    b. Minimum footing depth: 18 inches
    c. Minimum footing width: Varies/as required.
    d. Cohesion (to be confirmed during the final report): 100 psf
    e. Active Pressure (to be confirmed during the final report): 85 psf per foot of depth
    f. At-Rest Pressure (to be confirmed during the final report): 100 psf per foot of depth
    i. Passive Pressure (to be confirmed during the final report): 130 psf per foot of depth
    g. Allowable bearing pressures (to be confirmed during the final report):
        i. Static Loading (DL + LL): 1,000 psf
        ii. Short Term Loading (wind and seismic): 1,330 psf
2. Unless specifically outlined or indicated in the project geotechnical report, the following safety factors shall be used in accordance with ACI 350.4.R:

a. Buoyancy: 1.25
b. Overturning:
   i. Static Loading: 1.50 (DL + LL)
   ii. Short Term Loading (wind and seismic): 1.10
c. Sliding:
   i. Static Loading: 1.50 (DL + LL)
   ii. Short Term Loading (wind and seismic): 1.10

Table 3-14. Structural Materials of Construction

Material		Strength / ASTM
Concrete:	Structural [1]	f'c = 4,000 psi
	Civil and Sitework [1]	f'c = 3,000 psi
	Lean (unreinforced) [1]	f'c = 2,000 psi
Masonry:	Normal weight bock per ASTM C90	
	Concrete Masonry Units [1]	f'm =1,500 psi (assemblage)
	Mortar [1]	f'c = 1,800 psi, ASTM C270 M or S
	Grout [1]	f'c = 2,000 psi, ASTM C476
Reinforcement:	Typical (U.O.N.)	fy= 60 ksi, ASTM A615
	Welded and Special Seismic Force Resisting Systems	fy= 60 ksi, ASTM A706
Structural Steel:	Wide Flange Shapes	ASTM A992
	Hollow Structural Sections (HSS)	ASTM A500, Grade B
	Pipes	ASTM A53, Type E, Grade B
	Plates, Bars, Sheets (U.O.N.)	ASTM A36
	All other standard shapes	ASTM A36
	Bearing Bolts	ASTM F3125, Grade A490
	Slip-Critical Bolts	ASTM F3125, Grade F1852 or Grafe F2280 Twist-Of / Tension Control bolts in place of Grade A325 or Grade A490 Heavy Hex Head
	Welding	E70XX
Metal Deck:	Roof	fy= 38 ksi or 50 ksi, ASTM A653
Stainless Steel:	Typical and anaerobic conditions	Type 304
	Submerged or corrosive areas	Type 316
	Weldable	Type 304 L or Type 316 L
Aluminum:	All applications (U.O.N.)	6061-T6
	Handrails and grating	6061 or 6063

Table 3-14. Structural Materials of Construction (contd.)

Material		Strength / ASTM
Anchor Bolts:	Headed and dry conditions	ASTM F1554, Grade 36, 55
	Exterior conditions	ASTM A193, Grade B7
	Submerged and wet conditions	ASTM F593, Type 304 or 316
Waterstops:	New construction	PVC flat-strip
	Retrofit	Hydrophilic
Gaskets:	Neoprene	

Note:
[1] Required minimum compressive strength in 28-days.
Key:
ASTM = American Society for Testing and Materials
f'c = compressive stress
fy = yield stress
ksi = kips per square inch
psi = pounds per square inch
PVC = polyvinyl chloride

Architectural

Architectural Design Philosophy

The architectural style for the new electrical building will be consistent with the functional character and external appearance of the existing electrical building in order to create a unified appearance at the facility. The building will be designed to accommodate operation and maintenance of the electrical equipment.

Architectural Program

The new electrical building (also identified as the MCC building) will be designed as a one-story, 1,867 square foot facility of approximately 26'-8" x 70'-0" x 15'-4" clear height. To maximize efficiency and to minimize maintenance costs, special consideration will be given to the overall life cycle cost and constructability. Creative design will be balanced by the realities of traditional operating and maintenance practices. The architectural objective is to provide a project that is aesthetically pleasing, functional, and economical.

Architectural Design Criteria

The architectural parameters of the building and all its components will include compliance to state, local, and federal standards.

Codes, Standards, and References

- 2016 CBC
- 2016 California Energy Conservation Code
- Occupational Safety and Health Administration

- Americans with Disabilities Act (ADA)
- Accessible and Usable Buildings and Facilities ICC A117.1 – LatestEdition

Code Evaluation Based on the CBC, it has been determined that the occupancy classification for the new electrical building will be Group F-1 Moderate Hazard Factory Industrial Occupancy.

The construction classification has been identified as Type IIB.

The building/structure is exempt from ADA based on 2010 ADA Standards for Accessible Design, Section 203: "General Exceptions; Machinery Spaces: Spaces frequented only by service personnel for maintenance, repair or occasional monitoring of equipment shall not be required to comply with these requirements or to be on an accessible route. Machinery spaces include, but are not limited to, water or sewage treatment pump rooms and stations; electrical substations and transformer vaults; and highway and tunnel utility facilities." Except for regular monitoring and maintenance of equipment, the electrical building is not intended for human occupancy for extended periods of time. The primary purpose of the electrical building is to house electrical equipment in support of water conveyance.

General Standards

Exterior Walls The exterior walls will consist of integrally colored, 12-inch-by-8-inch-by-16-inch concrete masonry units. Surface textures will be split face, and smooth face. Concrete masonry units exposed to the exterior shall receive a spray-applied, clear penetrating sealer. All exterior walls will be fully grouted and reinforced as required by the code and/or contract documents.

The exterior material color and texture will match the existing adjacent building in order to create a uniform appearance on the project site.

Carpentry Pressure treated wood blocking, and roof nailers, as shown on the contract documents will be provided for rough carpentry work.

Moisture Protection Roof system will be provided with R-20 rigid insulation board.

Caulking, sealing, and moisture protection will be provided for weather tight construction.

A plastic vapor retarder will be placed over the backfill and under the new concrete floor slab.

Roof Construction The roof system for the building will consist of a Polyvinylidene Fluoride factory finish standing seam metal roofing system, on R-19 rigid insulation, attached to the roof structure. The roof system will meet UL Class A rating and satisfy wind uplift requirements for this area.

Polyvinylidene Fluoride factory finished flashing, gutters and down spouts will be provided.

Doors and Frames Exterior doors and frames will be flush galvanized steel with an epoxy/polyurethane protective coating.

Finish Hardware All doors will have heavy-duty panic hardware with stainless steel locksets, stainless steel hinges with non-removable security pins, closers, hold-open device, rain drips and weather stripping.

Louvers Aluminum louvers with factory finish consisting of 0.8-mil (0.02 mm) nominal primer with 0.8-mil (0.02 mm), Polyvinylidene Fluoride Color Coat will be provided as required.

Interior Finishes Interior finishes in the building will be as follows:

- Flooring will be concrete slab with a steel trowel finish.
- Walls will be unpainted concrete masonry units.
- Exposed structural ceilings will unfinished.

Signage Signage will be provided per the appropriate authorities, agencies, and the building code for applicable areas.

Specialties Fire protection will be provided with portable fire extinguishers per the appropriate authorities, agencies, and the building code.

Exterior Lighting Lighting shall satisfy functional and security needs while not creating light pollution in the form of point sources of direct glare which are visible from a distance. Fixtures shall be low level, directional light fixtures, which illuminate immediate areas, carefully selected for efficiency and cut-off.

This page left blank intentionally.

Chapter 4 Dam and Reservoir Elements

This Chapter summarizes the 275 TAF dam raise design and associated modification of appurtenant facilities, and dam construction activities. Detailed on stability and seismic analyses are included in Attachment 2. In addition, information on the Marina Complex Relocation, the new Los Vaqueros Watershed Trail, and the expanded recreation facilities is included.

275 TAF Dam Raise Design

Table 4-1 summarizes the characteristics of the existing 160-TAF reservoir (Alternative 4A), and the dam raise for the 275-TAF reservoir expansion (Alternatives 1A, 1B, and 2A). The existing dam would be raised by building on top of the existing dam structure. Reservoir expansion to 275 TAF would raise the water surface level 50 feet for a maximum reservoir water surface elevation of 560 feet above mean sea level (msl) (from 510 feet msl). The reservoir water surface area (inundation area) would expand approximately 600 acres from 1,900 acres to 2,500 acres.

Table 4-1. Characteristics of the Los Vaqueros Dam Modification

Reservoir Capacity (TAF)	Maximum Reservoir Water Surface Elevation (msl)	Dam Crest Elevation (msl)	Maximum Dam Height Above Downstream Toe (feet)	Total Embankment Volume (Existing plus New) (million cubic yards)	Dam Crest Length (feet)
No Action, Alternative 4A					
160	510	523	230	3.8	1,300
Alternatives 1A, 1B, and 2A					
275	560	572	282	7.6	1,630

Key:
msl = mean sea level
TAF = thousand acre-feet

Like the existing dam, the raised dam would be a central core earthfill embankment. Figure 4-1 shows a plan view of the proposed 275-TAF reservoir dam, and Figure 4-2 shows a profile view of the raised dam atop the existing dam. The dam would be raised by building on top of both the upstream and downstream shells of the dam. The existing vertical central core and the filter/drainage system would be raised as shown in Figure 4-2. The dam axis would move about 45 feet upstream. Detailed dam design drawings are included in Attachment 2.

The dam would be 282 feet high and have a crest (or top) elevation of 576 feet msl. The water surface elevation would be 560 feet msl when expanded to the 275-TAF capacity. The dam crest would be 30 feet wide and about 1,630 feet long. The downstream and upstream slopes would be about 2.25:1 and 3.5:1, respectively. The new embankment fill would add about 4.8 million cubic yards to the current dam volume of 2.8 million cubic yards for a total of 7.6 million cubic yards of embankment fill.

The existing reservoir would need to be drained prior to construction. It would remain drained and out of service throughout the estimated 3-year construction period and be refilled following construction completion. The process of draining the reservoir is described below. The raised dam would include monitoring and recording instrumentation, similar to the existing equipment, to measure internal water pressures within and seepage from the dam and foundation, settlement of the dam, and earthquake-induced accelerations and deformations. The instruments would include foundation and embankment piezometers, internal and surface settlement and movement sensors, a seepage measurement weir and a series of strong motion acceleragraphs.

There is no design required cofferdam on this project; the existing dam embankment provides adequate downstream flood protection during construction. However, a small cofferdam/gravel-cutoff will likely be constructed by the contractor (as part of their means and methods) to intercept ground water seepage and control summer creek inflows. Based on the original construction, these summer flows will be stored on a small pond and used as a construction water supply. As shown in Figure 4-2, the top of the dam is not removed until the summer of Year 2 and the dam embankment is completed in Year 2. The summer Probable Maximum Precipitation flood flow (total volume 20 TAF) can be safely routed through the existing outlet with the top of the dam removed at the start of the second construction season (Step 4, Year 2). Note that the reservoir volume at El 440 is 60 TAF and the cumulative volume of the winter (all-season) Probable Maximum Flow is 32 TAF.

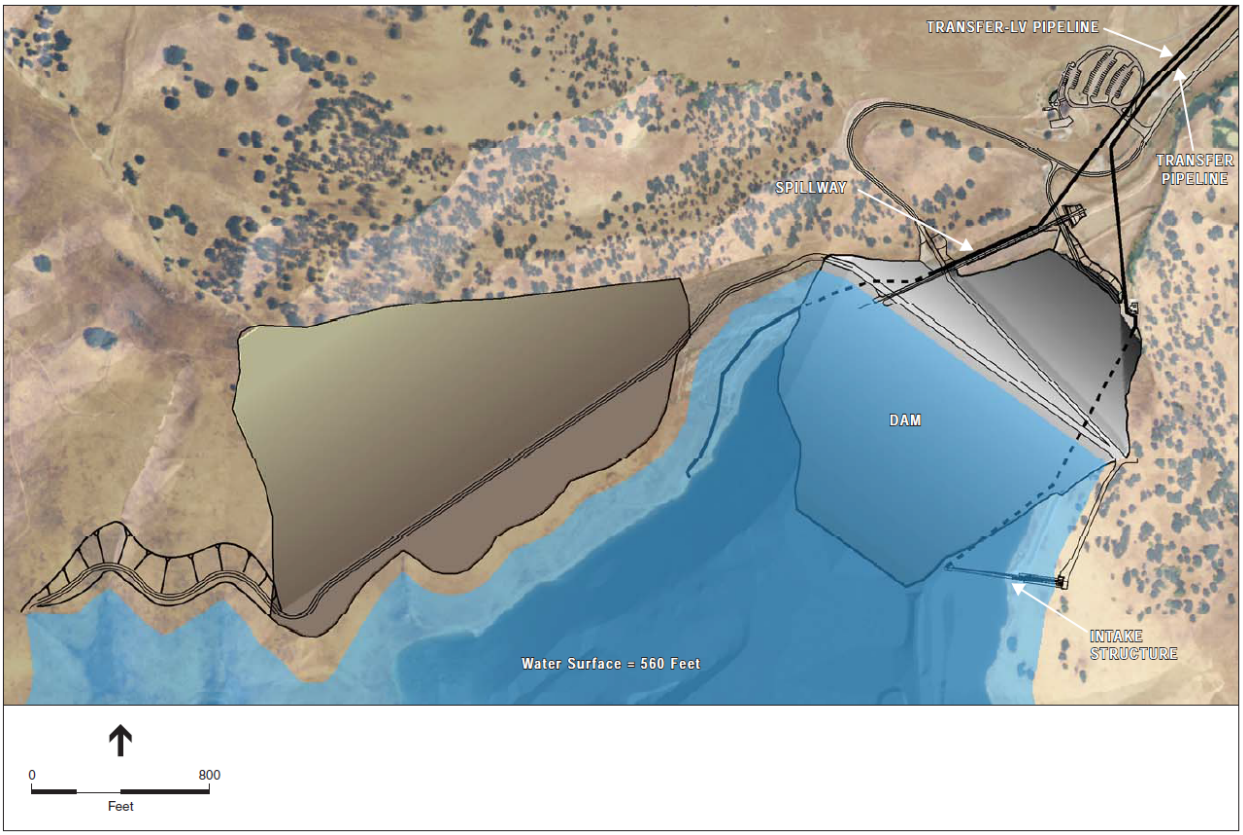


Figure 4-1. 275 TAF Reservoir – Plan View of Dam Raise

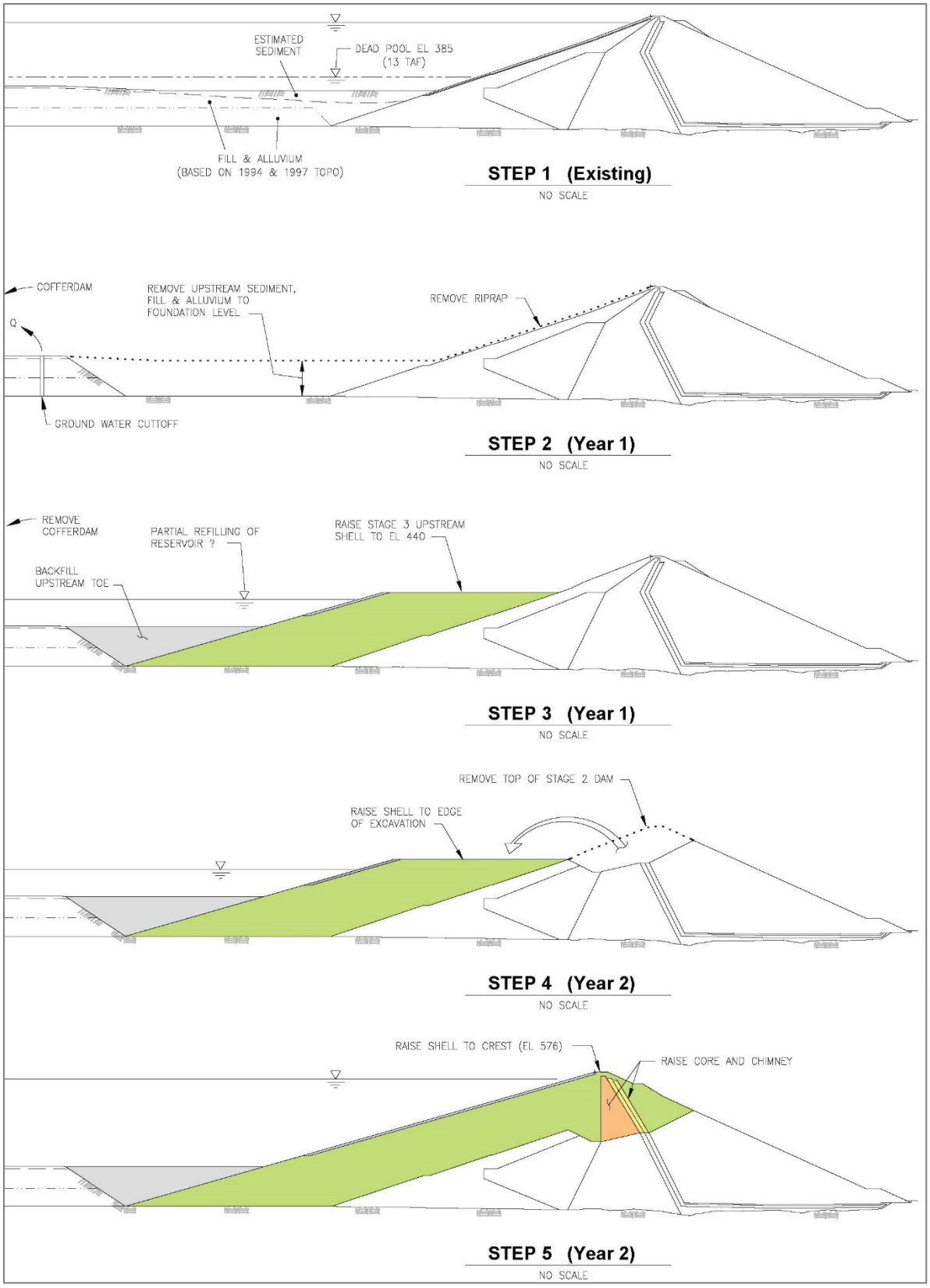


Figure 4-2. 275 TAF Reservoir – Profile View of Dam Raise & Construction Phasing

Appurtenant Facilities

Spillway

The spillway (a channel over the dam that allows for overflow from the reservoir) for the 275-TAF reservoir would be an extension of the existing spillway on Los Vaqueros Dam. The new portion of the spillway would be about 375 feet long and would have a rectangular cross-section of 15 feet with a 6' – 0" wall height (vertical). The existing stilling basin (an impoundment to slow the water conveyed through the spillway) at the base of the chute and a riprap-lined discharge channel to Kellogg Creek would be retained. This USBR Type II stilling basin, constructed as part of the Stage 1 dam raise, is 20' wide with wall height of 37' feet. There is a 120' transition (expansion) between the chute and stilling basin. The spillway would have the capacity to convey the Probable Maximum Flood to ensure that even in the most extreme storm conditions, water levels in the reservoir would not overtop the dam. The Probable Maximum Flood is based on the 72-hour Probable Maximum Precipitation storm in the 19 square mile catchment area. Routing the Probable Maximum Food through the expanded reservoir yields a reservoir surcharge of 10.7' with a maximum spillway discharge of 3,000 cfs.

Current plan and profile details, such as the slope of the spillway, will be verified through computational fluid dynamics modelling during the post-feasibility level design.

Inlet / Outlet Works

The fill/release capacity through Transfer Pipeline is limited to the existing capacity of 200 cfs/400 cfs. There would be no modifications to the existing inlet/outlet works with the 275 TAF dam (i.e., no additional ports, resizing of facilities or changes to any control systems at the dam). There will be changes/replacement of at least three of the slide gates in the intake ports, and possibly the two blow-off valves, in the outlet to accommodate the additional head in the reservoir. The sloping structure will also be extended up the slope to retain the same general configuration it has now.

All pump-in and release flows will be routed via the existing inlet/outlet works. The existing facility is a 7-foot-diameter, steel-lined sloping structure with five ports that can be used to release water from different reservoir water levels to satisfy water quality needs. Water flowing out of the reservoir through the port structure (also known as an intake structure because water is being brought into a water system from a reservoir) would be routed through the existing steel-and concrete-lined outlet tunnel to an outlet structure at the toe of the dam that includes various valves and connects to the Transfer Pipeline that runs to the Transfer Facility. The existing outlet tunnel, outlet structure, and associated valves would be reused without major modification.

The new second tunnel/pipe through the left abutment will be used only to comply with regulatory requirements for emergency reservoir evacuation. However, current designs and cost estimates allow for the possibility of a connection with the Transfer pipeline. This would provide additional flexibility for reservoir operations. A decision to include a connection to the Transfer pipeline will be made during future phases of design. DWR's Division of Safety of Dams guidelines for emergency drawdown (or "evacuation") of large reservoirs require that the dam facilities have the capability to lower the reservoir level by an amount equal to 10 percent of the hydraulic head behind

the dam in ten days, and to evacuate the entire reservoir in 120 days. These guidelines are met at Los Vaqueros Reservoir via the outlet tunnel and a valve in the outlet structure that discharges the emergency release flows directly into Kellogg Creek.

The existing inlet/outlet structure for Los Vaqueros Reservoir would remain at the same elevation for the proposed expansion of the reservoir and therefore would be at greater depth in the expanded reservoir. Surface algae blooms, occurring further from the intake/outlet structure would not pose any new water quality issues. Additional intakes located closer to the reservoir surface would not be needed for selective withdrawal, as the Los Vaqueros Reservoir does not and will not operate based on temperature considerations.

The sloping inlet/outlet structure was raised during the recent 160 TAF construction in the same manner as proposed for the 275 TAF project. The 160 TAF work provided data on the stability and geology of the foundation for this structure and did not raise concerns as to the stability of the inlet/outlet structure. This data will be augmented as necessary during future phases of design, as considered appropriate.

Reservoir Oxygenation System

The existing reservoir has an oxygenation system that is designed to enhance the quality of water in the hypolimnion, which is the bottom or lower zone of water within the reservoir. This system would need to be relocated and/or upgraded to accommodate the reservoir expansion. Oxygenating the hypolimnion helps maintain sufficient residual oxygen in the deeper reservoir waters, which improves water quality, reduces tastes and odors so water from this level in the reservoir can be used for consumption, and makes the water habitable for fish. During the oxygenation process, liquid oxygen is vaporized, piped to a diffuser grid on the bottom of the reservoir, and then released into the reservoir as oxygenated bubbles.

The existing oxygenation facilities are on the downstream face of the dam and include two horizontal liquid oxygen tanks, ambient vaporizers, control valving, instrumentation and telemetry panel, and site access for liquid oxygen delivery and operation personnel. Liquid oxygen is generated off site and trucked to facility storage tanks. These facilities would be relocated in the same general area as part of the dam modification process under any alternative and may be upgraded to effectively oxygenate the larger reservoir.

The expanded reservoir would be expected to stratify more frequently; therefore, the oxygenation system may need to be operated more frequently. Temperature and water quality modeling and analysis conducted for the 160 TAF Los Vaqueros Reservoir Expansion indicate that an expanded reservoir would have improved water quality with lower chlorophyll *a* concentrations, due to increased dilution of conservative tracers and nutrients introduced into the reservoir by episodic fillings by the larger reservoir volume as well as the increased likelihood of trapping of these nutrients below the thermocline (Flow Science Incorporated 2011).

Dam Construction

Construction of the expanded reservoir would involve the dam raise as well as construction of the appurtenant facilities. The following subsections describe the construction of these aspects of the project.

Dam Raise Materials

Raising the existing dam requires additional claystone and sandstone materials to enlarge the dam shell as well as clay material to extend the dam core. To minimize truck trip length and associated emissions and to reduce cost, most of the materials for the dam raise would be obtained from sites within the watershed from designated borrow areas. The dam would have a system of filters and drains to control seepage through the dam and foundation. Materials for sand filters and gravel drains would be imported from commercial sources within the region. Haul distances would be between 25 and 30 miles. Other materials required for construction of the dam raise and associated facilities include both raw and pre-fabricated materials that would be transported to the project site such as gravel, aggregate, bulk cement, steel, pipeline segments, pre-fabricated building materials, and mechanical and electrical equipment.

Sand, gravel, and rock materials imported to the project area would be tested prior to acquisition and transport to determine the presence of hazardous, corrosive, or other substances that could affect use of the materials, environmental exposure, or disposal options. CCWD's construction specifications require contractors to ensure these materials meet industry standards set forth by the American Society of Testing and Materials, among other groups.

Material Borrow Areas

The embankment fill for the 275 TAF dam is approximately 4.72 million cubic yards, which includes the fill volume replacing the volume excavated from the crest of the Stage 2 dam (0.46 million cubic yards). With the Stage 2 dam volume of approximately 3.60 million cubic yards, the total volume of the Stage 3 dam will be approximately 7.86 million cubic yards.

Except for relatively small volumes of sand and gravel and rock for the filters, drains, and riprap/bedding, all the additional fill will be obtained from on site. Most of the onsite materials (4.30 million cubic yards) will be for construction of the shells (Zone 4). A relatively small volume (0.3 million cubic yards) is required for the core (Zone 1). Attachment 2C provides detailed information on the borrow site areas.

Most of the 4.30 million cubic yards of earthfill for the 275-TAF dam raise would be used for the upstream and downstream shells. The proposed source for the shell materials would be within the 143-acre shell borrow area located on the southeast end of the prominent ridge separating the north and south arms of the existing reservoir, as shown in Figure 4-3. Most of the shell borrow area would be within the 275-TAF Los Vaqueros Reservoir boundary and would be inundated after construction. Part of the shell borrow area would result in a cut slope approximately 100 feet above the water line after inundation of the 275-TAF reservoir. The proposed grade would be approximately two percent, and the area would be revegetated. The Panoche formation claystones

and sandstones from both areas are anticipated to have excavation, compaction and strength characteristics similar to the materials used for both the original dam and the 160-TAF dam raise.

For the shell borrow area, a direct haul route across the reservoir floor (bisecting the waste disposal area available) is considered feasible, particularly due to the low sedimentation expected in the pump storage reservoir. Although this would be the most efficient route, the cost and schedule estimates for the longer haul route around the reservoir rim to avoid the valley floor could be covered by existing contingencies the feasibility-level estimates.

Clay for the core would be obtained from the same borrow source used for the 160-TAF construction, the naturally occurring alluvial deposits in the valley floor approximately 2.5 miles downstream of the dam. The borrow area would occur within the 58-acre area defined in Figure 4-3. The area defined by the limits includes the access haul road from Walnut Boulevard. The previously proposed core borrow area described the 2010 Final EIR/EIS was upstream of the dam in the area currently inundated by the 160-TAF Los Vaqueros Reservoir. The proposed downstream borrow source would produce the quality of materials required for the core without the need to dry saturated clays from the previously proposed, currently inundated core borrow area back to a suitable compaction moisture content.

Materials and Equipment Stockpile and Staging Areas

Although the dam raise would be constructed in large part from local materials quarried from nearby borrow areas, certain materials would need to be imported and stockpiled near the dam in sufficient quantity to maintain an adequate flow of materials. Some material would be stockpiled adjacent to the existing dam on the downstream side. An estimated 15-acre stockpile/staging area was identified along Walnut Boulevard near the entrance to the watershed. Alternative 4A would not require a 15-acre stockpile/staging area.

Materials Disposal

For the 275-TAF reservoir, excess earthen materials would be disposed of within the reservoir inundation zone at a suitable distance from the dam to avoid interference with reservoir operations.

Draining the Reservoir for Construction

Raising the existing dam for expansion to 275 TAF would require construction on the upstream and downstream sides of the existing dam and would therefore require that the reservoir be empty during construction. Draining the reservoir would be accomplished primarily by the planned release of the water into the CCWD distribution system, which could take six months to one year to accomplish. The existing reservoir water elevation would be drawn down to the level of the lowest port on the existing reservoir outlet (350 feet in elevation). The remaining 3 to 4 TAF of water that could not be released through the dam outlet would be pumped out through the lower port. It is expected that this water would be adequately mixed and aerated and would be either sent down the transfer pipeline for use in the CCWD service area or discharged to a creek or drainage channel consistent with regulations. Any water not suitable for release may require evaporation ponds or special treatment.

Based on extensive geological study during the design and construction of the original dam and the first expansion, evidence suggests acceptably low risk of landslides during reservoir drawdown. The reservoir draining process will be slow enough to allow significant excess pore pressure dissipation to occur. Similarly, the rate of reservoir change during operation is low and reservoir rim instability has not been observed to be an issue during normal operations of the existing reservoir. Current erosion around the reservoir has only produced scarps that periodically sluff off, but do not constitute any issue for the dam.

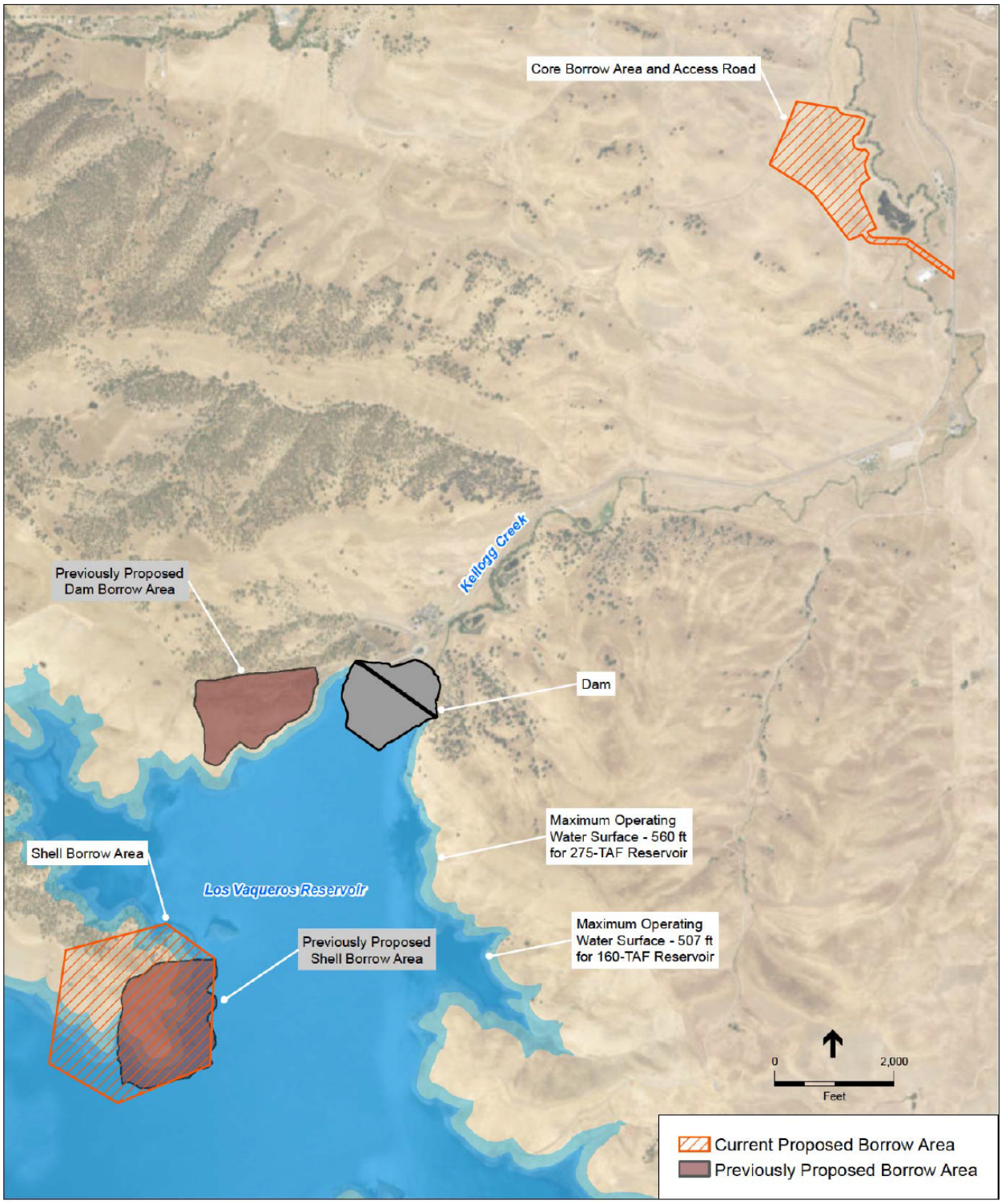


Figure 4-3. Proposed Borrow Locations for the 275 TAF Dam Raise

The Los Vaqueros Reservoir would be out of service for about four years from the time the reservoir was completely drained to allow for construction of the dam expansion through refilling the expanded reservoir. The amount of time needed to refill the reservoir would depend on hydrologic conditions and Delta water quality during the refilling. During this period, CCWD would be able to meet its water quality goals in all but short portions of the driest years using its current intakes at Old and Middle Rivers, Rock Slough intake, and its intertie with EBMUD.

Kellogg Creek Flow Bypass

Once the remaining water is removed, a groundwater cutoff trench would be installed upstream of the dam footprint to enable excavation of the foundation upstream of the toe of the existing dam. A temporary cofferdam would be constructed upstream of the cutoff trench. A temporary diversion pipe would be installed to divert any inflows from Kellogg Creek around the dam and into Kellogg Creek to maintain the flows required in CCWD's water rights and Biological Opinions and to sustain the habitats dependent on these flows.

Construction Activities

Construction of the 275-TAF reservoir dam, including appurtenant facilities, is estimated to require 24 to 30 months. Construction phasing is depicted on Figure 4-2. As described above, prior to construction, water would be drained from the existing reservoir. Once the remaining water is removed, a groundwater cutoff trench would be installed upstream of the dam footprint to enable excavation of the foundation upstream of the toe of the existing dam. A temporary cofferdam would be constructed upstream of the cutoff trench.

About 1,330,000 cubic yards of wet alluvium and spoil from the existing dam would be excavated between the groundwater cutoff and the upstream shell of the dam. The wet soil would be moved to a location on the reservoir floor to dry.

The existing two riprap gradations on the 160 dam will be stripped off. A new single riprap gradation will be specified for the 275 TAF dam. The new single riprap will have the same gradation specifications as the original dam construction. Riprap will be imported from commercial sources.

Los Vaqueros Reservoir is a pumped storage facility, with little to no sedimentation into the reservoir Kellogg Creek flows. The limited sediment accumulation at the dam will be due almost entirely to limited reservoir rim erosion and transport.

Within the volume of excavated material, 490,000 cubic yards of sediment are estimated, based on the conservative estimate for a sediment level of elevation 355 feet, five feet above the invert of the bottom port (See Attachment 2E). After the preparation of the construction cost estimate, diving inspections of the sediment around Port 5 (invert elevation of 350 feet) were undertaken as part of the fix of Gate 5. This inspection showed almost no sediment at the reservoir floor, at least near the intake. Consequently, and subject to verification by a bathymetric survey during pre-construction activities, the thickness, distribution and volume of sediment that will need to be excavated is anticipated be a small fraction of the conservative estimate assumed for this feasibility report. The excavation of sediment carries the highest contingency of all items in the cost estimate and in the scheduling.

A waste disposal area, as assumed for cost estimating purposes, was a large area upstream of the dam out to where the shell borrow is proposed. This area was developed in the original construction to obtain the clay for the dam core. This large area provides the construction contractor with flexibility for waste disposal operations.

Construction of the dam embankment would begin in the second half of Year 1 and be completed in Year 2. Grouting the upper abutments would occur concurrently with foundation excavation and embankment fill placement. About four months would be required to place about 100,000 cubic yards of concrete on the left abutment.

Construction of the extension of the existing sloping intake tower and structural modification of the existing outlet control structure could be completed in the first construction season. Construction of the mechanical/electrical and structural components of the outlet sloping intake structure and the downstream inlet/outlet control structures would be completed in Year 1 once the extension of the sloping intake structure is finished. Equipment would include dump trucks, a small bulldozer, vibratory rollers, front-end loaders, and the concrete on-site batch mixing plant.

Expanded Recreation Facilities

This section covers the expanded recreation facilities, as summarized in Table 4-2.

Table 4-2. Summary of Expanded Recreation Facilities

Facility	No Action	Alternatives 1A, 1B, 2A	Alternative 4A
Marina Complex Relocation	No change	Relocated upslope	No change
Los Vaqueros Watershed Trail	No change	Expanded	None
Los Vaqueros Interpretive Center	No change	Improved	Improved
Los Vaqueros Watershed Office Barn	No change	Seismically upgraded and improved	Seismically upgraded and improved

Marina Complex Relocation

For Alternatives 1A, 1B, and 2A, the existing Marina Complex, including the facilities at the south cove and the end of Los Vaqueros Road, would be inundated to make way for an expanded 275 TAF reservoir. Since Los Vaqueros Reservoir would not be expanded in Alternative 4A, the existing Marina Complex would not need to be relocated in that alternative.

In Alternatives 1A, 1B, and 2A, a new Marina Complex would replace the existing Marina Complex upslope of the existing facilities at the southern end of Los Vaqueros Reservoir (see Figure 4-4). The new Marina Complex would have a footprint of about 22 acres. This new Marina Complex replaces

the previously proposed marina facilities on the northern end of the Los Vaqueros Reservoir described in the Final EIS/EIR, as well as the approximately 8 acres of fishing facilities at the southern end of the Reservoir including fishing piers, fish cleaning stations, parking, etc., as previously proposed in the Final EIS/EIR. The new Marina Complex would be compliant with the ADA and would include:

1. Parking, including ADA-accessible stalls and turnouts as close and as level as possible to the reservoir;

2. A boat launch ramp for servicing the rental fleet and for contractor's boats;

3. Covered picnic areas with concrete tables/benches and play area, shade structures, remote restrooms, and other visitor amenities;

4. An outdoor amphitheater;

5. A Marina building, with room for a building lobby, interpretive displays, offices to accommodate up to 15 employees, requisite bathrooms and septic system, retail area, and food service area with sinks;

6. Outbuildings for storage, workshop space, water treatment and electrical equipment, and a large enclosed yard for larger items and other storage;

7. Fishing piers, fish cleaning stations, and a fish plant tube; and

8. Docks, which would include a dock surface smoother, two covered berths for patrol boats, berths for 50 electric-powered rental boats and three pontoon boats, davits (small cranes) to lift rental boats out of the water for cleaning, and a large boat house with room to hang life jacket/personal floatation devices and gear.

The connections to the trails near the new Marina Complex would be slightly modified from what was shown in the Final EIS/EIR, but the footprint area would remain the same as was previously analyzed.

New Los Vaqueros Watershed Trail

A new 0.5-mile ADA accessible interpretive trail would be built surrounding the Mortero Wetland Complex, which is located adjacent to the Walnut Staging Area at the northern end of the Los Vaqueros Watershed (see Figure 6-5). The new trail would include interpretive displays, viewing facilities, and shade structures and would generally follow the existing gravel road/trail with loops, turnouts, and rest areas. Approximately 0.5 acres of open space areas would be disturbed.

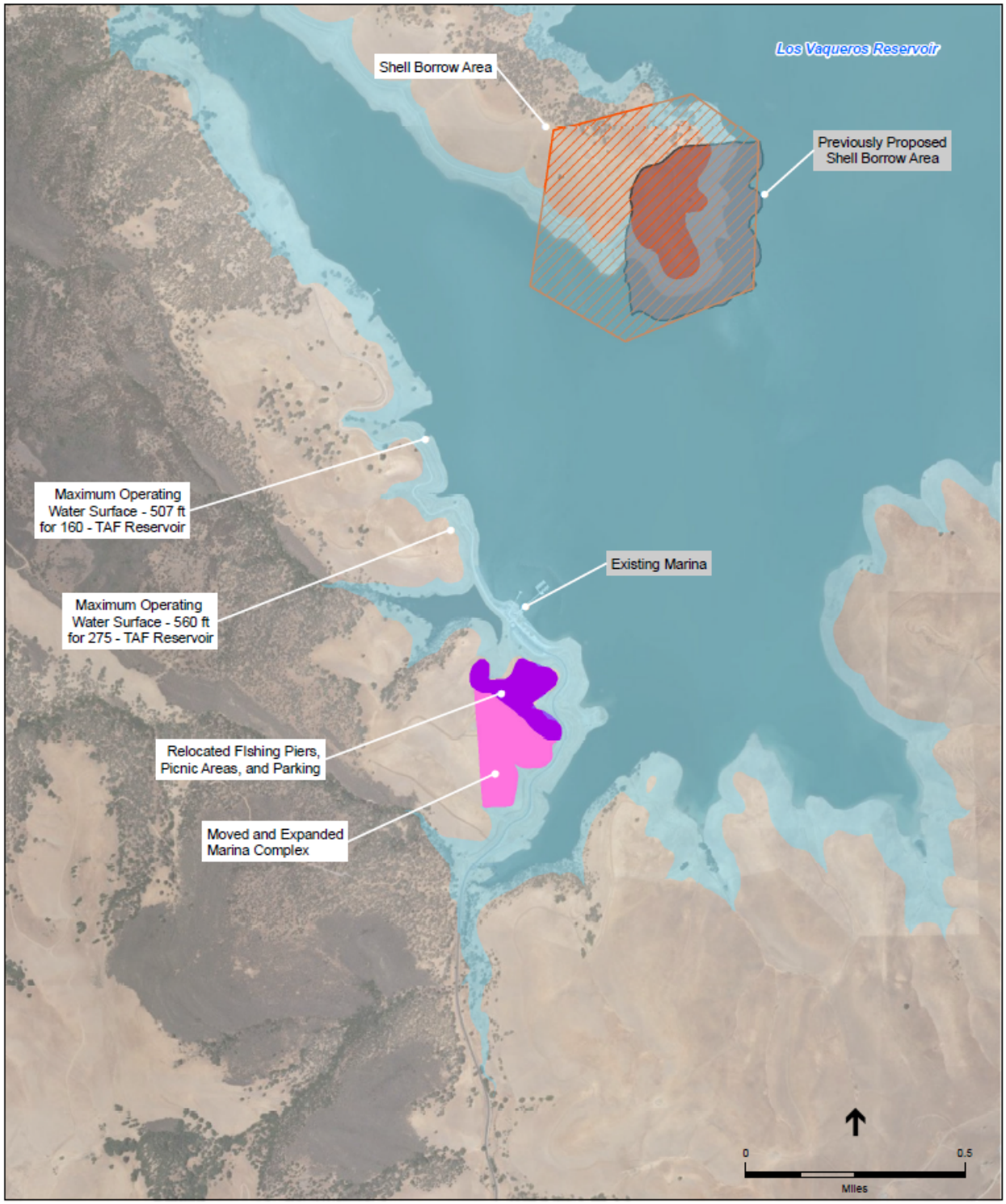


Figure 4-4. Proposed Relocation of the Marina Complex

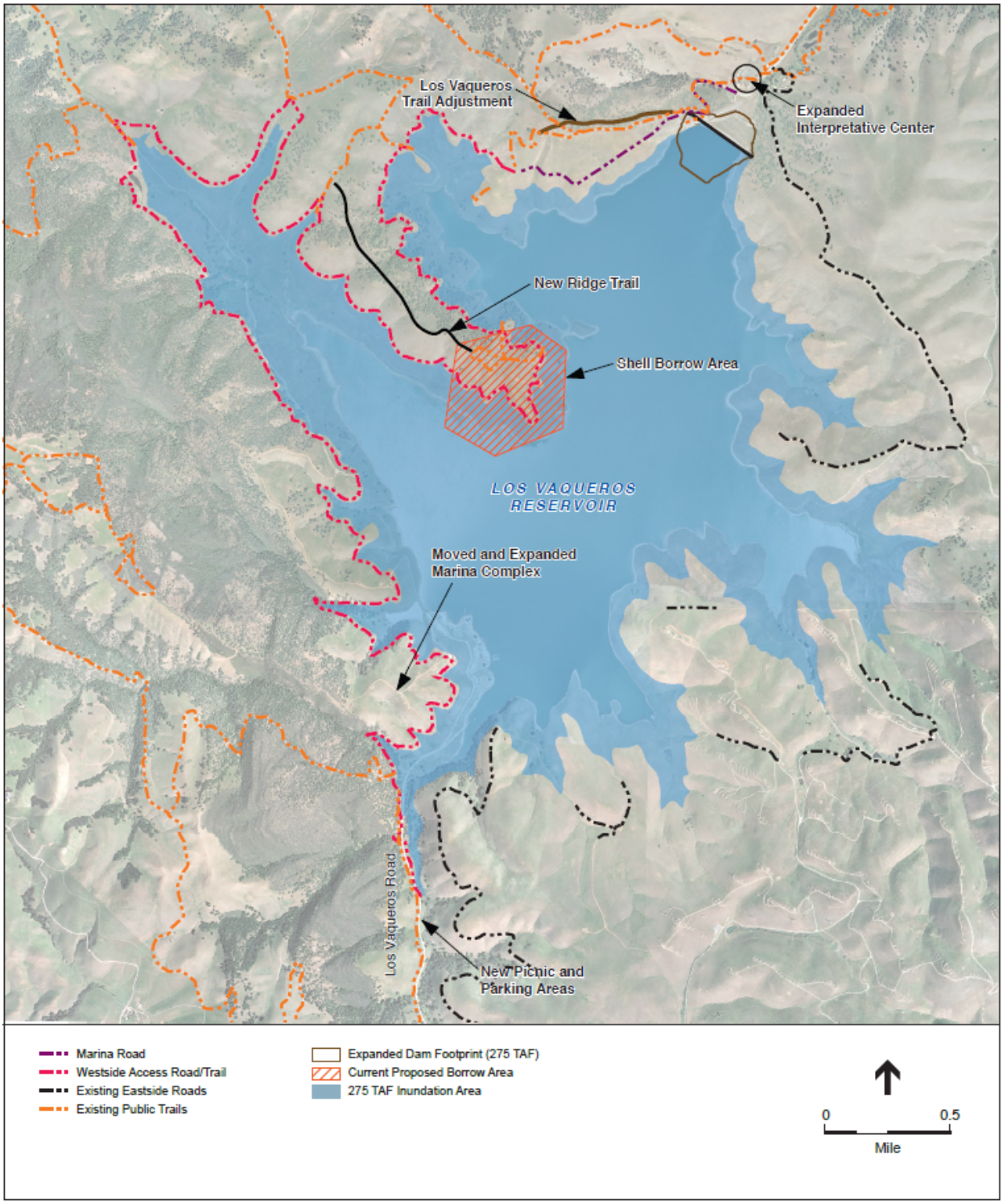


Figure 4-5. Los Vaqueros Watershed Trails

Los Vaqueros Interpretive Center

The previously proposed second interpretive center that was to be part of the Northern Marina Complex has been eliminated. Instead, the existing Los Vaqueros Interpretive Center would be upgraded and enlarged within the existing developed location just north of the dam along Kellogg Creek, as shown in Figure 6-5. This site has an educational pond, which would remain unchanged.

Los Vaqueros Watershed Office Barn

The existing old barn near the Los Vaqueros Watershed Office would be seismically and structurally upgraded (without expanding the existing footprint) and would contain an interpretive exhibit about ranching history in the area and a classroom area for demonstrations and to complement the existing outdoor education program. A new conservation and native plant demonstration garden of up to approximately 80' by 90' in area and an expanded parking area of up to approximately 60' by 80' to accommodate school buses would be located in the vicinity of the old barn. The new garden and parking facilities would be located within the existing footprint of disturbed area adjacent to the existing Watershed Office (see Figure 6-5).

Summary of Major Design Assumptions and Risks for Dam and Reservoir Elements

Table 4-3 summarizes the major engineering design assumptions and risks for specific items of the dam and reservoir elements. Many assumptions will be verified during future stages of design, as noted in the table.

Table 4-3. Summary of Major Design Assumptions and Risks for Dam and Appurtenant Facilities

Facility	Item	Assumptions and Risks
275 TAF Dam Raise	Upstream Dam Foundation	The site geology is well understood. The foundation of the existing was photographed and mapped in detail during construction in 1996/97. The foundation for the additional upstream shell is extrapolated from this information and we have a high degree of confidence in both the level of, and anticipated geology of, the foundation. The field investigation program will include borings to validate this assessment.
	Spillway	The existing spillway will be used. The lower peak discharge due to greater attenuation in the enlarged reservoir compensates for the higher velocity in the chute. This assessment will be validated with a computational fluid dynamics model of the raised spillway.
	Shell Borrow Area	The proposed shell borrow is a new area that has no subsurface investigation data. Area geology is anticipated to be similar to the borrow areas used in construction of the original dam (primarily Panoche Formation claystone with interbedded siltstone and sandstone). The 275TAF dam has been analyzed statically and dynamically using the lowest strength parameters developed for the original borrow sources. The risk of a design change requiring a slope less than the propose 3.5H:1V is small.

Key:
TAF = thousand acre-feet

This page left blank intentionally.

Chapter 5 Conveyance and Pumping Facilities

This Chapter documents the design development for:

- Upgrades to Existing Transfer Station
- Expanded Transfer Station
- Delta-Transfer Pipeline
- Transfer-Bethany Pipeline
- Neroly High Lift Pump Station

The Chapter also discusses potential modifications to allow the integration of the new facilities with the exiting Old River Intake and Pump Station and Middle River Intake and Pump Station.

In addition, the design for the Pumping Plant #1 improvements to accommodate higher flows is summarized.

A discussion of system hydraulic modeling is presented first, followed by a review of proposed pumping and ancillary facilities and existing facilities listed above. Engineering drawings supporting the design are provided in Attachment 3.

Hydraulic Modeling

A hydraulic analysis was conducted of the Los Vaqueros System to determine:

- Sizing of the Delta-Transfer Pipeline
- Sizing of the Transfer-Bethany Pipeline and the Transfer Expansion Pumps
- Maximum steady state and shut off pressures of the Middle River, Old River, Delta-Transfer, and Transfer-Bethany pipelines
- Transient pressures along the Middle River, Old River, Delta-Transfer, and Transfer-Bethany pipelines during a surge event to evaluate existing surge tanks and size proposed surge tanks at the ETPS

The proposed Delta-Transfer Pipeline begins at the connection of the Middle River Pipeline to the Old River Pipeline and parallel's the Old River Pipeline to the proposed ETPS.

The new Delta-Transfer Pipeline will be hydraulically connected to both the Middle River and Old River Pipelines. Through a series of valves and connection pipe arrangements, the system can be operated as either parallel pipelines providing flow split between both pump stations, or as a dedicated pipeline conveying water from either Old River or the Middle River pump stations to the Transfer Facility as well as the Neroly High Lift Pump Station. Under normal conditions both pipelines will be operated in parallel providing comingled flow from the Middle River and Old River Pump Stations to the Transfer Facility.

Delta-Transfer Pipeline sizing

The Delta-Transfer Pipeline is sized to convey 180 cfs at a maximum velocity of 10 ft/sec to minimize potential erosion of the cement mortar lining which can occur at sustained velocities over 12 ft/sec.

The headloss in the pipeline is directly related to the velocity in the pipeline for any given pipe diameter. As the pipe diameter decreases and the velocity increases, the headloss in the pipeline increases. There is a trade-off between increased pipe cost for a larger pipe diameter and increased pumping energy costs. Also, higher velocities increase the potential for more severe hydraulic transient conditions.

As identified in the Existing System Hydraulic Model TM (MWH 2015b), Hazen Williams C-Factors of 115 and 113 were determined from operational data for the Old River and Middle River Pipelines, respectively. A C-factor of 113 has been applied to the proposed Delta-Transfer Pipeline.

Using the flow and velocity estimates described above, a pipeline diameter of 66 inches has been selected for the new Delta-Transfer Pipeline. The hydraulic model was used to verify the sizing and hydraulic performance of the Delta-Transfer Pipeline assuming all pumps at both pump stations are operating, and operation of the system can occur either as an independent dedicated supply pipeline or operating in parallel with the Old River Pipeline. The model predicted flow and velocity within both the new Delta-Transfer Pipeline and Old River Pipeline for each operational scenario is summarized in Table 5-1.

When the pipelines are operated in parallel with water comingled at the Old River Pump Station, the estimated flow in the Delta-Transfer Pipeline is 184 cfs, flow in the Old River Pipeline is 314 cfs, and the total flow conveyed by both pump stations is approximately 500 cfs. Although not identified in Table 5-1, the effective pumping rates from the Middle River and Old River Pump Stations are 276 cfs and 219 cfs, respectively. The results of the hydraulic analysis show that the proposed 66-inch-diameter Delta-Transfer Pipeline is adequately sized and provides the 184 cfs flow at a velocity of 7.8 ft/sec.

As shown in Table 5-1, the estimated flow within the new Delta-Transfer Pipeline ranges from 200 cfs to 240 cfs when the pipeline is operating as a dedicated pipeline with either pump station providing supply.

Table 5-1. Comparison of Flow and Velocity for Various Pump Station and Pipeline Operational Scenarios

Operating Pump Station	Parallel Operation[1]				Independent Pipeline Operation			
	Delta-Transfer Pipeline		Old River Pipeline		Delta-Transfer Pipeline		Old River Pipeline	
	Flow (cfs)	Velocity (ft/sec)	Flow (cfs)	Velocity (ft/sec)	Flow (cfs)	Velocity (ft/sec)	Flow (cfs)	Velocity (ft/sec)
Middle River	---	---	---	---	240	10.1	283	8.5
Old River	---	---	---	---	200	8.4	255	7.7
Both Pump Stations	184	7.8	314	9.5	281	11.8	394	11.9

Note:
[1] Parallel operation assumes flow is comingled
Key:
cfs = cubic feet per second
ft/sec = feet per second

Working and Shut off Pressure

The working pressure is defined as the maximum operating pressure along the pipeline; it is based on the maximum steady state hydraulic grade line while flow is delivered through the Delta-Transfer Pipeline to the terminal reservoirs located at the Transfer Facility. Since the pipeline may be supplied from either the Middle River or Old River Pump Stations individually, or from both pump stations under a parallel operating condition, all three operating conditions must be considered. Furthermore, since the yard piping is set up so that either pipeline (Old River Pipeline or Delta-Transfer Pipeline) can be taken out of service for maintenance it is possible to direct the combined total flow from both pump stations through the Delta-Transfer Pipeline. Although not a normal operating condition, this operating scenario would yield the highest operating HGL, and should be considered the maximum operating HGL. The internal working pressure in the pipe at any point along the alignment is then equal to the difference between this maximum HGL and the pipe centerline elevation.

Mainline isolation valves are proposed along the new Delta-Transfer Pipeline just downstream from the meter vault on the Old River Pump Station site and just before the terminal reservoir turnout connection at the Transfer Facility. If the isolation valve near the reservoir turnout should be closed and either pump station is on line, the pumps would be pumping against a closed valve and the pressure in the pipeline would rise to the full pump shutoff pressure. The resulting pump shutoff pressures must also be considered in the design pressure of the pipe.

HGLs were developed from the model results for both maximum and minimum flow conditions. The maximum flow condition represents all pumps operating at each station and the minimum flow represents one pump operating at the Middle River Pump Station. The HGLs along with the pipeline elevation for the Delta-Transfer Pipeline are provided in Figure 5-1. The corresponding estimated pressures for each operational scenario are presented in Figure 5-2.

From Figure 5-2, the maximum shut off pressure occurs from the Middle River Pump Station. The maximum working pressure occurs when both pump stations are pumping through the Delta-Transfer Pipeline. The maximum shut off pressure ranges from 220 psi to 300 psi along the pipeline and the maximum working pressure ranges from 35 psi to 200 psi.

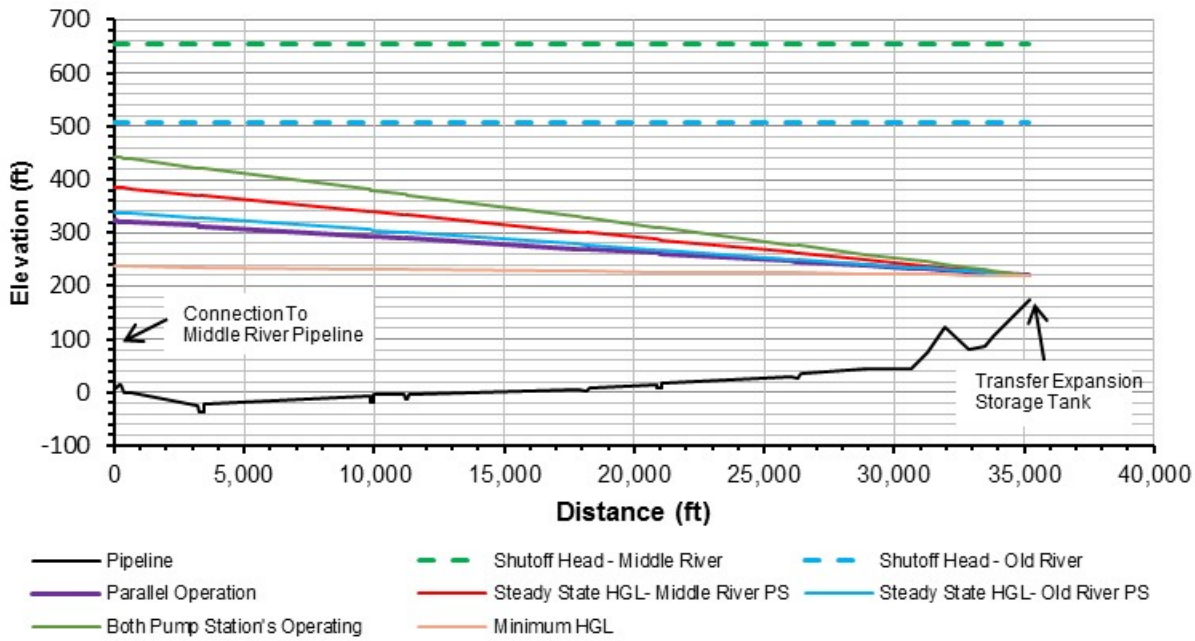


Figure 5-1. Hydraulic Grade Line – Delta-Transfer Pipeline

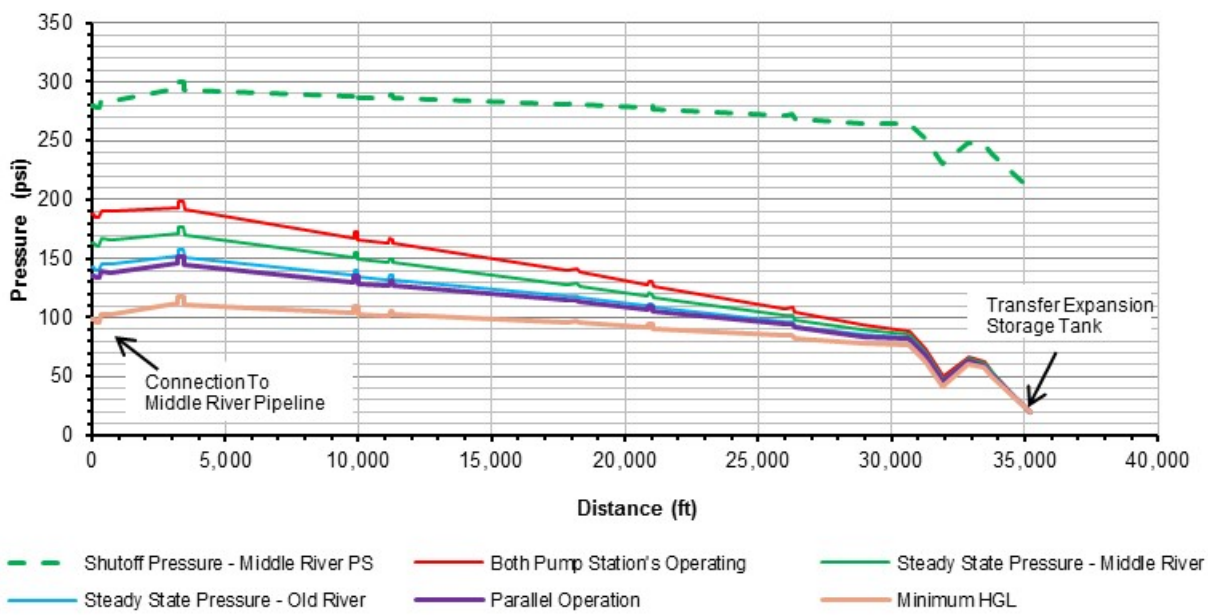


Figure 5-2. Pressure – Delta-Transfer Pipeline

Transfer-Bethany Pipeline and Expanded Transfer Pump Selection

The proposed Transfer-Bethany Pipeline was incorporated in to the existing system hydraulic model. The model has been used to size the pipeline assuming a maximum 300 cfs pumped from the expanded transfer pump station, a maximum of 400 cfs conveyed by gravity from the Los Vaqueros Reservoir, and a maximum velocity of approximately 10 ft/sec. Using the flow and velocity estimates described above, a pipeline diameter of 84 inches has been selected for the Transfer-Bethany Pipeline. An 84-inch-diameter pipeline provides an estimated velocity of 7.8 ft/sec at 300 cfs and 10.4 ft/sec at 400 cfs. Although the velocity at 400 cfs slightly exceeds the maximum proposed velocity of 10 ft/sec, the pipe sizing was determined to be acceptable since this operational scenario would occur infrequently and the estimated velocity is less than 12 ft/sec which is the critical velocity to prevent scour damage to cement mortar lining.

The model has been used to develop a system curve of the Transfer-Bethany pipeline assuming: an 84-inch-diameter; water depth of 20 feet in the ETPS Reservoir located on the Transfer Facility site; a water surface elevation of 245 feet in the Bethany Reservoir; and a C-Factor of 113. The selected C-Factor is consistent with the Delta-Transfer Pipeline and Middle River Pipeline as identified in the Existing System Model TM (MWH 2015b).

Pump configurations ranging from eight to four duty pumps were evaluated using pump performance curves from numerous pump manufacturers. Due to the shape and slope of the system curve, a single pump model could not be identified to meet the full range of flows crossing the system curve, which creates a critical operating point where the first pump does not cross the system curve.

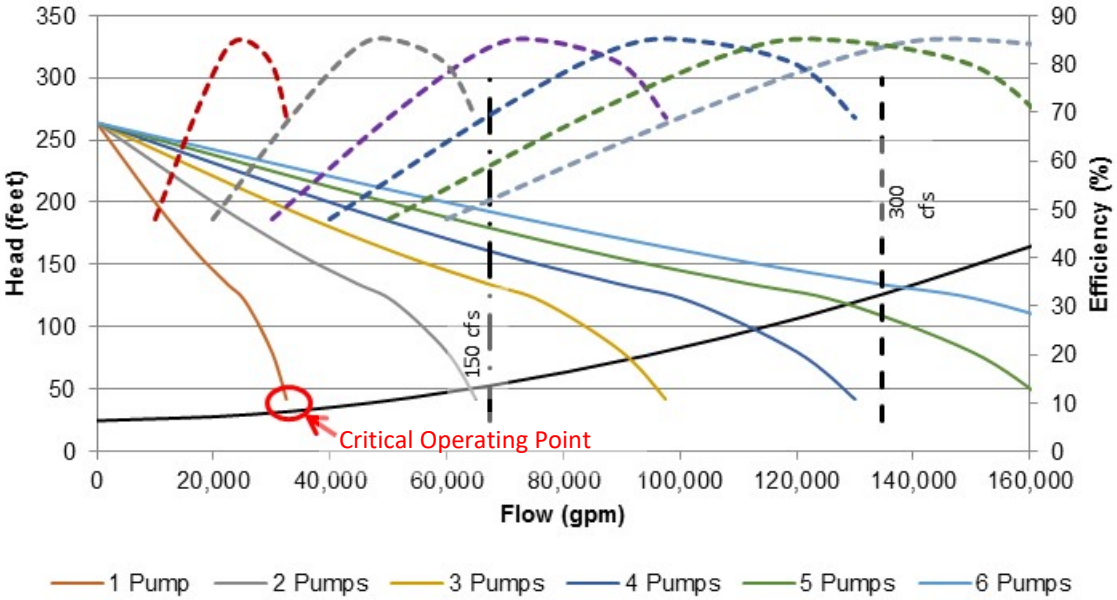
Based upon a review of available pumps, the six-pump configuration using Sulzer Model SJT-42KMC – 3-Stage pump operating at 590 revolutions per minute fitted with a 1,250 hp motor was selected as the preferred pump configuration for the ETPS. The system curve along with the preferred pump performance curve is presented in Figure 5-3. The selected pump provides high efficiencies (85 percent at best efficiency point) over the pump operating range including pump run out.

As shown in Figure 5-3, the pump performance curve does not cross the system curve when a single pump is operating, creating a critical operating point. There are three general approaches to address this concern. The first option is to set the minimum station flow at 140 cfs with two pumps operating together. This option is the simplest, economical and reliable method of operating the pump as compared to the other options, provided the District would agree to operate the system at a minimum flow of 140 cfs.

The second option would be using a VFD for each pump motor to adjust the pump speed so that the pump performance will intersect the system curve at approximately 90-percent speed. This will add slight complexity to the pump station control, additional cost for VFD and additional maintenance.

The third option would be to provide a throttling valve to create an artificial pressure increase so the operating point of the pump will be inside the Allowable Operating Region. This option would add cost for the pump control valve and complexity of controls.

Figure 5-4 shows the pipeline profile, the maximum and minimum hydraulic grade lines, and shut off head condition along the Transfer-Bethany Pipeline using the preferred pump.



Key:
% = percent
gpm = gallons per minute
rpm = revolutions per minute

Figure 5-3. Pump Selection – Expanded Transfer Pump Station

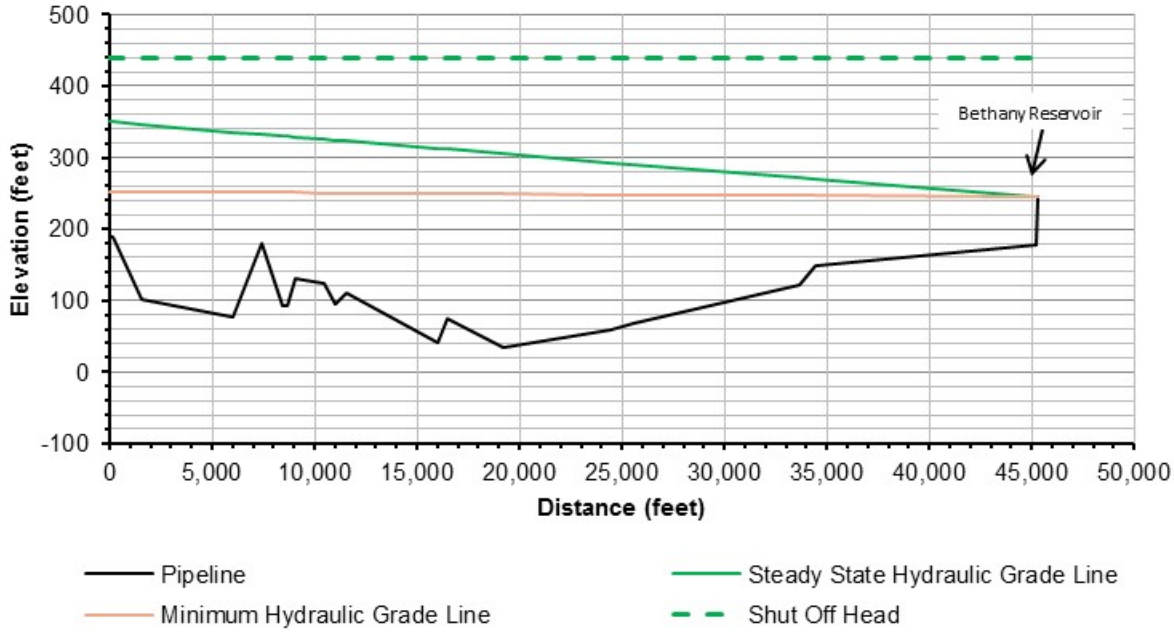


Figure 5-4. Hydraulic Grade Line – Transfer-Bethany Pipeline

Surge Analysis

Hydraulic transient pressures result from sudden velocity changes in the water flowing through a pipeline. These transient (or surge) pressures can propagate from closing a valve too rapidly or may result from an electrical power failure at a pump station that causes a sudden pump shut down. Other causes may include modulating a regulating valve too quickly or a sudden release of entrapped air from the pipeline. The most common cause of a pipeline surge condition for a pumped water transmission main is electric power failure at the pump station.

A preliminary hydraulic transient analysis has been completed for the Delta-Transfer Pipeline and associated pump stations as well as the Expanded Transfer Pump Station and Transfer-Bethany Pipeline using InfoSurge by Innovyze and the existing system hydraulic model.

The preliminary transient analysis evaluated surge conditions developed along the Old River, Middle River, new Delta-Transfer, and Transfer-Bethany pipelines due to sudden power loss occurring at the Middle River Pump Station, Old River Pump Station, and proposed ETPS. The results will be used to determine if the existing surge tanks at the Middle River and Old River Pump Stations are adequately sized to control surge conditions developed along the Old River, Middle River, and Delta-Transfer pipelines and size surge tanks at the ETPS to control surges along the Transfer-Bethany Pipeline.

Physical Facilities

The rated characteristics of the pumps for each pump station modeled are summarized in Table 5-2.

Table 5-2. Pump Characteristics

Pump Station	Old River	Middle River	Expanded Transfer
Pump Make/Model	Goulds 34GHX-34GHC	Fairbanks Morse 40GM-7100AW	Sulzer SJT-42KMC 3-Stage
Number of Pumps	5	5	6
Rated Flow (gpm)	26,000	24,580	25,500
Rated Head (ft)	250	364	120
Rated Efficiency (%)	88	87	85
Speed (rpm)	900	890	590
Motor Horsepower	2,100	3,000	1,250
Specific Speed	2,308	1,674	2,598
Total WR2 (lb-ft^2) [1]	5,536	4,800	4,200

Note:
[1] Estimated combined pump and motor rotational moment of inertia
Key:
% = percent
ft = feet
gpm = gallons per minute
lb-ft^2 = pounds per square foot
rpm = revolutions per minute

Both the Old River and Middle River Pump Stations use surge tanks to control transients. The physical features of these existing surge tanks are summarized in Table 5-3.

Table 5-3. Existing Surge Tank Summary (Old River and Middle River Pump Stations)

Pump Station	Old River	Middle River
Number of Surge Tanks	2	2
Volume / Tank (ft^3)	7,060	5,300
Steady State Air Content (%)	30 - 40	10 - 30
Number – Size of Connecting Pipe(s)	Outflow: 2 – 24″ diameter Inflow: 1 – 24″ diameter	Outflow: 2 – 24″ diameter Inflow: 2 – 24″ diameter

Key:
% = percent
ft^3 = cubic feet

Each surge tank at the Old River Pump Station has two 24-inch connection pipes, one of which is fitted with a check valve. Flow can freely exit the tank (downsurge) through both connection pipes but is restricted to only one connection (due to the check valve) upon flow return to the tank (upsurge). Based upon the Middle River As-built drawings, the two 24-inch connection pipes allow free discharge and return flow to the two Middle River surge tanks.

Assumptions and Methodology

The following general assumptions and boundary conditions have been used in the transient model development and throughout this analysis.

The wave speed, or celerity, was calculated to be 3,300 ft/sec assuming rigid pipe materials (concrete and steel). The pipe roughness (C-Factors) factors used correspond to the values identified in the hydraulic modelling section. A 1.2 polytrophic gas exponent was used to represent actual expansion and contraction of the surge tank's air volume.

Upon loss of power the model software uses the combined rotational moment of inertia of the pump and motor and a representative four quadrant pump curve to determine the decaying flow from the pump during the run down. The rotational moment of inertia (WR^2) of the combined pump and motor was estimated. Check valves were added just downstream from the pump nodes to simulate near instantaneous closure upon flow reversal.

When a downsurge of –14.7 pounds per square inch gauge (full vacuum) occurs in the transient model, the subsequent positive surge pressure results become erroneous. This is due to the limited capabilities of the transient model to represent two phase flows (gas and liquid) and predict "water hammer" spikes resulting from a vapor cavity collapse. Therefore, the formation of a full vacuum condition in the system is used as a qualitative measure of an unacceptable hydraulic condition since the upsurge pressure cannot be accurately determined. Without knowing the upsurge pressure, it is not possible to predict if a certain pipe material could withstand the resultant upsurge pressure. Therefore, for this work, a minimum allowable pressure of -5 pounds per square inch gauge was selected because pipelines are susceptible to cavitation and buckling from severe vacuum pressures and because vacuum valves have been found to choke at differential pressures greater than -7 pounds per square inch gauge. Also, the use of cement mortar lining is susceptible to cracking and flattening when subjected to tensional stresses that may result on the interior pipeline wall from full vacuum pressures.

Transient Analysis

Surge tanks were evaluated as the primary surge mitigation devices since they are used at all existing Los Vaqueros Project pump stations. Flywheels were not considered since the proposed pumps are "canned" type vertical turbine pumps. Air/vacuum valves may be considered as supplemental surge control at high points if surge tanks can be sized to mitigate the hydraulic transients.

Old River and Delta-Transfer Pipelines Since the proposed operation of the Old River and Delta-Transfer pipelines include a hydraulic connection at the existing Middle River Pipeline tie-in at the Old River Pipeline, the transient analysis of this system will include the following scenarios:

- **Scenario 1** – Simultaneous power loss at both pump stations while the pipelines are operated as parallel pipelines discharging to the Transfer Facility.
- **Scenario 2** – Power loss at Middle River Pump Station conveying flow through the Middle River and Delta-Transfer pipelines to the Transfer Facility.

- **Scenario 3** – Power loss at Old River Pump Station conveying flow through the Delta-Transfer Pipeline to the Transfer Facility.

- **Scenario 4** – Power loss at both the Middle River and Old River Pump Stations conveying flow through the Delta-Transfer Pipeline to the Transfer Facility.

The scenarios identified above will be used to determine if the existing surge tanks are adequate to protect the system and if required, recommend additional surge mitigation measures.

Initially, the model included air volume set points of 30 percent of the total volume in the Middle River surge tanks and 40 percent in the Old River surge tanks. The preliminary transient analysis results determined that the proposed air volume set point within the Middle River surge tanks required adjustment. The analysis determined that an air volume set point of 25 percent was required for the Middle River surge tanks and 40 percent within the Old River surge tanks. Using the proposed air volume set points resulted in adequate surge protection using the existing surge tanks.

The pipeline profile along with the minimum, maximum, and steady state hydraulic grade lines were estimated from the surge model for each scenario. Figures 5-5 and 5-6 show the surge modelling results along both the Old River and Middle River/Delta-Transfer pipelines for Scenarios 1 and 2. The surge modelling results for Scenarios 3 and 4 are shown in Figure 5-7. It should be noted that the hydraulic grade line begins at the Old River Pump Station under Scenario 3 (Figure 5-7) since Old River is pumping through the Delta-Transfer Pipeline to the Transfer Facility.

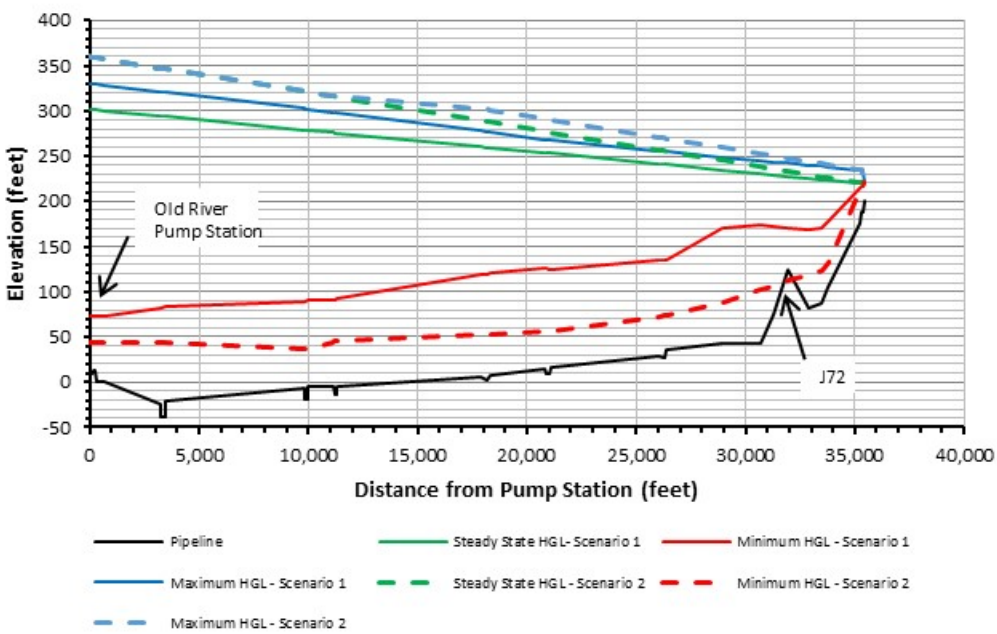


Figure 5-5. Elevations Following Loss of Power – Old River Pipeline – Scenarios 1 and 2

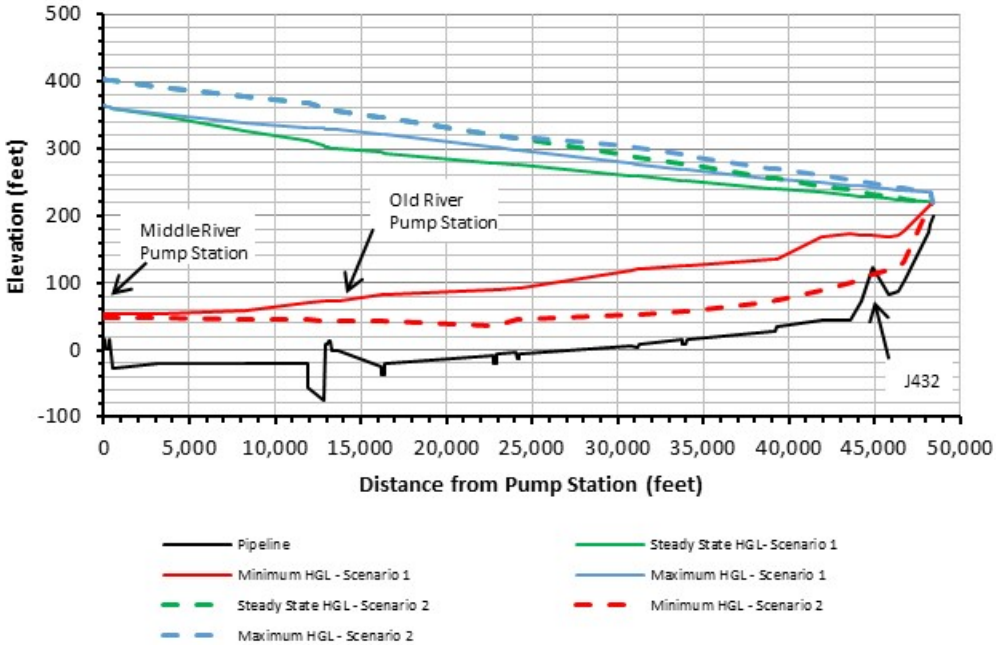


Figure 5-6. Elevations Following Loss of Power – Middle River / Delta-Transfer Pipeline – Scenarios 1 and 2

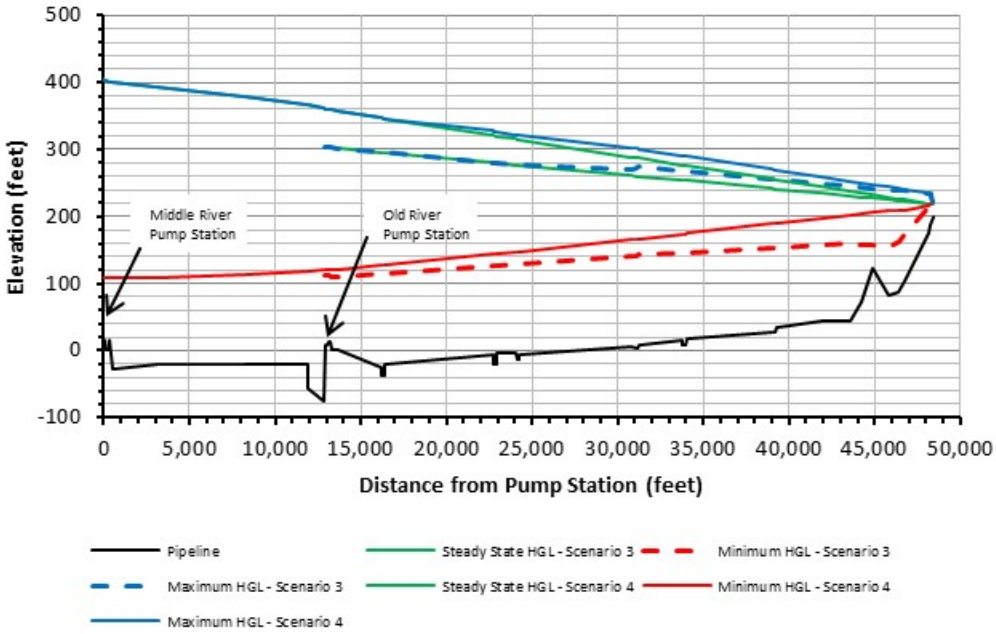


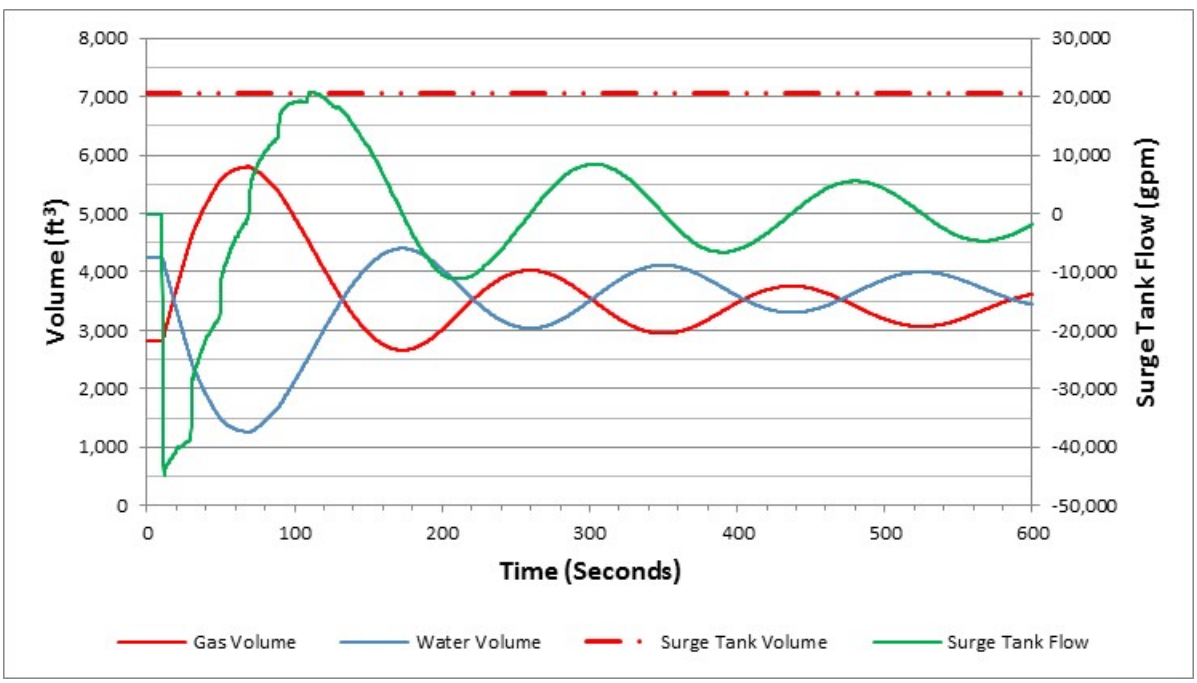
Figure 5-7. Elevations Following Loss of Power – Middle River / Delta-Transfer Pipeline – Scenarios 3 and 4

As shown in Figures 5-5, 5-6, and 5-7, the critical surge condition occurs under Scenario 2 when the two pipelines are used individually pumping directly from each pump station to the transfer facility

with no hydraulic connection between the two systems. Under this scenario, the minimum head falls below the pipeline at model junctions J72 (Figure 5-5) and J432 (Figure 5-6) with the estimated minimum pressure of approximately -4 psi occurring over ½ second then subsequently increasing and remaining positive for the duration of the analysis. These minimum pressures are acceptable and do not warrant additional surge mitigation devices to protect the pipeline during the downsurge.

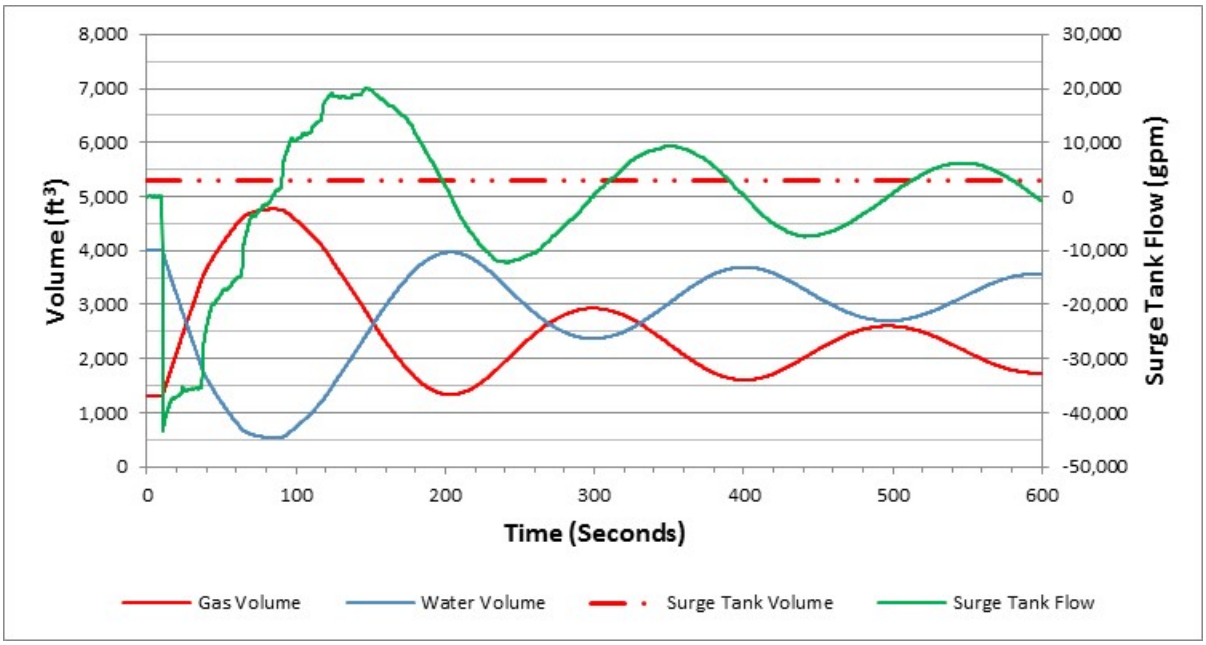
The model predicted performance of the existing surge tanks for the critical surge condition is shown in Figures 5-8 and 5-9. The red line shows the change in gas volume, with the red dashed line representing the total volume of the surge tank; the blue line shows the change in water volume; and the green line shows the flowrate in and out of the tank, with a negative flow representing flow out of the tank. As shown in Figures 5-8 and 5-9, the minimum water volume in the surge tank ranges from approximately 10 percent to 18 percent for both pump stations.

A refined transient analysis is recommended to be completed during the Investigation final design phase to confirm mitigation measures that should be employed to protect the pipe from excessive hydraulic transient conditions and confirm the maximum transient pressures for use in the final design of the pipeline and pump station.



Key:
ft^3 = cubic feet
gpm = gallons per minute

Figure 5-8. Old River Surge Tanks – Dedicated Flow through Old River Pipeline



Key:
ft^3 = cubic feet
gpm = gallons per minute

Figure 5-9. Middle River Surge Tanks – Dedicated Flow through Middle River / Delta-Transfer Pipeline

Expanded Transfer Pump Station and Transfer-Bethany Pipeline The transient analysis of the ETPS and Transfer-Bethany pipeline was evaluated with all six pumps operating (300 cfs), a 20-foot water depth on the Transfer Facility storage tanks, and a water surface elevation of 245 feet in the Bethany Reservoir. This evaluation was performed to determine the number and size of surge tanks required to mitigate transients developed due to power loss at the ETPS.

The transient analysis determined that three, 12-foot-diameter by 44-foot-long surge tanks providing a volume of 5,300 cubic feet (each), with an air volume set point of 40 percent, are required to mitigate the downsurge during power loss. Each surge tank is assumed to be connected to a 72-inch-diameter header pipe by two 18-inch-diameter pipelines. One of the 18-inch-diameter connection pipes is fitted with a check valve. This allows unrestricted flow from the surge tanks through the two 18-inch-diameter pipelines (downsurge), but restricts the flow entering the surge tank during the upsurge.

Figure 5-10 shows the pipeline profile as well as the minimum, maximum, and steady state hydraulic grade lines along the new Transfer-Bethany Pipeline. As shown in Figure 5-10, downsurge conditions are the most critical during the surge event since the maximum head during the surge event corresponds approximately to the steady state hydraulic grade line. The minimum head along the pipeline approximately 34,000 feet downstream from the ETPS approaches the pipeline elevation but remains positive.

The model predicted performance of the surge tanks is shown in Figure 5-11. The solid red line shows the change in gas volume, with the red dashed line representing the total volume of the surge tank. The blue line shows the change in water volume, and the green line shows the flowrate in and out of the tank, with a negative flow representing flow out of the tank. The minimum water volume within the surge tank is approximately 5 percent of the total volume.

The proposed surge tank sizing should be adequate for the expanded transfer pump station and Transfer-Bethany pipeline at a design flow of 300 cfs. Although the transient model was not evaluated when transferring water from the Los Vaqueros Reservoir to the Bethany Reservoir at the maximum design flow of 400 cfs, the closure time of the flow control valves should be set to minimize transients developed during the operation of these valves. A refined transient analysis is recommended to be completed during the final design of the pump station and pipeline to verify the assumptions and optimize the sizing and configuration of the surge tanks and determine the closure time of the flow control valves during the 400-cfs operating condition.

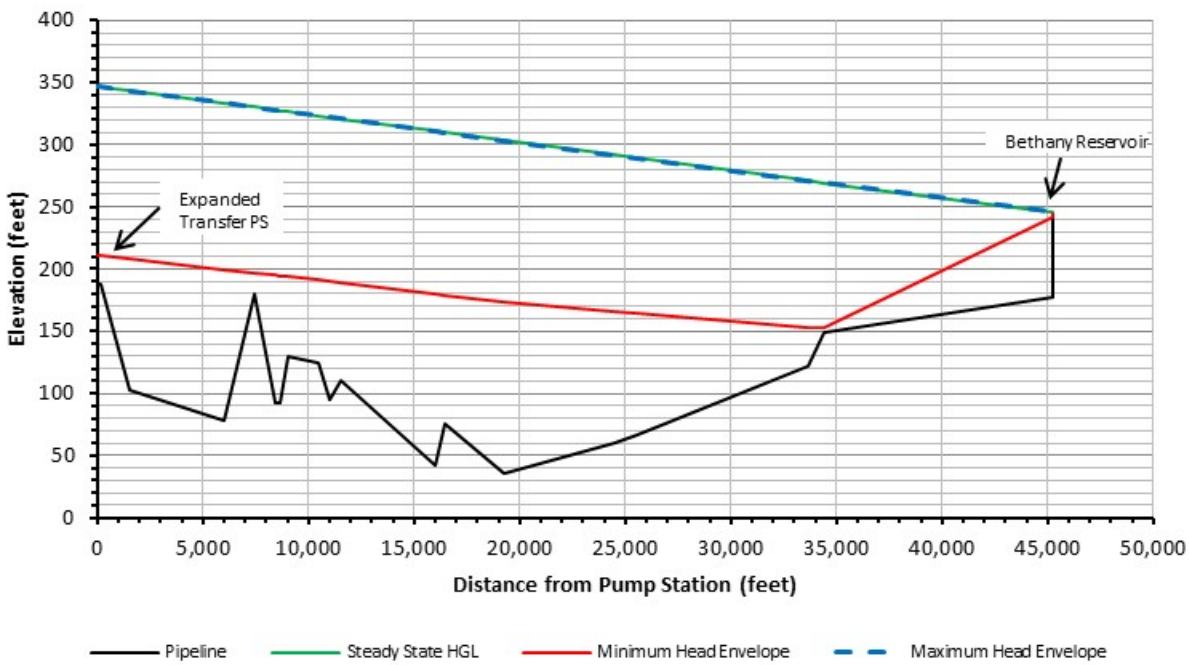
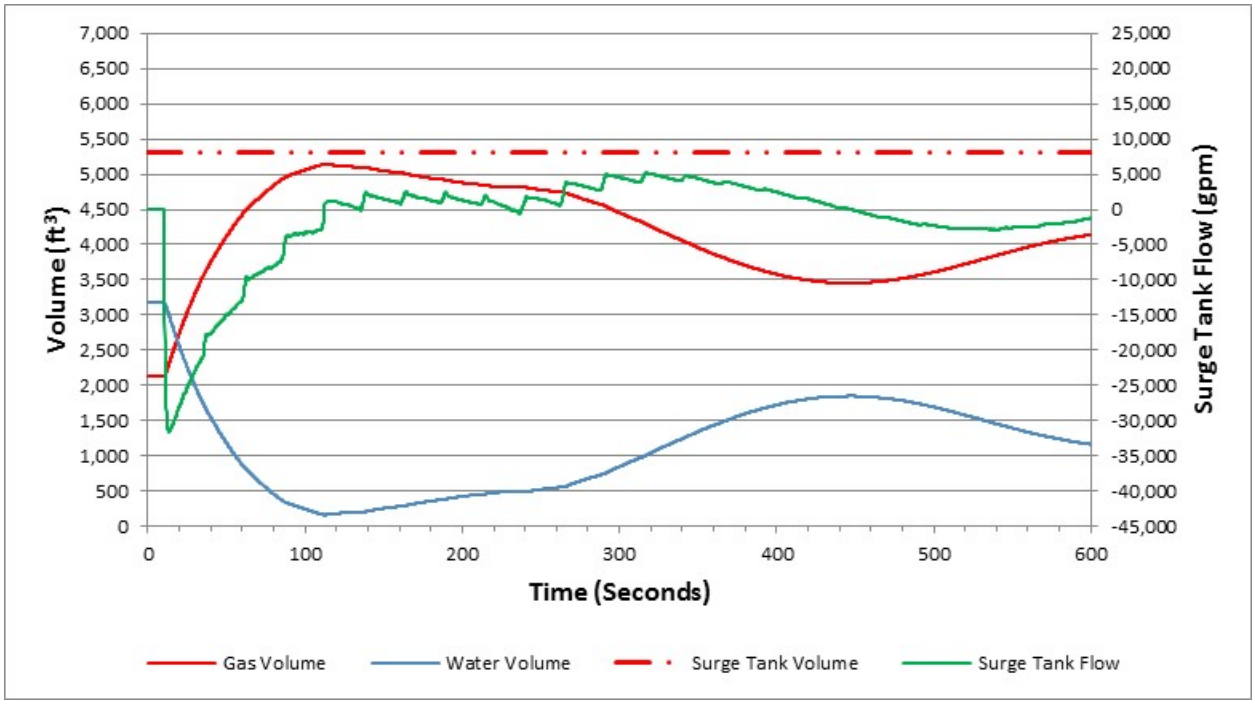


Figure 5-10. HGL Elevations Following Loss of Power – Transfer-Bethany Pipeline



Key:
ft^3 = cubic feet
gpm = gallons per minute

Figure 5-11. Expanded Transfer Surge Tanks

Transfer Pump Station Modifications

This section describes the modifications required at the existing Transfer Pump Station to maintain a 200 cfs pumping capacity at the new maximum Los Vaqueros Reservoir water surface elevation resulting from the proposed reservoir expansion. Hydraulic modeling was performed to estimate system requirements for the Transfer Pump Station with the expanded Los Vaqueros Reservoir water surface elevation. New pump and motor requirements were then estimated. New Transfer Pump Station Power and Control requirements were also evaluated. See Figure 5-12 for an overall site plan of the Transfer Pump Station Modifications. The general design criteria for all engineering disciplines presented in Chapter 3 are assumed for new facilities required to complete the transfer pump station modifications described below.

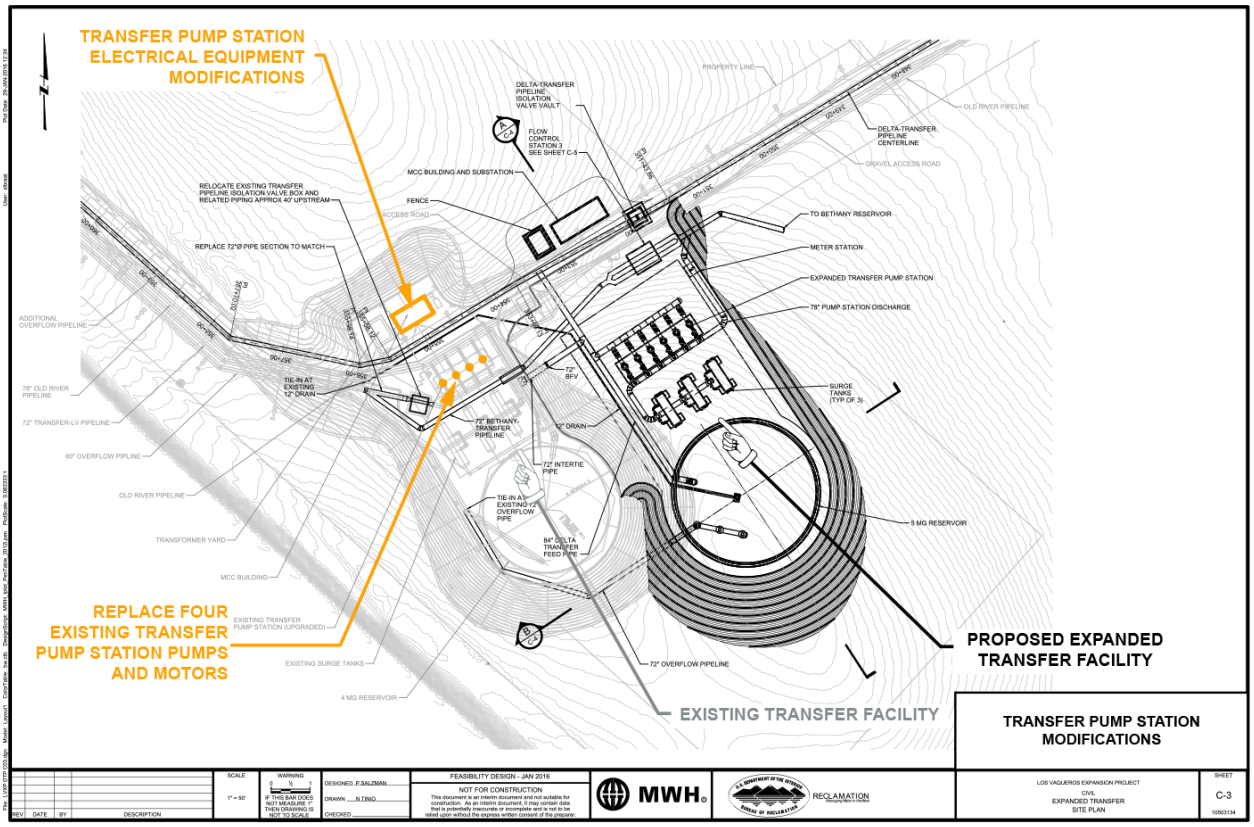


Figure 5-12. Transfer Pump Station Modifications

Hydraulic Modeling Summary

The proposed capacity expansion of the Los Vaqueros Reservoir will increase the storage volume to 275 TAF with operating levels ranging from elevation 448 feet to 560 feet. Based upon this maximum water surface elevation, the existing Transfer pumps do not meet the new hydraulic criteria to fill the reservoir. Hydraulic analyses were conducted using the Infowater model of the existing system to estimate improvements to the Transfer Pump Station to convey 200 cfs to Los Vaqueros Reservoir at the new maximum water surface elevation.

The hydraulic model was used to develop system curves of the Transfer system, which includes the 4-million-gallon Transfer Storage Tank, the four-pump Transfer Pump Station, and the 72-inch diameter Transfer Pipeline. A normal operating water depth of 20 feet in the Transfer Storage tank was assumed and Los Vaqueros Reservoir levels of 448 feet and 560 feet. A C-Factor of 135 was used to represent the hydraulic resistance of the transfer pipeline as identified in the Existing System Model TM.

The model estimated that the transfer pumps would require a duty point of 50 cfs at 385 feet Total Dynamic Head (TDH). Several pump manufacturers were contacted to obtain representative pump performance curves. Figure 5-13 shows the system curves for high and low reservoir levels along with the pump performance curve for WEHR Model 37TKM for single and multiple pump operation. An estimated 3,250 hp motor would be needed for this pump selection. The preferred

operating range of the pump is represented by the shaded region along the pump curve and ranges from approximately 50 cfs to 83 cfs.

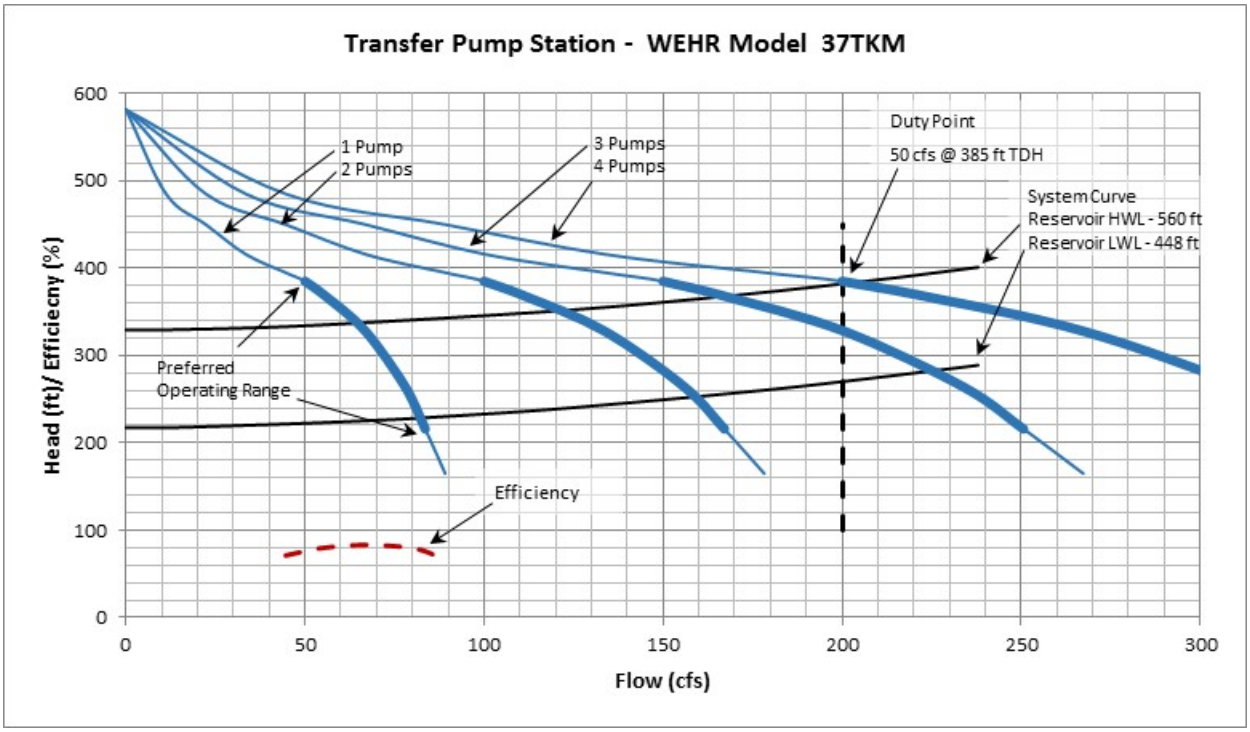


Figure 5-13. Transfer Pump Station System Curve

Figure 5-13 shows that the preferred operating range of the pump is large enough that it crosses the system curves corresponding to minimum and maximum reservoir levels indicating that VFDs or control valves are not required to control the discharge from the station at lower reservoir levels. This arrangement is consistent with the current pump station operation. Results also indicate that three pumps could be used under normal operating conditions to convey the 200 cfs design flow, which saves potential operational costs, and essentially provides a redundant pump. Three pumps operating at the minimum reservoir level (448 feet) would convey approximately 225 cfs to the Los Vaqueros Reservoir, this discharge provides a velocity of 8 feet per second, which is acceptable.

Since the pump duty point was selected to convey the design flow (200 cfs) at a full reservoir level; pump motor sizing could be minimized by reducing the required duty point. However, reducing the duty point also reduces the available discharge as the reservoir nears full operating conditions. Based upon the shape of the WEHR pump performance curve, selection of a pump duty point approximately 50 cfs at 325 feet TDH would reduce the available capacity to approximately 160 cfs under full reservoir conditions (Elevation (EL) 560 feet), with four pumps operating, and reduce motor sizing to approximately 2500 hp. This operational scenario should be evaluated further during design development if this alternative is selected.

The existing Transfer Pump Station surge system, as summarized in Table 5-4, was evaluated with the addition of the WEHR pump. Model results determined that the existing surge tanks located at

the Transfer Pump Station are adequate to protect the system. However, the surge system should be re-evaluated during design development.

Table 5-4. Existing Surge Tank Summary (Transfer Pump Station)

Pump Station	Transfer
Number of Surge Tanks	2
Volume / Tank (ft^3)	7,060
Steady State Air Content (%)	30 - 40
Number – Size of Connecting Pipe(s)	Outflow: 2 – 24″ diameter Inflow: 1 – 24″ diameter

Key:
% = percent
ft^3 = cubic feet

As previously stated, the preferred operating range of the pump crosses the system curves corresponding to minimum and maximum reservoir levels indicating that VFDs or control valves are not required to control the discharge from the station at lower reservoir levels. The existing transfer pipeline was evaluated by another consultant which determined that it was adequately sized for the additional operating pressure. Therefore, replacement of the existing transfer pumps is the only process mechanical improvement required at the Transfer Pump Station to convey the design discharge (200 cfs) to the proposed expanded Los Vaqueros Reservoir.

Power Requirements

The existing Transfer Pump Station was designed to accommodate up to 3,500 hp synchronous motors so no major additions or changes need to be performed or added regarding the existing facility electrical capacity. Minor MV MCC changes are required that include changing the current transformers and power fuses that are sized for 2,100 hp to 3,250 hp size units. The protective relays need all their settings adjusted for the new motor size. The motor excitation might need to be changed depending on the new motor particular needs as compared to the existing motors. Constant speed synchronous motors are assumed to be used to make use of their power factor correction capability and reuse the existing MCC set up for constant speed synchronous motor control and operation. The line reactors for the solid-state starters will likely need to be replaced. The existing transformer at 15 MVA is expected to be suitable for the four new 3,250 hp pump motors. The existing switchgear is sized for 15 MVA transformer and does not need to be changed. The wall mounted series line reactor may need to be replaced, or provided if not installed, to accommodate the new larger motor starting and running currents.

The PG&E feed to the Transfer Pump Station and related PG&E substation is expected to grow substantially as the existing feed probably only accommodates the four existing 2,100 hp pumps and is not expected to accommodate the replacement four 3,250 hp pumps and the new six 1,250 hp pumps of the new Expanded Transfer Pump Station. This was discussed in our previous Pumping and Controls Technical Memorandum (Pumping and Controls TM) and mentioned again here for completeness. Our design planning stops at the existing 21 kV service and that is where PG&E planning, engineering and design picks up. The PG&E infrastructure ahead of the pump station may

require capacity upgrades to meet the needs of the higher horsepower pump station. This work will need to be coordinated with PG&E during design. No cost for PG&E upgrades has been included in the opinion of probable construction cost (OPCC).

Control and Monitoring

The existing CCWD SCADA HMI and Transfer Pump Station and Reservoir PLC software packages will need to be modified to incorporate new analog and discrete I/O communicated from the new Neroly High Lift Pump Station flow meter, pressure transmitter and positions and statuses from the new Los Vaqueros and Neroly High Lift Pump Station pipeline isolation valve actuators. The planned Expanded Transfer Pump Station PLC will also need to be configured to similarly process the preceding information.

Expanded Transfer Pump Station and Reservoir

The ETPS and Reservoir will be used to direct water from the Old River, Middle River, or Neroly High Lift Pump Stations to Bethany Reservoir via the new Transfer-Bethany Pipeline. The Pump Station will have a 300 cfs design flow capacity and the reservoir will have a 5-million-gallon storage capacity. Refer to project design criteria presented in Chapter 3 and to the Hydraulic Modeling section of this chapter for additional design detail.

Facility Siting

A location adjacent to the existing Transfer Pump Station and Reservoir has been selected for the ETPS and Reservoir. The proposed site minimizes the length of piping to the Transfer-Bethany Pipeline tie-in and intertie piping between the Old River Pipeline and Delta-Transfer Pipeline supplies. The adjacent location will also help minimize additional operation and maintenance staff travel time.

Pump Station

The pump arrangement is similar to the existing Transfer Pump Station (refer to Design Drawings in Attachment 3C). Six 50 cfs capacity vertical turbine pumps powered by 1,250 hp constant speed motors will provide the pump station's 300-cfs design flow capacity. The pumps will each be located in a pressurized "can" or "barrel" configuration. Based on preliminary pump selection and HI design criteria the cans are tentatively sized at 72 inches in diameter.

Due to the wide range of system head requirements, design elements are required to maintain conditions within the maximum Allowable Operating Region at combined pump station flow rates less than 140 cfs (refer to System Hydraulic Modeling section of this chapter). Our preliminary design approach assumed that a motor actuated modulating valve (ball valve shown, although cone valve will also be evaluated) would be provided on each pump discharge to control pump performance at low system flows. It is recommended that a detailed evaluation of alternative approaches, such as setting a design minimum pump station flow rate greater than 140 cfs or expanding the investigation of pump alternatives to identify a pump that would perform acceptably under low flow conditions, be considered in the next phase of design.

Power will be provided to the pumps from a new substation and new MCC building as described later in this chapter.

Pump Station Suction and Discharge Piping

An 84-inch-diameter pipe will be routed from the Delta-Transfer Pipeline to the ETPS's buried 84-inch-diameter suction header. 54-inch-diameter buried suction pipes will be routed to the pump cans from the header. Manual butterfly isolation valves will be provided on each suction pipe.

The 30-inch pump discharge piping will be routed above ground before expanding to 36 inches in diameter and then being routed to the buried 78-inch-diameter discharge header. The discharge piping will include a manual butterfly isolation valve as well as a flow control ball valve, as previously described.

A buried 72-inch-diameter pipeline will be routed from the pump discharge header to surge tanks. Design features and operational procedures to mitigate any sediment accumulation or water stagnation in the 72-inch diameter pipeline will be examined in the next phase of design. It is anticipated that up to three surge tanks will be required as described in the System Hydraulic Modeling section of this chapter.

The discharge piping will be routed to the new Transfer-Bethany Pipeline, directly downstream from Flow Control Station 3. The Transfer-Bethany Pipeline will begin downstream from the discharge header of the existing Transfer Pump Station and in addition to facilitating pumped flow from the ETPS, will facilitate a gravity flow rate of up to 400 cfs from Los Vaqueros Reservoir to Bethany Reservoir. Flow Control Station 3 is required to control the high head flow from Los Vaqueros Reservoir and will be configured like the existing Flow Control Station 1. Flow from Low Vaqueros Reservoir will be split between two smaller pipes to facilitate control of up to 400 cfs total flow and each pipe segment will be equipped with isolation valves and motor operated sleeve valves to dissipate excess energy. The features of the Transfer-Bethany Pipeline are described later in this chapter. A feasibility-level Flow Control Station 3 layout is provided in Attachment 3C, for reference.

Reservoir

The reservoir will be a 5-million-gallon capacity above ground steel tank. Sizing of the tank was previously described in the Los Vaqueros Expansion Project Design Criteria Technical Memorandum (MWH 2016). The primary functions of the tank are summarized below, for reference:

- Provide a stable water surface elevation for operation of the pumps at the Old River and Middle River Pump Stations.
- Provide hydraulic level control for the flow control valves at Flow Control Stations 1 and 2.
- Provide a stable suction pressure for operation of the Expanded Transfer pumps.

- Provide storage volume required for the controlled shutdown of the Old River/Middle River pumps or the Transfer/Expanded Transfer pumps.

- Provide a controlled emergency overflow to prevent pressure buildup in the Los Vaqueros, Old River, or Delta-Transfer Pipelines.

The tank will have a 91-foot radius and will be approximately 30 feet tall. The tank will typically operate at the same 213-feet WSEL as the existing Transfer Facility reservoir tank. It is anticipated that the tank will be built on a reinforced concrete ring footing foundation with a layer of asphaltic cement pavement laid beneath the tank. Soil excavations for the new the reservoir will be used for fill. Any excess fill dirt will be stored and reused as backfill for other components or sent to a construction materials recycling facility.

Reservoir Piping

The 84-inch-diameter pipe routed to the pump station suction header will continue underground past the header and provide flow to and from the reservoir through an upturned 90-degree elbow. All piping under the reservoir will be concrete encased.

A buried 72-inch intertie pipeline will be provided between the 84-inch supply/withdrawal pipe and the existing 72-inch pipe supplying the existing Transfer Pump Station and Reservoir. The pipeline will include a motorized isolation valve. It is assumed that the isolation valve would normally be open to allow both pump stations to operate using a combined water source, however the valve could be closed to allow the pump stations to operate using different water sources.

It is currently assumed that the reservoir overflow piping configuration will be similar to the existing Transfer Pump Station reservoir. The piping will consist of three standpipes inside the reservoir, each with a weir near the top of the reservoir. Three overflow pipes would connect to a manifold, which would then combine to a single pipeline which would be routed to tie-in at the existing Transfer reservoir overflow pipeline which terminates at an energy dissipation structure at Kellogg Creek. Design criteria for the ETPS Reservoir overflow piping and the combined overflow piping will need to be confirmed and coordinated with currently proposed Los Vaqueros Reservoir overflow facilities' modifications.

A 12-inch sediment flushing and washdown drain pipe will be routed from the reservoir to a tie-in at the existing 12-inch drain pipe from the Transfer reservoir. The existing pipe continues to drying beds at the base of the hill. It is assumed that use of the drying beds may be staggered to accommodate the sediment generated by the ETPS Reservoir.

Dewatering

Likely dewatering approaches for the new Expanded Transfer excavations are based on previous geotechnical reports and experience documented in the construction completion report for the original Los Vaqueros Project. At the Expanded Transfer site, the use of trench sumps is assumed to be adequate for dewatering at the discharge piping excavations.

Power Requirements

Delivery of PG&E power is expected to follow the same overhead route and come from the same PG&E substation to deliver power to the new ETPS and Reservoir at 21 kV.

The ETPS and Reservoir will require a 21-kV substation to transform PG&E power down from the delivery voltage of 21 kV to the pump utilization voltage of 4.16 kV. The new substation will match the existing Transfer Pump Station substation to power the six new pumps. The auxiliary equipment and support equipment will be powered from a new 225 kVA dry-type indoor 480-volt 3-phase transformer and matching power distribution panel board to deliver 480 volts for utilization equipment. The 120-volt loads will be powered from a 45-kVA 3-phase transformer and matching lighting panel board. The 125 volts of direct current loads will be powered from the MCC building station 125 volts of direct current battery and its related charger via a DC distribution panel board. The power distribution and utilization equipment will be similar to the existing facilities.

Site lighting will be required. Maintenance receptacles both indoor and outdoor will be required. Instrumentation will require wiring in and around the MCC building, the pumps, the reservoir and the vaults. The MCC building will require ventilation. The surge tanks will require air compressors. A cathodic protection system will need to be supported. 480-volt welding receptacles for maintenance will be required.

Pump control valves will have standard 480-volt 3-phase AC motor actuators.

For the new underground valves and one new flow meter they will be located at or near the MCC building for the ETPS and Reservoir. The new meter and new underground valves are to be installed in vaults built to house them.

The loads in a typical vault are expected to match existing that would include lights, ventilation fans, cathodic protection, instrumentation, maintenance receptacles, irrigation controllers, sump pumps and the valve actuators. The large valve actuators are expected to match existing and use 125-volt DC motors. The much smaller bypass valve actuators are expected to match existing and use 480-volt 3-phase AC motor actuators.

See Chapter 3, the Electrical Design Criteria for details.

Control and Monitoring

The existing CCWD SCADA HMI and the new ETPS and Reservoir PLC software packages will incorporate new analog and discrete I/O that will control and monitor six new ETPS pumps, the new Expanded Transfer Reservoir, the new Expanded Transfer Surge Control System and the new Flow Control Station 3 that controls flow from the existing Los Vaqueros Dam to the existing Bethany Reservoir. The new signals will also include I/O from the new ETPS discharge flow meter, pressure transmitter and new Flow Control Station 3 flow control valves and positions and statuses from the new Transfer-Bethany pipeline isolation valve actuators as described above.

MCC Building

The architectural style for the new MCC building will be consistent with the functional character and external appearance of the existing electrical building to create a unified appearance at the facility. The building will be a slab-on-grade one-story, 1,867 square foot facility of approximately 26'-8" x 70'-0" x 15'-4" clear height.

Roof and wall insulation will be designed to meet California Energy Efficiency Standards.

The exterior walls will consist of integrally colored, 12-inch-by-8-inch-by-16-inch concrete masonry units. Surface textures will be split face, and smooth face. Concrete masonry units exposed to the exterior shall receive a spray-applied, clear penetrating sealer. All exterior walls will be fully grouted and reinforced as required by the code.

The roof system for the building will consist of a Polyvinylidene Fluoride (Kynar) factory finish standing seam metal roofing system, on rigid insulation, attached to the roof structure. The roof system will meet UL Class A rating and satisfy wind uplift requirements for this area.

Doors will be galvanized, hollow steel, painted with an epoxy/polyurethane coating. Doors will be sized for removal of equipment and meet the requirements for personnel egress. Doors will be designed so that the maximum operational force is 15-pound force to unlatch, 30-pound force to set the door in motion and 15-pound force to swing the leaf to a full open position.

The ventilation system will be similar to the existing Transfer Pump Station MCC building and will include louvered, doors and two exhaust fans with output ducted to louvered roof dormers. The ventilation system will be sized for sufficient air flow to maintain interior air temperature at no greater than ten degrees above exterior air temperature.

Delta-Transfer Pipeline

This section provides a summary of the design development of the Delta-Transfer Pipeline. Refer to the design criteria presented in Chapter 3 of this report for additional detail.

The Los Vaqueros Conveyance Facilities Pipelines (Bid Package 2) Old River, Transfer & Los Vaqueros Pipelines Record Drawings (Record Drawings) prepared by Montgomery Watson, May 1998 were used extensively in the Delta-Transfer Pipeline design. The Delta-Transfer Pipeline will parallel the existing Old River Pipeline and have similar criteria and appurtenances to that of the existing Old River Pipeline. Limited field reconnaissance and a review of current aerial photography was conducted to assess current surface facilities and support the design.

Pipe Materials

The estimated flow for the pipeline is 180 cubic feet per second. It is assumed that maximum pipe velocities will be limited to approximately 6 to 8 feet per second. Using these flow and velocity estimates a pipeline diameter of 66-inches was selected.

Several pipe materials are considered suitable for the anticipated operating pressures, soil conditions and size of the Delta-Transfer Pipeline; AWWA C200 steel pipe, and AWWA C300 reinforced concrete pressure pipe, steel cylinder type. Both pipeline materials were specified as alternatives for the Old River Pipeline. AWWA C200 mortar lined and coated steel pipe has been selected for the purposes of this feasibility level investigations. Reinforced concrete cylinder pipe and other lining and coating materials could be considered during detailed design work.

Pipeline Alignment

Conceptual level drawings (Attachment 3A – Delta-Transfer Pipeline Drawings) have been prepared to support the OPCC development. The Delta-Transfer Pipeline will be located parallel to the existing Old River Pipeline from the tie-in at the Old River Pump Station to the vicinity of the Transfer Facility, a distance of approximately 6 ½ miles. The Record Drawings for the Old River Pipeline were used as a basis for defining the proposed alignment and profile for the OPCC development. The existing Old River Pipeline is 78 inches in diameter.

The Delta-Transfer Pipeline alignment has been located with the intention of keeping the Delta-Transfer Pipeline on one side of the Old River Pipeline and within the existing permanent easement for the existing Old River Pipeline. The existing permanent easement is 85 feet wide and the existing Old River Pipeline is situated off center of the easement (i.e., 50 feet available on one side of the Old River Pipeline centerline and 35 feet is available on the opposite side). Typically, the side in which there is a 50-foot-wide corridor allows for the most optimal space for construction and later maintenance. The proposed Delta-Transfer Pipeline alignment will be placed between 15 to 25 feet offset from the centerline of the Old River Pipeline and installed within the existing easement along the north side of the Old River Pipeline which is typically the wider side of available easement. However, there are some relatively short sections where the north side of the alignment falls within the narrow side of the existing permanent easement.

Pipeline Construction Methods and Special Crossings

Most of the alignment will be installed by open cut construction, however, there are two locations where trenchless construction is necessary. There have been relatively few improvements in the area around the pipe easement since the Old River Pipeline was constructed so there are no locations where additional trenchless crossings are needed. Therefore, special crossing techniques are assumed to be similar to those techniques used for the Old River Pipeline. The trenchless crossings under the Byron Highway and Vasco road will both require 78-inch-diameter casings to support the bore and jack method assumed and to allow for subsequent installation of the 66-inch diameter Delta-Transfer Pipeline carrier pipe. The Union Pacific Railroad crossing will also need a casing to be installed by trenchless methods per Union Pacific Railroad standards. Although bore and jack method has been assumed for developing a cost estimate other trenchless methods, such as microtunneling, may be considered during later design work.

Pipeline Connections

The Delta-Transfer Pipeline runs from east to west beginning at the Old River Facility where there is an intake and a pump station. Currently the Old River Facility pumps raw water from the Old River to the Transfer Facility through the Old River Pipeline and, as of 2010 (when the Middle River

Facility was constructed), flow from the Middle River Facility is brought through the Old River Pipeline as well. To allow for maximum operational flexibility it is desirable to have the option to pump water from Middle River through either pipeline (existing Old River Pipeline or proposed Delta-Transfer Pipeline) as well as be able to pump water from Old River through either pipeline.

To accomplish this a connection to the Middle River Pipeline is planned which would then connect directly to the new Delta-Transfer Pipeline as well as a connection to the Old River Pipeline. Several valves will be needed to operate this configuration including the introduction of a 78-inch isolation valve to the existing Old River Pipeline. By using this configuration there will be flexibility in directing flow from both sources through either pipeline. These pipe connections are shown as yard piping and will be included with the Pumping and Transfer Facilities TM.

At the west end, the Delta-Transfer Pipeline connects to the Transfer Facility. This facility is currently used to convey flow to the Los Vaqueros Reservoir and to the Neroly Blending Facility. A proposed expanded Transfer Facility would have the ability to convey water through the proposed Bethany Pipeline (by others) to the Bethany Reservoir. The Delta-Transfer Pipeline will require connections to the Expanded Transfer Facility, the Transfer Facility, and to the Old River Pipeline. These pipe connections are shown in drawings included in Attachment 3C, as are required connections at the Old River Intake and Pumping facility.

Pipeline Profile and Appurtenances

The existing profile for the Old River Pipeline as shown on the Record Drawings was used as a basis for the creation of the new profile for the Delta-Transfer Pipeline. Similar design criteria were also used for the Delta-Transfer Pipeline and the new pipeline design also uses the NGVD 1929 datum. It has been assumed that the depth of cover from the surface to the elevation at the top of the Delta-Transfer Pipeline will be similar to the existing Old River Pipeline. Since the profile is assumed to be similar to the existing Old River Pipeline, appurtenances such as combination air release valve, air release valves, and blowoffs have been placed at locations similar to those that are existing. Manways for access into the pipeline will also be provided. Manways are planned at all blowoff, air release valve, and combination air release valve locations. No additional intermediate manways are planned.

Dewatering

Preliminary dewatering approaches for the Delta-Transfer Pipeline excavations are based on previous geotechnical reports and the construction completion report for the original Old River Pipeline which is in close parallel proximity to the proposed Delta-Transfer Pipeline.

Since the Delta-Transfer Pipeline parallels the existing Old River Pipeline it is assumed that similar groundwater conditions will exist during construction. During the Old River Pipeline construction, sumps in the trench bottom were found to be sufficient to manage water intruding into the trench in the higher ground profile areas beginning approximately where the pipe profile begins to rise in elevation from STA 264+00 to the end at the Transfer facility at STA 357+00. However, from STA 34+40 to STA 264+00, where the ground elevation is relatively low and near the river surface elevation, dewatering wells were necessary to keep the trench dry. Thus, the feasibility level design assumes that dewatering wells will be used between STA 8+00 to STA 264+00 and that trench

sumps will used from STA 264+00 to the tie-in with the Los Vaqueros Pipeline near the Transfer Pump Station.

Contamination

During construction of the Old River Pipeline considerable contamination was encountered at the crossing of Union Pacific Railroad and Hammond Road, leading to a significant change order cost. The source of the contamination was a gasoline pipeline running parallel to the railroad tracks. The extra cost to handle the contamination was mostly reimbursed by Chevron. Since Chevron took responsibility for the costs it is assumed that the contamination in the area was appropriately cleaned up; however, this possible contamination should be investigated and considered further during later design stages for the Delta-Transfer Pipeline.

Cathodic Protection

Assuming steel pipe is to be used for the construction of this pipeline, cathodic protection will be necessary due to the corrosive properties of the soil indicated in previous reports. Although no new soil corrosivity testing has been done at this time, it is assumed that the corrosion control and cathodic protection criteria for the existing Old River Pipeline are appropriate for this new pipeline, as well. Soil resistivity surveys for sizing cathodic protection systems will be completed during the next phase of design.

Based on the previous criteria for the Old River Pipeline, there will need to be an impressed current cathodic protection system using deep well anodes and test stations located at approximately every 1,000 feet, at foreign pipeline crossings, and at pipe casings. These are the assumed requirements at this stage of conceptual development. Presented below is Table 5-5 summarizing anticipated facilities needed for the cathodic protection of the Delta-Transfer Pipeline. The deep anodes would typically be drilled to a depth of approximately 215 feet with an active column length of 62 feet and a total of five anodes at each deep anode bed location. The information in the table is based on the Old River Pipeline proposed cathodic protection system for mortar lined and coated steel pipe. Although not required, as an added benefit, it may be desirable to connect the new CP system to the existing Old River Pipeline near each of the rectifier locations to provide cathodic protection to the Old River Pipeline to help extend the useful life of that facility. This would require cable connections between the pipelines at the rectifier locations and only slight modifications to the proposed rectifier/deep anode facilities. Further evaluation and investigation will be needed during the final design phase of this pipeline.

Table 5-5. Cathodic Protection System Test Stations and Rectifier/Deep Anode Bed Locations

Station	Description	Station	Description
8+00	Rectifier and Deep Well Anode	217+50	Corrosion Test Station
24+40	Current Span Test Station	225+00	Current Span Test Station
33+10	Corrosion Test Station	240+10	Rectifier and Deep Well Anode
43+00	Current Span Test Station	240+20	Foreign Pipeline Test Station
53+00	Corrosion Test Station	240+55	Foreign Pipeline Test Station
61+00	Current Span Test Station	242+40	Current Span Test Station
72+50	Corrosion Test Station	252+00	Corrosion Test Station
82+00	Rectifier and Deep Well Anode	261+20	Current Span Test Station
91+50	Current Span Test Station	261+40	Current Span Test Station
99+20	Current Span Test Station	271+20	Corrosion Test Station
112+00	Corrosion Test Station	289+50	Rectifier and Deep Well Anode
122+00	Corrosion Test Station	290+20	Current Span Test Station
127+85	Foreign Pipeline Test Station	300+00	Corrosion Test Station
141+30	Rectifier and Deep Well Anode	310+90	Current Span Test Station
150+00	Current Span Test Station	320+20	Corrosion Test Station
160+00	Corrosion Test Station	330+30	Current Span Test Station
170+90	Current Span Test Station	339+40	Casing test Station
180+00	Corrosion Test Station	340+65	Casing test Station
183+00	Rectifier and Deep Well Anode	348+14	Foreign Pipeline Test Station
196+90	Current Span Test Station	353+80	Rectifier and Deep Well Anode
209+50	Corrosion Test Station		

The cathodic protection system approach and facility locations will need to be confirmed during final design. The provided table is intended to be used for feasibility design and cost estimating purposes.

Additional Easements

To provide sufficient space for construction in a cost-effective manner it is recommended that additional temporary construction easements be acquired along the length of the proposed alignment. Locations and lengths of additional TCEs vary along the pipeline due to available space within and outside the easement. Typical trench construction layouts and easement requirements for construction of the pipeline have been prepared and are presented in Attachment 3B. The additional TCE requirements are shown on the plan and profile drawings where available, recognizing that there are some areas where it is not feasible to acquire additional easements due to existing development.

Along with the TCE needed for construction, it is suggested that additional permanent easements be acquired for future maintenance along particular lengths of the pipeline. In these areas the pipeline is being constructed in the narrow side of the available easement which leads to limited space on the

north side for future maintenance. By acquiring this additional easement, similar trench slopes can be used to excavate and access the pipe in the future if needed. The recommended additional permanent easements are also shown on the typical construction layouts in Attachment 3A-1 and on the plan and profile drawings in Attachment 3A.

Utilities

Utilities and utility crossings for the Delta-Transfer Pipeline have been identified using the Record Drawings for the existing Old River Pipeline. The Delta-Transfer Pipeline will parallel the existing Old River Pipeline within its right of way, and there have been limited development in the area. Limited field reconnaissance and a review of current aerial photography was also conducted to assess current surface facilities and support the design. Utilities are shown on the design drawings for Delta-Transfer Pipeline in Attachment 3A. During the detailed design phase for the preparation of the bid-package, utilities information need to be verified.

Using the previously described assumptions and criteria, a set of plan and profile drawings for the Delta-Transfer Pipeline have been created and can be found in Attachment 3A. The drawings have been developed using the Record Drawings from the Los Vaqueros Project, updated aerial images from 2014, and updated topography in the form of LiDAR mapping, from 2008. The aerial image is intended to assist in showing surface improvements above and near the proposed pipeline alignment. The drawings show the proposed pipeline relative to the existing Old River Pipeline as well as showing where the pipeline would be installed relative to existing structures.

Transfer-Bethany Pipeline

The Transfer-Bethany Pipeline would connect the Transfer Facility with the California Aqueduct. The Transfer-Bethany Pipeline would have a capacity of 300 cfs, and 84 inches in diameter. It will be approximately 8 miles long (about 41,000 feet). Water would be conveyed through the Transfer-Bethany Pipeline to Bethany Reservoir for delivery to South Bay water agencies, wildlife refuges, and other south of Delta CVP contractors. The general design criteria for all engineering disciplines is presented in Chapter 3 and also applies to the Transfer-Bethany Pipeline, further described below. Discipline design criteria is presented in Chapter 3 as follows: General criteria begins on page 3-1; Civil design criteria on page 3-2; Operational, Hydraulic, and Mechanical design criteria on page 3-22; Electrical criteria on page 3-29; Instrumentation design criteria on page 3-50; Structural design criteria on page 3-66; and Architectural design criteria on page 3-75.

Pipeline Alignment

The Transfer-Bethany Pipeline would start on the eastern side of Vasco Road near the Expanded Transfer Facility with a connection to the Delta-Transfer Pipeline and extend approximately 8 miles southeast to the California Aqueduct. The Transfer-Bethany Pipeline would likely follow valley alignments, crossing low-lying saddles to avoid steep terrain. The alignment would extend southeast generally parallel to Vasco Road for about 3.9 miles to the corner of where Armstrong Road turns south. The pipeline would continue south along Armstrong Road for about 1.3 miles and then traverse southeast overland approximately 1.5 miles to a point close to the California Aqueduct. The pipeline would continue an additional 0.4 mile south and then would terminate with an outfall

structure into the California Aqueduct. The Transfer-Bethany Pipeline would tie into the California Aqueduct just north of Bethany Reservoir in the Bethany Recreation Area. Plan and profiles of the Transfer-Bethany Pipeline are shown in in Attachment 3D.

A geotechnical investigation is planned to confirm existing ground conditions along the length of the pipeline sections, and to finalize the design.

Cathodic Protection

Assuming steel pipe is used for the pipeline, then cathodic protection will be necessary. Although no soil corrosivity reports have been completed at this time, it is assumed that the corrosion control and cathodic protection criteria applied to the existing Old River Pipeline can be used for the Transfer-Bethany Pipeline, as well. Soil resistivity surveys for sizing cathodic protection systems will be completed during the next phase of design.

Based on the criteria for the Old River Pipeline, test stations will be required at foreign pipeline crossings and at pipe casings. An impressed current system utilizing deep well anodes will be provided for corrosion protection. These are the assumed requirements at this stage of design development. Further investigations will be needed during the final design phase of this pipeline.

Utilities

Table 5-6 describes the utilities that have been identified along the Transfer-Bethany Pipeline.

Table 5-6. Transfer-Bethany Pipeline Utilities Summary

Station	Type	Description
Crossings		
84+00	UG Traffic Control	Conduit to Signal Ahead Warning Sign
86+00	OH Elec & Comm	Local small voltage and telephone
159+00	OH Elec & Comm	Local small voltage and telephone
208+00	Gas/Oil Transmission	Large PG&E and Chevron Transmission
220+00	OH Elec & Comm	Local small voltage and telephone
245+00	OH Elec & Comm	Local small voltage and telephone
266+00	OH Elec & Comm	Local small voltage and telephone
Parallel		
159+00 - 180+00	OH Elec & Comm	Local small voltage and telephone, No Conflict
355+00 - 415+00	OH Elec & Comm	Local small voltage and telephone, No Conflict

Key:
OH = overhead
PG&E = Pacific Gas & Electric Company
UG = underground

Neroly High Lift Pump Station

The development of planning level concepts for the proposed Neroly Pump Station is described in this section. The work is based upon a review of existing plan drawings, aerial photographs, and the existing system hydraulic model. Hydraulic modeling was performed to estimate system requirements for the Neroly High Lift Pump Station. Facility location, sizing, and planning-level design was then performed for the Canal Turnout, Pump Station, and Pipelines. Preliminary power and control requirements were also investigated. An overall site plan of proposed facilities and a profile of proposed suction and discharge pipelines is provided in Attachment 3E. The general design criteria elements for all engineering disciplines presented in Chapter 3 may be assumed for the new facilities described below. Discipline design criteria is presented in Chapter 3 as follows: General criteria begins on page 3-1; Civil design criteria on page 3-2; Operational, Hydraulic, and Mechanical design criteria on page 3-22; Electrical criteria on page 3-29; Instrumentation design criteria on page 3-50; Structural design criteria on page 3-66; and Architectural design criteria on page 3-75. In addition, geotechnical analyses can be found in the document "*Draft Technical Memorandum: Neroly Pump Station Design (Site B) Appendix B – Neroly Pump Station Preliminary Geotechnical Assessment"* included as Attachment 1C to this Appendix.

Hydraulic Modeling Summary

The proposed Neroly High Lift Pump Station will convey a maximum of 300 cfs from the Contra Costa Canal to the Transfer and Expanded Transfer Pump Station Storage Tanks through the existing Los Vaqueros Pipeline. Hydraulic analyses were completed using the Infowater model of the existing system. The hydraulic model was used to develop a system curve of the Neroly High Lift Pump Station assuming a minimum hydraulic grade of 76 feet at the Neroly High Lift Pump Station; water depth of 20 feet (design operating water depth, EL 220 feet) in the Transfer and Expanded Transfer Storage Tanks, which operate at the same WSEL; and a C-Factor of 125 was used to represent the hydraulic resistance of all piping, which is consistent with the findings of the Existing System Model TM.

Since the system must all be integrated, it was deemed prudent to match the current capacity of the Transfer and Expanded Transfer pumps. The Neroly High Lift Pump Station will contain six 50 cfs pumps to match the nominal capacity of pumps at Transfer and Expanded Transfer and to provide the maximum design capacity of 300 cfs determined from water system modeling conducted as part of this planning level analysis. Two of the pumps will be equipped with VFDs to assist in maintaining desired water surface elevations at the Transfer and Expanded Transfer PS storage tanks. Note that a Synchronous Transfer System will be used to start the motor with a VFD then parallel with Western Area Power Administration (WAPA) and transfer before starting the next motor to allow use of fewer VFDs. This will reduce the equipment footprint allowing installation of a smaller building. The current model determined that the pumps would require a duty point of 50 cfs at 215 feet TDH. Several pump manufacturers were contacted to obtain representative pump performance curves. The system curve along with the pump performance curve for WEHR Model 37TKM (4 Stage), which requires a minimum 1,750 hp motor, is presented in Figure 5-14. The preferred operating range of the pump is represented by the shaded region along the pump curve and ranges from approximately 37 cfs to 66 cfs.

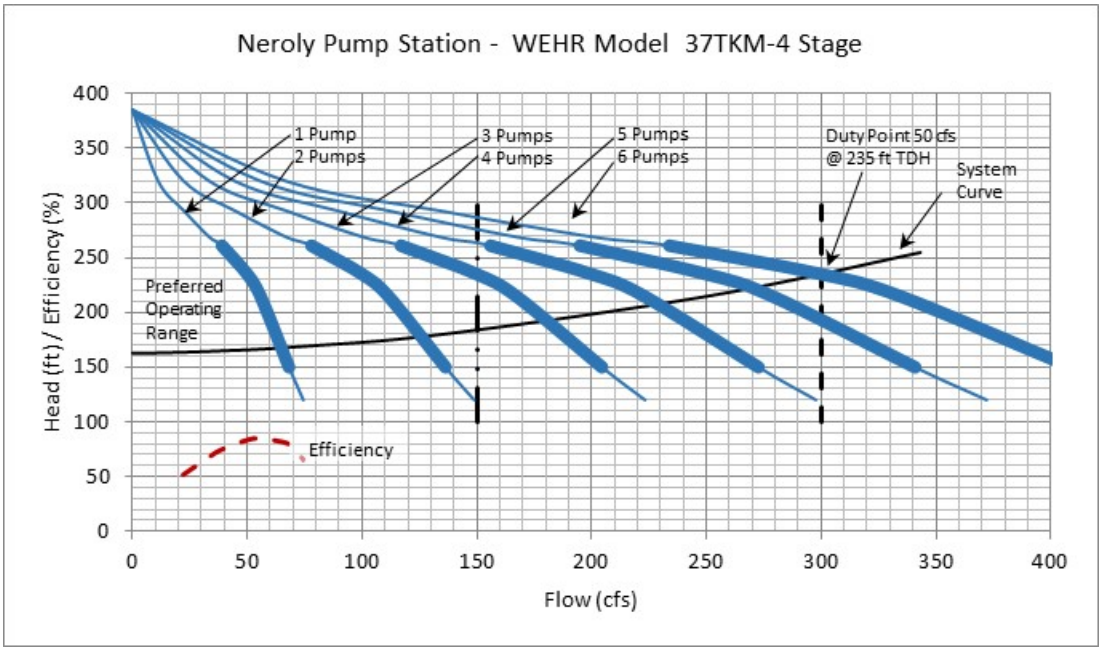
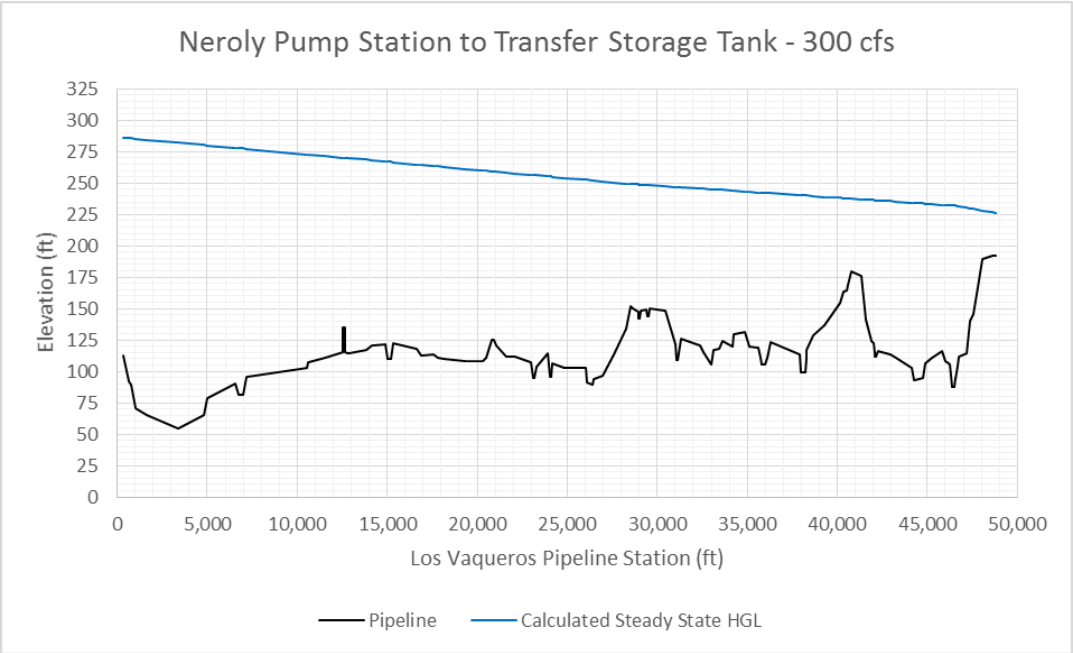


Figure 5-14. Neroly High Lift Pump Station System Curve

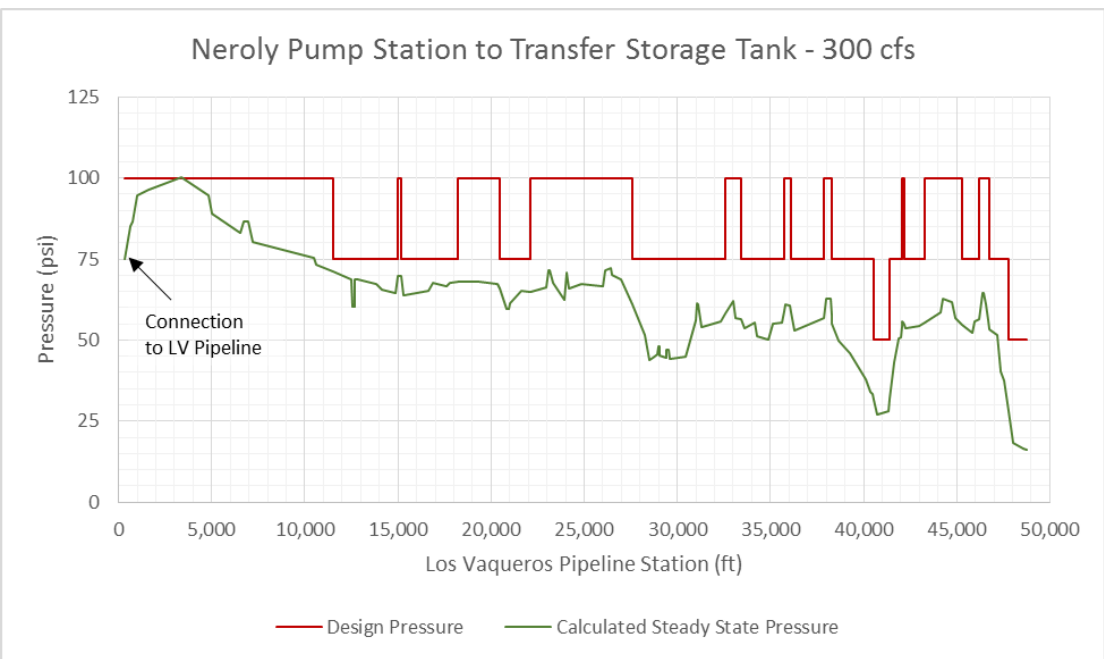
The hydraulic gradeline and elevation along the Los Vaqueros Pipeline from the Neroly High Lift Pump Station to the Transfer Storage Tank are shown in Figure 5-15.

Figure 5-16 compares the calculated steady state operating pressure from the proposed Neroly High Lift Pump Station to the pipeline pressure rating identified on the Los Vaqueros Pipeline As-built Drawings. Results show that the calculated operating pressure is less than the pipeline pressure rating, with the maximum operating pressure of 100 psi occurring approximately 3,600 feet downstream of the proposed Neroly High Lift Pump Station.



Key:
cfs – cubic feet per second
ft = feet
HGL = hydraulic grade line
LVP = Los Vaqueros Pipeline
psi = pounds per square inch

Figure 5-15. Hydraulic Gradeline – Los Vaqueros Pipeline – Neroly High Lift Pump Station to Transfer Storage Tank – 300 cfs



Key:
cfs – cubic feet per second
ft = feet
HGL = hydraulic grade line
LVP = Los Vaqueros Pipeline
psi = pounds per square inch

Figure 5-16. Comparison of Calculated Pressure and Pipeline Pressure Rating – Neroly High Lift and Los Vaqueros Pipelines – Neroly High Lift Pump Station to Transfer Storage Tank – 300 cfs

Surge Analysis

A preliminary surge analysis was performed for the proposed Neroly High Lift Pump Station. The model also included use of the existing combination air/vacuum valves along the Los Vaqueros Pipeline to assist in surge control. Surge model results predict that two 3,000-cubic-foot surge tanks are required at the proposed Neroly High Lift Pump Station. The tanks would each be 12-feet in diameter and approximately 30-feet long.

The surge head profile along the Los Vaqueros Pipeline following power failure at the Neroly High Lift Pump Station is presented in Figure 5-17. The pipeline is represented by the black line; the steady state gradeline (300 cfs) is shown by the gray line; the red line represents the minimum surge head; and the blue line is the maximum surge head. Results show that the proposed two 3,000-cubic-foot surge tanks located at the Neroly High Lift Pump Station along with the existing combination air/vacuum valves mitigate transients along the Los Vaqueros Pipeline resulting from power loss at the Neroly High Lift Pump Station. These results are considered preliminary and surge modelling should be re-evaluated during final design based upon the final layout of the proposed pump station and selected pump.

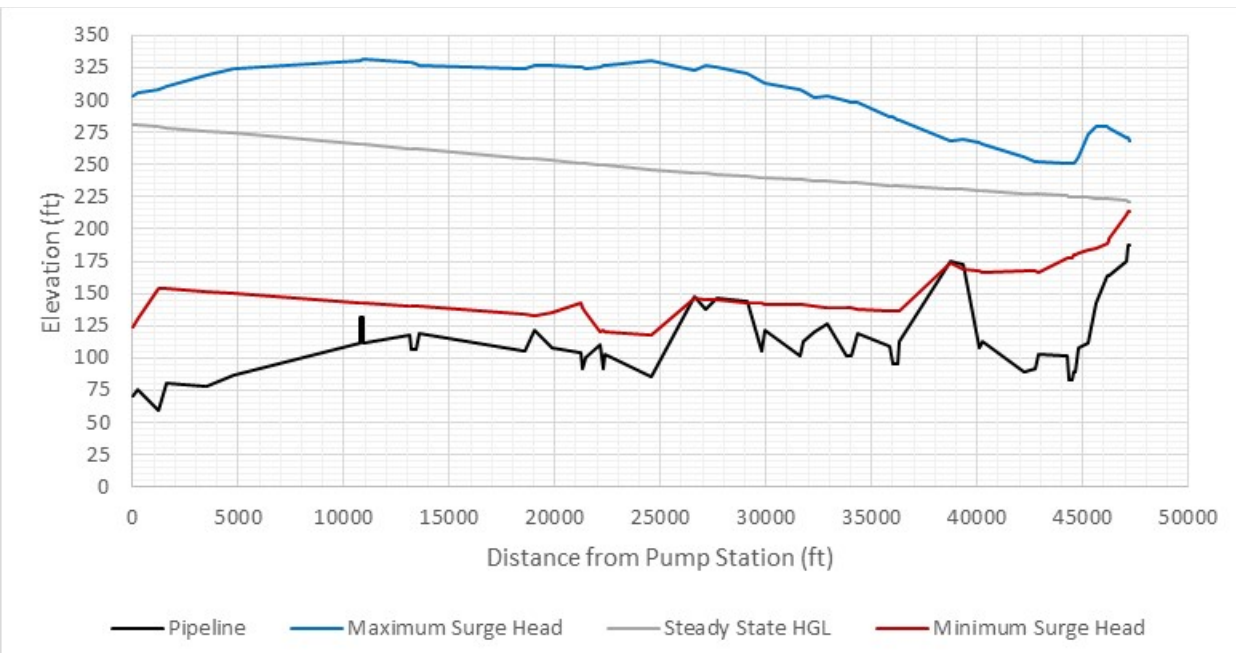


Figure 5-17. Surge Head Profile following Power Failure – Neroly High Lift Pump Station

Canal Turnout

The turnout from the Canal will be located approximately 337 feet upstream of Canal Pumping Plant 4. A paved access road will be routed to the canal turnout for routine inspection and maintenance.

The turnout will consist of a reinforced concrete structure with bar screens and motor operated slide gates, similar to the existing turnout for the Randall-Bold Water Treatment Plant. CCWD reported

that canal operating water depth in this reach varied between a minimum of 6.0 feet and a maximum of 9.3 feet, with an average depth of 8.6 feet. The bar screens will start at the top of the canal lining at approximate EL 80.9 and slope down to the canal base at approximate EL 70.0, matching the existing canal side slope of 1¼: 1. A concrete slab behind the screens will slope down to the invert of the twin 66-inch suction pipelines at approximately EL 61.0, where a concrete headwall will be constructed. This elevation will set the centerline of the 66-inch pipes at EL 64.5 which will provide approximately 11.5 feet of submergence at minimum canal operating depth.

Mounted to the approximately 20-foot-tall, 21.5-foot-long turnout headwall will be twin 66-inch square slide gates for suction pipeline isolation. The use of twin 66-inch suction pipes will reduce the depth of excavation required adjacent to the canal while meeting minimum submergence required to avoid pipeline air entrainment.

Pump Station

The Neroly High Lift Pump Station site is located immediately upstream of the Contra Costa Canal Pumping Plant 4 and the Neroly Blending facilities. The pump station will be constructed south of the Randall-Bold Intake Pipeline, at EL 91.5 (NAVD 88 Datum).

This site is largely undeveloped but limited space is available within existing property boundaries. Steep hillsides exist to the south and west of the proposed facilities. The current design for the site keeps proposed facilities within the property boundaries to avoid the purchase of additional property.

Use of the site will require rerouting an existing bike path. In addition, the existing 60-inch Randall Bold pipeline crosses through the site. Nearby 69kV WAPA transmission lines are available for power.

The twin 66-inch pipes from the canal turnout will include a reducer wye which will combine them into a single 84-inch suction pipe routed to the Neroly High Lift Pump Station. The 84-inch diameter suction header is located at centerline EL 60.5 at the Neroly High Lift Pump Station site; 48-inch diameter suction piping (centerline EL 59.25) from the header is routed to each pump using a tangential outlet to minimize potential sediment accumulation within the suction header. A canned vertical turbine pump arrangement was selected for the pumps, with the bottom of the pump cans at EL 46.0.

Each pump will be equipped with a 36-inch diameter discharge pipe and appurtenances located above grade which will be routed to an 84-inch diameter below grade header, similar to the layout of the existing Transfer Pump Station and to previous designs shown in the MWH Pumping and Controls TM. Appropriate check, isolation, and air and vacuum relief valves will be provided, as shown in pump station drawings provided in Attachment 3E. Please refer to Chapter 3 and Table 5-7 below for typical valve design criteria. Design features and operational procedures to mitigate any sediment accumulation or water stagnation in the 84-inch diameter pipeline segment adjacent to the surge tank piping connections will be examined in the next phase of design. All buried suction and discharge piping located under the pump station footprint will be concrete encased.

Table 5-7. Neroly Pump Station Design Criteria Summary

Item	Design Criteria
Type of Pumps	Vertical turbine pumps in barrels
Number of Pumps	6 (all duty)
Design Flow	50 cfs each
Total Pump Station Design Flow	300 cfs
Design TDH at Design Flow	215 feet
Pump Check	Slanting Disc Check Valve located on each pump discharge. Valves shall be compliant with AWWA C-508
Pump Isolation	Motorized Butterfly Valve, resilient seated AWWA C-504
Air Evacuation and Vacuum Relief	CARVs at two locations on each pump discharge. Valves shall be compliant with AWWA C-512.
Minimum Pump Efficiency at Best Efficiency Point	80 percent
Pump Materials of Construction:	
All materials in contact with water	NSF 61 and Lead Reduction Act Compliant
Impeller	316 stainless steel
Bowl	Ductile iron, epoxy lined and coated
Wear Rings	Hard stainless steel
Bowl Bearing	Lead free bismuth bronze
Intermediate Bearings	Neoprene with non-metallic backing
Pump Shaft	Open line shaft, product lubricated
Pump Column	Fabricated steel, epoxy lined and coated
Coupling	Adjustable spacer type coupling
Motor (also refer to Electrical discipline design criteria presented in this document)	VFD rated, two VFDs provided along with Synchronous Transfer System
Motor Horsepower	1,750 hp each
Neroly Pump Station Flow Meter Isolation Valve	Motorized Butterfly valve, resilient seated AWWA C-504, located in buried concrete vault
Process Piping Velocity	Pump Suction Piping: < 8 ft/sec Pump Discharge Piping: <10 ft/sec
Hydropneumatic surge tanks	Sized to mitigate surge pressures due to loss of power at the pump station

Key:
AWWA = American Water Works Association
cfs = cubic feet per second
ft/sec = feet per second
hp = horsepower
NSF = National Sanitation Foundation
TDH = Total Dynamic Head
VFD = variable frequency drive

Finished grade at the station site would be set at EL 91.5 based upon site topography. A paved road will provide access. This layout will require a relatively deep excavation. The deep excavation is due both to the relatively low canal water surface elevation and Hydraulic Institute submergence requirements for the can-style pump station. The bottom elevation of the pump cans was

established at 46.0 feet based on Hydraulic Institute recommendations and conservative design practice for pump suction inlet submergence distance below the incoming suction pipe. This puts the bottoms of the cans 46 feet below the pump station finished floor elevation of 92.0 feet. No isolation valves are required on the pump suction piping since the maximum suction water surface elevation is below the pump station finished floor elevation.

Pipelines

Design concepts were developed for the Neroly High Lift Pump Station suction and discharge piping. The development of feasibility level concepts for the pipelines are based on review of existing plan drawings, utility research, limited field reconnaissance, and aerial photographs.

Suction Pipeline

The maximum pump station design flow is 300 cfs. A suction piping configuration which includes two 66-inch diameter pipelines combining into a single 84-inch pipeline has been selected. The maximum velocity in the parallel 66-inch diameter intake pipe and 84-inch diameter suction header are 6.3 feet per second and 7.8 feet per second at maximum flow, respectively.

Cement mortar lined and coated steel pipe (AWWA C200) has been selected for the pipeline material based on the pipe diameter and the material properties. This pipe price is reflected in the current construction cost estimate. Reinforced concrete cylinder pipe (AWWA C300) could also be considered during further design development.

The suction pipeline is proposed to connect approximately perpendicular to the existing Canal. From there the pipeline extends south toward the Neroly High Lift Pump Station. The suction pipe is routed under the existing 60-inch diameter Randall-Bold Intake Pipeline. The suction pipeline ends at the planned Neroly High Lift Pump Station. The total length of the suction pipeline alignment is approximately 368 feet as shown. An access manway will be added just downstream of the transition from two 66-inch pipelines to the single 84-inch and will allow access to the suction pipeline for inspection and maintenance.

Discharge Pipeline

The discharge pipeline extends from the planned Neroly High Lift Pump Station to a connection point on the existing 90-inch diameter Los Vaqueros Pipeline (approximate Los Vaqueros Pipeline Station 4+80) located approximately 300 feet east of the Los Vaqueros Energy Recovery Facility. The discharge pipe is planned as a single 84-inch diameter pipe. At the maximum design flow rate the pipe velocity is approximately 7.8 feet per second, which is reasonable and acceptable.

Cement mortar lined and coated steel pipe (AWWA C200) has been assumed as the material of choice for this pipeline based on the pipe diameter and the material properties. Reinforced concrete cylinder pipe (AWWA C300) could also be considered during design development, since this is the material that was used for much of the existing Los Vaqueros Pipeline.

The discharge pipeline is proposed to extend southwesterly from the Neroly High Lift Pump Station discharge header, passing through a flow meter (located inside a vault) and ending at the

approximate Los Vaqueros Pipeline Station 4+80 connection. The total length of the discharge pipeline is approximately 424 feet as shown.

The Los Vaqueros Pipeline connection point is located just off the gravel access area at the east end of the Neroly Blending Facility. This location has been selected to provide accessibility from the existing gravel yard at the Neroly Blending Facility.

Two isolation valves placed in separate valve vaults are planned at the Los Vaqueros Pipeline connection point to isolate the Neroly High Lift Pump Station or the portion of the Los Vaqueros Pipeline between the connection point and the Contra Costa Canal. This two-vault approach is considered the most cost efficient due to the size of the vault that would otherwise be required to accommodate the two valves and tee in a single vault. The gravel access road will provide good access to the two valves for operation and maintenance. The top of the vaults will set at an appropriate level and appropriate grading will be provided so that there is good access to the top of the vaults. A manway access also will be incorporated into the Discharge Pipeline Isolation Valve Vault to provide access into the discharge pipeline for inspection, maintenance or repairs.

Suction and Discharge Pipeline Construction Methods

All the pipeline alignments will be installed by open cut construction. There will be a crossing of the discharge pipeline under the existing 60-inch diameter Randall-Bold Intake Pipeline. This can be done via open cut trenching by providing adequate support of the existing pipeline spanning the trench during construction.

Suction and Discharge Pipeline Profile and Appurtenances

Minimum cover depth criteria for the pipelines has been established as 5 feet.

The basic profile conditions are as follows.

1) Suction Pipelines – The dual 66-inch intake pipelines will start at the canal at a centerline elevation of approximately 64.5 feet and remain at this elevation until connecting to the reducing wye fitting. The 84-inch suction pipe will be sloped to a centerline elevation of approximately 60.5 feet at the Neroly High Lift Pump Station suction manifold.

2) Discharge Pipeline – The 84-inch diameter discharge pipeline profile starts at the Neroly High Lift Pump Station and is routed to the Los Vaqueros Pipeline assuming a minimum of 5 feet of cover of the discharge pipe. A flowmeter is in the flowmeter vault approximately 140 feet downstream of the pump station. A CARV will be installed within the 84-inch isolation valve vault just upstream of the Los Vaqueros Pipeline connection.

Pipeline Construction Easements

The suction pipeline alignment requires a permanent access width of approximately 85 feet plus additional temporary easement width (approximately 40 feet) for a total construction width of approximately 125 feet for the open trenched sections of the alignment. Most of this construction and future access area is on CCWD property where no easement is required. However, some temporary construction easements would be desirable on the adjacent property owned by Contra Costa County Flood Control and Water Conservation District, if possible. Temporary easement

width requirements should be confirmed during future design development. Costs for easements have not been included in the OPCC.

Dewatering

Likely dewatering approaches for the Neroly High Lift Pump Station excavations are based on previous geotechnical reports. At the Neroly High Lift Pump Station site, we anticipate that dewatering wells will be needed for the intake pipeline construction due to the deep excavation which is down near the canal level. The use of trench sumps is assumed to be adequate for dewatering at the discharge piping excavations.

Cathodic Protection

Assuming steel pipe is to be used for the construction of the suction and discharge pipelines then cathodic protection will be necessary. Although no soil corrosivity reports have been completed at this time, we have assumed that the corrosion control and cathodic protection criteria for the previous Old River Pipeline can be used for these new pipelines as well. Soil resistivity surveys for sizing cathodic protection systems will be completed during the next phase of design.

Based on the criteria for the Old River Pipeline, there will need to be test stations at foreign pipeline crossings, and at pipe casings. An impressed current system utilizing deep well anodes will be provided for corrosion protection. These are the assumed requirements at this stage of design development. Further investigations will be needed during the final design phase of this pipeline.

Los Vaqueros Pipeline Modifications

A preliminary analysis has been performed to determine whether the existing Los Vaqueros Pipeline can handle the pressure required by the new pumped operating condition from the Neroly High Lift Pump Station, and if not, to determine what modifications may be required to which portions of the pipeline. The first approximately 355 feet of pipe upstream of the Neroly Blending Facility is constructed of Class 75 (i.e., 75 pounds per square inch rating) pipe. The hydraulic analysis indicates that if the Neroly High Lift Pump Station connects to the upstream side of this Class 75 pipe and provides a valve that can be closed to isolate this section of the pipeline during Neroly High Lift Pump Station operation, the remainder of the Los Vaqueros Pipeline should be capable of handling the discharge pressure. This should be further confirmed during future design development. Installation of the isolation valve will require a short shutdown of the Los Vaqueros Pipeline to complete the tie-in.

Electrical

The major components of the Neroly High Lift Pump Station electrical design include providing VFD drives to two of the large pump motors to prevent excessive voltage drop problems and maintain a high power factor, designing running power factor correction capacitors for the large motors to keep the power factor at or above the WAPA requirement of 0.95, a Synchronous Transfer System, two isolated MCC setups and two isolated VFD setups for improved reliability upon major failure in one component. The Synchronous Transfer System starts the motor with a VFD then parallels with WAPA and transfers before starting the next motor to allow use of fewer VFDs to reduce the 4160-volt equipment lineup footprint allowing installation of a smaller building.

The design assumes power will be obtained from WAPA 69kV transmission line that feeds and ends at the CCWD Canal Pumping Plant #4 Lift Pump Station by tapping the 69kV line at the WAPA 69kV end pole. Therefore, installation of two more overhead 69kV line poles is assumed to bring power into the Neroly 69kV /4.16kV substation that will match the Middle River substation layout and equipment. All 69kV overhead line extension and pole design and construction would be done by WAPA and paid for by CCWD.

Contact was made with WAPA Power Operations Advisor and verbal feedback was provided indicating an interconnection request and deposits for various studies are required before any design and construction of WAPA facility improvements to accommodate the added Neroly PS load would occur. It is anticipated that the studies and WAPA site facilities construction would take approximately 1.5 years.

Detailed design criteria are provided in Chapter 3. The governing standards, codes and practices are required, as well as current California energy requirements. Construction materials and practices used for CCWD facilities will be required to be typical of the industry for the application. Readily available standard equipment and electrical control schemes will be used to meet requirements. Current WAPA standards and requirements will be followed, including a minimum power factor of 0.95 and a maximum voltage drop on starting motors. In addition, studies for new electrical facilities will be required in accordance with current standard industry practices. Current acceptance testing will be required consistent with industry standard testing practices to provide assurance of proper operation, proper installation and proper materials. Full documentation of the installation, equipment, systems and testing will be required in accordance with CCWD requirements.

Control and Monitoring

The existing CCWD SCADA HMI and the new Neroly High Lift Pump Station PLC software packages will incorporate new analog and discrete I/O that will control and monitor six new Neroly High Lift Pump Station pumps, the new Neroly High Lift Pump Station Surge Control System and the new Contra Costa Canal turnout gates. The new signals will also include I/O from the new Neroly High Lift Pump Station discharge ultrasonic flow meter, pressure transmitter and positions and statuses from the new Los Vaqueros and Neroly High Lift Pump Station pipeline isolation valve actuators. Incorporation of status of the Transfer and proposed Expanded Transfer Pump Station flow rates along with their respective Reservoir Tank water surface elevations will also be required.

Building and HVAC

The Neroly High Lift Pump Station building footprint, housing both the electrical equipment and mechanical pumps, is roughly 80 feet by 110 feet. The building will be slab on grade construction with concrete masonry unit parapet walls and single-ply insulated roofing over a structural steel deck and structural steel roof beam system. The interior will consist of 2 separate rooms, a Pump Room and an Electrical Room. The conditioned electrical room will be provided with interior insulated wall system to meet California Energy Code requirements. Exterior man doors with panic hardware will be provided as the main egress from each room. A double door will be provided at the electrical room for equipment removal. An overhead coiling door will be provided at the pump room for equipment removal and maintenance purposes. An interior man door will be provided between the two rooms for access. An exterior roof access ladder will be provided to access roof equipment.

Air conditioning will be provided for the new electrical MCC room serving the Neroly High Lift Pump Station by a roof mounted packaged air conditioning unit. The air conditioning unit will be equipped with variable speed compressors to closely match capacity to actual instantaneous loads at partial and low load conditions. The unit will also come with integral return /exhaust fans and airside economizer to take advantage of free cooling using outside air when outdoor conditions are favorable. The air conditioning unit will be sized to maintain an indoor space temperature of 85 degrees Fahrenheit on a design cooling day.

Ventilation for the new Neroly High Lift Pump Station pump room will be provided by roof mounted exhaust fans. Outside air will be drawn in through stationary sidewall louvers located in the exterior wall on the opposite side of the building from the pumps and exhaust fans. This cross-flow ventilation will facilitate removal of heat generated by the pump motors. The ventilation system will be sized for sufficient air flow to maintain interior air temperature at no greater than ten degrees above exterior air temperature.

Existing Old River Intake and Pump Station

The existing Old River Pump Station can produce a nominal maximum 250 cfs flow rate via the Old River Pipeline using five 50 cfs capacity vertical turbine pumps with constant speed motors. No modifications to this facility are proposed under the considered Investigation alternatives.

New facilities will be required at the Old River Pump Station site to integrate the new Delta-Transfer Pipeline (refer to Drawings C-1 and C-2 in Attachment 3C). A 78-inch-diameter butterfly valve and two 66-inch-diameter butterfly valves, along with a short segment of 66-inch-diameter pipe will be required to allow both the Old River and Middle River Pump Stations to discharge either to the Old River Pipeline or to the Delta-Transfer Pipeline. The 78-inch valve and a 78 x 66 x 78-inch tee will be cut into the existing Old River Pipeline. The 66-inch pipe routed from the tee will include a 66-inch butterfly valve and will connect to the Delta-Transfer Pipeline. In addition, a 72 x 66 x72-inch tee will be cut into the existing Middle River Pipeline and will include a 66-inch butterfly valve. The 66-inch pipeline routed from this tee will include a butterfly valve and will be the start of the Delta-Transfer Pipeline.

A flow meter and a downstream isolation valve station for the Delta-Transfer Pipeline will also be located at the Old River Pump Station site (refer to Drawings C-1 and C-2 in Attachment 3C). The meter and the valve station will be located in separate buried concrete vaults near similar existing vaults for the Old River Pipeline.

The isolation valve station will include a mainline motorized ball valve as well as a bypass line with modulating ball valve to be used during pipeline filling. The two valves are currently assumed to be 54 and 18 inches in diameter, respectively. Valve sizing will be confirmed in the next phase of design.

Power Requirements

The power source for the new equipment and new vaults that house them will be from the existing Old River Pump Station. All electric power to the existing vaults is provided by an existing 150 kVA 480 volt 3-phase transformer. The 150 kVA transformer powers power panel board PP-A. PP-A distributes power to the equipment in and around the vaults. To accommodate four new vaults and their associated equipment a larger transformer will replace the 150-kVA transformer with a new matching larger panel board that will back feed the existing 225-amp power panel board PP-A as well as feed all the new valve vault equipment and associated loads.

The loads in a typical vault are expected to match existing similar vaults that would include lights, ventilation fans, cathodic protection, battery chargers, instrumentation, maintenance receptacles, irrigation controllers, sump pumps and the valve actuators. The large valve actuators are expected to match existing and use 125-volt DC motors with a large battery and a trickle charger. The much smaller bypass valve actuators are expected to match existing and use 480-volt 3-phase AC motor actuators. The 120-volt loads will be supplied by a local outdoor mini-power center (combined encapsulated transformer and distribution load center) to match existing vault facilities.

Refer to Los Vaqueros Expansion Project Design Criteria Technical Memorandum (MWH 2016) for details.

Control and Monitoring

The existing CCWD SCADA HMI and Old River PLC software packages will need to be modified to incorporate new analog and discrete I/Os from the new Delta-Transfer Pipeline flow meter, pressure transmitter and positions and statuses from the new Delta-Transfer and Old River pipeline isolation valve actuators described above. Incorporation of status of the new ETPS and Reservoir flow rate and WSEL will also be required.

Existing Middle River Intake and Pump Station

The existing Middle River Pump Station can produce a nominal maximum 250 cfs flow rate via five 50 cfs capacity vertical turbine pumps. Three of the pumps have constant speed motors while the other two have variable frequency drives. No modifications to this facility are proposed under the considered Investigation alternatives.

Control and Monitoring

The existing CCWD SCADA HMI and Middle River PLC software packages will need to be modified to incorporate new analog and discrete I/O from the new Delta-Transfer Pipeline flow meter, pressure transmitter and positions and statuses from the new Delta-Transfer and Old River pipeline isolation valve actuators described above. Incorporation of status of the new ETPS and Reservoir flow rate and WSEL will also be required.

Pumping Plant #1 Improvement

Improvement of Pumping Plant #1 on the Contra Costa Canal would be needed to match the designed and permitted Rock Slough Intake diversion capacity of 350 cfs, allowing full use of the new Neroly High Lift Pumping Station. The separately approved Contra Costa Canal Replacement Project, which is replacing the open channel portion of the Contra Costa Canal with a buried pipe, will lower the operating water surface levels at Pumping Plant #1 due to the friction losses added by the pipeline. Pumping would be limited to approximately 200 cfs using the existing Pumping Plant #1 pumps after the completion of the Canal Replacement Project, which is assumed for the 160 TAF No Project/No Action Alternative. Larger horsepower pumps set at a lower elevation (than existing) at Pumping Plant #1 would be needed to move the same amount of water (350 cfs) as previously has been moved through this system. The Pumping Plant #1, without upgrades, would be adequate to deliver CCWD's maximum demands. However, Pumping Plant #1 upgrades are necessary to provide system capacity for project deliveries to Refuges and other water supply partners under the feasibility study alternatives. Therefore, this portion of the project is a critical component in delivering water to all project partners under the proposed alternatives.

A larger new building and upgraded electrical facilities are also included in the proposed upgrade of Pumping Plant #1 and would be built near the existing Pumping Plant #1 structure in the existing Contra Costa Canal right-of-way owned by Reclamation. (See Figure 5-18.) The proposed Pumping Plant #1 upgrade would involve demolition of the existing Pumping Plant #1 building and construction of a new building to house the upgraded pumps and appurtenances. The building would be constructed of concrete and would be similar in height to the existing Pumping Plant #1, approximately 35 feet tall. The square footage of the building would increase to approximately 4,000 square feet. The new pump station would have a total of six new pumps, three pumps in each of two parallel wet wells. A dedicated force main would carry flow from each pump. The below-grade valves would be housed within a valve box. The pump motors would be centered above the pumps and mounted on a floor slab with bottom elevation at approximately +16 feet. Refer to Chapter 3 for typical pump station and civil yard appurtenance design criteria. Additional information on the Pumping Plant #1 Improvements are discussed in Attachment 3F. A portion of these costs are not included in the project as the facility would require a portion of the improvements to maintain existing pumps under no-project conditions.

New power lines and substations would be required for the new Pumping Plant #1. Currently, incoming power is stepped down to 2300-volt, three phase, 60 hertz at a single existing Western Area Power Administration transformer with a capacity at 1500 kVA. The new pump station would require a maximum of 2,100 horsepower and would require two new 2000-kVA transformers.

To construct the new Pumping Plant #1, the encased portion of the Contra Costa Canal would be isolated and dewatered. Sheet piling is already installed around much of the forebay of Pumping Plant #1, and additional sheet piling would be installed to isolate the construction site from the Contra Costa Canal. The site would be excavated to construct the foundation for the building and the wet wells, and to tie into the encased portion of the Contra Costa Canal. The existing pipeline is buried approximately 15 feet below the grade line and excavation may need to occur down to 25 feet

below the grade line. During the construction of the foundation, wet wells, and pipeline tie-in, groundwater dewatering would be required to keep the site dry.

In addition, the Rock Slough Intake's fish screen requires improvements to its rake system to correct deficiencies and enable fish screen cleaning and weed removal as originally intended in Reclamation's design. This will allow the fish screen to function properly and allow Rock Slough Intake to operate as permitted. This portion of the project includes reviewing operations of the screen cleaning and debris collection system and recommending physical or operational modifications to ensure the protection of endangered fish species occurring at the facility. The work includes rake system investigation and design, boat access design and construction, work platform and debris handling improvements, as well as a log boom and block net.

Figure 5-18. Location of Proposed Pumping Plant # 1 Improvements

Summary of Major Design Assumptions and Risks for Conveyance and Pumping Facilities

Table 5-8 summarizes the major engineering design assumptions and risks for specific items at each of the primary conveyance and pumping facilities. Many assumptions will be verified during future stages of design.

Table 5-8. Summary of Major Design Assumptions and Risks for Conveyance and Pumping Facilities

Facility	Item	Assumptions and Risks
Transfer Pump Station Modifications	New Pump Selection	The assumed reservoir low-water levels and high-water levels of 448 feet and 560 feet, respectively, should be reconfirmed in the next phase of design. The availability of a suitable pump from several manufacturers to assure competitive bidding should also be reconfirmed. Of key importance is the ability of the pump to have stable operation over the range of reservoir water levels.
	Surge Mitigation	The preliminary surge modeling, which indicated that the existing surge tanks are sufficient to accommodate the new system conditions, should be reaffirmed after final pump selection.
	Pump Motors	Constant speed synchronous motors were selected to facilitate reuse of the existing MCC setup. Changing this assumption, such as the use of VFDs, would require modifications to the existing electrical system.
Expanded Transfer Pump Station and Reservoir	Pump Selection	The pumps are required to operate over a wide range of system flow and head conditions, making it challenging to select a pump that will have stable operation over the full range. System hydraulics should be rechecked after the Transfer-Bethany Pipeline alignment and diameter is reconfirmed. Pump selection should then be finalized to optimize coverage of the system flow and head range.
	Pump Operation	To cover the wide system flow/head range it was assumed that each pump would be provided with a modulating ball valve which would be used to increase head to keep the pumps on their curves during system low flow conditions. This solution is adequate due to the minimal time that low flows are anticipated. However, the possibility of narrowing the required system design flow range to allow the elimination of these valves should be revisited in the next phase of design.

Table 5-8. Summary of Major Design Assumptions and Risks for Conveyance and Pumping Facilities (contd.)

Facility	Item	Assumptions and Risks
Expanded Transfer Pump Station and Reservoir (contd.)	Power Requirements	Delivery of PG&E power is expected to follow the same overhead route and come from the same PG&E substation, approximately 5 miles away, as the exiting Transfer Facility to deliver power to the site at 21 kV. The power needs at the site will approximately double with the new pump station. Coordination with PG&E to develop distribution design requirements as well as any internal PG&E system modifications and all associated costs should begin as soon as possible in the next phase of design. It is possible that PG&E will require additional conservative design approaches or elements to minimize wildfire risk, which could add cost to the project.
Expanded Transfer Pump Station and Reservoir	5 Million Gallon Reservoir	An above-ground steel reservoir configuration was selected. This configuration offers competitive cost and consistent OM&R with the adjacent existing 4 MG steel reservoir. The option of constructing a prestressed concrete tank should be revisited in the next phase of design. In addition, seismic sloshing impacts on reservoir tank height and/or roof reinforcement should be defined in the next phase of design. Overflow piping from the new reservoir will be routed to tie into the existing 4 MG reservoir's 72-inch diameter overflow pipeline, which discharges to Kellogg Creek. The hydraulics of the combined overflow pipeline should be modeled in the next phase of design to confirm acceptable performance during overflow conditions.
	Facility OM&R	New site features including the outdoor pumps and surge tanks, electrical building, electrical substation, and above ground reservoir, will be similar to the corresponding existing features and associated OM&R requirements will be similar as well. Double doors will be provided at each end of the electrical building to facilitate equipment installation and maintenance. The paved site will be suitable for pneumatic-tire crane access for pump and motor removal for maintenance. The need for a defined concrete crane pad will be examined in the next phase of design.
Neroly High Lift Pump Station	Pump Motor Electrical Arrangement	Two of the six 1,750 hp pumps will be provided with VFDs to optimize flow control and to prevent excessive voltage drop problems during start and maintain a high-power factor at or above the WAPA requirement of 0.95. A Synchronous Transfer System is provided and starts the motor with a VFD then parallels with WAPA and transfers before starting the next motor to allow use of fewer VFDs to reduce the 4160-volt equipment lineup footprint allowing installation of a smaller building.

Table 5-8. Summary of Major Design Assumptions and Risks for Conveyance and Pumping Facilities (contd.)

Facility	Item	Assumptions and Risks
Neroly High Lift Pump Station (contd.)	Power Requirements	WAPA power will be obtained from a 69kv transmission line that feeds and ends at the adjacent CCWD Canal Pumping Plant #4 Lift Pump Station by tapping the 69kv line at the WAPA 69kv end pole. Two additional steel poles with concrete foundations will be required. A 69kv substation will be required. It is assumed that the substation arrangement will be approximately the same as the 69kv substation constructed as part of CCWD's Middle River Intake project. Both the new pump station and the existing adjacent Pumping Plant #4 Lift Pump Station use the same finite canal source water. When the new pump station is in operation there will be a corresponding reduction in flow, or no flow, through the Pumping Plant #4 Lift Pump Station. The reverse is also true. While it is not known whether WAPA internal upgrades will be required to serve the new pump station, the new functional power requirements will not be the full power requirement of both pump stations.
	Los Vaqueros Pipeline Modifications	The pump station discharge pipe will connect to the existing Los Vaqueros Pipeline, pushing flow uphill to the Transfer/Expanded Transfer reservoir, in the opposite direction of the current flow. The pressure in the lower portion of the pipeline will be increased relative to current conditions. The pressure class of the pipeline indicates that it is capable of safely operating with the increased pressure. The current condition of the existing pipeline should be examined, and a detailed evaluation of its pressure rating should be confirmed in the next phase of design.
Neroly High Lift Pump Station	Construction Excavation and Dewatering	The excavation depth for the short suction pipelines and the and the pump station pump cans will be up to approximately 30 feet and 46 feet, respectively. Open cut construction is assumed. Rock is likely at the 46-foot depth but is expected to be rippable using a multi-ripper. It is assumed that dewatering wells will be required. A detailed geotechnical investigation is required in the next phase of design.
	Facility OM&R	Double doors will be provided at each end of the electrical room to facilitate equipment installation and maintenance. The southwest corner of the facility has been reserved for a concrete crane pad to be used by a pneumatic-tire crane for pump and motor removal for maintenance. A 3-ton bridge crane is provided to remove valves and discharge pipe appurtenances. A roll-up door is provided to allow a truck to enter the pump station building and unload valves directly from the bridge crane. An exterior roof access ladder will be provided to access HVAC equipment and skylights.

Table 5-8. Summary of Major Design Assumptions and Risks for Conveyance and Pumping Facilities (contd.)

Facility	Item	Assumptions and Risks
Neroly High Lift Pump Station (contd.)	Tsunami Risk	It is assumed that the new and modified facilities could not be struck by a tsunami because the project area is located within the Delta at least 50 miles from the Pacific Ocean. Although no maps of tsunami hazards in the Delta were found in the publications reviewed, potential risks of catastrophic inundation are assumed to be small. This is because the tsunami hazards map west of the Delta area indicates a maximum inundation of 3 feet above mean sea level and tsunami effects would be attenuated in Suisun and Grizzly bays before reaching the proposed lift station site.
Transfer-Bethany Pipeline	Pipe Materials Procurement	Northwest Pipe Company recently bought Ameron International Water Transmission Group, changing the cost basis for the pipeline. Market conditions need to be reevaluated and the use of steel versus concrete pipe reviewed during final design.
	Geotechnical Conditions	Geotechnical investigation to confirm conservative assumptions and potentially reduce contingencies required during the next phase of design.
	Spoils	Suitable disposal locations need to be identified, potentially on adjacent farms. Potential exists for hazardous elements, which would be determined by taking samples during the geotechnical investigations along the pipeline alignment. Complete Phase 1 evaluation.
	Ground Water	Need to identify suitable disposable locations for pipeline trench dewatering water. Disposal will be in accordance with the California General Discharge Permit. Also need to evaluate if any hazardous elements may be in the groundwater. Samples should be taken during geotechnical study. A Phase 1 Environmental Site Assessment will be completed.
	Alignment Changes	A small section of the pipeline alignment is currently under review due to its proximity to a conservation easement as part of the environmental review process. The final alignment will need to be confirmed and easements acquired during final design.
	Narrow Temporary Construction Easement	The area near Byron Airport has a narrow construction corridor. A construction plan for this area will need to be developed during the next phase of design.
	Traffic Control	A portion of the pipeline parallels a moderately-trafficked regional transportation corridor. Preliminary traffic control plans will be needed in the next phase of design.
	Pavement Damage	Risk exists for possible settlement at trenchless crossings (two locations). These locations will require monitoring. Several older farm roads are in poor condition and will likely need a full replace at crossing locations.

Table 5-8. Summary of Major Design Assumptions and Risks Conveyance and Pumping Facilities (contd.)

Facility	Item	Assumptions and Risks
Transfer-Bethany Pipeline (contd.)	Tie-In to Old River Pipeline	Details for the tie-in to the existing Old River Pipeline should be developed during the next phase of design.
	California Aqueduct Canal Tie-In	The California Aqueduct cannot be taken out of service during construction, and care will be needed during construction to prevent damage to the canal. Coordination with DWR will be required to design and develop a construction plan for this tie-in.
	Surge/Vacuum	A surge analysis along the pipeline is planned for the next phase of design.
Delta-Transfer Pipeline	Alignment and Background	The alignment of the Delta-Transfer Pipeline parallels the existing Old River Pipeline for its entire length, largely within its existing permanent easement. The Geotechnical Report and Construction Completion Report for the Old River Pipeline were reviewed and used in development of Delta-Transfer Pipeline design.
Delta-Transfer Pipeline	Geotechnical Conditions	Geotechnical conditions for the Delta-Transfer Pipeline are described in detail in Appendix C, Attachment 1. Please refer to Attachment 1 for additional information. Several areas of risk are addressed below: • *Seismic Shaking* – Portions of the pipeline are in soils that are potentially liquefiable during seismic shaking. Additional geotechnical investigation will be performed in the next phase of design to quantify expected settlement. Use of the proposed welded steel pipe with welded joints will provide seismic flexibility relative to other possible pipe materials. Over-excavation on the order of 2 feet and gravel fill with geogrid reinforcement and geotextile wrap may be required, along with articulating pipe joints in key areas. Details will be developed in the next phase of design. • *Corrosive Soils* – Mitigation of the moderately corrosive to corrosive soils will be accomplished through the use of an impressed current cathodic protection system, similar to that employed for the Old River Pipeline. • *Expansive Soils* – Mitigation of the moderate to high expansion potential soils will be accomplished by the application of hydrated lime, removal of the expansive soil and replacement with non-expansive fill, prewetting, drainage, and use of protection barriers (coatings, geomembranes) • *Pipe Buoyancy* – Mitigation of pipe buoyancy in areas of high water table and those areas subjected to potential inundation would be through the use of a minimum of 6 feet of compacted engineered backfill. Use of soil anchors is unlikely to be needed.

Table 5-8. Summary of Major Design Assumptions and Risks Conveyance and Pumping Facilities (contd.)

Facility	Item	Assumptions and Risks
Delta-Transfer Pipeline (contd.)	Utility Coordination	The Delta-Transfer Pipeline will parallel the existing Old River Pipeline within its existing right of way. Utilities and utility crossings for the Pipeline have been identified using the Record Drawings for the existing Old River Pipeline. Additional utility verification and coordination work will be performed in the next phase of design.
	Contamination	During construction of the Old River Pipeline considerable contamination was encountered at the crossing of Union Pacific Railroad and Hammond Road, leading to a significant change order cost. The source of the contamination was a gasoline pipeline running parallel to the railroad tracks. The extra cost to handle the contamination was mostly reimbursed by Chevron. Since Chevron took responsibility for the costs it is assumed that the contamination in the area was appropriately cleaned up; however, this possible contamination should be investigated and considered further during later design stages for the Delta-Transfer Pipeline.
	Dewatering	Portions of the pipeline will have high groundwater conditions. During the Old River Pipeline construction, dewatering wells were necessary to keep the trench dry in the lower lying areas while sumps in the trench bottom were found to be sufficient to manage water intruding into the trench in the higher ground profile areas. Similar conditions and requirements are assumed for the Delta-Transfer Pipeline.

Key:
CCWD = Contra Costa Water District
hp = horsepower
HVAC = heating, ventilation, and air conditioning
kV = kilovolt
MCC = Motor Control Center
MG = million gallons
OM&R = operations, maintenance, and replacement
PG&E = Pacific Gas and Electric Company
WAPA = Western Area Power Administration
VFD = variable frequency drive

Chapter 6 Project Schedule and Field Cost Estimates

This chapter provides a summary description of the preliminary project schedule and potential work packages for the Investigation. It also describes the methods and general approach used in developing cost estimates for Investigation project facilities. Attachment 4A contains preliminary schedules for each of the potential work packages as well as an overall project schedule. Attachment 4B contains construction cost estimate worksheets for the seven potential work packages. Cost estimates of all project features have been developed to a feasibility-level. Appropriate contingencies for each feature have been applied to account for risk and uncertainty.

Project Schedule

The preliminary schedules for the work to be performed and the sequencing necessary to build the identified new facilities and modify existing facilities for the major components of the project alternatives have been included in this document (refer to Attachment 4A). The included major components are:

- Transfer-Bethany Pipeline
- Expanded Transfer Facility
- Transfer Pump Station Modifications
- Neroly High Lift Pump Station
- Pumping Plant #1 Improvements
- Los Vaqueros Reservoir Modifications – 275 TAF Dam Raise
- Los Vaqueros Marina Complex Relocation
- Los Vaqueros Watershed Trails
- Delta-Transfer Pipeline

Activities in the preliminary construction schedules were assigned durations that allow the work to be performed in accordance with activity requirements. Construction activities occur based on a normal five-day work week with major holidays and winter weather days as non-work days. Construction activities will be phased, when feasible, to avoid environmental impacts and/or effects on existing water operations.

The schedules include only facility design, construction, and project-specific permits. It is anticipated that the environmental review for the Investigation will be completed by early 2019 followed by the start of final design. It is also assumed that project-specific environmental work, including permitting, would be further refined during the respective design periods.

The preliminary construction schedules are based on a logical sequencing of work activities and interdependencies between features, as applicable. The preliminary construction schedule for each feature has been determined based on timing of work, location, and type of construction.

The preliminary construction schedules provide only one scenario of many possible scenarios to complete the work. Duration and project sequencing may and probably will vary as assumption and constraints evolve and become better defined during the final design and permitting process. The schedules represent the technical work constraints and do not try to anticipate budget, resource availability, all environmental constraints/windows, and other stakeholder preferences, which could impact the schedule. The schedules provide only a starting point and not the final baseline for discussions regarding regional resources, budget restrictions, stakeholder preferences, and contract coordination. As project design and permitting progress, a higher level of confidence regarding relevant assumptions and constraints will ensue and the schedule will become better defined.

Work Packages and Schedule Summary

The major components of the Investigation may be divided into individual "work packages" representing discrete projects that could be constructed and/or contracted independently. Summaries are included below for a possible work breakdown that includes seven work packages for distributing construction of the major facilities included in Alternatives 1A, 1B, 2A, and 4A. The approximate construction cost dollar values of the packages are provided. Please refer to the cost estimating section of this appendix for additional cost detail.

This work package distribution reflects only one approach and it is understood that alternative approaches will be developed and evaluated during the final design phase. A full analysis identifying strengths and weaknesses regarding packaging the work into construction contracts will be undertaken at that time.

Work Package 1: Transfer-Bethany Pipeline

Work Package 1 would include the construction of the Transfer-Bethany Pipeline. The work would include an approximately 42,000-foot-long pipeline and an outlet structure at the California Aqueduct. The pipeline will be needed to facilitate draining of the Los Vaqueros Reservoir for the proposed Dam raise. The dollar value of this work package is approximately $155 million (October 2015 price level).

Work Package 2: Expanded Transfer Pump Station and Transfer Pump Station Modifications

This work package would include construction of both the Expanded Transfer Pump Station, which will direct water to Bethany Reservoir, and the Transfer Pump Station Modifications, which will

direct water to the enlarged Los Vaqueros Reservoir. The Expanded Transfer Pump Station's ability to direct water to Bethany Reservoir will be needed to provide water system reliability during Los Vaqueros Reservoir modifications.

The Expanded Transfer Pump Station work will include a 6-pump, 300 cfs capacity pump station as well as a 5-million-gallon capacity steel reservoir. The project will also include significant site earthwork, surge tanks, reservoir overflow pipeline, and tie-ins to the Delta-Transfer Pipeline, Transfer-Bethany Pipeline, and existing Transfer Facility. The work would also include construction of a new power substation and approximately 5 miles of high voltage power lines routed to the site. The dollar value of this portion of the work package would be approximately $38 million (October 2015 price level).

The modifications to the existing Transfer Pump Station would include four replacement higher-head pumps and electrical system upgrades. The dollar value of this portion of the work package would be approximately $11 million (October 2015 price level).

Work Package 3: Neroly High Lift Pump Station

This work package would include construction of the six-pump, 300 cfs capacity Neroly High Lift Pump Station and associated CCWD main canal intake and suction and discharge pipelines, which will direct water to both the modified Transfer Pump Station and Expanded Transfer Pump Station. From these two pump stations, water may be directed to Los Vaqueros Reservoir or Bethany Reservoir, respectively. The Neroly High Lift Pump Station's ability to both use an alternate intake water source and direct water to Bethany Reservoir will be needed to provide water system reliability during Los Vaqueros Reservoir modifications. The dollar value of this work package is approximately $31 million (October 2015 price level).

Work Package 4: Pumping Plant #1 Improvements

Improvement of Pumping Plant #1 on the Contra Costa Canal would be needed to maintain the designed and permitted Rock Slough Intake diversion capacity of 350 cfs. The separately approved Contra Costa Canal Replacement Project, which is replacing the open channel portion of the Contra Costa Canal with a buried pipe, will lower the operating water surface levels at Pumping Plant #1 due to the friction losses added by the pipeline. Pumping would be limited to approximately 200 cfs using the existing Pumping Plant #1 pumps after the completion of the Canal Replacement Project. Larger horsepower pumps set at a lower elevation (than existing) at Pumping Plant #1 would be needed to move the same amount of water (350 cfs) as previously has been moved through this system. Completion of the replacement project will be required to maintain water system reliability during Los Vaqueros Reservoir modifications. In addition, improvements to the Rock Slough Fish Screen cleaning mechanism are required to maintain efficient operations of the Rock Slough Intake as part of this work package. The dollar value of this work package, less existing rehabilitation and maintenance needs at the Pumping Plant #1, is approximately $24 million (October 2015 price level).

Work Package 5: Los Vaqueros Reservoir Modifications

The Los Vaqueros Reservoir modifications required to increase the capacity enlargement to 275 TAF are best suited to a single work package procurement to maximize execution efficiencies. The

work package would include the construction of the enlarged dam, roller compacted concrete embankment, spillway, inlet and outlet works. Site preparation, ancillary roadway construction, and final grading and landscaping would also be included in the package. Coordination of the timing of the Los Vaqueros Reservoir drawdown and other associated operational impacts on the water storage and conveyance system have been considered and will be evaluated in more detail and a refined schedule relative to the other work packages will be developed in the next phase of project development. The dollar value of this work package is approximately $284 million (October 2015 price level). Details on the cost estimate for the work package are included in Attachment 2E.

Work Package 6: Expanded Recreation Facilities

The existing Marina Complex, including the facilities at the south cove and the end of Los Vaqueros Road, would be inundated to make way for an expanded 275 TAF reservoir. A new Marina Complex would replace the existing Marina Complex upslope of the existing facilities at the southern end of Los Vaqueros Reservoir. The new Marina Complex would have a footprint of about 22 acres. A new 0.5-mile ADA accessible interpretive trail would be built surrounding the Mortero Wetland Complex, which is located adjacent to the Walnut Staging Area at the northern end of the Los Vaqueros Watershed. The dollar value of this work package is approximately $25 million (October 2015 price level).

Work Package 7: Delta-Transfer Pipeline

Work Package 7 would include construction of the approximately 37,400-foot-long Delta-Transfer Pipeline. The pipeline work is primarily open cut but would include at least three bore and jack crossings. The work would also include tie-in facilities at both the Old River and Transfer Facilities. The tie-in construction would include isolation valve vaults and a metering valve vault. The dollar value of this work package is approximately $49 million (October 2015 price level).

It is anticipated that all work packages will be executed in approximately the numerical order indicated and all completed within a seven-year period. The attached schedule bar charts (see Attachment 4A) provide one version of the schedules. Schedule analyses to determine best-, likely-, and worst-case scenarios will be performed during the final design phase of the project. The approximate feasibility level design and construction schedule durations for the individual work packages in our judgment based on current analysis are presented in Table 6-1.

Table 6-1. Summary of Work Package Durations

Work Package	Approximate Duration[1]
WP1 – Transfer-Bethany Pipeline	5 years and 4 months
WP2 – Expanded Transfer Pump Station and Transfer Pump Station Modifications	4 years and 3 months
WP3 – Neroly High Lift Pump Station	5 years and 1 months
WP4 – Pumping Plant #1 Improvements	4 years and 2 months
WP5 – Los Vaqueros Reservoir Modifications	4 years and 6 months
WP6 – Expanded Recreation Facilities	3 years and 6 months
WP7 – Delta-Transfer Pipeline	4 years and 8 months

Note:
[1] Includes permitting, final design, procurement, construction, startup and testing, and project closeout
Key:
WP = Work Package

At this stage in design, the durations can be expected to vary by +/- 30-percent to the final durations. The schedules assume initial and sustained integration of technical, environmental, and cultural efforts during the pre-construction phase, and assume no schedule constraints related to these issues would be encountered. The schedules do not consider commercial concerns not yet identified in the planning process. Schedule and risk reduction will be continually addressed as the designs are fully developed.

For the dam raise, construction schedule assumes that the reservoir is at Elevation 350 feet at the start of the construction season. A great deal depends on the time required to excavate to the upstream foundation. Twenty weeks is assumed on the schedule, but this would require two large drag lines (with associated support trucks and equipment) to achieve. Unforeseen site conditions could increase the excavation schedule and the overall schedule for the embankment construction in subsequent years.

Cost Estimate Methods

The following sections define Reclamation cost estimate levels, project price level, allowances for Investigation alternatives, major cost estimate assumptions, and inherent risk and uncertainty of the cost estimates. Per Reclamation policy, feasibility level cost estimates do not require a basis-of-estimate document to convey the underlying detailed estimate assumptions.

Cost Estimate Levels

Different levels of cost estimates are required to plan and fund projects. As a project moves through its development, each subsequent estimate level reflects increasing detail and refinement of project features. Reclamation recognizes six different levels of construction cost estimates, as follows (Reclamation 2007a):

- Preliminary
- Appraisal
- Feasibility
- Percent Final Design (post-authorization)
- Prevalidation of Funds (Prevalidation)
- Independent Government Cost Estimate

Cost estimates are typically developed in the chronological order shown, and each supersedes the previous estimate. They differ in degree of detail, refinement, use, and confidence, depending on the amount of certainty regarding engineering and geological data, and other factors (e.g., environmental considerations, land acquisition costs, and procurement methods) known at the time the cost estimates are prepared (Reclamation 2007a). For the Investigation alternatives, feasibility-level cost estimates have been developed for project facilities. These cost estimates are based on minimum 10 percent design definition for all project facilities.

Price Level

All feature costs have been escalated or de-escalated using Reclamation construction cost trends indices to bring all costs to an October 2015 price level (Reclamation 2016). These costs are also escalated to a January 2018 price level within the main body chapters and other appendices of this feasibility report. To escalate costs to a January 2018 price level, the published Reclamation Construction Cost Trend's Composite trend for construction was used to escalate the total October 2015 price level cost of each facility.

Wage Rates

For all feature costs, indicated scope element unit rates are considered consistent with relevant California prevailing wage determinations. Crew compositions have not been fully developed for all items of the Investigation, but where daily crew pricing rates are indicated they reconcile to current or index adjusted market wages.

Field Cost Estimate Components and Allowances

Depending on the level of study, it is often impractical to identify all items or unknown risks associated with a project. Accordingly, appraisal, feasibility, and percent design estimates typically contain allowances shown as separate line items for mobilization, design contingencies, allowance for procurement strategies, and construction contingencies as part of the project field cost. The Investigation used typical percentages for these allowances per Reclamation policy. Field cost is an estimate of capital costs of a feature or project from award to construction closeout.

Mobilization

Mobilization costs include contractor bonds, and the cost of mobilizing contractor personnel and equipment to the project site during initial project setup and the contractor's field oversight

expenses. For most Investigation features, a value of 5 to 10 percent has been used for the mobilization allowance.

Design Contingency

Design contingency is intended to account for three types of uncertainties inherent as a project advances from the planning stage through final design, which directly affects the estimated cost of the project. These include (1) minor unlisted items, (2) minor design and scope changes, and (3) minor cost estimating refinements. For Investigation, typical design contingency allowances range from 10 to 20 percent of the subtotal of all listed pay items and mobilization. In general, the less refined the estimate, the higher the percentages used. As more details are developed to refine a specific cost estimate, the number of direct-cost line items increases, the accuracy of the quantity take-offs increases, and the allowance for design contingency decreases.

Allowance for Procurement Strategies

An allowance for procurement strategies may be included in appraisal- and feasibility-level cost estimates to account for additional costs when solicitations will be advertised and awarded under other than full and open competition or for alternative delivery schemes. These include solicitations that will be set aside under socioeconomic programs, along with solicitations that may limit competition or allow award to other than the lowest bid or proposal. For the Investigation, the assumed procurement method is a conventional design-bid-build approach under full and open competition for all project elements. Therefore, this allowance was set as 0 percent for the Investigation alternatives. More refined construction packages and alternative delivery methods may be considered during post-authorization engineering and design.

Construction Contingency

Appraisal- and feasibility-level cost estimates shall include a percentage allowance for construction contingencies as a separate line item to cover minor differences in actual and estimated quantities market unknowns, endangered species schedule constraints, project risks, unforeseeable difficulties at the site, changed site conditions, possible minor changes in plans, and other uncertainties. The allowance is based on engineering judgment of the major pay items in the estimate, reliability of the data, adequacy of the projected quantities, and general knowledge of site conditions. For the Investigation, the allowance ranges from 20 to 25 percent of the subtotal of all listed pay items, mobilization, design contingency, and allowance for procurement strategies. This level of construction contingency is typical of feasibility level estimates, per Reclamation policies.

Escalation from Notice to Proceed to Midpoint of Construction

Escalation from the notice to proceed to the midpoint of construction is included in all cost estimates as an assumed 2.75 percent interest rate.

Major Cost Estimate Assumptions

The assumptions listed for direct cost line items, and specifically factors used to determine indirect costs, are critically important to the overall accuracy of the estimate and should be reviewed and understood by all parties. The employed pricing methodology will be consistent with a semi-detailed unit price. All capital construction cost estimates have been escalated or de-escalated to October 2015 price level using Reclamation indices as previously noted. No escalation from notice to

proceed to mid-point of construction or escalation from published price level to notice to proceed is included in the cost estimates.

The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at the time the estimate was prepared. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market conditions, and other variable factors, and should include escalation from published price level to the notice to proceed in future feasibility-level estimates. Accordingly, the final project cost will vary from the estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding would need to be carefully reviewed before making specific funding decisions and/or establishing the project budget.

Competitive Market Conditions at the Time of Bid Tender

Estimates assume that Builder's Risk Insurance would be available to the contractor. If Builder's Risk Insurance is not available to the contractor because of the scope, security implications, or magnitude of the project, increased bid margins can be expected since the contractor would need to assume and include costs against those additional risks.

Procurement Strategy

It is envisioned that CCWD will lead and manage the Phase 2 expansion activities, including construction contract administration and the procurement strategy. CCWD expects to use a full and open bidding process, as was used during the Phase 1 expansion activities.

Major Cost Estimate Exclusions

Major exclusions from the cost estimates include the following:

- Costs associated with loss of water due to construction requirements affecting dam or conveyance operation
- Escalation from published price level to notice to proceed
- Impacts due to multiple construction contracts, market conditions, and number of bidders.

Program Cost Drivers

Although not included in the estimates of first costs, cost escalation can be a significant cost factor for the program and should be included for economic studies and future project budgeting. Total contingency is another significant cost driver. As explained previously, contingency consists of three separate components: estimating accuracy allowance, risk provision for unknowns supported by probability theory, and an unlisted items allowance.

Risk and Uncertainty

With each aspect of this report, certain assumptions have been made based on engineering and scientific judgment. Careful consideration has been given to the methodologies and evaluations for hydrology and system operations as well as cost estimates. Analyses have been developed with advanced modeling and estimating tools using historical data and trends. While this is an effective

way to help predict outcomes for future operations and costs, many uncertainties could affect the findings in this appendix. Various uncertainties and risks associated with the Investigation are discussed in Appendix A – Plan Formulation.

All cost estimates, even at a feasibility-level, have inherent risks and uncertainties. The Investigation team has no control over the costs of labor, materials, competitive bidding environments, unidentified field conditions, financial and/or commodity market conditions, or any other factors likely to affect the cost estimates of the Study alternatives, all of which are and will unavoidably remain in a state of change, especially in light of high market volatility attributable to Acts of God and other market forces or events beyond the control of the parties. As such, these estimates are based on normal market conditions, defined by stable resource supply/demand relationships, and do not account for extreme inflationary or deflationary market cycles. These estimates are a "snapshot in time" and their reliability will degrade over time. No warranty, promise, guarantee or representation, either expressed or implied, is given that proposals, bids, project construction costs, or cost of operations and maintenance functions will not vary significantly from these cost estimates.

Project Field Costs

Table 6-2 summarizes project field cost estimates for the Los Vaqueros Expansion alternative work packages in millions of dollars.

Table 6-2. Summary of Estimated Work Package Field Costs for All Alternatives ($ millions)

Item	Alternative			
	1A	1B	2A	4A
Work Package 1: Transfer-Bethany Pipeline				
Transfer-Bethany Conveyance Facilities OPCC	$155.34	$155.34	$155.34	$155.34
Work Package 2: Expanded Transfer Pump Station and Transfer Pump Station Modifications				
Expanded Transfer Pump Station OPCC	$38.30	$38.30	$38.30	$38.30
Existing Transfer Pump Station Modifications OPCC	$11.14	$11.14	$11.14	$11.14
Work Package 3: Neroly High Lift Pump Station				
Neroly High Lift Pump Station OPCC	$31.36	$31.36	$31.36	$31.36
Work Package 4: Pumping Plant #1 Improvements				
Pumping Plant #1 Improvements OPCC [1]	$24.32	$24.32	$24.32	$24.32
Work Package 5: Los Vaqueros Reservoir Modifications				
275 TAF Dam Raise OPCC	$283.54	$283.54	$283.54	$0.00
Work Package 6: Expanded Recreation Facilities				
Marina Complex Relocation OPCC	$23.06	$23.06	$23.06	$0.00
Watershed Trails OPCC	$0.65	$0.65	$0.65	$0.00
Los Vaqueros Interpretive Center Improvement OPCC	$0.79	$0.79	$0.79	$0.79
Watershed Office Barn and Interpretive Features OPCC	$0.81	$0.81	$0.81	$0.81
Work Package 7: Delta-Transfer Pipeline				
Delta-Transfer Pipeline OPCC	$48.66	$48.66	$48.66	$0.00
Total Field Cost for Work Packages	**$617.97**	**$617.97**	**$617.97**	**$262.06**

Notes:

General: October 2015 price levels. Non-contract costs, interest during construction, and annualized project costs are not included in this summary. Totals may not sum exactly due to rounding.

[1] Includes associated improvements to the Rock Slough Fish Screen cleaning mechanism. The costs are reduced by equivalent amount to existing PP#1 rehabilitation and maintenance requirements.

Key:

OPCC = opinion of probable construction cost

TAF = thousand acre-feet

Chapter 7 Project Capital and OM&R Costs

This chapter provides a description of the methods and general approach used to develop the project capital and OM&R project costs from the work package field costs described in Chapter 7. Attachment 4C includes the operation, maintenance, and replacement cost estimates and Attachment 4D includes the pumping cost worksheets. Cost estimates of all project features have been developed to a feasibility-level. Appropriate contingencies for each feature has been applied to account for risk and uncertainty.

Project costs in this Federal feasibility study do not include costs for local associated facilities planned by individual Local Agency Partners. These local facilities would provide additional benefits and services to CCWD and other Investigation local partners in conjunction with additional project deliveries. These local facilities were developed separately from the Feasibility Study but are linked to the operations of the project. These costs are included within the project costs considered in the state WSIP grant application. These local facilities include a new Brentwood Pipeline, a new EBMUD-CCWD Intertie Pump Station, installation of variable frequency drives at EBMUD's Walnut Creek Pumping Plant, a new ECCID intertie, and relining portions of EBMUD's Mokelumne Aqueduct. Additional information on these facilities is available in the Supplement and the Final EIS/EIR.

Capital Costs

Total capital cost is the sum of the construction costs and interest during construction. These cost components are described below. A final project cost summary is included at the end of this chapter for all Final Alternatives.

Construction Costs

Construction cost is the sum of the feature field costs plus non-contract costs. Project field costs are described in Chapter 7. Additional description follows. Non-contract costs for design, design services during construction, land acquisition, and administrative costs have been estimated as line items. In addition, non-contract costs related to environmental compliance, permitting, and mitigation are estimated through comparison with CCWD's historical costs incurred through the original Los Vaqueros Reservoir construction and the initial expansion to 160 TAF.

Field Costs

The project field costs have been developed to a feasibility-level and are summarized in Table 6-2 for the major work packages.

Non-Contract Costs

Non-contract costs refer to costs of work or services provided in support of the feature construction, and distributed costs (or other work that can be attributed to the feature as a whole). Distributed costs include facilitating services, investigations, design and specifications, construction management, environmental compliance, and archeological considerations.

Non-contract costs for the Investigation have been estimated using a combination of detailed cost estimates and historical information from the original reservoir construction and the Phase 1 expansions, which were both also led by CCWD. The major cost components with detailed cost estimates include design and design services during construction, construction management, land acquisition, and administrative costs. These estimates are included in Attachment 4E.

Design and Design Services During Construction

Estimates for design and design services during construction were estimated through a bottom-up approach for individual project work packages. Table 7-1 provides the final fee estimates to bring current feasibility-level designs through to final design and develop specifications. These design fees are based on estimated hours and consultant fees.

For the Transfer and Expanded Transfer Pump Station, the Neroly High Lift Pump Station, Pumping Plant #1 Improvements, and Delta-Transfer Pipeline, design costs are based on the number of drawings expected for each engineering discipline and the expected time to complete and review each drawing, in additional to project manager hours. Additional hours are included for developing specifications, preparing submittals, bid services, submittal reviews, responding to requests for information, project meetings, and change order support. These costs are considered as design services during construction. Potential site visits are included for certain engineering disciplines. Other direct costs are included as appropriate. Individual estimates by engineering discipline are shown within Attachment 4E.

Costs for the Transfer-Bethany Pipeline and Los Vaqueros Reservoir Modifications include significant additional geotechnical and surveying work, necessary to reach final design on these two work packages.

For the Expanded Recreation Facilities, design and design services during construction are estimated as ten percent of field costs based on common practice.

Table 7-1. Estimate of Design and Design Services During Construction for Investigation Alternatives by Work Package ($ millions)

Work Package	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
WP 1: Transfer-Bethany Pipeline[1]	$7.43	$7.43	$7.43	$7.43
WP 2: Transfer and Expanded Transfer Pump Station	$4.58	$4.58	$4.58	$4.58
WP 3: Neroly High Lift Pump Station	$4.36	$4.36	$4.36	$4.36
WP 4: Pumping Plant #1 Improvements	$4.16	$4.16	$4.16	$4.16
WP 5: Los Vaqueros Reservoir Modifications	$19.88	$19.88	$19.88	$0.00
WP 6: Expanded Recreation Facilities[1]	$2.53	$2.53	$2.53	$0.16
WP 7: Delta-Transfer Pipeline	$3.97	$3.97	$3.97	$0.00
Total	**$46.91**	**$46.91**	**$46.91**	**$20.69**

Key:
WP = Work Package
Notes:
General: October 2015 price levels. Detailed cost estimates are available in Attachment 4E, except as noted.
[1] Estimated as ten percent of field cost, rather than as a bottoms-up estimate.

These estimates fall within the accepted typical range of percentages of field costs for design and design services during construction. For Alternatives 1A, 1B, and 2A, the total design and design services during construction costs of $46.91 million. For Alternative 4A, the total design and design services during construction costs of $20.69 million.

Construction Management

Estimates for construction management were estimated through a bottoms-up approach for the project work packages. A work breakdown structure was created, including hours, overhead and additional costs related to materials testing, special inspections, cathodic protection inspections, and scheduling. These include construction management during preconstruction, construction, and start-up, testing and commissioning/tie in periods. The construction management fees for each of these components is shown in Table 7-2 below.

Typical construction management costs on projects, depending on project complexity, location, and other variables, range from 6 percent to 15 percent of field costs. Each project component was evaluated based on three separate construction phases: preconstruction; construction; and start-up, testing, and commissioning. The length of time for each project work package was evaluated based on the project schedule, as described in Chapter 7.

The preconstruction phase is the period from Bidding to Award and Notice to Proceed that generally includes construction management staff involved with analysis of bids, recommendation of award, review of conformed contract documents, and general preparation of tools and staff for the construction phase. For this phase, it was assumed that a full-time construction manager and a part time inspector would be required. Additional inspector time is provided for the Transfer-Bethany Pipeline, the Delta-Transfer Pipeline, and the Los Vaqueros Reservoir Modifications. The preconstruction phase for the work packages ranges from 1 month to 5.5 months.

The construction phase is the period from Notice to Proceed through Substantial or Final Completion that generally includes construction management staff involved in contract administration and field inspection activities. For this phase, it was assumed that all staff would be working on the project full time, including the construction manager, an inspector, an admin, and an assistant construction manager/resident engineer. The Transfer-Bethany Pipeline and the Delta-Transfer Pipeline are assumed to have two additional inspectors. The Los Vaqueros Reservoir Modifications are assumed to have an additional construction manager, two additional inspectors, two additional assistant construction manager/resident engineers, and an additional admin. The construction phase for the work packages ranges from 12 months to 30 months.

The start-up, testing, and commissioning phase is the period from Substation or Final Completion to Demobilization that generally includes demonstrating and proving project equipment and systems. For this phase, it was assumed that full time construction manager, assistant construction manager/resident engineer, and senior administrator would be required. A start-up specialist is assumed for the Transfer-Bethany Pipeline, the Delta-Transfer Pipeline, the Los Vaqueros Reservoir Modifications, the Expanded Transfer Pump Station, and the Neroly Pump Station. Additional part time work was assumed to the inspectors on each work package. The start-up, testing, and commissioning phase for the work packages ranges from 1.5 months to 4 months, except at the Neroly Pump Station where the phase is expected to last up to 10 months.

Non-labor costs can include costs such as equipment, vehicles, cloud-based management systems, per-diem and travel, and other costs. For this analysis, an allowance was used to estimate some amount of other direct costs with a typical 5 percent markup factor. Actual other direct costs may vary depending on the consultant scope and Agency agreements.

Additional subconsultant costs are included in the construction management costs under the assumption that the construction manager would manage the subconsultants providing the following services, using a 5 percent markup on subconsultant costs:

- Materials Testing –$10,500 per month for half the construction phase
- Special Inspection for Concrete and Welding –$7,350 per month for half the construction phase
- Coatings and Cathodic Protection –$5,250 per month for half the construction phase
- CPM Project Scheduling – $2,100 per month

These costs apply to all work packages, except the Los Vaqueros Reservoir modification. For these, subconsultant costs for materials testing, special inspections, coatings and cathodic protection, and scheduling are doubled, and their duration is assumed for the entire construction period.

Table 7-2. Estimate of Construction Management Fees for Investigation Alternatives by Work Package ($ millions)

Work Package	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
Work Package 1: Transfer-Bethany Pipeline	$8.17	$8.17	$8.17	$8.17
Work Package 2: Transfer and Expanded Transfer Pump Stations	$5.91	$5.91	$5.91	$5.91
Work Package 3: Neroly High Lift Pump Station	$4.26	$4.26	$4.26	$4.26
Work Package 4: Pumping Plant #1 Improvements	$3.07	$3.07	$3.07	$3.07
Work Package 5: Los Vaqueros Reservoir Modifications	$11.09	$11.09	$11.09	$0.00
Work Package 6: Expanded Recreation Facilities[1]	$1.98	$1.98	$1.98	$0.99
Work Package 7: Delta-Transfer Pipeline	$6.04	$6.04	$6.04	$0.00
Total	**$40.52**	**$40.52**	**$40.52**	**$22.40**

Notes:
General: October 2015 price levels. Detailed cost estimates are available in Attachment 4E, except as noted.
[1] Estimated as ten percent of field cost, rather than as a bottoms-up estimate.

These estimates fall within the accepted typical range of percentages of field costs for construction managements. For Alternatives 1A, 1B, and 2A, the total construction management costs of $40.52. For Alternative 4A, the total construction management costs of $22.40.

Permitting, Environmental Compliance & Mitigation

Permitting costs include the costs associated with the required regulatory permits. Environmental compliance describes the costs associated with the direct labor and service contract work directly required for implementing air quality, fisheries, botanical, wetlands, wildlife, cultural resources, geology and soils, water quality, land use, noise, paleontological, public health, recreation, transportation, utilities, and visual resources commitments and mitigation measures, such as pre-construction surveys, species relocations, dust abatement, air quality mitigation, Section 106, and resource management plans. Mitigation costs describe the construction cost for the mitigation implementation and mitigation land acquisition. These costs also include the cost of pre-construction environmental clearances.

Table 7-3 summarizes the compliance and permit actions required for project implementation.

Table 7-3. Summary of Compliance and Permit Actions for Project Implementation

Agency/Action	Recommended Prerequisites for Submittal [1]	Estimated Processing Time [2]	Anticipated Fees
Federal			
USACE Clean Water Act Section 404 Permit Rivers and Harbors Act Section 10 Permit	• Application. • ESA compliance document for submittal to USFWS/NMFS/CDFW. • Section 401 Water Quality Certification permit or application. • NEPA documentation (environmental compliance documents). • NHPA, Section 106 compliance documentation. • Wetland delineation. • CWA, Section 404 (b)(1) evaluation and identification of the Least Environmentally Damaging Practical Alternative. • Mitigation and monitoring plan.	24 months	$100 for Individual permit (may be waived for government permitees)
USFWS/NMFS Endangered Species Act Section 7 Biological Opinion	• Regular formal and informal technical consultation. • Biological Assessment.	18 months	None
NMFS Essential Fish Habitat Assessment	• Regular formal and informal technical consultation. • Biological Assessment. • NEPA documentation (environmental compliance documents).	18 months	None
USFWS Fish and Wildlife Coordination Act Coordination	• Service agreements among USFWS, NMFS, and CDFW. • Regular Informal technical coordination. • NEPA documentation (environmental compliance documents).	12 months	None
Federal (contd.)			
USFWS Bald and Golden Eagle Protection Act Permit	• Application. • NEPA documentation (environmental compliance document). • Pre-construction survey report(s). • Eagle Management Plan.	TBD	TBD
SHPO/ACHP NHPA, Section 106 Permit	• Historic Property Inventory Report. • Native American consultation.	24 months	None
BLM Special-Use Permits (e.g., livestock grazing, forest products)	• Application, if required.	TBD	TBD

Table 7-3. Summary of Compliance and Permit Actions for Project Implementation (contd.)

Agency/Action	Recommended Prerequisites for Submittal [1]	Estimated Processing Time [2]	Anticipated Fees
State			
Division of Safety of Dams	• Application.	24 months	$1 million+
Central Valley Water Board Clean Water Act Section 401 Permit	• Application. • Fish and Game Code Section 1602 application. • CWA Section 404 permit or application. • NEPA documentation (environmental compliance documents). • Mitigation and monitoring plan (if needed).	6 months	$500+
CDFW California Endangered Species Act Section 2081— Incidental Take Permit or 2080.1 Consistency Determination	• Informal technical consultation. • Application, if requesting a 2081 Incidental Take Permit. • Biological opinion and incidental take statement, if requesting a consistency determination.	9 months after Biological Opinions issued	None
CDFW Fish and Game Code Section 1600 Streambed Alteration Agreement	• Application. • CWA Section 401 Water Quality Certification permit or application. • CWA Section 404 permit or application. • NEPA documentation (environmental compliance documents). • Mitigation plan.	9 months	$4,000
CDFW Proposition 1	• Bond fund agreement for ecosystem benefits.	12 months	None
State Water Board Water Right Actions	• Application for new water right appropriation and petition for revision of Fully Appropriated Streams Declaration. • Draft (possibly final) environmental compliance documents.	12 months	$600,000
State Lands Commission Land Use Lease	• Application. • Draft environmental compliance documents.	9 months	$25
State of California Department of Transportation Encroachment Permit	• Application. • Permit Engineering Evaluation Report.	60 days	None
California Department of Conservation California Surface Mining and Reclamation Act Permit	• Application.	TBD	TBD

Table 7-3. Summary of Compliance and Permit Actions for Project Implementation (contd.)

Agency/Action	Recommended Prerequisites for Submittal [1]	Estimated Processing Time [2]	Anticipated Fees
Local			
Contra Costa County Construction-Related Permits	• Demolition, grading, building, mechanical, and utility construction and encroachment permits; and easements.	TBD	TBD
BAAQMD Dust Control Plan	• Dust Control Plan. • Dust Control Training Course. • Preapplication meeting (encouraged).	2 months	TBD
BAAQMD Authority to Construct and Permit to Operate	• Application. • Preapplication meeting (encouraged). • Required conformity and inclusion in the State Implementation Plan.	6 months	$75

Notes:
[1] All permit applications require detailed project description information.
[2] Anticipated processing time is estimated based on submittal of initial permit applications to permit issuance.
Key:
ACHP = Advisory Council on Historic Preservation
BAAQMD = Bay Area Air Quality Management District
BLM = U.S. Bureau of Land Management
CDFW = California Department of Fish and Wildlife
ESA = Endangered Species Act
NEPA = National Environmental Policy Act
NMFS = National Marine Fisheries Service
SHPO = State Historic Preservation Office
State Water Board = State Water Resources Control Board
TBD = to be determined
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

In addition, mitigation activities for the Final Alternatives are described in the Final EIS/EIR and the Supplement to the Final EIS/EIR. The following mitigation activities are a partial summary of those listed in the environmental documents for the Final Alternatives in the Supplement to the Final EIS/EIR:

- Preconstruction surveys by a qualified biologist for biological resources, including Alameda whipsnakes, special-status nesting birds, special-status reptile populations (San Joaquin coachwhip and coast-horned lizard), San Joaquin pocket mice, American badgers, special-status bats, California red-legged frogs, California tiger salamanders, San Joaquin kit foxes, burrowing owls, special-status plant species, golden eagles, bald eagles, and Swanson's hawks;

- Development of a Habitat Mitigation Plan to describe the protection and monitoring plan for biological resources, including Alameda whipsnakes, special-status plant species (Atriplex

populations), California red-legged frogs, and California tiger salamanders, as well as the mitigation and monitoring plan for wetlands habitat and vernal pool habitat;

- Compensation for lost habitat types including grasslands and oak woodland habitat, natural seasonal wetland, California red-legged frogs and California tiger salamander breeding pools, vernal pools, San Joaquin kit fox habitat, burrowing owl habitat, Swainson's hawk and golden eagle foraging habitat;
- Restoration and enhancement of the Kellogg Creek and adjacent natural uplands;
- Conservation easements for 0.75 acres of Prime Farmland in Contra Costa County;
- Revegetation of the shell and core borrow areas to blend with surrounding landscape;
- Cultural resources support, including updating the existing Cultural Resources Management Plan, cultural training and re-burials.

The exact area and location of mitigation lands that will be required for the project is currently unknown, but the impacted area will be 325 acres.

Costs for the activities described above are listed in Table 7-4. Alternative 4A will not require all these activities. The costs for permitting, environmental compliance, and mitigation total $91.9 million for Alternatives 1A, 1B, and 2A. These costs will be approximately $51.4 million for Alternative 4A.

Table 7-4. Estimated Costs for Permitting, Environmental Compliance, and Mitigation

Line Item	Description	Estimated Cost ($ millions)
Environmental Documentation	Environmental documentation and technical studies, including Transfer-Bethany Pipeline alternative alignment evaluation, Final Supplement to the Final EIS/EIR, and CEQA Findings and Mitigation Monitoring and Reporting Plan. Public Outreach.	$1.40
Regulatory Permitting	Biological Assessment for Federal Endangered Species Act compliance and Magnuson Stevens Fisheries Conservation and Management Act compliance; Clean Water Act Section 404/Section 10 Individual Permit Application; Clean Water Act Section 401 Clean Water Act Water Quality Certification Application; California Fish and Game Code Section 1602 Streambed Alteration Agreement Application; Section 2081 California Endangered Species Act Incidental Take Permit Application; Fish and Wildlife Coordination Act Report; National Historic Preservation Act Section 106 compliance; and Aquatic Resources Delineation. It does not include construction cost for the mitigation implementation and mitigation land acquisition.	$2.20
Operations Modeling	Modeling tasks to support refinement of project operations to track terms and requirements of various water rights; refine the Los Vaqueros daily operations model.	$0.70
Water Rights Permitting	Petition the State Board for change for CCWD's water right permit and assist Reclamation, DWR, and Local Agency Partners with preparation of change petitions as required.	$2.00
Compliance and Permit Fees	Includes VERA conformity mitigation fee, Section 106 cultural resources identification, and permit and mitigation fees (excluding land acquisition, easements, and credits). See Table 6-2 for list of permits. Includes 20% contingency.	$2.40
Tribal Coordination	Efforts associated with tribal issues and coordination.	$0.50
Comprehensive Biological Resources Mitigation and Compensation Program (Botanical and Wetlands Resources)	Natural Seasonal Wetland (Bulrush-cattail Series and Saltgrass Series), Valley Oak, Blue Oak Woodlands, and Fremont Cottonwood Series, Purple Needlegrass Grasslands, Jurisdictional Wetlands and Other Waters, Brewer's Dwarf-Flax. Includes 20% contingency.	$8.40

Table 7-4. Estimated Costs for Permitting, Environmental Compliance, and Mitigation (contd.)

Line Item	Description	Estimated Cost ($ millions)
Comprehensive Biological Resources Mitigation and Compensation Program (Wildlife Resources)	California red-legged frog and California tiger salamander, Western Pond Turtle, vernal pool branchiopods, vernal pool fairy shrimp habitat, San Joaquin Kit Fox, Burrowing Owl, Golden Eagle, Bald Eagle, and Swainson's Hawk, Alameda Whipsnake, Valley Elderberry Longhorn Beetle, Breeding and Migratory Birds, Nesting Raptors, Nonlisted Special-Status Reptile Species (San Joaquin Coachwhip and Coast Horned Lizard), Nonlisted Special- Status Mammal Species (American Badger, Special-Status Bats, and San Joaquin Pocket Mouse), Special-Status Bats. Includes 20% contingency.	$12.00
Cultural and Paleontological Resources Identification and Mitigation	Discovery, recovery, storage, mitigation, relocation. Includes 30% contingency.	$17.30
Mitigation, Monitoring, and Reporting Program for Physical Resources	Local Hydrology, Drainage and Groundwater, Land Use, Agricultural Resources, Transportation and Circulation, Air Quality, Noise, Utilities and Public Service Systems, Hazardous Materials / Public Health, Visual / Aesthetic Resources	$5.00
	Total Estimated Cost	**$91.90**

Note:
General: October 2015 price level.
Key:
% = percent
CCWD = Contra Costa Water District
CEQA = California Environmental Quality Act
DWR = Department of Water Resources
EIS = Environmental Impact Statement
EIR = Environmental Impact Report
Reclamation = U.S. Bureau of Reclamation
State Board = State Water Resources Control Board
VERA = Voluntary Emission Reduction Agreement

Administrative, Project Management, and Legal Services

These non-contract costs relate to the costs incurred by CCWD leading and managing Phase 2 expansion activities. Components include CCWD labor, legal services, and miscellaneous administrative costs, including purchased material, supplies, and equipment. CCWD staff hours for the project include general management, public affairs, engineering, operations and maintenance, construction, watershed/lands, finance, and planning department staff at CCWD. Overhead for this labor is also included in the estimate.

CCWD administrative, project management, and legal services costs were estimated for the Phase 2 expansion by estimating hours spent by staff on the project and multiplying by their hourly rates, including overhead costs. Estimated hours were developed by first estimating the overall percent of total hours spent on Investigation tasks for CCWD staff classifications and anticipated legal staff. The percent of time spent on the Investigation was multiplied by the total hours available during the

project duration. Staff were assumed to have 160 hours available per month over 84 months for Alternatives 1A, 1B, and 2A or 61 months for Alternative 4A, based on the current project schedule.

The anticipated CCWD administrative, project management, and legal services costs for Alternative 1A, 1B, and 2A are $48.4 million. The anticipated CCWD administrative, project management, and legal services costs for Alternative 4A are estimated at $35.2 million.

Project Lands and Easements

Project lands includes lands to be acquired in fee for affected lands, and in fee and by temporary or permanent easement for pipeline alignments, pump station footprints, and staging and construction activities. Using an abbreviated valuation process, values for private lands within or near the pipeline alignments have been estimated as $1.13 million (October 2015 price level) for Alternative 4A and $3.57 million (October 2015 price level) for Alternatives 1A, 1B, and 2A. Appendix E – Real Estate details acquisition criteria and valuation approach for project area lands. In addition, additional land acquisition would likely be required for environmental mitigation. The amount of required mitigation lands and their location have not been determined yet. Input from the resources agencies during permitting phase will determine these costs.

Summary

Table 7-5 provides a summary of the non-contract costs included in the project construction cost estimate.

Table 7-5. Summary of Non-Contract Costs for Final Alternatives ($ millions)

Non-Contract Cost	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
Design and Design Services During Construction	$46.91	$46.91	$46.91	$20.69
Construction Management	$40.52	$40.52	$40.52	$22.40
Permitting, Environmental Compliance & Mitigation[1]	$91.90	$91.90	$91.90	$51.40
Administrative, Project Management, and Legal Services	$48.40	$48.40	$48.40	$35.15
Project Lands and Easements[2]	$3.57	$3.57	$3.57	$1.13
Total	**$227.74**	**$227.74**	**$227.74**	**$129.64**

Notes:

October 2015 price levels. Totals may not sum exactly due to rounding. Where costs were developed as a percentage of field costs, the percentage used is shown in parenthesis after the cost component. Detailed cost estimates are available in Attachment 4E, except as noted.

[1] Permitting, environmental compliance, and mitigation costs described in Table 7-4.

[2] Project Lands and Easements costs were developed as described in Appendix E – Real Estate.

Interest During Construction

Interest during construction is interest that accrues on a loan that finances the construction of an alternative. Interest during construction was calculated for each project components. For this planning level interest during construction estimate, the construction cost spending forecast for each work package was estimated to be equal across the assumed schedule for that work package. The detailed construction schedule for all work packages is included in Attachment 4A.

Interest during construction is calculated for each individual component. Interest begins to accrue during pre-construction activities for each component until scheduled project close-out. Interest is accrued at the project discount rate of 3.5 percent. The total interest during construction for each alternative considers the sum of the interest during construction for each facility included in that alternative.

Annual Costs

Annual costs for the Investigation include interest and amortization of the capital costs; operations, maintenance, and replacement costs; conveyance costs to the Refuges outside project boundaries; and additional energy use costs due to additional pumping.

Interest and Amortization of Capital Costs

Costs are annualized to facilitate comparison to annual benefits. Total annual costs for each alternative have been estimated by interest and amortization of the investment cost over 100 years. A discount rate of 3.5 percent was used in the analysis of the project for the application for State of

California Water Storage Investment Program funding and is presented to allow for comparison with information provided in the application. For the feasibility report, the current Federal discount rate of 2.75 percent (January 2018) is used to calculate annual costs, consistent with other CALFED storage projects and Federal Principles and Guidelines

Annual OM&R for Project Facilities

Feature-specific OM&R cost estimates were developed to determine the annual cost of OM&R on Los Vaqueros project facilities. These cost estimates consider both additional annual operations and maintenance labor costs as well as the annualized cost of major replacements over 100 years. Replacement costs were identified on a schedule for line items identified from the project cost estimates. Both replacement costs and operation and maintenance costs are summarized in Attachment 4C.

Feature-specific OM&R cost estimate were developed for the proposed Transfer-Bethany Pipeline, Expanded Transfer Pump Station, Neroly High Lift Pump Station, Pumping Plant #1 Improvement, Los Vaqueros Dam and Reservoir Modifications, and Delta-Transfer Pipeline. Costs associated with the Pumping Plant #1 Improvements and Los Vaqueros Dam and Reservoir Modifications represent only the incremental costs associated with added or changed features at these sites.

It is assumed that the OM&R costs for the existing Transfer Pump Station modifications included in Work Package 2 and the recreation facilities included in Work Package 6 will not change significantly from pre-project levels. Therefore, no additional OM&R costs for these features were included in the annual OM&R for project facilities.

The feature-specific operation and maintenance costs are based on the associated labor costs to conduct operations and maintenance on the project facilities. Costs across the facilities were based on an assumed number of staff hours at each site. The number of hours was then multiplied by an hourly pay rate. Labor costs were drawn from data published by the U.S. Office of Personnel Management on General U.S. 2016 Pay Annual Rates (OPM 2014). These costs are consistent with the October 2015 price level assumed across all cost estimates, prior to escalation to January 2018 price levels.

The operations and maintenance staff hours assumed by individual facility over a twelve-month period are shown in Table 7-6. As noted above, no additional operations and maintenance work is expected at the expanded recreation facilities or due to improvements at the Transfer Pump Station. Only a small incremental change in operations and maintenance work is expected at the expanded Los Vaqueros Reservoir, while a larger incremental change is expected due to improvements and operational changes at the Pumping Plant #1 site. Generally, the remaining facilities are expected to require similar operations and maintenance staff hours.

Of the hours described in Table 7-6, 15 percent are assumed to earn overtime pay. In addition, the labor costs drawn from the U.S. Office of Personnel Management are adjusted with a 53 percent overhead for leave and benefits and a 40 percent administrative overhead. A 15 percent general

contingency is then added to the labor costs along with a 10 percent design contingency as well as a 10 percent non-contract cost assumption.

Table 7-6. Assumed Increase in Operations and Maintenance Staff Hours by Facility

Facility	Staff Hours Assumed over 12 Months
Transfer-Bethany Pipeline	2,190 hours
Expanded Transfer Pump Station	2,190 hours
Delta-Transfer Pipeline	2,190 hours
Neroly Pump Station	2,190 hours
Pumping Plant #1	1,752 hours
Los Vaqueros Reservoir	175 hours
Expanded Recreational Facilities	none
Transfer Pump Station	none

In addition to operations and maintenance cost, replacement costs for each facility was determined. To estimate replacement costs, each line item in the construction cost estimates was reviewed to determine its expected replacement schedule. The assumed replacement schedule used across all facilities is shown in Table 7-7. As shown, not all line items in the construction cost estimate require replacement.

Table 7-7. Assumed Replacement Schedule and Cost

Line Item Type	Assumed Replacement Schedule and Cost
Piping	100 percent cost replacement every 60 years
Valves	50 percent cost replacement every 20 years
Equipment	100 percent cost replacement at years 30, 60, and 90 (major replacement) 20 percent cost replacement at years 20, 40, 80, and 100 (minor rehabilitation)
Mixed Allowance Items	50 percent cost replacement every 50 years
Steel Reservoir	25 percent cost replacement every 25 years
Other	none

For items that require replacement, unit costs and quantities were assumed to remain consistent with the construction cost estimates. As shown in Table 7-7, a percent of the initial line item cost is assumed for the replacement cost. Similar to the construction cost estimates, the replacement cost estimates include contingencies determined for each facility listed in Table 7-8. In addition, a 25 percent non-contract cost amount is assumed.

Table 7-8. Assumed Replacement Cost Contingencies

Contingency Type	Contingency Assumed
Mobilization	5 percent
Design	10 percent
Construction	20 percent

The individual line item replacement costs, contingencies, and non-contract costs replacement costs over a 100-year period were summed to a total replacement cost. The total replacement costs were then annualized over a 100-year period using the fiscal year 2018 established Federal planning discount rate of 2.75 percent.

The annualized replacement costs and annual operations and maintenance costs for each facility is summarized in Table 7-9. As noted above, these costs are also shown in Attachment 4C in more detail.

Table 7-9. Summary of Annual OM&R for Project Facilities ($ millions, October 2015)

Facility	Total Annual OM&R for Project Facilities	
	Alternatives 1A, 1B, and 2A	Alternative 4A
275 TAF Dam Raise[1]	$0.45	$0.00
Transfer-Bethany Conveyance Facilities [1]	$2.10	$0.00
Delta-Transfer Pipeline	$1.95	$1.95
Expanded Transfer Pump Station	$1.95	$1.95
Existing Transfer Pump Station Modifications	$0.00	$0.00
Neroly High Lift Pump Station	$2.10	$2.10
Pumping Plant #1 Improvements	$1.45	$1.45
Los Vaqueros Expanded Recreational Facilities	$0.00	$0.00
Total Annual OM&R for Project Facilities [2]	**$10.00**	**$7.45**

Notes:
[1] Facilities not included in Alternative 4A.
Key:
OM&R = operations, maintenance, and replacement
TAF = thousand acre-feet

Increase in Replacement Costs for Existing Facilities

Proposed alternatives would result in existing facilities (e.g., Delta intakes and pumps, Los Vaqueros and Transfer Pipelines, etc.) being used more heavily to convey increased water deliveries than under without-project conditions. Incremental increases in replacement costs for the existing facilities due to increased use under the Final Alternatives are included as project costs.

Baseline replacement costs for existing facilities were primarily based off the recommendations provided in the 2006 Untreated Water Renewal/Replacement Study (CCWD 2006) and the 2013 Untreated Water Facilities Improvement Program Plan Update (CCWD 2013). The replacement frequencies recommended by these two studies include:

- Fish screen replacements every 10 to 15 years,
- Pump station pump rebuilding every 9 years, with a major upgrade every 25 years, and
- Surface preparation and repainting of tanks/surge equipment every 12 years.

No major pump station upgrades are assumed in this feasibility report, despite the study recommendations. In addition, baseline replacement costs for existing facilities considered in this feasibility report include relining a quarter of existing pipelines every 25 years, equivalent to 100 percent replacement every 100 years.

To determine the increase in replacement costs for existing facilities due to reoperation, the recommended frequency of replacement projects at each facility was increased in proportion to the increased usage at that facility.

CCWD Additional Energy Use Costs

Delivering new water supply from the expanded Los Vaqueros Reservoir to beneficiaries would increase energy use throughout the CCWD's system. Annual costs associated with increases in CCWD's system energy are shown in Attachment 4D. These costs have been developed based on changes in pumping and energy requirements for each alternative from Appendix B - Modeling. The price per kilowatt hour is estimated to be about $0.067, which is also consistent with energy costs assumed for the Upper San Joaquin River Basin Storage Investigation.

South-of-Delta Conveyance Costs for Refuges

Conveyance costs associated with moving Refuge water supplies through the proposed project facilities are included in the OM&R and energy costs described above. The Refuge Water Supply Program would incur additional costs to convey water from the head of the California Aqueduct (point of delivery from the proposed facilities) to the individual Refuge boundaries. These additional conveyance costs were estimated by Reclamation to be about $50 per acre-foot of delivered Refuge water. This is consistent with the costs assumed for the Upper San Joaquin River Basin Storage Investigation and results in long-term average annual costs of between $1.79 million for Alternative 1A to about $3.45 million for Alternative 2A.

Project Cost Summary

Table 7-10 summarizes estimated field, construction, capital, and annual costs for the Final Alternatives using October 2015 price levels and a discount rate of 3.5 percent per the State of California Water Storage Investment Program guidance to calculate both interest during construction and interest and amortization over the project planning horizon.

Table 7-11 summarizes these costs in January 2018 price levels, indexed using Reclamation construction indices from October 2015. This process does not account for potential increases in individual item costs due to recent changes in policy, such as increases in trade tariffs. In addition, Table 7-11 uses the fiscal year 2018 established Federal planning discount rate of 2.75 percent to calculate both interest during construction and interest and amortization over the project planning horizon.

Table 7-10. Estimated Capital and Annual Costs of the Final Alternatives ($ million, October 2015)

Cost Item	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
Opinion of Probable Construction Costs				
275 TAF Dam Raise	$283.54	$283.54	$283.54	$0.00
Transfer-Bethany Conveyance Facilities	$155.34	$155.34	$155.34	$155.34
Delta-Transfer Pipeline	$48.66	$48.66	$48.66	$0.00
Expanded Transfer Pump Station	$38.30	$38.30	$38.30	$38.30
Existing Transfer Pump Station Modifications	$11.14	$11.14	$11.14	$11.14
Neroly High Lift Pump Station	$31.36	$31.36	$31.36	$31.36
Pumping Plant #1 Improvements	$24.32	$24.32	$24.32	$24.32
Los Vaqueros Marina Complex Relocation	$23.06	$23.06	$23.06	$0.00
Los Vaqueros Watershed Trails	$0.65	$0.65	$0.65	$0.00
Los Vaqueros Interpretive Center Improvement	$0.79	$0.79	$0.79	$0.79
Los Vaqueros Watershed Office Barn and Interpretive Features	$0.81	$0.81	$0.81	$0.81
Total Field Cost	**$617.97**	**$617.97**	**$617.97**	**$262.06**
Non-Contract Cost [1]	$227.74	$227.74	$227.74	$129.64
Total Construction Cost	**$845.70**	**$845.70**	**$845.70**	**$391.70**
Interest During Construction [2]	$57.91	$57.91	$57.91	$26.88
Total Capital Cost	**$903.61**	**$903.61**	**$903.61**	**$418.58**
Annual OM&R for Project Facilities [3]	$10.00	$10.00	$10.00	$7.60
South-of-Delta Conveyance Costs for Refuges [4]	$1.79	$2.31	$3.45	$2.06
Increase in Replacement Costs for Existing Pumping and Intake Facilities	$0.95	$1.58	$0.71	$0.33
Increase in Replacement Costs for Existing Pipelines	$1.18	$1.18	$1.18	$1.18
Increased in Annual Energy Costs	$3.41	$4.51	$3.71	$3.08
Total Annual OM&R Cost	**$17.34**	**$19.58**	**$19.05**	**$14.25**
Interest and Amortization of Capital Costs [5]	$36.08	$32.67	$36.38	$18.22
Total Annual Cost	**$64.99**	**$52.25**	**$68.42**	**$41.28**

Table 7-10. Estimated Capital and Annual Costs of the Final Alternatives ($ million, October 2015) (contd.)

Notes:

General: October 2015 price levels. Totals may not sum exactly due to rounding.

[1] Non-contract costs, including planning, engineering, design, and construction management, are detailed within this Appendix and Attachment 4E. Costs for land acquisitions are also included, as described in Appendix E – Real Estate Appendix.

[2] Interest during construction is based on a 3.5 percent Federal discount rate over each facility's scheduled construction period.

[3] These operation, maintenance, and replacement costs cover only new or modified facilities.

[4] Cost incurred by the Refuge Water Supply Program convey water from the head of the California Aqueduct (point of delivery from the proposed facilities) to the individual Refuge boundaries. These additional conveyance costs were estimated by Reclamation to be about $50 per acre-foot of delivered Refuge water.

[6] Interest and amortization is based on a 3.5 percent Federal discount rate over a 100-year period of analysis.

Key:

OM&R = operation, maintenance, and replacement

TAF = thousand acre-feet

Table 7-11. Estimated Capital and Annual Costs of the Final Alternatives ($ million, January 2018)

Cost Item	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
Opinion of Probable Construction Costs				
275 TAF Dam Raise	$300.00	$300.00	$300.00	$0.00
Transfer-Bethany Conveyance Facilities	$164.36	$164.36	$164.36	$164.36
Delta-Transfer Pipeline	$51.48	$51.48	$51.48	$0.00
Expanded Transfer Pump Station	$40.52	$40.52	$40.52	$40.52
Existing Transfer Pump Station Modifications	$11.79	$11.79	$11.79	$11.79
Neroly High Lift Pump Station	$33.18	$33.18	$33.18	$33.18
Pumping Plant #1 Improvements	$25.73	$25.73	$25.73	$25.73
Los Vaqueros Marina Complex Relocation	$24.40	$24.40	$24.40	$0.00
Los Vaqueros Watershed Trails	$0.69	$0.69	$0.69	$0.00
Los Vaqueros Interpretive Center Improvement	$0.84	$0.84	$0.84	$0.84
Los Vaqueros Watershed Office Barn and Interpretive Features	$0.86	$0.86	$0.86	$0.86
Total Field Cost	**$653.84**	**$653.84**	**$653.84**	**$277.27**
Non-Contract Cost [1]	$240.95	$240.95	$240.95	$137.17
Total Construction Cost	**$894.79**	**$894.79**	**$894.79**	**$414.44**
Interest During Construction [2]	$47.70	$47.70	$47.70	$22.12

Table 7-11. Estimated Capital and Annual Costs of the Final Alternatives ($ million, January 2018) (contd.)

Cost Item	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 4A
Total Capital Cost	**$942.49**	**$942.49**	**$942.49**	**$436.55**
Annual OM&R for Project Facilities[3]	$10.58	$10.58	$10.58	$8.04
South-of-Delta Conveyance Costs for Refuges [4]	$1.89	$2.44	$3.65	$2.18
Increase in Replacement Costs for Existing Pumping and Intake Facilities	$1.01	$1.68	$0.75	$0.35
Increase in Replacement Costs for Existing Pipelines	$1.24	$1.24	$1.24	$1.24
Increased in Annual Energy Costs	$3.61	$4.77	$3.92	$3.26
Total Annual OM&R Cost	**$18.34**	**$20.72**	**$20.15**	**$15.07**
Interest and Amortization for Capital Costs [5]	$27.76	$27.76	$27.76	$12.86
Total Annual Cost	**$46.10**	**$48.48**	**$47.91**	**$27.93**

Notes:

General: January 2018 price levels. Totals may not sum exactly due to rounding.

[1] Non-contract costs, including planning, engineering, design, and construction management, are detailed within this Appendix and Attachment 4E. Costs for land acquisitions are also included, as described in Appendix E – Real Estate Appendix.

[2] Interest during construction is based on a 2.75 percent Federal discount rate over each facility's scheduled construction period.

[3] These operation, maintenance, and replacement costs cover only new or modified facilities.

[4] Cost incurred by the Refuge Water Supply Program convey water from the head of the California Aqueduct (point of delivery from the proposed facilities) to the individual Refuge boundaries. These additional conveyance costs were estimated by Reclamation to be about $50 per acre-foot of delivered Refuge water.

[5] Interest and amortization is based on a 2.75 percent Federal discount rate over a 100-year period of analysis.

Key:

OM&R = operations, maintenance, and replacement

TAF = thousand acre-feet

Chapter 8 References

CCWD. *See* Contra Costa Water District.

Contra Costa Water District. 2006. Untreated Water Renewal/Replacement Study. Prepared by HDR Engineering, Inc. April 2006.

_____. 2013. 2013 Untreated Water Facilities Improvement Program Plan Update. Prepared by Carollo. July 2013.

_____. 2017. About Us. Contra Costa Water District. Available at: http://www.ccwater.com/27/About-Us. Accessed August 28, 2017.

Department of Water Resources. 2009. Conceptual Engineering Report – Isolated Conveyance Facility – All Tunnel Option, Draft – Revision A, Volume 1. November 6, 2009.

_____. 2016. Bay Delta Conservation Plan, Final Environmental Impact Report/Environmental Impact Statement. Chapter 9 – Geology and Seismicity. December 2016.

DWR. *See* California Department of Water Resources.

Flow Science Incorporated. 2011. Los Vaqueros Reservoir Expansion to 160,000 Acre-Feet Water Quality Modeling. Prepared for Contra Costa Water District. August 15, 2011.

MWH. 2015a. Draft Addendum to Technical Memorandum: Geotechnical Considerations. October 2015.

_____. 2015b. Existing System Hydraulic Model Technical Memorandum. December 2015.

_____. 2016. Los Vaqueros Expansion Project Design Criteria Technical Memorandum. January 2016.

OPM. *See* U.S. Office of Personnel Management.

U.S. Office of Personnel Management. 2014. Pay & Leave, Salaries & Wages: Salary table 2014-GS. Available at: https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/salary-tables/14Tables/html/GS.aspx. Accessed March 5, 2019.

U.S. Department of the Interior, Bureau of Reclamation. 2007a. Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03. Denver, Colorado. October 2007.

_____. 2010. Environmental Impact Statement/Environmental Impact Report for Los Vaqueros Reservoir Expansion Project. March 2010.

_____. 2016. Construction Cost Trends. Technical Services Center; Estimating, Specifications, and Construction Management Group. Available at: http://www.usbr.gov/tsc/techreferences/mands/cct.html. Accessed January 27, 2016.