Pueblo Dam Hydroelectric Project

Design Documentation Report
Preliminary Design

Prepared for

Southeastern Colorado Water Conservancy District

June 2014

CH2MHILL

Design Report

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Acronyms and Abbreviations

AC	alternating current
ACI	American Concrete Institute
ANSI	American National Standards Institute
AWS	attraction water system
AWWA	American Water Works Association
B/C	Benefit/Cost
BMP	best management practice
cfs	cubic feet per second
CISP	cast iron soil pipe
DC	Direct current
DDR	Design Documentation Report
ft/sec	feet per second
HPU	hydraulic power unit
Hz	hertz
IBC	International Building Code
ID	inside diameter
IECC	International Energy Conservation Code
IMC	International Mechanical Code
IPC	International Plumbing Code
JUM	joint use manifold
kV	kilo-Volt
kVA	kilo-Volt Amperes
kW	kilowatt
kWh	kilowatt-hours
LED	light emitting diode
MCC	Motor Control Center
mgd	million gallons per day
MWh	megawatt-hours
O&M	operation and maintenance
PCP	plant control panel
pcf	pounds per cubic foot
pci	pounds per cubic inch
PDHP	Pueblo Dam Hydroelectric Project

PRBD	Pueblo Regional Building Department
psf	pounds per square foot
psi	pounds per square inch
psig	pounds per square inch gauge
Q	flow rate or discharge rate
Reclamation	U.S. Department of Interior, Bureau of Reclamation
rpm	revolutions per minute
SCADA	supervisory control and data acquisition
SDS	Southern Delivery System
TIV	Turbine Inlet Valve
USGS	U.S. Geological Survey
V	Volts
Vac	volts alternating current
Vdc	volts direct current
WSE	water surface elevation
WTP	water treatment plant

SECTION 1

Synopsis

1.1 General

This Design Documentation Report (DDR) presents development basis, design criteria, equipment, and concepts for construction of the Pueblo Dam Hydroelectric Project (PDHP).

This is a living document and its contents will be refined, expanded, and updated as the project design progresses. Version history is recorded on the Document Update Register that immediately follows the title page.

1.2 Location

The project is located downstream of Pueblo Dam, adjacent to the Arkansas River, with coordinates 38° 16' 12"N, 104° 43' 23"W. The power plant site is located within the limits of Pueblo County within the Pueblo Reservoir State Park Recreation Area. The land owner is the United States Federal Government.

1.3 Description of Facility

The powerhouse will be located approximately 500 (feet) ft downstream from the North Outlet Work's fixed cone valve facility and adjacent to a Reclamation water supply pipeline. The hydroelectric turbines will discharge into the Arkansas River below Pueblo Dam. The powerhouse will include two horizontal-shaft Francis-type hydroelectric turbines with synchronous generators. The generator will be rated 3-phase, 60 hertz (Hz) at 4160 volts (V). Generated electric power will be transmitted over an underground 13.2 kV transmission line from the power plant substation to the nearby Juniper Pump Station, where interconnection with the utility grid will occur.

1.4 Project Development Schedule

TABLE 1-1
Preliminary Development Schedule
Pueblo Dam Hydroelectric Project

Milestone	Date
Preliminary Design And Equipment Procurement Document Development	March 2014 – July 2014
Execution of the Lease of Power Privilege Contract	August 2014
Execution of Power Sales Agreements	August 2014
Procurement of Hydroelectric Equipment	August 2014 – September 2014
Negotiate and Award of Hydroelectric Equipment Contract	October 2014
Equipment Submittals	October 2014 – April 2015
Equipment Manufacture and Delivery`	January 2015 – August 2016
Final Design	December 2014 – July 2015
Power Plant Construction Contract Bid Period	August 2015
Construction Contract Award	September 2015
Construction	October 2015 – Spring 2017
Commissioning	Spring 2017

1.5 Cost

Table 1-2 summarizes the preliminary cost breakdown for development of the project (Appendix A presents construction cost details and additional information).

TABLE 1-2
Order-of-Magnitude Cost Estimate
Pueblo Dam Hydroelectric Project

Item	Cost
Total Construction Costs	$11,001,648
Owner Furnished Products and Project Interconnection Costs	$8,133,00
Project Administration Costs	$2,000,000
Estimated Total Capital Cost of Development	**$21,383,475**

1.6 Report Organization

This DDR is organized as follows:

- Section 1, Synopsis
- Section 2, Purpose and Introduction
- Section 3, Flow and Net Available Head
- Section 4, Generating Equipment
- Section 5, Operation and Energy Production
- Section 6, System Hydraulics and Transient Analysis
- Section 7, Powerhouse location and Arrangement
- Section 8, Interconnection Configuration and Operation
- Section 9, Economic Basis
- Section 10, Civil Design
- Section 11, Architectural Design
- Section 12, Structural Design
- Section 13, Geotechnical Design
- Section 14, Mechanical Design
- Section 15, Electrical Design
- Section 16, Operation and Maintenance
- Section 17, Construction Considerations
- Appendixes
  - A Construction Cost Estimate
  - B Surge Analysis for the Pueblo Hydro Facility Turbine Load Rejection
  - C Proposed Equipment Technical and Budgetary Price Information
  - D Project Drawings (to-date)
  - E Basic Economic Analysis

SECTION 2

Purpose and Introduction

2.1 General

The District began pursuing the development of hydroelectric power at the existing Pueblo Dam, near Pueblo, Colorado, in 2011. The dam is owned and operated by the U.S. Department of Interior, Bureau of Reclamation (Reclamation). CH2M HILL assisted the District and other parties in this process, including assistance with the preparation and submittal of a Lease of Power Privilege (LoPP) application to Reclamation. The LoPP application was accepted and the District, with its project partners, is currently in the process of developing and negotiating the lease with Reclamation, as well as establishing other project requirements, such as an energy sales agreement and funding.

In support of this process, CH2M HILL has recently prepared an update to the project's feasibility assessment. The District has now engaged CH2M HILL to prepare a preliminary design and procurement documents for the generating equipment. Ultimately, that equipment will be procured and a new power plant will be designed and constructed to house it.

The power plant is anticipated to consist of a cast-in-place concrete structure with metal roof, housing two turbine-generator units. An adjoining control room will house an office area, plant controls and switchgear, and a battery room. The power plant will be located adjacent to a Reclamation water supply pipeline and will discharge into the Arkansas River below Pueblo Dam. Generated electric power will be transmitted through an underground 13.2 kV transmission line from the power plant substation to the nearby Juniper Pump Station, where interconnection with the utility grid will occur. Water will be conveyed to the turbines from existing taps in the pipeline via new welded-steel penstocks.

The project will operate on programmed releases from Pueblo Dam. Releases are dictated by downstream water rights.

2.1.1 Reports and Studies Used in the Design Documentation Report

During prior phases of engineering work for this project, CH2M HILL prepared the following documents:

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014
- CH2M HILL, Surge Analysis for the Pueblo Hydro Facility Turbine Load Rejection, April 9, 2014

2.2 General Description

2.2.1 Location

The project is located downstream of Pueblo Dam, about 7-miles west of Pueblo, Colorado, adjacent to the Arkansas River, with coordinates 38° 16’ 12”N, 104° 43’ 23”W .

SECTION 3

Flow and Net Available Head Basis

3.1 General

In order to establish a basis for the design of hydroelectric turbine generators to be installed at the project, a basis for the flow and net head available to the equipment must be developed and endorsed by the District. The basis for flow and net head available includes both technical and future operation underpinnings, which are discussed in this section.

3.1.1 Reports and Studies Used to Develop this Section

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014

3.2 Hydrology and Flow Available to the Hydropower Plant

Quantification and qualification of flow available to this hydropower facility are based on the following data and criteria:

- Historical daily average Arkansas River flows below Pueblo Dam as recorded at the Colorado Department of Water Resources Station: ARKPUECO.07099400 ARKANSAS RIVER ABOVE PUEBLO, CO – October 1, 1983 through December 31, 2013.
- The maximum capacity of the River Outlet Works through the Pueblo Dam Connection (Work Package 1A) is 1,120 cfs (based on previous work performed during design of the SDS Pueblo Dam Connection). If river demands greater than 1,120 cfs are required to be discharged through Pueblo Dam, flows above 1,120 cfs are passed by means of the dam's three spillway gates.
- Flow through the 90-inch Reclamation pipeline to meet participant ultimate demands total 399 cfs. Of the 399 cfs, SDS and Pueblo West ultimate demands total 148 cfs. It is assumed that normal operating capacity reserves in the Reclamation Pipeline only need to consider SDS and non-redundant Pueblo West demands. Redundant demands would be supplied solely during emergency conditions in the event the South Outlet Works experiences an outage and therefore are not considered factors in sizing the hydroelectric equipment. Total system demands by SDS participants are presented in Table 3-1.

TABLE 3-1
System Demands by Participant
Pueblo Dam Hydroelectric Project

Demand Description	System Demand (mgd)	System Demand (cfs)	Comments
SDS	78	120	SDS Flow to Juniper Pump Station Turnout, Regular Capacity to be maintain in Pipeline
Pueblo West	18	28	SDS Flow to Pueblo West Turnout - Regular Capacity to be maintained in Pipeline
Pueblo West	12	19	JUM Existing Flow Redundancy to Pueblo West Turnout
Fountain Valley Authority	20	32	Intertie Redundancy
Arkansas Valley Conduit	20	32	Intertie Redundancy
Pueblo Board of Water Works at Comanche WTP	40	64	Intertie Redundancy
Pueblo Board of Water Works at Whitlock WTP	40	64	Intertie Redundancy

TABLE 3-1
System Demands by Participant
Pueblo Dam Hydroelectric Project

Demand Description	System Demand (mgd)	System Demand (cfs)	Comments
Fish Hatchery	26	40	Intertie Redundancy
Total	**254**	**399**	

Notes:

JUM = Joint Use Manifold
mgd = million gallons per day
WTP = water treatment plant

- Projected SDS and Pueblo West demands on water supplied from Pueblo Reservoir require a flow reduction be applied to historical Arkansas River streamflow data when used to project future flow available to the PDHP. These projected flow demands, in relation to time, are featured in Table 3-2. This data was provided by Steve Duling via email on 12/11/2013 sent to recipients Stephanie Harrison and Mark Rosser

TABLE 3-2
SDS and Pueblo West Demands on Water Entering Pueblo Reservoir
Pueblo Dam Hydroelectric Project

Time Period	SDS Mean Flow (mgd)	SDS Mean Flow (cfs)	Pueblo West Average Flow (mgd)	Pueblo West Average Flow (cfs)	Total Average Daily Demand (cfs)
2016 - 2020	5	7.74	0.8	1.24	8.97
2021 - 2025	14	21.66	1.6	2.48	24.14
2026 - 2030	10	15.47	2.5	3.87	19.34
2031 - 2035	15	23.21	3.5	5.42	28.63
2036 - 2040	21	32.49	4.4	6.81	39.30
2041 - 2045	26	40.23	5.4	8.36	48.59
2046 - 2050	30	46.42	6.4	9.90	56.32
2051 - 2053	35	54.16	7.1	10.99	65.14

- Hydraulic analyses performed by CH2M HILL indicate a Forebay elevation of 4824.0 ft provides sufficient hydraulic head to deliver the following flows: 120 cfs to the Juniper Pump Station, 28 cfs to Pueblo West Pump Station, and 735 cfs to the hydroelectric plant. A Forebay elevation of 4824.0 ft is associated with a gross (static) head of 80 ft at the turbines, which is expected to be less than the low head limit for operating the equipment (later defined) dictating the assessment of that effect. However, energy analyses can proceed independently of head evaluations for Pueblo West and Juniper Pump Stations, since flow can be delivered at all Forebay levels considered.
- Maximum allowable water velocity in the 90-inch Reclamation Pipeline was established during design of the SDS Pueblo Dam Connection to be 20 ft/sec, or 883 cfs. Thereby, the maximum allowable flow to the hydropower plant is 735 cfs (883 cfs minus 120 cfs {SDS} minus 28 cfs {PW}). The Reclamation Pipeline and 66-inch hydroelectric facility turnouts are lined with Seaguard 6000 Epoxy, tie coat, and surface coat.

- Maximum allowable velocity in each 66-inch turnout for the hydroelectric plant is assumed to be 30 ft/sec (712 cfs).
- No additional demands beyond stated SDS, Pueblo West, and redundant flows were considered.
- The minimum streamflow in the Arkansas River below Pueblo Dam is 20 cfs to meet the demands of the State Fishery. Typically, flow is maintained above 50 cfs during low flow months. Design of the fixed cone valve constructed in 2012 assumed a minimum release 50 cfs throughout the year. Preliminary tailwater elevation is based upon this 50 cfs figure.

3.3 Net Available Head

Quantification and qualification of available net head at the PDHP turbines is based on:

- Historical daily Pueblo Reservoir Forebay Elevations from Reclamation's Great Plains Region Hydromet, Station PUER – October 1, 1983 through December 31, 2013
- SDS Environmental Impact Statement (EIS) discussion of effects to future Pueblo Dam Forebay levels projected the following: 1) Existing to No Action, the reservoir level would be reduced an average 3.8 ft, and 2) No Action to Proposed Action, the reservoir level would be reduced an additional 2.6 ft between 2016 and 2050. Overall, the proposed action will result in an average reduction of reservoir water surface levels of 6.4 ft between 2016 and 2050 (Reference: Final EIS, Appendix E - Simulated Hydrology Results, page E-38; Monthly WSEL Summary, Direct Effects, Location: Pueblo Reservoir). As a result, a linearly decreasing correction factor is applied to historical reservoir elevations for use in projected energy production formulas.
- The tailwater energy grade elevation (water surface elevation plus velocity head) was estimated using the United States Army of Corps of Engineers one-dimensional hydraulic model, Hydrologic Engineering Center River Analysis System (HEC-RAS) version 4.1.0. The tailwater rating curve from the HEC-RAS model is provided as Table 3-3. The following assumptions were used to create the hydraulic model:
    - Bathymetric survey data from 2014 was combined with existing LiDAR-derived topography and used to generate 15 cross-sections in HEC-RAS to represent the reach from the downstream diversion dam (just upstream of the Juniper Road bridge) to the Fixed Cone Valve Facility outlet.
    - The downstream diversion dam served as the downstream hydraulic control as its prominence results in critical flow.
    - Manning's n roughness values were assigned based on aerial imagery and suggested roughness values presented in Chow, 1959. Roughness paramters were then calibrated using the Bureau of Reclamation's Pueblo Dam tailwater rating curve (approximately 4744.1 at 3,000 cfs) and comparison of historical imagery, which illustrated when flow was actively being conveyed in the lower Pueblo Dam tailrace or the second "bench" of the diversion dam, and flow measurements recorded at the USGS gage for the data of the aerial imagery.

TABLE 3-3
Tailwater Rating Curve
Pueblo Dam Hydroelectric Project

Fixed Cone Valve Facility Discharge	Power Plant Discharge	Pueblo Dam Spillway Gate Discharge	Total Flow in Outlet Channel	Water Surface Elevation at Power Plant
(cfs)	(cfs)	(cfs)	(cfs)	(ft)
0	0	0	0	4738.0
0	60	0	60	4738.6
0	250	0	250	4739.5
0	500	0	500	4740.2
0	734	0	734	4740.8
266	734	0	1,000	4741.3
266	734	200	1,250	4741.7
466	734	300	1,500	4742.1
466	734	800	2,000	4742.8
466	734	1300	2,500	4743.3
466	734	1800	3,000	4743.7

3.3.1.1 Methodology for Turbine Flow and Net Available Head at Turbine

Flow available for the turbines is based on the methodology featured in Table 3-4. Dates featured are "for example". Condition statements are based on spreadsheet formula syntax.

TABLE 3-4
Flow Methodology
Pueblo Dam Hydroelectric Project

A) Capacity of Tunnel Works – 1,120 cfs
B) Maximum Flow in Reclamation Pipeline based on Velocity Constraints – 883.6 cfs
C) Ultimate Flow Reserves for SDS and Pueblo West – 148 cfs
D) Maximum Hydro plant total Flow – (E)+(G) < 883.6 cfs – 148 cfs
E) Turbine 1 Rated Flow
F) Turbine 1 Minimum Flow
G) Turbine 2 Rated Flow
H) Turbine 2 Minimum Flow

Label	(1F)	(2F)	(3F)	(4F)	(5F)	(6F)	(7F)	(8F)
Description	Historic Date	Projected Date in the Future	Historic Arkansas River Flow (cfs)	SDS Average Daily Flow (cfs)	Pueblo West Average Daily Flow (cfs)	Flow Available to Hydroelectric Plant (cfs)	Flow Through Turbine 1 to Determine Headlosses (cfs)	Flow through Turbine 2 to Determine Headlosses (cfs)
Formula	4/1/1984	4/1/2017	From Gauge based on 4/1/1984	From Table 2 Projections based on (2F)	From Table 2 Projections based on (2F)	(3F)-(4F)-(5F)	=IF[(6F)>(F),{IF(6F)<(E),(6F),(E)},0]	=IF[(6F)-(7F)>(H), IF{(6F)-(7F)<(G),(6F)-(7F),(G)},0]

Available net head at the turbines is based on the methodology featured in Table 3-5:

TABLE 3-5
Net Head Methodology
Pueblo Dam Hydroelectric Project

I)	Rated Head Turbine 1	L)	Rated Head Turbine 2
J)	Maximum (Turbine Shutoff Head) Turbine 1	M)	Maximum (Turbine Shutoff Head) Turbine 2
K)	Minimum (Turbine Shutoff Head) Turbine 1	N)	Minimum (Turbine Shutoff Head) Turbine 2

Label	**(1H)**	**(2H)**	**(3H)**	**(4H)**	**(5H)**	**(6H)**	**(7H)**
Description	Historic Pueblo Dam Forebay Elevation (ft)	Linear Decrease in Historic Reservoir Levels Due to EIS (ft)	Headloss to Turbine 1	Headloss to Turbine 2	Tailrace WSEL (ft)	Net Head @ Turbine 1	Net Head @ Turbine 2
Formula	From Gauge based on 4/1/1984	-5.15E-04@(2F) + 2.18E+01	Equations and Lookup Tables with applicable (4F) (5F) (7F) (8F)	Equations and Lookup Tables with applicable (4F) (5F) (7F) (8F)	Forcast and Interopolate Table 3-3 Tailwater Rating Data	(1H)-(2H)-(3H)-(5H)	(1H)-(2H)-(4H)-(5H)

SECTION 4

Generating Equipment

4.1 General

This section presents the equipment selection of the PDHP. This section should be reviewed in close coordination with *Section 5 Operation and Energy Production*, as the equipment selection is directly connected with optimizing energy production of the project.

4.1.1 Reports and Studies Used to Develop this Section

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014
- Andritz Hydro January 20, 2014 Budgetary Price and Technical information for Pueblo Dam Hydroelectric Project (Appendix C)

4.2 Constant-Speed Equipment Selection

The March 21, 2014 Feasibility Update presented a preliminary selection of Turbine No. 1: 540 cfs and Turbine No. 2: 194 cfs. This selection was confirmed in consultation with a supplier and a budgetary quotation was obtained, as follows:

Turbine 1:

- Turbine type: Horizontal Francis, fixed-geometry.
- Runner Diameter: 4.92 ft
- Highest Permissible Centerline Setting: 4.3 ft (above T.W.)
- Rated Turbine Flow: 540 cfs
- Rated Turbine head: 114 ft
- Speed: 300 revolutions per minute (rpm)
- Maximum Turbine rated efficiency: 94 Percent
- Operating flow range: 189 to 540 cfs
- Operating head range: 92 to 138 ft
- Nominal generator type and nominal rating: Synchronous, 5,500 kW, 4160 Vac, 3-phase.

Turbine 2:

- Turbine type: Horizontal Francis, fixed-geometry.
- Runner Diameter: 2.79 ft
- Highest Permissible Centerline Setting: 4.3 ft (above T.W.)
- Rated Turbine Flow: 194 cfs
- Rated Turbine head: 114 ft
- Speed: 514 rpm
- Maximum Turbine rated efficiency: 94 Percent
- Operating flow range: 68 to 194 cfs
- Operating head range: 94 to 129 ft
- Nominal generator type and nominal rating: Synchronous, 1,500 kW, 4160 Vac, 3-phase.

The estimated budgetary equipment package cost is $6,650,000. This is inclusive of the two turbine-generators, inlet valves, Hydraulic Power Units (HPUs), controls, and switchgear F.O.B Pueblo Dam. Delivery time for the proposed equipment would be approximately 16 to 20 months after contract award. The quotation and performance curves for the selected turbines are featured in Appendix C. Information from these performance curves was used to predict annual energy production for the proposed installation.

SECTION 5

Operation and Energy Production

5.1 General

This section discusses the projected energy production and operation of the PDHD. This section is organized in three main parts including:

- Scope and Purpose
- Power Generation and Energy Production Methodology
- Energy Production

5.1.1 Reports and Studies Used to Develop this Section

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014

5.2 Power Generation and Energy Production Methodology

Energy produced by the hydroelectric equipment is based on the methodology featured in Table 5-1. This table should be used in conjunction with flow and net head methodology Tables 3-4 and 3-5.

TABLE 5-1
Energy Methodology
Pueblo Dam Hydroelectric Project

N) Max Powerplant Output (kW) – (O) + (P)

O) Turbine 1 Rated Output (kW) – Max of Column (5E)

P) Turbine 2 Rated Output (kW) – Max of Column (6E)

Q) Turbine 1 Average Annual Energy Production (kWh) – Sum Column (7E)/Data Count*365 Days

R) Turbine 2 Average Annual Energy Production (kWh) – Sum Column (8E)/Data Count*365 Days

Label	(1E)	(2E)	(3E)	(4E)	(5E)	(6E)	(7E)	(8E)
Description	Turbine 1 Flow used for Energy	Turbine 2 Flow used for Energy	Turbine 1 Efficiency	Turbine 2 Efficiency	Turbine 1 Power Output	Turbine 2 Power Output	Turbine 1 Daily Energy Projection	Turbine 2 Daily Energy Projection
Formula	=IF[(6H)<(K),0,IF{(6H)>(I),(7F),MIN(Manufacture provided flow curtailment equation due to reduced head based on (6H),(7F)}]	=IF[(7H)<(N),0,IF{(7H)>(L),(8F),MIN(Manufacture provided flow curtailment equation due to reduced head based on (7H),(8F)}]	=IF{(1E)>0,IF(6H)>(K), IF(6H<(J),lookup table of manufacturer provided efficiencies,0),0),0)*combined generator efficiency and line loss of 7 percent	=IF{(2E)>0,IF(7H)>(N),IF(7H<(M),lookup table of manufacturer provided efficiencies,0),0),0)*combined generator efficiency and line loss of 7 percent	(6H)*(1E)*(3E)/11.82	(7H)*(2E)*(4E)/11.82	(5E)*24	(7E)*24

5.3 Energy Production

- Energy production of the hydroelectric facility will vary widely because of the projected variation in heads and flow at the site. Additionally, the future energy production is dependent on the application of certain projected reductions because of planned changes in Forebay operations and demands from SDS and Pueblo West. This section presents energy production results with various assumptions based on the methodology previously presented and preliminary equipment selection identified in Section 4.
- Table 5-2 presents the annual energy production for each calendar year of record (1984 – 2013) without adjustment to both available flow because of future SDS and Pueblo West demands and Forebay levels because of future changes in operation of Pueblo Reservoir. This table therefore presents unaltered production, for the District to evaluate the implications of energy from year to year. Various sequences/combinations of low- and high-energy production years should be evaluated by the District as it pertains to the overall viability of developing the project.

TABLE 5-2
Annual Energy Production without Reductions for Future flow Demands of SDS and Changes to Pueblo Reservoir Operation
Pueblo Dam Hydroelectric Project

Year	Annual kWh Production
1984	32,277,210
1985	40,745,832
1986	38,257,360
1987	38,868,850
1988	30,616,025
1989	21,447,168
1990	8,442,411
1991	7,290,205
1992	11,181,563
1993	20,453,090
1994	20,789,897
1995	32,115,032
1996	27,217,962
1997	34,451,709
1998	26,953,501
1999	32,851,779
2000	28,215,410
2001	15,374,039
2002	6,351,693
2003	1,466,267
2004	6,565,589
2005	5,245,469
2006	12,765,368
2007	23,981,559

TABLE 5-2
Annual Energy Production without Reductions for Future flow Demands of SDS and Changes to Pueblo Reservoir Operation
Pueblo Dam Hydroelectric Project

Year	Annual kWh Production
2008	26,928,927
2009	24,111,251
2010	22,179,973
2011	21,837,897
2012	9,155,330
2013	9,134,876
Average	**21,242,441**

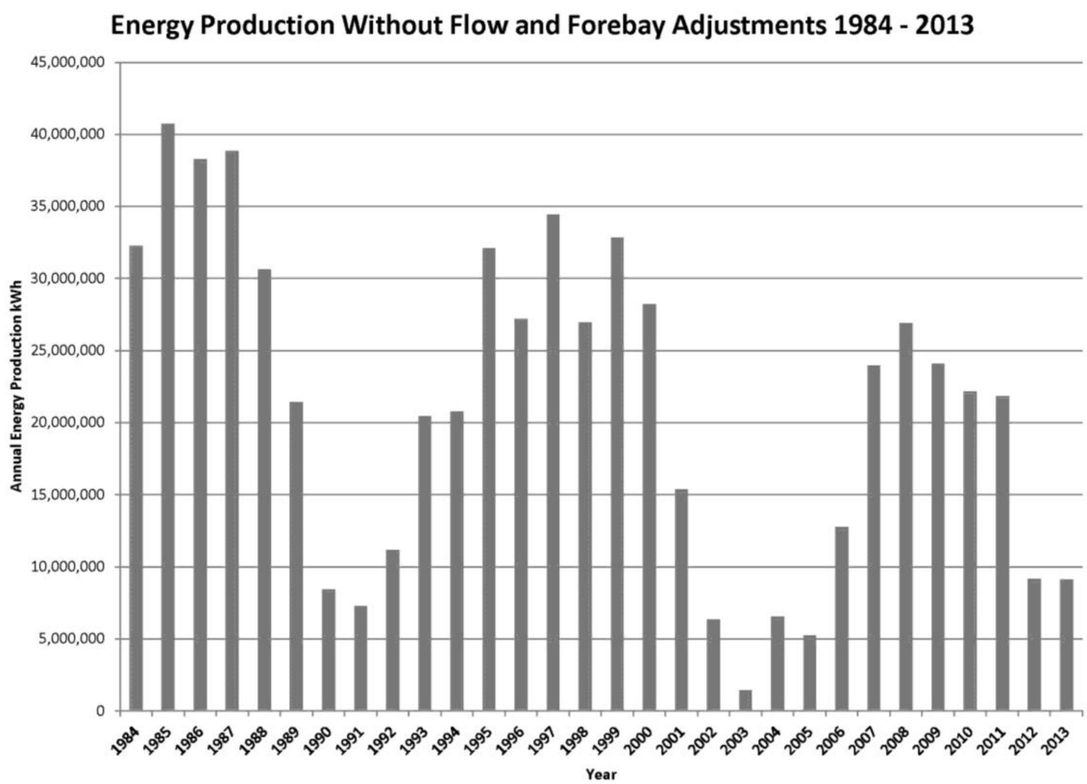

FIGURE 5-1
Annual Energy Production Without Reductions For Future Flow Demands Of SDS And Changes To Pueblo Reservoir Operation
Pueblo Dam Hydroelectric Project

Table 5-3 below presents the annual energy production for each calendar year of record (1984 – 2013) with adjustment to both available flow because of future SDS and Pueblo West demands and Forebay levels because of future changes in operation of Pueblo Reservoir. The table below is based on the assumption that January 1, 1984, is projected to January 1, 2017. Certain high-energy production years, such as 1985/2018, have greater annual energy production than when reductions are not applied (comparing Tables 5-2 and 5-3). This is because of an operating condition where historical Forebay data indicates a net head condition just above 138 ft. When applying a reservoir-level reduction to historical data, net head is reduced below the upper shutoff limit of the turbine, thereby generating power. These head boundaries are real, but their exact definition is artificial in the model, producing these small discrepancies. The significance of these discrepancies should be evaluated by the District in consultation with CH2M HILL.

TABLE 5-3
Annual Energy Production with Reductions for Future flow Demands of SDS and Changes to Pueblo Reservoir Operation
Pueblo Dam Hydroelectric Project

Year	Analysis Year	Annual kWh Production
1984	2017	32,169,480
1985	2018	40,878,691
1986	2019	38,883,328
1987	2020	38,435,398
1988	2021	29,677,848
1989	2022	19,480,721
1990	2023	6,848,467
1991	2024	6,554,653
1992	2025	8,819,310
1993	2026	16,063,950
1994	2027	16,343,213
1995	2028	31,269,036
1996	2029	26,482,293
1997	2030	33,288,792
1998	2031	24,613,570
1999	2032	30,689,811
2000	2033	27,081,635
2001	2034	11,283,376
2002	2035	3,814,822
2003	2036	723,636
2004	2037	2,147,475
2005	2038	2,678,712
2006	2039	7,318,695
2007	2040	20,117,601
2008	2041	23,889,692
2009	2042	20,681,644
2010	2043	20,223,627
2011	2044	19,662,497
2012	2045	6,548,821
2013	2046	4,942,265
	Average	**19,053,769**

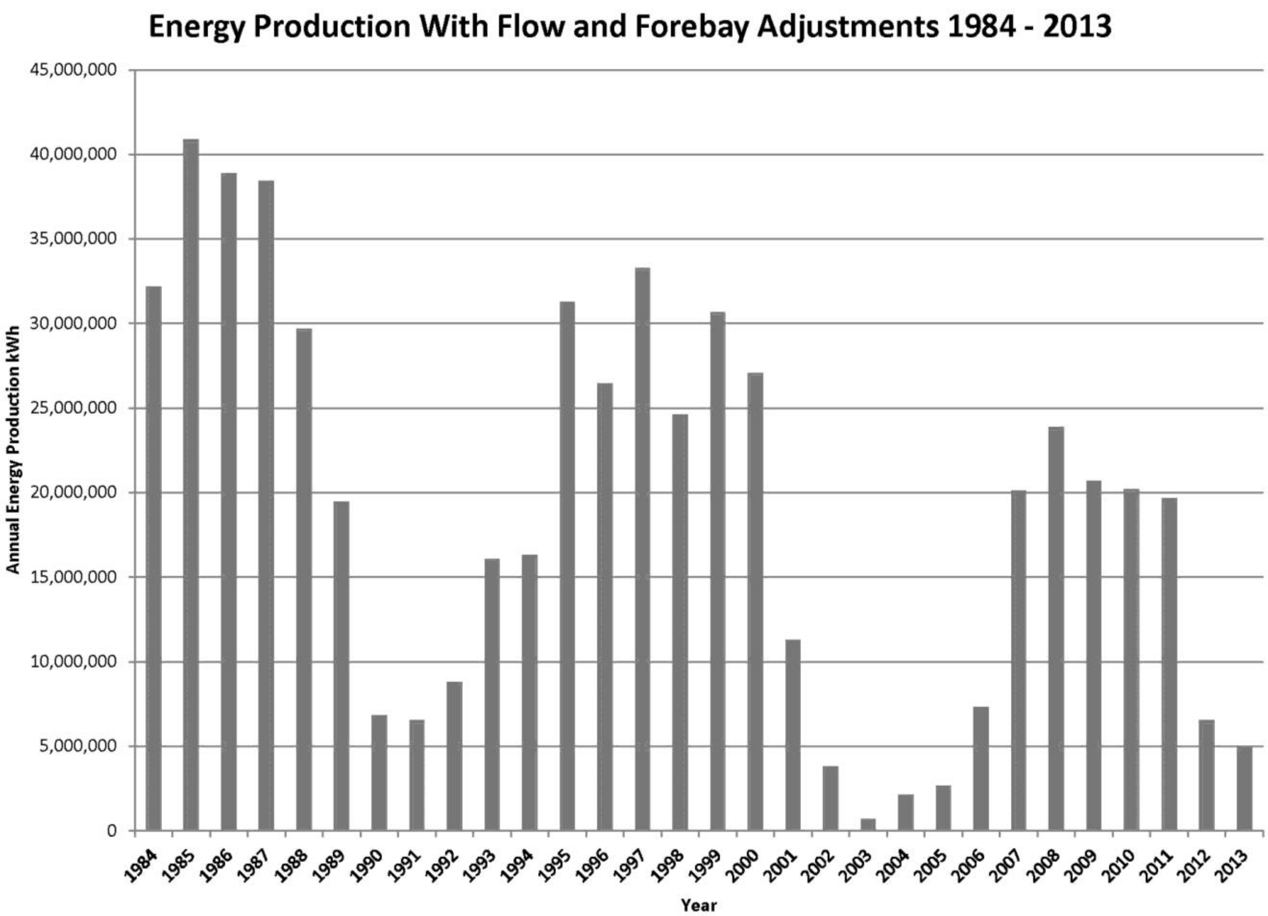

FIGURE 5-2
Annual Energy Production with Reductions for Future flow Demands of SDS and Changes to Pueblo Reservoir Operation
Pueblo Dam Hydroelectric Project

Increased demands on Arkansas River water because of future SDS and Pueblo West account for approximately 65 percent of the total effects of the adjustments. This is primarily because of the flow reductions altering a 66 cfs flow exceedance (lower flow limit of Turbine #2) from a less than 6 percent occurrence to a 20 percent occurrence when SDS and Pueblo West flow demand increases to an average of 56 cfs between 2045 and 2050. The reality of SDS and Pueblo West flow demands affecting the flow exceedance to this degree is probably quite uncertain since it is more likely flow will be managed differently in the summer months (curtail peak releases) to maintain higher base flows in the Arkansas River during low-flow months to achieve the minimum design flow of the fixed cone valve facility. This should be noted by the District and discussed with CH2M HILL.

SECTION 6

System Hydraulics and Transient Analysis

6.1 General

This section discusses the hydraulics of the conveyance system upstream of the PDHP as well as presents conclusions drawn from surge analysis performed on the conveyance system for operating scenarios when the facility is in place. This section is organized in three sections including:

- Scope and Purpose
- System Headlosses
- Conclusions from Surge Analysis

6.1.1 Reports and Studies Used to Develop this Section

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014

6.2 System Headlosses

The basis for system headlosses is presented in the Figures 6-1 through 6-4 and Tables 6-1 and 6-2. Headloss equations were developed from Computation Fluid Dynamic and U.S. Environmental Protection Agency Net Headloss models. Lookup Tables for bifurcation headlosses are derived from D.S. Miller's Internal Flow Systems Handbook.

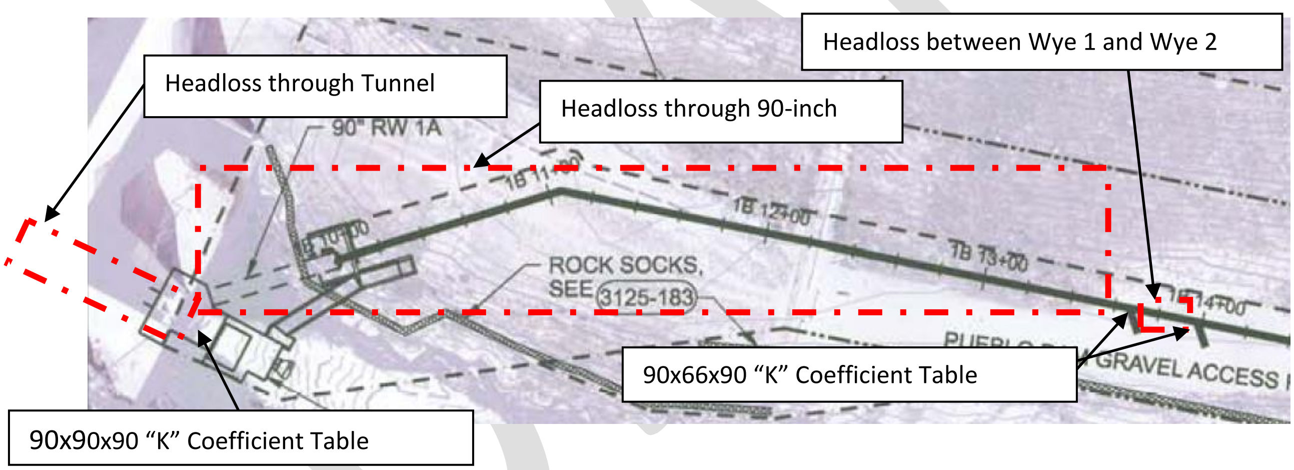

FIGURE 6-1
Headloss Map
Pueblo Dam Hydroelectric Project

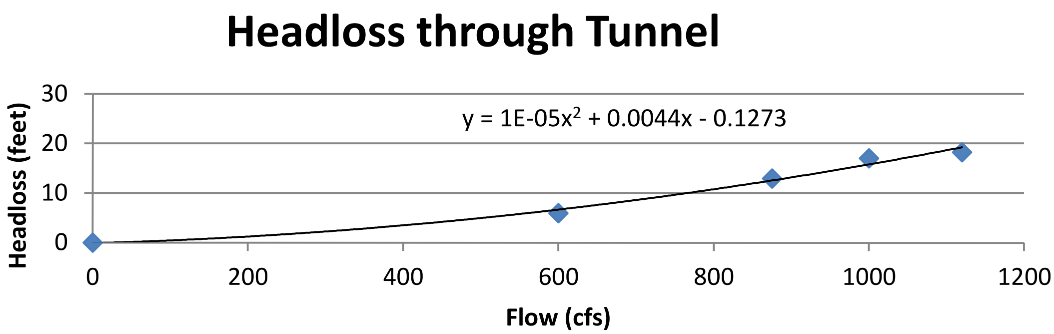

FIGURE 6-2
Headloss Through Tunnel Equation
Pueblo Dam Hydroelectric Project

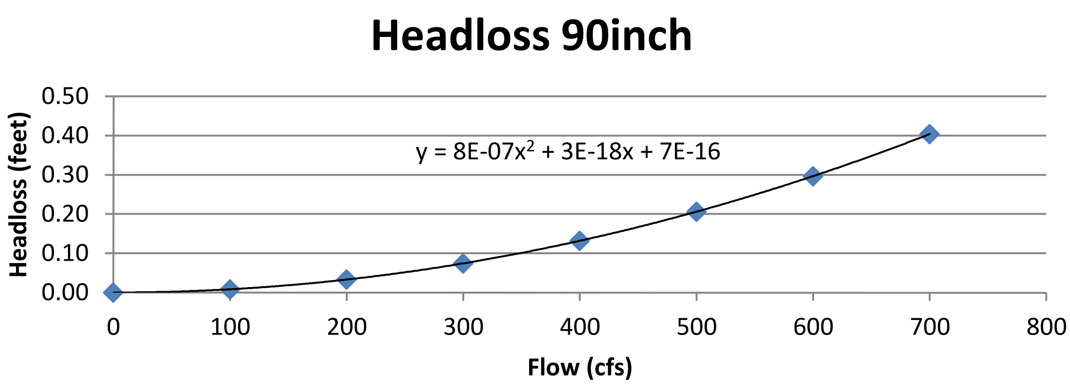

FIGURE 6-3
Headloss in 90-inch Equation
Pueblo Dam Hydroelectric Project

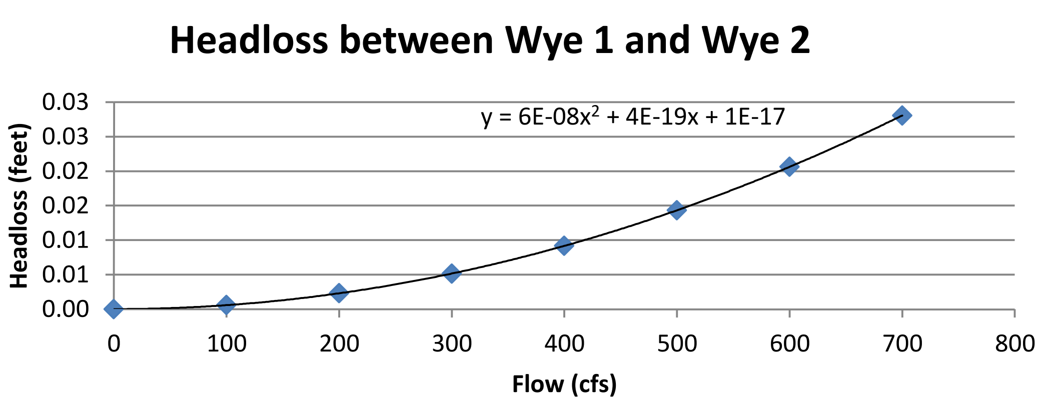

FIGURE 6-4
Headloss between Wye 1 and Wye 2 Equation
Pueblo Dam Hydroelectric Project

TABLE 6-1
K Values for 90 x 90 x 90 Wye
Pueblo Dam Hydroelectric Project

Area Ratio	Flow Ratio ($Q_{90}/Q_{upstream}$)	K Value Wye Branch	K Value Through Branch
1.00	0.00	0.80	0.05
1.00	0.10	0.78	0.00
1.00	0.20	0.68	-0.03
1.00	0.30	0.60	-0.03
1.00	0.40	0.50	-0.01
1.00	0.50	0.43	0.03
1.00	0.60	0.40	0.08
1.00	0.70	0.40	0.15
1.00	0.80	0.40	0.22
1.00	0.90	0.40	0.30
1.00	1.00	0.40	0.40

Note:
Q = flow rate or discharge rate

TABLE 6-2
K Values for 90 x 90 x 90 Wye
Pueblo Dam Hydroelectric Project

Area Ratio	Flow Ratio ($Q_{66}/Q_{upstream}$)	K Value Wye Branch	K Value Through Branch
0.54	0.00	0.80	0.05
0.54	0.10	0.80	0.00
0.54	0.20	0.75	-0.03
0.54	0.30	0.72	-0.03
0.54	0.40	0.70	-0.01
0.54	0.50	0.72	0.03
0.54	0.60	0.78	0.08
0.54	0.70	0.85	0.15
0.54	0.80	0.90	0.22
0.54	0.90	1.00	0.30
0.54	1.00	1.50	0.40

6.3 Surge Analysis

A surge analysis was performed for the hydro facility at the Pueblo Dam following turbine trip and load rejection. The analysis assumed that when the turbines trip, the Juniper pumps also trip. Results indicated that the maximum pressure at the hydro turnouts is 76 pounds per square inch (psi) which is only 6 psi higher than the maximum pressure predicted when only the Juniper pump station fails. At the Juniper pump suction, the maximum predicted pressure when simultaneous turbine trip and pump failure occurs is only

3 psi higher than when only the Juniper pumps fail. Turbine load rejection and runaway appear to cause only minor surge pressure differences as compared to predictions when the turbines do not trip. The conveyance system is adequately designed to accommodate the relatively small pressure transients created by the hydroelectric turbines tripping and the wicket gates closing over a 30-second period. Detailed documentation of the results of this analysis is presented in the technical memorandum featured as Appendix B.

SECTION 7
Powerhouse Location and Arrangement

7.1 General

This section discusses the power plant arrangement. This section is organized in two sections including:

- Scope and Purpose
- Power Plant Arrangement

7.1.1 Reports and Studies Used to Develop this Section

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014

7.2 Power Plant Arrangement

The powerhouse is anticipated to be a two-level cast-in-place concrete, metal-roofed structure located approximately 500 ft downstream from the fixed cone valve facility (Appendix D). Exterior architectural treatment remains to be established but appearance is planned to be consistent with that approved by Reclamation, State Parks, and Pueblo County for the Juniper Pump Station. Water supply to the turbines will be from two separate 66-inch (nominal) turnouts from the 90-inch Reclamation pipeline. The 66-inch turnouts were designed and constructed as part of the SDS project. Pipeline shop drawings actually indicate a 67-inch ID for these turnouts. Flow to Turbine #1 will be 540 cfs, suggesting a 67-inch x 72-inch enlargement on the tap to connect with the 72-inch Inlet Valve No. 1. Turbine #2 will require a 67x48 reducer for to the 48-inch Turbine Inlet Valve (TIV) No. 2.

The turbines and generators will be located below grade. A maintenance and control room will be located approximately 3 ft below the existing dam access road elevation of 4766 ft. The runner centerline of Turbine No. 1 will be approximately 4 ft above the minimum tailwater elevation of 4738, which is approximately 18 ft below the existing Pueblo Dam access road. To provide a uniform turbine room floor elevation of 4739.5 ft, the runner centerline of Turbine No. 2 will be approximately 1 foot above the minimum tailwater elevation, though a higher setting could be employed.

The building will have lighting, heating, cooling, and drainage systems and an overhead crane to remove the generator and turbine runner for maintenance. Switchgear, a control switchboard, and SCADA system interface will be installed in the control room area. Low voltage motor control center and power distribution panels will be provided for alternating current (AC) station service, along with a station battery and inverter to provide an uninterruptible power supply for the controls and computer equipment.

The turbines will be horizontal-shaft Francis-type with synchronous generators. The generators will be rated 3-phase, 60 Hz at 4160 volts (Vac). Auxilary equipment will include dedicated hydraulic power units. The generator will include a brushless excitation system and neutral grounding equipment. Both the turbine and the generator will have complete instrumentation for monitoring of critical machine operating parameters, including lube oil temperature and level, hydraulic power system status, speed, generator stator and bearing temperatures, and unit electrical output. A butterfly-type inlet valve and ultrasonic flow meter will be installed in each penstock to allow for unit isolation and flow measurement, respectively.

SECTION 8

Interconnection Configuration and Operation

8.1 General

Project interconnection refers to the electrical interface and power transmission to the electric utility grid. This interface is typically defined and regulated by interconnection and energy sales agreements with one or more serving electric utilities. Those agreements are being developed by the District. This section presents an overview and design basis for project interconnection, subject to the details of final interconnection and energy sales agreements. It is organized according to the following sub-headings:

- Scope and Purpose
- Interconnection Configuration
- Revenue Metering

8.1.1 Reports and Studies Used to Develop this Section

- Final Design Documents, Juniper Pump Station, May 13, 2013, CDM Smith, 555 17th Street, Suite 1100 Denver, CO 80202 Tel: (303) 383-2300

8.2 Interconnection Configuration

8.2.1 Generation and Transmission

Refer to the preliminary single-line diagram presented in the Project Drawings, Appendix D. The power plant generators are of the synchronous-type and rated 4160 Vac, 3-phase, 60 Hz. The power plant will also house two line-ups of medium voltage switchgear, the 5 kV generator switchgear and the 15 kV transmission switchgear. The generators will be synchronized to the 4.16 kV generator switchgear bus. Generator output will be stepped up to the transmission voltage of 13.2 kV via the power plant main transformer, located adjacent to the power plant. The high-side, or 13.2 kV transformer output will then be routed to the transmission switchgear bus, where an ac station service circuit breaker and transformer primary breaker are housed. Power plant output will then be routed to 13.2 kV interconnection bus at the Juniper Pump Station.

The transmission circuit between power plant and pump station will be routed underground by cable in accordance with Colorado State Parks requirements.

The approximate length of the 13.2 kV transmission line is 2,800 ft. Suitable routing, cable and conduit sizing, use of manholes, terminations, and installation methods for the underground transmission line will all be detailed during engineering design.

8.2.2 Interconnection

It is currently assumed that suitable provisions for power plant interconnection on the customer side of the serving utility's metering will be provided at the Juniper Pump Station. These details are currently being developed and coordinated.

Requirements will be established and details will be developed during project design.

8.2.3 Revenue Metering

It is currently assumed that the Black Hills Energy metering facilities at the Juniper Pump Station will be configured to provide necessary net metering of the power plant-pump station service. The details of this feature remain to be confirmed.

SECTION 9

Economic Basis

9.1 General

This section presents the conventional basis in which the District reviewed and determined development of the project is economically feasible. This section is organized in three sections including:

- Scope and Purpose
- Order-of-Magnitude Cost
- Economic Feasibility

9.1.1 Reports and Studies Used in the Design Documentation Report

During prior phases of engineering work for this project, CH2M HILL prepared the following documents

- CH2M HILL, Hydropower Feasibility Update, Pueblo Dam Hydroelectric Project March 21, 2014

9.2 Order-of-Magnitude Cost

As a part of the preliminary design of the Pueblo Dam Hydroelectric Project, a Class 3 Cost Estimate per the Association for the Advancement of Cost Engineering (AACE) International was prepared. A Class 3 Cost Estimate is defined as an estimate that is generally prepared to form the basis for budget authorization, appropriation, and/or funding. Typically a Class 3 estimate forms the initial control estimate against which all actual costs and resources will be monitored. Typical accuracy ranges for Class 3 estimates are -5% to -15% on the low side, and +10% to +20% on the high.

The cost estimate has been prepared for guidance in project evaluation and implementation based on the Preliminary Design Drawings and budgetary equipment costs obtained from various manufacturers. The final costs of the project will depend on actual labor and material costs, competitive market conditions, final project costs, implementation schedule and other variable factors.

Table 9-1 presents estimated costs for significant project elements: Detailed opinion of probable construction costs for the project can be found in Appendix A.

TABLE 9-1
Summary of development costs
Pueblo Dam Hydroelectric Project

Item	Cost
Total Construction Costs	$11,001,648
Owner Furnished Products and Project Interconnection Costs	$8,133,000
Project Administration Costs	$2,000,000
Estimated Total Capital Cost of Development	**$21,383,475**

9.3 Economic Feasibility

The conventional economic feasibility for developing a project is determined by comparing the present value of benefits (i.e., revenue from the sale of energy or monies saved by offsetting consumption) with the present value of costs (such as the capital cost for development or operation and maintenance [O&M] costs). This comparison can also take the form of the net present value (benefits minus costs) or Benefit/Cost (B/C) ratio. A basic financial-economic evaluation, illustrating the costs, benefits, and economic feasibility of developing the site, is presented in Appendix E.

9.3.1 Costs

Four principal costs are associated with development and operation of the facility:

- Project Development Cost – $19,662,162 major development cost elements include rock excavation ($1.8M) and Turbine/Generator costs ($6.3M). Rock excavation costs are based on using rock trenchers and excavation equipment (unit price of $125 per yard) as blasting will not be permitted at the site. A rock excavation contractor who has performed work at Pueblo Dam suggested that the proposed excavation could be accomplished for less than $100 per yard. CH2M HILL is currently soliciting budgetary estimates from other contractors for the rock excavation. Budgetary construction costs featured in Appendix A include a 15 percent contingency. Further refinement and opportunities to manage costs will be considered during design.
- Annual O&M costs – $168,466 in 2017 based on an average cost per kWh of $0.0085 and an average annual energy production associated with the Economic Evaluation attachment. The O&M costs were escalated 3.5 percent annually from the 2017 value. This is based on investigations performed by Colorado Springs Utilities during the 2011 LoPP Application efforts.
- Transmission and Wheeling – $3.75/ megawatt-hours (MWh) as provided by Colorado Springs Utilities during the 2011 LoPP Application efforts. Transmission and Wheeling costs to the project are carried by the project through 2027, at which time this cost ceases when Pueblo West and Juniper Pump Stations consume all energy produced by the hydropower plant. This general approach for accounting for such cost was specified by the District.
- Payments to the United States – Assumed to be at 3 mills/kWh for duration of evaluation.

Any other costs not specifically stated, such as monthly or annual fees charged by the interconnecting utility for interconnection facilities, are not included. These costs, if any, will be determined by the District during the negotiation of interconnection and energy sales agreements.

9.3.2 Benefits

In the absence of a District-specified value of energy to be used in this Feasibility Update, CH2M HILL has assumed an energy value of $55/MWh in 2017, escalating at 3 percent annually for the 25 year operation period evaluated. This assumption directly impacts project financial and economic feasibility and must be established by the District. Based on the benefit cost ratio determined for this feasibility update, initial energy values in the $50 to $55/MWh range, including any potential renewable energy credits, should be considered the minimum range to support project feasibility, assuming that all other factors (capital costs, financing rates, escalation rates, energy generation) stated remain unchanged.

9.3.2.1 Present Value of Benefits and Costs

Monies spent or accrued at different times or over a period must be discounted or escalated to a single point in time in order to be compared properly. For development of the PDHP the recurring benefits (annual energy savings/sales) and costs (capital and O&M) that occur throughout the life of the project are discounted to a 2014 Present Value (PV) for determination of a Benefit/Cost ratio. The period of analysis extends from 2014 to 2041 (25-year operating period, 2017-2041) and assumes a discount rate (cost of money) of 2.0 percent, as specified by the District.

Table 9-2 summarizes basic project operation and financial performance over the period of analysis, 2017 to 2041. The actual project development and funding approach of the District will dictate how such data must be applied to actual project financial scenarios. It is assumed that the District will complete such additional analyses in its final determinations of project funding and feasibility. The table summarizes the conventional feasibility of developing the site based on the financial-economic evaluation presented in Appendix E.

TABLE 9-2
B/C Ratio for Hydropower Development of the Site
Pueblo Dam Hydroelectric Project

Item	Value
2014 Total PV of Costs	$28,387,167
2014 Total PV of Revenue/Benefit	$28,516,068
2014 Net Present Value	$128,901
Overall PV B/C Ratio	**1.00**

SECTION 10

Civil Design

10.1 General

This section provides the basis for civil design for PDHP. The section is organized as follows:

- References
- Features

10.2 References

- Horizontal Datum: Colorado State Plane Coordiante System, Colorado Central Zone (FIPS 502) North American Datum of 1983 (NAD 83), US Survey Feet.
- Vertical Datum: National Geodetic Vertical Datum of 1929 (NAVD 29), US Survey Feet.

10.3 Features

10.3.1 Base Map

High Resolution color aerial photography (1"=200' (1:2400)) performed by CH2M HILL in 2009 will be used for the PDHP design documents and figures.

10.3.2 Existing Site and Utilities

In general, the following existing utilities are found within the vicinity of the PDHP:

- Reclamation 90-inch raw water pipeline
- Black Hills Energy Underground Electric – located north of Reclamation 90-inch raw water pipeline
- Reclamation 24-Pair Telephone – located between Black Hills Energy Electric and Reclamation 90-inch raw water pipeline
- Reclamation Fiber Optic Communications – located north of Reclamation 90-inch raw water pipeline between the Reclamation Valve Vault and Pueblo Dam.
- Future Reclamation Chemical Service Line – a stub for a future chemical service line, to be designed by CDM Smith, is located near the Southeast corner of the Reclamation Valve Vault.

A utility plan will be developed as part of the PDPH design to correctly depict the locations of each of the utilities identified above. As-built locations of these utilities will be made available by the Southern Delivery System Program. Potholing activities will be scheduled for utility locations that are unknown.

10.3.3 Survey Control Points

Horizontal coordinate values are based on Colorado Coordinate System Central Zone, 1983 (NAD 83). Vertical values are based on National Geodetic Vertical Datum 1929 and the 1960 Supplementary Adjustment (NGVD29). The following survey control points are within the location of the PDHP.

TABLE 10-1
PDHP Survey Control Points
Pueblo Dam Hydroelectric Project

Point	Northing	Easting	Elevation	Description
SDS-16	1178196.563	3232239.942	4941.71	3-1/4" Alum Cap
SDS-17	1171526.900	3232244.310	4960.11	3-1/4" Alum Cap
SDS-18	1167871.108	3226253.994	5144.02	3-1/4" Alum Cap
SDS-19	1161412.073	3224324.395	4771.63	3-1/4" Alum Cap
a50	1160304.191	3223052.740	4799.54	

10.3.4 Site Access/Egress

The PDHP is located on the north side of the Arkansas River, just west of Juniper Pump Station, which is west of Spillway Road. The PDHP is located within the limits of Pueblo County within the Pueblo Reservoir State Recreation Area. The land owner is the United States Federal Government.

Site access/egress will be from Spillway Road and along the dam access road on the north side of the Arkansas River. Vehicular traffic to and from the construction site shall be restricted to designated routes shown on a Haul Route Plan to be provided as part of the construction documents. A second access road will be constructed on the south side of the Arkansas River to place and later remove the cofferdam that will separate the work area from flowing water. The second access road will start from an existing parking lot and cross the Pueblo Dam spillway outlet.

Once construction is complete, site access/egress will be from the dam access road on the north side of the Arkansas River.

10.3.5 Construction Staging/Parking

A temporary construction staging area is planned just north of the PDHP. It is anticipated the construction staging area will be used for construction trailers, parking, and stockpile of equipment and materials. Limited construction traffic and parking will be allowed near the PDHP during construction.

Future parking spaces at the PDHP will be provided for operation and maintenance vehicles.

10.3.6 Site Utility Plan

The following utilities (excluding drainage features) are required for the operation of the PDHP:

- Station service transformer
- Step-up service transformer
- Oil-water separator
- Standby generator

The standby generator was located in close proximity to the electrical equipment in the PDHP that would be powered by the standby generator in the event that grid power is lost. A buffer of 3 feet was provided around the standby generator for personnel access. The two transformers were also located in close proximity to the electrical equipment contained within the PDHP. The two transformers were located north of the standby generator to offset the transformers from the main PDHP to provide a buffer in the event of a transformer failure that may result in a fire or explosion. Both transformers will be installed on equipment pads that include a trench that will intercept and contain oil that may leak from the transformers. The outlet from the transformer pad trench will contain a valve that will normally be closed to contain any leaked oil within the trench; any accumulated oil will be removed before the valve is opened to allow the trench to drain. To limit the discharge of remnant oil to the environment, the transformer pad trench outlet will drain to an oil-water separator; a drainage sump from inside the PDHP will also outlet to the oil-water separator. Due to the oil-water separators relation to the PDHP drainage sump and transformer pad drainage, the oil-water separator was located in close proximity to the two transformer containment pads. The oil-water separator will contain a series of baffles that will separate and retain any leaked oil (from runoff or drained water) to limit the discharge of oil to the environment. The oil-water separator will require periodic cleaning and maintenance to avoid the build-up of oil and loss of function.

10.3.7 Excavation Considerations

The existing surface is primarily a sandstone bedrock that will require rock saws to excavate and remove. As the proposed PDHP foundations are founded entirely on rock and a minimum of two feet below top of rock, rock will be excavated beneath the entirety of the structure. It is assumed that the excavated rock surface will remain stable at near-vertical slopes and that precision equipment can be utilized to precisely excavate (within a matter of feet, in plan view) rock to follow the foundation of the structure. To limit construction complexity, small areas of similar excavation depth were merged into a single area and excavated to the lowest foundation depth (thus resulting in some overexcavation).

10.3.8 Grading and Drainage

The final site will be graded to provide a near-level parking surface to the north of the structure; a slope of 0.01 ft/ft will be provided to drain rainfall runoff to the drainage system. The final graded surface immediately next to the PDHP Control room will be set 0.2 feet below the finished grade of the Control Room floor and drain away from the structure. Due to the steep terrain, retaining walls will be constructed immediately adjacent to the PDHP to allow the creation of the parking area several feet above existing grade.

The final graded site will be drained by two features: a catch basin on the west side of the parking lot and a trench drain immediately east of the PDHP Equipment Room. The catch basin will intercept runoff generated north of the PDHP and convey it to a swale before it outlets into the Arkansas River. The trench drain will drain the western side of the parking lot and intercept any runoff that may otherwise enter the PDHP Equipment Room loading dock; the trench drain will outlet to a swale on the eastern side of the PDHP before entering the Arkansas River. Roof runoff will drain directly to the downslope portion of the structure.
Erosion Control

The following sediment and erosion control provisions will be incorporated into the construction documents:

- Contractor will be required to develop Stormwater Management Plan and erosion control plan, and obtain approval from appropriate regulatory agencies prior to implementation.
- The placement of erosion and sediment control best management practices (BMPs), maintenance, and record keeping shall be in accordance with federal, state, and county standards.
- The first bmp to be installed on the site shall be orange safety fence, markers, or other approved means of defining the limits of construction, including construction limits adjacent to stream corridors and other areas to be preserved.
- Erosion and sediment control BMPs will be placed before the start of construction.
- Approved BMPs will be installed around stockpiled materials.
- Approved BMPs will be installed around staging areas and maintenance areas. Staging and maintenance areas are at the discretion of the contractor. Areas are to be protected and maintained as per federal, state, and county standards.
- Cleaning, refueling, or maintaining of equipment shall be prohibited within 500 ft of the Arkansas River.

- Contractor shall store and protect hazardous material per requirements of project permits. The storage or usage of hazardous materials shall be prohibited within 500 ft of the Arkansas River.
- Natural vegetation shall be retained and protected wherever possible. Exposure of soil to erosion by removal or disturbance of vegetation shall be limited to the area required for immediate construction operations.
- Traffic must enter/exit the site through the approved access point. A stabilized construction entrance will be required at access points on the site. Additional stabilized construction entrances may be added during construction.
- Cleanup of sediment or construction debris tracked onto adjacent paved areas per Reclamation, State Parks, and County standards. Paved areas including streets shall be kept clean throughout build-out and shall be cleaned, with a street sweeper or similar device. At first notice of accidental tracking, street washing is not allowed.
- Reclamation and State Parks reserves the right to require additional measures to ensure area streets are kept free of sediment and/or construction debris.
- Approved BMPs shall be maintained and kept in good repair for the duration of construction.
- Lining of temporary swales and ditches shall be in accordance with project standards. No permanent earth slopes greater than 3:1 shall be allowed.
- Any sediment or soil accumulations beyond the limits of construction shall be remediated immediately.
- A water source shall be available on site during construction activities and utilized as required to minimize dust from equipment and wind.
- Soils that will be stockpiled for more than 30 days shall be seeded and mulched within 14 days of stockpile construction. No stockpiles shall be placed within 100 ft of the top of bank of the Arkansas River.
- Disturbed areas including roads, shall be stabilized within 14 days of substantial completion of grading, including areas to remain dormant for longer than 30 days, whichever is less. This may require multiple mobilizations for seeding and mulching.
- Hazardous materials and chemicals can be stored on-site only in the staging area and only in an approved temporary structure.
- Reinforced rock berms shall be used on rocky soils and outcrops which do not allow the placement of stakes for silt fence or straw bales.

SECTION 11

Architectural Design

11.1 General

This section presents the architectural design basis for PDHP. The section is organized as follows:

- References
- Applicable Codes, Standards, and Regulations
- Code Analysis
- Features

11.2 References

- International Building Code 2009
- International Fire Code 2009
- International Mechanical Code 2009
- Uniform Plumbing Code 2009
- National Electrical Code 2011
- International Energy Code 2009

11.3 Code Analysis

- Basis: 2009 International Building Code (IBC)
- Occupancy: F-1 Electric Generation Plants
- Type II-B Construction
- Max Stories Allowed – 2; Actual 1 Story
- Maximum Height – 55’-0”; Actual Height ~ 40’-0”
- Maximum Allowable Area – 27,125 SF; Actual Area ~7,400 SF
- Incidental Use Are – Battery Room, 1 Hour Assemblies; Floor/Walls/Ceiling
- Fire Suppression System – Portable Fire Extinguishers
- Calculated Occupant Load – 25; Actual Number of Occupants - 5
- Required Exits – 2
- Maximum Exit Travel Distance – 200’-0”
- Fire Resistance Rating for Building Elements – None Required
- Interior Finish Flame and Smoke Development; Exit Passages – Class B, All other areas Class C

TABLE 11-1
Building Square Footages
Pueblo Dam Hydroelectric Project

Area	Component	Finished Floor Elevation (ft)	General Dimensions	Square Footage	Remarks
Control Room					
	Battery Room	4763.0	11 ft x 7 ft	77	
	Switchgear and Control Room	4763.0	75 ft x 23 ft	1,725	
Equipment Room Lower Level					
	Turbine Room	4739.5	80 ft x 48 ft	3,840	

TABLE 11-1
Building Square Footages
Pueblo Dam Hydroelectric Project

Area	Component	Finished Floor Elevation (ft)	General Dimensions	Square Footage	Remarks
	Turbine No. 1 Inlet Valve Pit	4733.9	15 ft x 13 ft	195	
	Turbine No. 2 Inlet Valve Pit	4733.9	11 ft x 10 ft	110	
	Dewatering Sump	4718.0	10 ft x 7 ft	70	
Equipment Room Upper Level					
	Equipment Staging Area	4763.0	50 ft x 20 ft	1000	

TABLE 11-2
Exterior Egress Requirements
Pueblo Dam Hydroelectric Project

Component	Inches per Occupant	Minimum Width	Minimum Exists	Exit Access Maximum Distance	Remarks
Vehicular Ramp	NA	NA	NA	NA	Ramp to be designed at 1:12 max slope
Tailbay Suspended Platforms	NA	36”	NA	NA	36” minimum width

TABLE 11-3
Project Stairways and Ladders
Pueblo Dam Hydroelectric Project

Area	Top Elevation	Bottom Elevation	Landings Required	Steps Required	Staircase Length	Remarks
Parking To Control Room	4766.0	4763.0	2	6	5’-6” plus landings	
Control Room and Equipment Loading Area to Turbine Floor	4763.0	4739.5	3	41	37’-7” plus landings	
Turbine Floor to TIV Pit	4739.5	4733.9	NA	NA	NA	Ladder
Turbine Floor to Dewatering Sump	4739.5	4718.0	NA	NA	NA	Ladder
Equipment Loading Area to Bridge Crane Platforms	4788.0	4763.0	NA	NA	NA	Ladder (CAGE)

TABLE 11-4
Mezzanines and Platforms
Pueblo Dam Hydroelectric Project

Area	Area Limitation	Egress Requirements	Openness	Remarks
Tailbay Gate Access Platforms	NA	22" minimum width	NA	42" Guardrails each side
Bridge Crane Platforms	NA	22" Minimum width	NA	Coordinated with Bridge Crane platform

TABLE 11-5
Climate Specific Requirements
Pueblo Dam Hydroelectric Project

Component Name/Description	Gross Area	Cont R-Value	Remarks
Roof	~7,400 SF	R-25	
Exterior Wall	~15,750 SF	R-11.4	
Window	~66 SF	U-0.38	
Door	~336 SF	U-0.37	
Floor	~7,400 SF	R-10	

TABLE 11-6
Safety Requirements
Pueblo Dam Hydroelectric Project

Area	Component	
Control Room	Battery Room	1-hour rated assemblies
Equipment Room Lower Level	Turbine Room	1-hour rated assemblies
	TIV Pit	Confined space signage
	Dewatering Sump	Confined space signage
Equipment Room Upper Level	Equipment Loading Area	Guard railing

11.4 Features

11.4.1 Building System and Components

- Walls
  - Cast in place concrete
- Roof
  - Standing seam metal panel roof system
  - Metal soffits
  - Possible Snow fence system
  - Designed Fascia to minimize bird nesting

- Doors
  - Insulated hollow metal at the exterior (16 gauge)
  - Hollow metal interior (18 gauge)
  - Canopies (wall mounted with turn buckles)
- Windows
  - Exterior (Insulated low-e, glass block, or translucent wall panel)
  - Interior (insulated tempered or safety glass)
  - Clerestory (Insulated low-e or translucent wall panel)
- Stairways
  - Open grate metal stairs or concrete filled metal pan on steel stringers
  - Steel handrail/guardrail
- Interior Finishes
  - Walls painted
  - Floors sealed with rubber base
  - Ceiling and structure painted
  - Doors and frames, factory painted
- Exterior Finishes
  - Smooth concrete with sack finish
  - Addtional architectural finshes to be determined during design phase (Examples: form liners, stains)
- Signage
  - As required by code (minimum). Final to be determined in the design process

11.4.2 Building Code Requirement Discussions

- Ventilation
- Transformer – location and containment
- Battery Room – ventilation, corrosion protection, fire protection
- Fire Extinguisher Systems
- Lightning Protection
- Energy Code – Not Required, implications to equipment life cycle

11.4.3 Egress Plan

This section is to be determined.

SECTION 12

Structural Design

12.1 General

This section presents the structural design basis for PDHP. The section is organized as follows:

- Applicable Codes, Standards, and Regulations
- Design Loads and Criteria
- Engineering Properties of Construction Materials
- Structural Design

12.2 Applicable Codes, Standards, and Regulations

12.2.1 Jurisdiction

The local building department with jurisdiction in the area of the project is the Pueblo Regional Building Department (PRBD). As a federal facility the powerhouse is exempt from the jurisdiction of the local building official. However, local codes will be adhered to in the structural design and referenced in the development of loads where applicable.

While the State of Colorado has adopted the 2012 IBC, local agencies are permitted to adopt separately. The PRBD has adopted the 2009 IBC but does not intend to adopt the 2012 (electing to adopt on a 6-year rotation vs. 3-year).

12.2.2 Applicable Codes & Standards

The structural design of all new facilities and modifications to existing structures will be in accordance with the following governing building codes and standards, listed in order of precedence:

The strength, serviceability, and quality for materials and design will meet the requirements of the following codes and standards:

- Aluminum Design Manual, 8th Edition, Aluminum Association
- American Concrete Institute (ACI)
  - ACI 318-08, Building Code Requirements for Structural Concrete
  - ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures
- American Institute of Steel Construction (AISC) 14th Edition, Steel Construction Manual
- American National Standards Institute (ANSI)/American Society of Civil Engineers (ASCE) 7-05, Minimum Design Loads for Buildings and Other Structures
- American Welding Society (AWS),
  - AWS D1.1-04, Structural Welding Code – Steel
  - AWS D1.2-03, Structural Welding Code – Aluminum
- 2009 IBC, with City of Pueblo Amendments
- International Code Council (ICC) Evaluation Service Reports as applicable for manufactured structural components
- National Association of Architectural Metal Manufacturers Metal Grating Manual and Heavy Duty Metal Grating Manual

12.3 Design Loads and Criteria

12.3.1 Occupancy Category

The Occupancy Category is a parameter defined in IBC that is used to determine the structural requirements based on occupancy, including the selection of importance factors for wind, snow, and earthquake loads.

Occupancy Category IV corresponds to essential facilities, which include power-generating stations required as emergency backup facilities. Occupancy Category III includes power-generating stations which are not required for emergency backup. This basis of design is prepared using an Occupancy Category IV. (Note: The primary impact of selecting Occupancy Category IV over III will be a 10 percent increase in the snow load since the importance factor for wind is the same for both categories and the seismic loads are not high and are not expected to control the design in most cases).

12.3.2 Dead Loads

Dead loads will include the weight of all structure construction materials, including walls, floors, roofs, ceilings, stairways, finishes, cladding, and other similar structural and architectural items. Loads will be determined based on generally accepted engineering practices.

12.3.3 Live Loads

Live loads are as follows:

- Mechanical rooms—200 pounds per square ft (psf)
- Electrical rooms—300 psf
- Stairways/access ways/heavy foot traffic—100 psf

12.3.4 Roof Live Loads

Roof live loads will be 20 psf, minimum.

12.3.5 Wind Loads

Wind loads are as follows:

- Basic wind speed (V)—90 mph (3-second gust)
- Exposure category—C
- Importance factor (I_W)—1.15

12.3.6 Snow Loads

Snow loads were obtained from are as follows:

- Ground snow load—20 psf (obtained from PRBD)
- Exposure Factor (Ce)—1.0
- Thermal Factor (Ct)—1.0
- Importance Factor (I_S)—1.2

12.3.7 Seismic Loads

Seismic loads are as follows:

- Seismic Design Category A
- Importance Factor (I_E)—1.5

For additional seismic parameters see Section 13, Geotechnical Design.

12.3.8 Earth Loads

Below-grade and water retaining structures will be designed for worst-case load combinations of full height of backfill plus surcharge with no resistance from soil or water on the opposite side.

Unless otherwise shown, the design of walls and their foundations will include a minimum surcharge pressure equivalent to 2 ft of earth.

Refer to Section 13, Geotechnical Design for design earth loads.

12.3.9 Overhead Travelling Bridge Crane and Monorail Hoist

- **Overhead Travelling Bridge Crane.** An overhead travelling bridge crane will be provided to lift and move any of the major pieces of equipment within the equipment room. The preliminary load capacity for this crane is 25 tons. The required capacity will be confirmed in the final design.
- **Monorail, Trolley and Hoist.** A monorail hoist will be provided to facilitate the removal of the tailbay gates. The preliminary load capacity for the monorail, trolley and hoist is 5 tons. The required capacity will be confirmed in the final design.

12.3.10 Other Loads

Other loads are as follows:

- **Equipment dead loads.** Weight of equipment exceeding the uniform design live load will be included in the design as an individual dead load.
- **Equipment vibration.** Vibration will be addressed on a case-by-case basis for equipment with rotating or reciprocating components. Vibration will be addressed by passive means, including the mass of equipment bases.
- **Groundwater.** Structures and portions of structures below the maximum expected groundwater elevation will be designed for saturated lateral soil pressures on walls and groundwater uplift pressures on slabs. Structures and portions of structures located above the maximum expected groundwater elevation may be designed for drained lateral soil pressures.

12.4 Engineering Properties of Construction Materials

12.4.1 Cast-in-Place Reinforced Concrete

Cast-in-place concrete will have a minimum 28-day compressive strength of 4,000 psi. Cement will be Type I or II. Hydraulic and below-grade structures will use Type II cement or Type I cement with fly ash added. If used, fly ash will be a minimum of 15 percent and a maximum of 25 percent of total weight of fly ash plus cement.

Reinforcing steel will conform to A615, Grade 60. Reinforcing to be welded will conform to ASTM A706.

Control, contraction, and expansion joints will be located and detailed on the drawings. Construction joint locations will be shown on the drawings where length of pour is critical for crack control. Construction joint locations may be revised during construction, subject to specified requirements and consultation with the structural engineer. Additionally, stresses in the reinforcing will be limited to control the potential for cracking and to limit crack propagation.

12.4.2 Structural Steel

Structural steel will conform to ASTM A992, unless shown otherwise. Square or rectangular steel tubing will conform to ASTM A500, Grade B.

Connection bolts will be high-strength bolts conforming to ASTM A325N or SC.

Unless otherwise shown, bolts indicated as machine bolts or anchor bolts will conform to ASTM A307 for carbon steel, A193 for stainless steel, and A153 for galvanized steel.

Welds will be performed by AWS-certified welders and will conform to AWS standards applicable to the material (such as steel, aluminum, stainless steel)

Stainless Steel, Type 316, will be used for bolts, fasteners, etc., where corrosion concerns dictate. Type 316L SST will be used for stainless steel which will be welded and is greater than ¼ inch in thickness.

12.4.3 Miscellaneous Materials

- Foot traffic grating will be galvanized steel bar grating.
- Handrail/guardrail will be a galvanized three-rail system with toe boards.

12.5 Structural Design

12.5.1 General

- Building Type: Bearing Wall – Ordinary Reinforced Concrete Shear Walls
- Below-grade and hydraulic structures will consist of cast-in-place concrete
- The roof will consist of galvanized metal decking over open web steel joists (see Architectural for description of roofing)
- Reinforced concrete columns integral with the exterior walls will support the bridge crane and monorail

12.5.2 Hydraulic Structural Components

Hydraulic structures are those structures (or components of structures) which retain or convey liquid. These structures will be designed for crack control in accordance with ACI 350 Code Requirements for Environmental Engineering Concrete Structures.

12.5.3 Non-Hydraulic Structures

Non-hydraulic structural components will be designed in accordance with ACI 318 Building Code Requirements for Structural Concrete.

12.5.4 Foundation

The foundation will be designed in accordance with the parameters identified in the Geotechnical Design portion of this report. This includes the use of shallow foundation systems (such as spread footings, mat slabs) which bear directly on bedrock. Minor structures such as retaining walls may bear on structural fill.

Portions of the structure which are subject to net uplift due to groundwater will be anchored to the rock using rock anchors.

SECTION 13

Geotechnical Design

13.1 General

This section presents the geotechnical design basis for the PDHP. The design basis has been developed using:

- Data presented in the *Southern Delivery System, Geologic and Geotechnical Data Report for Pueblo Dam Connections,* Technical Memorandum 22-E Geotechnical, prepared by RJH Consultants (2009).
- United States Geological Survey Earthquake Hazards Program, National Seismic Hazard Mapping Project: 2002 Data. http://earthquake.usgs.gov/designmaps/us/application.php. Accessed April 2, 2014.
- 2009 International Building Code (IBC, 2009).
- Engineering judgment.

Additional project boreholes are planned to be advanced within the powerplant footprint in 2014. The draft geotechnical design basis presented below should be re-evaluated and revised as appropriate when the findings from the 2014 investigation are available.

13.2 Site Location and Description

The powerplant is located on a sandstone bedrock outcrop on the north side of the Arkansas River downstream of Pueblo Dam. A thin layer of soil (up to 4 ft thick) may be present over the bedrock as the ground surface rises to the north away from the river toward the Reclamation pipeline. Some sparse shrubs, grasses, and trees are scattered across the site.

The existing ground surface along the river is at approximate elevation 4748 ft. The ground rises to the north to approximate elevation 4766 ft at the Reclamation pipeline. The powerplant structure foundation will be stepped and will bear at various elevations ranging from approximately elevation 4760 to 4716 ft. The normal water surface is elevation 4744 ft and the approximate river bottom elevation is 4740 ft. Significant rock excavation will be required to construct the powerplant and tailrace. Excavation in the river up to 28 ft below the normal water surface will be required.

Low retaining walls are proposed to create level parking areas and access ways. The retaining wall type may be mechanically stabilized earth (MSE) with either wire mesh facing or precast concrete facing panels. Alternately, the retaining walls may be cantilevered reinforced concrete.

13.2.1 Subsurface Conditions

The subsurface profile consists of Dakota Sandstone, comprised of well-cemented fine to medium-grained sand. On the north side of the site, the sandstone is overlain by a thin soil layer 0 to 4 ft thick comprised of fill and alluvium. The sandstone bedding generally strikes northeast and dips approximately 8 degrees to the southeast. There are multiple mapped near-vertical joint sets with spacing ranging from 1 to 30 ft. The sandstone is massive and contains carbonaceous laminates and occasional claystone lenses, which are generally up to 0.9 foot thick. Porosity is generally high with intermittent layers of low-porosity material. Vuggy layers are also present, with voids ranging from 1/8 to 3/8-inch in diameter. The sandstone ranges from intensely weathered to fresh, and fracturing ranges from unfractured to intensely fractured. Weathering and fracturing and generally decrease with depth. Fracture spacing ranges from very closely spaced to widely spaced, are close to open, smooth to stepped, with clean to very thin infilling. Fracture orientation ranges from horizontal to near vertical. Carbonaceous infilling is present primarily in the horizontal fractures. Rock quality designation values from nearby boreholes in the anticipated zone of excavation range from 29 to 100, with rock quality designation generally increasing with depth. Hardness ranged from H-4 to H-2 using the Bureau of Reclamation *Engineering Geology Field Manual* rock hardness alpha-numeric descriptors (United States Department of the Interior, 1998).

Unconfined compressive strengths of six sandstone core samples ranged from 2,550 to and 4,360 psi.

Direct shear testing of existing joints indicated apparent cohesion of 10.8 to 20.9 psi and effective friction angles of 22.8 to 41.3 degrees.

Dry density of the sandstone ranges from 121 to 140 pounds per cubic foot (pcf), with an average of 134 pcf.

13.2.2 Groundwater

Groundwater is directly related to the level of the Arkansas River, which has a normal water surface elevation of 4744 ft. Excavation for the powerhouse and tailrace will require a cofferdam and active dewatering. Packer testing in the sandstone indicated hydraulic conductivity up to 6×10^{-4} centimeters per second.

13.3 Design Basis Recommendations

The design basis recommendations presented below are based on the data presented in the *Geologic and Geotechnical Data Report for Pueblo Dam Connections* (RJH, 2009),), U.S. Geological Survey (USGS) seismic hazard mapping (USGS, 2014), and engineering judgment. Preliminary recommendations are provided for:

- Foundations
- Lateral Earth Pressures
- Seismic Design Criteria
- Excavation Methods and Dewatering
- Ground Anchors

13.3.1 Foundations

Shallow foundations (such as spread footings, thickened slabs, and mats) are recommended for support of the powerhouse. Spread footings are anticipated to bear directly on the sandstone. All loose materials, soil, and rock spalls should be removed from the sandstone surface and the excavation should be dewatered prior to constructing the footings. Depressions and overbreak areas should be backfilled with concrete after complete removal of loose materials. Foundations bearing on sandstone should have a minimum width of 1 ft. Settlement of footings constructed directly on the sandstone is expected to be negligible.

If cantilever reinforced concrete retaining walls are constructed, the wall footings are generally expected to be constructed directly on the shallow sandstone surface. However, some may be constructed on structural fill depending on the location. If the retaining wall is supported by a reinforced concrete spread footing, the footing should not bear on dissimilar materials, that is, partly on compacted fill and partly on sandstone. Foundations bearing on compacted structural fill should have a minimum width of 3 ft. Total settlement of footings constructed on compacted structural fill is expected to be immediate and less than 0.5 inches. Differential settlement of footings constructed on compacted structural fill is expected to be less than half of the total.

Recommended bearing resistances for preliminary design are provided in Table 13-1 along with sliding coefficients for cast-in-place concrete.

TABLE 13-1
Bearing Resistance and Sliding Coefficients for Preliminary Design of Shallow Foundations
Pueblo Dam Hydroelectric Project

Foundation Material	Nominal (Ultimate) Bearing Resistance (psf)	Service (Allowable) Bearing Resistance (psf)	Sliding Coefficient (tan δ)
Dakota Sandstone Bedrock	25,000	10,000	0.7
Compacted Structural Fill	6,000	2,000	0.55

Thickened slabs and mats may be constructed either directly on the sandstone surface or on a layer of compacted structural fill. In order to avoid stress concentrations, it is important that slabs and mats not bear partly on rock and partly on fill. If necessary, the sandstone should be over-excavated and backfilled with structural fill to provide uniform support of slabs and mats. Preliminary recommended subgrade modulus values are provided in Table 13-2.

TABLE 13-2
Subgrade Modulus for Foundation Materials
Pueblo Dam Hydroelectric Project

Foundation Material	Subgrade Modulus (pci)
Dakota Sandstone Bedrock	1,000
Compacted Structural Fill	200

Note:
pci – pounds per cubic inch

The subgrade modulus values in Table 13-2 are for a 1 square ft loaded area. The appropriate design value typically decreases if the size of the loaded area is greater. The geotechnical engineer will be able to provide adjusted recommendations when actual slab and mat dimensions are defined.

The frost depth is 36 inches (PRDB, 2014).

13.3.2 Lateral Earth Pressures

The sandstone is not expected to impose lateral earth pressures on the powerhouse structure. However powerhouse wall design should account for full hydrostatic pressure below the design flood level of the Arkansas River.

Walls retaining soils are not expected to be constructed below the maximum water level. Therefore soil retaining walls should be designed for drained lateral earth pressures. Weep holes and similar means of escape should be provided for surface infiltration to exit from behind the walls because vertical infiltration into the sandstone is not expected to occur. Lateral earth pressure recommendations for level (horizontal), free-draining, granular backfill are provided in Table 13-3.

TABLE 13-3
Lateral Earth Pressures
Pueblo Dam Hydroelectric Project

Parameter	Recommended Preliminary Design Value
Traffic Surcharge	260 psf
Retained Soil Moist Unit Weight	130 pcf
Retained Soil Internal Friction Angle	35 degrees
Coefficient of Active Earth Pressure, K_a	0.26
Equivalent Active Fluid Pressure	34 pcf
Coefficient of At-Rest Earth Pressure, K_o	0.43
Equivalent At-Rest Fluid Pressure	56
Coefficient of Passive Earth Pressure, K_p	2.89
Equivalent Passive Fluid Pressure	376
Coefficient of Friction between Granular Backfill and Formed Concrete, tan δ	0.45
Coefficient of Seismic Active Earth Pressure for Yielding Wall, K_{ae}	0.33
Equivalent Seismic Active Earth Pressure for Yielding Wall	43 pcf

Active and passive earth pressures are appropriate to analyze flexible walls or walls that can rotate. At-rest earth pressure is appropriate to analyze rigid walls or walls that that are restrained from rotating. Full mobilization of passive earth pressure requires the rotational displacement of the top of wall of 0.02H or more (where H is the height of the wall). Wall deflection of 0.002 H is required to mobilize active earth pressure. The pressure distributions are triangular. The resultants will act at a point 0.33 times the wall height, measured up from the wall toe. Passive earth pressure against spread footings should be ignored.

Seismic active lateral earth pressure should be assumed to have an inverted triangular distribution with the resultant acting 0.6 times the wall height above the base of wall.

13.3.3 Seismic Design Criteria

The powerplant site is massive, competent sandstone bedrock with moderate fracturing and weathering. Therefore the site meets the criteria for Site Class B. Table 13-4 presents recommended seismic criteria for an essential facility for an event with a 2,475-year return period (USGS, 2014).

TABLE 13-4
Seismic Design Recommendations
Pueblo Dam Hydroelectric Project

S_S (g)	S_1 (g)	S_{MS} (g)	S_{M1} (g)	S_{DS} (g)	S_{D1} (g)
0.199	0.062	0.199	0.062	0.132	0.041

g = acceleration of gravity
S_S = MCE Spectral Response Acceleration at Short Periods
S_1 = MCE Spectral Response Acceleration at 1-Second Period
S_{MS} = MCE Spectral Response Acceleration at Short Periods as Adjusted for Site Effects
S_{M1} = MCE Spectral Response Acceleration at 1-Second Period as Adjusted for Site Effects
S_{DS} = Design Spectral Response Acceleration at Short Periods
S_{D1} = Design Spectral Response Acceleration at 1-Second Period

13.3.4 Excavation Methods and Dewatering

The existing ground surface along the river is at approximate elevation 4748 ft. The ground rises to the north to approximate elevation 4766 ft at the Reclamation pipeline. The powerhouse structure foundation will be stepped and will bear at various elevations ranging from approximately elevation 4760 to 4716 ft. The normal water surface is elevation 4744 ft and the approximate river bottom elevation is 4740 ft. Significant rock excavation will be required to construct the powerhouse and tailrace. Excavation in the river up to 28 ft below the normal water surface of the Arkansas River will require construction of a cofferdam and active dewatering.

The excavation will primarily be in sandstone bedrock. Blasting is not allowed by the Bureau of Reclamation because of proximity to Pueblo Dam and potential liquefaction concerns in the vicinity. Excavation will require hydraulic hammering and possibly rock sawing. It is anticipated that that sandstone cannot be ripped.

Excavations should be sloped and shored as necessary to protect workers and existing facilities, and in order to comply with federal, state, and local regulations. For preliminary planning purposes, the sandstone may be assumed to stand vertically.

13.3.5 Ground Anchors

The powerhouse is anticipated to be a partially submerged, water-tight structure. Therefore ground anchors are expected to be necessary to prevent the structure from floating. The massive sandstone bedrock foundation material is expected to provide satisfactory anchorage for properly designed post-tensioned anchors. Ground anchor design and anticipated bond stresses are beyond the scope of this draft design basis document.

13.4 References

International Code Council, 2009. International Building Code.

Pueblo Regional Building Department (PRBD). 2014. *Frequently Asked Questions*. http://www.prbd.com/faq.php. Accessed April 1.

RJH Consultants, Inc., 2009. *Southern Delivery System, Geologic and Geotechnical Data Report for Pueblo Dam Connections.* Technical Memorandum 22-E Geotechnical. Prepared for Colorado Springs Utilities. September 28.

United States Department of the Interior, Bureau of Reclamation (USBR), 1998. Engineering Geology Field Manual. Second Edition.

United States Geological Survey (USGS), 2014. *Earthquake Hazards Program, National Seismic Hazard Mapping Project: 2002 Data.* http://earthquake.usgs.gov/designmaps/us/application.php. Accessed April 1.

SECTION 14

Mechanical Design

14.1 General

This section presents the mechanical design basis for the PDHP. Refer to the Project Drawings included in Appendix D. The section is organized as follows:

- Applicable Codes and Standards
- Piping Flow Streams and Preliminary Material Selections
- Penstock Design and Flow Measurement
- Plumbing Systems Design Criteria and Description of Systems
- HVAC Systems Criteria and Preliminary Systems Selection
- Tailbay Gates

14.2 Applicable Codes and Standards

The design will be based on the following codes and standards:

- ASME B31.1 Power Piping
- ASME B31.9 Building Services Piping
- ASHRAE Handbook of Fundamentals
- International Energy Conservation Code (IECC)
- International Fire Code (IFC)
- International Mechanical Code (IMC)
- International Plumbing Code (IPC)

14.3 Piping

14.3.1 General

14.3.1.1 Flow Stream Identification

- PD Penstock/Spiral Case Drain
- BCW Bearing Cooling Water
- GD Gravity Drain
- DSD Drainage Sump Discharge
- DWD Dewatering Sump Discharge
- D Drain (Plumbing)
- SW Water (Plant Service)
- TE Tailbay Equalization Line
- TDF Tailbay Drain and Fill Line
- TIB TIV Bypass
- HPF High Pressure Hydraulic Fluid

14.3.2 Pipe Material

14.3.2.1 Penstock/Spiral Case Drain, Tailbay Equalization and Drain/Fill, Turbine Inlet Valve Bypass Piping

Piping that may be subject to turbine inlet pressure, and tailbay equalization piping will be schedule 40 carbon steel with welded joints and flanged connections at valves and equipment. Piping will be designed and installed in accordance with ASME B31.9.

14.3.2.2 Plant Service Water, Bearing Cooling Water Piping

Plant service water and bearing cooling water piping above slab will be seamless copper Type L hard-drawn tubing with wrought copper socket fittings and solder joints. Piping under slab will be schedule 40 carbon steel with threaded joints. Piping will be designed and installed in accordance with ASME B31.9 and the IPC.

14.3.2.3 Sump Discharge Piping

Sump discharge piping up to 2 inches for the dewatering and drainage sumps will be seamless copper Type L hard-drawn tubing with wrought copper socket fittings and solder joints. Large-bore discharge piping from the dewatering sump will be schedule 40 carbon steel, with welded joints and flanged connections at valves and equipment.

14.3.2.4 Hydraulic Fluid Piping

Hydraulic fluid piping is anticipated up to ¾ inch. Rigid hydraulic piping will be stainless steel, type 316 tubing. Joints will be flareless compression fittings or 316L socket-weld fittings. Final connections between rigid piping and hydraulic equipment will be made with high pressure hydraulic hose comprising a nitrile tube and stainless steel braided reinforcing jacket with an oil-resistant synthetic cover. Where threaded connections are required at unions or equipment, 2,000-pound WOG rated fittings with integral ground seats will be used and threads will be wrapped with Teflon thread seal tape. Piping will be designed and installed in accordance with ASME B31.1.

Where necessary, provisions for bypass, air bleeding, and drainage will be provided between HPUs and actuators.

14.3.2.5 Gravity Piping

Piping from hub or area drains to sumps and waste and vent piping under the slab will be cast iron soil pipe (CISP). Sizes range from 2 to 6 inches in diameter. CISP is selected for its strength and long-term resistance to lubricating and hydraulic oils. No-hub joints will be used for under slab CISP.

Gravity piping above the slab will be seamless copper Type L hard-drawn tubing with wrought copper socket fittings and solder joints.

Gravity piping will be designed and installed in accordance with the IPC.

14.4 Penstock

14.4.1 General Arrangement

Two individual penstocks will be constructed. The upstream 66-inch turnout from the 90-inch pipeline supply a 66-inch x 72-inch enlargement, followed by approximately 100-feet of 72-inch penstock, before supplying turbine inlet valve (TIV) for Unit No. 1. The downstream 66-inch turnout will extend approximately 70 ft; reduce to 48-inch pipe, and then supply TIV for Unit No. 2. The nominal diameters of the penstocks were selected to limit headlosses and coordinate with the turbine inlet valve diameters recommended by the turbine manufacturer.

14.4.2 Pipe Velocity and Pressure Design Criteria

Tables 14-1 through 14-3 indicate the flow, velocity, and pressure criteria used to design the Penstock.

TABLE 14-1
Maximum Flow Criteria
Pueblo Dam Hydroelectric Project

Pueblo Dam Forebay WSE	Turbine No. 1 Penstock (cfs)	Turbine No. 2 Penstock (cfs)
4898.0 (Maximum)	540	194

TABLE 14-2
Maximum Velocity Criteria
Pueblo Dam Hydroelectric Project

Pueblo Dam Forebay WSE	Turbine No. 1 Penstock	Turbine No. 2 Penstock
4898.0 (Maximum)	67-inch ID Section: 22.1 ft/sec 72-inch ID Section: 19.1 ft/sec	67-inch ID Section: 7.9 ft/sec 48-inch ID Section: 15.4 ft/sec

Note:
ID = Inside Diameter
ft/sec = feet per second

TABLE 14-3
Static Pressure Criteria
Pueblo Dam Hydroelectric Project

Pueblo Dam Forebay WSE	Turbine #1 (CL Elevation 4739.0 ft)	Turbine #2 (CL Elevation 4739.0 ft)
4898.0 (Maximum)	68.9 psig	68.9 psig

Notes:
psig = pounds per square inch gauge

14.4.3 Wall Thickness Requirements

The required wall thickness for the penstock is based upon the internal pressures, collapse pressure, handling, and increased stresses at mitered bends. The analyses employed the American Water Works Association (AWWA) Manual M11 and AWWA C200 requirements. The pressure design will be updated in accordance with the results of the final transient analysis.

14.4.4 Thermal Expansion of the Penstock

Temperature fluctuations in the penstocks must be accounted for by either allowing for thermal movement through expansion joints or by restraining the pipe and resisting the force developed in the pipe. The design criteria used for the thermal design is an installation temperature range of 45 to 55 degrees Fahrenheit (°F). Exposed sections are very limited and are not expected to result in significant thermal movement. Each TIV will be followed by a restrained dismantling joint.

14.4.5 Longitudinal Thrust Restraint

This thrust force is a result of the internal pressure and velocity of the water. The only anticipated mechanical connection is the dismantling joint between each TIV and the associated turbine spiral casing. That joint will be equipped with thrust restraint. The embedment and thrust block for each spiral casing will be designed to restrain any resultant forces.

14.4.6 Corrosion and Erosion Protection of Penstocks

A qualitative corrosion and erosion evaluation was performed to determine a recommended material type for the penstock based on Lake Pueblo's water quality information and maximum water velocities. Erosion of carbon steel in fresh water occurs at velocities higher than 60 to 65 ft/sec. Normal maximum operating velocity in the penstocks will be less than 20 ft/sec with a velocity of approximately 22.1 ft/sec occurring in the short 66-inch turnout prior to the 66x72 inch enlargement of penstock No. 1.

Coatings and Linings: Polyurethane linings are frequently used for penstocks subject to high velocity conditions. Certain polyurethane linings can handle up to 30 ft/sec. Cement–mortar linings perform best when flow velocities are in normal ranges. When the flow velocity exceeds approximately 20 ft/sec (6.1 meters per second), special studies may be required to determine the suitability of the cement-mortar lining material.

14.4.7 Penstock Material Selection and Design, Lining, and Coating

A carbon steel material is recommended as technically viable and is most cost effective. Polyurethane lining and coating is recommended to be installed on the carbon steel penstock.

14.4.8 Buried Penstock Design

The buried penstock will be designed for HS-20 wheel loading, in accordance with AWWA M11. The maximum wheel loading corresponds with the minimum depth of burial. The design uses a 3 foot minimum depth of burial for this design check. Wheel loading is also checked at an 8 foot depth of burial. Wheel loading is negligible at greater depths.

The steel penstock is considered a flexible conduit, meaning that it relies on the soil to provide resistance to external loads. The ability for the soil to provide support is based on the stiffness of the soil and is represented by E' ("E prime") in AWWA M11. This parameter is based on the soil type and compaction effort. The design uses an E' corresponding to fine-grained material with 95 percent relative compaction. Coarse-grained materials will provide additional support. Specification requirements for backfill of the pipe will be written to correspond with this as a minimum value.

14.4.9 Air/Vacuum Valve Considerations

The penstock has a down-gradient arrangement. As such, an air/vacuum valves are not required. The top of each turbine's spiral casing will be provided with an air-release valve to exhaust air during filling.

14.4.10 Flow Measurement

Each penstock will be equipped with a multipath transit-time ultrasonic flow meter for individual turbine flow measurement. The flow meters will be installed upstream of each turbine inlet valve, located in an alcove integral to the equipment room.

14.5 Plumbing Systems

Plumbing systems include plant service water, drains, sumps and associated pumps, and air and vacuum relief valves.

14.5.1 Service Water

Service water will be provided for equipment cooling needs and to serve hose valves distributed within the facility.

14.5.1.1 Turbine Inlet Valve Bypass

The TIV Bypass assemblies will provide pressure equalization across each TIV when the TIV is in closed position. A motorized butterfly valve will be used to control the TIV Bypass. Manually-operated butterfly-type isolation valves will be provided across the bypass valve.

14.5.1.2 Service Water Supply (Penstock Tap)

Supply for the service water system will be provided by a 2-inch tap at the penstock, as part of the TIV Bypass assembly on one unit. Service water will be routed to the strainer system prior to being regulated to 80 psig for distribution throughout the facility.

14.5.1.3 Strainer System

The service water strainer system will comprise a motorized strainer with automatic backwash cycle, in parallel with a basket strainer for bypass duty. Quarter-turn ball valves will provide isolation capabilities for the parallel strainers.

14.5.1.4 Bearing Cooling Water

Service water will be routed to bearing cooling water supply assemblies for each turbine unit. The supply assemblies will control flow of cooling water by solenoid-actuated valves. The solenoid valves will be mounted to an aluminum mounting plate with ball valves and piping arranged to allow isolation and bypass of the solenoid valves, and each solenoid will be provided with a wye-type strainer to remove suspended matter that passes the service water strainer system. Monitoring instrumentation will include pressure gauge, low pressure switch, and low flow switch.

14.5.1.5 Hose Valves

Hose valves will be located throughout the facility to provide convenient washdown and general maintenance capability. A rack will be provided adjacent to each valve for hose storage.

14.5.2 Drains

Drainage receptors and piping will be provided above slab to collect all bearing cooling water return, turbine shaft seal drainage, strainer backwash, and HVAC condensate, and route it to floor or hub drains. Drainage piping below slab will be routed from floor or hub drains to the drainage sump. The penstock and spiral case drains are routed to the dewatering sump. Drainage piping will be sloped as required for the service in accordance with the IPC.

14.5.2.1 Floor Drains

An un-trapped floor drain will be located in the TIV pit for Unit No. 2, to allow draining of the TIV pit to the drainage sump. The drainage sump is located in the Unit No. 1 TIV pit. Additional floor drains will be provided with traps and located to accept discharge from HVAC cooling units and incidental sources.

14.5.2.2 Penstock Drain

Penstocks will be provided with a valved drain immediately upstream of each TIV. A 6-inch drain line will be routed below slab to the dewatering sump, and provided with a valved connection to the drain discharge header.

14.5.2.3 Spiral Case Drain

Spiral case drains will be provided immediately downstream of each TIV. A valved, 6-inch tap from the bottom of the spiral case will connect to the penstock drain below slab and run in a common line to the valved connection in the dewatering sump.

14.5.2.4 Bearing Cooling Water Drain

Bearing cooling water will be routed to a hub drain at floor level, located near the turbine.

14.5.2.5 Turbine Shaft Seal Drain

The turbine seal outlet will be provided with a piped connection to route the discharge to the hub drain near the turbine.

14.5.2.6 Turbine Hub Drain

Each turbine unit will be provided with a hub drain located at floor level, to collect bearing cooling water, shaft seal water, and incidental discharge from the spiral case air-release valve.

14.5.2.7 Head Cover Pressure Equalization Pipe Assembly

Depending on turbine design, each turbine may be provided with a head cover pressure equalization line from head cover ports to the associated tailbay. This system will be provided with the turbine. If provided, a sight-glass-type level gauge will be provided in the vertical section of the piping to provide tailbay level indication.

14.5.2.8 Tailbay Drain and Vent

An un-trapped floor drain will be located in each tailbay, and routed to the dewatering sump. The drains will allow draining of the tailbays for dewatering, and will provide the connection with the tailbay equalization system for filling the tailbays. Each tailbay will also be provided with a vent to the tailrace area.

14.5.2.9 Tailbay Equalization System

The tailbay equalization system will provide tailbay drain and fill capabilities by means of an arrangement of isolation valves. Tailbay equalization will serve to adjust the static water level in the tailbays to match the water level in the tailrace, allowing operation of the tailbay gates. The tailbay equalization system will also connect to the tailbay floor drains.

14.5.3 Sumps

Sumps will provide collection basins for drainage systems and will be sized relative to the required pumping volume to meet various operating demands.

14.5.3.1 Dewatering Sump

The dewatering sump will provide dewatering capability for the penstock branches (primary dewatering capability for the Reclamation Pipeline provided by others), spiral case, and tailbay systems. Discharge from the dewatering sump will be routed to the tailrace.

A large sump pump will provide a high discharge as required to completely dewater the major components of the system, and will be sized based on the flow rate from the penstock and spiral case drains, and anticipated tailbay gate leakage.

A smaller, duty sump pump will provide periodic operation based on level float switches installed in the sump. The smaller pump will be sized for approximately 50 percent duty based on continuous flows from the bearing cooling water and shaft seals.

14.5.3.2 Drainage Sump

The drainage sump will be located in the Unit No. 1 TIV pit. It will collect flows from area drains, condensate drains, and incidental sources. In the event of a spill of hydraulic fluid or general washdown, flows will be directed by floor slope to the drainage sump.

A duplex pumping system will provide alternating duty/standby pumping from the drainage sump through an oil water separator, with final effluent routed to an onsite drain field or holding tank for pumping and disposal off-site. Pump control will be by level float switches installed in the sump.

14.5.4 Air Valves

Air valves will provide air and vacuum relief for draining and filling of system components. Air valves will be sized as required for design flows and with sufficient pressure capability for the system served.

14.5.4.1 Spiral Case

An air valve will be located at the top of the spiral case assembly, sized and provided by the turbine manufacturer. The outlet of the spiral case air valve will be piped to the nearby turbine hub drain, to collect incidental liquid discharged from the air valve.

14.5.5 Hydraulic Power Unit Systems

A hydraulic power unit system will be provided with each turbine unit, sized by the turbine system manufacturer for power and pressure required to operate TIV and turbine wicket gate actuators.

14.5.5.1 Turbine Inlet Valves

High pressure hydraulic fluid will be routed to each turbine inlet valve to supply single-acting hydraulic actuators that operate the TIVs for turbine isolation. Return piping will carry piston leakage back to the hydraulic power unit.

14.5.5.2 Wicket Gates

Turbine wicket gates will control flow through the turbines. High pressure hydraulic fluid will be routed to double-acting wicket gates actuators for modulating control of the gate openings, and return piping will carry lower pressure fluid back to the hydraulic power unit.

14.6 HVAC Systems

14.6.1 Climate Information, Temperature Maintenance, and Building Envelope

Climate data used in the project and the associated building envelope requirements are based on the IECC and ASHRAE Handbook of Fundamentals. Climate information and interior design temperatures are shown in Table 14-4. Building envelope requirements are shown in Section 11 Architectural Design.

TABLE 14-4
Climate Information and Design Temperatures
Pueblo Dam Hydroelectric Project

Description	Value	Remarks
Building Location (for weather data)	Pueblo County, Colorado	Weather data as recorded at Pueblo Memorial Airport
Climate Zone	5B	IECC, 2012
Heating Degree Days	5496	ASHRAE Fundamentals, 2009
Cooling Degree Days	932	ASHRAE Fundamentals, 2009
Heating DB	-2.0 degF	99.6% Occurrence, per ASHRAE
Cooling DB / WB	98.4 / 62.7 degF	0.4% Occurrence, per ASHRAE
Heating Design Temps		
	65 degF	Control Room
	45 degF	Battery Room, freeze protection only
	45 degF	Equipment Room, freeze protection only
Cooling Design Temps		
	75 degF	Control Room
	Ambient + 5 degF	Battery Room, ventilation only
	Ambient + 5 degF	Equipment Room, ventilation only

14.6.2 Heating

Indoor temperatures in the facility will be maintained during the heating season by electric heat, sized for envelope losses and minimum ventilation.

14.6.2.1 Control Room

The control room's forced air system will be equipped with thermostatically-controlled multi-stage electric duct heat, arranged to distribute heat across the entire space.

14.6.2.2 Battery Room

The battery room will be provided with a single unit heater, explosion proof for the battery room environment. The unit heater will be controlled by an integral thermostat.

14.6.2.3 Equipment Room

The turbine room will be provided with several unit heaters, arranged to distribute heat across the entire space. Control will be by wall-mounted thermostats located approximately 5 ft above the floor.

14.6.3 Cooling and Ventilation

14.6.3.1 Control Room

The control room will be provided with a split system direct expansion cooling unit, providing minimum ventilation and cooling to the space. The condensing unit will be located in the turbine room or outdoors, as determined during design.

The control room will be ventilated in accordance with the IMC, and the cooling unit will be provided with economizer capability based on outdoor dry bulb temperature.

14.6.3.2 Battery Room

The battery room will be provided with exhaust ventilation only, at a rate as required for temperature maintenance and as required to maintain concentrations of hydrogen below 25 percent of the Lower Explosive Limit and maintain concentrations of oxygen above the minimum requirements prescribed by OSHA, whichever is greatest.

14.6.3.3 Equipment Room

The equipment room will be ventilated by multiple axial exhaust fans, located near the roof. Intake air will be through inlet louvers located opposite the exhaust fans, with inlet plenums shaped to direct the intake air toward the floor. All openings will be provided with motorized dampers interlocked with fan operation. Each fan will be controlled by a simple thermostat, with graduated set points to stage the fans based on indoor temperature.

14.7 Gates

14.7.1 Tailbay Gates

Each unit’s tailbay will be provided with a bulkhead-type isolation gate deployed using the monorail hoist. Gate sealing will be accomplished by a J-seal system, operated by integral springs and offset guides. Gate removal requires that the tailbay be filled and equalized with the tailrace WSE. When not deployed, each gate can be dogged in its gate well above the tailrace water level.

SECTION 15

Electrical Design

15.1 General

This section presents the electrical design basis for the PDHP. The section is organized as follows:

- Applicable Codes, Standards, and Regulations
- Area Classifications
- Existing Electrical Systems
- Electrical Power Generating Systems
- Station Service Electrical Systems
- General Facility Electrical Systems
- Instrumentation and Control

15.2 Applicable Codes, Standards, and Regulations

The design will be based on the following codes and standards:

Codes

- 2011 National Electrical Code (NEC, NFPA 70)

Standards

- ANSI
- National Electrical Manufacturers Association
- Institute of Electrical and Electronic Engineers
- Instrument Society of America
- Insulated Cable Engineers Association
- Occupational Safety and Health Administration
- ASTM International
- Underwriters Laboratories, Inc.
- Illuminating Engineering Society
- National Fire Protection Association

15.3 Area Classifications

Area classifications (classified, or hazardous locations) will be established on the basis of the NEC or other applicable codes. At this time, only the Battery Room has been identified as a classified area. Any such areas will be specified on the drawings.

15.4 Existing Electrical Systems

There are no existing electrical systems within the construction scope of this project. Utility interconnection will be made at the existing Juniper Pump Station, and is described under Section 8 of this report.

15.5 Electrical Power Generating Systems

15.5.1 Overview

The generating systems include those concerned with the generators and their interconnection with the utility grid, including the generator and transformer switchgear. Refer to the conceptual single-line diagram included with the Project Drawings in Appendix D.

15.5.2 Generators

Electrical power will be generated by two horizontal-shaft, synchronous generators, each operating at 4,160 V, 3-phase, 60-Hz. Each generator will be air-cooled, 2-bearing-type, with open drip-proof enclosure, pedestal-type bearings, rotating brushless exciter, and disk-type brake. Individual ratings are anticipated to be:

- Unit 1: 5,500 kW, 6,111 kVA, 0.9 power factor (PF), 300 rpm.
- Unit 2: 1,500 kW, 1,667 kVA, 0.9 PF, 514 rpm.

15.5.3 Power Terminal Cubicles

Each generator will be equipped with an adjacent power terminal cubicle. This cubicle will house:

- Phase and neutral winding terminations.
- Neutral grounding transformer and resistor (for high-resistance grounding).
- Current and voltage potential transformers.

15.5.4 Generator Switchgear

The Control Room will house the 5 kV metal-enclosed generator switchgear. Bus rating is expected to be 1,200 amperes. This switchgear will house:

- Two vacuum-type draw-out-style generator circuit breakers
- Current and voltage potential transformers
- Ground overvoltage relaying
- Outgoing line section to the main step-up transformer

15.5.5 Main Step-up Transformer

The main step-up transformer, T-1, will be installed adjacent to the powerhouse and will be of the liquid-insulated power transformer-type in accordance with ANSI C57.12. Its purpose is to step-up power plant output voltage to the transmission voltage of 13.2 kV. This transformer will have the following ratings and features:

- 13200Y/7621-4160 Vac (grd wye-delta)
- 7.5/10 MVA OA/FA at 65 degree C
- Fully-enclosed primary and secondary termination compartments.
- Oil-filled (seed-based biodegradable fluid may be considered if desired) and fan-cooled

The standard monitoring and protective functions are anticipated, including pressure relief, sudden pressure relay, winding temperature, liquid temperature, and liquid level.

15.5.6 Transformer Switchgear

The Control Room will also house the 15 kV metal-enclosed transformer switchgear. Bus rating is expected to be 1,200 amperes. This switchgear will house:

- A vacuum-type draw-out-style transformer primary circuit breaker
- A vacuum-type draw-out-style ac station service circuit breaker
- Current and voltage potential transformers
- Transformer differential and line overcurrent relays
- Outgoing line section to the transmission line

15.6 Station Service Electrical Systems

15.6.1 Station Service Transformer

The 13.2 kV ac station service feeder from the transformer switchgear will serve a dedicated station service transformer, located exterior to the power plant to provide 480 Vac, 3-phase low voltage ac station service for facility loads. This transformer will have the following ratings and features:

- 13200-480Y/277 Vac
- Size rating (kVA) to be determined
- Delta-Grd Wye-connected windings
- Oil-filled, convection-cooled, padmounted-style.

15.6.2 Station Service Normal Power Distribution

Station normal power will be distributed via a 480 Vac Motor Control Center (MCC). This MCC will directly or indirectly (via panelboards) serve the following loads:

- Normal power 480 Vac distribution panelboard
- Normal power 208Y/120 Vac panelboard, via step-down transformer
- Bridge crane
- Monorail
- Exhaust fans
- Unit heaters
- Air conditioning
- Automatic transfer switch

15.6.3 Standby Power Supply

There will not be a generator set for standby power supply. Instead, standby power will be received from the standby power system of the Juniper Pump Station via a 480 Vac feeder, routed adjacent to the 13.2 kV transmission line. This feeder will require upsizing to control voltage drop within acceptable limits. A start signal will also routed from the power plant automatic transfer switch to the Juniper Pump Station standby genset.

15.6.4 Automatic Transfer Switch

An automatic transfer switch (ATS) will be installed to switch between the normal station service feeder (supplied from the normal service MCC), and the 480 Vac standby power feeder from the Juniper Pump Station. The load side of this ATS will serve the station service standby power MCC.

15.6.5 Station Service Standby Power Distribution

Station service standby power will be provided by a 480 Vac MCC. This MCC will directly or indirectly (via panelboards) serve the following loads:

- Standby power 480 Vac distribution panelboard
- Standby power 208Y/120 Vac panelboard, via step-down transformer
- HPUs
- Sump pumps
- Station dc System battery chargers
- Power plant lighting and convenience receptacles
- TIV bypass valve actuators
- Step-up transformer T-1 cooling fans

15.6.6 Station dc Service Power Distribution

A Direct Current (dc) power distribution system will be provided to supply power generation controls and protection, as well as selected critical loads. This system will consist of the following items:

- 125 Vdc battery bank, tentatively sized at 200 Ampere-hours
- Redundant 125 Vdc battery chargers
- 125 Vdc panelboard

The dc system will serve the following loads:

- Emergency lighting
- HPU controls
- Switchgear controls and protection
- Step-up transformer T-1 controls and protection
- Plant Control Panel (PCP, unit controls and protection)
- Any other powerhouse loads deemed critical to safety

15.7 General Facility Electrical Systems

15.7.1 Facility Lighting

Lighting will be provided throughout the interior and exterior of the facility. A conventional luminaire selection would be of the fluorescent tube or High Intensity Discharge (HID) types. Fixtures employing Light Emitting Diodes will be investigated during design for energy savings and lifecycle benefits.

The Table 15-1 summarizes the details of a preliminary illumination plan:

TABLE 15-1
Facility Illumination Plan
Pueblo Dam Hydroelectric Project

Area	Fixture	# of Fixtures	Fixture Watts	Total Watts
Switchgear and Control Room	Fluorescent	16	64	1024
Battery Room	Class I, Div 2 Fluorescent	1	64	64
Equipment Room Upper Level	Metal Halide HID	2	400	800
Equipment Room Lower Level	Metal Halide HID	6	1000	6000
TIV Pit	Vapor-tight Fluorescent	4	64	256
Drainage Sump	NEMA 250, Type 6 Rated Fluorescent	1	32	32
Emergency Egress Lights	LED	22	10	220
Exterior Building Areas	Metal Halide HID	9	175	1575

15.7.2 Facility Convenience Receptacles

Convenience power receptacles, 20A, 120 Vac-rated duplex-type, will be distributed throughout the facility. A higher density of receptacles will be installed within the Control Room, tailored to SCADA and other plant control needs. Weatherproof receptacles will be provided on the exterior of the facility at key locations. All receptacles will be of the 5-mA trip GFCI type. If desired, 3-phase receptacles for portable welding equipment can also be provided at selected locations.

15.7.3 Facility Intrusion Detection

Provisions will be tailored to District needs. Door supervision switches can be installed at all exterior access doors, including the main roll-up door. These can provide status indication to the power plant SCADA system for each door to alert supervising personnel of any unauthorized entry. Provisions for CCTV cameras can also be made.

15.7.4 Facility Hazardous Gas Detection / Fire Detection

Hydrogen gas detection will be installed within the Battery Room to provide status indication of elevated hydrogen levels. An alarm signal will be sent to the power plant SCADA system. Heat detector-type fire detection will also be provided in the Battery Room.

No additional fire detection provisions are planned. Whether or not any additional facility fire detection can be evaluated on the basis of District preference, special hazards, or property loss prevention considerations when considered against personnel response time from a remote site.

15.7.5 Facility Grounding & Lightning Protection

A comprehensive facility grounding system, and a lightning protection system, will be installed and detailed in the design documents. The lightning protection system will only be bonded to the facility grounding system exterior to the structure at selected ground rods or plates.

15.8 Instrumentation and Control

15.8.1 Plant Control Panel

A PCP, or control switchboard, will be provided with the pre-purchased generating equipment package. The PCP will be located in the Control Room. The PCP will provide a complete system of manual and automatic monitoring, protection, and control for the turbine-generator units. The PCP functions will be housed in a multi-section cabinet. All critical functions will be of fail-safe design and powered from the station battery. Conventional relay logic, Programmable Logic Controller (PLC) logic, or a blend of these technologies can be provided. The PCP will also provide digital or discrete interface with the District’s SCADA system, facilitating remote monitoring and control. It is currently assumed that the District will install its own SCADA hardware at the power plant and the interface will be implemented via Ethernet or similar digital connectivity.

15.8.2 Ultrasonic Flowmeter

Each penstock will be equipped with an ultrasonic flowmeter installed just upstream of each TIV. It is anticipated that the flowmeter system will be of the multi-path arrangement, according to accuracy needs. Final configuration, path quantity, and transducer quantity will be determined during design.

SECTION 16

Operations and Maintenance

16.1 General

The power plant design anticipates providing the features and capability to support local and remote monitoring and control of the generating units. It is assumed that units will be operated to achieve the release of prescribed flows through the power plant, in accordance with their operating limits. Local manual, local automatic, and remote automatic modes of operation are planned.

Power plant and equipment features necessary to support convenient maintenance of the generating units and other plant equipment are planned, including, for example, access roadways, inspection and access hatchways, dewatering and drainage systems, illumination systems, bridge crane, and tailbay monorail hoist.

16.2 Features

Specific features will be specified further as design progresses.

SECTION 17

Construction

17.1 General

The means and methods of construction will be left at the discretion of the Contractor. However, construction sequencing and constructability have been considered and must continue to be studied during the final design phase. In particular, the access to the hatchery, construction of special features, and continued operation of the hatchery during construction must be points of consideration. The section is organized as follows:

- Construction Consideration

17.2 Construction Access

This section is to be determined.

Appendix A
Cost Estimate

Appendix B
Surge Analysis for the Pueblo Hydro Facility Turbine Load Rejection

Appendix C
Proposed Equipment Technical and Budgetary Price Information

Appendix D
Project Drawings (to-date)

Appendix E
Basic Economic Analysis