FINAL TECHNICAL REPORT

MODERNIZATION OF THE BOULDER CANYON HYDROELECTRIC PROJECT

DE-EE0002675

JANUARY 1, 2010 – DECEMBER 31, 2012

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EXECUTIVE SUMMARY

The Boulder Canyon Hydroelectric Project (BCH) was purchased by the City of Boulder, CO (the city) in 2001. Project facilities were originally constructed in 1910 and upgraded in the 1930s and 1940s. By 2009, the two 10 MW turbine/generators had reached or were nearing the end of their useful lives. One generator had grounded out and was beyond repair, reducing plant capacity to 10 MW. The remaining 10 MW unit was expected to fail at any time.

When the BCH power plant was originally constructed, a sizeable water supply was available for the sole purpose of hydroelectric power generation. Between 1950 and 2001, that water supply had gradually been converted to municipal water supply by the city. By 2001, the water available for hydroelectric power generation at BCH could not support even one 10 MW unit. Boulder lacked the financial resources to modernize the facilities, and Boulder anticipated that when the single, operational historical unit failed, the project would cease operation.

In 2009, the City of Boulder applied for and received a U.S. Department of Energy (DOE) grant for $1.18 million toward a total estimated project cost of $5.155 million to modernize BCH. The federal funding allowed Boulder to move forward with plant modifications that would ensure BCH would continue operation. Federal funding was made available through the American Recovery and Reinvestment Act (ARRA) of 2009.

Boulder determined that a single 5 MW turbine/generator would be the most appropriate capacity, given the reduced water supply to the plant. Average annual BCH generation with the old 10 MW unit had been about 8,500 MW-hr, whereas annual generation with a new, efficient turbine could average 11,000 to 12,000 MW-hr. The incremental change in annual generation represents a 30% increase in generation over pre-project conditions.

The old turbine/generator was a single nozzle Pelton turbine with a 5-to-1 flow turndown and a maximum turbine/generator efficiency of 82%. The new unit is a double nozzle Pelton turbine with a 10-to-1 flow turndown and a maximum turbine/generator efficiency of 88%. This alone represents a 6% increase in overall efficiency. The old turbine operated at low efficiencies due to age and non-optimal sizing of the turbine for the water flow available to the unit. It was shut down whenever water flow dropped to less than 4-5 cfs, and at that flow, efficiency was 55 to 60%. The new turbine will operate in the range of 70 to 88% efficiency through a large portion of the existing flow range and would only have to be shut down at flow rates less than 3.7 cfs. Efficiency is expected to increase by 15-30%, depending on flow.

In addition to the installation of new equipment, other goals for the project included:

- Increasing safety at Boulder Canyon Hydro
- Increasing protection of the Boulder Creek environment

- Modernizing and integrating control equipment into Boulder's municipal water supply system, and
- Preserving significant historical engineering information prior to power plant modernization.

From January 1, 2010 through December 31, 2012, combined consultant and contractor personnel hours paid for by both the city and the federal government have totaled approximately 40,000. This equates roughly to seven people working full time on the project from January 2010 through December 2012.

This project also involved considerable material expense (steel pipe, a variety of valves, electrical equipment, and the various components of the turbine and generator), which were not accounted for in terms of hours spent on the project. However, the material expense related to this project did help to create or preserve manufacturing/industrial jobs throughout the United States. As required by ARRA, the various components of the hydroelectric project were manufactured or substantially transformed in the U.S.

BCH is eligible for nomination to the National Register of Historic Places due in part to its unique engineering features and innovative construction techniques. Special efforts were directed toward documenting the (largely original) interior of the plant and installing new equipment without modifying the power plant exterior in order to preserve the historical significance of the facility. In addition, a significant portion of the historical equipment within the power plant was preserved in place.

The modernization project began with DOE grant award on January 1, 2010, and the project was completed on December 31, 2012. In addition to city engineering and hydroelectric staff, major project participants included AECOM (design/engineering) Canyon Industries (turbine/generator manufacture), Gracon Corporation (general construction contractor), Exponential Engineering Company (electrical engineering) and URS Corporation (historical documentation), as well as numerous other subcontractors and consultants.

LIST OF ACRONYMS

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
API	American Petroleum Institute
ARRA	American Recovery and Reinvestment Act of 2009
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BCH	Boulder Canyon Hydroelectric Project
CFS	Cubic feet per second
City	The City of Boulder, Colorado
DOE	Department of Energy
FERC	Federal Energy Regulatory Commission
HPU	Hydraulic pressure unit
HVAC	Heating, ventilation and air conditioning
kWh	Kilowatt hours
LPU	Lubrication pressure unit
MCC	Motor control center
MGD	Millions of gallons per day
MW	Megawatt
MW-hr	Megawatt hours
O&M	Operation and maintenance
PLC	Programmable logic controller
PMG	Permanent magnet generator

PSCo	Public Service Company of Colorado, a wholly owned subsidiary of Xcel Energy
PSI	Pounds per square inch
RPM	Revolutions per minute
SCADA	Supervisory control and data acquisition
SHPO	State Historic Preservation Officer
TBD	To be determined
TIV	Turbine isolation valve
USBR	U.S. Bureau of Reclamation
V	Volt
WTP	Water treatment plant

INTRODUCTION

Boulder is located on the Front Range of the Rocky Mountains and provides water service to approximately 29,000 residential, commercial and industrial accounts with an annual treated water demand of approximately 19,000 acre-feet or 6.2 billion gallons. The Boulder Creek watershed is the city's primary municipal water supply source. The Boulder Creek watershed water supply system also provides clean, renewable energy from generation of electricity at hydroelectric plants installed on municipal water supply pipelines.

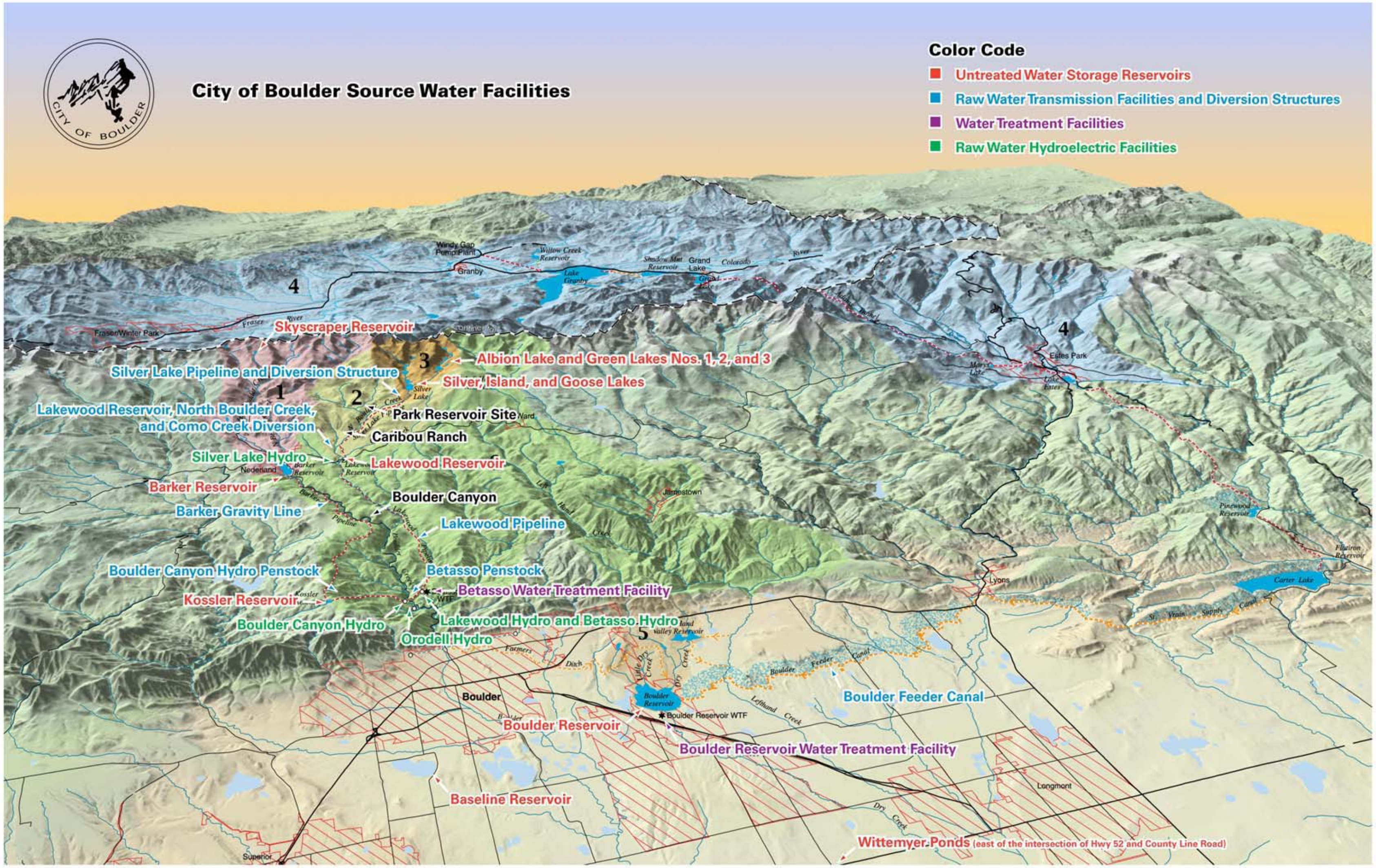
Beginning in the early 1980s, Boulder recognized the potential for hydroelectric energy generation within its water system and began developing facilities to produce electricity as a by-product of its water utility operations. Today, Boulder owns and operates eight hydroelectric facilities on its raw water transmission and treated water distribution systems (Figure 1). These hydroelectric plants produce environmentally friendly hydroelectricity by making use of pressure developed in municipal water supply pipelines due to the large elevation drop between the city's diversion points in the mountains and delivery points on the plains. This pressure must be reduced to treat and deliver the water for municipal purposes and would otherwise be wasted through pressure-reducing valves.

The city's hydro plants are operated in a manner that does not diminish the primary purpose of supplying municipal water. Revenue from the sale of the electricity allows the city's Water Utility to maintain lower water rates for its customers. By the end of 2011, the city had generated approximately 612,531,557 kilowatt hours (kWh) of electricity since its first hydroelectric project began operation in 1985. Sale of this power has produced over $27 million in revenue and has provided environmental benefits by displacing the need to burn approximately 306,266 tons of coal, preventing the greenhouse gas emissions that would have resulted from traditional coal-fired power generation facilities. The city's hydro facilities have frequently been cited in industry literature as an example of how electricity can be derived with no additional environmental effects from water facilities that are in existence and required for other purposes.

The existing Boulder Canyon Hydroelectric facility is located on Boulder Creek west of the city. The power plant generates using untreated water diverted at Barker Reservoir located near the town of Nederland at an elevation of about 8500 feet. The water is transported approximately 11.5 miles in the Barker Gravity Pipeline to a small regulating reservoir and then through the Boulder Canyon Penstock to the Boulder Canyon Hydro building at an elevation that is 1,800 feet lower, thereby producing 840 psi of pressure.

Although the hydro plant originally operated with two 10 megawatt (MW) turbine/generators, one of the generators failed in 2000. The remaining operational turbine and generator date to 1936 and were at the end of their expected lives. Without a new turbine and generator, operation of the hydro was expected to cease within 5 years or less.

FIGURE 1: CITY OF BOULDER SOURCE WATER FACILITIES



BACKGROUND

Project Objectives

The city's objectives for modernization of the power plant included the following:

- **Increase generation and efficiency of the 100-year-old hydroelectric facility.** With the redirection of much of the historic water flow to the power plant to municipal uses over the past 50 years, the existing, vintage 1936 turbine/generator was too large to operate efficiently within the available flow rates. With a new, appropriately sized unit, generation will increase by as much as 30 percent, and turbine efficiency will increase by 18 to 48 percent, depending on flow.

- **Increase safety for both personnel and equipment.** Replacement of deteriorated wiring will eliminate asbestos in the existing wiring and reduce the hazards to personnel and equipment from electrical shorts.

- **Increase environmental protection.** Decommissioning aging transformers, installing improved protection from lightning strikes, and removal of an old hydraulic oil storage tank adjacent to Boulder Creek will improve protection against oil spills.

- **Modernize and integrate control equipment into the municipal water system.** The original (1910) turbine isolation valve was replaced with a valve that can be remotely operated and will close automatically upon an emergency turbine stop as protection against equipment and piping damage.

- **Preserve significant historical engineering information prior to plant modernization.** Boulder Canyon Hydro is considered eligible for nomination to the National Register of Historic Places due in part to its unique engineering features and innovative construction techniques. Documentation of technical engineering data in accordance with Historic American Engineering Record standards prior to plant modernization ensured that this information is preserved.

- **Complete modernization with minimal regulatory delay to contribute to economic recovery through the creation and/or preservation of jobs.** The city believed this project could be completed within approximately two years. The project was anticipated to produce approximately 10 new full time equivalent jobs for a one year period.

Project Scope

The city defined five main tasks for this project, as follows:

Task 1.0 Equipment Procurement
The projected lead time for the turbine and generator package was estimated at 490 calendar days (approximately 16 months) from receipt of Purchase Order. In order to meet the project schedule, the city contracted for the turbine and generator as owner supplied equipment.

Task 2.0 Engineering Design Services
Final design and preparation of a complete specification and drawing bid package for replacing the existing 10 MW Pelton unit at Boulder Canyon Hydroelectric facility with a modern, more efficient 5 MW Pelton unit included:

- Geotechnical review – a review of the existing geotechnical data was performed to analyze the impact of the proposed modifications.
- Structural design – the existing unit was embedded in concrete. This concrete was removed and new concrete supports were installed for the new unit.
- Civil design – minor modifications were required in the tailrace area to accommodate the new unit. Piping modifications were required upstream of the new turbine to accommodate the smaller size.
- Hydro-mechanical – the design of the hydro-mechanical equipment including the turbine, generator, hydraulic power unit, controls and switchgear and inlet valve was completed in consultation with the turbine/generator manufacturer.
- Electrical and Controls – the electrical and controls design was based on upgrading the existing equipment to meet the requirements of the new unit.

Existing specifications used on previous City of Boulder projects were used as a basis for the Boulder Canyon Hydro specifications. Utilization of the existing technical specifications facilitated efficient use of time and budget.

Subtask 2.1 Final Permitting Activities
The city received a conduit exemption from licensing from the Federal Regulatory Energy Commission for the Boulder Canyon Hydro Project in November of 2011. The exemption was granted for the old equipment and capacity of 10 MW. With the replacement of generating Unit B with a new, 5 MW unit, an amendment to the exemption was required. The city received the amendment from FERC on September 27, 2012.

Subtask 2.2 Historic Preservation Considerations
DOE entered into a memorandum of agreement with the Colorado State Historic Preservation Officer in August 2010 concerning mitigation of adverse effects to the historically significant power plant. Work included in-depth research of the history of the plant, reproduction of historic photos and drawings to archival conditions, and preparation of a narrative history of the power plant.

Task 3.0 Construction Contract
Bid documents for the construction phase of the project were issued in August 2011.

Task 4.0 Construction
The construction phase included the following efforts:

- Mobilization
- Hazardous materials removal– asbestos clad wiring was removed in accordance with approved abatement policies.
- Generating transformer removal and replacement
- Demolition
- Concrete and subfloor modifications to accommodate the new unit.
- Delivery and installation of the new unit
- Installation of electrical and control equipment
- Testing and commissioning
- Demobilization.

Task 5.0 Project Management and Reporting
The Boulder Canyon Hydro Modernization Project involved a large number of contractors, subcontractors and consultants scattered throughout Colorado and the nation (see Table 1), necessitating rigorous and attentive project management.

Project Funding

In June 2009, the Department of Energy (DOE) announced a grant opportunity for funding of up to 50% of costs for projects that would maintain conventional hydropower as an attractive electricity production option and increase electricity generation, efficiency and environmental performance of existing facilities. In August 2009, the city submitted a grant application to the Department of Energy for $2,500,000 toward a total estimated project cost of $5,155,000 for modernization of the BCH power plant. In November 2009, DOE informed the city that it would provide $1.18 million in federal funding for the project.

The city proposed funding the remaining $3.975 million in anticipated project costs by borrowing money from the Lakewood Pipeline Remediation Reserve. The loan is to be repaid with 3% interest using future power sale revenues. The Boulder City Council approved accepting the DOE grant and borrowing the balance of the needed funding from Lakewood Pipeline reserve in January 2010.

Table 1: Boulder Canyon Hydroelectric Modernization Project
Key Participants

Organization	Key Individuals	Role/Responsibility
City of Boulder, Utilities Division	Joe Taddeucci Jake Gesner Barry Hammond Lindsey Greene Ken Baird Kate Patterson	Project Manager Hydroelectric Program Manager Hydroelectric Technician Hydroelectric Technician Utilities Division Finance Manager Public Works Administration
Department of Energy	Rajesh Dham Matthew Hess Gary Nowakowski Erik Mauer Pam Brodie	Lead - Hydropower Technology Development Project Officer Project Officer CAS-Navarro Project Engineer Contracting Officer
AECOM	Richard Dulin Patrick Willis Ed Serfozo	Project Manager (Design Engineer) Project Engineer Project Engineer
Alstom Grid		Circuit switcher manufacturer
Exponential Energy Corporation	Tom Ghidossi Joe Koonce	Project Manager (Electrical Engineer) Project Engineer
Canyon Industries	Brett Bauer Richard New Rob James	Vice President/Project Manager (Equipment) President Customer Service Manager
Consilium Partners, LLC	John Bills	City Project Manager Support Construction Supervision
Gracon Corporation	Alan Havens Dave Ream Diana Williamson	Project Manager (Construction) Project Superintendent Project Administration
Kris Kranzush	Kris Kranzush	City Project Manager Support DOE Coordination Environmental and cultural services
URS Corporation • Native Cultural Services	Gordon Tucker Brian Shaw Peter Gleichman	Project Manager (Historical Mitigation) Historian Historian
Virginia Transformer		Generating transformer manufacturer

RESULTS

Design Criteria and Equipment

The following is a general description of the design criteria and equipment utilized on the project. Project components satisfied the ARRA and “Buy American” requirements.

1. Structural Design
   a. Design Codes and References: ACI, AISC, ASTM, USBR

   b. Structures were designed to carry dead loads, live loads, and equipment loads

2. Hydraulic Design
   a. Transient mitigation was incorporated into the design through the control of the valve open/close speeds

   b. System design will accommodate 30MGD capacity for delivery to Betasso Water Treatment Plant

   c. Due to the short length of penstock, no transient analysis was performed and current nozzle speeds were matched.

3. Penstock Design
   a. Design Codes and References: ASTM and API 5L, or ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, ASCE Engineering Practice No. 79, USBR

   b. The penstock shall have an interior lining and exterior coating.

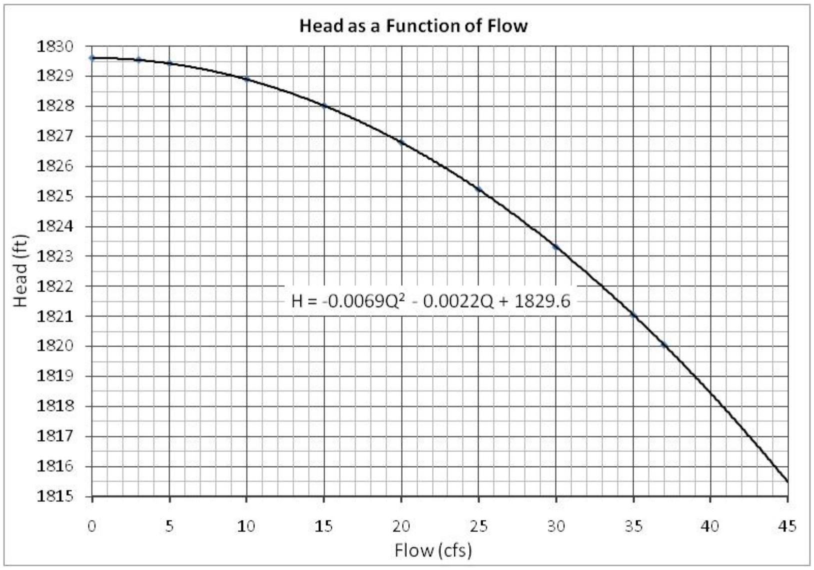
   c. All joints received full penetration butt welds and were subject to ultrasonic and/or radiographic testing.

   d. Fully restrained dismantling joints were provided as needed,

4. Turbine Selection & Design
   a. Turbine Design Data
      1. Static Head: 1830 feet
      2. Flow range from 3.7 cfs to 37 cfs
      3. Unit Size: 5 MW
      4. Type of Turbine: Pelton
      5. Horizontal Shaft
      6. Number of Nozzles (TBD by the manufacturer)
      7. Runner Diameter (TBD by the manufacturer)
      8. Design Pressure (including surge): 1190 psi
      9 Minimum guaranteed turbine efficiency: 90.5%
      10. Nominal speed: 900 rpm

11. A fully restrained dismantling joint was provided downstream of the turbine inlet valve.
12. A spare runner was included in the Equipment Package.
13. The operator for the turbine deflector is hydraulically actuated and includes a counterweight to act as an emergency backup.
14. The following graph shows the available dynamic head for a given flow:

Figure 2: Available Dynamic Head by Flow



5. High Pressure Isolation Valves
   a. Design Pressure, including surge: 1190 psi

   b. Turbine Inlet Valve (TIV):
      1. 24" Full port ball valve with double acting hydraulic cylinders.
      2. Position limit switches.
      3. The actuator includes a hand pump for emergency closure.

   c. Turbine Brake Jet Valve: hydraulically operated

   d. TIV Bypass Valves: (2) 2-inch, Class 600 flanged plug valves. First valve is electrically actuated and second valve is manually operated:
      1. Serck Audco Super H pressure balanced taper plug valves
      2. Electric motor actuator is a Triac Controls Series WE

6. Hydraulic Pressure Unit
   a. Operates the turbine (nozzles, deflector, and water brake), turbine inlet valve, generator brake, and Betasso Bypass Valve.

b. Includes two (2) pumps and electric motors, tank, valves, stainless steel piping, fittings, filters, wiring, instruments, control panel, and oil containment tray.

c. Two sets of accumulator tanks (sized for one complete cycle)
   1. One complete cycle is defined as close/open/close.
   2. One set of accumulators were sized for simultaneous operation of the turbine (nozzles, deflector, water brake).
   3. One set of accumulators were sized for simultaneous operation of the TIV and the Betasso Bypass valve.

d. Environmentally friendly lubricants and hydraulic fluids were used.

7. Lubrication Pressure Unit
   a. Includes two pumps and electric motors, oil reservoir, valves, piping/tubing, fittings, filters, wiring, instruments, control panel, and oil containment tray.

   b. Site glass in return piping for viewing flow to LPU.

   c. Environmentally friendly lubricants and hydraulic fluids were used.

8. Ultrasonic Flowmeter
   a. Flowmeter system consists of ultrasonic transducers, coaxial cables, and a surface mounted console enclosure

   b. Flow range: 0-38 ft^3/sec

   c. 8-path acoustic transit time measurement type, mounted in a 4 cross 4 pattern

   d Tolerance in the flow rate indication:+/-0.5-1.0%

   e. The flowmeter is manufactured by Accusonic.

9. Pressure Transmitters
   a. Pressure gages and transmitters were installed for monitoring penstock and turbine inlet pressures

   b. Upper range limit: 1000 psi

   c. Typical Measurement range: 0 to 800 psi

10. Generator
   a. The generator is a Synchronous Generator manufactured by Hyundai-Ideal.

b. The excitation system for the generator is the brushless type.

c. The bearings were designed to meet the requirements of the generator and turbine system and for long life and low maintenance.

d. Bearings are oil lubricated with Babbit linings

e. Generator Shaft Vibration monitoring equipment was provided (Bentley Nevada).

f. Generator ratings: 0.9 PF, 96% efficiency, 5.0 MW, 4.16KV, three phase, wye connected, 60 Hz

g. Digital excitation control system equipment is a Basler Model DECS-100-B15

h. Permanent Magnet Generator (PMG) for excitation system power

i. Speed sensors: Tachpac 10, Al-Tek Instruments

j. Tachometer: Tachpac 10, Al-Tek Instruments

11. Electrical Components
    a. Generator protection and neutral ground protective relay: SEL (Schweitzer Engineering Laboratories)

    b. Governor: Clifton Labs Ltd, Z-180 digital phase lock loop type

    c. Shaft displacement/runout/key phasor monitoring system – Bentley Nevada
    d. Transformer: Unit A Transformer to be removed, Unit B Transformer to be replaced.

    e. Oil-filled, fan-cooled, mineral (environmentally friendly filled) [Panolin TRAFOSYNTH 2 or approved equal]

    f. Neutral grounding equipment

12. Controls,SCADA, Switchgear, and Station Service
    a. Electrical control, monitoring, protection, and metering equipment

    b. Automatic synchronizer

    c. PLC system for automatic and SCADA control, and monitoring communications: PLC is an Allen Bradley

    d. Full manual, automatic, and SCADA operation capabilities

e. Motor control center (MCC) includes motor starters, circuit breakers, control equipment, and enclosure

f. Redundant station service power system

g. Removed existing 230V, 3-phase station service transformers and distribution equipment

h New station service power is 480V, 3-phase, 208V 3-phase. Replace existing 230V, 3-phase crane motor with motor rated 480V, 3-phase.

i. Step-up autotransformer to supply other existing 230V, 3-phase motor operated equipment from new 208V, 3-phase station service panelboard

j. Obtained backup station service feed from PSCo[1]. Backup station service feed includes transformer and automatic transfer switch. PSCo station service transformer is powered from existing 25KV feed to hydro plant.

k. BCH SCADA to Betasso WTP communications utilizes existing fiber optic cable terminated at the Betasso pipeline drain vault location.

The following table identifies which project components are in the Equipment Package vs. the Construction Package.

Table 2: Components of the Equipment and Construction Packages

Equipment Package furnished by Canyon Industries	**Construction Package [2]**
• Pelton Turbine • Synchronous Generator • 24" Ball Valve (TIV) • 2" bypass line and valves around TIV • Dismantling joint downstream of TIV • Ultrasonic Flowmeter • Turbine inlet piping from TIV to turbine	• Removal of existing piping, equipment, old wiring/cables, and concrete • Switchgear equipment • Step-up transformer (Virginia Transformer-manufacture; Gracon Corporation-installation) • Station service equipment (Sturgeon Electric) • Circuit switcher (Alstom Grid-manufacture;

[1] PSCo is a wholly owned subsidiary of Xcel Energy.
[2] Unless otherwise noted, these items were completed by Gracon Corporation or their subcontractors. The step-up transformer, circuit switcher and station service equipment were owner-furnished items.

Equipment Package furnished by Canyon Industries	Construction Package [2]
• HPU • LPU • Pressure Transmitters • Generator Shaft Vibration Monitoring Equipment • Speed sensors & switches • Tachometer • Supervision of installation, testing, and commissioning of turbine/generator unit • Operation and Maintenance Manuals of supplier provided equipment & valves • New Betasso Bypass 30" Ball Valve	Gracon Corporation-installation) • MCC equipment • PLC equipment • Protective relaying equipment • Neutral grounding equipment • Control Panel • SCADA Interface • New conduit and wiring • Pressure Transmitters • Piping from existing Unit A line to new TIV • Installation of all piping and equipment • O&M manuals of contractor supplied valves & equipment • Asbestos remediation • Lead paint remediation • Protect in place designated items of historic/current value • New concrete/structural • HVAC System • Respecting access and interconnection agreement with PSCo

Key Decisions by the City of Boulder

1. Reduction of unit size from 6 MW to 5 MW

    a. The feasibility study that was completed in 2005 had estimated that a flow range of 3.7 to 37 cfs for the new BCH turbine would maximize power production based on historic flows and expected future flows. At this flow range, unit size would be approximately 5 MW.

    b. At the beginning of the design, there were discussions about the potential for higher pipeline flows in the future. An increased flow range was set at 4.5 to 45 cfs, which was based on the capacity of the pipeline feeding Kossler Reservoir. This flow range was used as the basis for building the technical specifications for the equipment package bidding documents which resulted in a 6 MW unit.

    c. After selecting Canyon Industries as the successful turbine supplier, they pointed out that the flows that the city had showed in its performance table would be better suited for a 5 MW unit. AECOM estimated that a 5 MW unit would increase the present worth revenue value by about $100,000 over the life of the project. Canyon Industries also offered a $75,000 deduct for downsizing to a 5 MW unit.

    d. The decision was made to reduce the size of the unit to 5 MW and set the flow range to 3.7 to 37 cfs. The city confirmed that the only time when 45 cfs would be available is during spring runoff and early summer. That timeframe also coincides with an increase in municipal demand, so a portion of the 45 cfs would be going to the Betasso WTP. Therefore, it would be unlikely that more than 37 cfs would be available for BCH for any extended period of time.

2. Replacement of Unit A vs. Unit B

    a. Originally there had been debate on whether Unit A or B should be replaced. It was recognized that the piping layout and the construction would be easier if Unit B was replaced. The schedule was unclear at the time, though, and it was thought that it would be better to keep Unit B running as long as possible.

    b. At the Turbine/Generator Kickoff Meeting in December 2010, the issue was raised again. After further discussion, it was decided that it would be simpler to replace Unit B rather than Unit A. The following decision matrix table was used to make a final decision:

Table 3: Considerations in Deciding Whether to Replace Unit A or Unit B

Consideration	Replace Unit A	Replace Unit B	Notes
Civil Design / Construction		✓	The Unit B tailrace concrete was evaluated, and its adequacy was confirmed. Based on that assessment, replacing Unit B made more sense because the need to remove a large portion of concrete in between the two units was eliminated.
Mechanical Design / Construction		✓	The bypass piping was much simpler/more logical by replacing Unit B.
Electrical Design / Construction		✓	Unit B replacement allowed more convenient placement of generator excitation, neutral grounding, and control cabinets within the building. Conduit runs to the equipment were shorter with fewer obstructions. The existing control room did not have to be disturbed. The 460 V power distribution conduit and conductor runs were be shorter and conduit installation was less complicated. Unit B controls and power circuits did not have to remain in service allowing easier installation of the new equipment. There were no drawbacks associated with the electrical installation by replacing Unit B rather than Unit A.
Water Delivery during Construction		✓	The length of time the Barker source needed to be out of service was less due to the relative ease of the bypass piping changes and the ability to install a new isolation valve on the Unit B side.
PSCo Coordination associated with shared facilities		✓	PSCo coordination was easier with replacement of Unit B.
Historical Preservation/DOE Funding	**?**	**?**	Originally selected Unit A for replacement because we saw value in Unit B being fully operational (presumably) when it was shut down. The photography had already been done based on the assumption that Unit A was being replaced. (Additional photography was done to account for the change.)
Future Operations / Convenience		✓	Easier for operations staff

Other Upgrades to the Plant and Site

During construction other upgrades and maintenance were performed to the facility and site as part of the project:

1. Replacement of the Unit B tailrace concrete.
2. Supply and exhaust fans were added to the plant's HVAC system.
3. The North access bridge was evaluated and many of the timber planks were replaced. Steel plates were also set down on the bridge to better distribute weight.

4. The plant crane was serviced and many parts were replaced to ensure proper performance during construction.

Historical Documentation

Removal of historical equipment from the power house and modification of the interior layout of the building would have constituted an adverse effect to the significance of BCH. To mitigate for this adverse effect, DOE and the Colorado State Historic Preservation Officer (SHPO) entered into a Memorandum of Agreement which provided for:

- Medium format photography of the plant interior as well as exterior equipment and features prior to any proposed construction. Photographs were printed on archival paper and submitted to the SHPO.
- Reprint of select historical photographs on archival paper for submittal to the SHPO.
- Reproduction of measured drawings documenting the history of the plant on archival paper for submittal to the SHPO.
- Preparation of a narrative history of the plant and project.
- Preservation in place of historical equipment within the plant.
- Off-site preservation of historical equipment which required removal.

In addition, it was known that the existing historical record for BCH contained errors, inconsistencies and contradictions. The city attempted through historical research to correct errors in the site documentation. Many inconsistencies were resolved.

Documentation was submitted to the SHPO in September 2011 and approved on September 29, 2011. Duplicate documentation was prepared for donation to the Boulder Public Library Carnegie Branch for Local History. The narrative history of the plant/project is contained in Appendix 1 of this report.

Construction Activities

General

This section of the report summarizes, in a chronological manner, the equipment manufacture and on-site construction activities of the BCH refurbishment. Full-time inspection was not provided during construction, but periodic reviews were completed by the city and their consultants. The following is a summary of the events.

January 1, 2010	DOE award of $1.18 million for modernization of BCH
March 30, 2010	DOE released hold on funding at completion of NEPA compliance
September 2010	Bid package issued for turbine/generator procurement
October 7, 2010	Bid due date for turbine/generator

January 3, 2011	Notice to Proceed with equipment manufacturing issued to Canyon Industries
March 7, 2011	Project kick-off meeting with Canyon Industries and DOE
March 28, 2011	Approval of Canyon Industries' first stage submittals
April 13, 2011	Final shop drawings from Canyon Industries
May 13, 2011	Receipt of first turbine runner casting by Canyon Industries
June 8, 2011	Receipt of second turbine runner casting by Canyon Industries
October, 2011	Construction contract awarded to Gracon Corporation
November 13, 2011	Preconstruction meeting
November 17, 2011	Gracon began mobilization
December 2011	Gracon worked to complete mechanical equipment demolition.
January 2012	Gracon removed concrete and some rock to prepare for new equipment. The concrete was extremely hard. On January 31, 2012 Gracon began to un-bolt the Betasso piping which began the water supply shutdown for the city.
January 24, 2012	Completion of equipment shop assembly by Canyon Industries
February 17, 2012	Equipment delivered to Boulder
February 2012	Continued demo of concrete, rock, and removal of the Unit B turbine isolation valve. Demo was completed by end of month and forming began for concrete.
March 2012	Concrete forming and placement continued throughout the month. Setting of sole plates for new TIV and Betasso Bypass valve was completed. New TIV valve was installed. The Betasso bypass piping was delivered and installation began immediately. Transformer A was removed at the end of the month.
April 2012	Concrete work was completed for equipment pads and turbine pit. Gracon began to set turbine casing and layout for generator. New transformer from Virginia Transformer was installed.
May 2012	Gracon completed installation of walkways, accumulator tanks, turbine casing, TIV, nozzles, piping, and began generator installation. The circuit switchers were delivered and installed.

June 2012 — Gracon completed installation of generator, HPU, LPU, and stainless steel tubing for HPU and LPU.

July 2012 — Gracon completed final clean-up and punch list items. Electrical (MWI) and Programming (EPE) subcontractors worked with AECOM and Exponential to commission equipment.

August 2012 — Final electrical install and testing were completed including SCADA work. Canyon Industries and city worked through start-up of unit.

September 14,2012 — Completed final walk-through with Gracon. This is the date of Substantial Completion.

October 4 2012 — Project completion ceremony

December 31, 2012 — End of DOE project

March 31, 2013 — Completion of final reporting to DOE

September 14,2014 — End of 2-year Warranty Period.

Key points in the construction project are shown in the photographs contained in Appendix 2.

Project Management and Reporting

Because of the large number of project team members and their scattered locations, special project management efforts were needed to ensure the project remained on schedule and within scope. Weekly conference calls were conducted to monitor project schedule, budget and progress. Minutes were kept of most of the calls. Recurring weekly calls occurred for the following groups:

- Equipment group, including city engineering and hydroelectric staff, the turbine manufacturer, the design engineer, and others as needed.
- Construction group, including city engineering and hydroelectric staff, the construction contractor, key subcontractors as needed, construction supervision consultant, the design engineer, the electrical engineer and the turbine manufacturer.
- Consultant group, including city engineering and hydroelectric staff, design and electrical engineers, construction supervision personnel and permitting specialist.

In addition, monthly teleconferences were held by city staff and DOE personnel.

Reports and other deliverables were provided to DOE in accordance with the Federal Assistance Reporting Checklist. Standard reporting requirements included:

- Quarterly American Recovery and Reinvestment Act Report
- Quarterly Federal Financial Report

- Quarterly Technical Progress Report
- Semi-annual Davis Bacon Act Compliance Report
- Monthly Planned vs. Actual Expenditure Report
- Monthly Grant Draw Back-up Documentation

Due to the federal funding, compliance with a variety of federal statutes was required, and monitoring and documenting compliance was a part of overall project management. Federal statutes and regulations applicable to this project included:

- National Environmental Policy Act
- National Historic Preservation Act
- Threatened and Endangered Species Act
- Buy American Act
- Davis Bacon and Related Acts
- American Recovery and Reinvestment Act
- DOE implementing regulations at 10 CFR 600.

Project Schedule

In its grant application, the city proposed project completion by December 31, 2011, based on the following considerations:

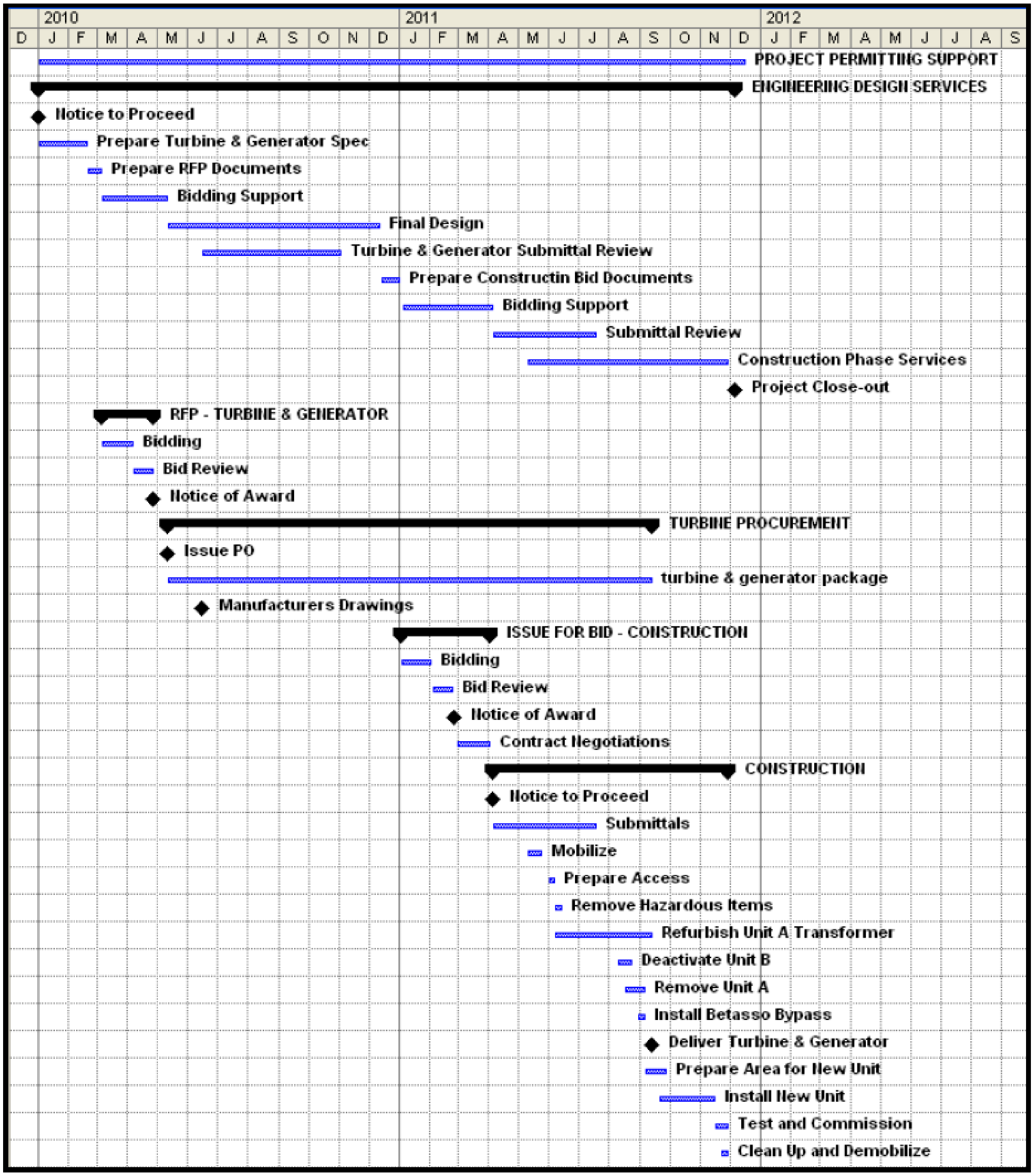
- Feasibility studies, including turbine sizing, had been completed. This would allow the city to order the turbine/generator as owner-procured equipment shortly after grant award.
- The city had completed the necessary consultation and application processes for the FERC authorization of this project and expected to have a conduit exemption from licensing in hand in the first few months of the project.
- AECOM would be the design engineer for this project. AECOM completed the feasibility study for turbine replacement, had designed and constructed two of the city's other hydroelectric plants and was very familiar with the existing and proposed facilities.
- Final design, contracting, remaining minor permitting efforts, and other aspects of the project (historic documentation, surge protection, transformer refurbishment/decommissioning and oil storage tank replacement) could be completed in advance of turbine delivery.
- The power house is an existing structure. Therefore, modernization of the interior equipment could be undertaken with no seasonal restrictions or weather-related delays.

Ultimately, DOE determined the project substantially complete as of September 30, 2012 and complete as of December 31, 2012. The extension of the final completion date was issued to allow extra time for final project reporting.

Contributing factors to the extension of the project schedule by one year include:

- A DOE hold on project funding while it achieved National Environmental Policy Act compliance for the project. This delayed the project by about 90 days.
- Changes in project scope, including:
    - Initially, the city had proposed replacing BCH generating Unit A. Additional design was required when the city ultimately decided to replace generating Unit B.
    - The city had anticipated refurbishment in-place of the existing generating transformer associated with the project at the time the grant proposal was submitted. It was ultimately determined that complete transformer replacement was necessary. This necessitated a separate procurement process with the transformer manufacturer.
- Because the BCH site is also the location of a PSCo substation, and because PSCo was the previous owner of BCH, there was an unavoidable overlap of city and PSCo facilities at the time of BCH purchase in 2001. PSCo proposed a substation upgrade concurrent with the hydroelectric project upgrade which afforded the perfect opportunity to finally separate PSCo and city facilities and equipment. This required additional coordination with PSCo in terms of work scheduling. It also resulted in removal of both antiquated generating transformers from the site.
- It was determined that the city needed to replace the existing station service transformer at the hydroelectric plant. This required additional engineering design and procurement processes.
- It was determined that new circuit switching equipment would be required for the new generating transformer. This work was not anticipated at the time the grant application was submitted and required separate design and procurement efforts.
- Planned system outages for Barker Gravity Line maintenance limited the water available at BCH for final project testing until 2013.
- The city’s power purchase agreement with PSCo for BCH expired in 2009. Negotiation of a new power purchase agreement has extended into 2013.

Table 4: Original Project Schedule



Contract Schedules

The city's two major contracts associated with this project were with Canyon Industries for owner procured equipment and with Gracon Corporation for construction. Provisions of these contracts are summarized in Table 5.

Table 5: Major Contract Milestones by Contractor

Contractor	Milestone	Contract Date
Canyon Industries	Notice to Proceed (NTP)	
	Deliver turbine/generator package to project site	No later than 420 days after NTP
	Completion and acceptance of equipment testing, start-up and training	No later than 505 days after NTP
Gracon Corporation	NTP	
	Test and commission	220 days after NTP nut no sooner than May 22, 2012
	Completion of all work including clean up	250 days after NTP

Canyon Industries met all contract milestones. Gracon Corporation's substantial and final project completion dates were extended via change orders to September 14 and October 2, 2012, respectively. Gracon Corporation met both revised contract milestone dates.

Project Cost

Project costs through December 31, 2012 are summarized in this section to correspond to the DOE end of project. Relatively minor additional costs are anticipated by the city in 2013 related to project close-out and reporting, final equipment testing and continuing power purchase agreement negotiations with PSCo.

The original estimate to complete this project was $5,062,100, as shown below:

Table 6: Original (2009) Project Estimate

ITEM	ORIGINAL ESTIMATE
Equipment	
Turbine/Generator	$2,473,000
Refurbish generating transformer	$ 100,000
Construction	
Cost[3]	$1,599 ,100
Engineering	
Design/Construction	$ 640,000
Project Permitting/Support	$ 100,000
City of Boulder Staff Cost	$ 150,000
Totals	$5,062,100
Federal Cost Share	$1,180,000
Recipient Cost Share	$3,882,100

Total project costs as of December 31, 2012 were $5,862,858, an increase of $800,758 over the original estimate. The principal reasons for the cost increase include:

- During the course of the project, an opportunity arose to completely separate city and PSCo equipment and facilities which had previously been co-located within the power plant. PSCo required minor new easements on city property and new equipment to accommodate the changes. City payment to PSCo to complete this work was $145,000.
- The city had anticipated refurbishment of the existing generating transformer associated with the project at the time the grant proposal was submitted. It was subsequently determined that complete transformer replacement was necessary. This increased project cost by approximately $150,000.
- The cost of removing the two old generating transformers was approximately $60,000.
- The city also replaced the existing station service transformer at the hydroelectric plant. This work was not anticipated at the time the grant application was submitted and increased equipment, engineering design, construction and construction supervision costs by approximately $50,000.
- The city installed new circuit switching equipment required for the new generating transformer. This work was not anticipated at the time the grant application was submitted and increased equipment, engineering design, construction and construction supervision costs by approximately $40,000.
- General Contractor cost for the installation of the new turbine and generating equipment was approximately $350,000 higher than anticipated at the time the grant application was submitted.
- The project required approximately one year more than originally anticipated to complete. This resulted in higher consultant costs for continuing project involvement and accounts for the remaining balance of the increased costs.

[3] Excludes the cost of the Betasso bypass valve ($92,900) which was removed from the scope of the DOE project.

Contractors and Consultants

The contracts issued by the city for the project equipment and construction are summarized as follows:

Table 7: Equipment and Construction Contracts

Company	Role	Purchase Order	Initial Cost	Final Cost
Canyon Industries	Turbine/Generator	DP005825	$2,010,245.00[4]	$2,039,639.00
Gracon Corp.	Construction	DP006246	$1,926,200.00	$2,165,790.99
Virginia Transformer	Generating Transformer		$ 237,315.00	$ 237,315.00
Alstom Grid	Circuit Switcher	DP006264	$ 34,245.00	$ 37,045.00
Sturgeon Electric	Station Service Upgrade	DP006458	$ 43,367.00	$ 64,232.49

This project also involved a team of consultants. Consultant contract value/costs are summarized as follows:

Table 8: Consultant Contracts

Company	Role	Purchase Order	Initial Cost	Final Cost
AECOM	Design Engineer	DP006691	$ 640,000.00	$ 983,037.69
Exponential Engineering	Electrical Engineer	DP00632	$ 58,920.00	$ 94,113.75
URS Corporation	Historical Mitigation	DP005941	$ 50,000.00	$ 50,816.43

In addition, two consultants participated in the project through on-call continuing services agreements. Consilium Partners provided project manager assistance and construction supervision services, and Kris Kranzush provided project administration, permitting and DOE coordination.

Summary of Federal Expenditures

In accordance with grant requirements, federal expenditures were tracked separately from expenditure of city cost share funds. The following summarizes federal and city expenditures for the project as of December 31, 2012:

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[4] Includes the Betasso bypass valve ($92,900.00) which remained in Canyon's contract even though it was removed from the DOE project scope.

Table 9: Summary of Project Expenditures
12/31/2012

PAYEE	FEDERAL	COST SHARE	TOTAL
AECOM	$ 387,117.51	$ 595,920.18	$ 983,037.69
Alstom Grid	----	$ 37,045.00	$ 37,045.00
Canyon Industries[5]	$ 647,690.18	$ 1,201,304.34	$ 1,848,994.52
City Payroll/Benefits	-----	$ 161,175.36	$ 161,175.36
Consilium Partners	$ 1,928.17	$ 43,084.03	$ 45,012.20
Exponential Engineering	$ 4,500.00	$ 89,613.75	$ 94,113.75
Gracon Corporation	$ 76,222.00	$ 2,089,568.99	$ 2,165,790.99
Kris Kranzush	$ 37,114.57	$ 135,406.28	$ 172,520.85
Sturgeon Electric	----	$ 64,232.49	$ 64,232.49
URS Corporation	$ 25,408.22	$ 25,408.21	$ 50,816.43
Virginia Transformer	----	$ 237,315.00	$ 237,315.00
Misc. Expense	$ 19.35	$ 2,784.08	$ 2,803.43
Total	$1,180,000.00	$ 4,682,857.71	$ 5,862,857.71

There will be additional costs associated with project reporting, close-out and final testing during 2013. These costs will accrue to the cost share account.

[5] Final payment to Canyon Industries will not be made until successful testing of the unit occurs in early 2013.

CONCLUSIONS

Boulder achieved its primary objectives for the BCH Modernization Project, as follows:

- **Increase generation and efficiency of the 100-year-old hydroelectric facility.**
  A comparison of past and anticipated future performance of BCH is as follows:

Table 10: Comparison of Past and Anticipated Future Project Performance

	Existing 10 MW Unit	Proposed 5 MW Unit	Change from Existing
Expected Life	<5 years	50 years	>45 years
Average Annual MW-hr	8,500	11,660	3,160
Total lifetime MW-hr	42,500	583,000	540,500
Offset in Coal Consumption (tons)	22,000	300,000	278,000
Offset in SO_2 Emissions (tons)	30	450	420
Offset in NO_X Emissions (tons)	70	900	830
Offset in CO_2 Emissions (tons)	22,000	303,000	281,000

- **Increase safety for both personnel and equipment.**
  New "live" wiring has been installed, and asbestos clad wiring has been eliminated (except where preserved for historical purposes).
- **Increase environmental protection.**
  The city removed two 1940s oil-cooled, generating transformer units located on the bank of Boulder Creek and replaced them with a state of the art, smaller transformer and circuit switcher.
- **Modernize and integrate control equipment into the municipal water system.**
  The turbine isolation valve was replaced with a valve that can be remotely operated and will close automatically upon an emergency turbine stop as protection against equipment and piping damage.
- **Preserve significant historical engineering information prior to plant modernization.**
  Through photography, measured drawings and historical research, a complete and accurate record of the BCH history has been provided to state and local historical archives. Boulder was able to complete a major upgrade to a significant historical site without adverse effects.
- **Complete modernization with minimal regulatory delay to contribute to economic recovery through the creation and/or preservation of jobs.**
  Boulder received authorization from the Federal Energy Regulatory Commission to commercially operate the new BCH generating equipment on September 27, 2012. Barriers to start-up have included both a planned water system outage for pipeline maintenance and the need to negotiate a new power purchase agreement with the local electric utility. Commercial operation of the plant is anticipated in the first half of 2013.

From January 1, 2010 through December 31, 2012, combined consultant and contractor personnel hours paid for by both the city and the federal government have totaled approximately 40,000. This equates roughly to eight people working full time on the project from January 2010 through December 2012.

APPENDIX 1

History of the Boulder Canyon Hydroelectric Project

Extracted from:
Modernization of the Boulder Canyon Hydroelectric Project
Documentation of Historically Significant Features and Equipment
URS Corporation, September 14, 2011

INTRODUCTION

The Boulder Canyon Hydroelectric Project (BCH) is a power-generating system located between Boulder and Nederland, Colorado along Colorado Highway 119 and Boulder and Middle Boulder Creeks. BCH, which consists of Barker Dam and Reservoir, the Barker gravity line, Kossler Dams and Reservoir, the Boulder Canyon Penstock, and the Boulder Canyon power plant, is recorded as Site 5BL752. The Boulder Canyon power plant and associated structures, which are the focus of this study, have been recorded as Site 5BL754. The power plant site is surrounded by steep, forested hills and includes a hydroelectric generating power plant (built 1909-1910), two transformer yards (Feature 5 completed in 1909 and Feature 6 completed in the late 1940s), a seven-bay vehicle garage (1937), four storage buildings (circa 1940 to 1950), and a contemporary switching building (1992). Detailed construction plans were found for the seven-bay garage, dated 1937, but a similar structure appears on a 1932 sketch map of the site. The majority of the power generating and switching equipment inside the power plant was installed during the 1930s when the plant was substantially rebuilt. The piping, gates, and other fixtures used to direct the flow of the water used for power generation are almost all original, dating to 1909-1910.

The water that is used for generating electricity is obtained from Barker Reservoir and Middle Boulder Creek, and is transported in a gravity pipeline (approximately 11.7 miles in length) from Barker Dam (located on the eastern edge of Nederland, Colorado) to Kossler Reservoir (located southwest of the power plant). From Kossler Reservoir, the water runs down a steep hill through a steel pressure line or penstock to the power plant. Kossler Reservoir is 1,800 feet higher in elevation than BCH, and penstock water pressure reaches approximately 840 pounds per square inch (psi) at the power plant. When constructed in 1909-1910, the primary water source for BCH was Barker Reservoir. In the years since, the primary use of the reservoir has shifted to that of municipal water storage for the City of Boulder (City). BCH now operates primarily on stream flow diverted from Middle Boulder Creek and directed to BCH through the gravity pipeline and penstock. Following generation, the water is discharged back to Boulder Creek at the power plant to meet in-stream flow requirements or downstream senior water rights. The City's Barker Reservoir/Middle Boulder Creek water supply is also transported by the gravity line, Kossler Reservoir, and the penstock, but it by-passes the hydroelectric plant upstream of the turbines and is transported to the Betasso Water Treatment Plant north of BCH for treatment and distribution within the City.

The City is currently undertaking replacement of one of two turbine/generators that are located in the 1909-1910 hydroelectric generating building. Two turbines/generators, each capable of producing 5 megawatts (MW) of power, were originally installed in the building. In the mid-1930s, upgrades to the generators increased the capacities to 10 MW each, for a total plant capacity of 20 MW. One generator (Unit A) failed in 2000 and was not repaired. The other unit (Unit B) has continued to supply power and will be replaced by a new 5-MW unit, which is the appropriate capacity for the water now available for generation at BCH. The City will leave the existing Unit A turbine/generator in place, but it will be inoperable. The City is also planning to replace transformers (c. 1940), install enhanced lightning protection, upgrade the wiring, remove and replace an old storage tank, and install a state-of-the-art turbine isolation valve and remote monitoring and operation equipment. In conjunction with new equipment installation, much of the large cast-iron piping within the power plant building (c. 1909) that directs water to the turbines, and several small pumps and controllers will be replaced (City of Boulder, Department of Public Works 2009a:3)

The writing of this context has presented certain factual challenges untangling the identities of the corporate entities that planned, constructed, and operated the Boulder Canyon Hydroelectric system. The system was proposed by the Denver-Eureka Power Company (DEPC), construction was started by the Eastern Colorado Power Company (ECPC) and continued under the auspices of the Central Colorado Power Company (CCPC), which operated the plant from 1910 until 1913. In April of 1913, the Colorado Power Company (CPC) was formed to acquire the assets of several companies, including the CCPC. In 1924, CPC merged with Public Service Company of Colorado (PSCo). In 2000, PSCo merged with Northern States Power and Southwestern Public Service to form Xcel Energy, Inc. (Xcel). In 2001, Xcel sold BCH to the City, which continues to operate the plant today. The City sells the electricity generated at the BCH power plant to Xcel.

Several sources have been used to compile this context. The most comprehensive history of BCH, and one that has been the foundation of most subsequent work, was written by W. Clinton DuVall, a professor of electrical engineering at the University of Colorado, who taught there from 1919 until 1957. DuVall briefly worked for CCPC after completing college (University of Colorado College of Engineering 2011). DuVall produced his history of the site at some unknown date, in the form of an article that appeared in the *Boulder Daily Camera* (BDC). This piece, which detailed the development and construction of the plant, was reprinted in the BDC on July 14, 1960 to mark the 50th anniversary of the site. The exact date of the original article is unknown. The reprinted article notes only that, “It was written for the *Camera* many years ago by W. Clint [sic] DuVall…” (DuVall 1960).

Other histories of the plant have been produced, including several published by PSCo (1959, 1960a, 1960b, 1976, McAdams and Volstad 1982) and accounts written by Barbara Kossler (1960), Manuel Weiss (1980), Andrew Ferguson (2008), and Kris Kranzush (2010a). One of the underlying goals for this context was to analyze and attempt to reconcile conflicting statements that appeared in these various histories and to develop a comprehensive summary of the planning, construction, and operation of the plant. With the exception of a report by Curtis and Hine (1906), primary documents from the involved corporations relating to the period of construction are not present in the library archives examined for this study. Some primary documents apparently exist at PSCo/Xcel (see the article by McAdams and Volstad 1982). Xcel has not responded to requests for information. Newspaper articles published during the period of construction and throughout the operation of BCH, and photographs from the construction period provide the best historical documentation of BCH.

REGULATORY HISTORY

The use of water for hydroelectric power generation is regulated by the federal government. Early federal stream legislation had to do chiefly with preventing or removing obstructions to navigation. The Federal Water Power Act of 1901, however, empowered the Secretary of the Interior to permit rights-of-way through public lands and forest reservations “for electrical plants, poles, and lines for the generation and distribution of electric power” (Pinchot 1946), and the original filing for BCH with the U.S. Department of the Interior may have occurred in compliance with the 1901 Act.

The Federal Water Power Act of 1920 firmly established the principle of federal regulation of water power projects, limited licenses to not more than 50 years, and provided for government recapture of the power at the end of the franchise. The Act of 1920 provided for the administration of the Act by a commission of three – the Secretaries of War, U.S. Department of the Interior, and U.S. Department of Agriculture. The 1930 Reorganization Act provided for an independent commission of five full-time members authorized to employ a staff of its own (Pinchot 1946).

The Federal Power Act of 1935 authorized the Commission established under the 1930 Reorganization Act to regulate the interstate transmission and sale of electric energy. Federal control of water power continues today under the 1935 Act and its many subsequent amendments.

The Secretary of the Interior is authorized by 43 United States Code §1714 to make, modify, extend, or revoke withdrawals of land from the public domain. Withdrawals prevent an area of federal land from settlement, sale, location, or entry under some or all of the general land laws (e.g., those pertaining to homesteading or mining) for the purposes of limiting activities under those laws. Withdrawal maintains other public values in the area or reserves the area for a particular public purpose. Withdrawal also occurs by the transfer of jurisdiction over an area of federal land from one federal agency to another (USLegal.com 2011). A common means of withdrawal is by Executive Order.

There is a federal power withdrawal overlaying portions of the Barker Gravity Pipeline and Penstock that were not already private property when BCH began, reserving these areas for use in power production. The date of this withdrawal is not known, and documentation of this withdrawal was not examined in conjunction with this study. It presumably could be obtained from the Bureau of Land Management.

The last license for the hydroelectric project was issued by the Federal Energy Regulatory Commission (FERC) in 1979 and expired in 2009. The City applied to FERC in March of 2009 to convert the existing license for BCH to a conduit exemption from licensing. The exemption was granted in November 2010.

CORPORATE HISTORY

The earliest recorded proposal for a Boulder Canyon Hydroelectric plant was made by DEPC. DEPC filed an application in June 1903 with the U.S. Department of the Interior to construct a dam to take water from Boulder Creek by Tungsten (located east of Nederland) through a gravity line to the present location of Kossler Reservoir, then down the mountain slope to a hydroelectric plant located near the present-day site of BCH (DuVall 1960). The water rights for the project were appropriated on December 18, 1906 and reviewed and adjudicated on October 18, 1928 (Kranzush 2010b:3). DuVall (1960) reported that the equity of the DEPC was purchased by the CCPC from W. Hollingsworth McLeod.

The CCPC was incorporated on November 13, 1906, to promote the ideas of Leonard E. Curtis and Henry Hine to use the Colorado River (then called the Grand River) for hydropower. Curtis and Hine were electrical and hydraulic engineers in Colorado Springs who had been studying the Colorado River for several years and proposed constructing power plants at Shoshone (near Glenwood Springs) and at Gore Canyon (near Kremmling), with a storage reservoir at Williams Fork (Curtis and Hine 1906; Stone 1918:317, 318).

The CCPC was founded with a capital investment of $22.5 million (Stone 1918:317). According to DuVall (1960), the Chairman of the Board was Myron T. Herrick of Cleveland, Ohio; the President was J.R. McKee; and Leonard Curtis, Henry Hine, S.Z. Mitchell, and Copley Amory were Vice Presidents. Additional people on the Board of Directors were David H. Moffat, J.A. Hayes, Irving W. Bonbright, Geo. L. Peabody, Orland B. Wilcox, and Horace G. Lunt. Stone (1918:317) lists the above people as "incorporators and first directors," and excludes S.Z. Mitchell, I.W. Bonbright, and G.L. Peabody. Stone includes four names not listed by DuVall: Charles A. McNeill, George B. Tripp, George B. Bucknan, and T.P. Hanson.

Herrick, a former governor of Ohio, was a wealthy businessman who helped start The National Carbon Company that later became the Eveready Battery Company (Ohio Historical Society 2009). Along with many mine and railroad holdings throughout the state, Moffat is significant to Colorado history for his development of the 6.3-mile long Moffat Tunnel through the Continental Divide, allowing intercontinental railroad traffic to go over the Rocky Mountains. Moffat's work with the transportation industry helped to make Denver the railroad hub for the West, and as such established Colorado as a nationally important commercial and industrial center (State of Colorado 2011).

The corporate history of the CCPC was more complex than that presented by Stone and DuVall. An article in the BDC on March 6, 1910 entitled, "Herrick In Control of Central Power," states that Curtis and Hine retired from CCPC, and "F.C.Wolcott, G.H. Walbridge, and Myron T. Herrick, representing the General Electric Co. and eastern financial interests, were elected to the board. S.Z. Mitchell, another representative of the electrical corporation, is on the board" (Boulder Daily Camera 1910a). One can only guess at the reasons Curtis and Hine "retired" from the company, or were forced out. A BDC article published on January 4, 1908, however, states that the company "…is headed by ex-Governor Myron T. Herrick of Cleveland, Ohio. G.H. Walbridge of Colorado Springs is General Manager of the company, Albert Carr, Engineer of Construction, and J.W.E. Taylor, Superintendent. All of the above are men of affairs and have been identified with the construction of some of the greatest industrial projects of modern times."

According to Stone (1918:318), "Messrs. Curtis and Hine undertook the construction of a finely planned system at Shoshone, on the Grand River (now the Colorado River), "…its construction was progressing so satisfactorily that a second company was formed on May 13, 1907, and known as the Eastern Colorado Power Company, with Horace G. Lunt, John T. Adams, and Henry Hine as incorporators. The purpose of this was to build a dam at Nederland in Boulder County, with a complete plant on Middle Boulder Creek."

Construction of the plant that is today known as BCH by the ECPC began on April 10, 1907 (Boulder Daily Camera 1908). A BDC article on July 11, 1907 reported, "Many Men Wanted – Hydraulic Company needs men and will pay good wages." "The power house of the Eastern Colorado Power Co. at Four Mile wants for probably 20 months, men in numbers, and wages…" (Boulder Daily Camera 1907a)[1]

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[1]The article went on to state, "This is a free notice copied from a circular issued by the company and because it is regarded as being of interest to men who are seeking work:

Needed:	350 Pick & Shovel men,	at $2.50/day
	150 Hammermen	" " and up/day
	30 2-Horse Skinners	" "
	10 4-Horse Skinners	" $3.00/day

On July 26, 1907, the BDC reported, "Hundreds Laid Off", "Payroll of Eastern Hydraulic Co. cut down by sweeping order laying the men off for 10 days or more," and, "Several hundred men laid off by Eastern Hydraulic Co., nothing doing until Aug 15 on the huge works in Boulder County save at the Nederland Dam site at Sulphide. General Superintendent Taylor -- "Reason is work is ahead of machinery" (Boulder Daily Camera 1907b)

By January 1908, the ECPC was described as a subsidiary of the CCPC (Boulder Daily Camera 1908). According to histories published by PSCo, construction was halted by the economic depression of 1907, and the ECPC, "having had financial difficulties, was taken over by the CCPC" (Public Service Company of Colorado 1960a). The PSCo brochure produced for the 50th anniversary of the hydroelectric plant, with the text also printed in the BDC (Public Service Company of Colorado 1960b), states that construction did not resume until 1909, "this time under the auspices of the CCPC, which had combined assets with the ECPC."

Whatever the precise corporate relationship of the ECPC and the CPCC was, plans with both ECPC and CCPC labels were produced for the project through 1909. The ECPC continued to be mentioned in newspaper articles (Boulder Daily Camera 1909, 1910b) at the same time the CCPC was referred to in other articles about the BCH.

A BDC article dated February 18, 1911 titled, "Manufacturer Wants Pay from Power Co.," discussed the lawsuit the I.P. Morris Co. filed against the ECPC for payment of $79,038.80 for manufacturing and installing two impulse water wheels with necessary accessories in June 1907.[2] The original contract for the water wheels was with the Electric and Hydraulic Co., which later disposed of its interest in the property to ECPC. Other defendants named were the "Central Colorado Power Co., of which the Eastern Colorado Power Co. is a subsidiary, Knickerbocker Trust Co. –which holds a deed of trust from Central Colorado Power, & the McArthur Bros. Co. & Reinforced Concrete Pipe Co. (which have filed liens on Power Co.'s property). I.P. Morris Co. seeks decree of first lien."

The "Electric and Hydraulic Co." named in the above article does not appear in any other source. It is unknown if the "Eastern Hydraulic Co." named in the July 26, 1907 BDC article quoted above is the same company, a misnomer, or some sort of subsidiary of the ECPC (Boulder Daily Camera 1907b).

It thus appears that ECPC did become a subsidiary of CCPC, as both companies were operating during construction of the project. ECPC is named as a "subsidiary concern" of CCPC as late as November 1912 (Boulder Daily Camera 1912).

DuVall's history (1960) makes no mention of the ECPC, and his assertion that the "Boulder Canyon Project is a part of the original plan of the CCPC to develop hydro-electric power in Colorado" is incorrect. The CCPC's original plan was for projects at Shoshone, Gore Canyon, and Williams Fork. The BCH was conceived later, and put into play by the ECPC. The two

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50 Tracklayers	" $2.50/day
50 Hoist & Tram Men	" " "

Board - $5.25/week
Hospital Fee - $1.00/month
Pay Day on the 12th of every month."

[2]If power house construction indeed began on April 10, 1907 as reported in the BDC on January 4, 1908, construction would have proceeded at an incredible rate to allow turbine installation in June 1907. One of these dates may be incorrect.

companies shared leadership, in particular Henry Hine and Horace G. Lunt, were incorporators of both companies, but the companies were originally separate corporations. The statements in PSCo histories indicate that the ECPC started construction on BCH in 1906 and are clearly incorrect, since the ECPC wasn't formed until 1907.

The assertions by the PSCo histories (1960a, 1960b, 1976), and repeated by Weiss (1980), that construction was halted by the economic depression of 1907 and not resumed until 1909 are incorrect, as are the statements that the Barker Dam site wasn't chosen until 1909. The depression did affect construction, resulting in a large reduction in manpower. The BDC article published on January 4, 1908 states that, "During the fall, previous to the failure of the Knickerbocker Trust Company, between 600 and 700 men were employed at the various camps… The original plans, which provided for the construction of the Sulphide dam first, were changed and work was shifted to the Barker meadows, where winter quarters were built and arrangements made to push the construction through… A steam shovel is now at work below the dam site… ….about 50 men are now employed at the Barker dam and this will be increased as fast as weather conditions permit the working of a larger force. It is expected that by the first of May, 300 men will be employed at Barker meadows, when the work will go forward night and day."

The original plans for BCH included two dams, two power plants, and a storage reservoir in Boulder Valley. The location chosen for one of the dams (Sulphide Flats, to create "Nederland Reservoir") was found to be unsuitable, and as described above, work was switched to the second dam site in Barker Meadows on land owned by Hannah Barker, who refused to sell the land to the power company. The land was acquired through condemnation proceedings, with a legal fight for valuation filed by Barker (Boulder Daily Camera 1907c, City of Boulder, Department of Public Works 2009a).

It is unclear if work was actually halted on the project sometime in 1908, or just slowed. There is an absence of news articles about the project after January of 1908 and until 1909.

CCPC ultimately completed two plants in the state—BCH and the Shoshone plant along the Colorado River near Glenwood Springs. A third plant, planned for a site in Gore Canyon near Kremmling, was never completed (DuVall 1960).

On March 16, 1910, the stockholders of the CCPC elected (or re-elected) Myron T. Herrick as Chairman of the Board. Herrick …"is said to be one of the largest stockholders in the General Electric company, a corporation which handles millions like ordinary capitalists do thousands. S.Z. Mitchell, another General Electric representative is on the board, and Mitchell is also identified with many of the million-dollar corporations in which Henry L. Doherty, of the Denver Gas & Electric company, is a conspicuous figure. The complete board of directors selected yesterday is as follows: Myron T. Herrick, J.R. McKee, George C. Lee, Jr., George L. Peabody, Copley Armory, Irving W. Bonbright, F.C. Walcott, Starling W. Childs, Bulkeley Wells, G.H. Walbridge, and O.B. Wilcox." O.B. Wilcox stated, "…It is all nonsense to talk of the Central being behind a gigantic power trust. We will fill our own particular field and there is plenty of room for everybody" (Boulder Daily Camera 1910c).

By November of 1912, George H. Walbridge was President of CCPC and Lyman P. Hammond was Vice President. They were appointed as co-receivers by the federal court as CCPC was placed in receivership, on application by the Columbia-Knickerbocker Trust Company of New York. The action stemmed from the default of agreement charged to CCPC in permitting liens to be obtained against its property, and inability of CCPC to make the first semi-annual payment of interest on its debts. CCPC is described as the largest producer of electric power in the state, including supplying one-half the power of the Denver Gas and Electric Co. (Boulder Daily Camera 1912).

In April 1913, the CPC was formed and took over the properties of the CCPC and ECPC (Stone 1918:318). Officers of the CPC in January of 1918, all of New York City, were George H. Walbridge, President; S.Z. Mitchell and L.P. Hammond, Vice Presidents; and Irwin W. Day, Treasurer. “The Colorado Power Company is controlled by Bonbright & Co. of New York, which firm also is closely identified with the General Electric interests” (Stone 1918:320).

PROJECT HISTORY

Construction of Barker Dam, Kossler Reservoir, BCH, and the gravity pipeline (shown on Figure 1) began in earnest in 1908-1909. By October 1909, the three dams that formed Kossler Reservoir and the 11.7-mile gravity pipeline were completed, and the first water flowed through the gravity pipeline on September 1, 1909 (Public Service Company of Colorado 1959:2). Construction on Barker Dam and various parts of the system continued until completion in 1910.

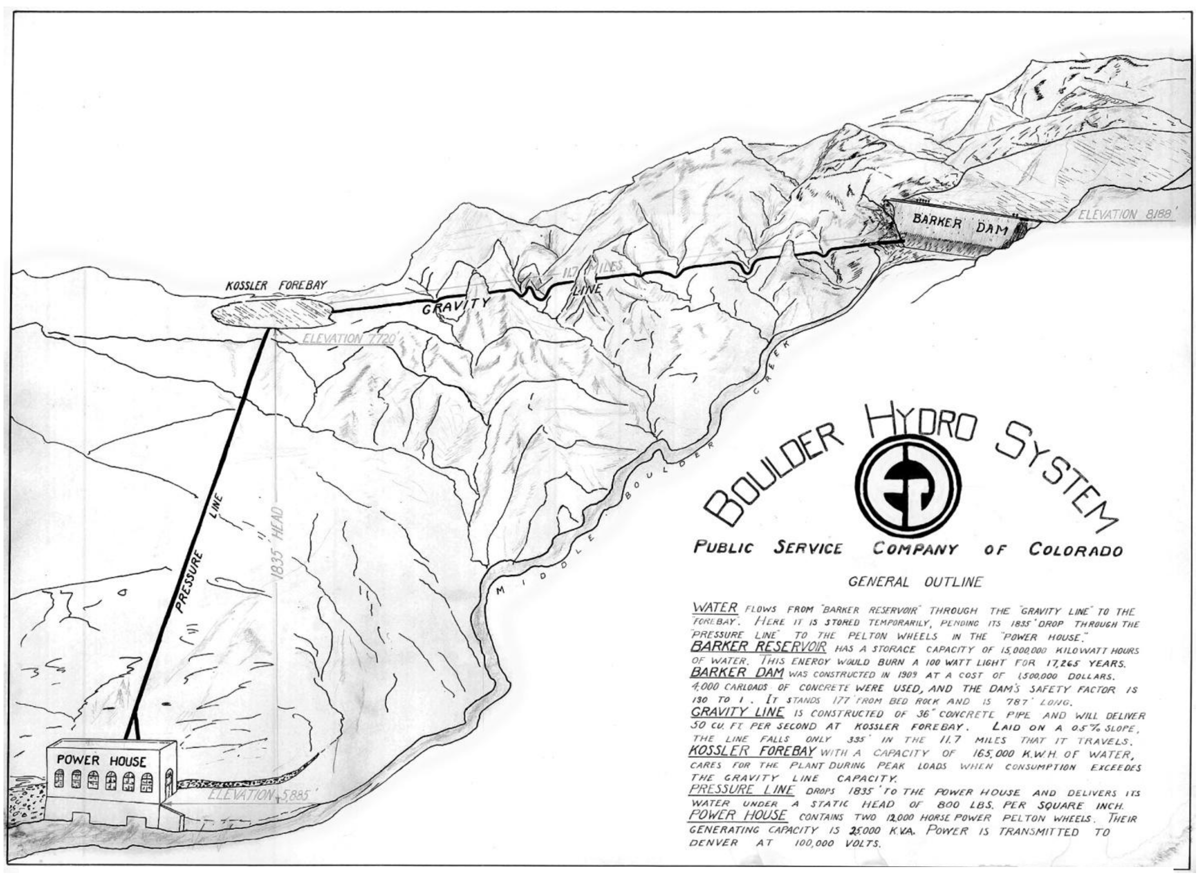

Figure 1. Boulder Hydro System – PSCo, c. 1920.
Image: Betasso Water Treatment Plant Collection.

Barker Dam was designed by the J.G. White Company, a prominent civil engineering company based in New York City with wide experience in dam construction and other large-scale projects. The actual construction was managed by W.G. Finkle and McFarland Doble, two consulting engineers from San Francisco, while the McArthur Brothers Company served as the general contractor (DuVall 1960). Little information has been found on Finkle, Doble, or the McArthur Brothers. It is known that the MacArthur Brothers Company was involved in large construction projects across the United States.

The dam structure, which cost $2.7 million, was built with a storage capacity of 500 million gallons (12,000 acre-feet) and measures 175 feet in height with a width of 720 feet and is made of cyclopean concrete. In 1946 and 1947, PSCo modified the outlet works on Barker Dam and made improvements to the upstream face of the dam. In 1971, the spillway was enlarged with a new 125-foot ogee crest with a curved channel and a warped floor. Cosmetic improvements were made to the downstream face of the dam in 1971. The dam was secured in the early 1980s with post-tensioned anchors to increase the factor of safety. The City paid for the repair at a cost of $3,315,000 and received a perpetual right to use 8,000 acre-feet of Barker Reservoir storage from PSCo in return (City of Boulder, Department of Public Works 2009b).

The main dam at Kossler Reservoir is much smaller, standing 18 feet high with a width of 450 feet. It was built to contain approximately 5 million gallons of water. Very little design and construction documentation is available for the Kossler Reservoir dams and appurtenant facilities, and few repairs or modifications have been made over the years (City of Boulder, Department of Public Works 2009b). The City plans to install a stability berm and toe drain system on the main (southeast) Kossler Dam in 2011.

The gravity pipeline that feeds water from Barker Reservoir to Kossler Reservoir is approximately 11.7 miles in length, and consists of a cylinder made of reinforced concrete sections (Figure 2), each measuring 36 to 38 inches in diameter (Public Service Company of Colorado 1959).

Figure 2. Workers fabricating steel-reinforced concrete gravity pipeline sections at one of the work sites (perhaps Magnolia work camp) established during the project. Photo: Carnegie Branch Library for Local History, Boulder, Colorado, *Boulder Daily Camera* Collection.

Construction of the gravity pipeline required a substantial amount of engineering and work to complete. The pipeline crossed a landscape made up of steep, rugged hillsides, sheer rock faces, heavily forested areas, and meadows. Few roads existed, and supplies and materials had to be carried to work areas with great difficulty. In some areas, tunnels and inverted siphons had to be built.

Water stored at Kossler Reservoir flows to the power plant through a steel pipeline or penstock that regulates the flow of water into the plant. The line is 58 inches in diameter at the top of the system (where it leaves Kossler Reservoir) and narrows to a line that is 44 inches in diameter near the bottom, with thicker side walls to contain the higher pressure (DuVall 1960). This line drops more than 1,800 feet in elevation (Figure 3) and gathers a pressure of 840 psi (the highest recorded at a hydroelectric plant at that time) by the time it arrives at the plant (DuVall 1960).

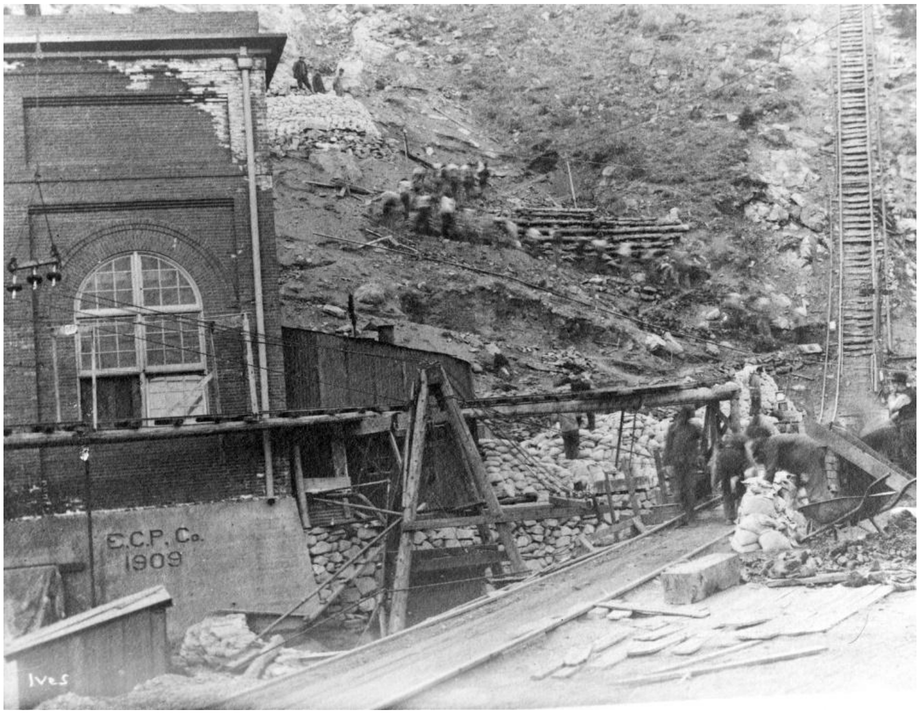

Figure 3. Construction of the BCH building and pressure line. Note the rail track used to move materials that traveled up the hill adjacent to the building. Photo: Western History Collection, The Denver Public Library.

The construction of this pipeline, which enters the building on the south side of BCH, required special engineering and fabrication techniques. The system consists of a steel line buried in the side of a steep hillside southwest of the plant. When constructed, the line consisted of steel sections held together with 2-inch rivets. The tremendous pressure generated by the water flow overwhelmed these connections, and the pipeline suffered constant leaks and joint failures. Engineers determined that a new method of joining the pipe sections was needed. A welder skilled in using acetylene gases (a new technique that was just emerging) traveled to the site from Kansas City, Missouri. The welder and workers at the plant determined that the metal around each joint had to be ball-peened (struck with the rounded end of a ball-peen hammer) during the welding process. This process strengthened the joint sufficiently. BCH has been recognized as the site that introduced the steel penstock method of welding to the world (DuVall 1960). In 1994, the Boulder Canyon Hydroelectric Facility Penstock was awarded the Historical Welded Structure Award by the American Welding Society as it was the first structure in which acetylene welding in conjunction with the ball-peen welding procedure was used and significantly advanced penstock technology when constructed in 1910.

The construction of the plant presented its own challenges. The site was located along a twisted path in Boulder Canyon, more than 1 mile from the nearest rail stop. Equipment and building materials were brought to the rail yards in Boulder where they were transferred to narrow-gauge cars for transport to Orodell (located in Four Mile Canyon). There they were unloaded and transferred to horse-drawn wagons that brought them to the power plant site. Many items were so large that individual components had to be shipped piece-by-piece. Heavy equipment, like the turbines and generators, required as many as sixteen horses to pull one wagon.

Figure 4. Interior of BCH, August 4, 1910, opening day. Note Unit B is in the foreground.
Photo: Carnegie Branch Library for Local History, Boulder, Colorado, *Boulder Daily Camera* Collection.

Steel transmission towers were used to hold the wires that transmitted the power that would be generated to Boulder and Denver. The use of steel for these types of towers was unusual, but it was thought this material would better endure lightning strikes, high winds, and harsh winter conditions that the transmission lines would face (DuVall 1960).

Approximately 18 months after construction started on the buildings for the power plant, the BCH plant began generating power (on August 4, 1910). Two I.P. Morris Waterwheels were connected to two General Electric generators, each producing 5,000 kilowatts (KW) of power, for a total capacity of 10,000 KW (Figure 4).

When completed, BCH was seen as the most advanced plant of its type in the nation and was visited by a large number of engineers and power company representatives from across the country (DuVall 1960). Pictures of the plant also appeared in many technical journals and magazines (DuVall 1960).

Ownership of BCH changed hands in 1913, when the CPC purchased CCPC. In 1924, CPC merged with PSCo (McAdams and Volstad1982). The BCH site contained five houses where the plant operators and their families lived. One long-time resident and operator was Everett H. Brines, who worked at BCH for 38 years (1920-1958). He and his wife, Daisy Irene, raised six children at the site, and lived in one of the small houses there until Everett reached the mandatory retirement age of 65. Everett Brines wrote an informal memoir that included numerous stories about living and working at the plant. He recalled that he was paid $90 a month to operate the switch board at the plant. His compensation also included free rent, water, and utilities. Brines tells a story about constructing electric resistance heaters out of wire to help heat the houses at BCH. As Brines relates: “The resistance in the iron wire caused them to heat. The coils had no insulation and they were dangerous. How we ever raised the kids without more accidents, I’ll never know. June [one of his daughters] fell into one of the heaters and was burned pretty bad. She still has scars on her back…Stan [a son] also got burned and still has the scars…We finally made some screens to put on the heaters so they weren’t so dangerous” (Brines 2010:22).

Brines also recalled lightning strikes at the plant that would “throw a load on our generators and they would start to groan and make a hell of a noise” (Brines 2010:24). Brines also relates how, on November 1, 1933, he lost his right hand when he accidently touched one of the 13,000-kilovolt (KV) circuit breakers. The resulting arc burned his hand so badly it had to be amputated. Later he was given an artificial hand, but he found it troublesome and never used it (Brines 2010:28). The Brines memoir mentions many families significant to the history of western Boulder County, including Sweeney, Betasso, and Blanchard, and gives a good overview of the social life in Boulder and Boulder County during the early 20th century.

In 1928, the Unit A turbine was replaced with a larger Pelton wheel. The new turbine had a capacity of 12,000 horsepower (HP), while the original was rated for 10,200 HP. The installation of this turbine caused the closure of BCH for 1 week.

BCH was substantially rebuilt in the mid-1930s, when new generators, circuit breakers, and control panels were installed. The small tool shop on the northern side of the building was expanded, and a clerestory monitor was installed on the roof (Figure 5 shows the plant before the renovation; Figure 6 shows the plant in 1936, following the 1935 rebuild). Much of the equipment currently installed in the plant dates to this period. An article from 1932 reported that the work would cost $225,000 (Boulder Daily Camera 1932). The new generators that were installed in the plant doubled the capacity of each unit to 10,000 MW, and the total modernization project cost $287,000 (Boulder Daily Camera 1947). It is not known if any of the funds used for this reconstruction came from New Deal agencies or programs or was paid for solely by PSCo. A search of records from that period failed to identify the funding source for this work, but it should be noted that this was a substantial expenditure for any company to make during the Great Depression.

Figure 5. BCH, c. 1925, before a substantial renovation and modernization project took place in the mid-1930s.
Photo: Western History Collection, The Denver Public Library.

The plant was upgraded again in 1948, when a new transformer yard was completed on the north side of the plant. This project required the construction of a large retaining wall along Boulder Creek that created a flat area containing two transformers that serve the A and B generators inside the building. Some records suggest that the retaining wall and resulting yard may have been built in the 1930s, but the transformers were not installed until the late 1940s. The transformers are designated as Bank A and Bank B (serving the Unit A and B generators) and transfer power into the 115-KV transmission lines located above the yard (Figure 6). In addition, new power lines were built to transmit power

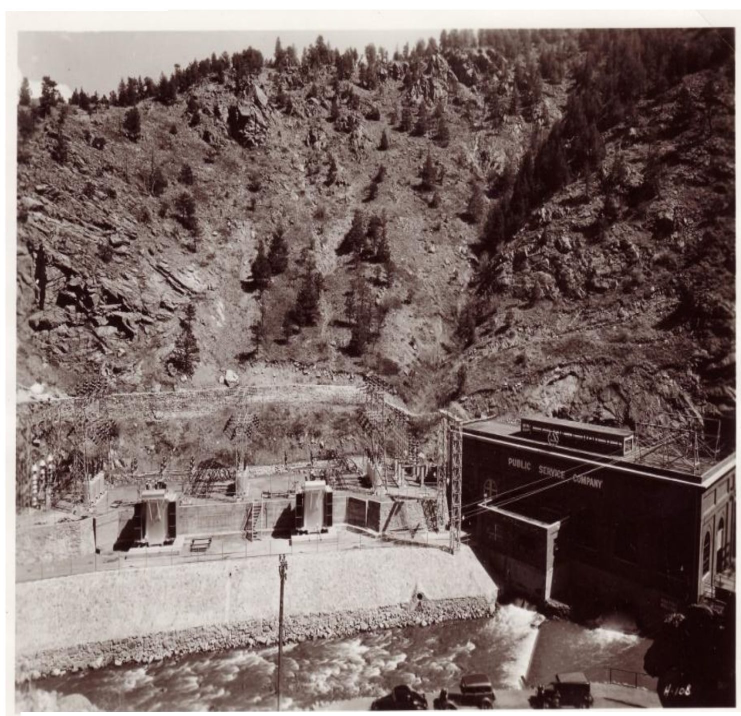

Figure 6. BCH, summer of 1936, after the 1935 rebuild and the construction of the northern transformer yard.
Photo: Betasso Water Treatment Collection.

from the plant. Two 13,000-MW lines were planned and built using 55 tons of copper wire on a 5-mile line (Boulder Daily Camera 1948)

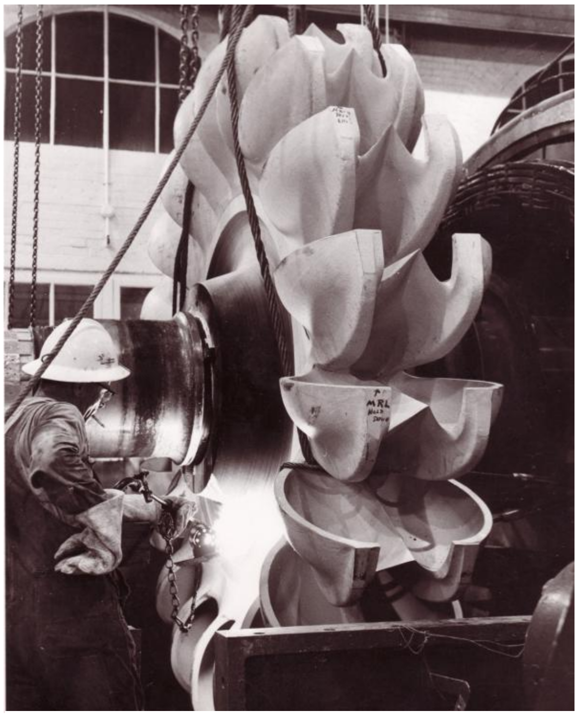

Figure 7. A worker heating the hub of the new water wheel, June 1959.
Photo: Betasso Water Treatment Collection.

In 1959, the Unit B turbine at the plant was replaced. The new wheel was a 9-ton, 110-inch diameter wheel from the Pelton Division of the Baldwin-Lima-Hamilton Corporation of Philadelphia (Figure 7). The wheel was cast in Switzerland and machined in San Francisco, California, and was expected to last for at least 30 years (Boulder Daily Camera 1959). One of the two generators at the plant had to be rebuilt in 1964 after an operating mishap caused so much vibration that the generator broke its mounting bolts and lifted itself out of its pit, causing substantial damage (Ferguson 2008:1).

More changes occurred in the ownership of the plant during the late 1990s and early 2000s. The first change occurred when PSCo merged with the Texas-based Southwestern Public Service Company in 1997 to form New Century Energies (NCE). This was followed by the 2000 merger of NCE and the Minneapolis, Minnesota-based Northern States Power Companies, which resulted in the formation of Xcel. A year later, in 2001, the City purchased BCH, along with the Barker and Kossler Dams and Reservoirs, the Barker gravity line, and the BCH penstock from Xcel for $12.4 million (Thompson and Westmore 2002:iii). Shortly before the City purchased BCH, the Unit A generator failed and was not repaired.

The City was awarded $1.18 million in federal funds by the U.S. Department of Energy in January 2010. The money will be used to partially defray the cost of replacing the remaining operating turbine/generator at BCH (Unit B) with a new 5-MW unit. The City will leave the other c. 1936 turbine (Unit A) in place, but it will be inoperable. Even at a smaller capacity than the existing equipment, actual annual generation will increase by about 30 percent because of the increased efficiency of the new equipment and the decreased operational downtime compared to the old equipment (City of Boulder, Department of Public Works 2009a:3). The total project cost will be $5.15 million.

ELIGIBILITY

When BCH was constructed in 1910, it featured the highest head hydroelectric plant in the western United States, and possibly in the country, and helped create new sources of electrical power for the growing cities of Boulder and Denver. It is therefore recommended as eligible for nomination to the National Register of Historic Place (NRHP) under Criterion A. BCH was backed by several investors of historic importance (most notable were Myron T. Herrick and David Moffat) and is therefore recommended as eligible for nomination to the NRHP under Criterion B. The plant is notable in terms of construction difficulty and technological challenges.

The steel penstock/pressure line running from Kossler Reservoir to the plant was the first recorded use of the ball-peen hammer method of welding. Due in part to its unique engineering features and innovative construction techniques, BCH is considered eligible for listing on the NRHP under Criterion C at the local level (for power generation to Boulder and Denver), the state level (for regional power generation and playing a role in the development of hydro-electric power in Colorado), and at the national level (the technical innovations that occurred and that were used in later projects).

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APPENDIX 2

Construction Photographs

Construction Photographs

Figure 1 – Removal of Old Turbine & Generator (12/1/11)

Figure 2 – Removed Turbine Piping (12/20/11)

Construction Photographs

Figure 3 – Turbine Pit Concrete Demo (1/12/12)

Figure 4 – Removal of Existing TIV (2/16/12)

Construction Photographs

Figure 5 – Delivery of Turbine & Piping (2/22/12)

Figure 6 - Reinforcement Install for Turbine Pit (3/2/12)

Construction Photographs

Figure 7 – Installation of New TIV (3/15/12)

Figure 8 – Betasso Bypass Piping (4/6/12)

Construction Photographs

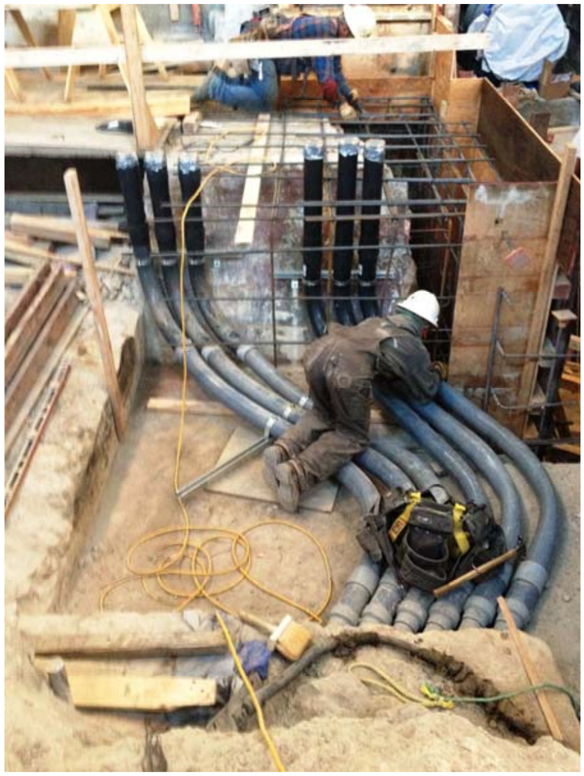

Figure 9 – Electrical Conduit Install (4/6/12)

Figure 10 – Betasso Bypass Valve (4/10/12)

Construction Photographs

Figure 11 – Concrete Removal (4/18/12)

Figure 12 – Transporting New Transformer Across Access Bridge (4/19/12)

Construction Photographs

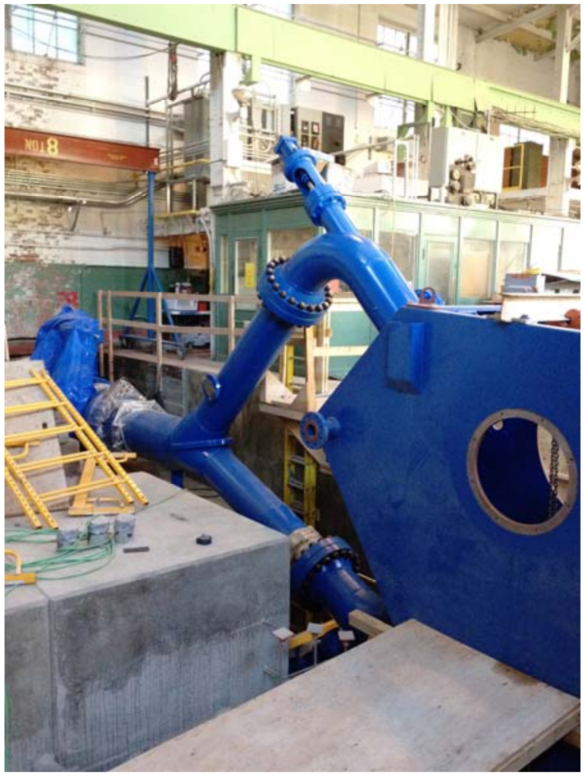

Figure 13 – Turbine Housing & Piping Install (5/3/12)

Figure 14 – Reinforcement Install for HPU & LPU Pad (5/10/12)

Construction Photographs

Figure 15 – Accumulator Tanks Install (5/15/12)

Figure 16 – Circuit Switcher Install (5/15/12)

Construction Photographs

Figure 17 – Generator Sole Plates (5/15/12)

Figure 18 – LPU Install (5/29/12)

Construction Photographs

Figure 19 – Generator Install (6/5/12)

Figure 20 – Turbine Runner Install (6/14/12)

Construction Photographs

Figure 21 – Walkway & Accumulator Tanks (6/14/12)

Figure 22 – Equipment Overview

Construction Photographs

Figure 23 – Turbine & Generator Assembly (9/6/12)