California Energy Commission

CONSULTANT REPORT

Design and Construction of Alturas Schools Geothermal Heating Project

Prepared for: **California Energy Commission**
Prepared by: **Modoc Joint Unified School District**

Gavin Newsom, Governor

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PREFACE

The California Energy Commission's Geothermal Grant and Loan Program provides funding to local jurisdictions and private entities for a variety of geothermal projects.

Design and Construction of Alturas Schools Geothermal Heating Project is the final report for the Geothermal Grant and Loan Program grant Agreement Number GEO-14-002, conducted by Modoc Joint Unified School District. The information from this project contributes to the Geothermal Grant and Loan Program's overall goals to:

- Promote the use and development of California's vast geothermal energy resources.
- Mitigate any adverse impacts caused by geothermal development.
- Help local jurisdictions offset the costs of providing public services necessitated by geothermal development.

For more information about the Geothermal Grant and Loan Program, please visit the Energy Commission's website on the [Geothermal Grant and Loan Program page](http://www.energy.ca.gov/geothermal/grda.html) (http://www.energy.ca.gov/geothermal/grda.html), or contact the Energy Commission's Renewable Energy Division toll-free in California at 844-454-2906 and outside California at 916-653-0237.

ABSTRACT

Using direct source geothermal groundwater for heating involves transferring heat from hot groundwater to a building system's heating water. Efficiently using natural heat from the earth provides a sustainable heat source that does not burn fossil fuels or use large amounts of electricity.

The City of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources. Using this resource puts the heating costs under local control, brings revenue into the local area, and provides cost savings for the Modoc Joint Unified School District (MJUSD).

The California Energy Commission funded this project to construct an injection well and all necessary piping, controls, and other components to provide a functional geothermal heating system for three schools in the MJUSD. The system was also designed with additional heating capacity for other facilities in the future.

This project showed that direct source geothermal heating projects are a viable option for rural communities with available geothermal resources. With the system operating approximately six hours per day during the October through April heating season, the annual savings was estimated to be $37,000 by offsetting costs for heating oil. The system can provide approximately five times the necessary capacity to heat the three schools, so additional facilities can feasibly be connected in the future. The project is estimated to save $4.2 million, if further developed to maximum potential over the 30-year life of the system, making more money available to the school district.

MJUSD successfully completed a project that can serve as a model for other small, rural communities that want to use their local geothermal resources. MJUSD is extending the piping to a new hospital for the Last Frontier Healthcare District under another California Energy Commission grant (Agreement Number GEO-16-001), which also includes additional building retrofits and control system improvements to improve the efficiency of the heating system.

Keywords: geothermal, direct use geothermal, injection well, Modoc County, Alturas

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Introduction

Using direct source geothermal groundwater for heating is not a new concept - it involves transferring heat from hot groundwater to a building system's heating water using a heat exchanger. Geothermal water is pumped and extracted from the production well to the heat exchanger through a closed loop system, where the source of the water from production to injection is the same. After the heat is transferred to the building's heating system, the water is re-injected back into the groundwater source through an injection well. Using an injection well minimizes water loss and avoids contamination of the surface water as the water is re-injected into the same water body from where it came.

Natural heat from the earth provides an efficient and sustainable heat source that does not burn fossil fuels or use large amounts of electricity. This heating concept may be relatively straightforward, but executing geothermal projects, including the associated infrastructure, is not simple.

The City of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources. The Modoc Joint Unified School District (MJUSD) has been using geothermal water to heat portions of their schools since the early 1990s. Using this sustainable natural resource puts the heating costs under local control, brings revenue into the local area, and allows the MJUSD to apply the savings toward educational opportunities in Modoc County that will benefit the approximately 800 students in these schools.

Purpose

The purpose of this project was to develop a functional geothermal heating system for Alturas Elementary School, Modoc Middle School, and Modoc High School. The system was also to be designed with additional heating capacity for other facilities in the future.

The project was to capitalize on prior improvements that MJUSD completed in 1992, which included construction of a geothermal production well and installation of piping and controls for the elementary and middle school. There were disposal issues with the spent geothermal fluid because an injection well had not been constructed and the fluids were being discharged into surface water. An injection well is required to operate the system because geothermal water contains contaminates such as high chloride levels that cannot be discharged into surface water, but can be re-injected into the same water body from which it came. Without an injection well, the system could not be operated and the production well was forced to shut down.

In 2016, MJUSD ceased operation of the geothermal heating system for the Modoc High School Gymnasium and Shop buildings because the California Regional Water Quality

Control Board no longer allowed disposal of the fluid into the City of Alturas storm system. An injection well was required to be able to use the production well and operate the geothermal heating system.

Objectives

The scope of this project was to construct an injection well and all necessary piping, controls, and other components to provide a complete geothermal heating system that did not discharge geothermal fluid to other locations or contaminate the surface water.

The project scope included the following tasks:

- Construct a new geothermal injection well to receive the water from the existing production well.
- Install new piping from the existing production well to the Elementary School, Middle School, and High School, then connect the heating systems to the new injection well.
- Design the heating system with sufficient capacity for the three schools and also for other facilities to connect in the future. Design modifications to the existing systems in the three schools to provide a complete geothermal system, including controls and communications.
- Install necessary pumps, controls, and communications to operate the heating systems for all three schools.
- Extend piping to the Alturas Swimming Pool location so this facility could be connected to that geothermal heating system in the future. Final connection to the pool's heating system was not in the scope of this grant.

Conclusions and Recommendations

The tasks for this grant agreement were successfully completed, resulting in a functional geothermal heating system that provided heat to the three schools. The injection well had a targeted depth of 1,900 ft, however it was drilled significantly deeper to meet injection expectations and ultimately terminated at 3,240 ft. This resulted in a budget reallocation increasing funds for drilling and reducing funds available for the planned building retrofit. This change was determined necessary for the success of the grant agreement. Tests showed that there was adequate geothermal water supply from the production well, which supplies 175 degrees Fahrenheit (°F) (79 degrees Celsius [C]°) water, and enough capacity for the injection well to take all of the water used in the system and return it to the groundwater aquifer. This project was able to integrate existing systems that have not operated in more than 25 years.

The system can provide approximately five times the necessary capacity to heat the three schools, so additional facilities can be connected in the future, including the Alturas Swimming Pool.

Benefits to California

This project, awarded $3,155,759, showed that direct source geothermal heating projects are a viable option for rural communities with available geothermal resources. The system is supplying approximately 1 million British Thermal Units per hour (BTU/hr) when heating all three schools, equivalent to 10 gallons of heating oil per hour. At $3 per gallon, this equates to cost savings of $30 per hour for the October through April heating season. With the system operating approximately six hours per day during the heating season, the annual savings is estimated to be approximately $37,000. The system has the capability to supply 5.5 million BTU/hr. If additional facilities are connected and the system was operated at full capacity, it would supply the equivalent of 40 gallons of heating oil per hour.

MJUSD is estimated to save $4.2 million over the life of the system, which is likely to last as long as 30 years. Although there are large capital expenses associated with production and injection wells, geothermal heating can provide significant cost savings when analyzed over the lifetime of the system. The cost savings along with the assistance of grant funds made this project viable. Serving approximately 800 students throughout Modoc County, MJUSD plans to use the savings to hire additional teachers, expand programs, consider an extended school day, provide more student activities, and teach students about geothermal resources.

MJUSD successfully completed a project that can serve as a model for other small, rural communities that want to use their local geothermal resources. Often designers are not aware of existing geothermal resources or are unfamiliar with their application. Many communities think the resource is unavailable or that the resource water is not hot enough. Past geothermal projects have successfully used water with an average temperature of 120 °F (49°C).

Last Frontier Healthcare District is constructing a new hospital in Alturas and expressed interest in connecting to the geothermal heating system. MJUSD plans to complete a piping extension to the hospital under another California Energy Commission grant (Agreement Number GEO-16-001), which also includes additional building retrofits and control system improvements to improve the efficiency of the heating system.

CHAPTER 1: Project Description, Project Assessment, and Design

Introduction

Using direct source geothermal groundwater for heating is not a new concept - it has been used successfully in many areas that have geothermal heat resources, including Klamath Falls, Oregon; Boise, Idaho; Lakeview, Oregon; and Canby, California. The concept involves using the hot groundwater to heat a hydronic heating system in a building via a heat exchanger, which transfers heat to the building system's heating water. The geothermal water is pumped and extracted from the supply or production well to the heat exchanger. Heat is transferred to the building's hydronic system, and then the geothermal water is re-injected back into the aquifer through an injection well. Re-injection ensures minimal net water loss or aquifer stress. An injection well is also required because geothermal water contains contaminates such as high chloride levels that cannot be discharged into surface water.

The system provides a sustainable heat source without burning fossil fuels or using large amounts of electricity in resistance type heating. In this closed-loop system, there are no concerns of water contamination when discharging geothermal water into surface water, because the geothermal water is moving from one location to another within the same aquifer. Efficiently using natural heat from the earth does not result in any carbon emissions, unlike burning fossil fuels. The heating concept may be relatively simple, but executing geothermal projects including the associated infrastructure is not simple.

The City of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources. Using this sustainable natural resource puts the heating costs under local control, brings revenue into the local area, and allows the Modoc Joint Unified School District (MJUSD) to spend the savings for better educational opportunities in Modoc County.

In 1992, MJUSD constructed a geothermal production well with associated piping and controls in the Modoc Middle School (Middle School) and Alturas Elementary School (Elementary School). An injection well had not been constructed at that time, so the system could not be operated.

Project Purpose

The purpose of this project was to develop a complete geothermal heating system for three schools which capitalized on the prior improvements completed by MJUSD in

1992. Appendix A shows a map of the project site. The project scope included the following tasks:

- Construct new geothermal injection well to receive the geothermal effluent from the existing production well.
- Install new piping from the existing production well to the Elementary School, Middle School, and Modoc High School (High School) and connect the heating systems to the new injection well.
- Design the heating system with sufficient capacity to allow other facilities to connect in the future.
- Install necessary pumps and controls to operate the heating systems for all three schools.
- Extend piping to the Alturas Swimming Pool location so this facility could be connected to that geothermal heating system in the future. Final connection to the pool's heating system was not in the scope of this grant.

Review of Existing Data

The initial phase of the project was to review existing well data for Production Wells AL-1 (Well AL-1) and AL-2 (Well AL-2). Well AL-1 was previously used to heat the High School Gymnasium (Gym) and Shop Building. This phase also included inspection of all heating systems in the buildings. Extensive review of existing conditions was required to ensure the best possible geothermal water application. Anderson Engineering & Surveying, Inc. (AES) reviewed existing data of all existing wells in the area including all published geological information for the Alturas area.

Existing Production Well AL-2

This project used existing geothermal Production Well AL-2, which was drilled by the MJUSD in 1992. This well was never used because of issues related to the disposal of spent geothermal fluid into surface water. The goal of this project was to construct an injection well and install the necessary piping so that Well AL-2 could be used to develop a complete closed-loop heating system. The first step in the preliminary testing and project design process was to verify that Well AL-2 had the necessary capacity for the planned system.

Well AL-2 had not been opened in 25 years, so its condition was verified. MJUSD received approval from the California Regional Water Quality Control Board to conduct the flow test. A 22-hour flow test was conducted to monitor well pressures and flows and obtain water samples for chemical analysis. Flows were limited to the amount that could be disposed of on the ground surface and through surface drainage ditches. Figure 1 shows a portion of the piping used for the flow test. Results of the test are shown in Table 1.

The flow test verified the findings made in the original report prepared by Plumas Hydrogeology in 1992. Well AL-2 was capable of high flows exceeding 500 gallons per minute (gpm) at 80 pounds per square inch (psi). Shut-in artesian pressure was 100 psi at the well head. Large geothermal flow at this pressure has considerable energy and requires no pumping to flow through the heating system area.

Figure 1: Flow Test Piping

Photo Credit: Anderson Engineering & Surveying, Inc.

Table 1: Flow Test of Well AL-2

Date	Time	Temp. C°	Temp. F°	Conduct ms/cm	Flow GPM	Head Pressure	Casing Height	Comments
7/16/2015						100 psi		
	8:51 AM	15.2	59.4	2.41			0.52	
	9:07 AM							Stop test leaking gasket
	9:17 AM				450			Restart test
	9:27	67.1	152.8	2.36			0.85	
	10:53	73.2	163.8	2.35				
	12:25	73.9	165.0	2.34	450	85psi	0.94	sample taken
	3:05 PM	80.5	176.9	2.3	500	85 psi		
	4:11 PM				570	85 psi		
	4:27 PM				580	85 psi		water on ditch at Warner St - 115°F
	5:00 PM	80.3	176.5	2.36		85 psi	0.97	
	6:20 PM							water on ditch at Warner St - 115°F
	7:45 PM	80	176.0	2.33	554	85 psi		pH 7.23
	8:45 PM							Some water leaking around
								dam on 4th St
	11:30 PM					82 psi		Little water on South side
								of 4th St
July 17th								
	4:30 AM	81.8	179.2	2.18	550	80 psi		pH 7.34 sample taken
	5:00 AM					105 psi		End test Well pressure
								immediate to 105

Source: Anderson Engineering & Surveying, Inc.

New Injection Well AL-4

The location of the injection well was critical to the project. Locating an injection well too close to the production well can cool the geothermal resource over time because of the injection of cooler water back into the aquifer after heat extraction. The injection well also had to be located on MJUSD property or City of Alturas property to avoid real estate costs. Figure 2 shows the location of the injection well site.

The injection well site was selected after reviewing all published data and consulting with MJUSD's subcontractor Dale Bugenig, Consulting Hydrogeologist, LLC and Burkhard Brome of Plumas Hydrogeology. A site on Alturas Municipal Airport property was selected for the following reasons:

- The land was available.
- No development was planned for the area.
- Distance from the production well ensured no cooling of source water or thermal breakthrough.
- All available geologic data supported the viability of the site.

Figure 2: Injection Well AL-4 Location

Photo Credit: Anderson Engineering & Surveying, Inc.

MJUSD's subcontractor Anderson Engineering & Surveying, Inc. (AES) prepared bid documents on behalf of MJUSD for the drilling subcontract.

Piping Design

A field survey was conducted to locate all right-of-ways along the piping route. The piping route was selected to maximize project efficiency while locating piping on MJUSD property and within City of Alturas street right-of-ways.

Six-inch, insulated ductile iron pipe was selected as the carrier pipe because of its long life and tough insulation jacket, which provided flows with very little temperature loss (three to four percent in the length of the line). This type of piping has been used successfully on other geothermal heating projects. The six-inch diameter allows for higher flows if any additional geothermal users are added in the future.

The piping route crossed Highway 395 and the railroad tracks. AES obtained permits from the California Department of Transportation and Union Pacific Railroad for boring underneath the highway and the railroad tracks.

AES prepared the construction bid package to solicit competitive bids.

Building System Modifications

The existing heating systems in the buildings for all three schools required upgrades and modifications to operate with the new system. AES, with the assistance of Brian Brown of Brian Brown Engineering (AES's subcontractor), performed inspections of all the buildings and their heating systems in April 2015 and October 2016. Based on the results of these inspections, they developed a list of retrofit tasks that were necessary for the system to operate as well as additional retrofits recommended for optimal system operation. The retrofits that were absolutely necessary for system operation were included in the design and subsequently constructed in this project.

The following retrofit tasks were included in the design:

- Modoc High School
- The High School campus is located on 4th Street and contains several buildings including Modoc Middle School & Alturas Elementary School

  The two schools are located on one campus and share a heating system that was connected to the original geothermal equipment installed in 1992. Figure 4 shows a map of the Middle School campus and Figure 5 shows a map of the Elementary School campus. The original system was designed to supply geothermal heat to the Elementary School in series with the Middle School, which operated from a single pump in the Middle School. The geothermal heat for the Middle School could not operate unless the flow also circulated through the Elementary School. This project redesigned the operation to improve efficiency and flexibility.

  - Reconfigure piping to allow independent operation of the two schools.
  - Install new pumps to serve the Elementary School.
  - Connect the original geothermal equipment to new production and injection pipeline.
  - Install new controls in the Middle School Heat Exchanger Building.

- Alturas Swimming Pool
  - o Extend pipeline from Middle School Heat Exchanger Building and production well to swimming pool location so pool facility can be connected in the future (not in the scope of this grant).

Retrofit work performed in the school buildings required approval through the California Division of the State Architect (DSA). Semingson Architects obtained approval from DSA for the existing systems at the Middle School and Elementary School, which had not been done before this project. Semingson Architects also prepared the design drawings for the work in the High School and received DSA approval.

Figure 3 shows a map of the High School campus.

- o Transferred piping connections for the High School Gym and Shop Building. Install piping to connect the Gym and Shop Building (which were previously heated with the old geothermal system) to the new production and injection well pipeline.
- o Convert the original steam-operated heating system to hydronic operation, and then connect the remaining buildings to the new system using the existing unit ventilators.
- o Retrofit cabinet unit heaters in the Science Wing for hydronic heat.
- o Install new geothermal heat exchanger in the boiler room in the Main Building.
- o Convert boilers from steam to hot water operation.
- o Remove existing steam traps in existing steam piping.
- o Install new lead-lag circulation pumps with variable frequency drives (VFDs) to circulate return heating water to existing geothermal heating systems in the Gym and Shop Building.
- o Install new heating water expansion tank and make-up piping in the boiler room.
- o Install controls and associated wiring in boiler room for operation of system.

- Modoc Middle School & Alturas Elementary School

  The two schools are located on one campus and share a heating system that was connected to the original geothermal equipment installed in 1992. Figure 4 shows a map of the Middle School campus and Figure 5 shows a map of the Elementary School campus. The original system was designed to supply geothermal heat to the Elementary School in series with the Middle School, which operated from a single pump in the Middle School. The geothermal heat for the Middle School could not operate unless the flow also circulated through the Elementary School. This project redesigned the operation to improve efficiency and flexibility.

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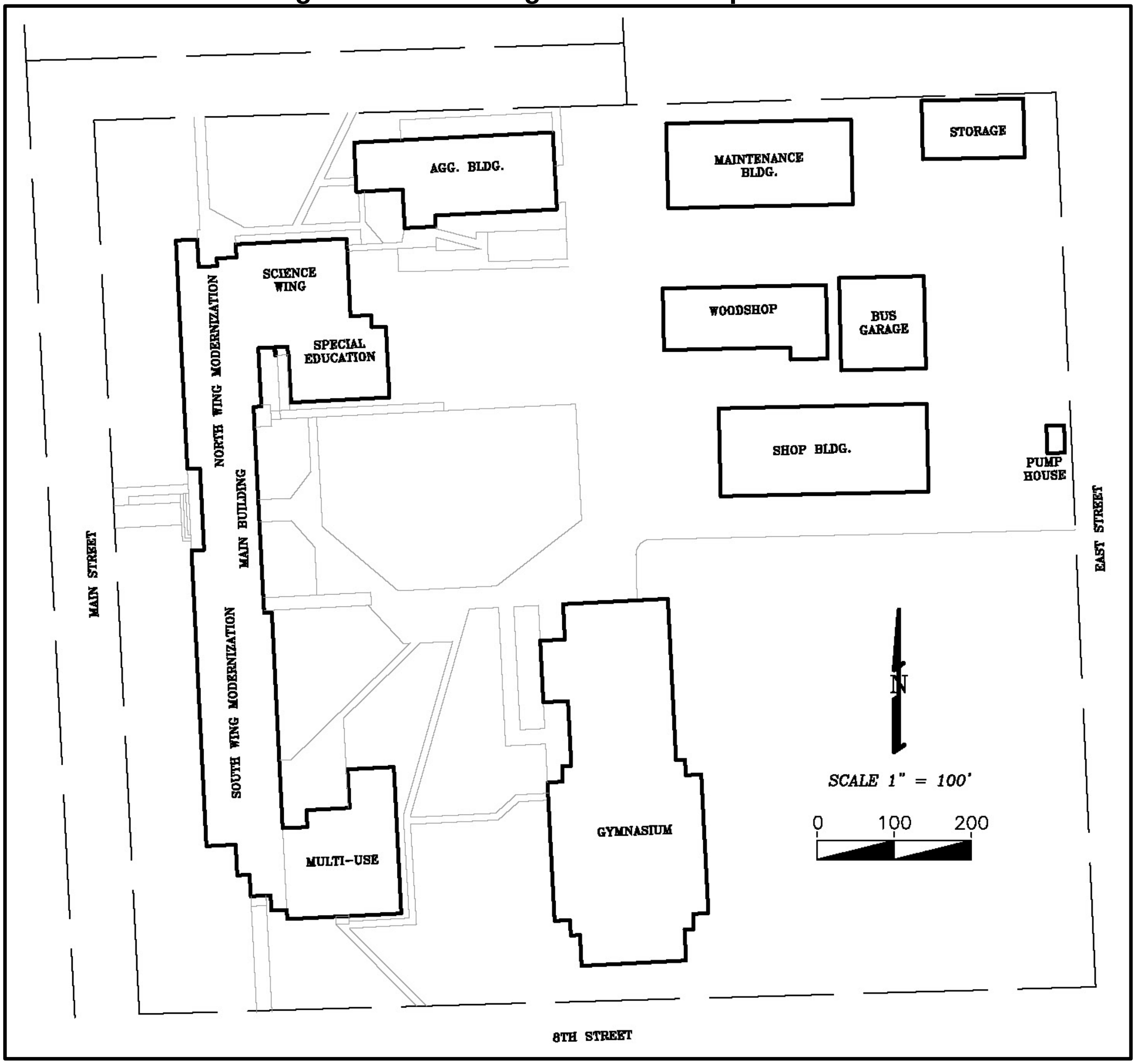
Figure 3: Modoc High School Campus



Source: AES

Figure 4: Modoc Middle School Campus

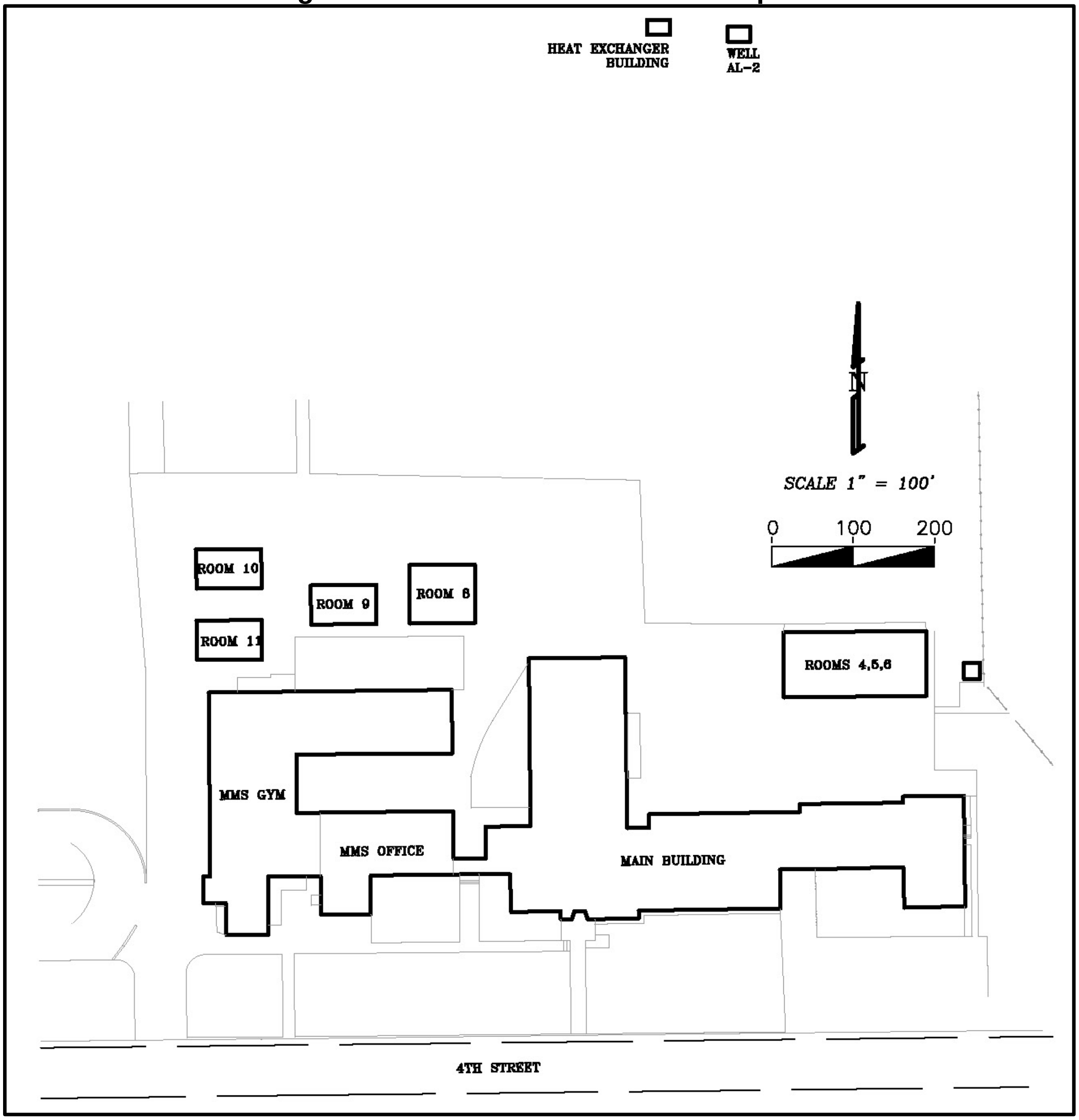
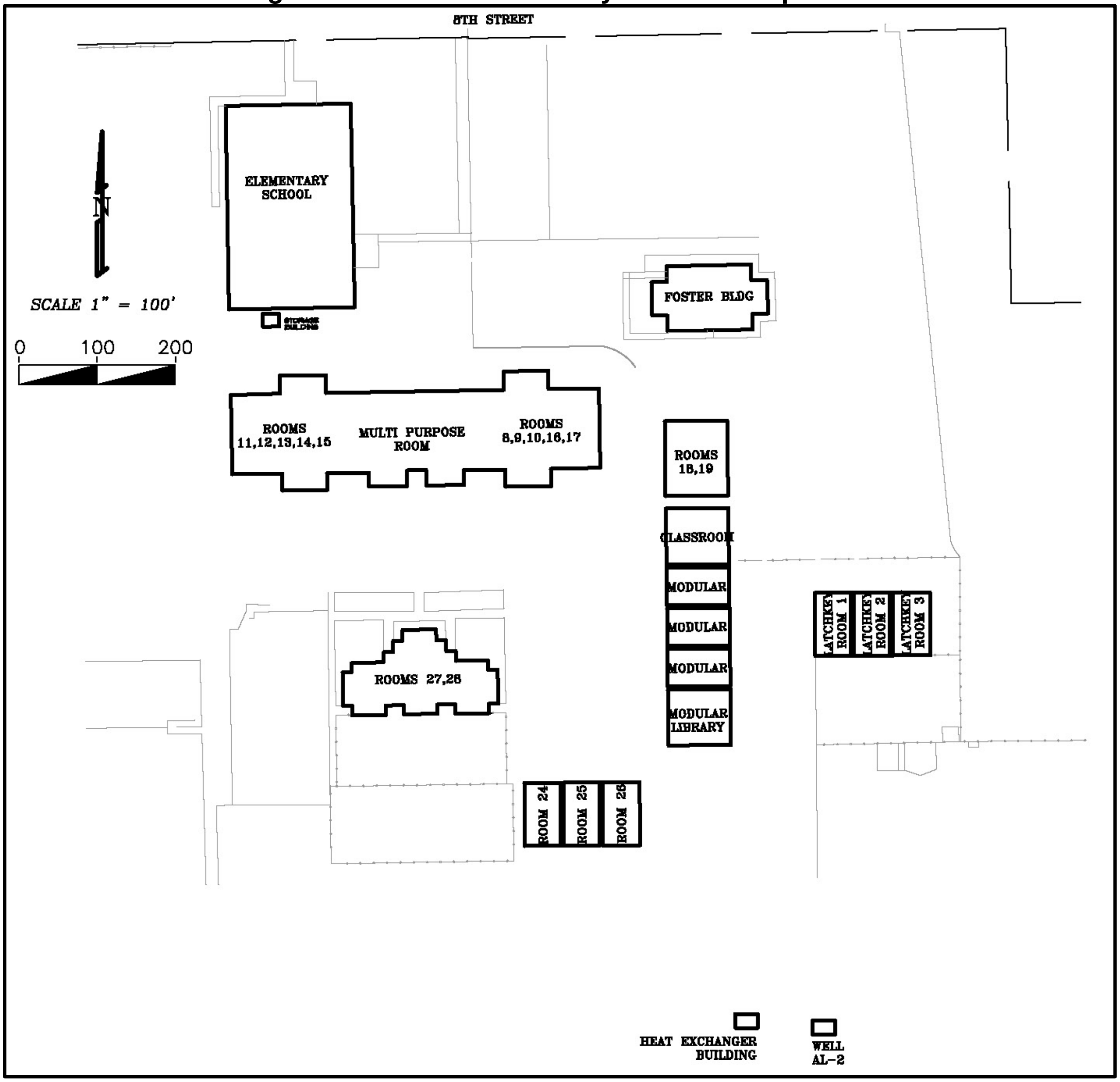


Figure 5: Alturas Elementary School Campus



CHAPTER 2:
Project Construction

After all preliminary testing and design was complete, the project moved into the construction phases. Construction of the project was divided into three phases: injection well drilling, piping installation, and building retrofits and controls.

Injection Well Drilling

Without adequate injection capacity, the rest of the system could not operate, making this the most critical part of the project.

The target depth for Injection Well AL-4 was 1,900 feet (ft). This target depth was based on the geologic formations encountered in Well AL-2, located approximately three-quarter miles to the northeast. However, geologic conditions at depths beneath Alturas are not known with a high degree of certainty.[1]

MJUSD subcontracted with Boart Longyear of Salt Lake City, Utah for the drilling work. Geothermal well drilling is a specialty field within the well drilling industry, and not all large drilling companies provide this service.

Drilling Operations

Well AL-4 was drilled using the flooded dual-tube reverse-rotary drilling method. This method was selected to combat the lost-circulation conditions anticipated during the drilling of Well AL-4 based on the conditions experienced with Wells AL-1 and AL-2. Another advantage of this method compared to the direct mud-rotary method employed previously was its ability to obtain formation samples if circulation is lost.[2]

Boart Longyear utilized a reverse-circulation drill rig (Figure 7). The rig operated on a sub-structure necessary for the aboveground installation of blowout prevention equipment. This equipment was required because of the anticipated flowing artesian conditions and temperature of the geothermal resource.[3]

Drilling began on March 14, 2016, and was terminated on April 30, 2016, at a depth of 3,240 ft. An abbreviated log of the formation materials penetrated by the borehole is provided in Table 2. Drilling operations were terminated only after it was deduced fractures were encountered below a depth of 3,080 ft. The well was developed by surging and airlift pumping through the drill pipe. The temperature of the airlift

[1] (Bugenig, Bohm and Anderson Engineering & Surveying, Inc. 2017)

[2] Ibid., 10

[3] Ibid.

discharge upon completion of drilling was measured at 170 degrees Fahrenheit (°F) (76.7 degrees Celsius [°C]) and the well began to flow at a rate of 92 gpm.[4]

Figure 6: Drill Rig Set-up

Photo Credit: Anderson Engineering & Surveying, Inc.

Figure 7: Drill Rig

Photo Credit: Dale C. Bugenig, Consulting Hydrogeologist, LLC

4 Ibid., 11

Table 2: Lithologic Log of the Well AL-4 Borehole

Depth Interval (feet below land surface [ft bls])	Description
Land Surface (LS) to 30	Brown to reddish brown volcanic sediments with cinders
30 to 220	Clayey, silty sand and gravel
220 to 265	Silty sand and gravel
265 to 290	Yellowish brown sandy clay
290 to 335	Medium to course sand
335 to 370	Light yellowish brown silty, clayey sand
370 to 400	Brown and dark grey tuffaceous sand
400 to 470	Light brown and grey tuffaceous sediment or weakly indurated tuff
470 to 500	Volcanic sand and gravel
500 to 615	Grey and black volcanic sand and gravel
615 to 810	Light to medium grey and olive grey, fine grained tuff or tuffaceous sediments
810 to 820	Multi-colored volcanic sand
820 to 1,115	Very fine grained tuffaceous sediments or weakly indurated tuff with lithic fragments
1,115 to 1,155	Basalt lava flow
1,155 to 1,174	Reddish brown tuff and volcanic ash
1,174 to 1,205	Basalt lava flow or mud flow with grey ash matrix
1,205 to 1,844	Dark grey to black tuff and lithic tuff, weakly to moderately indurated. Contains clear zeolite fragments. A series of tuff units occasionally transitioning from fine grained to coarser grained from top to bottom.
1,844 to 2,040	Grey to dark grey densely welded, indurated tuff and lithic tuff
2.040 to 2,252	Basalt lava flow. At 2,110 ft the borehole yielded approximately 1 gpm when air-lifted.
2,252 to 2,360	Grey to pale grey tuff
2,360 to 2,400	Basalt lava flow
2,400 to 2,490	Weathered basalt lava flow or basalt mudflow
2,490 to 2,760	Basalt lava flows, amygdular with zeoloite fragments. Series of flows with the upper/lower flow boundaries marked by change in color from black to reddish brown, presumably at cooling breaks
2,760 to 3,240	Dark to medium grey densely-welded tuff. Potentially permeable fractures were indicated starting at approximately 3,080 ft bls.

Source: Dale C. Bugenig, Consulting Hydrogeologist, LLC

Borehole Geophysical Logging

Borehole geophysical logs were acquired after drilling of the 14-3/4 inch (in) diameter borehole was terminated at 1,854 ft below land surface. The logs included data such as fluid resistivity, point resistance, long- and short-normal resistivity, lateral resistivity, spontaneous potential, natural gamma radiation, temperature, and deviation. [5]

Generally, the geophysical log is consistent with the descriptive lithology of the formations penetrated by the borehole. From a geothermal resource standpoint, the log suggests relatively fine-grained material logged as tuff or tuffaceous sediments below a depth of 1,210 ft. These sediments likely serve as an aquitard that inhibits upward migration of geothermal fluids from a deep resource.[6]

The temperature log provided little useful information due to the short time that elapsed between the time the drilling fluid circulation stopped and when the hole was logged. The maximum temperature of 106°F (41.1°C) was reached at a depth of 1,400 ft, reversing to 103°F (39.4°C) at the bottom of the borehole.

The deviation log shows the bottom of the borehole drifts to the southwest and is offset by 5.8 ft, for an average deviation of 3.75 in per 100 ft, within the maximum deviation of 6 in per 100 ft allowed under the well drilling contract.[7]

Well Construction Details

Well AL-4 was designed to be drilled to a depth of 1,900 ft based on the premise that the subsurface conditions at the site might be similar to those at Well AL-2. The preliminary well design called for a 10 3/4-in diameter blank production casing installed to a depth of approximately 1,800 ft below land surface where it was anticipated that the 14 3/4-in diameter borehole would be terminated in a densely welded tuff. Fractures in the tuff below this depth were expected to be the source of the geothermal fluids and suitable to receive fluids from Well AL-2 injected into Well AL-4. Figure 8 shows a photograph of drilling activities.

The production casing was landed in densely welded tuff at a depth of 1,854 ft and the annulus from the bottom of the casing to the land surface were sealed with cement grout. The annular seal was designed to prevent geothermal fluids originating at depth or pressurized injectate (geothermal effluent from the heating system) from migrating upward to shallower alluvial deposits comprising an aquifer exploited as a source of supply to municipal and irrigation wells.[8]

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5 Ibid., 13

6 Ibid.

7 Ibid.

8 Ibid.

Subsequent observations made during drilling indicated that, unlike Well AL-2, the formation immediately below the casing was relatively impermeable and that the injection capacity of Well AL-4 was too low to meet project goals. Below the target depth of 1,900 ft, drilling proceeded incrementally, ultimately terminating at a depth of 3,240 ft. As drilling progressed, the formation's ability to receive injected water was appraised. These appraisals included measuring the temperature of the drilling fluids at the land surface immediately after resuming drilling and after adding a drill rod, and stopping periodically to develop the well, measure airlift discharge, and check for flowing artesian conditions indicative of permeable formation materials.[9] Final construction of the well is summarized in Table 3.

Figure 8: Drilling of Injection Well AL-4

Photo Credit: Anderson Engineering & Surveying, Inc.

Temperature of Drilling Fluid Returns

Previous testing of Well AL-2 indicated it was capable of flowing under artesian conditions at a rate of more than 500 gpm and with a fluid temperature of approximately 180°F (82.2°C). Similar conditions were anticipated at the Well AL-4 site. Additionally, a temperature log for a borehole drilled previously on Airport property suggested similar temperatures at the 1,900 ft target depth at the site. Unfortunately, the location of the previous borehole drilled at this airport is unknown.[10]

The temperature of the drilling fluid returns was monitored as drilling progressed, as these can provide an indication of permeable, hot-water production zones that would be amenable to re-injection. Specifically, the maximum temperature of the drilling fluid was measured after circulation was resumed after adding a length of drill rod. Temperature measurements are shown in Table 4.

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9 Ibid., 12

10 Ibid., 10

Well Testing

AES performed an injection test of the completed well beginning April 30, 2016. The source of the water was the City of Alturas distribution system and the water was pumped down the well via the drill pipe. Injection rates were monitored using flow meters, and pressure at the wellhead was measured with a pressure gauge.[11]

- Injection commenced: 15:45 hours on 4/30/16
- Injection rate: varied between 265 and 240 gpm, averaged 249.9 gpm
- Injection ceased: 15:14 hours on 5/1/16
- Injection pressure at the conclusion of testing: 230 psig

The data from the injection test are plotted in Figure 9, which shows injection pressure plots as a straight line when plotted versus the logarithm of time. Extrapolating the trend of the data into the future yields:

- After 1 year of continuous injection at a rate of 249.9 gpm, injection pressure was predicted to be approximately 314 psig.
- After 5 years of continuous injection at a rate of 249.9 gpm, injection pressure was predicted to be approximately 336 psig.

Water Chemistry

A water sample was collected from the artesian flow discharge of Well AL-4 where the borehole had been drilled to a depth of 3,170 ft, and after the well had been developed by surging and airlift pumping.[12] The sample was submitted to Basic Laboratory, Inc. for analysis. Analytical results are provided in Table 5.

Overall Results

The construction of the Injection Well AL-4 was ultimately a success. The project resulted in a functional well with adequate injection capacity to meet the needs of the current system that would supply heat to the MJUSD school buildings. The injection well also had sufficient capacity for the planned expansion to heat the Alturas Swimming Pool and the future Last Frontier Healthcare District hospital facility. Last Frontier Healthcare District is constructing a new hospital facility in Alturas and had expressed interest in connecting to the geothermal heating system.

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11 Ibid., 12

12 Ibid., 14

Table 3: Well AL-4 Construction Summary

Depth Interval (Feet Below Land Surface)	Description
Borehole Diameter	
LS to 41	28 in
41 to 200	22 in
200 to 1,854	14 3/4 in
1,854 to 3,240	8 3/4 in
Casing	
LS to 41	Surface Casing: 24-in diameter steel
LS to 200	Conductor Casing: 16-in diameter steel
+2 to 1,854	Production Casing: 10 3/4-in outer diameter. American Petroleum Institute K55 threaded and coupled steel pipe. The well was completed as an open borehole below the production casing.
Annular Seal	
LS to 41	Cement grout pumped from the bottom of the annulus surrounding the 24-in casing from the bottom to the land surface via a tremie pipe.
LS to 200	Cement grout pumped from the bottom of the annulus surrounding the 16-in casing to the land surface via a tremie pipe, including the annulus between the 16-in diameter and 22-in diameter conductor casing.
LS to 1,854	Cement grout placed from the bottom of the 8-in casing to a depth of 170 ft bls. Cement rose to within the annulus between the 8-in and 16-in casing strings but did not return to the land surface. Cement pumped via a tremie pipe from 170 ft to the land surface completed the annular seal.

Source: Dale C. Bugenig, Consulting Hydrogeologist, LLC

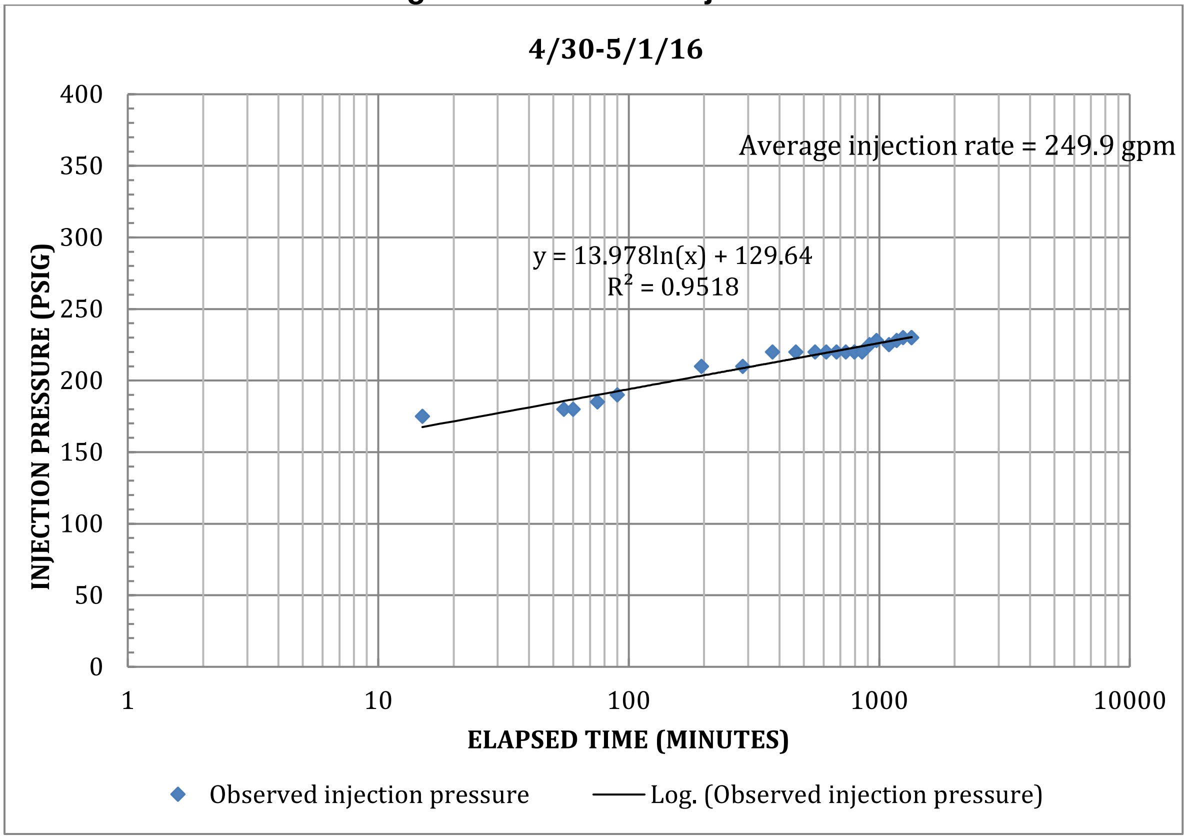
Table 4: Selected Temperatures Measured During Drilling of Well AL-4

Depth (ft bls)	Temperature (°F/°C)	Remarks
2110	120/48.9	Maximum drilling fluid temperature after adding a drill rod.
2250	140/60	Maximum temperature on resuming circulation after tripping the bottom-hole assembly to unplug bit.
2390	130/54.4	Maximum drilling fluid temperature after adding a drill rod.
2590	140/60	Maximum drilling fluid temperature after adding a drill rod.
2760	170/76.7	Maximum temperature during airlift pumping at a rate of approximately 110 gpm. After airlift development the well flowed at 25 gpm.
2910	150/65.6	Maximum drilling fluid temperature after adding a drill rod.
2950	160/71.1	Maximum drilling fluid temperature after adding a drill rod.
3230	160,170/71.1, 76.7	Maximum drilling fluid temperature and airlift temperature. Well flowed at a rate of 92 gpm after airlift development.

Source: Dale C. Bugenig, Consulting Hydrogeologist, LLC

The additional depth required to reach an adequate injection zone increased the cost of the well portion of the project by approximately $400,000. This cost increase impacted the remainder of the project, resulting in revisions to the planned building retrofits. These revisions included postponing some ventilation and control system improvements that would have increased the efficiency of the heating system. Fortunately, the cost savings from using the existing systems in the Middle School and Elementary School and some cost savings during the piping installation phase allowed the majority of the building retrofits to be completed so the heating system could be operated in the buildings at all three schools.

Figure 9: Well AL-4 Injection Test



Source: Dale C. Bugenig, Consulting Hydrogeologist, LLC

Table 5: Results of Chemical Analysis of Water Sampled from Well AL-4

Parameter	Result
General Chemistry	
Specific Conductance, micro (µ) mhos per centimeter	2,510
Total Dissolved Solids, milligrams per liter (mg/l)	1,590
Hardness as calcium carbonate ($CaCO_3$), mg/l	64
Bicarbonate, mg/l	265
Carbonate, mg/l	<1
Hydroxide, mg/l	<1
Chloride, mg/l	445
Fluoride, mg/l	0.93
Nitrate (NO_3^-), mg/l	<0.02
Nitrite (NO_2^-), mg/l	0.01
Nitrate + Nitrite, as N, mg/L	<0.02
Sulfate (SO_4^{-2}), mg/L	418
Total Phosphorous (P), mg/l	0.30
Metals (total)	

Parameter	Result
Aluminum, micrograms per liter (µg/l)	1,200
Antimony, µg/l	1.9
Arsenic, µg/l	716
Barium, µg/l	12.3
Beryllium, µg/l	<0.5
Boron, µg/l	11,800
Calcium, mg/l	25.3
Cadmium, µg/l	<0.25
Chromium, µg/l	0.7
Cobalt, µg/l	0.5
Copper, µg/l	12.5
Iron, µg/l	2,420
Lead, µg/l	40.3
Lithium, µg/l	194
Magnesium, mg/l	0.6
Manganese, µg/l	79.1
Mercury, µg/l	0.07
Nickel, µg/l	1.3
Potassium, mg/l	6.2
Selenium, µg/l	<2.0
Silicon, mg/l	56.6
Silver, µg/l	<0.05
Sodium, mg/l	496
Thallium, µg/l	<1.0
Zinc, µg/l	3.6
Metals (dissolved)	
Calcium, mg/l	24.6
Iron, µg/l	989
Magnesium, mg/l	0.3
Manganese, µg/l	60.4
Potassium, mg/l	5.5
Sodium, mg/l	493

Source: Dale C. Bugenig, Consulting Hydrogeologist, LLC

Piping Installation

MJUSD’s subcontractor Eagle Peak Rock & Paving, Inc. (Eagle Peak) of Alturas, California installed the piping and the conduit for the fiber optic communication cable as well as constructing the injection well building at the injection site from August 2016 through March 2017.

The pipeline boring underneath Highway 395 and railroad right-of-way began in December 2016 and extended through the end of February 2017. Final paving and other miscellaneous items were completed in May and June of 2017. The majority of

Eagle Peak's work completed (99 percent) was funded by this grant, with the remaining one percent in match funds provided by MJUSD.

The piping used was factory insulated, iron pipe manufactured by Thermacor. Ductile iron offers long life and resistance to hot water. The pipes were delivered pre-insulated with a high-density polyethylene (HDPE) plastic jacket to prevent water intrusion into the insulation at the joints. A heat shrink cover was applied to all joints. Eagle Peak used low cement content slurry to fill around the pipe instead of compacting 3/4-in minus gravel material. Geothermal piping was placed in a 16-in steel casing for both supply and return lines. Figure 10 shows a photograph of the piping installation and Figure 11 shows a photograph of the bore pit.

Figure 10: Piping Installation

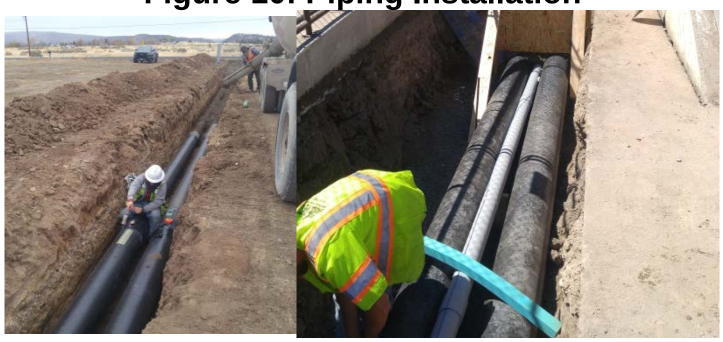


Photo Credit: Anderson Engineering & Surveying, Inc.

Figure 11: Bore Pit

Photo Credit: Anderson Engineering & Surveying, Inc.

After the project was substantially complete, the pipe was flushed to remove construction debris and pressure tested for tightness. Eagle Peak also installed the conduit for the fiber optic communication cable. This was installed at the same time as the piping.

This phase of the project encountered numerous difficulties during construction. There was difficulty locating existing utilities at the school facilities, which caused delays due to utility repairs. An underground storage tank was discovered at the High School during the start of the project, causing additional delays. The tank was an abandoned 550-gallon tank containing heating oil. Research of records indicated the tank had been installed in the 1930's and had not been used since approximately 1960. The tank and its contents had to be properly removed, and the former tank area was backfilled with dirt. MJUSD retained Ed Staub & Sons, a local company certified to provide tank decommissioning services. The tank was removed and sent to Klamath Metals for disposal. Soil samples were collected for analysis and there was no evidence of site contamination. The cost for the tank decommissioning and removal was paid directly by MJUSD, and was not included in the grant agreement.

There were also problems encountered when Eagle Peak pulled the fiber optic communications cable through the installed conduit. The cable was not installed properly and was not functional. MJUSD retained McCombs Electric to install new fiber optic cable at no additional cost to MJUSD. The reinstallation of the fiber optic cable was completed July 7, 2017. The installed fiber optic cable was tested for continuity and was functioning properly.

Overall Results

The piping installation phase of the project was ultimately successful and resulted in full installation of the necessary supply piping, installation of the required fiber optic communication cable, and construction of the injection well building at the injection well site.

This phase did experience significant schedule delays, which required extending the grant term so that the building retrofits could be completed.

Building Retrofits and Controls

Since the retrofit and control portion of the project required a number of very specific tasks, this portion of the work was not combined into a single construction contract. Several local specialty contractors performed the various tasks under separate subcontracts.

Middle School and Elementary School Buildings

Existing Conditions

Existing equipment from the 1992 project was utilized in both the Middle School and Elementary School buildings. Existing geothermal equipment, piping, and controls included:

- Heat Exchanger Building that included a plate and frame heat exchanger and piping connections to the Middle School and Elementary School.
- Circulation pumps in the Middle School and Elementary School.
- Circulation pumps in the Middle School boiler room to circulate heating water from the Middle School to the Heat Exchanger Building and Elementary School.
- Heating coils in existing air handlers and fan-coil units where needed to provide hydronic heating.

- Hydronic piping in the Elementary School buildings and Middle School Gym.
- Controls consisting of an Alerton IBEX gateway and MicroView Disk Operating System (DOS)-based digital controls in the Heat Exchanger Building and Middle School boiler room.

The existing heating equipment in the Middle School was originally designed for steam heat, so it operates best at a higher water temperature than the geothermal water. The heating equipment installed in 1992 in the Elementary School buildings and Middle School gym were designed to operate with lower water temperature to best utilize the geothermal heat. The piping and pumping system was designed to cascade the water from the Middle School to the Elementary School. The heating system was piped in series, with a single circulation pump and an installed spare pump. The pumps were designed for high pumping head, with 30-horsepower motors. A variable frequency drive allowed adjustment in pump speed to better match the heating load. The piping arrangement made it impossible to operate the Middle School without also operating the Elementary School.

The 1992 heating equipment for the Middle School gym was activated several years ago by connecting the piping to the existing heating water piping system. Some of the existing fan-coil units in the Elementary School were retrofitted with cooling coils, and activated to provide cooling to the classrooms. The rest of the 1992 heating system was never completed - pipes were not flushed, filled, or pressure tested, and controls were not programmed or activated. Subsequent construction at the campus damaged the buried pipeline at various undocumented locations. Since this system was not activated, the school buildings continued to use their original (pre-1992 project) heating systems. The middle school utilized an oil fired boiler system and the elementary school buildings had a combination of electric and heat pump systems.

DSA inspected the heating system after the 1992 project was abandoned and identified numerous deficiencies in the equipment and pipe supports. This project needed to address those deficiencies before completing the new retrofit work.

New Construction

The objective of this project was to achieve the maximum benefit available from the geothermal resource as quickly as possible, while retaining as much of the existing equipment as feasible to save time and cost. Once the injection well and pipeline were completed, the Middle School provided the best opportunity to quickly realize benefit from the geothermal system. New construction activities completed in the Middle School:

- Revised the piping in the Heat Exchanger Building to de-couple operation of the Middle School from the Elementary School. Added pumps and controls to provide cascaded temperature operation with primary-secondary pumping loops rather than series operation.

- Flushed and pressure-tested the piping between the Middle School's Heat Exchanger Building and boiler room.
- Installed new Alerton controls on a Building, Automation, and Control Network (BACnet) system in the boiler room and Heat Exchanger Building, using existing panels, wiring, control valves, and sensors where possible.
- Installed fiber-optic data communication cables between the Middle School, Heat Exchanger Building, injection well, and High School to provide control communication. Established remote monitoring and communication capabilities using a virtual private network (VPN).
- Activated the existing circulation pump and VFD to operate the Middle School heating system.

Figure 12 shows a photograph of the heat exchanger for the Middle School and Elementary School.

Figure 12: New Heat Exchanger for Middle and Elementary Schools

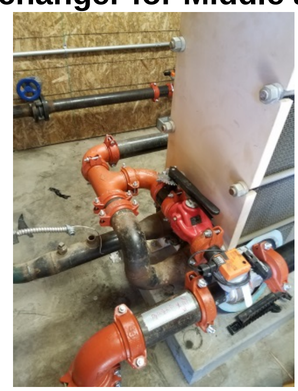


Photo Credit: Anderson Engineering & Surveying, Inc.

New construction activities completed in the Elementary School:

- Repaired, flushed, and pressure-tested existing buried piping.
- Investigated control work needed in the Elementary School buildings to operate the geothermal heat.
- Repaired deficiencies to the existing system as required by DSA.

Figure 13 shows the circulating pumps for the Elementary School, located in the Heat Exchanger Building.

Figure 13: Elementary School Circulating Pumps in New Heat Exchanger Building

Photo Credit: Anderson Engineering & Surveying, Inc.

High School

Existing Conditions

The High School main building was heated by low-pressure steam, supplied by oil-fired boilers in a basement boiler room. Steam was distributed to cast iron radiators or cabinet unit heaters with a steam coil.

The High School gym and shop were previously heated by a geothermal system installed in the early 1990s, fed from local Production Well AL-1. Use of this well was discontinued in 2016.

New Construction

Once the pipeline was completed, the initial objective was to reactivate the existing geothermal heating system. The original geothermal system operated at about 15 psi, the minimum pressure needed to circulate the water and discharge to the storm sewer. The new system operates at near 100 psi, the static artesian head of the production well. The higher pressure revealed leaks in the original buried geothermal piping and the shop heat exchanger. The piping leaks were repaired, and a replacement heat exchanger was installed. The system has been operating since January 2018, providing heat to the Gym.

The High School Main Building required a new heat exchanger, piping, pumps, and controls in the boiler room to interface between the geothermal system and the building heating system. The boilers were converted from steam to hot water operation. Figure 14 is a photograph of the completed hot water boiler conversion in the high school boiler room. Existing distribution piping in the building was reused, with the steam traps removed from heating equipment. Figure 15 shows the new heat exchanger installed at the High School.

Figure 14: High School Boiler Room

Hot water boiler after conversion

Photo Credit: Anderson Engineering & Surveying, Inc.

Figure 15: High School Heat Exchanger

Photo Credit: Anderson Engineering & Surveying, Inc.

The High School Gym and Shop Building were designed to cascade off of the High School Main Building. The new equipment and piping allowed the system to re-use available heat in the water and also reduce the water volume needed from the production well.

The piping for the High School Gym and Shop Building were disconnected from the original geothermal well and geothermal water disposal, and connected to the new system and controls.

Specialty Repair & Construction

Construction activities for the building retrofits and control systems were accomplished by a variety of specialty services through MJUSD:

- Heard Plumbing
- Copp's Irrigation
- McCombs Electric
- CR Combustion
- Joe Lloyd Construction
- Shasta Union High School District
- Semingson Architects
- Harbert Roofing

Since the project integrated new equipment with existing equipment that was installed 25 years ago, it was cost effective to design modifications in the field in consultation with local specialty contractors. This portion of the project involved more repair work rather than new construction. The goal was to utilize as much of the existing equipment as possible, keeping costs down but still achieving a functional heating system. A full design and construction bid package would have been difficult to prepare ahead of time, since the condition of the existing equipment and the extent of the repairs needed was not known. Utilizing the specialty contractors on a purchase order basis saved time and allowed the design team to work with the contractor during the construction process. Design decisions were made in the field as each issue was discovered, preventing re-design costs and change orders every time existing conditions varied from the original design. Purchase orders were generated for individual portions of the work as the project progressed, meaning the design team and the contractors did not have to guess what would be required for the whole project upfront.

Numerous specialized trades were involved including electrical, plumbing, roofing, and specialized boiler conversion. It can be very difficult to obtain bids from large general contractors to supply all of these services on a retrofit type project. The construction activities were supervised by AES and Brian Brown Engineering. Various changes were made in the field to accommodate existing piping and equipment. The majority of these construction activities were paid for with match funds provided by MJUSD.

Heard Plumbing

MJUSD's subcontractor Heard Plumbing provided plumbing installation and modification to the existing systems. This work involved testing and flushing existing pipelines, as well as installing new piping, pumps, and heat exchangers. Heard Plumbing worked from drawings provided by AES and worked closely with AES and Brian Brown Engineering during the construction. Numerous issues were not discovered until testing and start-up began and items had to be replaced or retrofitted at that time. Although this did take additional time, the project was able to salvage and use many of the in-place items including pumps and existing heat exchangers, helping to offset unexpected costs related to the drilling work.

Copp's Irrigation

MJUSD's subcontractor Copp's Irrigation provided the injection pumps at the injection well location. Copp's Irrigation's cost was significantly lower than other quotes submitted for the high-pressure injection pumps and related manifold piping. These pumps connect directly into the geothermal return line and inject the water back into the aquifer via the injection well. Two pumps were installed for alternating service and lead-lag needs. Pump flow is controlled by VFD's, one for each pump. The pumps require a high head due to the injection pressures. Figure 16 is a photograph of the injection well pumps installed at the injection well.

McCombs Electric

MJUSD's subcontractor McCombs Electric provided electrical wiring to all pumps and control systems. This work included wiring for circulation pumps, verification of existing equipment wiring, and communication line extensions. McCombs also provided ventilation fans and louvers for the new injection well building and existing production well building needed to support the operation of the injection well and production well, respectively.

Figure 16: Injection Well Pumps

Photo Credit: Anderson Engineering & Surveying, Inc.

CR Combustion

MJUSD's subcontractor CR Combustion provided boiler piping and retrofitted the boilers in the High School from steam to hot water operation. They also provided teardown and cleaning of the heat exchanger located in the High School Gym.

Joe Lloyd Construction

MJUSD's subcontractor Joe Lloyd Construction provided concrete equipment pads in the High School boiler room, interior finishes on the Middle School Heat Exchanger Building, and minor carpentry.

Shasta Union High School District

Under a separate contract with MJUSD outside of this agreement, Shasta Union High School District provided set up of control communication lines into MJUSD's computer system, termination of the fiber optic cables inside the buildings, and conversion to copper connections for the control panels. Shasta Union High School District contracted with MJUSD to provide technical support for their computer systems. This work allowed the control system to be monitored and controlled remotely from an internet connection.

Semingson Architects

Plans had been submitted to DSA for approval of the 1992 project at that time but they had never been approved. MJUSD's subcontractor Semingson Architects revised the old plans and obtained DSA approval. DSA would not issue final approval until additional bracing for the heating pipes had been installed.

Harbert Roofing

MJUSD subcontracted with Harbert Roofing to install bracing to the heating pipes and incidental items in all three schools. This work had to be completed before starting heat flow to these buildings.

Overall Results

The building retrofits and control systems took additional time due to the complexity of integrating the new equipment with the existing systems. Since the 1992 geothermal equipment had not been used for 25 years, numerous leaks and maintenance issues were discovered during construction. Additional time was required to verify that existing components would work and to repair leaks as they were discovered. However, this portion of the project was very successful. The 1992 equipment was successfully integrated with new equipment to achieve a functional system.

CHAPTER 3:
System Commissioning & Start-Up

The following commissioning activities were completed to verify proper operation of all three school's heating systems from the geothermal supply:

- Tested the production well's control valves, and water supply piping.
- Tested injection pumps and control equipment at the injection well.
- Verified operation of existing pumps and controls in the Middle School.
- Tested piping and pumps in the Middle School Heat Exchanger Building.
- Tested Elementary School piping.
- Tested new equipment in the High School boiler room.

Brian Brown Engineering witnessed and accepted the tests and final commissioning.

Production Well Water Supply Piping with Controls

The geothermal water from the production well to the new High School pipeline and the existing Middle School heat exchanger can be controlled by separate motorized valves at the production wellhead. The production well's supply pressure and temperature were monitored and recorded in a trend log.

Injection Well Pumps and Controls

The injection well building contains two injection booster pumps. These pumps operate in parallel to provide enough pressure to circulate the geothermal water through the pipelines and building heat exchangers, and inject the cooled geothermal water back to the aquifer. Pump motors are powered by VFDs for variable speed and flow operation. The Alerton pump controller is connected via fiber optic cable to the control system in the Middle School Heat Exchanger Building. Brian Brown Engineering completed the following operation and verification activities:

- Operated pumps to check rotation.
- Tested VFDs and pumps running from minimum to maximum speed.
- Programmed control sensors for injection temperature, injection pressure, pipeline pressure, and pump flow. Verified that the information transmitted from the sensors to the computer software matched direct readings from the gauges.

- Programmed Alerton controller for automatic remote-controlled start, stable speed operation, and automatic lead-lag pump operation.
- Programmed trend logs on pumps, pressures, and temperature to monitor system operation. Trend logs recorded and saved data on pressure, temperature, and flow.

Middle School Pumps and Controls

The existing equipment included two heating water circulation pumps, controls and a VFD. Since this equipment had not been used since 1992, Brian Brown Engineering performed the following commissioning and start-up activities for the pumps and controls:

- Operated the existing pumps and VFDs and checked pump rotation.
- Verified that the VFDs and pumps circulated water to the geothermal heat exchanger, and heated water through the building heating system.
- Disconnected existing control sensors from the original pump controller and connected the existing and new sensors to the new Alerton pump controller.
- Tested operation of the new controls with existing pump VFD and existing backup boilers.
- Programmed trend logs on pumps, pressures, and temperature to monitor system operation.

Elementary School and Middle School Heating System Reconfiguration

The geothermal heating system was reconfigured to allow independent operation of the two schools; this required new pumps to serve the Elementary School and new controls in the Middle School Heat Exchanger Building.

Brian Brown Engineering performed the following start-up and verification activities:

- Operated the original geothermal heat exchanger with the Middle School heating system.
- Tested operation of the new Elementary School pumps and VFDs.
- Programmed new Alerton pump controller connected to a mix of existing and new sensors.
- Programmed trend logs on pumps, pressures, and temperature to monitor system operation.

Elementary School Piping

Heard Plumbing flushed and pressure tested the existing piping from the Middle School Heat Exchanger Building to the Elementary School. A pressure test was also performed on the existing hydronic piping in the Elementary School.

High School Heating System

The High School's Main Building heating system originally operated on low-pressure steam, supplied by two boilers in a basement boiler room. This project included installation of pumps, heat exchangers and piping in the boiler room, conversion of the boilers from steam to hot water operation, and conversion of the building heating system to hot water operation. Brian Brown Engineering performed the following verification activities:

- Pressure-tested the new piping supplying the Gym and Shop Building. Pipe was tested at a pressure of 125 psi.
- Tested operation of the new pumps and VFDs in the Boiler Room.
- Verified conversion of boiler operation from steam to hot water.
- Programmed and tested new controls. Verified new heating system with controls for the Gym and Shop Building.
- Monitored building heating operation. Recorded temperature in rooms and adjusted pump run times.

CHAPTER 4: Results and Conclusion

This project had the following goals:

- Reuse the existing geothermal system components as much as possible to develop a complete geothermal heating system for all the school buildings.
- Extend the piping to the Alturas Swimming Pool.
- Develop adequate capacity to connect additional facilities in the future, including the planned hospital building.

This project was able to achieve all these goals. The geothermal production and injection wells have been operating since early November 2017. As of April 2018, the injection well pressures have remained constant at 175 psi, better than expected. Figure 17 shows the injection pressure at Well AL-4 and Figure 18 shows the pump flows at Well AL-4.

The injection well had a targeted depth of 1,900 ft, however it was drilled significantly deeper to meet injection expectations and ultimately terminated at 3,240 ft. This resulted in a budget reallocation increasing funds for drilling and reducing funds available for the planned building retrofit.

The Middle School heating system has been operating since early November 2017. The High School Gym has been operating on the new system since January 2018. The High School Shop Building's geothermal operation began in March 2018. The Shop Building's operation was delayed because there was a leak in the existing building piping that had to be repaired before the system could operate. The remaining High School buildings became operational in early April 2018. The Elementary School's geothermal operation started in April 2018, after completion of the pipe support retrofits.

System temperatures have remained steady when the system is in use. Water is leaving Production Well AL-2 at a temperature of 175°F (79.4°C), dropping to 140°F (60°C) as it cycles through the buildings, and entering the Injection Well AL-4 at 120°F (48.9°C); this shows an average net heat use of 55°F (12.8°C). Figure 19 shows the temperature trend for the geothermal supply, heat exchanger return, and injection. The steady trends show constant heating. The drops in temperature values indicate the system shutting off when heat is not needed, which is generally in the afternoon.

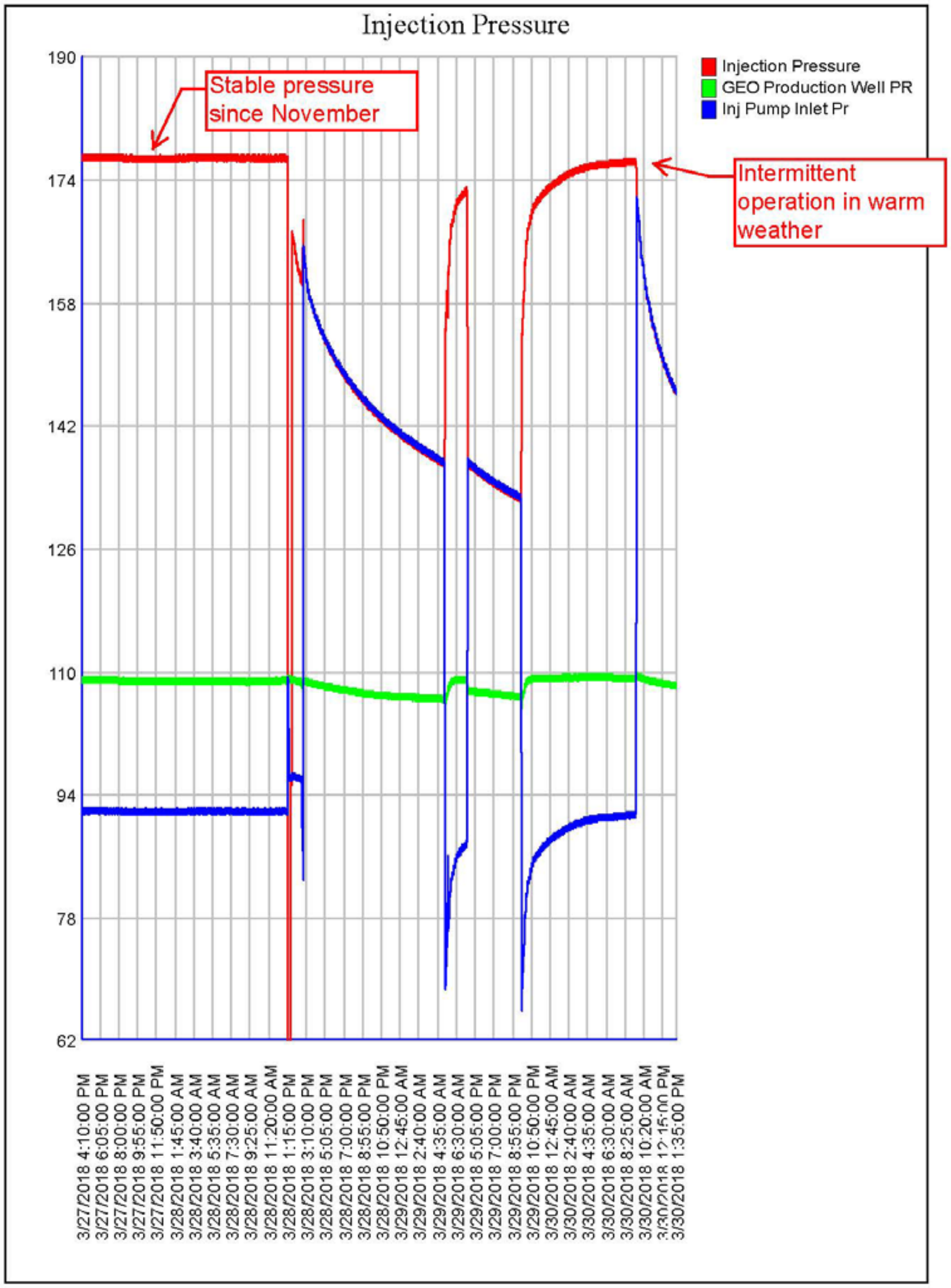
MJUSD has already seen a reduction in heating costs. The Middle School reduced fuel oil consumption by over 8,000 gallons in six months, saving about $25,000. The energy savings will allow more spending on education and public programs instead of fossil fuels. MJUSD plans to use the cost savings to fund college field trips, increase students' access to technology, provide professional development for staff, hire additional staff to meet the increasingly complex needs of students, fund field trips to enhance student career options, and consider an extended school day.

Since April 2018, the system has been supplying an average of 1 million BTUs per hour to the three schools; this is the equivalent of 10 gallons of heating oil per hour. At a heating oil cost of $3 per gallon (average cost in the area during April 2018), the system is saving MJUSD approximately $30 per hour during the heating season, which generally runs from October through April. Heating needs vary greatly throughout the heating season, but the system operates an average of six hours per day, which equates to an average annual savings of $37,000 for MJUSD.

The system has additional capacity for more community use including the Alturas Swimming Pool and new hospital. The system can easily supply 5.5 million BTUs per hour and still operate below the projected injection pressure at Well AL-4; this is the equivalent of 40 gallons of heating oil per hour. The system will be capable of providing sustainable heat to the Alturas community for possibly 30 years.

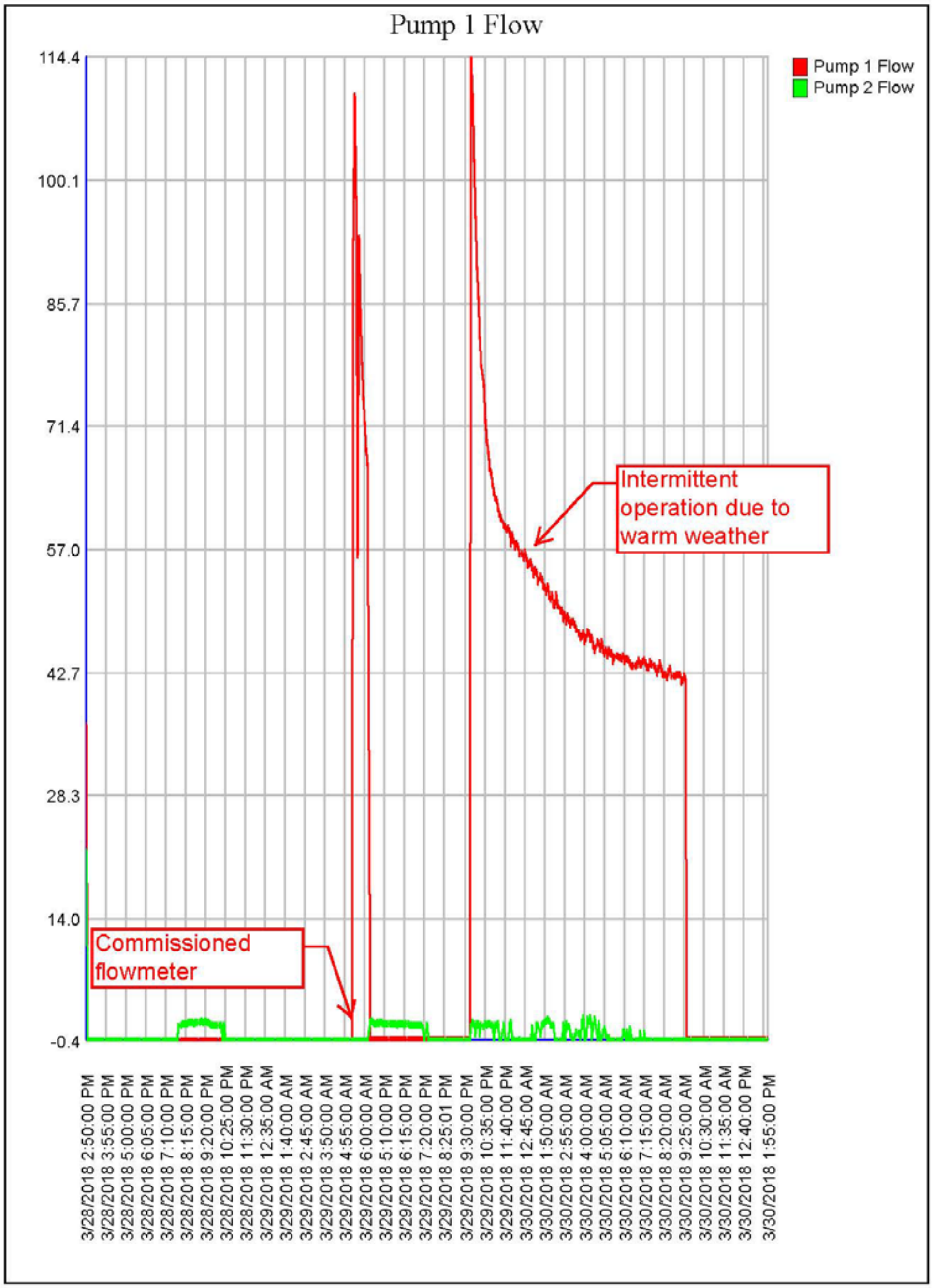
Renewable energy applications, such as direct source geothermal heating, have long-term environmental and economic benefits. Despite these benefits, geothermal water is often overlooked as a viable heating source due to a lack of awareness of existing geothermal resources or familiarity with their application. Many communities think the resource is not available or that the geothermal water is not “hot” enough. Extremely high temperatures are not essential; the Henley High School project in Klamath Falls, Oregon was successful with water temperatures of 120°F (48.9°C). Water at 80°F (26.7°C) is still a viable resource for smaller applications such as heat pumps.

Figure 17: Injection Pressure at Well AL-4 (psi versus time)



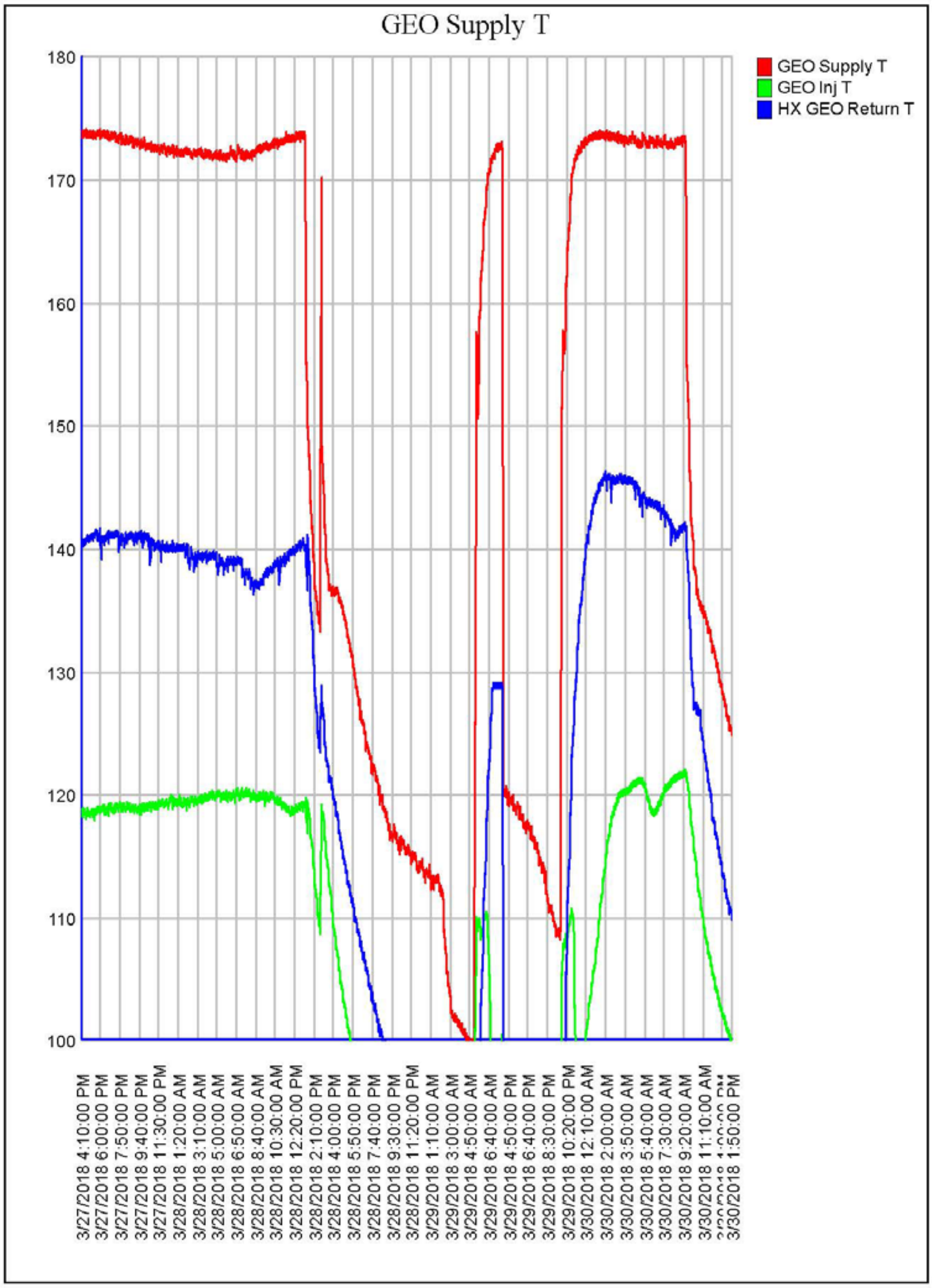
Source: Brian Brown Engineering, LLC

Figure 18: Injection Well Pump Flow (gpm versus time)



Source: Brian Brown Engineering. LLC

Figure 19: Geothermal System Temperatures (°F versus time)



Source: Brian Brown Engineering, LLC

GLOSSARY

Abbreviation, Acronym, or Term	Definition
aquifer	A body of permeable rock which can contain or transmit groundwater
aquitard	A geologic formation that may contain groundwater but is incapable of transferring that water to the surface.
BACnet	Building, Automation, and Control Network
bls	below land surface
BTU	British Thermal Unit. The amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
°C	degrees Celsius
DSA	(California) Division of the State Architect
ductile iron	A graphite-rich cast iron containing magnesium where the graphite is in the form of nodules instead of flakes.
Elementary School	Alturas Elementary School
Energy Commission	California Energy Commission
°F	degrees Fahrenheit
ft	feet
flooded dual-tube reverse-rotary drilling method	A well drilling method. As the drill bit rotates, a suction type pump is used to pull the cuttings loosened by the bit, through the hollow drill stem to the surface. Water from a supply pit near the rig circulates through a trench to the open drilled hole. This water serves to raise the water level in the drill hole to pit level so that hydrostatic pressure is applied against the wall of the open hole to prevent caving.
geothermal effluent	Geothermal wastewater discharged from the system.
gpm	Gallons per minute
Gym	Gymnasium

Abbreviation, Acronym, or Term	**Definition**
High School	Modoc High School
hydronic	A heating (or cooling) system in which heat is transported using circulating water
in	inch, inches
infrastructure	The basic physical and organizational structures and facilities needed for the operation of a society or enterprise.
injection well	A well that places fluid deep underground into porous rock formations.
“lead-lag” pumps	Pumps operated in parallel so that only one pump operates during low demand and both pumps can operate during high demand.
lithology	The study of the general physical characteristics of rocks.
LS	land surface
mg/l, µg/l	milligrams per liter, micrograms per liter
Middle School	Modoc Middle School
MJUSD	Modoc Joint Unified School District
psi; psig	pounds per square inch; pounds per square inch gauge
Shut-in Artesian Pressure	The natural artesian pressure of a well, which allows for water flows without pumping.
tremie	Watertight pipe with a conical hopper at its upper end. Used to pour concrete under water.
tuffaceous	Containing greater than 50 percent tuff, which is a type of rock made of volcanic ash.
VFD	Variable Frequency Drive A type of adjustable-speed drive used in electro-mechanical drive systems to control motor speed and torque by varying motor input frequency and voltage.
Well AL-1	Existing Production Well AL-1
Well AL-2	Existing Production Well AL-2

Abbreviation, Acronym, or Term	Definition
Well AL-4	New Injection Well AL-4

APPENDIX A:
Project Map