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Boise's Geothermal Direct Use District Heating

Jon Gunnerson, Roy Mink

150 N Capitol Blvd., Boise, Idaho 83701

jgunnerson@cityofboise.org,

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ABSTRACT

The geothermal springs near Boise Idaho have a long history. They were originally used by Native Americans, then by trappers, miners, and early settlers along the Oregon Trail. Development began in 1890 when the first two wells were drilled to supply hot water to a natatorium and houses being constructed in east Boise. This system, currently referred to as the Boise Warm Springs Water District (BWSWD) continues to operate today serving approximately 350 houses and businesses. Additional wells were drilled in the 1980's by the City of Boise, the State of Idaho and the Veterans Administration to develop a geothermal district heating system within each of their service areas. Today, Boise is site of the nation's oldest and largest geothermal district heating system and may well boast as one of the largest in the world. The geothermal resource is a fault controlled system within cretaceous rocks of the Idaho Batholith. Geothermal fluids move up a fault-fracture system along the Boise foothills to the northeast of the city with outflow within interbedded basalt, porphyritic rhyolite and sandstone/conglomerate units underlying the Boise area. The City of Boise, the Veterans Administration and the BWSWD wells produce from the fractured granitic rocks associated with the Boise Front Fault while the wells supplying the State of Idaho system are developed in the porphyritic rhyolitic units. The City of Boise system currently heats over 90 commercial, government, and institutional buildings comprising over 6 million square feet (557,418 square meters) of space utilizing 177°F (80°C) geothermal water. In addition to the historic geothermal district heating system, a commercial green house was started in 1930 and continues to provide fruits and vegetables to residents of Boise. The State of Idaho geothermal heating complex heats 11 state owned buildings totaling approximately 800,000 square feet (74,322 square meters) including the state capital building, which is the only US state capital being heated by geothermal energy . The US Veterans Administration system heats 19 buildings totaling approximately 500,000 square feet (46,452 square meters) of space. The City of Boise, the State of Idaho, the Veterans Administration and the Warm Springs Water District heating systems make an approximate total of 7.5 million square feet (696,773 square meters) heated by geothermal resources. Although primarily utilized for space heating, these systems also heat domestic water, sidewalk-snowmelt systems, recreational pools, laundry facilities and other direct use applications.

INTRODUCTION

Deep below earth's surface is a natural resource that the City of Boise, Idaho, USA has been utilizing for more than a century. A reservoir of geothermally heated water exists under the City's downtown. From heating buildings to sidewalk snowmelt and warming recreational pools, the City of Boise's geothermal heating utility is innovative, renewable and sustainable. Geothermal heating in Boise is credited to be the oldest and largest in the United States, an accomplishment we are proud of.

Today the City of Boise operates the largest of the four geothermal heating districts in downtown Boise. The City's system, which has been in operation since 1983, withdraws naturally heated 80.6°C (177˚F) water. The geothermal water is used primarily for space/building heating, but is also used for sidewalk snowmelt, domestic water heating, heating public swimming pools, laundry facilities and other various direct uses. Currently the City system heats over 90 buildings equaling over 557,478 m^2 (6,000,000'^{2}). All used water is collected and injected back into the aquifer making this clean utility very sustainable.

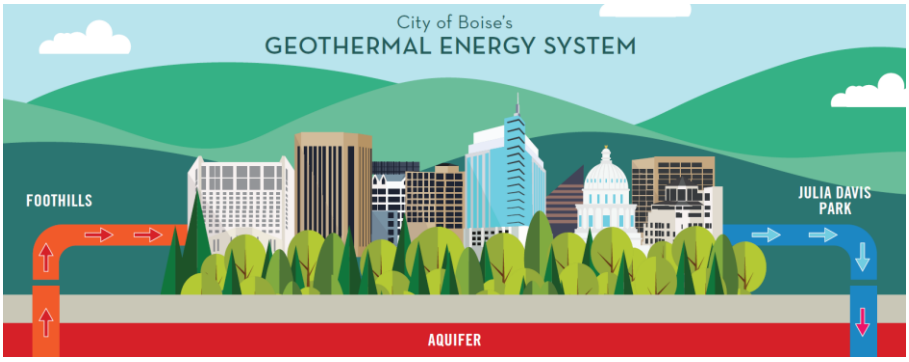


Figure 1 - Boise's Geothermal Energy System

PRE-HISTORY

Geothermal energy in Boise has a long history of use. Numerous artesian hot springs historically flowed out of the Boise foothills. For centuries the springs were used by the Shoshone, Bannock and Paiute Native American tribes as wintering

campsites utilizing the natural hot water for bathing, cooking, warmth, and medicinal beliefs. By the mid 1800's, as America was on its quest for western exploration, miners and pioneers looked forward to stopping in the Boise Valley for rest and bathing in the natural hot waters. Before long, the attractiveness of the natural hot springs made them a popular destination, causing many of the larger springs to develop into resorts.

GEOTHERMAL AQUIFER

The geothermal aquifer supplying geothermal fluids for the system is a sequence of rhyolite unites and minor arkosic and tuffaceous sediments of the Miocene Idavada Group. The aquifer is confined by a unit of impermeable basaltic tuffs. The aquifer is a fracture dominated system yielding 65 - 82°C (150 - 180°F) thermal waters at rates of 2291 – 4542 lpm (600 – 1200 gpm). Granitic rocks of the Idaho Batholith underlie the Idaho Group. Thermal water convects upward through northwest trending range front faults.

FIRST GEOTHERMAL HEATING DISTRICT

In the late 1800's three businessmen sought to drill wells near a Boise area hot spring to provide hot water to nearby houses, businesses and hotels. In 1891, a series of wells were completed providing a natural artesian flow of approximately 3,000,000 liters per day (800,000 gallons per day) of 79°C (175˚F) water. The initial natural pressure of the artesian wells was reported to be sufficient to force the hot water to the top floor of a five story building. Due to the success of the volume, temperature and pressure of the hot-water wells, there was vast interest in using this new utility. The original investors connected their nearby homes and additionally, the Idaho State Penitentiary which was also in the area. Several other homes were quickly added to the geothermal system, most still in existence today. Shortly after, one of the most notable structures, the Boise Natatorium opened in 1893. The Natatorium was a 1,394 m^2 (15,000'^{2}) structure with a 20 m x 35 m (65' x12') swimming pool and also offered 50 bath houses, dressing rooms, parlors, card rooms, a dining room and a café all heated directly by geothermal water. Unfortunately, the Natatorium suffered a fire and fell into disrepair in 1934 and was closed permanently.

Upper Left: Figure 2 - CW Moore House, First house to be heated by Geothermal Water. In existence today

Upper Right: Figure 3 - Natatorium Interior

Bottom: Natatorium Exterior

Today, this original geothermal heating district (Boise Warm Springs Water District) still exists. Shortly after the proven success of using geothermal water for heating, the nation's first geothermally heated greenhouse began operation in north Boise, providing year round fruits and vegetables to residents of Boise. This greenhouse, operated by fourth generation Edwards' family continues today and has been a leader in geothermal greenhouse success across the United States and world.

BOISE'S 4 GEOTHERMAL HEATING DISTRICTS

There is a total of four geothermal heating districts in Boise providing a substantial amount of thermal energy to heat a large number of buildings in and around downtown.

The original Boise Warm Springs District System is still in operation providing heat to approximately 350 homes.

The State of Idaho operates a geothermal heating district that heats the State Capital and Capital Mall complex (See Figure 4). This is the only US State Capitol to be heated by geothermal energy. Commissioned in 1982, currently this district heats 11 State owned buildings totaling approximately 74,322 m^2 (800,000'^{2}).

Figure 4 – Boise, Idaho State Capital

Another small, yet efficient geothermal heating district in Boise serves the US Department of Veterans Affairs and VA Hospital. This geothermal heating district heats 19 buildings equating to approximately 46,451 m^2 (500,000'^{2}).

The fourth geothermal heating district is owned and operated by the City of Boise. Currently the nation's largest, the City's system heats over 90 commercial, governmental and institutional buildings in downtown equating to over 557,478 m^2 (6,000,000'^{2}). The map (Figure 5) below illustrates the location of these four separate geothermal heating districts. (**Green** = Warm Springs Water District, **Teal** = State of Idaho, **Blue** = Veterans Administration, **Pink** =City of Boise)

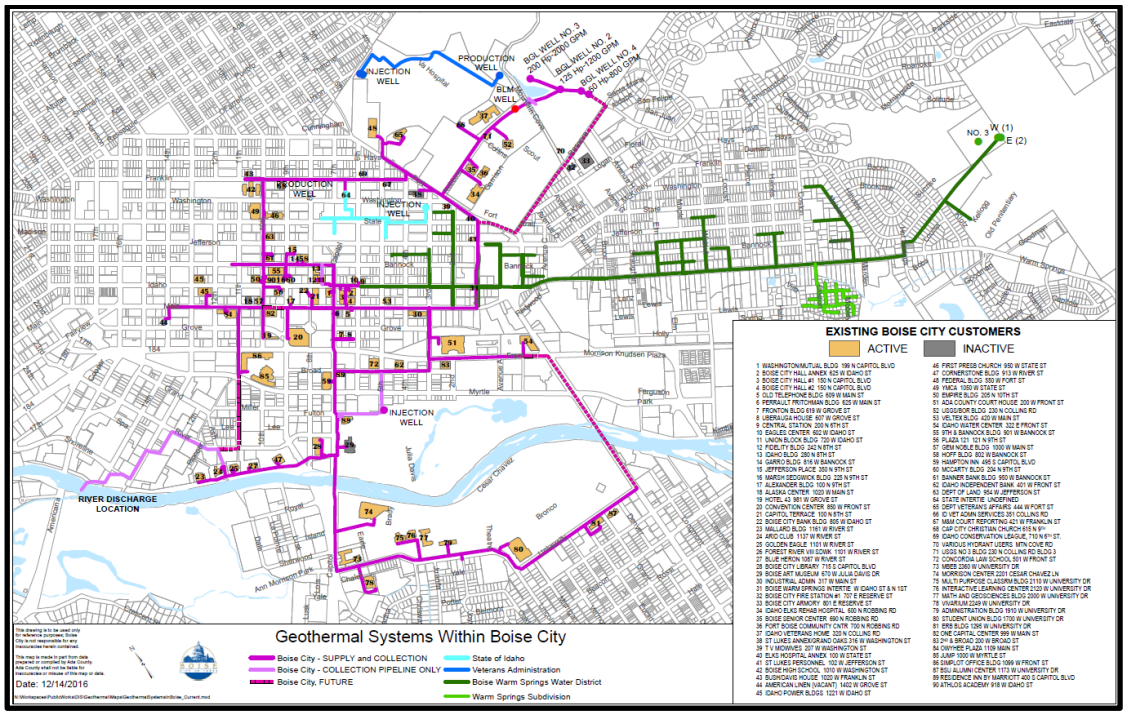


Figure 5 - Location of the four geothermal heating districts in the Boise area.

CITY OF BOISE GEOTHERMAL HEATING SYSTEM

The City of Boise's geothermal heating utility delivers naturally heated 80.6°C (177˚F) water through a network of pipes that warms more than 557,481 m^2 (6,000,000'^{2}) – a number that is growing rapidly. After the water is circulated through the heating district it is safely injected back into the aquifer making a closed loop system. No fossil fuels are used at any step of the process, which keeps the environmental impact lower than other heating options.

The City of Boise has three production wells ranging in depths from 122 to 244 m (400 to 800') deep. These wells are capable of producing over 15,142 lpm (4000 gpm) of 80.1°C (177˚F) water. As of 2018, during cold mornings, flows peak at approximately 7192 lpm (1900 gpm). This allows for redundancy of pumping production and provides a high level-of-service to the customers. In addition, there is ample pumping capacity available for potential future growth and development.

Currently the City has three disposal locations for the used geothermal water. The preferred disposal is re-injection or putting the geothermal water back into the same aquifer it was pumped out of. This is the preferred method of disposal which helps to maintain geothermal aquifer sustainability. The City also has regulatory approval to discharge into the Boise River, however there are temperature and flow restraints that limit the duration this can be done. A last option is to send the used water into some large infiltration basins located north of downtown.

The City system operates a two-pipe, closed loop geothermal system. The supply pipe delivers geothermal water directly to buildings at temperatures ranging from 71°C to 79°C (160˚F to 175˚F) at pressures between 40 and 70 pounds per square inch depending on the building's geographic location. The collection pipe collects the used geothermal water for disposal. Buildings on average remove approximately 10°C (50˚F) from the geothermal fluid, resulting in disposal water ranging in temperatures between 43°C (110˚F) and 51.7°C (125˚F) at pressures between 10 and 35 pounds per square inch.

The pressure differential between the supply and collection pipes is maintained to direct the geothermal water from the supply pipe to the collection pipe without the necessity of buildings to provide any additional pumping energy. The system typically has a pressure differential of 30 psi, however is designed to maintain a minimum of a 10 psi differential during peak flows. See Figure 6.

A Variable Frequency Drive (VFD) at the production wells maintains a constant supply pressure throughout the system. The collection side is also set to maintain a pressure and is accomplished using a pressure sustaining valve during low flows - under 1893 gpm (500 gpm) and a VFD pump control during higher flows.

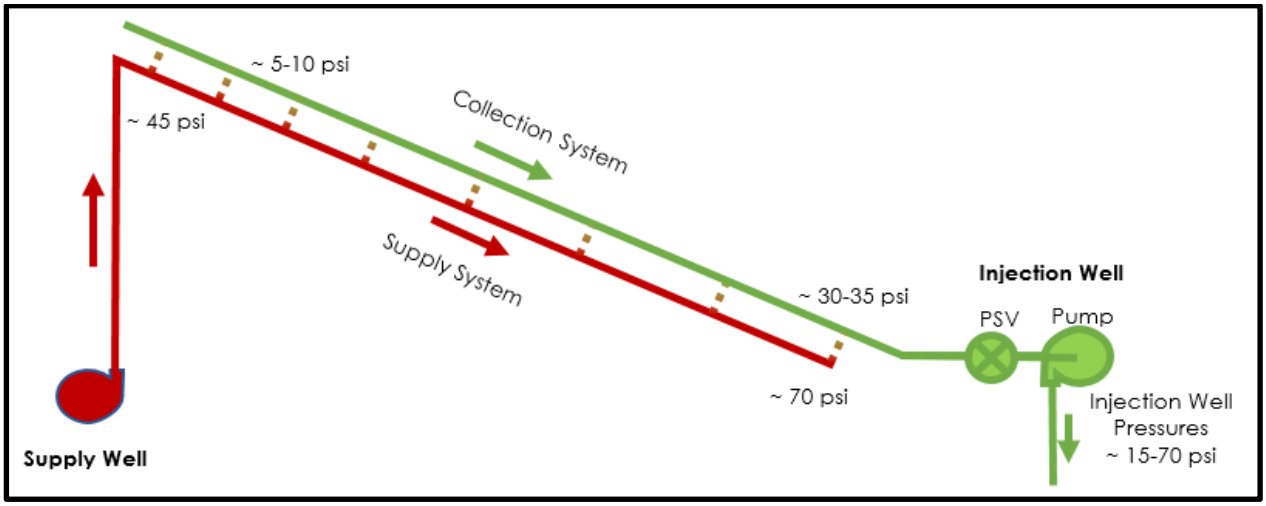


Figure 6 - Production and injection well operation diagram.

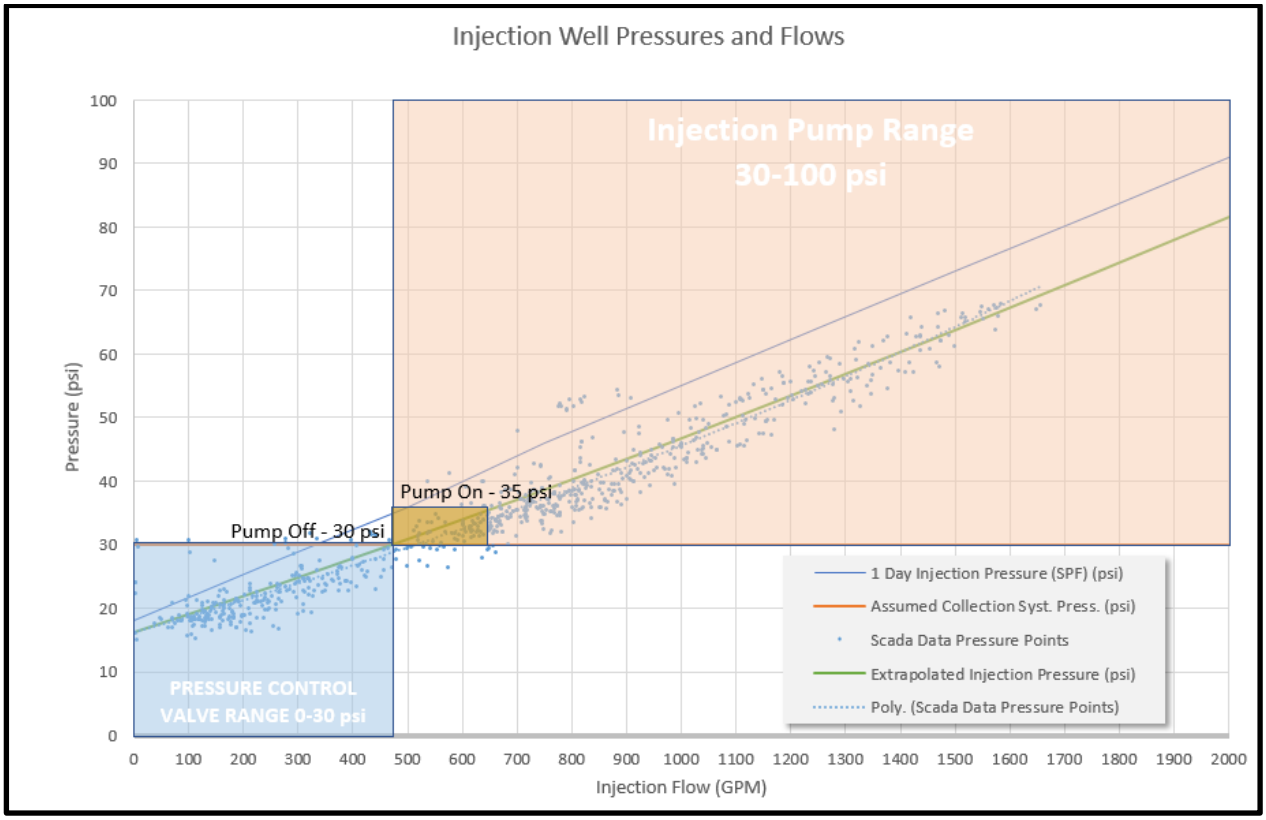


Figure 7 - Injection well pressures and flows.

SUCCESS OF RE-INJECTION

When the City's geothermal system was first developed in 1982, used water was disposed into the Boise River. Almost immediately the geothermal aquifer levels began to decline as all used geothermal water was released directly into the river. Within the first five years of operation, the aquifer levels declined nearly 9 meters (30 feet). It was apparent the geothermal water was being mined, and the rate of withdrawal was much greater than the natural rate of recharge.

With a considerable investment in infrastructure, the future of maintaining a large heating district was uncertain. Solely discharging to the Boise River was unsustainable for the natural resource. With limited options, the City invested in drilling an injection well to dispose the used geothermal water. The well site was chosen to prevent cross-contamination with any other geothermal production wells and at a site unlikely for future development.

The geothermal injection well was completed and commissioned in 1999. Immediately, aquifer levels began to recover. All discharge to the Boise River stopped by 2003, except in rare times when the injection well is unusable, typically due to maintenance. Aquifer levels continued to climb and in 2013 reached levels exceeding the average level present before the City production wells were put into operation. Aquifer temperatures remain steady at 80.6°C (177˚F}. Re-injecting used geothermal waters was an enormous success in helping to insure the future of the City's geothermal heating utility district.

With available pumping capacity and a healthy aquifer, conditions are ideal to grow the City's geothermal system.

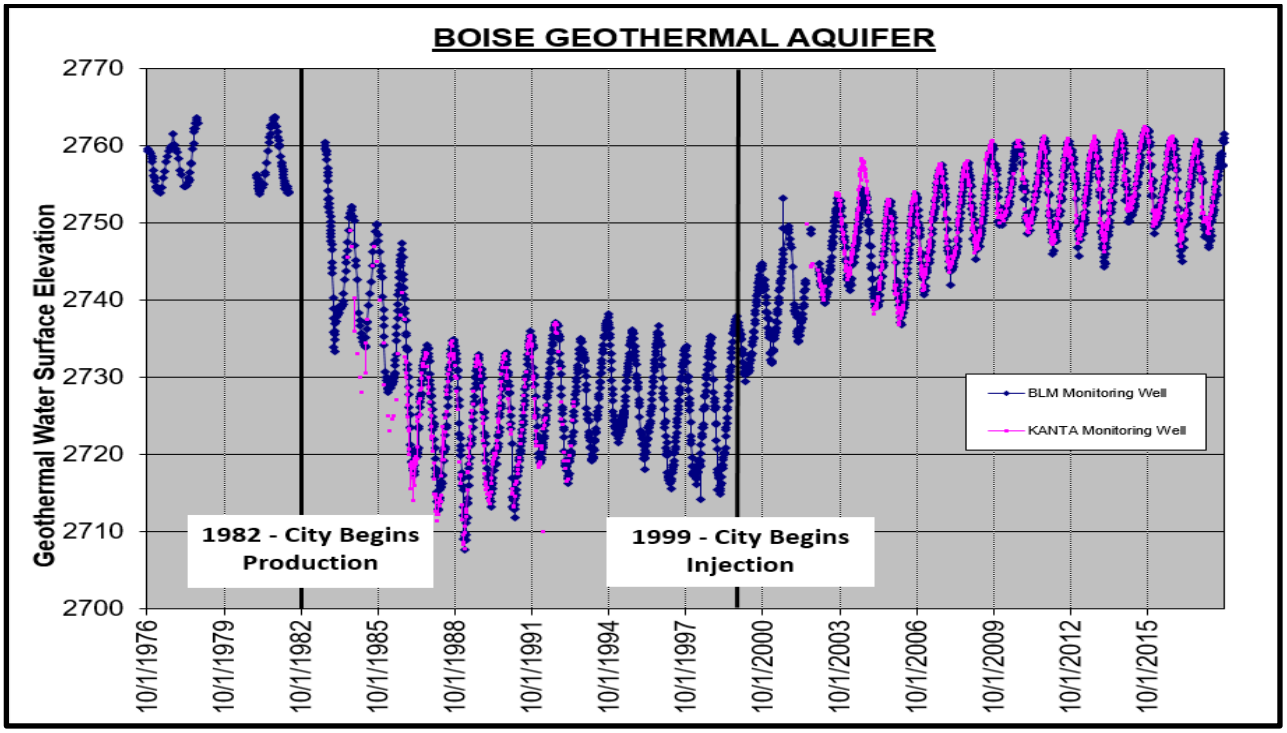


Figure 8 - Geothermal aquifer levels 1976 to 2018.

CITY'S INNOVATION

Thermography is a new tool used in assessing the geothermal pipelines to identify leaks and anomalies before they surface and become a larger problem. Infrared photos of the geothermal utility are taken annually and reviewed for 'hot-spots' or any evidence of change from years prior. See Figure 9. This technology has identified multiple leaks and allowed repairs to be made on the utility's terms, rather than acting rectroactively. Taking this proactive approach saves money, reduces labor costs, limits disruptions to the public, and allows building users to prepare for an upcoming shut down.

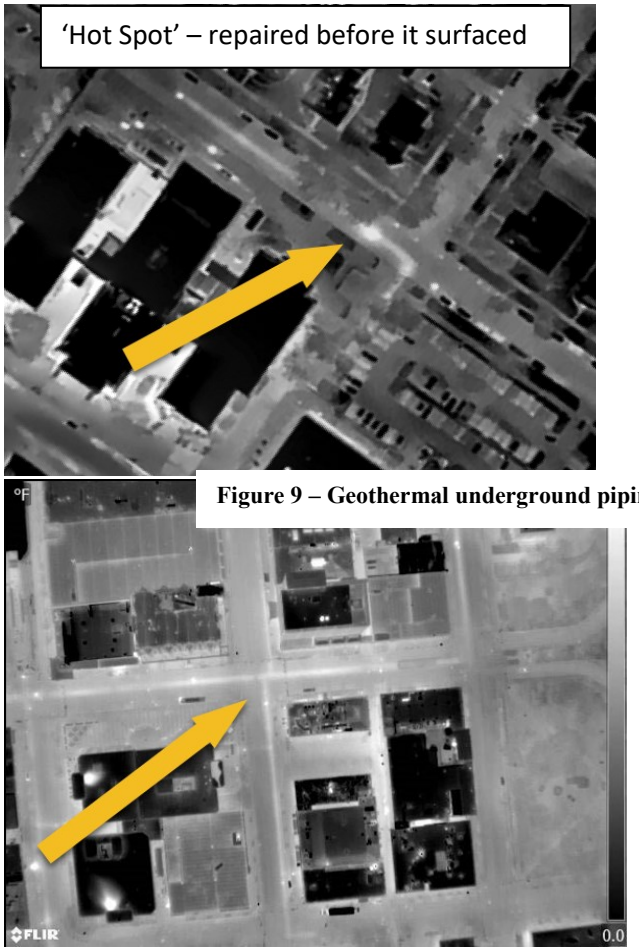


Figure 9 – Geothermal underground piping showing use of thermography

In addition to identifying 'hot spots', thermography has vastly improved the mapping system and is being used for a variety of other thermal applications. Thermography has greatly improved the level of service provided to customers and is a great tool that provides for a more manageable utility.

BOISE LIV DISTRICT

The LIV District is the City of Boise's first urban neighborhood built on sustainable practices. LIV stands for Lasting, Innovative, and Vibrant. The district incorporates green stormwater management, sustainable building practices, and promotes renewable energies.

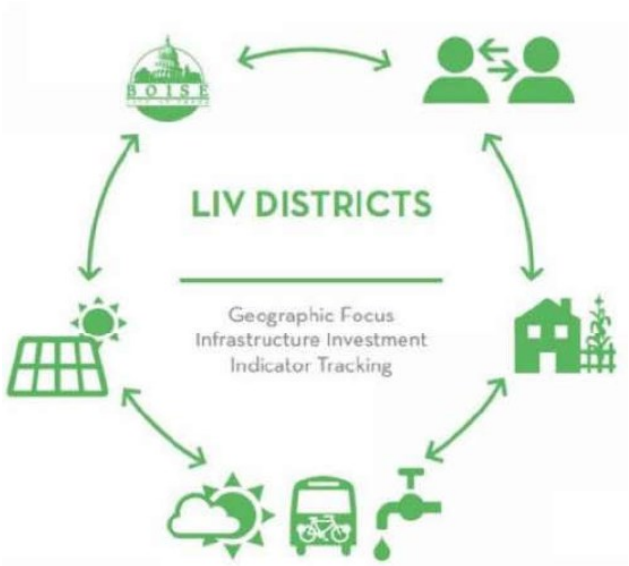


Figure 10 – LIV District concept

The LIV District is heated by geothermal water. However, what sets this area apart is that the City incentivizes the use of the collection of used 48.9°C (120°F) water. This reuse of a renewable resource allows buildings to use waste geothermal water at a discounted rate and works well for heat pump buildings/technologies. This water has already been pumped, already been used, and is ready for reinjection. Instead, it is now diverted through the LIV District so buildings can extract additional heat from this reclaimed water. This approach of reusing the collection water encourages more efficient use of the natural resource, as well as allows the system to grow and expand without pumping additional water. See Figure 10.

CITY'S GEOTHERMAL PUBLIC ART & EDUCATION

The City of Boise is dedicated to providing its citizens with opportunities to learn about their unique local environment and ways to live sustainably within it. The geothermal heating district provides opportunities through both education and Public art.

Figure 11. Bronze plaque presented to each geothermally heated building Boise .

Each building heated by the City's geothermal district is provided a bronze plaque created by local artist, Ward Hooper, to commemorate their commitment to using this clean, natural resource. The plaques, in addition to displaying a pledge to sustainability, also enlighten residents, the public, and visitors of the prodigious utility that is unique to Boise.

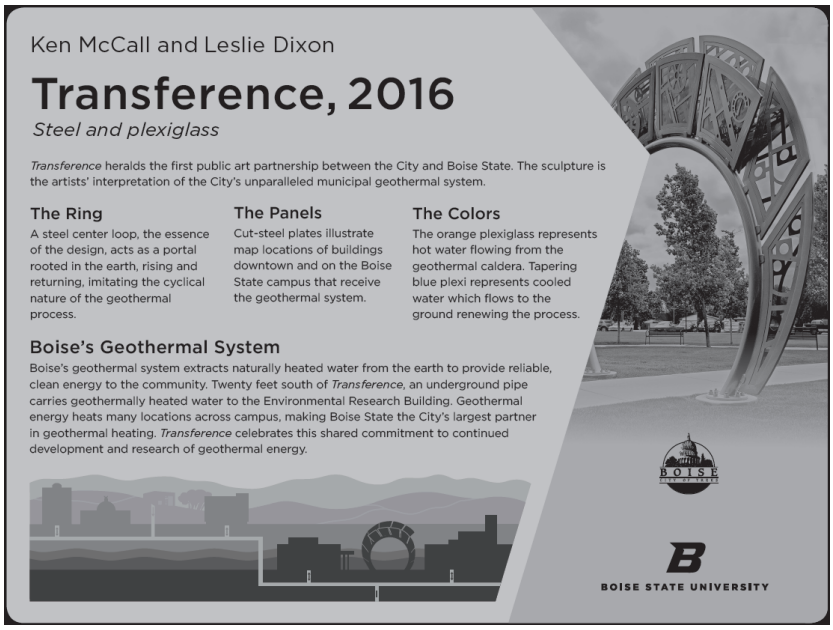
The City of Boise also hosts the Water Shed Center, an educational center that provides free, year-round events and activities for all ages. The Water Shed Center introduces the public to water protection and conservation through hands-on exhibits. One of the newest exhibits is 'The Heat Beneath Your Feet'. A portrayal of Boise's direct-use geothermal system, this exhibit includes interactive education about the geology and technology that provide a local sustainable energy source; information about Idaho's expansive geothermal potential; an historic photographic timeline of the geothermal development that led to Boise's growth; and an anamorphic painting of the earth peeled away to reveal hot depths below. The painting, completed in 2017 by London-based artist Joe Hill, appears 3-dimensional when viewed from a particular angle.

Figure 12 – 'The Heat Beneath Your Feet' Exhibit

Visitors can take their photos "teetering on the edge" of the hot abyss and share them through social media. *The Heat Beneath Your Feet* provides a compelling look at this green energy source that is as old as the earth itself. See Figure 12.

The City of Boise has also partnered with other agencies to commission geothermal related artwork. A recent example is the partnership with Boise State University to commission 'Transference' shown in Figure 13. Public art portraying geothermal energy is a successful way to recognize this clean resource and bring it to the attention of a wide range of diverse groups who may not typically discuss utilities and infrastructure.

Figure 13 – Transference display



CONCLUSION

The City of Boise continues to look for innovative ways to use the geothermal heating utility – including heating greenhouses, showers, and laundry facilities, as well as helping buildings and water systems run more efficiently. We are committed to helping our users optimize their own building's system to perform as efficiently as possible, ensuring the most responsible use of this natural resource.