# Geothermal Feasibility Study, Upper Clear Creek Watershed: 1041 Permit Contents

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March 21st, 2013

## Contents


Background ..... 5

Applicant Information ..... 5

Project Information ..... 6

- Plans and Specifications in Detail ..... 6
- Alternatives and Projects Considered ..... 6
  - Geothermal Power Production ..... 6
  - Agriculture ..... 7
  - District Heating ..... 7
  - Direct Use ..... 7
- Schedule for Designing, Permitting, Constructing, and Operating ..... 8
- Project Need ..... 9
- Conservation Techniques ..... 10
- Adjacent Property Owners ..... 10

Property Rights ..... 10

- Permits and Approvals Required ..... 10
- Planned Access to Project Site (legal right) ..... 12
- Persons of Interest ..... 12

Technical and Financial Feasibility ..... 13

- Construction Cost and Time ..... 13
- Table 3: Geophysical Survey Cost and Time ..... 14
- Table 4: Borehole Logging Cost and Time ..... 15
- Revenues and Operating Expense ..... 15
- Debt Amount and Services ..... 15
- Who Pays/Who Benefits ..... 15

Decommissioning ..... 15

- Properties to be Reclaimed ..... 15
- Cost of Removed Material (18'' Depth) ..... 16
- Cost of Road Repair ..... 16
- Time of Decommissioning ..... 16

Socioeconomic Impacts ..... 16

- Land Use ..... 16
- Local Government Services ..... 16

Housing ..... 16
Financial Burden on Locals ..... 17
Local Economy ..... 17
Demographic Information ..... 17
Recreational Opportunities ..... 17
Historical Importance ..... 17
Nuisance ..... 18
Environmental Impacts ..... 19
Air Quality ..... 19
Visual Quality ..... 19
Water Quality ..... 19
Flood Plains and Wetland Areas ..... 20
Habitats ..... 20
Plant Life ..... 21
Surface Water Quality ..... 21
Introduction ..... 21
Clear Creek County Water Resources and Hydrology ..... 21
Water Resources ..... 21
Hydrology ..... 25
Potential Impacts ..... 27
Monitoring Requirements ..... 27
Groundwater Analysis ..... 28
Introduction ..... 28
Geology ..... 29
Water Wells ..... 32
Groundwater/Surface Water Impacts ..... 34
Geochemical Data ..... 36
Geologic Conditions ..... 37
Hazardous Materials ..... 38
Monitoring and Mitigation Plan ..... 38
Maps ..... 42
Zoning Map ..... 42
Vicinity Map ..... 43

Roads and Access ..... 48
Description of Access Route ..... 48
Dust Control Procedures ..... 49
Road Maintenance Program/Schedule ..... 49
New Roads or Access Routes ..... 49
Works Cited ..... 50

## Background

The possibility of using geothermal energy to directly heat existing or planned structures in Clear Creek County (CCC) is currently being studied. Geothermal heating taps into the earth's renewable resources by capturing the heat from the subsurface and transferring to the surface as useable heat energy. This idea has great potential in the Clear Creek Watershed (CCW), particularly along the I-70 corridor between Georgetown and the U.S. 40 interchange. While extensive studies and geothermal exploration wells have yet to be completed, it is necessary to begin researching possible socioeconomic and environmental impacts if a geothermal heating system were to be implemented.

This report contains all of the major components required in a 1041 permit application. 1041 regulations apply for matters of state interest and are meant to promote the general health of the citizens and environment of CCC. For more information on the 1041 guidelines themselves, consult "Guidelines and Regulations for Matters of State Interest [1]."

Due to the early stages of the geothermal exploration project, this report will remain somewhat vague and will only be able to cover general environmental and socioeconomic factors to be considered. Therefore, it will not be a technical document. Many revisions will need to be made before applying for the 1041 permit that will be required before any construction and geothermal implementation can actually begin. Instead, this document is meant to serve as a reference in gathering information for a 1041 permit, as well as a reference for anyone looking to gain a quick understanding of the multidimensional impacts of a geothermal heating system.

## Applicant Information

The applicant for the 1041 will be whoever pursues this project. In the 1041, they will need to include the following information:

1) The names, addresses, telephone, email address and fax number, organizational form, and business of the applicant and, if different, the owner of the Project.

2) The names, addresses and qualifications, including those areas of expertise and experience with projects directly related or similar to that proposed in the application, of individuals who are or will be responsible for constructing and operating the Project.

3) Authorization of the application by the Project owner, if different than the applicant.

4) Documentation of the applicant's financial and technical capability to develop and operate the Project, including a description of the applicant's experience developing and operating similar projects.

5) Written qualifications of report preparers [1].

# Project Information

## Plans and Specifications in Detail

In order for a geothermal heating application to be considered, it is first necessary to conduct a geothermal survey. Such a survey can be designed to a client's specific needs and willingness to take risks, but will likely include a combination of geophysical survey techniques, as well as a series of exploratory wells [2]. Once this is completed, and the heat source has been identified, there are a number of different uses for the geothermal energy. This document explores the possibilities of heating a future light rail station or the use of thermal waters for a spa and wellness center. Both of these plans generally share the same specifications [3].

The first set of specifications involves the source itself. It must be located within the 575 square mile area of the Clear Creek Watershed, and it must yield temperatures at or above 100°F to be economically viable [2]. The location of the source is important as well. It must have no immediate negative impacts on historical or cultural property, no immediate negative impacts on recreation, and no negative impacts on water quality within 30 days of project completion. Of course, zoning laws must be followed as well.

Finding the heat source involves a number of specifications, but the heat implementation must follow certain rules as well. Other than existing regulatory laws, the geothermal heat implementation should aim to expel a maximum of 0.35lb/MWh of criteria air pollutants or less during operation, should operate at a minimum efficiency of 30%, and should have maximum operational noise levels of 100 dB or less [1].

## Alternatives and Projects Considered

There are a number of different geothermal technologies that were considered for development in the Upper Clear Creek Watershed. Ultimately the choice of a viable technology depends on the geothermal heat flow of the site. The technologies may be broken down into four categories that include:

- Geothermal Energy Plants
- Greenhouses and Aquaculture
- District Heating
- Direct Use

### Geothermal Power Production

Geothermal energy plants can be subdivided into four different types of plants. Those plants include direct steam, flash steam, binary systems and hybrid systems. Direct steam plants pull steam directly from a well, run it through a series piping to bring the steam to the turbine, and then subsequently turn a turbine that generates electricity [4] [5]. Because of the electricity drop a large amount of steam is let off. This steam, like a typical cola plant, is released via the control tower. After going through the necessary cleaning, the fluid is re-injected back into the ground. Flash steam involves highly pressurized water liquid that is condensed, run through a series of control mechanisms to a turbine that generates electricity. The excess steam is also released through a control tower, and the cleaned waste fluid is re-injected back into the reservoir [4]. Binary plants involve liquid or steam that is a much lower temperatures that the vapor and liquid harnessed for flash steam generation and direct steam generation. This liquid is run through an evaporator, which is used to het a substance that has a much lower boiling point than water. The lower vapor point substance generates steam, the steam then turns a turbine to generate electricity.

The geothermal water is re-injected into the reservoir [4]. The hybrid plant uses a combination of the techniques in the other plants. In Table 1, temperature ranges, operation costs, thermodynamic efficiencies and cycles, and typical size of plants are given. Many of these technologies can be scaled to fit various applications. These numbers simply serve as a guideline for initial technological consideration.

**Table 1: Geothermal Power Production** [5] [4] [3]

| Type of Plant | Temp Range °C | Efficiency | Cycle | Typical Size MW |
|---|---|---|---|---|
| **Direct Steam** | 230-350 | 15-20 | Incomplete | 10-150 |
| **Flash Steam** | 200-350 | 7-12 | Incomplete | 10-50 |
| **Binary Cycle** | 120-190 | 5-12 | Kalian, Organic Rankin | .1-30 |
| **Hybrid** | Varies | Varies | Varies | Varies |

### Agriculture

Geothermal greenhouses and aquaculture systems are other types of technology that have been harnessed successfully for past applications. These systems are desirable because they use minimal amounts of heat, can be combined with other systems, and they provide economic resources to a community. A summary of the technology is shown in Table 2 below:

**Table 2: Overview of Geothermal Aquaculture and Greenhouses** [2] [6] [7]

| Type of Tech | Temp Ranges | Subunits | Cost of Construction | Common Problems |
|---|---|---|---|---|
| **Greenhouses** | 100-150 °F | Ground Heated/ Air Heated | Depends on Materials | Large start-up cost |
| **Aquaculture** | Depends on Fish Species | Indoor/Outdoor | Depends on Construction | Pollution from fish, |

Greenhouses and aquaculture facilities can also be combined with thermal spas, centralized heating systems, and other geothermal applications such as timber drying.

### District Heating

Heat generated from geothermal resources can be used individually or on a large scale. Individuals using geothermal energy to heat their housed usually make use of simple heat pumps, simple piping structures, heat exchangers and various types of radiators. Larger scale facilities become much more complex and can supply heat to a variety of buildings [2]. District heating can serve as a good way to heat a number of facilities. Multiple examples of small and large scale facilities exist throughout the world. Determining if these facilities are economically viable depends upon the quality of the geothermal source, heat demands of a community, and a number of other design factors [2].

### Direct Use

There are many of other applications that may be suitable. Since these facilities are usually unique cases it is difficult to find technical information generalizing how the geothermal energy is used [2]. The other technologies that were considered are listed below:

- Timber Drying
- Wellness Center
- Food Processing
- Chemical Processing
- Beat and Sugar Extraction
- Food Drying [2]

Most of these technologies have potential for development in Clear Creek County. It is important to consider other geothermal projects currently underway to gain insight into the process. Currently, there are several projects in development in Colorado. The most significant of these projects is the survey and construction of a geothermal plant in Chaffee County outside of Salida, Colorado. The development of this project is controlled by Mount Princeton Geothermal, LLC. Funding for the project has come from a variety of locations but estimates for the overall cost of the project is not given. At this point Mt. Princeton Geothermal LLC plans to construct a small binary geothermal energy plant to provide energy for the local prison [8].

The town of Pagosa Springs has also developed a centralized heating system that provides heat to residents. The plant was constructed in 1982 using two geothermal wells. Most of the residents enjoy the use of the technology to heat their homes, and there are plans to bring more customers online. Before this may occur water rights must be transferred to the geothermal energy facility [9]. The water also has a number of different types of metals and contaminants present. Proper maintenance needs to be ensured to protect residents from risk of contamination and pollution. The project has been a success and serves the community well during the winter and fall months. This project serves as the best example of geothermal energy being utilized in Colorado [9].

## Schedule for Designing, Permitting, Constructing, and Operating

The proposed project schedule is shown below. This schedule has a start date of May 15th to simulate the kick-off of the project right after the spring semester. The schedule my change, due to possible variables, therefore flex time has been built into it to accommodate delays and plan alterations. Overall, the schedule shows the project can be finished in 252 days. The permitting and approval stages are the most time-consuming steps of the project. Permitting and approval can be completed in roughly 180 days. By law, the Division must respond within 10 working days or the permit is automatically approved. Use permits from local agencies, like the 1041, can take longer, depending on the local agency, and the level of environmental review required. Surveying is penciled in for 36 days, which may vary depending on the available equipment and work force. Site preparation, vegetation removal, and grading can be completed in 5 days. Drilling of the estimated four wells and testing of these wells can be completed in 10 days. The construction phase has a length of 14 days. A week was inserted after this phase for flex time. The geothermal system, according to the schedule, would be ready for operation by February 17, 2014. From there, the County can put the geothermal power into whichever end-use they deem appropriate.

| Date | Task | Estimated Work Days | Comments |
|---|---|---|---|
| 5/15/2013 | Start Date<br>• Permits<br>o Drilling | 10 each (estimated 180 days total) | Permits must be responded to within 10 days or they are automatically |

| | | | |
|---|---|---|---|
| | ○ 1041 (120 days)<br>○ Water<br>○ Geothermal<br>○ Construction | | approved, the 1041 permit is an exception though due to the environmental review required. |
| 11/6/2013 | Surveys | | |
| | • Gravity Survey | 6 | Measurement of gravity at regularly spaced grid points to control instrument drift. |
| | • Magnetic Survey | 6 | Records spatial variation, used in geophysics |
| | • Active Micro-Seismic Survey | 6 | Can be done in present wells to save time and money, tests for different formations in the subsurface. |
| | • Direct Current Resistivity | 6 | Also tests for formations below the surface. |
| | • Geological | 12 | Both academic and physical task, not much recent information on the area, physical survey is a must. |
| 12/25/2013 | Site preparation, Vegetation removal, and Grading | 5 | In preparation for well drilling at multiple locations. |
| 1/13/2014 | Well drilling | 8 | 4 wells, 2 days each to account for machine trouble and moving equipment. |
| 1/23/2014 | Well Testing | 2 | Running well yield tests, monitor ground water flows, test for constituents of concern. |
| 1/27/2014 | Construction | 14 | Installation of heat pumps, housing for pumps, etc. |
| | FLEX TIME | 7 | |
| 2/17/2014 | End-Use Construction | varies | This date concludes the construction of the geothermal system. Clear Creek County may now begin the construction of the end use of their choice. |

## Project Need

As energy demands grow, new energy alternatives are being researched. Colorado is at the front of this innovation, and many counties are looking into alternative and cleaner energy, such as geothermal. Pagosa Springs, one example of an existing geothermal application in Colorado, has a local geothermal

heating system described in the "Direct Use" section above, operating with heated groundwater up to 149°F [9]. The Clear Creek Watershed understands that there may be some heat underneath Clear Creek, and their goal is to study the area for a plausible location to use and apply geothermal energy. Alternative technologies are described above in the "Alternatives and Projects Considered" section.

### Conservation Techniques

There are many ways to conserve geothermal energy. One way is to protect the many thermal resources, such as hot springs, geysers, etc. [10]. Additionally, it is important to protect the value of them, such as the ecological and aesthetic values. Another method is to develop improved directional drilling techniques to minimize surface disturbance. The third method is developing methods of containing geothermal steam and brine, as well as gases and chemical components [11]. Fourth, monitor the environmental impacts as well as gather data on the site. The final method is to implement geothermal reservoir management procedures to maintain a balance between withdrawals and recharge [11].

### Adjacent Property Owners

As the project is not far along enough, the specific location has yet to be chosen. As such, adjacent property owners are unable to be identified. However, to see all property owners within Clear Creek County, refer to the Zoning and Property Map in the Maps Section of this report.

## Property Rights

Development in the area shown in the Vicinity Map will most likely occur on county land (see Zoning Map for more information) or on land designated as Mineral Zoning (M1, M2). Property rights on county land will be minimal while development on Mineral Zones will be trickier. These issues can be dealt with by either purchasing mineral claims or by gaining permission from the property owners to explore geothermal resources on their land [12]. Either option will require assessment of water quality, air quality, sewage systems, and access to electricity. Mineral claims in Clear Creek County and Gilpin County go back all the way to the 19$^{th}$ Century. In the Property and Zoning map some of these claims are shown. Permission will need to be gained from these owners to ensure successful development.

### Permits and Approvals Required

Federal, State, and local regulatory requirements are applicable to this project. The necessary permits can be found in Table – and --. These tables describe the permits needed, which jurisdiction the permit falls under, the timeline of the permit, and any additional comments. Additional permits may be required as project elements develop.

Federal Permits Required:

| Federal Permits Required | | | | |
|---|---|---|---|---|
| Jurisdiction | Permit | Trigger/Nexus | Estimated Application Timeline | Comments |
| Department of Commerce | Impacts to telecommunication systems and radar | Interference with communications or radar | 10 days | Must be submitted 90 days prior to construction |
| State Engineer's | Geothermal Well | Drilling of wells | 10 days | Requires |

| | | | | |
|---|---|---|---|---|
| Office | Permit | with intent to use for geothermal purposes | | description of drilling locations, geology and hydrology in area |
| SDWA | Groundwater standards after reinjection | Reinjection of water after heat is extracted. | 10 days | Well monitoring for constituents, works with water rights permit in next table |

Colorado Division of Water Resources, "Steps for Applying for Type A or B Geothermal Well permit", Office of State Engineer (SEO), pp. 1-2

Local Permits Required:

| Jurisdiction | Permit | Trigger/Nexus | Estimated Application Timeline | Comments |
|---|---|---|---|---|
| County Development | 1041 Permit Process | Required per Clear Creek County zoning regulations as a permitted principle use per §606.10 | 120 days | Time will vary depending on acceptance of research. County will go through extensive review and consideration |
| | Water Rights Permits | Required at state and local level, groundwater and surface water | 10 days | Can be done in tandem with the 1041 permit process |
| | Best Management Practices (BMP's) Permits | Required for roads, driveways, and construction of structures | 10 days | Can be done in tandem with the 1041 permit process |
| | Drilling Permits | Different requirements for different types of wells | 10 days | |
| | Electrical, Mechanical, Plumbing Permits | All required by Clear Creek County | Varies | Can be done in tandem with 1041 Permit Process |
| | Building Permits | Potential end use structures, pump housing | 10 days | Can be done in tandem with the 1041 permit process |

[##] State of Colorado, "Rules and Regulations for Water Well Construction, Pump Installation, Cistern Installation, and Monitoring and Observation Hole/Well Construction", pp. 2, 13, 38-45. http://water.state.co.us/DWRIPub/Documents/constructionrules05.pdf

## Planned Access to Project Site (legal right)

Having the legal right to access the project site depends on the specific location being considered the project site, and the zoning laws that are in place there. The geothermal exploration process will be conducted over a large area. This area is composed of three basic zones.

The first zone is M-1, which follows general mining provisions. These zones are very beneficial to the project and legally, access is permitted to workers for this project [13]. The second major zone in the area is MR-1. These areas follow residential provisions and those involved in the project do not have permission to access these areas. If particular areas are crucial to the project and fall under the MR-1 provisions, it is possible to get permission to access the land from the land owners, but this should only be attempted if absolutely necessary. The final zone that exists is PD or Planned Development [13]. This major zone exists on the southern end of I-70 near the U.S. 40 interchange. This zone is also beneficial to project work because not only will the geothermal surveyors be allowed to access the area, but it is also possible to construct the previously mentioned hotel or light rail station. For more detailed information on zoning laws see the Table in Appendix xx.

## Persons of Interest

In the development of the geothermal feasibility study, Clear Energy has received technical support from a number of different individuals from The Colorado School of Mines and from industry. Below is a list of persons of interest:

**Dr. Marte Gutierrez, Ph.D., Technical Advisor**

Dr. Marte Gutierrez is the James R. Paden Chair and Distinguished Professor at the Division of Engineering, Colorado School of Mines. Prior to joining CSM, he was Post-doctoral Fellow, Senior Engineer and Program Leader at the Norwegian Geotechnical Institute, and Associate Professor/Professor at Virginia Tech. He has held visiting professorship and researcher positions in China, Chile, France, Japan and South Korea. He has published more than 150 papers in book chapters, journals and conference proceedings, has given keynote and invited lectures at a number of conferences, and is responsible for more than $7.5 million in research funding. He was a Board Member and Treasurer of the US Council for Geotechnical Education and Research (USUCGER), and is a member of the Editorial Boards of four international Journals. He is the co-recipient of the 2011 Geotechnical Research Medal from UK's Institute of Civil Engineers.

**Paul Morgan, Colorado Geologic Survey**

Paul Morgan is the senior geothermal geologist at the Colorado Geological Survey. He has provided invaluable information regarding geothermal development.

**Dr. Yaoguo Li, Ph.D., Associate Professor, The Colorado School of Mines**

Yaoguo's research interests are in inverse theory, practical algorithms for inverting geophysical data, and the application of these algorithms in resource exploration and production, environmental, and geotechnical problems. His education, research and employment are listed below:

- 1992: Ph.D., Geophysics, University of British Columbia, Vancouver, Canada
- 1983: B.A.Sc., Geophysics, Wuhan College of Geology, Wuhan, China

- 1999 -- present: Associate Professor, Department of Geophysics, Colorado School of Mines, Golden, CO
- 1993 -- 1997: Research Associate, UBC-Geophysical Inversion Facility, Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, Canada
- 1992 -- 1993: Post-doctoral Fellow, UBC-Geophysical Inversion Facility, Department of Geophysics and Astronomy, University of British Columbia, Vancouver, Canada
- 1983 -- 1985: Technician, Qinghai Research Institute of Geology, China

- 1999--present: Principal investigator of the research consortium "Gravity and Magnetics Research Consortium" (GMRC) in the Department of Geophysics, Colorado School of Mines.
- 1998--1999: Co-principal investigator of the research consortium "Inversion of 3D DC resistivity and induced polarization data" (INDI) at the UBC-Geophysical Inversion Facility, University of British Columbia.
- 1992--1998: Co-principal investigator of the research consortium "Joint and cooperative inversion of geophysical and geological data sets" (JACI) at the UBC-Geophysical Inversion Facility, University of British Columbia.

- 1998-present: Member of Editorial Board, Journal of Applied Geophysics.
- 1998: PhD thesis external examiner, Monash University
- 1999: PhD thesis external examiner, Aarhus University

**Peggy Stokstad, Clear Creek Economic Development Corporation**

The Clear Creek Economic Development Corporation is a non-profit corporation responsible for job creation and retention in Clear Creek County. CCEDC is Clear Creek County's primary agency for economic development services with the goal of assisting in insuring a diversified economy. Since 1984, CCEDC has been assisting new and expanding businesses in Clear Creek and Gilpin Counties with business loans and financial services. The Development Corporation administers four different loan programs, to meet the needs of small to medium-sized businesses located in either Clear Creek or Gilpin Counties. Because one size does not fit all, CCEDC features a full range of financing options.

**Bryce Romig, P.E., Environmental Manager, Climax Molybdenum Company**

Bryce Romig is the chief environmental manager at the Henderson Mine in Clear Creek County. Mr. Romig has provided information regarding waters pulled from mining operation including the flow rates and temperature profiles of those waters.

# Technical and Financial Feasibility

## Construction Cost and Time

In order to select a site and begin the design process, the subsurface must be thoroughly explored and characterized. Exploration methods incorporate information from geology, geophysics, geochemistry, thermodynamics, petroleum engineering, and environmental engineering. Using these methods in conjunction aids in the discovery of geologic anomalies where thermal activity is likely to be. Hot spots are common in rift zones, subduction zones and mantle plumes. Exploration involves not only identifying geothermal bodies, but also the hydrologic properties of the subsurface and the porosity and permeability of the rock. An aquifer with an adequate recharge rate is important for determining the production rate and life of the thermal resource [11]. Exploration can be a costly endeavor. As much as 42% of the

expenses associated with geothermal production can be attributed to the exploration process [11]. The majority of exploration costs are from drilling operations to confirm or deny the viability of the reservoir. Drilling provides the most accurate data for characterizing a site but it is also the most costly. Geophysics and geochemistry may be employed to offset the drilling costs. These techniques are less expensive and can increase the success rate of exploratory drilling. Generally the first exploratory wells have a success rate of 25% but the use of geophysics and geochemistry may increase that percentage to 60% to 80% [11].

A geophysical survey relies on the combination of survey techniques to develop an understanding of the subsurface and determine an appropriate drill site. It is important to combine techniques in the survey as each one alone may offer ambiguous results. The combination of techniques makes it possible to determine the overarching structural trends of the subsurface. For the area of interest, the following techniques are appropriate include: Direct Current Resistivity, Self-Potential, Micro-Seismology, Gravity Survey and Magnetic Survey.

Drilling offers the most accurate data for characterizing a site. Well logging is a technique that records temperature, pressure and fluid flow in the bore hole in order to determine characteristics of the surrounding rock and water. These are all important parameters to consider when characterizing a site [11]. Down hole measurements can be made in several ways. A sensor package can be lowered into the hole on an electrical cable that sends back signals in real time as it traverses the wellbore. A logging tool with on board memory can also be lowered into the hole on an ordinary cable, taking readings as it descends, and then brought back to the surface to collect the data. A memory tool can also be part of the bottom hole assembly and retrieved when needed. Finally an instrument package may be constructed with in the bottom hole assembly that sends data remotely to the surface. This method provides real time data but is expensive and subject to damage by high temperatures [11]. Tables 3 and 4 below outline the cost and time associated with geothermal exploration.

**Table 3: Geophysical Survey Cost and Time**

| | Equipment Rental per day[1] | Equipment Prep Cost[1] | # people | Estimated Days Worked | Total Hours[2] | Hourly Rate[3] | Total |
|---|---|---|---|---|---|---|---|
| **Active Micro-Seismic Survey** | 135.00 | 105.00 | 2 | 6 | 96 | 20.00 | |
| **Direct Current Resistivity** | 125.00 | 115.00 | 2 | 6 | 96 | 20.00 | |
| **Gravity Survey** | 135.00 | 250.00 | 2 | 6 | 96 | 20.00 | |
| **Magnetic Survey** | 205.00 | 300.00 | 2 | 6 | 96 | 20.00 | |
| | | | | | | | |
| **Totals** | **$3,600.00** | **$770.00** | | | | **$ 7,680.00** | **$12,050.00** |

**Table 4: Borehole Logging Cost and Time**

| | Cost Per foot[4] | Feet Drilled | Equipment Rental per day | Equipment Prep Cost | Total Cost per Well |
|---|---|---|---|---|---|
| **Drilling** | 40.00 | 1500 | | | |
| **Borehole Logger** | | | 200 | 200 | |
| **Totals** | | **$60,000.00** | **$400.00** | **$200.00** | **$60,600.00** |

**Notes:**

[1]Equipment rental rates are based on information from The Environmental Equipment Supply. *Geophysics Equipment Rental Price Quote.* [Online] Available: http://www.envisupply.com/rentals/geophysics-rental-instruments.htm?gclid=CJeQ4vexrrMCFfBcMgodb10AkA [November 1, 2012]

[2]Number based on an 8 hour work day.

[3]Number based on hourly rate and per diem pay per worker.

[4]Number based on costs estimates found in "Handbook of Best Practices for Geothermal Drilling" prepared by Sandia National Laboratories. [Online] Available: https://dl-web.dropbox.com/get/Sr.%20Design%2C%20Clear%20Energy/06%20Resources/06.2%20Technical%20Resources/drillinghandbook.pdf?w=AABd0bygz3XDNe4Lm7SPJCrdxiAPFtrjsiGADZvcE0oVyg [November 1, 2012]

More information is needed to estimate the cost and time of construction for the chosen geothermal application.

### Revenues and Operating Expense

More information is needed to estimate the revenues and operating expenses associated with the chosen geothermal application.

### Debt Amount and Services

The total amount needed for the exploration process is roughly $72,000. More information is needed to determine the total debt amount associated with the chosen geothermal application and how that debt will be serviced.

### Who Pays/Who Benefits

Clear Creek County would benefit from a thorough exploration of the Upper Clear Creek Watershed. An understanding of the geothermal resources available in Clear Creek County could spur development and increase economic activity of the region. The geothermal exploration may be commissioned and paid for by Clear Creek County in an effort to increase development of the region.

## Decommissioning

### Properties to be Reclaimed

Should the geothermal survey or technology need to be decommissioned, multiple properties will need to be reclaimed. These include:

- All facilities and wells
- Gravel from well pads, access roads, and other sites
- Re-contouring the surface
- Restoring vegetation [14]

### Cost of Removed Material (18" Depth)

The cost of the removed materials up to 18" in depth will vary based on the location and specific technology. All contaminated soil must be removed or treated.

### Cost of Road Repair

The cost of repairing the roads will vary based on the location and specific technology. Roads may become compacted due to heavy loads, which can reduce aeration and permeability of the soils underneath. In addition, reclamation introduces a social cost. Trucks involved in the reclamation process may increase traffic on some roads. However, these costs also vary depending on location.

### Time of Decommissioning

The time to decommission the geothermal survey or technology may vary, depending on the location and specific technologies used for surveying and energy generation. However, a complete decommissioning will take up to a few years to reclaim all the necessary components [15].

## Socioeconomic Impacts

### Land Use

Refer to zoning map below.

### Local Government Services

There are a variety of government services within Clear Creek County. The Gilpin County Human Service is a private company for social and human resources. There is also the Idaho Springs City Hall. Black Hawk Public Works is comprised of four departments: administration, streets, fleet maintenance, and buildings to maintain the cities good standing. Another service is the Park County Social Service Department, which include financial, medical, energy assistance, food assistance, and child welfare services. Many of the local government services embody these forms of assistance. Other services include libraries, hospitals, schools, banks, and other like services.

http://www.manta.com/c/mm8yf8x/clear-creek-county-human-service

### Housing

There are a total of 5,128 housing units in Clear Creek County. 4,019 of those houses are occupied. Owners occupy 3,059 of the houses, while 960 houses are renter occupied. Of those houses, 919 are for seasonal and recreational use. The average household size of owner-occupied houses is 2.38, while the average household size of renter-occupied houses is 2.10. It is important to note these numbers to plan construction accordingly and to minimize impact on these communities. [16]

## Financial Burden on Locals

The demand for alternative energy is a growing trend across the nation. Here in Colorado there is large demand, especially along the developing areas of the front-range. The use of geothermal energy in any of the various applications described in this report will assist in the price of electricity. Because of the nature of the power supply system, all the energy from the well will be directly inputted into the most desirable end use; therefore the only burden to the public would be a possible slight tax increase to fund the expense of the initial startup and small electricity cost due to a pump. Over time, the cost would be offset by the money saved during operation.

## Local Economy

Geothermal energy is one of the newest energy opportunities available to Clear Creek County. Unfortunately, it is also the most under-researched topic. The local economies of the towns located in the Upper Clear Creek Watershed could benefit from the implementation of the geothermal technology. Clear Creek could make this a tourist attraction, as the technology is new and educational. This project would encourage foot traffic in local stores if the energy was used to heat sidewalks of main streets because it would get rid of the safety hazards in the winter. If the energy from the geothermal wells was used to heat a hotel at the proposed location, this would benefit the local economy because a hotel would allow tourists to stay in the area and the hotel would be able to lower its rates due to the money it would be saving on heating bills. Also, if the energy was put towards a potential rail station this would also allow for more people passing through the area, benefiting the local economy.

## Demographic Information

Clear Creek County has a population of almost 9000 people, with the majority between 35 and 54 years old [17]. Over the next 30 years (through 2040), the population of Clear Creek County is expected to grow to 14,000, with the population increasing by 2,000 people each decade$_2$. The average household income for Clear Creek is about $35,500, compared to $48,000 for the regions surrounding Clear Creek [17]. Citizens of Clear Creek County are involved in a variety of employment industries, the majority being personal service, public administrations, and extractive activities [17]. Most workers living in Clear Creek County commute; Clear Creel is the 3$^{rd}$ most popular commuting destination behind Jefferson County and Denver County. Unfortunately, 78% of workers drive alone to work, compared to 7% who carpool [17].

## Recreational Opportunities

There are an abundance of recreational activities in Clear Creek County. Residents of Clear Creek County, as well as tourists and visitors, use outdoor activities such as kayaking, rafting, rock climbing, fishing, and hiking as a relaxing vacation. These recreational activities will not be impacted by a geothermal survey. However, construction of roads or a geothermal technology may cause erosion, which could negatively impact rock climbing. Also, a hazardous spill may cause the creek's water quality to get worse, which can impact creek activities, including fishing, kayaking, and rafting. These may possibly deter tourists from visiting Clear Creek County again, ultimately decreasing Clear Creek's revenue.

## Historical Importance

Clear Creek County has a variety of historically significant districts, including important industrial, conservation, and exploration sites. These districts are listed below [13]:

- Argo Tunnel and Mill (Industry)
- Echo Lake Park (Architecture/Engineering)
- Georgetown-Silver Plume Historic District (Settlement)
- Idaho Springs Downtown Commercial District (Commerce)
- Summit Lake Park (Architecture/Engineering)

As a mitigation plan, one should consult FEMA's (Federal Emergency Management Agency) 4 steps to develop a mitigation plan [18]. This includes:

1. Create goals and objectives for the specific historic district
2. Identify, evaluate and prioritize actions
3. Prepare an implementation strategy
4. Incorporate historic property protection efforts into hazard mitigation plan

To safely mitigate damage to these historic sites, this plan must be consulted and worked with the community. However, a geothermal study should have minimal effect on all of these historic sites.

If dinosaur bones are found during this project, Curator of Paleontology Ian Miller of the Denver Museum of Nature and Science should be contacted [19]. If human bones are found, the police should be contacted in case they are of any forensic use [20]. If an artifact is found, contact Dr. Richard Wilshusen at the Office of Archaeology and Historical Preservation [19].

### Nuisance

The project becomes a nuisance when unwanted sights, noises, or smells, are experienced by the public. Unfortunately, the burden of a nuisance is not shared by all, but is usually impeded on a small group of nearby residents or commercial districts. Exactly where and who is affected depends on the precise location chosen to drill the exploratory well(s), and where possible further construction occurs. These locations, however, must follow zoning laws. The geothermal exploration will likely occur on M1 or M2 zoning designations, and further construction on Planned Development land. These zones do not have residential dwellings, but homes can still be nearby. Commercial developments can also experience nuisances.

To minimize nuisances, hay bales work great for blocking noise and unwanted visuals. Hay is a cheap and easy barrier to implement, and the practice is often used. Mufflers would also be installed on all gas-powered vehicles and engines, further reducing the noise levels. With the combination of these practices, the noise law can remain at or below 50dB, at the boundary of the site, thus remaining within the nighttime boundaries of the Colorado Noise Law [21]. Smells are harder to predict and control, but usually are not as bothersome. The sulfur smell is likely to be the only significant smell, but with good practice, that smell would not linger. For more information on the smells, see the below section regarding air quality.

# Environmental Impacts

## Air Quality

The air will be impacted by periodical vents from the geothermal well, as well as from common construction and industrial practices. Both of these effects will be managed individually. Construction will release dust particles and particulates into the air from unpaved roads, particularly during windy days. This can be minimized through dust control procedures (see Dust Control Procedures section). Construction will also cause an increase in exhaust fumes, but these will not exceed levels of other common construction practices such as road maintenance.

The emissions from geothermal wells vary from well to well. One can usually expect mostly carbon dioxide and steam, both of which cause no health concerns. Hydrogen sulfide is also common, and trace amounts of mercury, ammonia, boron, and arsenic can also exits [21]. Although these plumes would be dangerous in large doses with continued exposure, the plume of a test well is low in density and floats quickly into the upper atmosphere where it disperses. Hydrogen sulfide tends to be a major concern of the public because of its rotten egg smell. Adverse health effects are believed to occur when concentrations reach above 300 ppm in the air, but due to the strong smell, it is easily detectable at only 5 ppm. Special alarms can be put in place to detect when, if at all, these gases reach dangerous concentrations. Outside the site boundaries, the gases will have dispersed and reached safe concentrations.

## Visual Quality

A geophysical survey is hardly noticeable in the short time that they are occurring and have no significant visual impacts. Constructing a large facility to use the geothermal heat, such as a hotel or light-rail station, requires permits of itself that address the visual aspects of the buildings. Therefore, the only environmental impacts of visual quality necessary to consider would be those of drilling a geothermal well.

Ordinance 703.5 of the Clear Creek County Zoning Regulations states that there is no limitation on the height that operations take, assuming that they are occurring in a M1 or M2-zoned area. However, other regulations state that no junk or unused equipment can be in visual range, and that no fences, trees, or shrubs can be erected that may pose danger to those traveling on roads. Assuming that the drilling process takes place in one of the mining areas, it can be assumed that all visual regulations would be easy to follow without the construction of extra fences and visual blocks. Equipment will be used that is colored in plain green, brown, or tan colors which are less distracting and blend into the forested environment. By doing so, the drilling activities can be visually subordinate to the natural environment.

### Water Quality

Colorado is fairly stringent when it comes to water quality assessment. When geothermal wells are developed a harmless drilling fluid must be used. Waste disposal follows discharge regulations established by the EPA and the CDPHE. At this time Clear Energy does not know what the impacts on the water quality will be. Key chemical constituents that may play a role are listed below. Proper monitoring will need to be performed to ensure that the necessary precautions are taken to ensure proper safety.

- Hydrogen Sulfide ($H_2S$)

- Ammonia ($NH_4$)
- Chloride ($Cl^-$)
- Oxygen ($O_2$)
- pH
- Carbon Dioxide ($CO_2$)
- Sulfate ($SO_4$)
- Calcium Carbonate ($CaCO_3$)
- Calcium Sulfate ($CaSO_4$)
- Biological Species [2]

Understanding of each these species will be required to ensure minimal impacts on water quality of Clear Creek Watershed.

### Flood Plains and Wetland Areas

The implementation of a geothermal heating system will have a negligible impact on the floodplain. Floodplains are affected by upstream changes in terrain, particularly vegetation cover, and natural and manmade dams. A floodplain can also be altered by major changes in topography at the location of interest and below. A geothermal heating system will require one or more wells to be drilled, but will not make any drastic changes at the surface, other than the possible construction of a small shed to house a heat exchanger. Due to the lack of surface interference, the impact on the floodplain can be considered negligible.

The impact of geothermal heating on wetland areas will be minimal as well. The same factors that affect a flood plain also affect wetland areas, with the difference that wetlands are often more fragile and diverse ecosystems. For this reason, wetland areas will be avoided at all times. Wetlands also often serve remedial purposes when considering water quality and acid mine runoff, and their importance, as well as the state regulations surrounding them, is quite extreme. No major wetland areas exist in the Clear Creek Watershed, but small wetlands are scattered throughout the area. These will be possible to avoid, and therefore, will not be of major concern.

### Habitats

Clear Creek hosts a variety of important terrestrial and aquatic life because of its highly developed setting. The large amount of open space allows many different species of animals to flourish, including deer, elk, foxes, coyotes, and songbirds [33]. Although the Clear Creek water does not support much aquatic life, they usually stock the river with bass and bluegill [34]. Clear Creek County also has been seen to host a few endangered species, including the bald eagle. Although the bald eagle is more seen in the Denver area, it would not be unreasonable to spot one in Clear Creek [34].

Because geothermal energy is so clean, it does not damage the surrounding ecosystems. However, construction may damage habitats, disrupt migration patterns, and disturb wildlife. In addition, accidental spills of hazardous waste may contaminate the water, making it uninhabitable for fish. Although a spill is possible, it is highly unlikely [33]. A post construction mortality study may be necessary due to the amount of species it could potentially affect.

### Plant Life

Because of the large open space, a large variety of plants inhabit Clear Creek County, including the rare moonwort. Although it is not on the endangered species list, moonwort is very susceptible to human intervention, especially development. They grow in small clusters, but they are very difficult to find because of their small size [35]. A geothermal survey or construction of access routes may disturb or destroy this species in some places. It should be carefully looked for prior to construction.

## Surface Water Quality

### Introduction

Impacts to surface water quality will be minimal from geothermal exploration. Ground source heat pumps will also cause minimal impacts, but some of the effects will be discussed later in this section of the 1041 form. Impacts from a possible spa will be greater but will be minimal pending that the spa re-injects water back into the ground. Characterizing and understanding surface water begins by accessing Clear Creek County's overall surface water resources. A summary of these findings is given in the next section. Discussion then moves on to how the three alternatives chosen from research will impact surface water quality.

### Clear Creek County Water Resources and Hydrology

#### Water Resources

Determining impacts on surface water begins with a characterization of the Clear Creek Watershed. Clear Creek Watershed is composed of 10 distinct Watersheds. Two of these watersheds exist separately from the Clear Creek Watershed while the other eight feed into the upper and lower portions of Clear Creek. A summary of the Watershed is shown in Figure 1 and a breakdown of the watershed is shown in Figure 2.

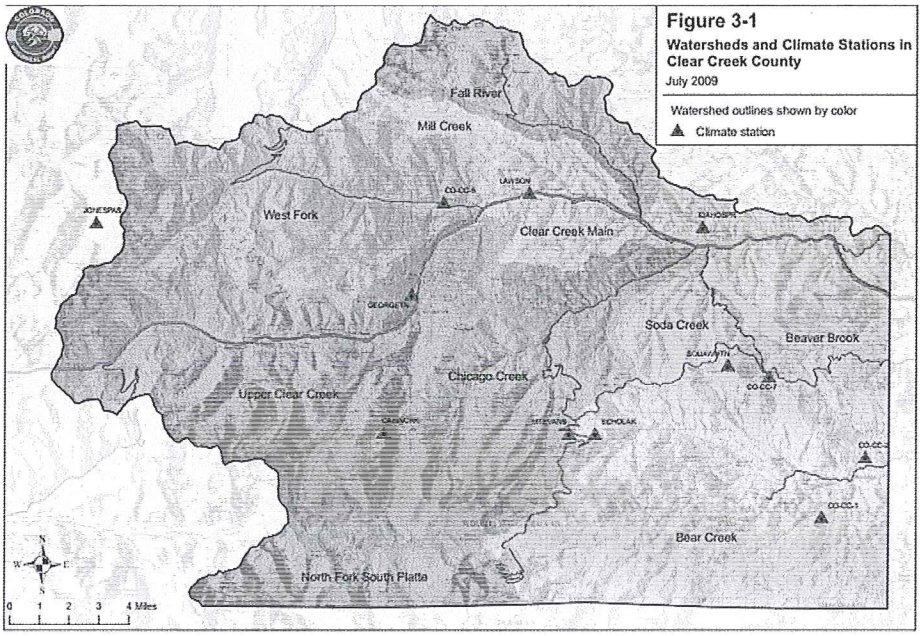
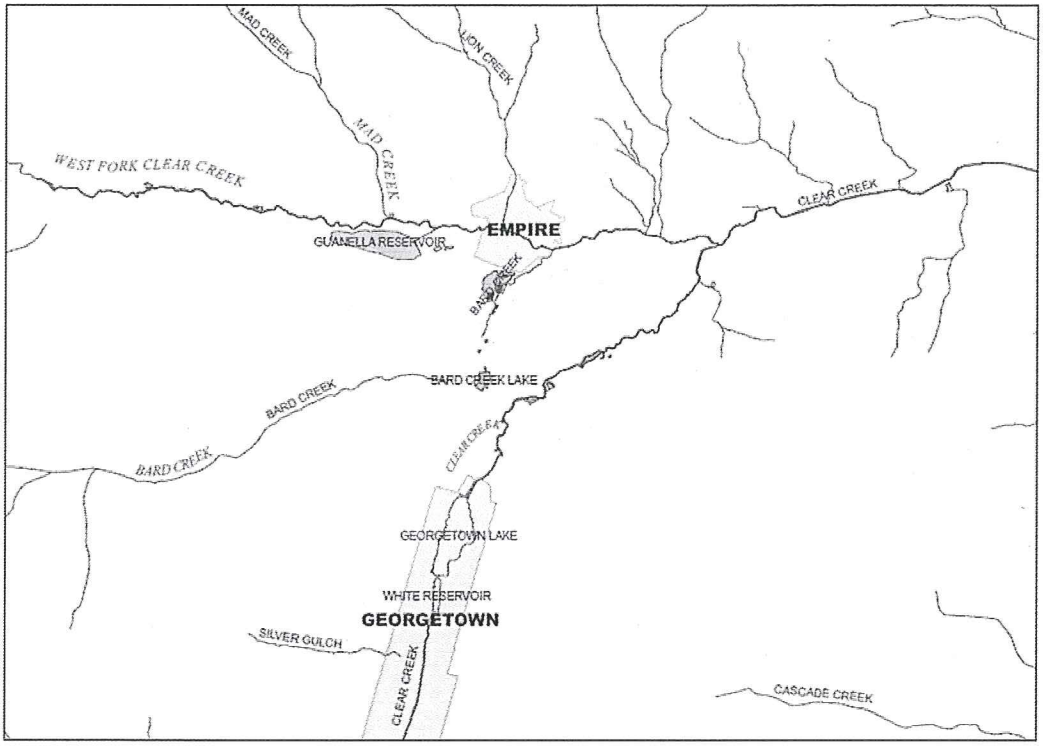



Figure 1: A Breakdown of the Ten Watersheds found throughout Clear Creek County [22]

Overview of the watershed shows that three surface water areas will be affected by geothermal exploration. These areas are: The Upper Clear Creek Watershed, the Main Clear Creek Watershed, and portions of the Chicago Creek watershed. Geophysical tools do not have any impact on the environment. Exploratory wells will also have minimal impact on surface water quality. Geothermal heat pumps and larger exploratory wells present the greatest potential to impact surface water quality. In figure 2 the major streams, reservoirs, and lakes of the area are shown along with the topography of the area. Surface water and groundwater interactions in Clear Creek County have not been investigated by the Colorado Geological Survey or the United States Geological Survey. Facts known about surface water and groundwater interactions are given later on this in this report.




Map of the Impacted Surface Waterways for Geothermal Development

**Figure 2: Map of Affected Waterways for Geothermal Development [23][1]**

Table 1 and Table 2 summarize major surface water resources in Clear Creek County. Geothermal resource exploration will have little to no impact on these surface water bodies, but when development begins using heat pumps there will be several issues that may impact these water bodies. They are discussed later on this section of the 1041 matter of state interest analysis.

[1] Map was constructed using ARC-GIS data provided by the county. All construction was performed by Clear Energy

Table 1: Summary of Streams in Clear Creek County with Average Flows [24]

| Stream | Length (mile) | Average Flow (cfs) |
|---|---|---|
| Bard Creek | 7.0 | 1.5 |
| Beaver Brook | 6.2 | 0.8 |
| Chicago Creek | 11.9 | 2.3 |
| Clear Creek | 13.5 | 10.0 |
| Fall River | 8.5 | 3.6 |
| Herman Gulch | 3.5 | 2.0 |
| Leavenworth Creek | 7.1 | 1.5 |
| Little Bear Creek | 3.0 | 1.0 |
| Mill Creek | 6.9 | 3.0 |
| North Clear Creek | 5.5 | 1.5 |
| Ralston Creek | 7.6 | 0.5 |
| Soda Creek | 6.4 | 1.0 |
| S. Chicago Creek | 2.9 | 1.0 |
| S. Clear Creek | 2.9 | 3.0 |
| W Chicago Creek | 7.0 | 1.5 |
| W Fork Clear Creek | 13.4 | 7.7 |
| Woods Creek | 2.2 | 1.0 |
| Total Average and Length | 115.5 | 2.5 |

Table 2: Summary of Reservoirs and their Ownership Along the Clear Creek Watershed [24]

| Reservoir | Owner | Size (Acre-Ft) |
|---|---|---|
| Braukman | Agricultural Ditch and Reservoir Company | 102 |
| Upper Chinns | | 100 |
| Lower Chinns | | 102 |
| Fall River | | 890 |
| Loch Lomond | | 875 |
| Lake Caroline | | 144 |
| Reynolds | | 55 |
| Braukman | | 102 |
| Ice Lake | | 511 |
| Hole in the Ground | Central City | 28 |
| Chase Gulch | | 600 |
| Arvada | City of Arvada | 5800 |
| Pomona #2 and #3 | | 80 |
| Upper Urad | City of Golden | 320 |
| Lower Urad | | 252 |
| Idaho Springs | City of Idaho Springs | 215 |
| Reynolods | | 55 |
| Standley | Farmers Reservoir and Irrigation Company | 42380 |
| Fairmont | Consolidated Mutual Water Company | 979 |
| Maple Grove | | 1043 |
| Duke Lake | Coors Brewing Company | 295 |
| Rolling | | 28 |
| St Mary's Lake | | 47 |
| Churches | Denver Water Board | 48 |
| Upper Long Lake | | 1500 |
| Lower Long Lake | | 292 |
| Raltson | | 13200 |
| Broad | Farmers High Line Canal and Reservoir Company | 92 |
| Hyatt | | 1095 |
| Leyden | | 1152 |
| Upper Beaver Brook | Lookout Mountain Water District | 257 |
| Lower Beaver Brook | | 30 |
| Lookout Mountain | | 100 |
| Upper Cabin Creek | Public Service Company | 1577 |
| Lower Cabin Creek | | 1988 |
| Clear Lake | | 590 |
| Copeland Lake | | 73 |
| Dewey | | 54 |
| Green Lake | | 270 |
| Murray | | 80 |
| Silver Dollar Lake | | 440 |
| Georgetown | Town of Georgetown | 292 |
| Murray | | 90 |
| Hidden Lake | Mayham Reservoir Company | 270 |
| Tucker Lake | Denver View Reservoir and Irrigation Company | 586 |
| Jim Baker | City of Westminister | 900 |
| Total | | 78867 |

Like many other mountain communities across Colorado there is a number of surface water resources located throughout the community. Streams and reservoirs serve a number of businesses, residents, and commercial interests. The analysis presented in Table 1 and Table 2 demonstrates that there are a number of stakeholders that have a vested interest in the water of Clear Creek. 17 Streams flow through the area of Clear Creek with an average flow of 2.5 cfs. There are 45 reservoirs with a total storage capacity of approximately 80,000 acre-ft. There are industrial, residential, agricultural, and recreational stakeholders that have a vested interest in each of these resources. Analyzing how geothermal development will impact these communities is paramount to successful development.

### Hydrology

As a whole the Upper Clear Creek Watershed represents an area of net water gain because water gained from precipitation exceeds potential forms of evapotranspiration [22]. Table 3 shows values for average precipitation measured at 13 different locations along the watershed. Average precipitation for key areas in the water shed is approximate 22 inches. The key areas that will be impacted by the proposed geothermal exploration are: Georgetown, Cabin Creek, Grizzly Peak, Jones Pass, Empire, and Idaho Springs. The other weather stations were excluded from the average calculation because there are at distance far enough away from the exploration area that impacts to these areas will be minimal.

**Table 3: Summary of Average Annual Precipitation of Weather Stations Located throughout the Clear Creek Watershed [22].**

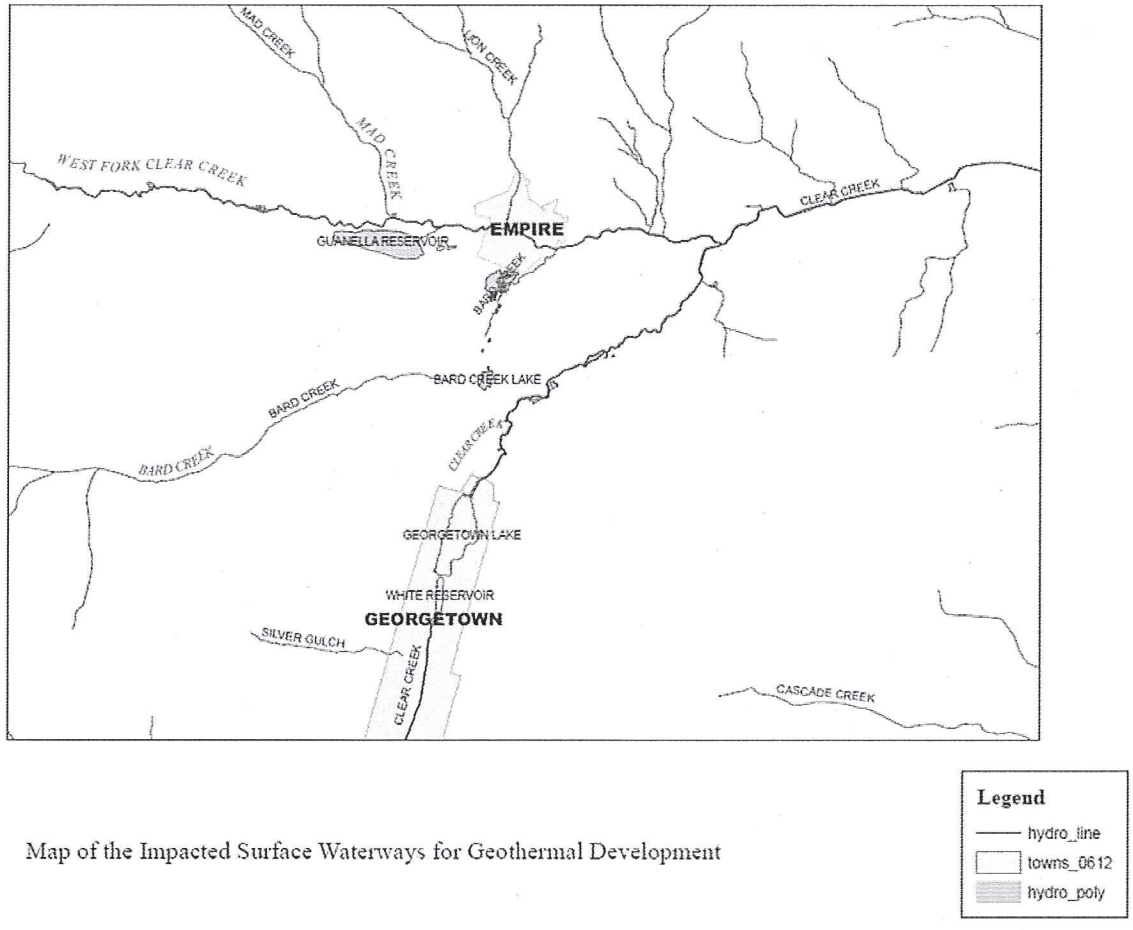
| Weather Station | Watershed | Elevation (ft) | Average Annual Precipitation (in) |
|---|---|---|---|
| Georgetown | Upper Clear Creek | 8520 | 16.42 |
| Cabin Creek | | 10020 | 19.73 |
| Grizzly Peak | | 11100 | 32.47 |
| Evergreen 1 | Bear Creek | 7789 | 20.31 |
| Evergreen 2 | | 8097 | 22.83 |
| Blue Valley | | 9800 | 25.21 |
| Echo Lake | | 10600 | 28.02 |
| Mt. Evans Research Stn | Chicago Creek | 10630 | 32.89 |
| Idaho Springs | Clear Creek Main | 7566 | 15.52 |
| Lawson | | 8100 | 16.06 |
| Empire | West Fork of Clear Creek | 8684 | 15.7 |
| Jones Pass | | 10400 | 34.32 |
| Squaw Mountain | Beaver Brook | 11509 | 25.09 |
| Average of Key Areas | | | 22.36 |

Most of the precipitation that falls in the lower areas of Clear Creek County is lost as evapotranspiration. Due to the altitude and their colder temperatures precipitation is usually stored during winter months as snow [22].

Preliminary exploration using geophysical methods and well drilling will have no impact on surface water quality, precipitation levels, recharge levels, or the flow of Clear Creek County resources. When the

exploration area is narrowed after a preliminary geophysical investigation an assessment will be done of the following:

- Legal Location
- Presiding Local Government (Clear Creek County and Grand County, Municipalities of Georgetown and Empire)
- Geographic Setting
    A. Hydrology-streams, reservoirs, wetlands at or near drill site.
    B. Elevation
    C. Topography Nearby Roads
    D. Site Access
    E. Nearby Structures




Map of the Impacted Surface Waterways for Geothermal Development

**Figure 3: Figure of Impacted Waterways for Geothermal Development Near Empire**

Out of this list the greatest impact on resources will be the hydrology of the county. Reservoirs located near the reservoir are shown in Figure 3. Figure 3 is a map constructed in ARC-GIS giving the survey area and the potential areas that may be affected by drilling. Evidence thus far of potential geothermal sources in the area suggests that all of the flow is non-tributary and should not have an effect on any of these resources. Geothermal waste in Colorado is usually re-injected into the ground. Assessment of

groundwater/surface water interactions will need to be investigated to ensure that there is no ill effects created from the injection. Some of the known interactions are discussed below.

1. Areas of interest are silver plume granite and boulder creek granite. These rock formations contain water at higher temperatures. This source is non-tributary and should not create any interactions with surface water [25] [26] [27] [28].
2. Faulting that extends to Clear Creek may create water quality issues if surveying finds that geothermal activity from this faulting is large enough to cause water quality issues [25]. See the geology section of the groundwater effects for further discussion.
3. Any exploration shown in the area of Figure 4 will require an investigation of surface water/groundwater interactions because injection will most likely be the way in which waste from exploratory wells will be mitigated.
4. There are usually three ways to get rid of waste produced from geothermal exploration. These methods are:
    A. Surface Water Storage and Processing
    B. Reinjection

Reinjection will only have an impact on water quality if there are large surface water interactions present in the area shown in Figure 4. Examining the geology there will only be impacts from the alluvial deposits and faulting that occurs near Empire. See the geology section of the groundwater impacts for more discussion of potential impacts.

Exploratory drilling may produce grout and disturb the area surrounding the well. For drinking wells there are regulations regarding their construction and monitoring. Issues with these systems are discussed further in the groundwater section of the report.

### Potential Impacts

Water quality in Colorado is managed by the EPA in conjunction with Colorado Department of Health and Environmental Services. Primary standards called Maximum Contaminant Levels (MCL) and secondary standards called Maximum Contaminant Level Goals (MCLGs) mirror those established by the EPA. Most of the time drilling fluids used during exploration can be made of salt brine and clays that have little to no toxic additives. Occasionally, oil may be used as lubricant but not in the use of exploratory wells. Drilling fluid largely depends on the type of well that is being drilled and the type of rock and soil being drilled through. Since geothermal development is still in the exploratory stage determination of effects of drilling fluid on surface water quality is largely hypothetical. The drilling fluid will most likely be made of some form of clay, polymer additives, and saltwater solution. Salt in water is regulated as a secondary contaminant and cannot exceed concentrations in excess of 250 mg/L. Corrosivity is another thing regulated under MCLGs. Drilling fluid will need to be more thoroughly analyzed once more is known about the type of soil and rock that will be explored through the drilling of water wells.

### Monitoring Requirements

According to Colorado State Law geothermal wells need to be characterized and continually monitored. When analyzing a geothermal fluid the following chemicals should be considered:

- Hydrogen Sulfide ($H_2S$)
- Ammonia ($NH_4$)
- Chloride ($Cl^-$)
- Oxygen ($O_2$)
- pH
- Carbon Dioxide ($CO_2$)
- Sulfate ($SO_4$)
- Calcium Carbonate ($CaCO_3$)
- Calcium Sulfate ($CaSO_4$)
- Biological Species

These chemical species can significantly alter freshwater quality, and can also impact aquatic life present in freshwater streams. Chemical characterization will need to be completed no matter what type of project is chosen. General water quality of geothermal projects is monitored by meters, gauges, and an initial quality test done when the well is initially permitted. Similar regulations exist for drinking water wells. Decisions about these aspects of concern will be formalized once a permit has been approved. Waste from exploration can be discharged at certain locations pending the correct forms of permitting.

# Groundwater Analysis

## Introduction

The geology of Clear Creek demonstrates the complexity of a growing mountain range. Multiple faults, synclines, anticlines, and intrusions create an environment that is simultaneously prime for geothermal development and difficult to characterize. Geological data for the three sites chosen at Empire, Georgetown, and Idaho Springs include: stratigraphy studies, geochemical analyses, geothermal characterizations, lithographic studies, data obtained from Henderson Mine, groundwater surveys, and geological maps obtained from the Colorado Geological Society and United States Geological Survey. Each of these pieces of information establishes a foundation to set up initial design parameters. The geology reveals two facts about groundwater quality of the Clear Creek area: (1) not much is known about the subsurface and (2) there is little understanding about groundwater and surface water interactions.

## Geology

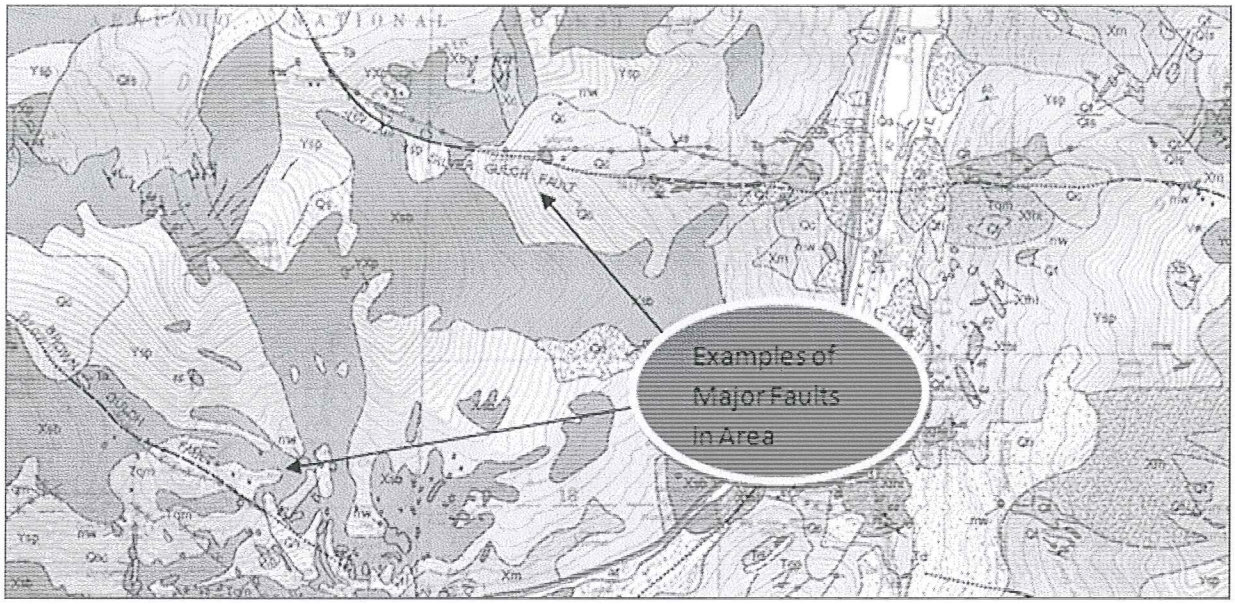



**Figure 4: Geologic Map of Georgetown and Empire Quadrangle. Examples of faulting are highlighted for discussion [25].**

As stated earlier there is very little information about groundwater in Clear Creek County. What is known at this point is there is water present in the Silver Plume Granite formation and this water may have contact with faults below the surface. Extensive faulting and anticlines in the Empire and Georgetown area indicate movement beneath the subsurface. In Figure 1 several of these features are highlighted. Throughout the area indicate that water could move from the subsurface towards to deposits closer to the surface. Rock formations that contain water in the figure above are granite formations. Granite along with diorite can be an indication of geothermal activity [2]. There are exceptions to this generalized pattern but for an area like Clear Creek the pattern holds throughout the entire watershed.

In the figure below key rock formation in the stratigraphy column are highlighted. The young igneous rock formations range in age from 35 to 68 million years [29]. The granite formations are quite bit older and have already cooled to a point that make them unlikely evidence for geothermal activity [29]. The granite formations are highlighted because some of the rock formations—like the Silver Plume Granite—show evidence of radioactivity and also contain non-tributary sources of groundwater [27] [28]. A breakdown of the key rock formations are shown in Table 1. Table 1 includes: age, type of rock, key mineral components, rock designation, and significance. The surface soil deposits reveal little geothermal significance.

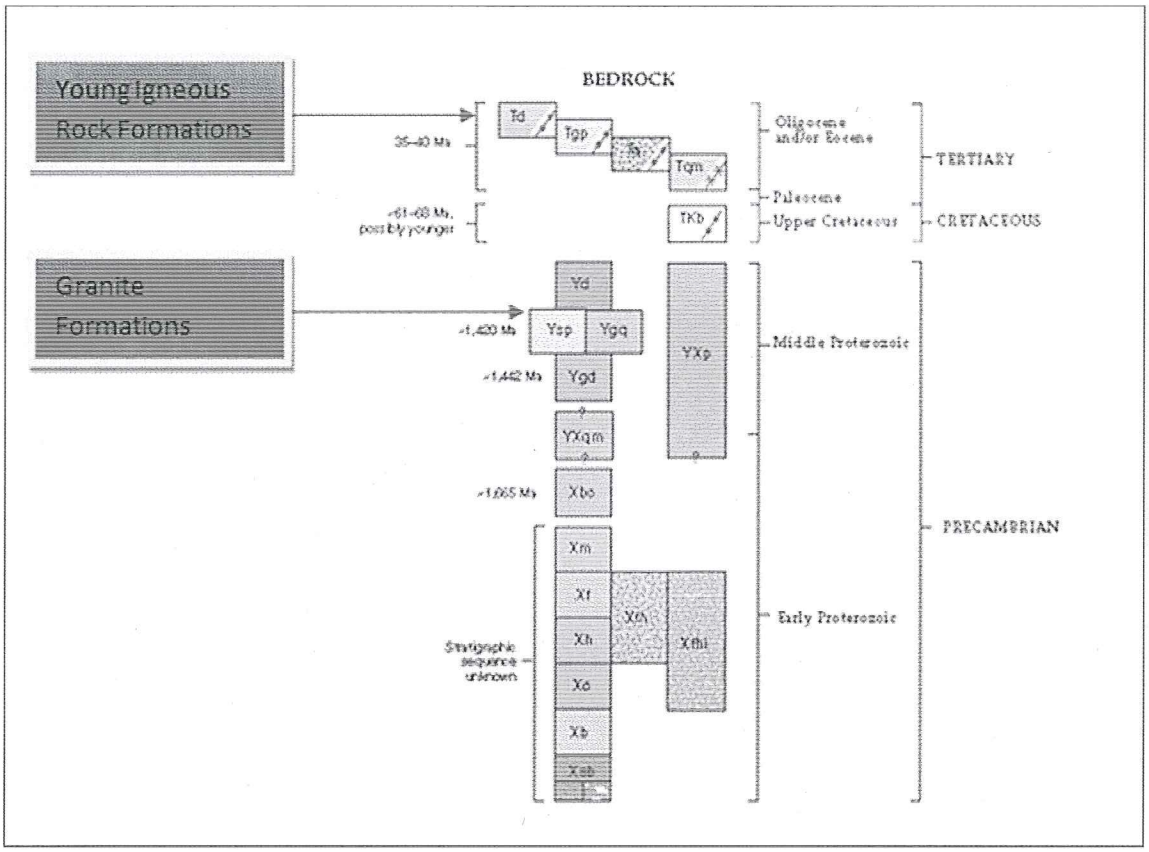



**Figure 5: Depiction of the Stratigraphic Column for the Bedrock of Georgetown and Empire Junction [25].**

The geology of the sites that Clear Energy is interested in have three patterns that indicate a presence of geothermal activity. These patterns are: high heat flow, extensive faulting, and granite formations with a significant volume of non-tributary groundwater [28]. These patterns demonstrate that these areas have great potential for geothermal development. Further exploration is necessary to characterize and understand the site. The key geological data obtained from United States Geological Survey and the Colorado Geological Survey is summarized in the Table below. A map of the final selected is shown at the end of the section of this report. Areas of possible development are also highlighted.

**Table 4: A Table Summarizing Key Geological Information [29]**

| Rock Formation | Designation | Age | Key Minerals | Classification |
|---|---|---|---|---|
| **Dacite** | Td | 35-36 Ma | Feldspar, Kalsite | Igneous |
| **Granite Porphyry** | Tgp | 36.6- 4.8 Ma | Biotite, Quartz, Orthoclase | Igneous |
| **Alaskite Porphyry** | Ta | 37.0 ± 4 Ma | Quartz, Plagioclase, Orthoclase | Igneous |
| **Quartz Monzonite Porphyry** | Tqm | 35 to 40 Ma | Quartz, phenocrysts, | Igneous |

| | | | | |
|---|---|---|---|---|
| | | | plagioclase | |
| **Bostonite Porphyry** | Tkb | 35 to 40 Ma (est) | Quartz and Amphibole | Igneous |
| **Diorite and Associated Hornblendite** | Yd | 1000 Ma (est) | Plagioclase, biotite, quartz | Igneous |
| **Silver Plume Granite** | Ysp | 1422 ± 2 Ma | Plagioclase and Quartz | Igneous |
| **Biotite Muscovite Granite** | Ygq | 1422 ± 2 Ma | Quartz, Biotite, and Plagioclase | Igneous |

Areas for potential development involve exploration at depths of approximately 100 m to 1000 m. This depth is significantly deeper than any of the water wells of the area. To ensure safety permitting given by the state of Colorado will be followed to ensure accuracy and proper handling. Further discussion of water quality issues can be seen in the Water Quality section of this paper. Main areas of concern for exploratory impact and ground source heat pump development are the water wells in the area and surface water/groundwater interactions. A discussion of the hydrology of the area can be seen in the Surface Water Quality section of this permit application. Soils of the area also reveal several key parameters.

Figure 4 shows the surface deposits in the area. Porosity assessments of these soils have not been performed, but looking at a scale seen in Figure 5. One can tell that the majority of soils are made of sand and cobbles. Soils that have high porosity have a tendency to allow large amounts of fluid to pass through them. No geothermal drilling will occur at the surface. Risks of contamination from said fluids should therefore be minimal. Caution should be taken to keep spills from occurring at the surface since the soil is highly porous.

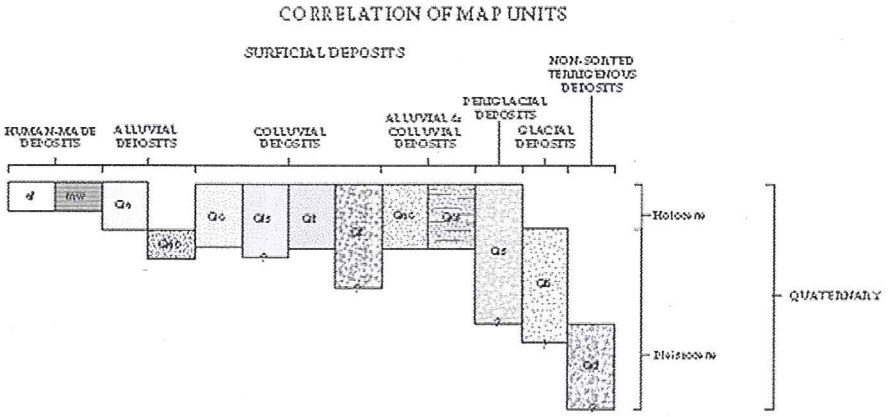



Figure 6: Overview of Surficial Soil Deposits. Sedimentary Rock and Sandstone [25].

From the chart below one can see that sandy soils tend to be far more porous than silts or clays. Percentage makeup of the soils in the area not known at this point. Cone Penitrometer Testing and Well Analysis will give more information about the soil quality of the area.

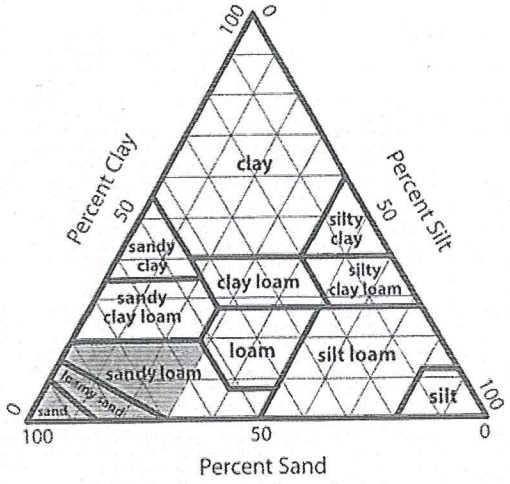



Figure 7: Breakdown of Soil Porosity

## Water Wells

Water wells are the main area of concern for geothermal development. While exploratory methods will have minimal impacts on the use of these wells. A survey and understanding of surface water and groundwater interactions should be developed to ensure no major water ways are impacted by geothermal development. In Figure 3 one can see that there are very few active drinking water wells near areas for potential development. These wells average depths ranging from 300 to 1000 ft. and should have minimal impact on the overall water quality of the area.

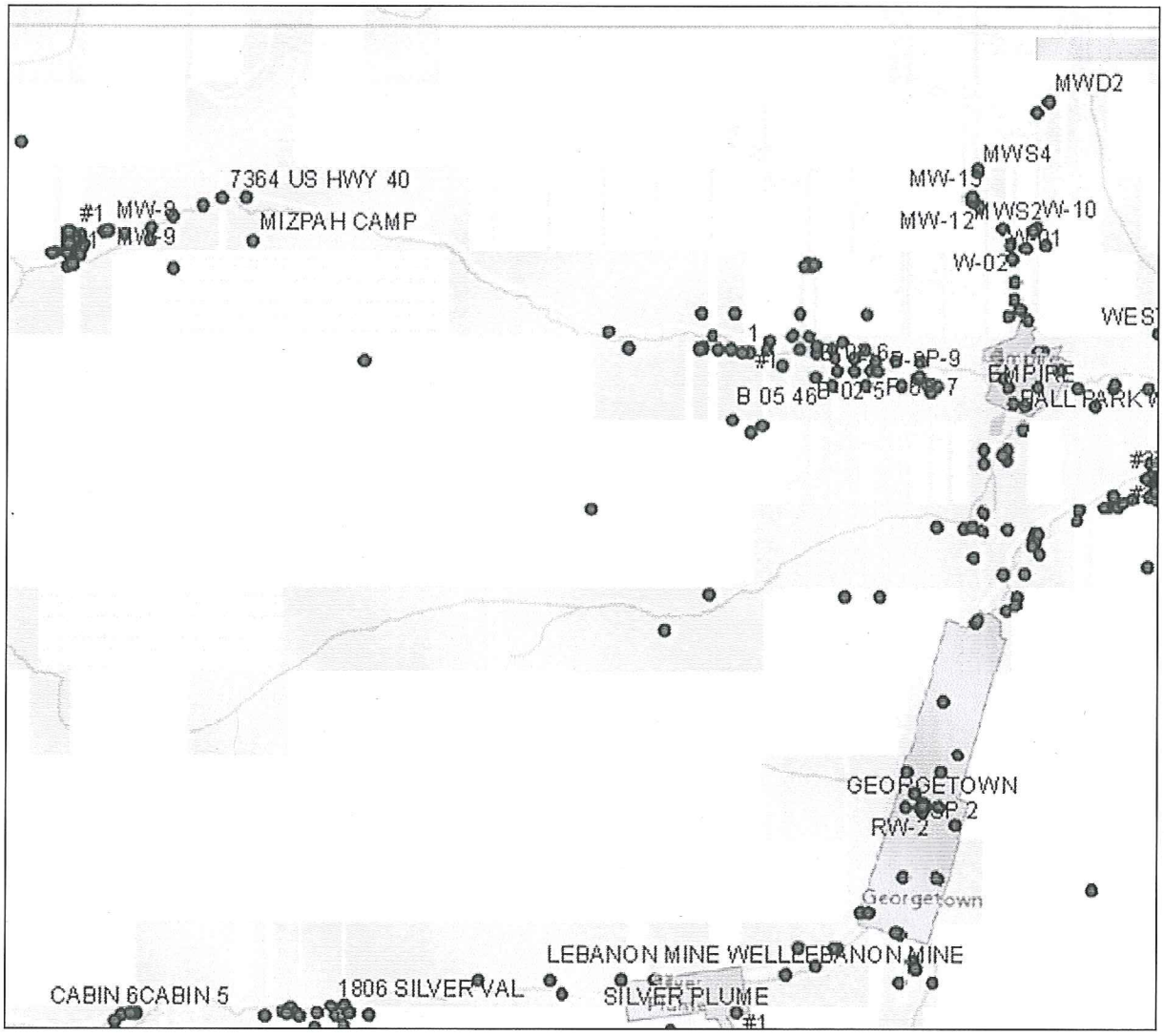



**Figure 8: A Map of the Major Water Wells in the Area**

Water well impacts will need to be determined along with the other areas discussed in surface water impacts during exploration. The Colorado permitting process requires a four step process that assesses four different areas. They are:

- Legal Location
- Presiding Local Government (Clear Creek County and Grand County, Municipalities of Georgetown and Empire)
- Geographic Setting
    A. Hydrology-streams, reservoirs, wetlands at or near drill site.
    B. Elevation
    C. Topography Nearby Roads
    D. Site Access
    E. Nearby Structures [30]

Many of these areas have already been covered in the 1041 but more information needs to be gathered on the hydrology of the area, the geology of the area, and how the geology impacts geothermal development in Clear Creek County. A monitoring system should be developed to ensure minimal impacts occur on water quality throughout the region.

### Groundwater/Surface Water Impacts

Aquifers and groundwater recharge is not understood in Clear Creek County at this point. In Figure 6 a map of information about aquifers of the area is shown, and in Figure 7 recharge determinations are also shown. Most water deposited in Clear Creek County goes into surface water bodies and does not enter groundwater sources. Potential areas for exploration are non-tributary in nature, and the impacts on these sources should be minimal.

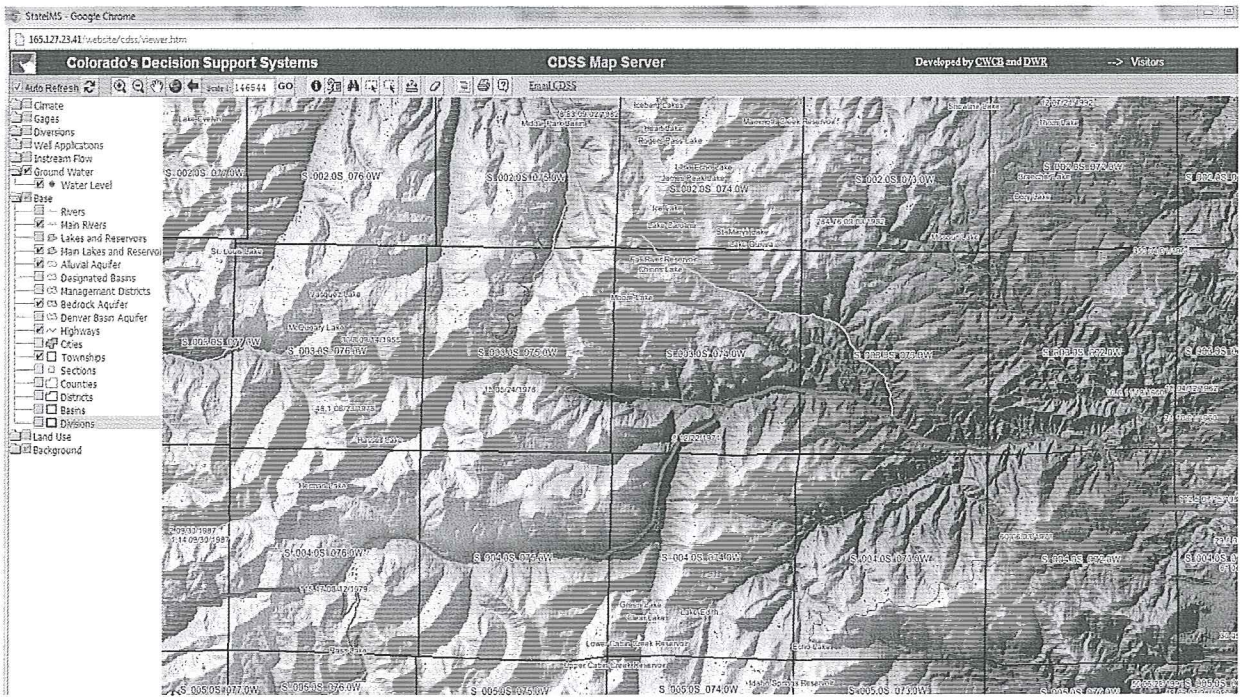



**Figure 9: Breakdown of Information about the Aquifer. Gray color indicates no known information [31].**

Figure 5 shows areas of potential recharge throughout the area. Recharge throughout the entire area is very small. This is important to geothermal development because it means that contamination that will occur will most likely remain isolated in areas.

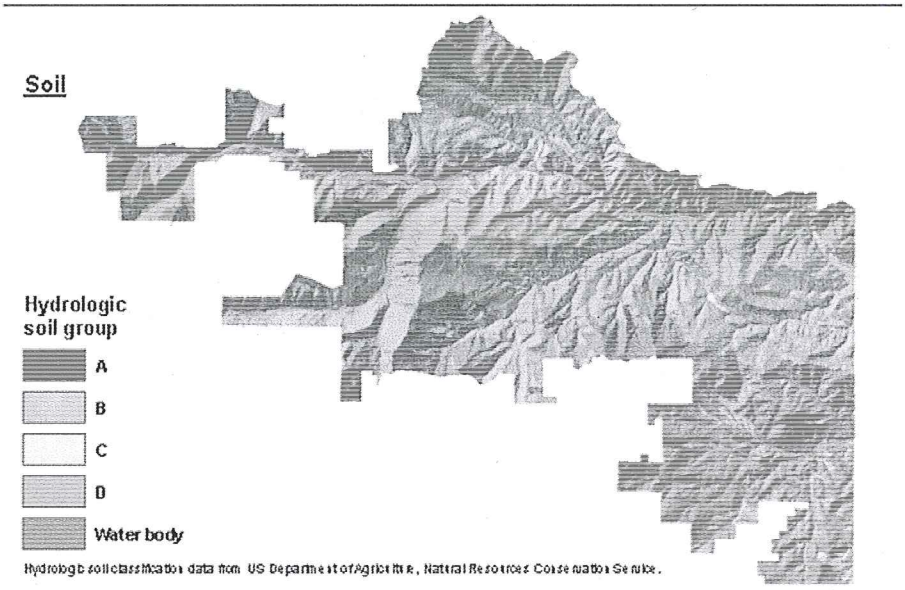
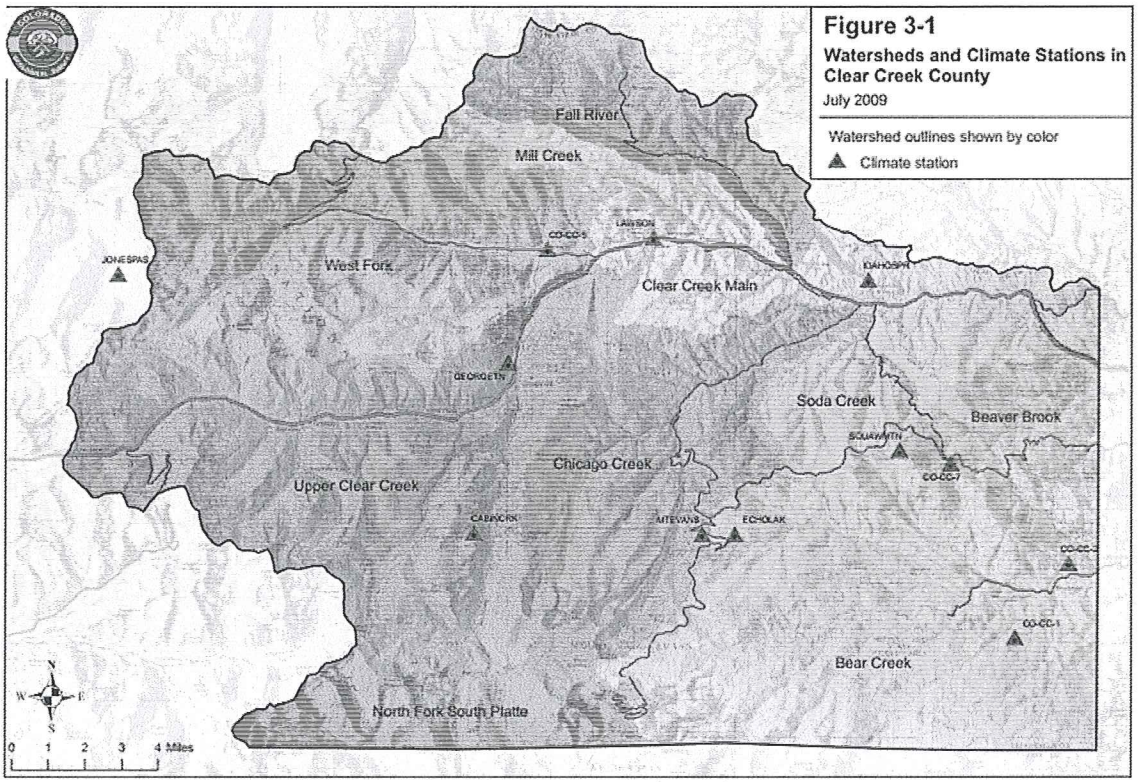



**Figure 10: A Soil Classification System Developed by the Colorado Geological Survey. Very little recharge in the area [22].**



### Geochemical Data

When geological engineers, geologists, and geophysicists look for geothermal activity they use geochemical data to substantiate evidence seen in stratigraphy and geological deposits. Geochemistry associated with geothermal activity can be site specific and complicated. Generally, geochemists look at sulfur and silicate based reactions. They also look at the concentration of metals and in cases of extreme radioactivity they may examine the decay of Uranium and Thorium. A summary of the key geochemical reactions are given below:

Chemistry data for the surface was found during a USGS study conducted in 1957. A summary of the data is given in Table 2. Key patterns that were observed in this data were high presence of silicates and low sulfur content. There was no significant source of radioactivity. The geochemical data observed in Table 2 support the initial assessment that geothermal activity comes from faulting or radioactivity. Radioactive heating is dubious as the main source of heating because a large rock surface area is needed for it to be a significant source [27].

**Table 5: A Breakdown of Geochemistry Present in Young Igneous Rocks [32]**

| Rock For.* | Hornblende Granodiorite Porph. | | | | Biotite Granodiorite Porph | | | | BQMP** | Granite Sp. | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.1 | 63.8 | 62.1 | 63.6 | 65.4 | 66.3 | 68.6 | 69.4 | 65.7 | 76.4 | 65.9 |
| $Al_2O_3$ | 18.4 | 16.2 | 17.6 | 16.6 | 16.8 | 16.2 | 15.8 | 16.2 | 15.4 | 12.4 | 16.2 |
| $Fe_2O_3$ | 4.3 | 2.7 | 2.7 | 2.7 | 2.6 | 2.2 | 1.2 | 1.5 | 1.5 | 1.4 | 2.3 |
| FeO | 2.8 | 2.4 | 2.1 | 3.0 | 2.0 | 2.0 | 1.3 | 0.9 | 1.2 | 0.7 | 1.8 |
| MgO | 2.0 | 1.5 | 1.4 | 1.6 | 1.1 | 1.1 | 0.7 | 0.6 | 0.8 | 0.2 | 1.1 |
| CaO | 4.6 | 5.0 | 5.3 | 3.8 | 3.2 | 2.4 | 3.0 | 1.6 | 2.8 | 0.6 | 3.2 |
| $Na_2O$ | 4.1 | 3.5 | 4.3 | 3.0 | 3.3 | 3.8 | 3.8 | 4.6 | 4.0 | 2.3 | 3.7 |
| $K_2O$ | 1.7 | 3.2 | 2.8 | 3.1 | 3.6 | 3.8 | 3.7 | 3.8 | 3.6 | 5.9 | 3.5 |
| $H_2O(+)$ | 2.4 | 0.4 | 0.4 | 1.2 | 0.9 | 1.1 | 0.5 | 1.0 | 0.5 | 0.5 | 0.9 |
| $H_2O(-)$ | 2.4 | 0.4 | 0.1 | 1.2 | 0.9 | 0.3 | 0.1 | 1.0 | 1.0 | 0.5 | 0.8 |
| $TiO_2$ | 0.8 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.1 | 0.4 |
| $P_2O_5$ | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 | 0.5 | 0.0 | 0.3 |
| MnO | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.1 |
| $CO_2$ | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 2.6 | 0.0 | 0.3 |
| Cl | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | NA | 0.0 | 0.0 |
| F | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | NA | 0.0 | 0.1 |
| S | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | NA | 0.0 | 0.0 |
| Total | 102.3 | 100.4 | 99.8 | 100.7 | 100.8 | 99.8 | 99.5 | 101.1 | 99.9 | 101.1 | 100.6 |

* Chemical Data taken from a geological study conducted in Empire. Full Source given at end of the Presentation
** Biotite Quartz Monzonite Porphyry

In the table above there are two patterns that should be noted:

1. There is a large presence of silicates indicating the possibility of large geothermal activity
2. There is low sulfur content indicating that the flow is related more too subsurface movement than magmatic heating. Magmatic heating is a rare phenomenon in Colorado and only occurs in the Glenwood Springs region [27].

The geochemical data given demonstrates that the surface contact of the bedrock should be low. Temperatures should also be relatively low, and should have minimal impact on groundwater quality. A more thorough assessment of the water quality will need to be done once an initial exploration assessment gives more information about geothermal resources in the area. Permitting will ensure that the proper steps are taken to ensure impacts are minimal.

### Geologic Conditions

The key rocks and minerals consist of Young Rock Formations and Silver Plume Granite. There is a high silicon dioxide content within the rocks, which suggest geothermal activity. The age of the rocks range from the early Proterozoic era to the Quaternary era. The types of rocks include: gneiss, biotite, schist, hornblende, and amphibolite. These rocks are mainly made of granite, gabbro, and various forms of hornblende. The later eras of geology include the fountain formation, various kinds of glacial till, and different kinds of gravel. Additionally, multiple faults, anticlines, and synforms exist within the Clear Creek watershed.

### Hazardous Materials

Contaminants of concern within Clear Creek County are mainly heavy metals. These include: zinc, copper, manganese, cadmium, lead, and arsenic. These contaminants have affected media such as soil, surface water, leachate, groundwater, and liquid waste. Many of these contaminants are the result of mine waste piles and tunnel discharges. The contaminants of concern for aquatic life are zinc, copper, cadmium, and manganese. These metals are found in the surface waters of the region and present potential harm to aquatic life. The contaminants of concern for humans are arsenic and lead. These contaminants may seep into the groundwater to which humans use as a water source. Additionally, inhalation of the contaminants through airborne dust or accidental ingestion could be hazardous for humans.

http://www.epa.gov/region8/superfund/co/ccclearcreek/index.html#3

## Monitoring and Mitigation Plan

The 1041 application requires that a developer establish a program to monitor and report on mitigation measures adopted as part of the environmental review process to avoid or reduce the severity and magnitude of potentially significant environmental impacts associated with project implementation. This plan must be adopted at the time that the agency determines to carry out a project for which a 1041 has been prepared, to ensure that mitigation measures identified in the 1041 are carefully implemented. Below is a table that includes the full text of the mitigation measures identified in the 1041.

**Table 4: Mitigation Measures** [36]

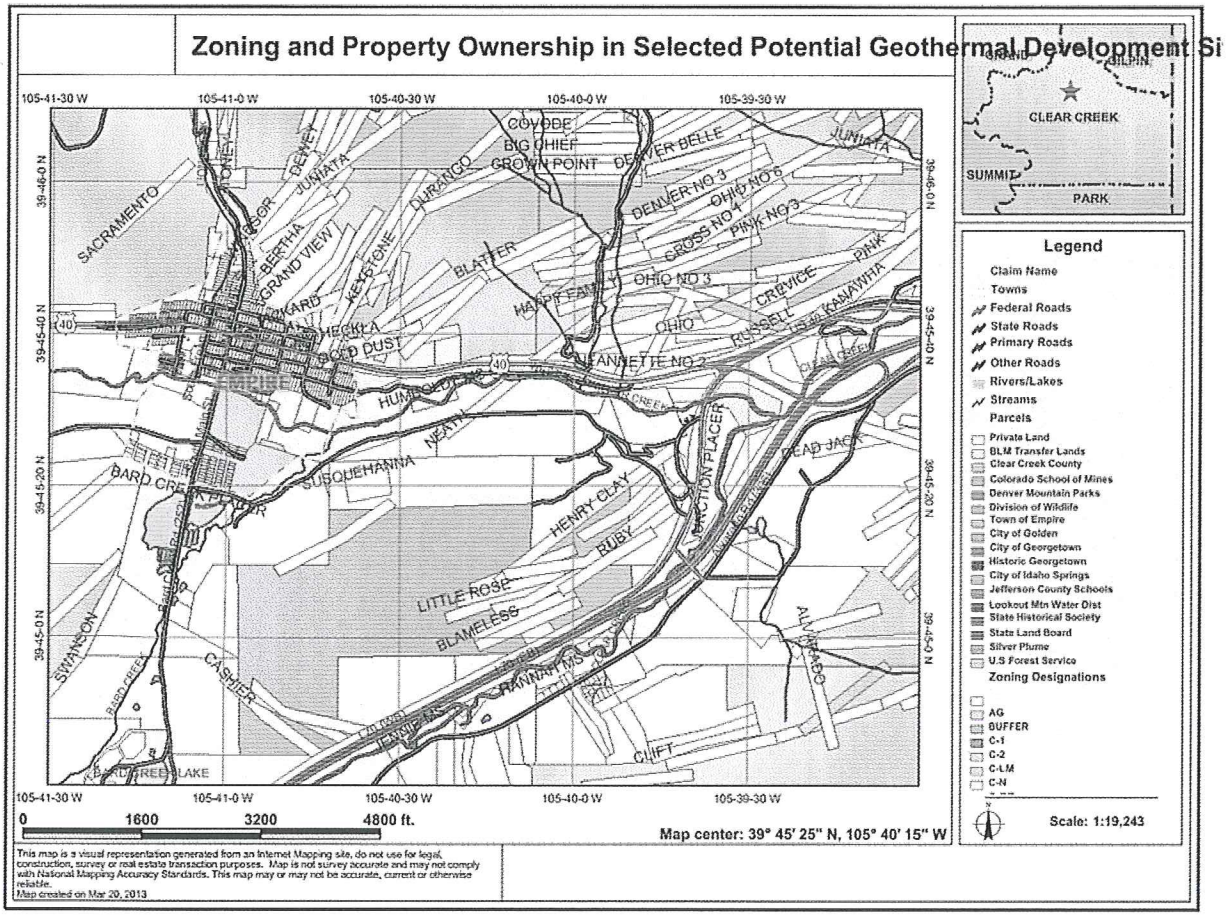
| Significant Impact | Mitigation Measure | Monitoring Responsibility | Mitigation Timing |
|---|---|---|---|
| **Aesthetics and Visual Quality:** a.) The proposed project could alter views site, and could result in a substantial adverse effect to a scenic vista or b.) substantially damage scenic resources, alter the existing visual character of the project site and could substantially degrade the existing visual character and quality of the site and its surroundings or c.) would introduce new sources of light and glare into the site and increase the overall level of ambient light in the site vicinity. | a.) no mitigation identified<br>b.) no mitigation identified<br>c.) All new buildings on the site constructed shall incorporate design standards that ensure lighting would be designed to confine illumination to its specific site, in order to minimize light spillage to adjacent buildings and open space areas. Consistent with safety considerations, project buildings shall shield and orient light sources so that they are not directly visible from outside their immediate surroundings. | a.) Facilities planning<br>b.) Facilities planning<br>c.) Facilities planning | a.) Project design and review process<br>b.) Project design and review process<br>c.) Project design and review process |
| **Air Quality:** Construction of new facilities would generate short-term emissions of fugitive dust and criteria air pollutants that would affect local air quality in the vicinity of construction sites. a.) Dust abatement calls for "basic" control measures that should be implemented at all construction sites, "enhanced" control measures that should be | a.) Water all active construction areas at least twice daily. Watering should be sufficient to prevent airborne dust from leaving the site. Increased watering frequency may be necessary whenever wind speeds exceed 15 miles per hour. Reclaimed water should be used whenever possible. Cover all trucks hauling soil, sand, and | a.) Inspection during construction activities.<br>b.) Inspection during construction activities. | a.) During project design and review process and environmental review and approval process.<br>b.) During project design and review process and environmental review and approval process. |

| | | | |
|---|---|---|---|
| | Floristic surveys shall also be conducted in designated Perimeter Open Space. All occurrences of special-status plant populations, if any, shall be mapped. | | |
| **Noise:** Development under the proposed LRDP would result in temporary noise impacts related to construction and demolition activities. | Construction/demolition activities would be limited to a schedule that minimizes disruption to uses surrounding the project site as much as possible. Such activities would be limited to the hours designated in Clear Creek County noise ordinance(s), as applicable to the location of the project. This would eliminate or substantially reduce noise impacts during the more noise-sensitive nighttime hours and on days when construction noise might be more disturbing. To the maximum extent feasible, equipment and trucks used for project construction shall utilize the best available noise control techniques (e.g., improved mufflers, equipment redesign, use of intake silencers, ducts, engine enclosures and acoustically-attenuating shields or shrouds, wherever feasible). Stationary noise sources shall be located as far from adjacent receptors as possible. At locations where noise may affect neighboring residential uses, a comprehensive construction noise control specification to implement construction/demolition noise controls, such as noise attenuation barriers, siting of construction laydown and vehicle staging areas, and community outreach, as appropriate to specific projects. The specification will include such information as general provisions, definitions, submittal requirements, construction limitations, requirements for noise and vibration monitoring and control plans, noise control materials and methods. This document will be modified as appropriate for a particular construction project and included within the construction specification. | Construction Inspection | During Construction Activities |
| **Transportation Traffic:** Implementation of the project would degrade level of service at certain local intersections. | The project shall work with Clear Creek County to design and install a traffic management program. The project will provide flaggers as necessary and other traffic control techniques as needed. | Construction Inspection | During Construction Activities |
| **Utilities, Service System, Energy:** a.) | **a.)** A program shall be implemented to ensure that additional wastewater flows from | Construction Inspection | During Construction Activities |

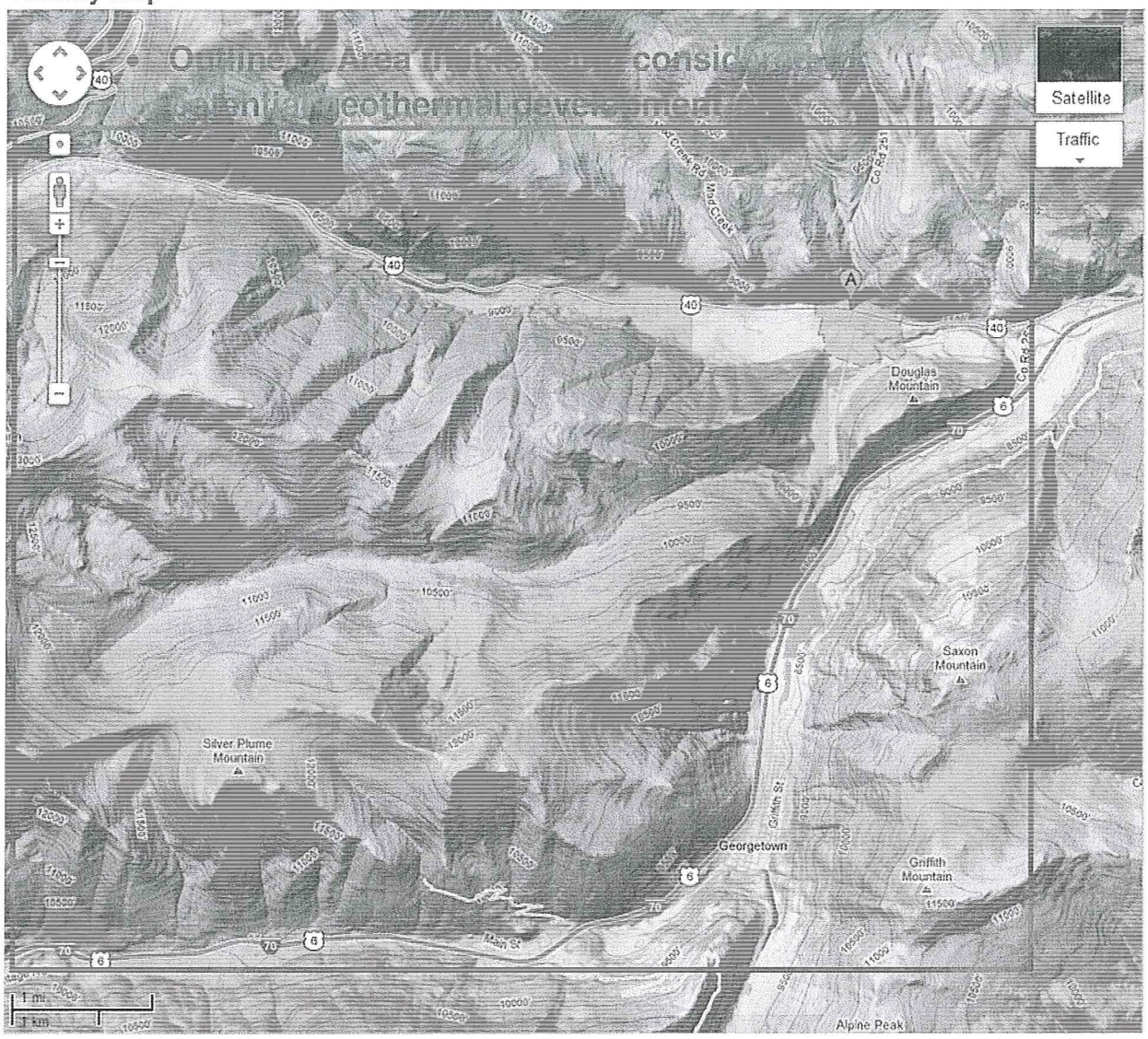
| | | | |
|---|---|---|---|
| Implementation of the project would generate additional wastewater, requiring system improvements to ensure that additional wastewater flows from the facility are directed into unconstrained sub-basins. b.) On-site construction due to development proposed under the 2006 LDRP would generate construction waste and debris. | the facility are directed into unconstrained sub-basins, as necessary and appropriate. **b.)** A program shall be developed for maximizing diversion of construction and demolition materials associated with the construction of the proposed project from landfill disposal. | | |
| | | | |

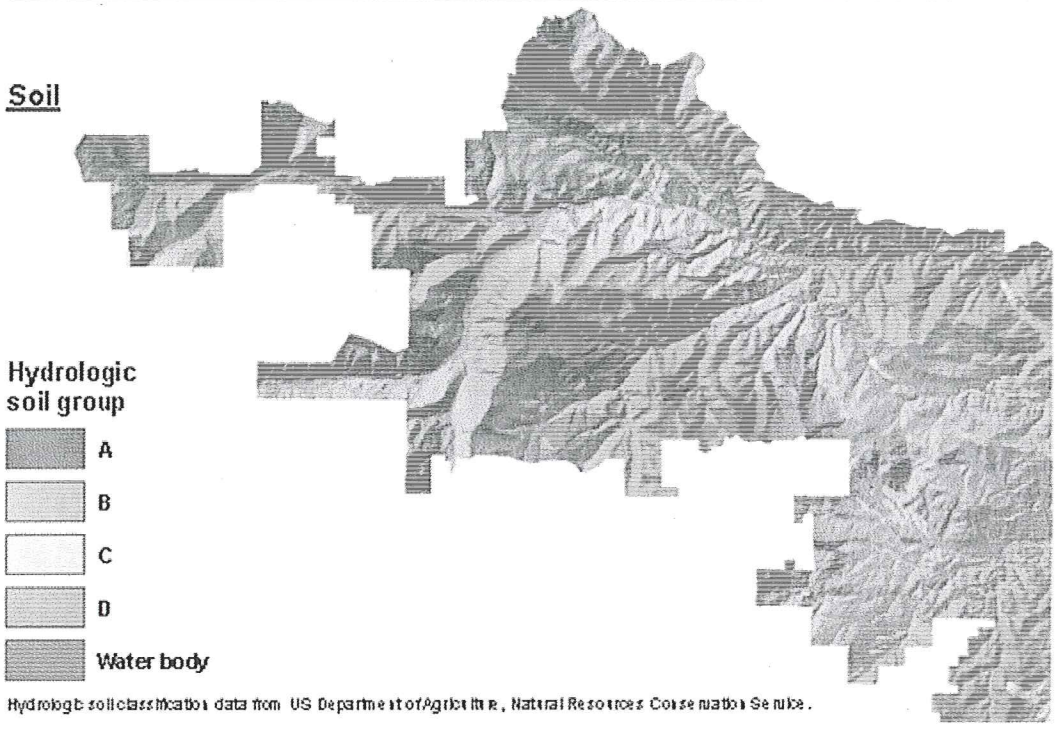
# Maps

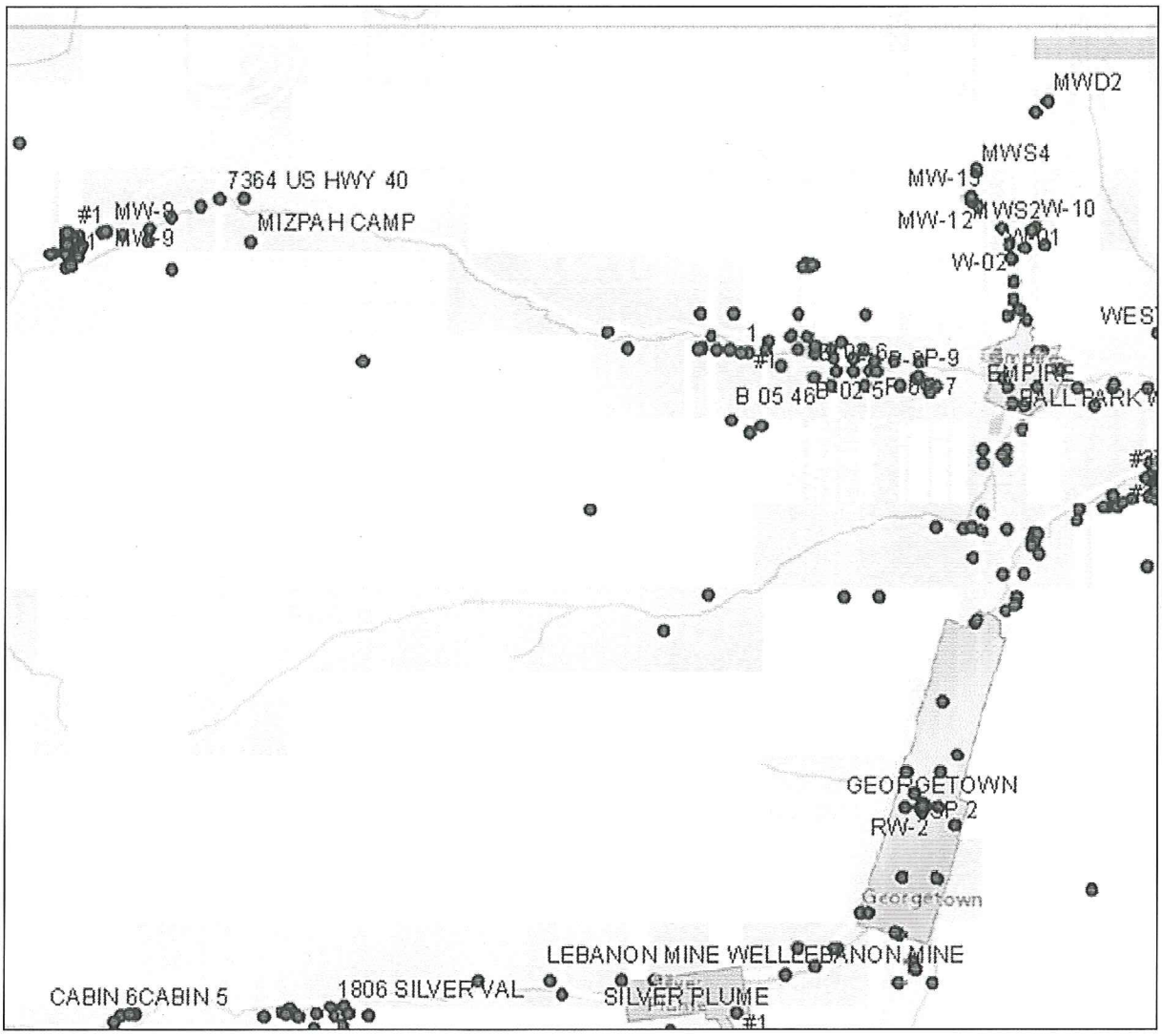
## Zoning Map



## Vicinity Map




Soil
Hydrologic soil group
A
B
C
D
Water body
Hydrologic soil classification data from US Department of Agriculture, Natural Resources Conservation Service.


MWD2
MWS4
MW-19
7364 US HWY 40
#1 MW-8
MW-9
MIZPAH CAMP
MW-12
MWS2
W-10
W-02
WES
EMPIRE
B 05 46
GEORGETOWN
RW-2
Georgetown
LEBANON MINE WELL
LEBANON MINE
CABIN 6
CABIN 5
1806 SILVER VAL
SILVER PLUME
#1

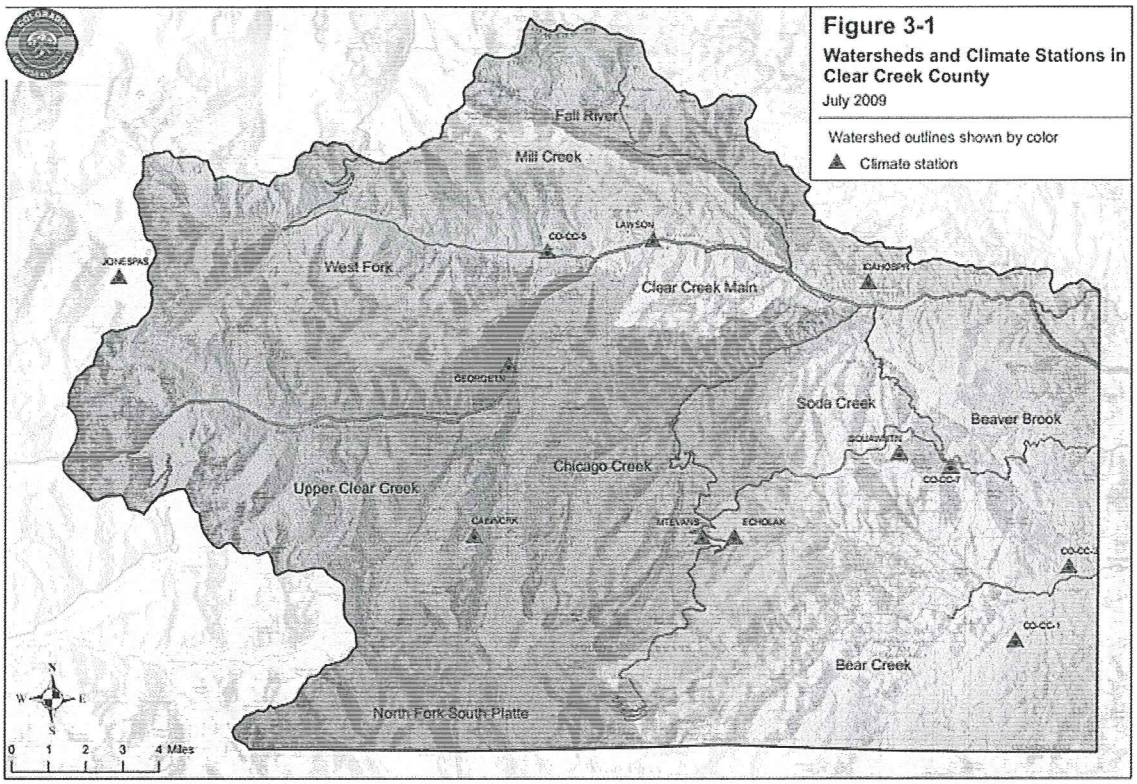
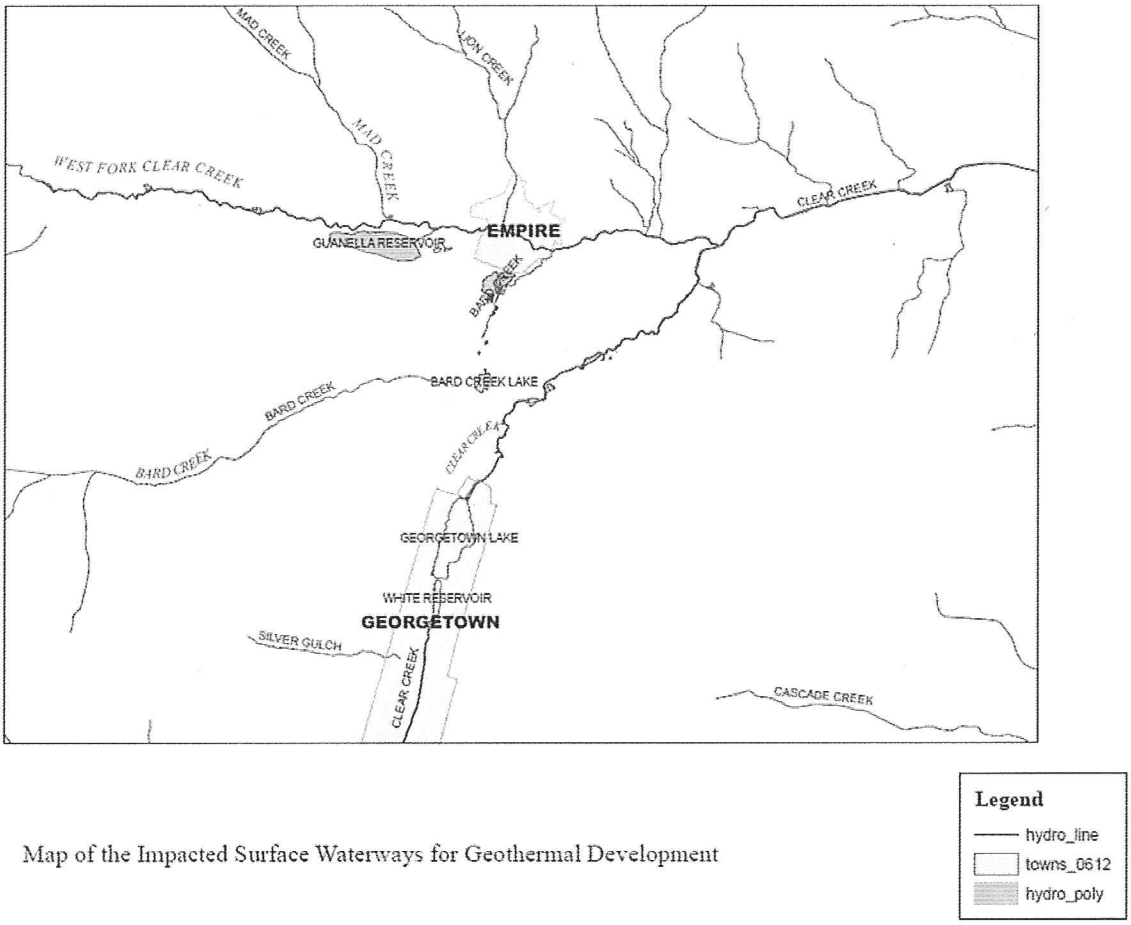
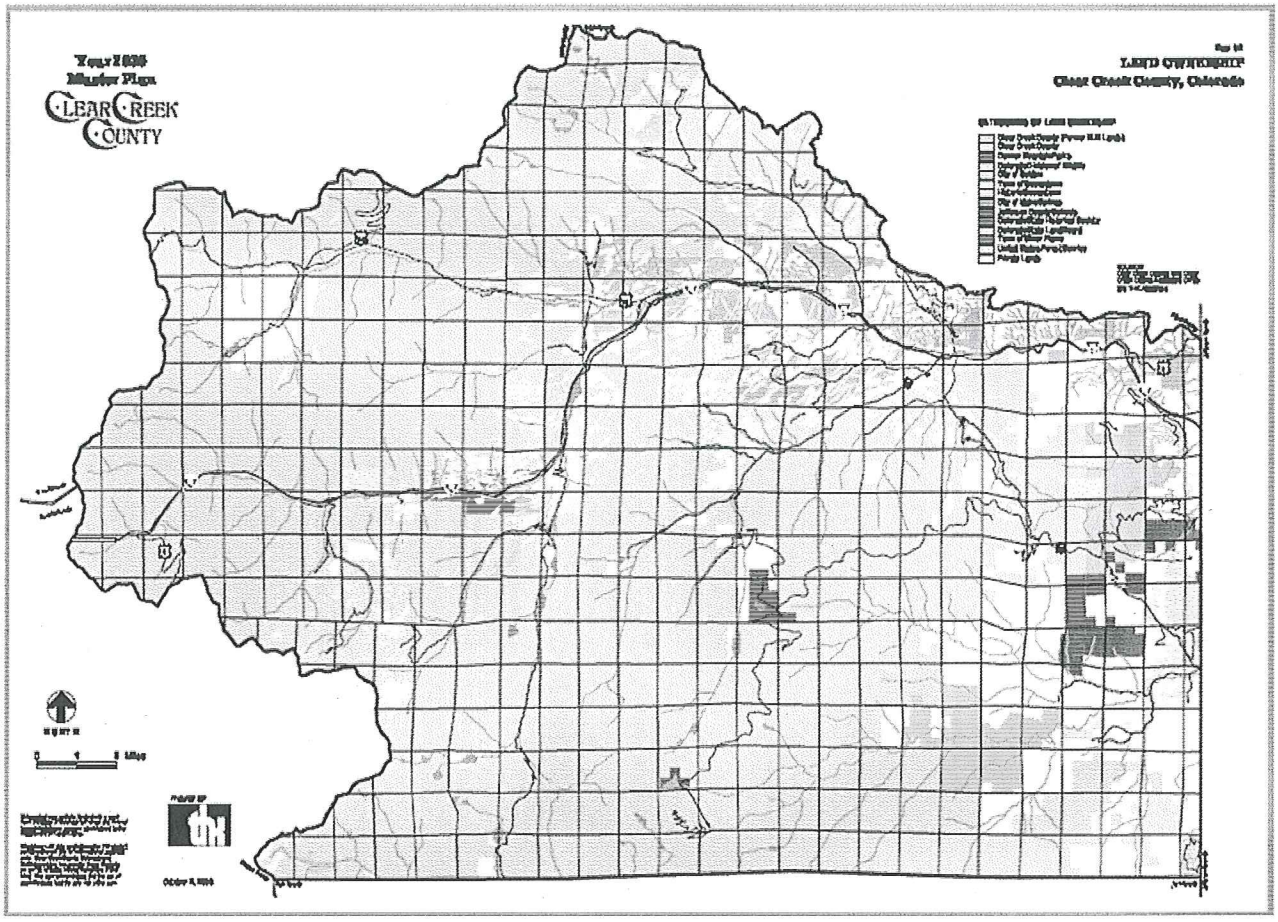


Figure 3-1
Watersheds and Climate Stations in Clear Creek County
July 2009
Watershed outlines shown by color
Climate station
Fall River
Mill Creek
LAWSON
CO-CC-5
JONESPAS
West Fork
Clear Creek Main
IDAHOSPR
GEORGETN
Soda Creek
Beaver Brook
SQUAWTN
CO-CC-7
Chicago Creek
Upper Clear Creek
CARVCRK
MTEVANS
ECHOLAK
CO-CC-2
CO-CC-1
Bear Creek
North Fork South Platte
N
W
E
S
0 1 2 3 4 Miles




Map of the Impacted Surface Waterways for Geothermal Development




## Roads and Access

The impact on existing traffic patterns will be dependent on the exact location chosen to construct the geothermal system. Even so, impact will likely be very low. Implementation will not require the destruction or alteration of any major roads or highways.

It is also likely that the geothermal activity will attract interest and additional tourism from nearby communities. It may be wise to plan to build a small informational booth with additional parking to accommodate for those interested in learning about the new heating system. Altogether, there may be a slight increase in people visiting the newly developed geothermal area. These people should have the opportunity to park their vehicles in a designated location. At the same time, the influx of traffic generated by the geothermal heating will not be great enough to alter existing traffic patterns of the area. However, if a new commercial building is planned to be constructed as well, the impact on existing traffic patterns will need to be reevaluated.

## Description of Access Route

Because the project is in its early phases, an exact access route cannot yet be determined. However, it can be assumed that anyone working on the project will likely approach the area through I-70, then exit on to the frontage road, and possibly branch off from there onto existing old dirt and mining roads, or other minor access roads. When compared with the normal traffic patterns that I-70 and the frontage road

experiences through Clear Creek County, the extra vehicles from this project will be minimal and not of concern. The only major issues arise if and when an exploratory well is proposed to be drilled. In this case, multiple vehicles and possibly a larger drilling rig will access the area and may be required to remain stationary on one of the minor dirt roads. Appropriate visual indicators will be used, such as orange cones. If it is expected that such a procedure significantly disrupt existing traffic patterns or completely block the flow of traffic, extra permits may be required.

## Dust Control Procedures

Dust control procedures are only necessary on non-paved roads that will experience extensive traffic. Should this occur, it would be in the best interest of those working on the project to hire experienced contractors. These contractors would use environmentally friendly, state-of-the-art dust control systems to eliminate the problem. If the area and timeframe requiring the dust control treatment is small enough, workers may choose to avoid private contractors and use dust control agents purchased by licensed vendors.

## Road Maintenance Program/Schedule

Road maintenance varies between individual roads. Interstate 70, is federally maintained and assuming all Colorado Department of Transportation (CDOT) rules and regulations are followed, I-70 will not need extra maintenance. The use of frontage roads is likely as well. These roads will be used only for direct transportation though, and will not be tested by anything more than heavy trucks. Again, CDOT will be responsible for maintenance of these frontage roads.

Smaller roads such as old dirt mining roads are not maintained by CDOT, and it will be the responsibility of Clear Creek County to maintain them. Such roads will be used for surveying and exploratory purposes, and may have inconsistent flows of vehicles, or vehicles parked in the middle of them. The use of these roads by Clear Creek County will span less than one year to finish the geophysical surveys. For this reason, assuming the roads are passable to begin with, extra scheduled maintenance will not be necessary. If circumstances put large and impeding potholes in these roads, gravel can be trucked in to quickly fill the holes.

## New Roads or Access Routes

It is possible that additional roads will be needed if construction of new buildings for which the geothermal energy will be applied is to occur. If this is the case, additional parking must be planned for to accompany that particular building's needs. Because the project is in its early phases, exact new access routes cannot yet be determined. See the previous section, "Description of Access Routes" for information regarding possible access routes that are already in place.

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