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Chapter 6
Geothermal Resources

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GEOTHERMAL RESOURCES

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Introduction

Geothermal resources refer to the natural sources of heat energy that come from volcanic activity beneath the Earth's surface. Geothermal heat energy can be captured and used for electricity at a variety of scales—from individual households to large industrial power plants. In Lake County, geothermal resources also support recreation and tourism as the county's popular hot springs are fueled by the area's geothermal resources.

This Geothermal Resources Element provides an overview of the county's geothermal resources and related industries. This element includes goals, policies, and actions that work to preserve the environment and support economic opportunities stemming from geothermal resources unique to the county.

Background

Much of Lake County is in the Quaternary Clear Lake Volcanic Field, the source of the region's rich volcanic soils, natural hot springs, and picturesque mountains. The county's geothermal resources are primarily concentrated along its western border in the Middletown, Cobb Mountain, and Kelseyville planning areas in and around the Clear Lake Volcanic Field, where a large magma chamber (approximately 8.7 miles in diameter) lies about 4.3 miles below the surface. The magma chamber is the source of heat for numerous thermal springs, electricity generated by The Geysers geothermal field, and deposits of valuable minerals. The Geysers geothermal field is known for its high-temperature resources, but there is ongoing exploration of low-temperature resources.

Low-temperature geothermal resources consist of heat (less than 300 degrees Fahrenheit) that is extracted from geothermal fluid for direct use, such as space heating and refrigeration.

High-temperature geothermal resources have temperatures above 300 degrees Fahrenheit and can be used for electrical power generation.

Geothermal Projects in Lake County

Underground magma chambers from the Clear Lake Volcanic Field power the geothermal field and network of power plants known as The Geysers, which is partially located in Lake County, along its southwest border. In geothermal fields, also called steam fields, geothermal gases rise from small openings or "vents" and can be captured for energy. The Geysers is the largest geothermal field in the world, spanning 45 square miles across Lake, Mendocino, and Sonoma Counties, according to the

United States Geological Survey (USGS). It contains a complex of 18 geothermal power plants, drawing steam from more than 350 wells.

Throughout the 1970s and 1980s, The Geysers reservoir produced significantly more steam than condensate water was replenished, leading to decreased steam pressure and threatening the sustainability of future power generation. In 1990, a collaborative between The Geysers operators, Lake County Sanitation District (LACOSAN), and the California Energy Commission initiated a project to use treated wastewater in Lake County to augment water needs for The Geysers geothermal power plant. Since 1997, the Southeast Geysers Effluent Pipeline has collected and conveyed wastewater effluent from Lake County to The Geysers geothermal power plant; it is considered the world's first wastewater-to-geothermal injection project. Today, approximately 9 million gallons of treated wastewater is collected each day from Lake County businesses and households and injected into the reservoir to help maintain the continuous pressure needed to create steam. In addition, The Geysers more recently added two Battery Energy Storage Systems (BESS) to store energy produced by steam fields for a more reliable and resilient delivery of electricity.

The Geysers have continuously generated commercial electricity for the northern California power grid since 1960 and currently produce enough electricity to power 725,000 homes. USGS reports that electricity output from The Geysers accounted for 7 percent of the renewable energy (and 50 percent of geothermal energy) produced in the state in 2018.

Historically, geothermal energy production has been concentrated in the southern part of the c~~C~~ounty in the Kelseyville, Cobb, and Middletown Planning Areas. More recently, interest in potentially expanding geothermal projects to other areas of the c~~C~~ounty has grown, particularly with the development of new technologies ~~enabling geothermal heat generation from heated rocks rather than from steam vents located sufficiently close to the earth's surface, thereby expanding~~that expand areas of potential geothermal energy generation.

Emerging Technology

Globally, there is growing interest in harnessing hot rock geothermal energy. Unlike traditional geothermal power generation that relies on hot water or steam near the earth's surface, hot rock geothermal energy is generated from drilling deep into the earth and injecting water into drilled wells to create steam. Hot rock geothermal energy is another renewable energy source with potential to produce vast amounts of energy. Development of this technology is still in exploratory phases as high-temperature drilling presents many challenges, but research into this new field is ongoing, including at The Geysers. Like other geothermal energy sources, hot rock geothermal has the potential to cause adverse impacts, such as induced seismic activity. The goals, policies, and actions in this element work to ensure existing and future geothermal operations preserve public safety and practice appropriate environmental stewardship.

Benefits

Lake County enjoys significant benefits from its geothermal resources. In addition to providing a reliable source of renewable energy, geothermal activity in Lake County supports the local economy

through both energy production and tourism, attracting visitors to its hot spring resorts. Educational programs on sustainable energy in the geothermal fields also promote eco-tourism. The Economic Development Elements of each local planning area include policies promoting continued geothermal resource operations in support of local economic development.

Management Issues

While the benefits are vast, geothermal resources present some challenges, requiring careful management of the resources and other steps to mitigate risks.

The Geysers Geothermal Power Plant generates enough electricity to power 750,000 homes.

Fire Risk

Areas with geothermal activity can have safety risks, including risks from fire due to the release of combustible gases or fluids. Geothermal cooling towers that are dry or not adequately wet can also catch fire, posing wildfire and air pollution threats. Electrical power infrastructure, including geothermal power plants, are also associated with heightened fire risks. Lake County already faces significant wildfire risk due to the region's hilly topography and relatively dry summers. Wildfire is addressed in detail in the Health and Safety Element (Chapter 5).

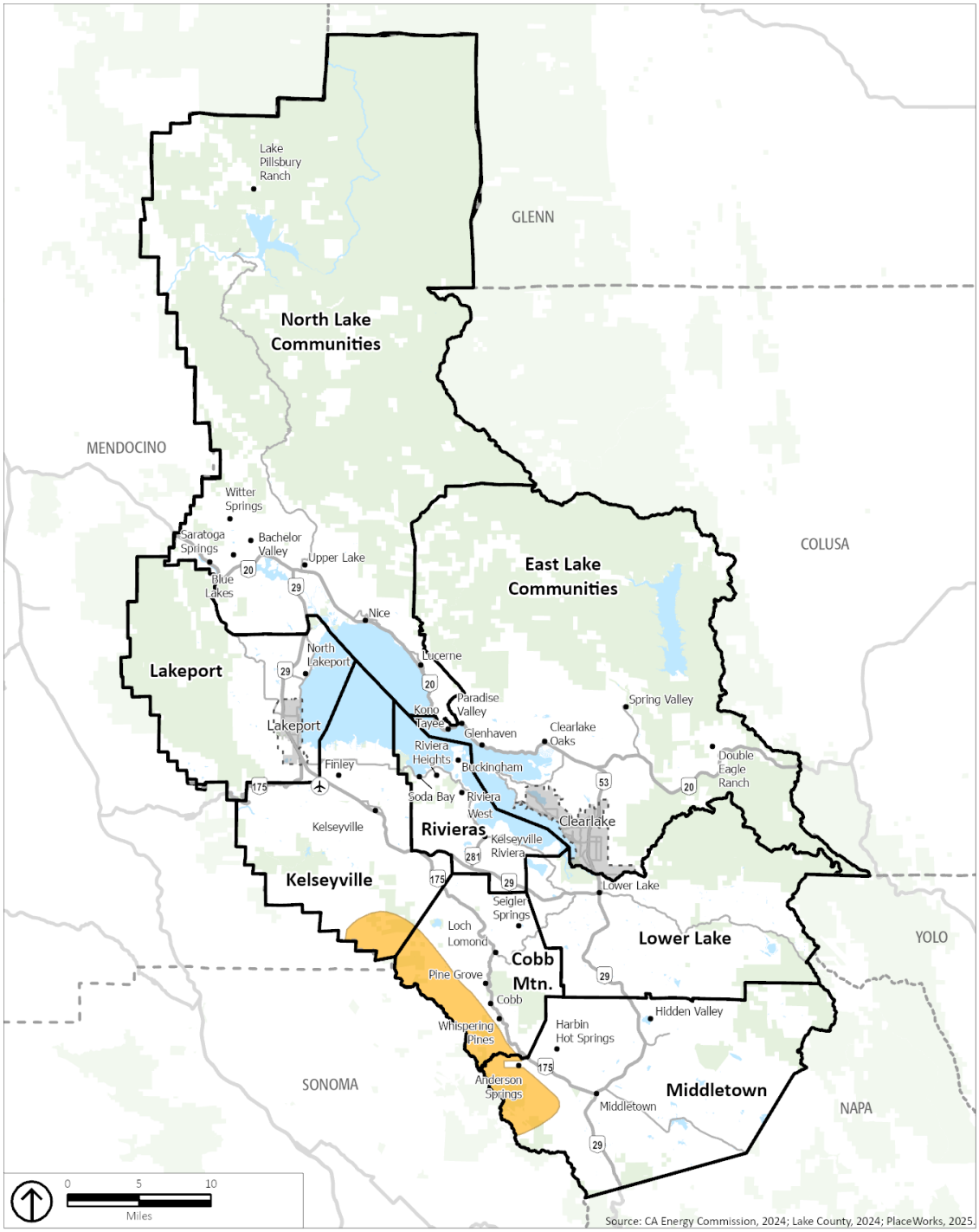
Health and Quality of Life Impacts

Geothermal gases are a public nuisance and can be dangerous at high concentrations but can be rapidly diluted to harmless levels in the open air. However, at times, these gases can transport significant distances without dilution. Geothermal gases commonly contain a combination of hydrogen sulfide, methane, and carbon dioxide, but they can contain other gases, including radon, a harmful radioactive gas. Gases can seep into buildings through cracks in foundations and utilities. Houses with cement foundations are at heightened risk. Some gases are odorless and colorless and can be very difficult to identify. Gases can make people sick when they accumulate in enclosed spaces or low-lying areas. At high levels, they can cause toxic reactions, suffocation, or sometimes explosion. Children and pets are particularly vulnerable due to their proximity to the ground where gases vent. The County posts resources on its website to help community members assess and minimize the risk of exposure.

In addition to these health risks, the industrial activities associated with the region's geothermal resources can be disruptive to everyday life in nearby areas, potentially causing air and noise pollution among other environmental impacts described below. As further detailed below, the Lake County Air Quality Management District (LCAQMD) monitors local air quality, including at The Geysers.

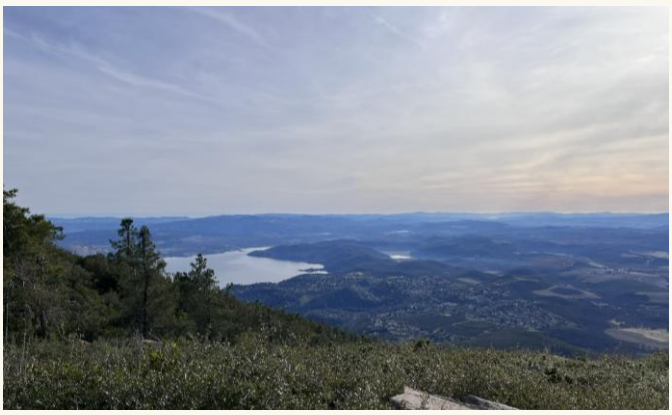
Figure GR-1 shows areas with the greatest likelihood of future development of traditional, hot steam geothermal activities, where air pollution and other hazards related to geothermal steam power generation may occur.

Figure GR-1 Primary Geothermal Resource Areas



Environmental Impacts

The use of geothermal resources for electricity or recreation requires careful environmental management and planning to address potential impacts on human health as well as air quality, groundwater, soil stability, and ecosystems. Emissions of geothermal gases, such as hydrogen sulfide, methane, and carbon dioxide, can pose air quality concerns. LCAQMD monitors and helps minimize geothermal gas emissions in coordination with the geothermal industry members (Calpine, NCPA, AltaRock, Open Mountain Energy, etc.) who operate The Geysers power plants, and in compliance with air quality regulations set by the United States Environmental Protection Agency (EPA) under the federal Clean Air Act (CAA) and the California Air Resources Board (CARB) under California Health and Safety Code.



Lake County enjoys healthy air quality, but geothermal operations can pose air quality concerns.

In addition to potentially harmful air emissions, geothermal fluid extraction can affect soil stabilization, groundwater quality, and ecosystems. Geothermal fluid migration during the extraction processes has the risk of draining and contaminating groundwater resources. The Geysers geothermal field implements a wastewater reuse program that injects effluent (wastewater) from the wastewater treatment facility into the wells of the geothermal reservoir. This effluent recycling pipeline helps conserve water resources and replenishes geothermal steam, but it can also lead to induced seismic activity. Additionally, geothermal activities can disrupt local ecosystems due to concentrations of geothermal gases and the change in soil chemistry and temperature at venting sites.

Finally, the county's geothermal resources produce mercury and feed the region's mercury mines. While the Sulphur Bank Mercury Mine has not been in operation since 1957, the area was declared a Superfund environmental clean-up site by the U.S. Environmental Protection Agency and is still being actively remediated today. Groundwater and soil may potentially contain mercury or other harmful compounds from the Sulphur Bank Mercury Mine and/or natural volcanic activity. For this reason, clean-up sites like the Sulphur Bank Mercury Mine are identified as potential 'sensitive receptors', which are environmental, ecological, or human elements that could be adversely affected by nearby development and land use impacts (e.g., noise, land disturbance, and waste generation~~, etc.~~). Sensitive receptors must be identified during environmental impact assessments to ensure that project design, siting, and operations minimize potential harm. Environmental clean-up sites are sensitive receptors because impacts to these sites could result in harm to the surrounding ecosystem if hazardous materials in the soil and water on the site are disturbed. Other sensitive receptors include land uses like homes and schools, sensitive ecological habitats, and groundwater water systems.

Goals, Policies, and Actions

Goal GR-1	Research and innovation that optimize the use of geothermal resources to generate sustainable energy and benefit Lake County.

Policies

GR-1.1

Support the use of new technological and operational measures that better conserve geothermal resources~~,~~ and/or increase efficiencies in power generation~~, and/or otherwise expand geothermal energy development potential~~.

GR-1.2

Encourage development and testing of new technologies to reduce environmental impacts of geothermal activities.

GR-1.3

Encourage and support public and private-sector organizations to participate in the cooperative study and demonstration of low-temperature direct uses, in coordination with local economic development efforts to retain and create jobs.

Direct use refers to systems using underground "low-temperature" geothermal fluid or steam for various direct applications, such as heating homes and other buildings, greenhouses, or swimming pools.

Actions

GR-1.a

Review current geothermal setback requirements and amend as necessary~~:~~, taking into account technological and industry advances~~,~~ and preservation of residential communities, water supply, and environmental and Tribal Cultural resources.~~Review current geothermal setback map and requirements in Article 27 of the Zoning Ordinance for potential updates and amendments to accommodate technological and industry advances to support geothermal and other sustainable power generation options~~.

GR-1.b

Provide staff with ongoing training opportunities to maintain their awareness of the latest technology and regulations affecting the geothermal industry.

GR-1.c

Cooperate with relevant local agencies to evaluate and implement appropriate geothermal resource conservation practices, such as injection programs designed to lengthen reservoir life.

GR-1.d

Work with the geothermal industry and appropriate State agencies to develop public education materials that will inform and encourage the public to implement direct-use geothermal technologies in private construction.

GR-1.e

Prepare a map identifying areas with potential for direct use of low-temperature geothermal resources.

Goal GR-2	Well-defined and consistent geothermal planning processes that involve collective participation of residents, Tribes, industries, and public agencies.

Policies

GR-2.1

Provide comprehensive information to the public regarding geothermal permitting procedures and current and proposed projects in a clear and timely manner.

GR-2.2

Coordinate with federal, Tribal, state, regional, and local agencies exercising local geothermal responsibilities to ensure consistency between their policies and regulations and this General Plan.

GR-2.3

Coordinate geothermal planning and management activities with neighboring counties.

GR-2.4

Encourage the cooperative exploration of opportunities for providing wholesale power to local agencies (e.g., community service districts) from transmission lines constructed in their vicinity, as well as local geothermal energy distribution in the county.

GR-2.5

Ensure continued cooperation between the geothermal industry and local job training and hiring programs and encourage geothermal developers to hire from the local community.

GR-2.6

Encourage geothermal developers and operators to purchase from and contract with local vendors and support development of auxiliary businesses to the geothermal industry.

Actions

GR-2.a

Provide information on the County's website about geothermal resources, including details about opportunities for direct use of geothermal resources in both residential and nonresidential settings, as well as up-to-date information about geothermal applications.

GR-2.b

Collaborate with geothermal operators to hold community meetings to gain input on geothermal issues and disseminate information on planned and ongoing operations.

GR-2.c

Reactivate and convene the Geothermal Advisory Committee on a periodic basis to review geothermal issues and explore opportunities for increased public and private partnerships that would promote economic development.

Goal GR-3	Geothermal resource development and operations that minimize impacts on the local environment.

Policies

GR-3.1

Support the development and use of geothermal battery energy storage projects in Lake County.

GR-3.2

Require new geothermal power plant applicants to demonstrate sufficient geothermal resources to support existing and proposed power generation.

GR-3.3

Require the removal or conversion of all aboveground geothermal facilities and site reclamation upon completion of the life of the facility. To ensure sufficient funding for facility removal, require adequate financial assurances as part of the project's final development plan.

GR-3.4

Encourage geothermal resource developers to use measures designed to minimize land disturbance, such as directional drilling, wherever feasible and appropriate to avoid environmental impacts, while mitigating environmental impacts of all geothermal development, including directional drilling.

Directional drilling is a technique used to access geothermal resources by drilling in a non-vertical direction, which minimizes surface disruption.

GR-3.5

Require that geothermal resource developers obtain and comply with waste discharge permits for drilling sumps (including the analysis of discharged material) and geothermal releases to the air, water, or land and consider technological solutions to further reduce environmental impacts.

GR-3.6

Require geothermal operators to monitor subsidence detection networks and establish other monitoring programs to determine the extent of induced subsidence in areas that could be affected by permitted geothermal project activities.

GR-3.7

In consultation with informed parties, such as the California Geologic Energy Management Division, Bureau of Land Management, and other experts, as appropriate, require subsidence monitoring and mitigation as a condition of approval for proposed geothermal operations. Require corrective measures if monitoring indicates that the geothermal operation has caused land subsidence creating a hazard or significant adverse impact on the local environment.

GR-3.8

Require detailed geotechnical investigations prior to all exploratory drilling for geothermal resources. These investigations must demonstrate how the operations will be seismically safe.

GR-3.9

Require geothermal resource developers to provide roadway access to operations from public thoroughfares via new or existing roads, requiring any new roads to be built and maintained in conformance with County standards. Encourage the use of existing roads ~~and trails~~ for geothermal projects whenever feasible.

GR-3.10

Require developers to implement and maintain erosion control and soil stabilization techniques throughout the life of geothermal development projects, including post-construction best management practices.

GR-3.11

Require revegetation of geothermal development sites using native plant species to minimize soil erosion and restore and enhance habitat.

GR-3.12

Support next-generation and closed-loop geothermal technologies that reduce noise, groundwater consumption, and surface disturbance compared to conventional geothermal operations, particularly on sites containing legacy or abandoned geothermal wells.

Action

GR-3.a

Conduct annual monitoring inspections of permitted geothermal power generation facilities. As a part of annual monitoring, require geothermal operators to submit reports summarizing information related to operations, power generation, seismic activity, and similar data and demonstrating compliance with all use permit conditions of approval, environmental mitigations, and State regulations.

GR-3.b

Collaborate with Tribal governments to develop recommendations for minimizing soil erosion and supporting habitat enhancement using Tribal Ecological Knowledge practices.

Goal GR-4	Geothermal resource development and operations that support healthy and safe communities and a high quality of life in Lake County.

Policies

GR-4.1

Prohibit new geothermal operations near residences, commercial resorts, ground and surface water resources like Clear Lake, environmental clean-up sites like the Sulphur Bank Mine Superfund Site, and~~or~~ other sensitive receptors unless sufficient measures to mitigate impacts are incorporated into the project design, as determined by the County. Discourage development of sensitive receptors in the primary geothermal resource areas (shown in **Figure GR-1**), where there is reasonable likelihood of future geothermal development.

GR-4.2

Require information on geothermal resources and related activities to be included in real property sale disclosures in the unincorporated county, including:

- Information on health risks associated with the county's geothermal resources and a map of areas at highest risk of exposure to geothermal gases (to be prepared under **Action GR-4.b**), and
- A map with accompanying information on primary steam-dominated geothermal resource areas (shown in **Figure GR-1**), direct-use areas, and new technology areas where there is reasonable likelihood of future geothermal development.

GR-4.3

Require a preventative noise abatement program incorporating best-available control technology design features for construction, operation, and maintenance of geothermal facilities.

GR-4.4

Require ongoing monitoring of geothermal noise sources over the life of geothermal projects.

GR-4.5

Require installation of sufficiently detailed signs at all geothermal project sites to facilitate emergency response and warn the public of potential hazards.

GR-4.6

Require geothermal resource developers to prepare and maintain emergency plans for hazardous incidents, including, but not limited to, blow-outs, fluid spills, earthquakes, fires, and worker accidents. Emergency plans must be consistent with the policies and procedures of responsible public safety agencies and ensure cooperation between industry security, medical and firefighting personnel, and corresponding public safety agencies.

GR-4.7

Require geothermal resource developers to establish protocols for the issuance of timely public notifications during air pollution emergency events.

~~GR-4.7~~GR-4.8

Require geothermal operations to minimize the generation of hazardous waste and materials from geothermal activities and ensure the safe handling and disposal of any hazardous materials or waste generated.

~~GR-4.8~~GR-4.9

Require geothermal operations to use appropriate technologies and practices to minimize the impacts of induced seismicity on sensitive receptors.

~~GR-4.9~~GR-4.10

Require geothermal operators to monitor and analyze seismic data to determine the effects of geothermal production and injection on seismic activities associated with the development.

~~GR-4.10~~GR-4.11

Ensure geothermal facilities are consistent with the geothermal setback requirements in Article 27 of the Zoning Ordinance and sited to minimize visual impacts by:

- Avoiding interference with scenic views and ensuring that facilities are visually integrated with the surrounding setting to the greatest extent possible.
- Minimizing view obstructions of ridgelines or other visually prominent features to the extent feasible.
- Using non-glare towers and non-specular lines, which more readily blend into the natural landscape.
- Reconstructing or consolidating existing transmission facilities and corridors to accommodate additional line capacity in an environmentally sound manner.

GR-4.12

Require geothermal resource developers to evaluate cumulative impacts of the project in combination with all other known geothermal projects in the region. Evaluations must include an assessment of the effects of induced seismicity from geothermal operations and appropriate mitigation measures.

GR-4.13

Explore and develop community benefit agreements with geothermal resource operators, where appropriate, to maximize the benefits of geothermal resource activities to local residents.

~~GR-4.11~~GR-4.14

To offset the cumulative effects of geothermal development on tourism and recreation, seek community benefits agreements negotiated with geothermal project applicants to enhance tourism and recreation in the area.

Actions

GR-4.a

Maintain up-to-date maps on the County's website and in the database developed per **Action GR-2.a** of the primary geothermal resource areas (shown in **Figure GR-1**), where there is reasonable likelihood of future geothermal development.

GR-4.b

Assess and map areas with the greatest exposure to potential risks associated with geothermal resources, share the map with the community, and use it to inform engagement efforts to minimize risks.

GR-4.c

Periodically administer messaging campaigns to notify the community of potential risks associated with the county's geothermal resources and options to minimize those risks. The messaging campaign should consider a variety of strategies, such as utility bill inserts and social media messaging, and prioritize reaching those situated in areas at greatest risk of exposure.

~~**GR-4.d**~~

~~Evaluate the need to comprehensively assess the effects of induced seismicity from geothermal operations and develop mitigation recommendations. As part of this evaluation, consider available data from the U.S. Geological Survey.~~

Goal GR-5	Geothermal resource development and operations that protect water quality and supply.

Policies

GR-5.1

Ensure that future geothermal projects do not adversely impact groundwater or surface water quality or diminish supply needed for domestic, Tribal beneficial, and agricultural uses and seek opportunities to minimize adverse impacts of any existing geothermal operations.

GR-5.2

When reviewing applications for geothermal development permits, require the development and application of technologies that use less water.

GR-5.3

Require an analysis of the geothermal industry's current and future water needs prior to initiation of an expanded reservoir injection program involving the increased use of surface or groundwater.

GR-5.4

Require geothermal operations to use best-available control technologies to prevent and rapidly detect water pollution.

GR-5.5

Require applicants for new geothermal extraction facilities to assess potential impacts to shared agricultural groundwater aquifers.

Action

GR-5.a

Coordinate with the geothermal industry and other interested agencies to determine long-term water needs for proper geothermal reservoir maintenance.

Goal GR-6	Geothermal resource development and operations that protect air quality.

Policies

GR-6.1

Encourage geothermal resource activities to avoid or otherwise minimize and mitigate ground disturbance of areas with naturally occurring asbestos.

GR-6.2

Encourage geothermal operators to monitor air quality to ensure the rapid detection of air pollution events.

GR-6.3

Require geothermal operations to use the best-available air pollution control technology in all operations where feasible or otherwise required to be consistent with the requirements of the Lake County Air Quality Management District. Ensure operations minimize emissions, avoid vegetation damage and increased fog or haze conditions, prevent nuisance odors, and control dust.

GR-6.4

When feasible, require steam fields and power plants to be intertied and equipped with automated supervisory control systems or other design measures to minimize air emissions during forced or scheduled outage, startup, or curtailment events and require all automated systems to default to closed during power or communications outages.

GR-6.5

Encourage the retrofitting of older geothermal power plants with best-available air pollution control technology and other technologies that can reduce overall environmental impacts.