APPENDIX Z

DEIS AND DRAFT SUPPLEMENTAL EIS PUBLIC COMMENTS AND RESPONSE MATRICES

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APPENDIX Z – DEIS AND DRAFT SUPPLEMENTAL EIS PUBLIC COMMENTS AND RESPONSE MATRICES

Z1.0 INTRODUCTION

Public comments and responses to comments on the Draft Environmental Impact Statement (DEIS) and the Draft Supplemental Environmental Impact Statement (DSEIS) and Plan Amendment (PA) are presented in this appendix as discussed in Section 5.6 of this Final Supplemental Environmental Impact Statement (FSEIS)/PA.

Z2.0 RESPONSE TO COMMENTS

Z2.1 Common Responses

Many of the comments received on the DEIS/PA and DSEIS/PA discussed the same issues or environmental concerns. Rather than repeat responses, Common Responses are provided here:

Z2.1.1 Common Response #1 - Subsequent National Environmental Policy Act Environmental Review

Commenters and Comments Addressed

Commenter	Comments
A-California Unions for Reliable Energy	A-1, A-2
E-County of Inyo-Board of Supervisors	E-3
J-Environmental Protection Agency	J-2
K-Rose Valley Properties, LLC	K-1, K-12, K-16, K-17
L-Little Lake Ranch	L-1, L-5, L-6, L-7, L-17, L-23, L-25, L-26, L-27
AA-County of Inyo Board of Supervisors	AA-2
BB- Lahontan Regional Water Quality Control Board	BB-1, BB-2, BB-3, BB-4
CC-Environmental Protection Agency	CC-4, CC-5, CC-7, CC-8, CC-9, CC-10
DD-Big Pine Paiute Tribe	DD-1, DD-4, DD-5
EE- Consolidated NGO Comments- Amargosa Conservancy, et al.	EE-3, EE-4, EE-5, EE-6, EE-7, EE-12, EE-13, EE-14
FF- Center for Biological Diversity	FF-3, FF-5, FF-6, FF-11, FF-12
GG – Basin and Range Watch	GG-4

Summary of Issues Raised

1. Comments were received that questioned the adequacy of impacts created as a result of geothermal project exploration and development as described in the DEIS/PA or DSEIS/PA and that environmental impacts would not be detailed enough or adequately assessed to evaluate for approval of future development proposals.

2. Comments were received that suggested the DEIS/PA or DSEIS/PA did not take a “hard look” at impacts, or did not account for project specific impacts and suggested specific mitigation or monitoring should be applied.

3. Comments noted the lack of site-specific impacts because the Reasonably Foreseeable Development (RFD) scenario was used to assess potential impacts.

Response

The National Environmental Policy Act (NEPA) of 1969 (implemented by regulations in Title 40 Code of Federal Regulations [CFR] Part 1500-1508) establishes a framework for federal decision-making and ensures that agencies (Bureau of Land Management [BLM] and all other federal agencies) take environmental factors into account when considering actions and making decisions. It requires the federal agencies to follow a particular process in making decisions and to disclose the information and analysis used to support those decisions. Decisions may be made to assess the impacts of a specific project proposal, or may be related to the implementation or change of land use policies (e.g., regarding public lands planning and management by the BLM).

As stated in this FSEIS/PA (Section 1.3), the alternatives address decisions regarding whether or not to amend the California Desert Conservation Area (CDCA) Plan, and if so, how it should be done. The second decision is whether or not to issue one or more of the three pending geothermal leases, and under what stipulations or constraints that might be necessary to protect other resource values. The decisions to be made as a result of the analysis contained within the FSEIS/PA do not include approval of a site development plan. No site-specific project proposal has been submitted to the BLM in a Plan of Operations (POO). Section 2.2.1 of the FSEIS/PA has been revised to clarify lessee submittal requirements to potentially include applications for Geothermal Drilling Permits (GDPs) and a Plan of Development (POD). However, in order to assess the impacts of amending the CDCA and opening up the Haiwee Geothermal Lease Area (HGLA) for geothermal exploration, development, and leasing, an RFD scenario was required to model a reasonably anticipated development scenario. The RFD scenario depends upon reasonable assumptions for the levels of exploration and development that could be anticipated based on the estimated resource potential; however, without a site-specific POO/POD it is not possible to analyze site-specific impacts, nor is it necessary to provide the BLM with a baseline impact scenario for the decision making process at this planning level.

As required by 43 CFR Part 3272.12 and in addition to the POO, a Utilization Plan must also be submitted by a project proponent that includes a description of proposed measures to prevent or control fires, prevent soil erosion, protect surface and groundwater, protect fish and wildlife, minimize noise and air pollution, minimize hazards to public health and safety during normal operations, and protect cultural, visual, and other natural resources. The BLM would not authorize any specific geothermal energy development or ground disturbance based solely on the decisions supported by this FSEIS/PA. The issuance of a lease for geothermal resources as a result of this FSEIS/PA lays the groundwork for future exploration and development but does not confer the right to engage in any activities involving ground disturbance or activities that may impact the resources of the lease area. Any future geothermal project or other energy exploration and development that may be proposed within the HGLA will be evaluated under a separate NEPA analysis on a site and project-specific basis. Any subsequent site-specific geothermal exploration or development would require further environmental analysis, and depending on the potential significance of the impacts, could be conducted through an Environmental Assessment or an Environmental Impact Statement (EIS) that could incorporate by reference or be tiered to this FSEIS/PA and the BLM's Programmatic EIS for Geothermal Leasing in the Western United States (BLM 2008c).

The BLM's decision-making process for the HGLA is consistent with NEPA and other applicable statutes, regulations, plans, and policies. The RFD scenario presented in the FSEIS/PA is not a worst-case scenario, but rather is considered to be a reasonable and science-based projection that relies upon logical and technically based assumptions of the anticipated geothermal development for a defined area and period of time. The BLM will consider each proposed project on its own merits if and as they are submitted by a project proponent.

The level of analysis and the specificity of impacts in the FSEIS/PA is appropriate for the planning level decision to be made for the HGLA. Furthermore, a more specific impact analysis would not make the document more accurate, and in fact, could call into question the more specific assumptions for a development scenario. Approval of Alternatives A, B, or C as described in the DSEIS/PA would result in issuance of the three pending geothermal leases in part or in full as detailed in the alternative descriptions. BLM requires a subsequent POO be submitted by a proponent for site-specific exploration and development activities on approved lease land. At that time, site-specific NEPA and other environmental review would be conducted by the BLM to determine the specific effects of the geothermal plant type (e.g., dual-flash, binary, or air-cooled), interconnection routes and requirements, pipeline requirements, etc. The NEPA review would inform the public, the agencies, and the decision maker of those effects and of the site-specific actions that may be taken.

The BLM took a "hard look" at potential impacts of the HGLA geothermal exploration and development program alternatives appropriate for decision-making regarding land use planning and leasing. A "hard look" under NEPA consists of a reasoned analysis containing quantitative or detailed qualitative information (refer to BLM NEPA Handbook H-1790-1). A hard look considered in the EIS during any NEPA process, whether for land use plan decisions or specific project proposals, includes assumptions spelled out (e.g., RFD scenario), methodologies disclosed, inconsistencies explained, contradictory evidence rebutted, appropriate records referenced, analysis grounded in science, guesswork eliminated, and contain easily understandable and supported conclusions.

Z2.1.2 Common Response #2 – Groundwater Consumption

Commenters and Comments Addressed

Commenter	Comments
B-Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-6
F-Big Pine Paiute Tribe	F-5
H-Dept. of Navy-China Lake Naval Air Weapons Station	H-3
K-Rose Valley Properties, LLC	K-4
L-Little Lake Ranch	L-10, L-18, L-19, L-20, L-31
O-Center for Biological Diversity	O-1
FF-Center for Biological Diversity	FF-1, FF-4
GG-Basin and Range Watch	GG-2

Summary of Issues Raised

1. Comments were related to the effects on groundwater resources should the BLM decide in this action to lease lands for geothermal exploration and development within the HGLA.

2. Comments related to water resource utilization, protection, monitoring, alternative sources of water, and analysis of the water budget (i.e., Safe Yield).

Response

The FSEIS/PA includes groundwater level triggers (i.e., standards) and other mitigation measures to protect groundwater resources. In addition, lease terms will include a protective groundwater resources stipulation, SA-HGLA-10, that is intended to prevent impacts to groundwater supplies. The potential for reduction or drawdown of groundwater levels, should such impacts occur, is a definitive impact that can be measured and monitored with more precision than estimates involving groundwater recharge and water budget estimates. As stated in Section 2.4.1 of the FSEIS/PA, stipulations would be in place to curtail pumping if specific groundwater trigger levels are reached. This same protective threshold, and all stipulations provided in Appendix K of the FSEIS/PA, is included in all of the action alternatives that would authorize leases (Alternatives A, B and C).

As stated in Common Response #1, other specific mitigation and protection measures would be reviewed during the NEPA process required for any site-specific plan submitted by a project proponent in the future. The BLM is relying upon groundwater level triggers established under the Hydrologic Monitoring and Mitigation Plan and Conditional Use Permit #2007-003/Coso Operating Company, LLC, which was permitted in May 2009. If a POO is approved through a subsequent NEPA environmental review and SA-HGLA-10 (d), groundwater pumping within the HGLA may also be approved subject to the groundwater level triggers at Little Lake. However, if the monitoring shows the groundwater level triggers are exceeded at any time, all groundwater pumping for geothermal activity would be terminated within the HGLA. These trigger levels, along with the specific mitigation and monitoring measures developed by the BLM during subsequent NEPA and other environmental review would be implemented for a specific POO and would ensure groundwater resources are adequately protected. See Chapter 2 (Section 2.4.1) of the FSEIS/PA regarding consumptive water use stipulations (SA-HGLA-10) has been revised (see below).

An explanation of what factors make up a 10% drop (or more) to the average annual flow of water flowing into the surface features at Little Lake was included in the DEIS/PA on page 4-45. For example, the maximum groundwater table drawdown at the north end of the Little Lake Ranch property (at the Little Lake Ranch North well) is to be limited to less than 0.4 feet from current levels. These groundwater level thresholds were also adopted for the impact analysis in the DEIS/PA and DSEIS/PA. Although any and all studies submitted by commenters will be duly considered by the BLM, further study of groundwater, geothermal, or other resources is not necessary to satisfy NEPA requirements or provide informed decision making at the planning level.

As stated in Appendix K of the FSEIS/PA, a specific project proposal, if approved, would require a detailed Water Monitoring, Management, and Mitigation Plan that must be prepared prior to the development or use of any water resources within the HGLA. The plan would address mitigation measures that would be required to mitigate project impacts and would describe the management and use of all project-related water resources, including monitoring of the quality and quantity of all surface water and groundwater used for the project. In conjunction with the drawdown triggers implemented as part of stipulation SA-HGLA-10, groundwater resources would be adequately monitored and protected.

Page 2-12 of the DEIS states, "(g)roundwater extraction for consumptive use during exploration, development, and project operations activities may be allowed for some leasing applications, to the extent that groundwater use, in combination with all other authorized groundwater uses, does not exceed the safe yield or recharge rate to the Rose Valley Aquifer, and does not cause a decline of 10% or more to the average annual fluctuation of water flowing into the surface features at Little Lake, when combined with all other uses that have been approved within the Rose Valley." Stipulation SA-HGLA-10 contained in Appendix K of the FSEIS/PA has been changed from the 2012 DEIS to clarify that groundwater extraction for consumptive use during geothermal exploration and development activities may be allowed for some leases to the extent that groundwater extraction and water loss to the Rose Valley Aquifer, in combination with all other authorized groundwater uses, does not exceed the safe yield for the Rose Valley Aquifer, and does not cause a decline of 10 percent or more to the *average annual flow of water flowing into the surface features* at Little Lake, when combined with all other approved uses.

The Safe Yield, as defined in Appendix K, SA-HGLA-10(g) of the FSEIS/PA, includes all inflows and outflows, and is expressed in *acre-feet per year*. Any and all groundwater outflow, including Coso's Hay Ranch, is considered in the Safe Yield formula, whether it is from subsurface fracturing occurring from a seismic event, withdrawal from unrelated wells or projects, or other outflows. Minor short-term extractions or more significant withdrawals for geothermal exploration and development are not expected to cause serious water decline rates. Further, any decreases will be measured and monitored.

It is not a requirement of NEPA that the analysis consider the protection of any specific resource (such as groundwater) as an alternative that must be carried forward for analysis in the FSEIS/PA; BLM's mission requires protection of all resource values under its multiple use, sustained yield mandate. This is especially true when considering amendment of a land use plan, since Resource Management Plans are fundamental to the FLPMA, the BLM's organic Act. All BLM authorizations must be provided for and consistent with the terms, conditions, and decisions of the land use plan that is ultimately approved. Therefore, each of the alternatives would include consideration of sustaining groundwater resources, among other resource values and uses. As required by 40 CFR Part 1502.14, the EIS must examine all reasonable alternatives to the Proposed Action that addresses the purpose and need of the action. As stated in Chapter 1, the purpose of the Proposed Action (Section 1.3) is to consider the role and use of geothermal energy with regard to: (1) developing clean renewable energy; (2) meeting the increasing energy demands of the nation; (3) reducing reliance on foreign energy imports; (4) reducing greenhouse gas emissions; and (5) improving national security. The purpose of the action also includes responding to the increasing interest in geothermal leasing opportunities on federal land by addressing three pending geothermal lease applications and by "pre-screening" land in the HGLA for its suitability for this kind of development through the planning process. The need for the Proposed Action is to allocate specific lands in the HGLA as closed, open, or open with constraints to geothermal leasing, and for making a leasing decision for each of the three current non-competitive lease applications pending to grant, deny, or grant a lease with modifications.

In determining the scope of alternatives to be considered that addresses the purpose and need, the emphasis is on what is "reasonable" rather than on whether the BLM is capable of carrying out a particular alternative, or whether an action alternative protects a specific resource. Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense. A reasonable range of alternatives was developed and analyzed in the DEIS/PA and revised for the DSEIS/PA based on the land allocations established in the Desert Renewable Energy Conservation Plan (DRECP) Land Use Plan Amendment (LUPA). Commenters requested that an alternative be developed to address maximum conservation of groundwater and other environmental resources. Alternative D effectively addresses a maximum conservation of groundwater and other environmental resources alternative (on BLM-administered land) by closing the entire HGLA to geothermal exploration, development, and leasing outside of the Development Focus Area (DFA). Without modifying the purpose and need for the Proposed Action or introducing goals and objectives to implement additional groundwater protection measures or development restrictions, Alternative D represents the action alternative emphasizing "maximum protection of groundwater resources" by not allowing any (geothermal) development in areas that are not already authorized under the DRECP LUPA.

Groundwater may provide a source of water for geothermal development to be used for dust control, drilling, and evaporative losses. The identification of other sources of water, as requested by several commenters, to protect groundwater resources would be speculative because a specific POO has not been received by the BLM at this time. Subsequent NEPA and other environmental review would be done to analyze specific impacts and mitigation of groundwater resources. The potential acquisition of other water from alternative sources would be the responsibility of, and an operational and financial decision made by, a project proponent and would be proposed in a POO. At the planning and leasing stages, it is not reasonable, nor informative, to speculate that water may be piped, trucked or otherwise transported to the site for use during the construction, operations, and maintenance of exploration or generating facilities, but the viability and feasibility of any specific source procurement would be dependent on the scale, location, functional requirements, and other factors related to a specific plan.

Z2.1.3 Common Response #3 – Adequacy of Studies/Technologies Proposed

Commenters and Comments Addressed

Commenter	Comments
B-Defenders of Wildlife/Sierra Club/Kerncrest Audubon	B-5
J-Environmental Protection Agency	J-8
L-Little Lake Ranch	L-3, L-8, L-14, L-22, L-28, L-29 L-30, L-32
EE - Consolidated NGO Comments - Amargosa Conservancy, et al.	EE-1, EE-11
FF - Center for Biological Diversity	FF-2, FF-9, FF-10, FF-13
GG - Basin and Range Watch	GG-1

Summary of Issues Raised

1. Comments were received that related to the adequacy and utilization of studies in the DEIS/PA OR DSEIS/PA, including the development of the RFD.

2. Comments were received that questioned why a "dry" or "air" cooling geothermal plant was not more thoroughly considered in the analysis.

Response

As stated in the FSEIS/PA (Executive Summary), the BLM considered an RFD scenario in order to assess the effects of realization of a geothermal leasing program in the HGLA. The RFD did not assume the "best case" use of water consumption for a potential project, but one that would likely be utilized and proposed given the nature of the geothermal resource in the HGLA. As stated in the FSEIS/PA (Section 2.3.1), the occurrence of very high temperature dry steam reservoirs suitable for "flash" plant designs like Coso are rare and are not anticipated to be proposed by a geothermal developer in the HGLA. The efficiency of power generation for air-cooled systems is affected by the difference between the temperature of the fluid exiting the turbine and the temperature of the cooling medium. In the case of the HGLA climate setting, high ambient temperatures would pose a problem with cooling the power plant which would reduce the overall efficiency of the plant during times of greatest regional energy production need (see Section 2.3.1.3 of the FSEIS). Such a plant would, therefore, not likely be proposed by a geothermal developer. Also, proposing a dry-cooled binary geothermal plant in the RFD would not adequately represent anticipated technology that would be used and would underestimate potential impacts on which the BLM is basing the planning decision. As noted in Common Response #1, however, should a project proponent choose to develop a geothermal plant based on a dry steam or dry cooling technology, impacts to water resources would be assessed based on the proposal and a decision on the project rendered accordingly.

The BLM considers the data collection and analyses in the FSEIS/PA to be adequate for the BLM to make a planning level decision to amend the current land use plan (CDCA, as amended). The data and analysis relied upon in the FSEIS/PA is adequate to inform the BLM's consideration of the proposed HGLA and to allow a reasoned choice among the action alternatives that satisfy the purpose and need for the action, and the No-Action Alternative. Accordingly, the additional information requested in various comments is not necessary for NEPA adequacy and, therefore, would not trigger a need to supplement the analysis.

NEPA procedures ensure that "high quality" environmental information is available before actions are taken (40 CFR Part 1500.1). A "hard look" under NEPA consists of a reasoned analysis containing quantitative or detailed qualitative information (see BLM NEPA Handbook H-1790-1 [Jan. 30, 2008]). Further, the data and analyses provided in the NEPA analysis about the affected environment should be commensurate with the importance of the impact, with less important material summarized, consolidated, or simply referenced (40 CFR Part 1502.15). The analyses relied on quantitative data where possible, detailed qualitative data under other circumstances, and studies performed by others. It is appropriate for the BLM to rely on available information if it is of high quality and sufficient to allow a reasoned analysis of particular impacts, and the BLM need not necessarily postpone its consideration of a proposal while additional data is being developed.

A complete inventory of all groundwater resources, springs, surface water features, and stream flows is not necessary for planning level decision-making and the NEPA process does not seek to prove or disprove adverse impacts created as the result of an action. Also, the environmental studies in this FSEIS are not intended to "prove" cause-and-effect relationships, but instead are meant to provide appropriate environmental analysis to inform the decision maker for designating geothermal exploration and development within the HGLA. Groundwater, geothermal, and other subsurface geologically related studies are rarely definitive due to the difficulty of acquiring direct observational data and the reliance on groundwater modeling to predict effects. The conclusions of studies are subject to interpretation by professionals, and of course, professional judgment can and does vary. The studies that were compiled and utilized during the data collection and impact analysis process are sufficient to support this informed planning level decision.

Z2.2 Individual Draft Environmental Impact Statement and Draft Supplemental Environmental Impact Statement Comments and Responses

In this section, responses are provided for each individual comment received on the DEIS/PA and DSEIS/PA. Where a comment is addressed as part of a Common Response, the individual response provided in this section refers the reader to the applicable Common Response. NEPA requires all substantive comments - whether environmental or procedural in nature - to be addressed and attached to the FSEIS/PA (40 CFR Part 1503.4(b)). All substantive comments received on the DEIS and DSEIS/PA are included in Tables Z-1 and Z-2. All original comment letters are also included at the end of this Appendix.

Individual DEIS/PA and DSEIS/PA Comments and Responses

TABLE Z-1 RESPONSE TO SUBSTANTIVE COMMENTS RECEIVED ON DEIS/PA

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
California Unions for Reliable Energy	A-1	However, we are concerned that the BLM intends to use the proposed EIS to approve future development proposals and grant exceptions to the proposed list of lease stipulations. The BLM must affirmatively require all future envelopment proposals to conduct subsequent NEPA review.	As stated in the DSEIS/PA, all future specific project proposals will require a separate NEPA environmental review on a specific POO. The BLM is required to conduct an environmental review to support planning decisions, as well as decision-making regarding specific proposals from private or government entities. This is a programmatic EIS used to determine whether or not leasing for geothermal exploration and development would occur in the HGLA, and if so, under what conditions. The DEIS and DSEIS have evaluated the impacts of an RFD scenario because there is no specific project proposal or POO from any entity at this time. Also, see Common Response #1.
California Unions for Reliable Energy	A-2	In addition, the BLM must require that all exceptions to the proposed lease stipulations be supported with subsequent NEPA review. If the BLM grants an exception to any of these lease stipulations, it must take a "hard look" at the environmental consequences of its action.	BLM agrees that all exceptions to the proposed lease stipulations would be analyzed in subsequent NEPA and other environmental review done for a specific project POO. See Common Response #1 and Response to Comment A-1.
California Unions for Reliable Energy	A-3	We request that the BLM affirmatively require all future development proposals to prepare subsequent NEPA review before permits are granted or exceptions to lease stipulations are approved.	See Response to Comment A-1.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-1	BLM should recognize and apply the management standard for Limited Use Class lands affected by the HGLA and demonstrate which of the alternatives meet this standard. Those that do not should be identified as such in the FEIS.	The Limited Use Class as defined by the CDCA has been superseded by DRECP Land Use Allocations: Development Focus Area (DFA), Area of Critical Environment Concern (ACEC), and Special Recreation Management Area (SRMA) within the HGLA. Each of these land use allocations have been discussed in Section 3.11.1.1 of the DSEIS/PA.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-2	BLM should analyze each of the alternatives to determine whether or not they are consistent with the purposes of the Mohave Ground Squirrel WHMA. Those that do not should be identified as such in the FEIS.	The HGLA leasing program, if approved, would be done consistently with the Mohave Ground Squirrel WHMA under all Alternatives detailed in the DSEIS. The amount of ground disturbance within the WHMA is tracked by BLM so that compliance with the agreement is maintained and will be maintained under all Alternatives.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-3	BLM should analyze each of the alternatives and determine whether or not they are consistent with the management goals and objectives of the Rose Valley Habitat Management Area. Those that do not should be identified as such in the FEIS.	BLM has analyzed the consistency with the Rose Valley Habitat Management Area Plan. Alternative B (Preferred Alternative) and Alternative C in the DSEIS would best meet the goals of the Rose Valley Habitat Management Area Plan. Alternative A would be inconsistent if sensitive areas were disturbed during exploration and development, but even under this scenario the BLM would enforce environmental laws and existing permit stipulations.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-4	The management requirements of the Mohave Ground Squirrel WHMA include not only a one-percent cap on habitat loss requirement, but a compensatory habitat loss requirement. The latter provision is absent from the description of the existing regulatory environment. BLM should account for the amount of habitat loss on public lands that has occurred from 2006 and identify how much more habitat could be lost while complying with the one-percent loss threshold.	The amount of ground disturbance within the WHMA is tracked by BLM so that compliance with the agreement is maintained. None of these provisions affect the leasing program being considered in this action or with the decision on leasing within the HGLA, which is the subject of this NEPA environmental review.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-5	In April of 1980, BLM published the "Field Ecology Technical Report on the Coso Geothermal Study Area" which was prepared under BLM contract with Rockwell International. Philip Leitner was the lead investigator and author of this report. His field studies included systematic live trapping and opportunistic sightings of the Mohave Ground Squirrel in the Coso Geothermal Study Area, some of which occurred within and adjacent to the proposed HGLA. BLM should obtain this document and include the occurrence data for this species within the Proposed HGLA in the FEIS.	While this data is still considered relevant after 30 years, including the occurrence data from this report would not change the adequacy or accuracy of the DEIS (or DSEIS), and would not affect the decision-making process by the BLM for geothermal leasing within the HGLA. See Common Response #3.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-6	Existing levels of groundwater consumption in Rose Valley are already projected to cause significant adverse impact to the wetland environment at Little Lake. The FEIS should account for this in the analysis of existing and cumulative impacts associated with groundwater consumption.	The BLM will continue to monitor the important groundwater levels using the groundwater trigger levels and manage this aspect with actual groundwater levels. The use of groundwater level triggers is a definitive way to track impacts that can be measured and monitored. Also, see Common Response #2.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-7	Lacking is an accounting of specific direct and indirect impacts of land uses in terms of acres of habitat lost and direct impacts to key species of concern such as the Desert Tortoise arid Mohave Ground Squirrel. BLM should provide a much more definitive cumulative impact analysis for the affected region that focuses on the Rose Valley extending from Little Lake to Haiwee Reservoir and from the Coso Geothermal field to the base of the Sierra Nevada. We consider it especially important that this analysis account for public land habitat impacts and loss authorized by BLM since the West Mojave Plan amendments were signed in 2006 establishing the Mohave Ground Squirrel WHMA, as well as those occurring on public lands within the Rose Valley Habitat Management Plan Area since the CDCA Plan was signed in 1980. It is especially important to include habitat loss associated with all of the geothermal support facilities located near Coso Junction and the water pipeline for the Hay Ranch Water Extraction and Water Delivery Project approved by the BLM in 2009. Impacts to habitat linkages through the Rose Valley area should be addressed in the FEIS.	See Response to Comment A-1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-8	Please expand on the nature and effectiveness of “no surface occupancy” and “closed to geothermal leasing” in the FEIS. Please explain if one is superior in providing protection of sensitive resources or if they would accomplish the same goal. Also please indicate if each would prevent further loss and fragmentation of habitat due to support facilities such as access roads, pipelines and electrical transmission lines.	NSO means that the no use or disturbance is permitted on the surface of the NSO lands; thus, geothermal or support facilities, including pipelines, roads, and transmission would not occur in a geographical area designated as NSO and surface resources would be undisturbed. However, the subsurface mineral estate can still be leased, allowing the geothermal reservoir underlying the NSO lands to be accessed and developed from lands outside the NSO area. The NSO stipulation would be used for controlling development that conflicts with activities, uses, or values in a given area. Minor surface disturbance may be allowed that enhances or protects resources or provides some other goal (such as accommodation for public interpretation, trail construction for viewing, etc.) so long as it does not negatively affect the resource. The availability of an area to geothermal leasing is a broader term that does not provide provisions for protection of specific resources, but applies a planning designation (“available”, “suitable”) relative to a specific (geothermal) resource extraction in a geographical area.
Defenders of Wildlife/Sierra Club/Kerncrest Audubon Society	B-9	Alternatives C and D do not provide protection for Mohave Ground Squirrel habitat linkages through the larger, well vegetated canyons that connect Rose Valley with Cactus Flat and McCloud Flat. These additional linkages should be identified and included in a revised description of Alternatives C and D.	As proposals for development are submitted to the BLM and specific NEPA analysis is conducted for these specific proposals, BLM will evaluate important Mohave Ground Squirrel linkages.
County of Inyo-Board of Supervisors	E-1	In Section 1.5.13 (pg. 1-18) Inyo County Water Policy is addressed. In addition to this, Inyo County Code, Chapter 18.77: Regulation of Water Transfers Undertaken Pursuant to Water Code Section 1810, Sales of Surface Water or Groundwater by the City of Los Angeles, and the Transfer or Transport of Water from Groundwater Basins Located in Whole or in Part Within, needs to be included.	Thank you for providing this reference. This was included in the DSEIS and is included in the FSEIS in Section 3.6.1.
County of Inyo-Board of Supervisors	E-2	In Section 3.6.1 (pg. 3-30) General Plan policies WR-1, WR-2 and WR-3 are described, in addition to these Inyo County Code, Chapter 18.77: Regulation of Water Transfers Undertaken Pursuant to Water Code Section 1810, Sales of Surface Water or Groundwater by the City of Los Angeles, and the Transfer or Transport of Water from Groundwater Basins Located in Whole or in Part Within, needs to be included.	Thank you for providing this reference. This was included in the DSEIS and is included in the FSEIS in Section 3.6.1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
County of Inyo-Board of Supervisors	E-3	Section 3.18.2 (pg. 3-123) states that due to the rural setting and a lack of a diverse system of roads . . . the scope of the analysis limited to US 395 and SR 190, we disagree with the lack of analysis of local roads. Please include an analysis of County roads that may be impacted, especially Coso-Gill Station road that is mentioned in 3.18.2. This analysis needs to include any road improvements that may be necessary due to exploration and development of geothermal resources in the area.	See Common Response #1.
County of Inyo-Board of Supervisors	E-4	However, in Chapter 4, Environmental Consequences: Impacts to Public Services, on page 4-157 it states that given the very low population impacts described for the HGLA, correspondingly low impacts on public services can be expected. We would like to point out that with low population, impacts will be felt more greatly than if they are experienced in in a densely populated area. More specifically, since Inyo County does have a low population, its public service supplies are not well equipped for increases, however small they may seem. We would like to see this issue better addressed.	The DSEIS included language to account for your comment which is also reflected in Section 4.19.1.3 of the FSEIS/PA.
County of Inyo-Board of Supervisors	E-5	In Chapter 4, Environmental Consequences: Impacts to Public Revenues, page 4-158, in light of the uncertainties that have been discussed with regard to geothermal lease payments, which leads to the questionable ability of geothermal energy projects paying for themselves, how will the additional costs to Inyo County for services, including but not limited to police, fire, water and sanitary services, be mitigated?	Section 4.19.1.4 of the FSEIS and DSEIS has been updated to include a discussion on revenues generated by sales taxes, property taxes, hotel occupancy taxes that would mitigate costs to the County.
Big Pine Paiute Tribe	F-1	The Tribe recommends Alternative B for this Project: Close the entire HGLA to geothermal exploration, development and leasing; amend the CDCA Plan to have HGLA closed and unavailable for geothermal exploration, development and leasing; deny authorization of all pending leases within the HGLA.	Under current management, the CDCA as amended by the DRECP LUPA allows for geothermal development within DFAs. No alternative, as detailed in the DSEIS, is currently being considered by the BLM that amends the CDCA (as amended by the DRECP LUPA) to close DFAs to geothermal development, as the DEIS Alternative B proposed.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Big Pine Paiute Tribe	F-2	The ethnographic landscape for the HGLA should be analyzed in a “Native American Issues and Concerns” section of the EIS. The DEIS does not contain such a section which is usually included in EISs for projects in the Great Basin. There is a “Government-to-Government Consultation with Indian Tribes” section, but this contains no analysis and is no substitute for an in-depth “Native American Issues and Concerns” section. In addition, the “Government-to-Government Consultation with Indian Tribes” section provides incomplete information which should be corrected in the Final EIS. Bill Helmer, Tribal Historic Preservation Officer for the Big Pine Paiute Tribe, attended the field trip to the HGLA on July 21, 2011, but is not listed in the DEIS.	An updated “Summary of Government-to-Government Tribal Consultation” was included Section 5.4.2 of the DSEIS and is included in Section 5.4.2 of the FSEIS. Ethnographic concerns were updated for the DSEIS and in the FSEIS in Section 5.4.1. No specific sites have been identified within the HGLA in the ethnographic literature or through tribal consultation.
Big Pine Paiute Tribe	F-3	The DEIS states on p. 5-9: “In the discussions noted above [two field trips to the HGLA with tribal representatives], no specific TCPs, archaeological sites, locations of important historic events, sacred sites, sources of raw material used to make tools or sacred objects, or traditional hunting and gathering areas have been identified within the HGLA. In contrast, the idea that the entire landscape is sacred, was expressed. Additionally, no specific sites have been identified as eligible for listing in the NRHP.” However, Mr. Helmer expressed the need for an ethnographic or cultural landscape analysis for the area slated for geothermal development.	Refer to Response F-2.
Big Pine Paiute Tribe	F-4	Finally, on p. 5-8, it is stated: “Native American Tribes participating in the Scoping Process requested an opportunity for additional involvement, particularly through the Section 106 consultation process (see Section 5.3.8),” although there is no “Section 5.3.8.”	The reference to Section 5.3.8 has been removed from the EIS. Section 4.0 of Appendix H in the FSEIS/PA includes discussion of Native American Tribal involvement requests.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Big Pine Paiute Tribe	F-5	The DEIS acknowledges awareness of regional water concerns and examines some existing conditions in the Rose Valley area including current groundwater pumping and its potential adverse effects. In spite of this, the DEIS recommends an alternative allowing HGLA exploration, and potential leasing and development. It is not clear what is meant by this statement made for the preferred and other alternatives, "groundwater extraction for consumptive use would be prohibited." Geothermal energy inevitably removes and through evaporation "consumes" water from the earth. The Tribe's analysis pf the Coso Hay Ranch project shows large projects involving water are inappropriate in the Rose Valley region.	The impacts of specific exploration, development, or operation would be the subject of further and separate NEPA environmental review at the time that specific proposals are made by specific project proponents. The BLM is relying upon the groundwater level triggers established under the HMMP and Conditional Use Permit #2007-003/Coso Operating Company, LLC, which was permitted in May 2009. If groundwater levels drop to established minimum levels, the terms of the stipulation would require halting all groundwater use controlled by the BLM. Also, see Common Response #2 and Response to Comment A-1.
Dept. of Navy-China Lake Naval Air Weapons Station	H-1	The Airspace above to proposed Haiwee Geothermal Leasing Area is part of a 20,000 square mile military special use airspace known as the R-2508. Part of the leasing area, adjacent to the Naval Air Weapons Station China Lake land range, lies under airspace Restricted from the ground to unlimited. The majority of the leasing area is under a Military Operations Area which has a floor of 200 feet above ground level. Geothermal development in this area is generally considered compatible with military use of the airspace, however coordination with the military may be required.	Reference to the noted airspace was added to the DSEIS and is included in Section 4.11.1 of the FSEIS.
Dept. of Navy-China Lake Naval Air Weapons Station	H-2	Text on pages 3-36 and 4-42 needs to be changed to read: The Coso Hot Springs are 1.25 miles east-northeast of the Coso geothermal field. If any connection between the hot springs and the geothermal reservoir exists, it is complex and not understood. - This information is from a complication of work/studies that have been conducted for the GPO regarding the Coso Hot Springs.	BLM agrees with the word changes you suggest, and these changes were reflected in the DSEIS/PA and is included in Section 3.6.1of the FSEIS/PA.
Dept. of Navy-China Lake Naval Air Weapons Station	H-3	Text on p. 3-48, Current Ground Water: Our concern is how will the water usage of the proposed geothermal projects be monitored in order to differentiate between impacts from the Hay Ranch Water Extraction project and this project. We do not want Hay Ranch Water Extraction project monitoring wells to be triggered by water production from this project.	Coso's Hay Ranch water extraction is not expected to trigger critical thresholds during this term of pumping. BLM cannot determine specifically how any project would be configured beyond some reasonable assumptions, such as what was done for the RFD scenario. Also, see Common Response #2.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Dept. of Navy-China Lake Naval Air Weapons Station	H-4	Text on p. 4-185, Section 4.23 Residual Impacts: The bullet point that reads: "Potential short-term and local impacts to ground water" Needs to read: "Potential short-term and long-term, and local impacts to ground water." Other sections have both short-term and long-term stated, but this bullet does not.	BLM agrees with the word changes you suggest, as follows: *"If geothermal leases were developed and issued following thorough NEPA analysis, evaluation of alternatives, and meeting the appropriate requirements, the following general residual impacts could be expected under BLM's Haiwee RDF scenario:* • *Potential short-term and long-term, and local impacts to ground water;"*
Los Angeles Department of Power and Water	I-1	LADWP respectfully requests cooperation from the Bureau of Land Management in ensuring that this general process to protect LADWP's infrastructure is met.	BLM will coordinate with LADWP to participate in the subsequent NEPA environmental reviews that are expected to occur when and if a project proponent makes a specific proposal and Plan of Operation.
Los Angeles Department of Power and Water	I-2	Any permitting for additional future pumping from Rose Valley should take into account current and already planned pumping from Rose Valley. Future exploratory drilling activities should take all necessary precautionary measures, along with extensive monitoring activities, to ensure that quality of the water in the aquifers of Rose Valley is not impacted.	BLM intends to work with Inyo County and other entities to monitor groundwater levels, including the groundwater trigger levels that would cease groundwater pumping activities if reached. The BLM agrees that future pumping from the Rose Valley Aquifer should consider current and planned pumping activities. A full suite of best management practices (BMPs) and stipulations have been included in the DSEIS/PA and the FSEIS/PA (see Appendix A and Appendix K) to protect the groundwater quality in the Rose Valley Aquifer.
Environmental Protection Agency	J-1	The FEIS should identify the potential sources of water. We recommend that this discussion include consideration of whether it would be feasible to use sources such as wastewater for geothermal well drilling, injection and power plant operations.	As stated in the DSEIS/PA, Lease Stipulation SA-HGLA-10 has been updated in the DSEIS/PA and removes SA-HGLA-10a, 10b and 10c listed in the 2012 DEIS/PA. This is because 10a, 10b, and 10c are duplicative of the rest of the SA-HGLA-10 which requires expressed approval of the Authorized Officer for groundwater extraction for consumptive use prior to project activities. Further, stipulations developed and adopted in the Final Programmatic EIS for Geothermal Leasing in the Western United States (PEIS), October 2008, along with Standard Stipulations on Form 3200-24a, are hereby adopted for this FSEIS. Lease stipulations and procedures for the HGLA will be applied as outlined in the PEIS. Additionally, the DRECP LUPA CMA-23 also requires similar limits and studies in relation to the use of water in the area of the HGLA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Environmental Protection Agency	J-2	The FEIS should clarify that any subsequent site specific geothermal exploration or development projects would require further environmental analysis, which could be conducted through either an environmental assessment or an EIS that could tier to the subject FEIS and the BLM's Programmatic EIS for Geothermal Leasing in the Western United States (2008). The BLM should elaborate on the process that individual offices will use to determine whether an EA or EIS will be prepared for subsequent projects, and identify the mechanism, screening criteria, and/or thresholds that would be used to make these decisions. We recommend that consistent standards for determining the appropriate level of NEPA review for individual projects be identified and implemented to ensure that impacts are consistently identified, analyzed and disclosed.	The DEIS/PA and DSEIS/PA repeatedly discusses the need for site-specific NEPA review for geothermal development proposals within the HGLA (see DEIS, pages 1-2, 1-8, 2-5, 2-7, 2-8, 2-24, etc.; DSEIS, pages 8, 10, etc.). The manner of NEPA compliance is up to agency discretion. Also, see Common Response #1 and Response to Comment A-1.
Environmental Protection Agency	J-3	The FEIS should correct any inconsistencies related to consumptive groundwater use in the text of the documents and, specifically, in the Special Administrative Stipulation SA-HGLA-10. The FEIS should ensure that the BMPs that are adopted from the Renewable Energy Action Team Best Practices and Guidance Manual reflect any changes incorporated in the December 2010 version of that document.	Consumption of groundwater within the HGLA would be prohibited unless allowed by exemption under SA-HGLA-10 (as modified from the DEIS/PA and discussed on page 14 of the DSEIS/PA) through the NEPA and other environmental review that would be done on subsequent site-specific proposals and a POO. Clarification has been made with regard to the consumptive use of water in the FSEIS/PA in Sections 2.1-Introduction and 2.2-Alternatives within each alternative description.
Environmental Protection Agency	J-4	Include, in the FEIS, the most current practices that reduce the potential for raptor fatalities and injuries from power lines. These practices can be found in the "Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006", Edison Electric Institute, Avian Power Line Interaction Committee and California Energy Commission.	BLM has updated the references in Appendix X-References of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Environmental Protection Agency	J-5	The FEIS should discuss the potential impact of climate change on the effectiveness of proposed BMPs, lease stipulations and mitigation measures. The NEPA analysis for each subsequent site specific project should discuss the potential impact of climate change on that project, and incorporate mitigation measures, as appropriate. The NEPA analyses for subsequent site specific projects should also assess how the projected impacts of each individual project could be exacerbated by climate change.	BLM agrees that climate change should be addressed in each of the subsequent site-specific project environmental and other reviews under NEPA, but the addition of more information on climate change would not affect the planning decision on geothermal leasing within the HGLA.
Environmental Protection Agency	J-6	The FEIS should discuss compliance with CAA § 112(r), EPCRA §§ 303, 311, & 312 and the California Accidental Release Prevention (CalARP) program, as applicable.	BLM has added narrative on compliance with the CalARP Program was included in the DSEIS and is included in Section 4.12.1 of the FSEIS.
Environmental Protection Agency	J-7	Consider expanding the number of tribes invited for consultation to include the Battle Mountain Band Council, Big Sandy Rancheria, Bridgeport Paiute Tribe, Cold Springs Rancheria, Goshute Business Council, Duckwater Shoshone Tribe, Elko Band Council, Ely Shoshone Tribe, North Fork Rancheria, Picayune Rancheria, Santa Rosa Indian Community, South Fork Band Council, Table Mountain Rancheria, Tule River Indian Tribes, U Tu Utu Gwaitu Tribal Council and the, Wells Band. Describe, in the FEIS, the process and outcome of government-to-government consultation between the BLM and each of the tribal governments within the project area, including any issues that were raised and how those issues were addressed in relation to the proposed action and selection of a preferred alternative.	As you suggested, BLM has evaluated the list of Tribes provided for relevance to the Native American Consultation efforts for this leasing program decision and has determined that it's modification is not necessary. Tribal consultation, outcome of consultation and issues raised is part of the Section 106 process, not the NEPA process.
Environmental Protection Agency	J-8	The FEIS should clarify whether a binary cycle plant may be implemented vice dual-flash steam, and if so, the binary plant design should be carried forward in the analysis. Binary plants typically require less water use and use a low boiling point organic working fluid.	BLM developed the RFD based on what was considered at the time to be a reasonable scenario. Since the water use of a binary system is normally less, it was not used in the analysis for two reasons. BLM believes it to be a reasonable approach to include the technology with the greater impacts in the RFD scenario, on the assumption that the technology with the lesser included impacts would, thereby, be accounted for. Also, see Common Response #3.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Rose Valley Properties, LLC	K-1	Geothermal lease suitability comes from geological hydrological studies conducted in the leasing area. It is not clear as to how the determination from this document will classify the pending lease applications suitable for geothermal development.	The three pending leases would be approved if Alternatives A or B as defined in the DSEIS are selected in the ROD. Under Alternative B partial approval of pending lease applications outside of ACEC/NCL and within DFA land use allocations would occur. It would be up to the proponent to then complete a POO that would specifically describe the activities being proposed during exploration and development. A site-specific NEPA environmental review would be performed specifically for that POO. Also, see Common Response #1.
Rose Valley Properties, LLC	K-2	Alternative A: This document uses the phrase that “maybe water will be allowed for some leasing applications” geothermal projects. All geothermal projects require water for exploration, construction and operation. The language should say “will need water" instead of “maybe allowed".	BLM could allow consumptive water use under stipulation SA-HGLA-10 (as modified in the DSEIS) following the subsequent NEPA and other environmental review on a proponent’s site-specific proposal in a Plan of Operations. Chapter 2 of the DSEIS/PA and FSEIS/PA regarding has been revised with regards to consumptive water use stipulations (SA-HGLA-10) and the alternatives discussed.
Rose Valley Properties, LLC	K-3	Soils: long term, there would be storm water runoff. A stipulation should be made that pads need to be constructed with a slope to the sump to prevent erosion.	A Stormwater Pollution Prevention Plan (SWPPP) would be required for any subsequent site-specific actions by a project proponent following environmental review under the NEPA. This is detailed in Section 4.5.2.1 of the DEIS/PA and Section 4.6.2 of the DSEIS/PA and FSEIS/PA.
Rose Valley Properties, LLC	K-4	Water Resources: How will water use be monitored? Will water use rely solely on produced water after the wells have been drilled?	Water use would be permitted through and coordinated with the Inyo County process. Monitoring will occur using existing monitoring wells and data reviewed on a regular basis. The BLM intends to use groundwater trigger levels to manage the water use and levels to maintain what are agreed by BLM to be the maximum allowable change. Also, see Common Response #2.
Rose Valley Properties, LLC	K-5	Public Health and Safety; H_2S is a safety concern in geothermal use in this area. A plan for H_2S monitoring should be included with the possibility for the use of H_2S abatement or control.	If these compounds are found to be involved in the resource and are determined to be a public safety concern, the BLM would evaluate these impacts in subsequent site-specific NEPA environmental review, including possible controls and mitigation.
Rose Valley Properties, LLC	K-6	The document needs to include specifics per the Geothermal Resource Operational Orders (GROs) to well spacing and well pad size for proper impacts to the environment. There needs to be a discussion on the waste generated from drilling such as drilling muds and cuttings. Drilling will result in the use of water and in the emission of pollutants that are not accounted for in this document.	Refer to page 2-49 and 2-50 of the DEIS/PA for treatment of drilling mud from exploration activities. Specific drilling and emission impacts will be analyzed further in the site-specific NEPA and other environmental review that would be done if and when a proponent submits a POO.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Rose Valley Properties, LLC	K-7	Depending on the size of the pipeline, the could be significant amount of permanent surface disturbance to state protected Mohave ground squirrel and federal protected desert tortoise habitat from the installation of the pipeline. The EIS isn't very clear on if the pipeline would be buried along the roads or will be installed on the surface. There isn't any consideration for disturbed surface of expansion loops. Also, there should be some discussion due to the many transmission lines in the area that the pipeline will need to meet the electrical requirements for electrical potential corrosion.	See Response to Comment A-1.
Rose Valley Properties, LLC	K-8	Please include number of days for deep well drilling as anticipated.	The estimates provided on page 2-10 of the DEIS/PA (between 90-150 days) are included with the RFD scenario for the HGLA (Appendix B).
Rose Valley Properties, LLC	K-9	The document needs to consider the evacuation of power from the site via substation interconnects and transmission lines. Are the leases contemplated adequate for the evacuation of power from the site? The surface disturbance of the inter-connects and transmission lines must be included in the impact analyses.	See Response to Comment A-1.
Rose Valley Properties, LLC	K-10	Geothermal Technologies: The probability of hydro-fracturing at the proposed depth of the wells in the HGLA should be mentioned and subsequent: impacts discussed.	The process of hydraulic fracturing, or hydrofracking, is described on page 2-51 of the DEIS (and referenced by the DSEIS/PA), and this description describes the issues and risks.
Rose Valley Properties, LLC	K-11	What is Inyo County's "Safe Yield"?	Refer to item (g) on page 2-43 of the DEIS/PA for a definition of safe yield.
Rose Valley Properties, LLC	K-12	The impact analysis requires the impacts of all released pollutants through dispersion modeling. There is no consideration of the drift or the mention of air analyses studies.	See Common Response #1 and Response to Comment A-1.
Rose Valley Properties, LLC	K-13	The EIS does not address long-term water of plant operational impacts on existing water supply.	See Response to Comment A-1.
Rose Valley Properties, LLC	K-14	There needs to be a discussion on the use of BMPs for drilling wastes that are generated.	Section A.3.11, BMP #13 of Appendix A in the DSEIS/PA and FSEIS/PA discusses control of drilling waste.

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Rose Valley Properties, LLC	K-15	Stipulations are required for the mitigation of dust generated during construction and then ongoing for the entirety of the project.	Dust control methods are described in the BMP, mitigation measures, and stipulations provided in Section A.3.1, Appendix A and Stipulation TL-HGLA-1 (k), Appendix K of the DSEIS/PA and FSEIS/PA.
Rose Valley Properties, LLC	K-16	Please provide potential impacts and mitigation steps for private and public landholders who have mineral and water rights in areas directly surrounded by the proposed lands to be leased.	See Common Response #1.
Rose Valley Properties, LLC	K-17	Inyo County has evaluated the true groundwater recharge capability of the Rose Valley. No new geothermal development should occur until the recharge to the basin is better known. The county is currently evaluating projects that may have additional impacts to the basin. These impacts also need to be considered in any BLM review.	BLM agrees that cumulative effects analysis of specific actions would need to be prepared when a specific POO is proposed by a proponent, and BLM completes a specific NEPA environmental review. Also, see Common Response #1 and Response to Comment A-1.
Little Lake Ranch	L-1	The DEIS is not entirely consistent, however, in that BLM says that the leases do not authorize any specific energy development based on the DEIS (Page 1-2). Please describe in greater detail what the specific terms and conditions of any lease may be so that the actual authorized uses may be assessed as part of the DEIS process, or better yet, a form of the leases that may be granted.	See Common Response #1 and Response to Comment A-1.
Little Lake Ranch	L-2	Other than the proposed length of the leases, beginning with 10 years for exploration followed by a 40 year term for actual resource development (Page 1-10), the actual terms and conditions of proposed future leases are not specified other than the leases are supposed to address a variety of factors, including sanitation, water quality, wildlife, cultural resource protection and reclamation. Nonetheless, none of the specific terms or proposed protections are set forth, even in a general sense. Please provide additional details.	See Response to Comment A-1.
Little Lake Ranch	L-3	Please explain and justify the decision to eliminate Alternate Geothermal Technologies that could minimize or completely eliminate the waste of water resources.	The rationale for eliminating other geothermal technologies is provided in Section 2.4.3 of the DEIS/PA and further elaborated on in Section 2.3.1 of the DSEIS/PA. Also, see Common Response #3.
Little Lake Ranch	L-4	Please specify exactly how such activities are prohibited under the lease and what “limited rights” to exploration and development may be. What types of development activities would be permitted?	See Response to Comment A-1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-5	BLM generally outlines what it considers to be the Reasonably Foreseeable Development Scenario ("RFD") related to the HGLA. The DEIS does not, however, clearly and succinctly define what the RFD is. In particular, while there are references to exploration and construction activities, there are also many references to resource development which suggest the actual exploitation of the geothermal resource and the production of electricity. The specific limitations on the proposed leases under the RFD must be clearly defined.	The specific limitations on development under the RFD scenario are clearly spelled out on Page 2-8 of the DEIS/PA and Appendix B. See Common Response #1.
Little Lake Ranch	L-6	While the DEIS suggests that no action is currently contemplated or allowed for the development of the geothermal resources, the RFD assumes there will only be two 30-megawatt ("MW") geothermal facilities including fifteen (15) production wells and seven (7) injection wells. If no development is being authorized or analyzed by the DEIS, it is unclear why the RFD would consider future development. (Page 2-8). Please explain.	The RFD scenario is not a proposal for specific development. The RFD scenario was developed to determine the magnitude and extent of possible impacts of the leasing activity that is being potentially considered for the HGLA in this FSEIS/PA. Also, see Common Response #1.
Little Lake Ranch	L-7	Please explain what the BLM considers to be "standard review methods" for the protection of ground water.	The standard review methods refer to the environmental review (NEPA) process the BLM is obligated to comply with for consideration of any development proposal on lands it manages. The standard review methods for BLM to consider groundwater protection include review of all State and local public agency actions and regulations in order to be as consistent as possible with resource management in the region, and to complete the environmental analysis in a public and open NEPA process. Having gone through the public process, the BLM would consistently apply the lease conditions and stipulations that are identified during the NEPA analysis, to approve or deny geothermal leases and project developments. Also, see Common Response #1.
Little Lake Ranch	L-8	Why does the RFD assume that dual-flash technology will be used, simply because that is the technology of Coso?	See Common Response #3 and Appendix B.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-9	Rather than suggest that binary geothermal systems “use relatively less water that dual-flash systems”, (pg. 2-11) identify the true differential in total water losses through evaporation compared to a fully-contained system.	The DSEIS and FSEIS includes discussion to more precisely discuss the differences between dual-flash and binary geothermal systems. Argonne National Labs was also commissioned to perform supplemental analysis of water consumption for dual-flash and binary geothermal plant technologies in response to public comments received on the DEIS/PA as described in Sections 1.1 and 4.6.1 of the DSEIS/PA.
Little Lake Ranch	L-10	The final environmental impact report (“FEIR”) adopted by the County for the Coso project established a threshold of significance at a decline of 10% of the water flowing into the surface features as Little Lake. Explain why the DEIS alters this standard by not allowing a decline of “10% or more to the average annual fluctuation of water flowing into the surface features at Little Lake”. (Page 2-12)	The BLM will rely on actual monitoring data and water levels rather than rely on experts interpreting how much is the actual 10% decline, which would be impossible to know with certainty. The use of groundwater level triggers instead is a definitive impact level that can be measured and monitored with more precision than estimates that involve groundwater recharge estimates. Also, see Common Response #2.
Little Lake Ranch	L-11	Compare the utilization of water resources under proposed Alternative A at Page 2-12 to the use of water resources under the Preferred Alternative C at Page 2-17. The description of significant impacts set forth of Alternative A is not repeated in Alternative C. Why not? Explain why Special Administrative Stipulations SA-HGLA-10a, b and c are all eliminated in Alternative A, but remain in Alternative C. Explain why SA-HGLA-10d is eliminated in Alternative C. (page 2-17).	The range of alternatives and associated stipulations have been revised as reflected in the DSEIS/PA. As stated in the DSEIS/PA and in this FSEIS/PA in Section 2.4.1, Lease Stipulation SA-HGLA-10 has been updated and removes SA-HGLA-10a, 10b and 10c listed in the 2012 Draft EIS because 10a, 10b and 10c are duplicative of the rest of the SA-HGLA-10 which requires expressed approval of the Authorized Officer for groundwater extraction for consumptive use prior to project activities.
Little Lake Ranch	L-12	Are the Special Administrative Stipulations described in Section 2.6 the sole measures to protect ground water resources within Rose Valley? Why do each of the proposed Alternatives which allow some geothermal leasing have differences with respect to protection of water resources?	See Response to Comment L-11.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-13	The DEIS rejects the possible use of a binary geothermal plant system before any exploration done and before any actual knowledge is obtained with respect to the characteristics of the geothermal resource in the HGLA. No legitimate reason is advanced other than Coso uses a dual-flash plant with wet cooling towers. The evaporative cooling process results in the de-watering of the geothermal resource and may, in the future, depend upon imported water to preserve the resource. What are of the impacts of evaporative cooling on a geothermal resource? Would the use of a binary plant, even if less efficient, prolong the life and utility of the geothermal resource? Compare the potential longevity of the power plants using a binary plant compared to dual-flash. Other than the relative proximity of Coso, what is the actual and factual data that supports the speculative premise that the geothermal resource HGLA will be the same or remarkably similar to Coso? (Page 2- 25).	Neither the DEIS/PA nor DSEIS/PA explicitly rejects the idea that a binary geothermal plant system may possibly be proposed in the HGLA, only that the dual-flash was a reasonable assumption for the RFD scenario. However, Section 2.3.1.1 of the FSEIS/PA describes the differences between the binary system and a flash system, and the rationale for choosing the flash for the RFD scenario. As stated on page 2-4 of the DEIS, numerous technical papers and geologic analyses have documented the similarities in geologic setting between the HGLA lands and Coso KGRA. It is not known whether the use of a binary system would prolong the life and utility of a geothermal resource. The BLM determined a reasonable set of assumptions for the RFD scenario, and those assumptions are valid for this analysis.
Little Lake Ranch	L-14	The DEIS further rejects with no credible evidence or analysis the use, in whole or part, of a dry cooling system. No consideration has been given to a combination of dry and wet cooling facilities to materially reduce both the (a) loss of water through evaporation and the degradation of the geothermal system itself or (b) the elimination of the need for any imported water. Where is the analysis that air or dry cooling is not feasible?	BLM has not determined that other technologies would not be used or would not be feasible; however, in the RFD scenario the BLM has made reasonable assumptions in order to complete the analysis of possible environmental consequences that may result from geothermal development, to inform planning and leasing decisions in the HGLA. These assumptions are valid for the analysis and comparison of alternatives in this action, because they present the greater level of impacts, which includes the lesser impacts that may result from the use of more conservative technology, if that were to happen. A specific POO would be needed from a developer before the actual technology and specific ground disturbing activities would be determined. Also, see Common Response #3.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-15	SA-HGLA-10(b) should be written in the disjunctive so that consumptive water use is allowed only if such use does not exceed safe yield or cause a decline of ten percent (10%) or more of water flowing into Little Lake. (Page 2-42). Moreover, please better define what is meant by a ten percent (10%) decline of the "annual fluctuation of water." Provide a specific example to demonstrate what water reductions would constitute such a decline. How is the decline measured? What is the beginning assumption of the amount of water flowing into Little Lake? How will BLM determine what the annual fluctuation is? What measurement protocols will be put into place to ascertain whether the ten percent (10%) has been reached? Why is this standard different than the standard used in the FEIS adopted by the County?	As stated in the DSEIS/PA and in this FSEIS/PA in Section 2.4.1, Lease Stipulation SA-HGLA-10 has been updated and removes SA-HGLA-10a, 10b, and 10c listed in the 2012 DEIS because 10a, 10b, and 10c are duplicative of the rest of the SA-HGLA-10 which requires expressed approval of the Authorized Officer for groundwater extraction for consumptive use prior to project activities. Monitoring will be done to determine the groundwater levels to be used in the groundwater level triggers. The annual fluctuation will be determined by the actual measurements and not by modeling.
Little Lake Ranch	L-16	Please better define what is considered "development activities" with respect to SA-HGLA-10(b). Is this limited to the construction and instillation of the power plant facilities but not operation? If operations are excluded, it should be so stated.	As stated in the DSEIS/PA and in this FSEIS/PA in Section 2.4.1, Lease Stipulation SA-HGLA-10 has been updated and removes SA-HGLA-10a, 10b, and 10c listed in the 2012 DEIS because 10a, 10b, and 10c are duplicative of the rest of the SA-HGLA-10.
Little Lake Ranch	L-17	Why does SA-HGLA-10(d) lack the requirement for a plan of operations together with mitigation and remediation plans set forth in SA—HGLA-10(c)? (Page 2-43).	Refer to Common Response #1.
Little Lake Ranch	L-18	The data derived from such monitoring is entirely absent from the DEIS. While it is obviously critical for a water budget to be established, why does the DEIS ignore all of the data compiled from the Coso monitoring? Given the amount of data already collected, why does the DEIS not contain an analysis of what the current water budget may be?	See Common Response #2.
Little Lake Ranch	L-19	The time parameters for determining Safe Yield are not defined such that this formula does not refer to a single year, period of years or any other time element. How will the Safe Yield be determined when Coso's pumping stops? If Coso's pumping has already depleted the Rose Valley Aquifer by 5,000 acre-feet per year since Coso began pumping, would be the proposed concept of Safe Yield allow any of the applicants to pump a newly-described recharge amount to prevent the recovery of the Rose Valley Aquifer? What protections are provided to allow the Aquifer to regain its historical underground water levels?	See Common Response #2.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-20	The public is given no ability to address the adequacy of water or what effects the utilization of such water may have upon vital public resources including consumptive use by others, and the impacts upon habitat and wildlife in and around the area if such water resources were depleted.	See Common Response #2.
Little Lake Ranch	L-21	Please list which BMPs will be incorporated and which will not. If BMPs will only be incorporated after future environmental review, then why are they discussed here?	BMPs would be identified as appropriate for specific Proposed Actions, and are presented in Appendix A and Appendix K to fully disclose the extent of measures available to the BLM to protect the sensitive resources of the HGLA.
Little Lake Ranch	L-22	The suggestions that flash power plants are more water friendly than binary plants is questionable. While dry cooling can be less efficient in very hot weather, no mention is made of the efficiency of dry cooling in cold weather. The DEIS should provide the facts of using each type of technology, and not provide a biased view against dry cooling or binary systems even though they may not produce over a typical year the same amount of total energy.	See Common Response #3 and Response to Comment L-4.
Little Lake Ranch	L-23	Please clarify whether injection is contemplative of only geofluid, or if there is a thought of injecting groundwater that is unrelated to the geofluids or from imported water. The deferral of any analysis of the use of surface or groundwater for the cooling of a geothermal facility cannot be postponed until a later date. How can the public be assured that the condition will be satisfied that sufficient water supply must be guaranteed by an applicant before any lease is approved?	See Common Response #1 and Response to Comment A-1.
Little Lake Ranch	L-24	Who will ensure compliance and what will the stipulations be? Once a lease or permits are granted, what procedures will be in place to ensure compliance?	The specifics of compliance would be determined when a specific action is proposed by a proponent as reflected in the decision document (e.g., Record of Decision). The BLM is required to consider mitigation measures as specified in the Council on Environmental Quality regulations 1502.14 and 1502.16(h) for preparing an EIS.
Little Lake Ranch	L-25	The DEIS admits that geothermal exploration results for Coso are not readily available in the public domain. (Page 3-51). Please explain why this is an adequate response for the need for an adequate environmental investigation.	The BLM is analyzing the action of leasing in the HGLA, not a site-specific project action. The analysis is adequate for BLM to make a decision on this action. See Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-26	Please explain why the use of evaporative cooling system should be allowed. In a dual-flash geothermal facility, calculate how geothermal fluids are produced and what percentage of such fluids are lost through evaporation. How long will it take before the geothermal resource is damaged or affected by the losses?	See Common Response #1 and Response to Comment A-1.
Little Lake Ranch	L-27	The DEIS states that the issuance of the three pending lease applications will not authorize any construction or development of geothermal resources. (Page 4-2) Nonetheless, there are a multitude of references throughout the DEIS to the “development” of the resources. While the intent of the DEIS seems to limit its scope to exploration activities, there is an unnecessary confusion in the document as to whether or not development activities will be permitted or not. Since the form and terms of the actual leases are not provided, more clarity is demanded. A specific limitation on what would be allowed within the HGLA should be set forth and all references to the possibility of future development or construction of geothermal facilities should be eliminated.	See Common Response #1 and Response to Comment A-1.
Little Lake Ranch	L-28	There has never been a study or report of what the amount of water flowed into Little Lake before the Coso pumping began. If the DEIS suggests that such flow is known, please provide the current analysis of what such flows were before the commencement of Coso’s pumping. How does the DEIS propose to determine what will represent a ten percent (10%) decrease in such flow?	See Common Response #3.
Little Lake Ranch	L-29	The DEIS suggests that make-up water will be needed to compensate for evaporative losses during plant operations. (Page 4-45). Some, but not all, of this loss is due to the evaporative wet cooling towers. No source of water to provide this make-up water has been identified. Why then has the concept of dry cooling been eliminated from consideration?	See Common Response #3 and Response to Comment L-14.
Little Lake Ranch	L-30	Why does the DEIS perpetuate a logical impossibility with respect to the amount of water that may be available to operate the geothermal facility using dual flash technology? More importantly, why does the BLM reject, without any study whatsoever, the utilization in whole or in part of an air-cooling system?	See Common Response #3 and Response to Comment L-14.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-31	If the use of groundwater for consumptive use is prohibited, (Page 4-45), where will the water come from? BLM cannot possibly approve leases which will obviously require water sources when the source of such water supplies has not been identified.	BLM cannot prevent a private entity from securing water by the legal means available to them. Also, see Common Response #2.
Little Lake Ranch	L-32	If the geothermal resource is being harmed through water lost through evaporative cooling, why is this process even being considered? Why are not alternate technologies being considered, such as air cooling?	Air cooling has been considered on page 2-26 of the DEIS/PA, and was eliminated because power is most needed regionally in the summer cooling season when the geothermal resource would be least efficient. Also, see Common Response #3.
Little Lake Ranch	L-33	Why does the modeling in Appendix G assume that there is no other groundwater extraction? (Page 4-49).	BLM assumes there will be no groundwater extraction from below the HGLA, and that a proponent has the right to obtain water from any legal source available.
Little Lake Ranch	L-34	It is unclear as to what consumptive use is proposed, disallowed or possibly used. (Page 4-50). Please confirm under Alternative C that no consumptive use of groundwater would be allowed under any circumstances. (Page 4-51).	Alternative B in the DSEIS has effectively replaced DEIS/PA Alternative C; Alternative D as defined in the DEIS/PA has been eliminated from further consideration. Under the current alternatives identified in the DSEIS/PA, consumptive water use is restricted by stipulation for Alternatives A and B, but may be allowed for some leases. The proposed action is a land use allocation and lease issuance. The identified stipulations would be applied, as appropriate, if and when a proposal for any consumptive use is approved. Because this analysis is designed to inform the decision-maker regarding potential impacts of different land allocation schemes, as well as issuance of these leases, certain analytical assumptions and professional judgments have been made by our resource experts, based on the sort of development reasonably possible, and the anticipated protective aspect of the stipulations considered for adoption.
Little Lake Ranch	L-35	Confirm that under Alternative D, all consumptive use of groundwater would be prohibited, without exception or waiver. (Page 4-52).	Alternative D as defined in the DEIS/PA has been eliminated from further consideration.
Little Lake Ranch	L-36	Why does Appendix G refer to the Draft EIR for the Coso project from 2008, rather than the Final EIR for Coso?	The information in the Draft Final Environmental Impact Report (EIR) is identical to the information in the Final EIR regarding groundwater flow rates. The reference to the Draft EIR rather than the Final EIR for the Coso project does not affect the decision or the information available to the decision maker for this land use decision for geothermal leasing in the HGLA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Little Lake Ranch	L-37	The conclusion reached by Appendix G that groundwater inflows equal or slightly exceeded groundwater outflows during the last five years is suspect (Page G-17). Does this consider or ignore the Coso pumping?	Appendix G does consider Coso groundwater pumping in the model. There is no data available that would cause BLM to modify that statement, and because this wouldn't affect the decision to be made by the BLM on this land use decision for geothermal leasing, no further information has been provided in the FSEIS.
Little Lake Ranch	L-38	The DEIS suggests that water could be extracted from a single well at a rate of 1,000 AFY for 30 years without reducing groundwater flow into Little Lake by more than 10% (Page G-49) Where is the data and proof for this statement? Oddly, the New Model suggests that such a minor amount of pumping could still reduce the underground water level at Little Lake Ranch North Well by 3.5 feet, which is nearly ten times the allowable draw down under Coso FEIR, as updated and revised by DBS.	Various predictions and models have been considered by the BLM during the assessment of potential environmental impacts described in the DEIS/PA and DSEIS/PA. The simulated inflow and outflows for the model for estimating the groundwater flow to Little Lake is explained in Appendix G of the DSEIS/PA and FSEIS/PA. Brown and Caldwell developed a three-dimensional, numerical model of the Rose Valley groundwater basin which was then revised, and recalibrated for the Hay Ranch Groundwater Extraction Project EIR, and, revised and recalibrated, by GEOLOGICA for the HGLA DEIS study. As explained in Appendix G, groundwater flow evaluations were conducted using the United States Geological Survey's MODFLOW computer code implemented in the Groundwater Vistas graphical environment. The revised model incorporates new groundwater elevation data and lithologic information from monitoring well drilling and logging conducted for the Hay Ranch Monitoring Project, as well as time-drawdown data from a 6-1/2-day pumping test conducted on the LADWP property in March 2009. No further models are needed for BLM to understand the possible effects of leasing for geothermal exploration and development within the HGLA, and no changes have been reflected in the FSEIS/PA.
Center for Biological Diversity	O-1	The failure to adequately address impacts to water resources by BLM renders the document inadequate under NEPA as does the BLM's failure to provide any alternative that would ensure conservation of water resources is prioritized. The proposed plan amendment which would allow for significant impacts to water resources is also inconsistent with FLPMA which requires BLM to prevent unnecessary or undue degradation of public lands. 43 U.S.C § 1732(b). The BLM has failed to show that it is necessary to approve either the leasing area or the pending leases at this time or that BLM has fully explored other suitable alternatives, including alternative geothermal technologies which use far less water.	See Common Response #2.

Table Z-2 Responses to Substantive Comments Received on the DSEIS/PA

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Inyo County-Board of Supervisors	AA-1	We are concerned about coordination with the County pursuant to Federal Land Policy Management Act (FLPMA) of 1976.	Thank you for your comment. The BLM will coordinate with the applicable federal, state and local agencies as necessary, while processing applications for geothermal exploration and development.
Inyo County-Board of Supervisors	AA-2	Section 3.18.2 still does not provide an adequate analysis of County maintained roads that may be impacted by the HGLA. We would still like to see an analysis of County roads that may be impacted, especially Coso-Gill Station road. This analysis needs to include any impacts that will result in necessary road improvements due to increased use for exploration and development of geothermal resources in the area.	See Common Response #1.
Lahontan Regional Water Quality Control Board	BB-1	Lahontan Water Board staff are concerned about the potential impacts to water quality and hydrology that such projects may present and request that BLM analyze these impacts as part of the environmental review process.	See Common Response #1.
Lahontan Regional Water Quality Control Board	BB-2	The Haiwee Geothermal Leasing Area is in a tectonically active transitional zone, yet the DSEIS presented no analysis on the threat to groundwater should any geothermal well casing be compromised because of an earthquake. Staff recommend adding a paragraph to Chapter 3.6 of the DSEIS to address this concern.	The potential compromising of well casings as a result of seismic activity would be an indirect effect of geothermal leasing. As described in Section 3.4.2 of the DSEIS/PA, seismic risk evaluation will be conducted for specific project proposals. Also, see Common Response #1.
Lahontan Regional Water Quality Control Board	BB-3	The DSEIS describes water quantity in detail but briefly describes hydrologic hazards such as flooding or the impact these hydrological hazards will have on geothermal facilities and water quality. Stating that geothermal facilities will not be built in flood prone areas is not sufficient. Staff recommend adding a paragraph to Section 3.6.2 of the DSEIS describing the impacts that hydrologic hazards will have on the geothermal facilities and any mitigations need to protect water quality.	See Response to Comment AA-3. Also, see Common Response #1.
Lahontan Regional Water Quality Control Board	BB-4	Appendix A: We recommend maintaining natural drainage channels and flow paths throughout the Project site to avoid no net loss of function and value of waters of the state because of Project implementation.	See Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Lahontan Regional Water Quality Control Board	BB-5	Projects that have the potential to discharge to or otherwise impact groundwater or surface waters in the Lahontan Region, either directly or indirectly, must comply with all applicable water quality standards and prohibitions, including provisions of the Basin Plan.	Your comment is noted. The developer of specific projects will be required to comply with all federal, state, and local laws and regulations as a condition of approval.
Lahontan Regional Water Quality Control Board	BB-6	Streambed alteration and/or discharge of fill material to a surface water may require a CWA, Section 401 water quality certification for impacts to federal waters (waters of the U.S.), or dredge and fill waste discharge requirements for impacts to non-federal waters, both issued by the Lahontan Water Board. All unavoidable permanent impacts to waters of the State must be mitigated to ensure no net loss of beneficial use and wetland function and value. Water Board staff coordinate mitigation requirements with staff from federal and other state regulatory agencies. In determining appropriate mitigation ratios for impacts to waters of the State, we consider Basin Plan requirements (minimum 1.5 to 1 mitigation ratio for impacts to wetlands) and utilize 12501-SPD Regulatory Program Standard Operating Procedure for Determination of Mitigation Ratios, published December 2012 by the United States Army Corps of Engineers, South Pacific Division.	See Response to Comment BB-5.
Lahontan Regional Water Quality Control Board	BB-7	Land disturbance of more than 1 acre may require a CWA, section 402(p) storm water permit, including a National Pollutant Discharge Elimination System General Construction Storm Water Permit, Water Quality Order 2009-0009-DWQ, obtained from the State Water Board, or individual storm water permit obtained from the Lahontan Water Board.	See Response to Comment BB-5.
Lahontan Regional Water Quality Control Board	BB-8	We request that the draft DSEIS recognize the potential permits that may be required for the Project, as outlined above, and identify the specific activities that may trigger these permitting actions in the appropriate sections of the environmental document. Early consultation with Water Board staff regarding potential permitting is recommended.	See Response to Comment BB-5.
EPA	CC-1	Revise the legend in Figure L-4 to more clearly show the SRMAs. Revise Figure L-4 to correctly identify State lands.	Figure L-4 has been modified in this FSEIS/PA to reflect the changes requested.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
EPA	CC-2	Clarify, in the FSEIS, the reasons why the southwestern section of the HGLA was reclassified from 'a sensitive resource area' to a DFA. Likewise, clarify why the areas that were formerly 'proposed open for geothermal development' have been re-designated as ACECs. Explain the reasoning behind these changes, beyond the fact that it occurred in conjunction with the DRECP LUPA ROD.	Information relative to the current land use designations under the DRECP can be located within the DRECP.
EPA	CC-3	Illustrate, in the FSEIS, the extent of the Mojave Ground Squirrel ACEC, including the area located within the HGLA. Describe the habitat for the Mohave ground squirrel within the HGLA, specifically noting the condition of habitat in the DFA, as compared to the rest of the HGLA.	The location and extent of the Mojave Ground Squirrel ACEC is depicted in Appendix J-4, revised based on Response to Comment CC-1.
EPA	CC-4	Appendix G of the DSEIS indicates that groundwater modeling simulations conclude that pumping at a reduced rate could be sustained for 30 years without reducing water flow towards Little Lake by more than 10 percent; however, the same simulations indicate that the maximum predicted drawdown at the Little Lake Ranch North well could exceed 3.5 ft — which exceeds the Maximum Acceptable Drawdown threshold of 0.4 feet established for this well. The DSEIS does not indicate if there is a lower pumping rate that would enable both sets of criteria to be met either under simulation conditions or given ongoing pumping.	See Common Response #1.
EPA	CC-5	According to the DSEIS, the groundwater flow model did not consider the effects of other major groundwater development projects, including the Hay Ranch Groundwater Extraction and Transfer project and the Los Angeles Department of Water and Power's (LADWP) proposed Haiwee Reservoir Seepage Capture project (Appendix G). Although the effects of additional pumping are expected to be additive, they were not included in the modeling analysis. Without evaluating ongoing pumping efforts and completing a water supply assessment, it is unclear what water resources, if any, are available.	The cumulative impacts to groundwater were detailed in Section 4.21.2 of the DSEIS/PA. Also, see Common Response #1.
EPA	CC-6	Although the DSEIS states that the Argonne Lab modeling effort supports the water use assumptions used in the groundwater flow model, the details of the study are not included in the DSEIS. According to information presented in Appendix B, the complete report summarizing the study should be contained in Appendix J; however, Appendix J is not available on BLM's E-Planning website, nor is it listed in the DSEIS table of contents.	Similar to other references cited in the literature cited section of the DSEIS/PA, the Argonne's Summary of Modeling Effort was cited and referred to as literature used to inform the DSEIS/PA. The BLM will include the Summary of Modeling Effort on the ePlanning website coincident with the release of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
EPA	CC-7	Identify, in the FSEIS, the potential sources of water. Discuss any impacts associated with the appropriation of this water, including impacts to wetland habitats. Discuss whether it would be feasible to use other sources, such as treated wastewater, for geothermal drilling, injection and power plant operations.	The use of degraded or reclaimed water sources to the extent practicable are required as a Best Management Practice as described in Appendix A of the DSEIS/PA. See Common Response #1.
EPA	CC-8	Describe, in the FSEIS, quantities of groundwater associated with the Hay Ranch Extraction and Delivery System project and the LADWP' s Haiwee Seepage Recovery project. Identify any other sources of groundwater consumption within the basin. Incorporate these data into the numerical groundwater flow model and discuss results.	These projects were discussed in Section 4.21 of the DSEIS/PA. Groundwater extraction assumptions for the Hay Ranch are provided in Appendix G. Additional modelling of the LADWP project would not alter the baseline impact scenario for the decision making process at this planning level. Also, see Common Response #1.
EPA	CC-9	Complete a water supply assessment for the basin. Identify pumping rates over the last 10 years within the basin. Given ongoing pumping efforts, discuss whether there is groundwater available for consumption within the basin.	As stated in Section 3.6.1 of the DSEIS/PA and Section 3.11 of the DEIS, Inyo County regulates geothermal resource development, including exploratory wells and production projects, through a Conditional Use Permit (CUP) process, and would evaluate availability of groundwater. Also, see Common Response #1.
EPA	CC-10	Include, in the FSEIS, the draft evaluation guidance that BLM has developed for use to determine seismic risk related to geothermal development. Clarify whether this guidance was used by BLM in the HGLA or requires more site-specific project information. Discuss the results of the risk assessment that BLM has conducted. Discuss, in the FSEIS, ground deformation or any other impacts in the HGLA that can be attributed to the recent Ridgecrest earthquakes.	See Common Response #1.
Big Pine Paiute Tribe of Owens Valley	DD-1	Overall, the Tribe recommends the entire HGLA be closed to geothermal exploration, development, and leasing. The Tribe makes this recommendation based on the long-term adverse impacts geothermal development would have on the ethnographic landscape and on the water resources of Rose Valley and the surrounding region including Coso Hot Springs. The Tribe notes that, unlike the 2012 DEIS, there is not an alternative equivalent to Alternative B of that DEIS. The most acceptable alternative in the 2019 DSEIS is Alternative D, but this alternative does not permanently close the entire area to development because it may at a future time allow development in parts of the area.	Under current management, the CDCA as amended by the DRECP LUPA allows for geothermal development only within DFAs. Also, see Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Big Pine Paiute Tribe of Owens Valley	DD-2	In its previous comments, the Tribe said that the EIS is not considered complete by the Tribe without the inclusion of a "Native American Issues and Concerns" section. The DSEIS does not contain such a section which may and should be included in EISs for projects in the Great Basin. For example, the Legislative EIS for the Nevada Test and Training Range contained Appendix K: Native American Perspectives. This 152-page section was prepared by Tribal members of tribes affected by the project.	An updated "Summary of Government-to-Government Tribal Consultation" was included Section 5.4.2 of the DSEIS and is included in Section 5.4.2 of the FSEIS/PA . Ethnographic concerns were updated for the DSEIS and in the FSEIS/PA in Section 3.8.2.2. No specific sites have been identified within the HGLA in the ethnographic literature or through tribal consultation.
Big Pine Paiute Tribe of Owens Valley	DD-3	In its previous comments, the Tribe recommended BLM commission an analysis of the ethnographic landscape.	See Response to Comment DD-2.
Big Pine Paiute Tribe of Owens Valley	DD-4	Considering the location of the HGLA, there are only two reliable ways to procure water: pump it from the ground or transport water to the site. Groundwater levels at monitoring wells throughout the valley, and particularly in the south where Little Lake is located and the groundwater basin naturally discharges, have dropped dramatically over the past decade. These declines have occurred even though pumping at the Hay Ranch has not been at the maximum rate allowed by the county. The Tribe's analysis of data resulting from the Coso Hay Ranch Project shows unacceptable groundwater depletion, which may have consequences for Little Lake and any future water uses in Rose Valley. The changes seen in the Tribe's analysis of the Coso Hay Ranch project indicate that large projects involving water, such as development in the HGLA, are inappropriate in the Rose Valley region. Geothermal wells do not last forever, and as this resource is depleted, it may have effects on availability of ground water in other parts of the aquifer system. Furthermore, as discussed below, development in the HGLA has the potential to affect resources of critical importance to the Tribe.	See Common Response #1 and Sections 3.6, 4.6, and 4.21 of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Big Pine Paiute Tribe of Owens Valley	DD-5	In previous comments, the Tribe and other tribes requested an analysis be performed regarding potential impacts of geothermal development in the HGLA on conditions in the vicinity of Coso Hot Springs. The Tribe asserts that, regardless of complexity, there needs to be an analysis of the potential connection between the HGLA and the Coso Hot Springs. The Tribe is in possession of several annual Coso Hot Springs monitoring reports from the consulting firm, Geologica, which prepares the reports for Naval Air Weapons Station, China Lake. Assuming these are the reports to which the EIS refers, these reports simply present routine monitoring data and do not analyze for any connection between Coso Hot Springs and the HGLA. The statements addressing potential impacts to Coso Hot Springs by geothermal development in the HGLA are unsubstantiated and inadequate for and EIS. Because the data indicate Coso Hot Springs has already been adversely effected by nearby geothermal development, the Tribe remains concerned about compounding the adverse effects by commencing new geothermal development in the HGLA.	See Common Response #1 and Sections 3.6, 4.6, and 4.21 of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-1	We recommend that BLM analyze the Dry Cooling System technology alternative because we believe that dry cooling technology is feasible, reasonably cost effective and would conserve substantial amounts of ground water from Rose Valley. The Coso Operating Company that maintains and operates the existing geothermal powerplants in the Coso KGRA uses water cooling technology, which is among the most water use intensive cooling technologies. While the efficiency of a dry cooled system is reduced in the hot summer months, it is feasible during the remainder of the year when ambient air temperatures are lower, especially in the late fall through early spring seasons. Furthermore, dry cooling would eliminate the substantial waste of groundwater associated with the wet cooling technology currently used at Coso powerplants. Using air cooled steam condensing technology, while not as efficient as the current water-cooled steam condensers, should not be rejected from analysis.	See Common Response #3 and Response to Comment L-14.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-2	BLM is charged with managing public lands in the HGLA under the provisions of FLPMA, including geothermal leasing, in a manner that sustains the groundwater resource and environmental quality. BLM is obligated to not only consider, but to analyze an alternative to geothermal leasing in the HGLA that limits geothermal technology to the use of air-cooled steam condensers for the purpose of conserving and sustaining groundwater for the use and benefit of current and future generations.	The BLM is obligated to consider a range of reasonable alternatives in order to render a decision on this planning effort. The BLM believes it to be a reasonable approach to include the technology with the greater impacts in the RFD scenario, on the assumption that the technology with the lesser included impacts would, thereby, be accounted for.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments- Amargosa Conservancy, et al.	EE-3	The most current groundwater flow model for Rose Valley was published in 2017 by Inyo County. This study concluded that the annual recharge to the Rose Valley is 3,623 acre-feet/year, significantly less than the 5,100 acre-feet/year reported by Argonne National Laboratory in its report to the BLM in 2016. Thus, the most recent estimate of sustained yield of groundwater withdrawal from Rose Valley is 3,623 acre-feet. The most recent use of groundwater from Rose Valley by Coso Operating Company was 1,611 acre-feet/year from June 1, 2017 through May 31, 2019, which is also allowed to extend to year 2021 as per the conditional use permit from Inyo County. LADWP has a proposal to extract approximately 870 acre-ft of groundwater on property they own at the north end of Rose Valley, and Argonne National Laboratory estimated that 1,830 acre-feet/year would be needed to support new geothermal powerplants in the HGLA under the Reasonable Foreseeable Development scenario for Alternative A (BLM-Preferred Alternative).	See Common Response #1 and Sections 3.6.2, 4.6.1, 4.11.1, 4.21 and Appendix O of the DSEIS/PA.
Consolidated NGO Comments- Amargosa Conservancy, et al.	EE-4	Combined, the current and projected groundwater consumption totals 2,481 acre-feet/year, leaving approximately 1,142 acre-feet/year available within the sustainable yield of the basin. This amount is less than the 1,830 acre-feet/year needed to support geothermal development under Argonne's Reasonable Foreseeable Development scenario by 688 acre-feet.	See Common Response #1 and Sections 3.6.2, 4.6.1, 4.11.1, 4.21 and Appendix O of the DSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-5	BLM should update the current use of groundwater in Rose Valley by accounting for the annual amounts, in acre-feet for the following, and add the total to the analysis of current groundwater consumption: ● 30 domestic wells in the Dunmovin area that BLM reports exist and that are assumed to consume relatively small quantities of groundwater for domestic uses and small scale irrigation in the Dunmovin area. ● Coso Ranch South well, southern Coso Junction Store well (Coso Junction #2), and the Cal- trans well at Coso Junction that are regularly used by businesses in the area. ● Coso Ranch South well that provides water at a rate of 5 – 10 tanker truckload per day for the Cal-Pumice mine. ● Coso Junction Store well that supplies the general store and Coso Operating Company offices at Coso Junction. ● A well at the north end of the Little Lake Ranch property that provides water to a local cinder mine.	See Common Response #1 and Sections 3.6.2, 4.6.1, 4.11.1, 4.21 and Appendix O of the DSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-6	Groundwater is not subject to appropriation under California law, so the statement that "…each project developer would need to obtain water rights" needs to be corrected. Please clarify what water would potentially be available given that BLM has decided to prohibit consumptive use of groundwater from Rose Valley, and how such water would be legally obtained for use in geothermal development. The only alternative in the DSEIS for the HGLA that is reasonable given that BLM has decided to prohibit the consumptive use of groundwater is Alternative D (No Action), which would allow leasing and development in the DFA, but lands within the HGLA outside of existing DFAs would not be made available for geothermal leasing, exploration and development and would remain under current management as specified in the CDCA Plan, as amended. Any proposed geothermal facilities in the DFA would be under the CDCA Plan, as amended. The current pending lease applications would be neither denied nor authorized and would be processed in conformance with the CDCA Plan, as amended.	The BLM cannot prevent a private entity from securing water by the legal means available to them. The FEIS/PA reflects a correction to the language regarding water rights to reflect this. See Common Response #1.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-7	It is critically important to note that the above analysis did not consider the effects of groundwater pumping for the Coso Hay Ranch Groundwater Extraction and Transfer Project or the LADWP's proposed Haiwee Reservoir water seepage capture project. When added, the cumulative impact analysis would show much greater use of groundwater and adverse impacts to Little Lake.	These Project were covered in Section 4.21 of the DSEIS/PA. See Common Response #1.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-8	Please indicate how many acres for each of the above conservation lands occur within the HGLA boundary.	Acres for each of the special designated areas within the HGLA have been added to Sections 3.16.2 and 3.17.2 of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-9	Also, the CDCA Plan, as amended in 2016, prohibits renewable energy development, including geothermal, within the above conservation lands for the purpose of protecting them and their associated significant biological, cultural and scenic values. Section 202(c)(3) of FLPMA requires that the Secretary of the Interior, through BLM, “give priority to the designation and protection of areas of critical environmental concern.” Alternative A (BLM-Preferred Alternative) and other alternatives that would allow any geothermal development within these ACECs is contrary to BLM’s legal obligations under FLPMA. Therefore, the No Action Alternative is the only one that meets this requirement, because it would restrict leasing and development to only those lands within the DFA. Alternative A (BLM-Preferred Alternative) and other alternatives that would allow any geothermal development within these lands is contrary to BLM’s legal mandate under the Omnibus Public Lands Management Act. The only alternative that meets this requirement is the No Action Alternative. Due to the overarching management standards essential for the agency to fulfill its conservation mandate, BLM should not allow geothermal development within ACECs and CDNCLs. Allowing for geothermal development within ACECs and CDNCLs is clearly contrary to the laws and policies outlined above. The only alternative that satisfies BLMs legal requirements is the No Action Alternative because it would restrict leasing and development to only those lands within the DFA.	The BLM has the authority to amend land use plans under 43 CFR Part 1610.5-5. The purposes of the HGLA CDCA plan amendment would be to change the allowable uses within ACEC (and other allocation) areas, as described in Section 1.3.1, page 8 and Section 1.3.2, page 9 of the DSEIS/PA. The land use plan amendment being proposed for the HGLA does not change the land use designations established under the DRECP LUPA. All alternatives identified in the DSEIS/PA would implement stipulations to protect sensitive resources and their associated significant biological, cultural and scenic values or would not allow geothermal exploration and development in sensitive areas/ACEC/NCLs, as currently detailed in the DCRECP LUPA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-10	We echo the concerns of the Big Pine Paiute Tribe of the Owens Valley set forth in their comment letter of July 23, 2012, that the approval of the pending geothermal leases and the opening of the entire HGLA to geothermal development will have irreversible and significant impacts on this ethnographic landscape and the interconnected sites located within. We also support the Tribe's call for an Ethnographic Landscape Analysis to be included as part of the BLM's EIS within an added "Native American Issues and Concerns" section and that this Analysis follow the guidelines set forth by the Advisory Council on Historic Preservation on Native American Traditional Landscapes and the Section 106 Review Process.	See Response to Comment DD-2.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-11	We recommend the species occurrence description be updated to include observations of Desert tortoise and Mohave ground squirrel.	The DEIS/PA acknowledges that desert tortoise and Mohave ground squirrel are sensitive resources that are known to occur within the HGLA. Stipulations have been identified both in the DRECP LUPA and the HGLA EIS to protect these resources under all alternatives. Additional stipulations may be implemented depending on the potential impacts evaluated as a result of a site-specific proposal and NEPA evaluation. The inclusion of additional occurrence data would not affect the decision-making process by the BLM for geothermal leasing within the HGLA. Also, see Common Response #3.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-12	BLM should identify areas within the DFA that should be designated for no-surface occupancy based on the presence of the desert tortoise and Mohave ground squirrel as documented through additional field surveys, the California Natural Diversity Database and the results of P. Leitner's Mohave ground squirrel surveys in support of the EIS for geothermal leasing in the Coso KGRA.	Alternative B allows geothermal leasing, exploration, and development throughout the entire HGLA, but with NSO stipulation in sensitive areas. See Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-13	BLM needs to include a focused analysis of the use in the area of the HGLA, particularly as it relates to off-road vehicle use. Our concern relates to the fact that current open routes could be closed if geothermal projects are constructed within the HGLA area, potentially displacing off-road vehicles into currently undisturbed habitat. Because the Eastern Sierra SRMA's goal (stated above) focuses on maintaining the natural character of the landscape, industrial development in the HGLA coupled with the potential additional routes from displacement of existing routes will degrade the experience for which the SRMA was established.	See Common Response #1.
Consolidated NGO Comments-Amargosa Conservancy, et al.	EE-14	As part of the analysis requested above, BLM needs to also analyze the cumulative fragmentation of wildlife habitat that would result of industrial geothermal installations and new roads were constructed in the area. The HGLA may fall within key wildlife connectivity areas as identified in the Desert Linkages report and this important issue needs to be fully addressed in the supplemental NEPA review.	See Common Response #1.
Center for Biological Diversity	FF-1	Unfortunately, the DSEIS fails to adequately address several issues including, most importantly, the inconsistency of Alternatives A and B with critical resource conservation goals, the limited water availability in this area, and impacts of water use for the proposed leases on other resources.	The BLM does not agree that Alternatives A and B are not consistent with critical resource conservation goals. Both of these Alternatives provide for protection of resources through the implementation of stipulations and/or a No Surface Occupancy requirement. See Common Response #2.
Center for Biological Diversity	FF-2	Impacts to water resources and the lack of any reasonable justification for BLM's rejection of a requirement for dry-cooling technology in order to conserve water in this arid region is not adequately analyzed.	See Common Response #3 and Section 2.3.1 of the DSEIS/PA and FSEIS/PA.
Center for Biological Diversity	FF-3	BLM's failure to address potential for land subsidence or other changes due to groundwater extraction.	As described in Section 3.4.2 of the DSEIS/PA, seismic risk evaluation will be conducted for specific project proposals. Also, see Common Response #1 and Section 2.3.1 of the DSEIS/PA and FSEIS/PA.
Center for Biological Diversity	FF-4	BLM's failure to ensure long term groundwater monitoring and management with effective triggers to prevent overdrafting of the already heavily utilized Rose Valley aquifer, including an analysis of off-site impacts of waters that wildlife rely on.	See Common Response #2.
Center for Biological Diversity	FF-5	BLM's failure to take a hard look at the displacement of recreational activities including designated routes in the DFA if/when industrial geothermal facilities and their requisite fences are constructed and lead to the creation of new unlawful routes.	See Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Center for Biological Diversity	FF-6	BLM's failure to adequately identify and analyze displacement of rare and threatened wildlife by geothermal development, including Mohave ground squirrel in core habitat, and the fragmentation of the habitat.	See Common Response #1 and Section 4.7 of the FSEIS/PA.
Center for Biological Diversity	FF-7	BLM's failure to identify and analyze impacts to wildlife connectivity between the Coso Range and the southern Sierra Nevada Mountains due to the construction of industrial projects in the DFA.	See Section 4.7.2.1, pages 4-60 of the DSEIS/PA refers to general habitat fragmentation, which is adequate for this planning level assessment and decision. Also, see Common Response #1
Center for Biological Diversity	FF-8	BLM's failure to fully consider mitigation measures for these and other impacts.	Best management practices, mitigation measures and reclamation performance standards are provided in detailed in Appendix A of the DSEIS/PA .
Center for Biological Diversity	FF-9	For example, the DSEIS fails to adequately explain why dry cooling is not required in any alternative. Many modern geothermal facilities (including many in similar ecosystems in Nevada), are closed-loop and dry-cooled.	See Common Response #3, Response to Comment L-14, and Appendix B of the FSEIS/PA.
Center for Biological Diversity	FF-10	BLM does not appear to have fully investigated the potential impacts to surface and groundwater which can be wide-reaching. For example, good data exists on the impacts to surface thermal water features of the Long Valley caldera, near Mammoth, California from development of geothermal production in this area.	See Common Response #3.
Center for Biological Diversity	FF-11	It is also imperative that BLM take a hard look at the potential impacts of geothermal development before designating the HGLA and approving any leases because post-lease or post construction mitigation measures are of limited utility and have not been shown to be able to mitigate the impacts once a geothermal project is built and running.	See Common Response #1.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Center for Biological Diversity	FF-12	Second, even when it is feasible to detect impacts, by the time those impacts are detected, it may be too late to mitigate them. Thus, even if the most extreme mitigation measure of a temporary cessation of pumping and reinjection were to be selected as mitigation as part of adaptive management, it is not clear that this would prevent impacts. It can take years or even decades for aquifers to recover from depletion or significant perturbation. Since groundwater-dependent ecosystems are entirely reliant on discharge of groundwater for their life and reproductive cycles, even one season of reduced spring flows could result in catastrophic population declines for spring dependent species. There is no realistic mitigation for impacts to thermal features; such impacts are inherent in the technology. In sum, the potential for BLM to impose a suite of marginally effective mitigation measures after the fact cannot be used as a substitute for adequate analysis of impacts of development in the HGLA before making a decision. The needed additional analysis must include analysis of at least one alternative that would both be consistent with existing planning and require measures such as dry-cooling and closed loop operations to minimize water use for all development.	See Common Response #1.
Center for Biological Diversity	FF-13	However, unless BLM undertakes additional analysis of impacts to surface and groundwater resources and also modifies Alternative C (or considers a new alternative as suggested above) to require additional protective measures, most importantly dry cooling and closed loop operation to reduce impacts to water resources, BLM must reject all of the action alternatives in the DSEIS and choose Alternative D (No Action).	See Common Response #3 and Response to Comment L-14.
Basin and Range Watch	GG-1	The EIS does not review a dry cooling only alternative. Dry-cooling can be the difference between a couple hundred acre-feet of water and thousands of acre feet of water. In an arid region like this, this should be the only alternative considered.	See Common Response #3, Response to Comment L-4, and Appendix B of the FSEIS/PA.

COMMENTER NAME	COMMENT ID	EXTRACTED/SUMMARIZED COMMENT	RESPONSE
Basin and Range Watch	GG-2	Degrading surface water quality by increasing erosion and sedimentation, or altering spring discharged water chemistry, it could alter water quantity by reducing spring discharge rates, decreasing groundwater supply, or interfering substantially with groundwater recharge, it could alter surface or geothermal water temperatures.	See Common Response #2.
Basin and Range Watch	GG-3	The project would potentially impact 33 rare or sensitive plants, desert tortoise and the Mojave ground squirrel. Also this species list does not include the possibility of the Panamint alligator lizard (*Elgaria panamintina*) inhabiting the area. There is a confirmed Panamint alligator lizard sighting from Haiwee Springs, in the Coso Range, not far from the proposed project site. Panamint alligator lizards are BLM sensitive species and the sighting occurred in 1993.	The BLM used the current existing scientific data to inform the development of the DSEIS. Current existing scientific data does not support sightings of the Panamint alligator lizard (*Elgaria panamintina*). When the BLM receives a proposal for development, species-specific surveys will be required.
Basin and Range Watch	GG-4	The Visual Resources analysis fails to provide good Key Observation Points (KOPs). In fact, the supplemental provides absolutely no KOPs. The project should not even be considered on VRM Class II lands. Geothermal projects cannot maintain this objective. This kind of development would also be inconsistent with VRM Class III Objectives which are to partially retain the existing character of the landscape. The size of these projects completely alter the view. There would be no partial maintaining of the VRM Class.	See Common Response #1.

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Z3.0 ORIGINAL BRACKETED COMMENT LETTERS

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LETTER A

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August 2, 2012

VIA EMAIL

Bureau of Land Management
California Desert District Office
Attn: Peter Godfrey, HGLA Project Manager
22835 Calle San Joan de Los Lagos
Moreno Valley, CA 92553

Re: Comments on Draft Environmental Impact Statement for the Haiwee Geothermal Leasing Area and California Desert Conservation Area Plan Amendment

Dear Mr. Godfrey:

We are writing on behalf of California Unions for Reliable Energy regarding the Draft EIS and Draft Proposed Amendment to the California Desert Conservation Area Plan for the Haiwee Geothermal Leasing Area ("HGLA"). The BLM has identified Alternative C as the preferred alternative in its NEPA analysis. Alternatives C and D would open the HGLA to geothermal exploration *and* development.

We appreciate the work that BLM has invested in this process, and we enthusiastically support the efforts of the Obama administration to develop renewable energy. These efforts have helped dramatically expand renewable energy while creating thousands of good jobs. We want to see the Obama administration continuing to expand renewable energy and create jobs in a way that is environmentally sustainable over the long term.

However, we are concerned that the BLM intends to use the proposed EIS to approve future development proposals and grant exceptions to the proposed list of lease stipulations. The BLM's use of the proposed EIS in this manner would permit environmental impacts to occur that were not evaluated in a NEPA document. The 1
BLM must affirmatively require all future development proposals to conduct subsequent NEPA review.

NEPA declares it a matter of federal policy to preserve important historic, cultural and natural aspects of our national heritage. To achieve this goal, NEPA requires that agencies take a "hard look" at the environmental consequences of a proposed action.[1] "General statements about 'possible' effects and 'some risk' do not constitute a 'hard look' absent a justification regarding why more definitive information could not be provided."[2] An EIS must account for the "specific impacts" of a project.[3] 1 (Con't)

If the BLM relies on the proposed EIS to approve future development proposals, the BLM will not be taking a hard look at the project's "specific impacts." In fact, the Draft EIS admits that "it is difficult to quantify specific, direct impacts . . . on locations or specific resources."[4] Specifically, impacts to air quality, wildlife- and plant-species, surface waters, traffic, and mineral resources may not be accurately assessed without specific project construction and development information.[5] Because it is impossible for the Draft EIS to take a "hard look" at the specific impacts of a future geothermal project, the BLM must require subsequent NEPA review when specific development projects are proposed.

In addition, the BLM must require that all exceptions to the proposed lease stipulations be supported with subsequent NEPA review. As described in the Draft EIS, a lease stipulation is a condition of lease issuance that identifies processes or requirements that the lessee shall follow during all phases of the lease.[6] The proposed lease stipulations included in the Draft EIS protect sensitive resource areas, sensitive species and their habitats, historic properties and water resources from impacts associated with future geothermal development.[7] If the BLM grants an exception to any of these lease stipulations, it must take a "hard look" at the environmental consequences of its action.[8] 2

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[1] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989); *Dubois*, 102 F.3d at 1284 (1st Cir. 1996); *see also* S. Fork Band Council of W. Shoshone of Nev. v. U.S. Dep't of the Interior, 588 F.3d 718, 727 (9th Cir. 2009).
[2] Neighbors of Cuddy Mountain v. U.S. Forest Serv., 137 F.3d 1372, 1380 (9th Cir. 1998).
[3] Muckleshoot Indian Tribe v. U.S. Forest Serv., 177 F.3d 800, 810 (9th Cir. 1999).
[4] Draft EIS, p. 4-2.
[5] *Id.* at p. 4-15, 4-60, 4-113, 4-136, 4-187.
[6] Draft EIS, p. 2-28.
[7] *See id.* at pp. 2-29 to 2-44.
[8] *See* Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989); *Dubois*, 102 F.3d at 1284 (1st Cir. 1996); *see also* S. Fork Band Council of W. Shoshone of Nev. v. U.S. Dep't of the Interior, 588 F.3d 718, 727 (9th Cir. 2009).

We request that the BLM affirmatively require all future development proposals to prepare subsequent NEPA review before permits are granted or exceptions to lease stipulations are approved. By faithfully complying with the requirements of NEPA, BLM will help ensure that development of renewable energy on BLM land will be sustainable, and the renewable energy potential of the area will be fully realized. 3

Sincerely,

Robyn C. Purchia

RCP:clv

LETTER B

Defenders of Wildlife
Sierra Club
Kerncrest Audubon Society

August 2, 2012

Peter Godfrey, HGLA Project Manager
California Desert District
Bureau of Land Management
22835 Calle San Juan de Los Lagos
Moreno Valley, CA 92553
(Via email: pgodfrey@blm.gov)

Re: Comments on Draft Environmental Impact Statement for the Proposed Haiwee Geothermal Leasing Area

Dear Mr. Godfrey:

Thank you for the opportunity to review and provide comments on the Draft Environmental Impact Statement (DEIS) for the Proposed Haiwee Geothermal Leasing Area (HGLA). These comments are submitted on behalf of Defenders of Wildlife ("Defenders'), the Sierra Club and the Kerncrest Audubon Society.

Defenders is a national conservation organization with 1.1 million members and supporters nationally, including 67,000 in California. Defenders is dedicated to protecting all wild animals and plants in their natural communities. To this end, we employ science, public education and participation, media, legislative advocacy, litigation, and proactive on-the-ground solutions in order to impede the accelerating rate of extinction of species, associated loss of biological diversity, and habitat alteration and destruction.

The Sierra Club is a national nonprofit organization of approximately 1.3 million members and supporters (approximately 250,000 of whom live in California) dedicated to exploring, enjoying, and protecting the wild places of the earth; to practicing and promoting the responsible use of the earth's ecosystems and resources; to educating and enlisting humanity to protect and restore the quality of the natural and human environment; and to using all lawful means to carry out these objectives. The Sierra Club's concerns encompass protecting our public lands, wildlife, air and water while at the same time rapidly increasing our use of renewable energy to reduce global warming.

The Kerncrest Audubon Society is a chapter of the National Audubon Society, representing those members who live in the Indian Wells and Kern River Valleys and the Northern Mojave Desert. They conduct activities that provide opportunities to learn about wildlife, especially birds, and their natural surroundings. The chapter worked with the Ridgecrest Field Office of the BLM to construct a Watchable Wildlife facility at an overlook above Little Lake and conducts field trips to that site and to the lake.

Defenders attended a BLM scoping meeting for the proposed HGLA in Ridgecrest in 2009 and submitted written scoping comments on November 5, 2009. We have reviewed the DEIS for the HGLA and offer the following comments for consideration in preparing a Final Environmental Impact Statement (FEIS):

1. Affected Environment – Land Use Classification

In 2006 BLM approved Alternative B of the West Mojave Plan which amended the California Desert Conservation Area (CDCA) Plan. This decision established the Mohave Ground Squirrel Wildlife Habitat Management Area (WHMA) and designated 136,230 acres of public land to Limited Use Class to provide greater protection of public land habitat for this species. According to the CDCA Plan, Limited Use Class "…protects sensitive, natural, scenic, ecological, and cultural resource values. Public lands designated as Class L are managed to provide for generally lower-intensity, carefully controlled multiple use of resources, while ensuring that sensitive values are not significantly diminished." CDCA Plan, as amended, p. 13.

Comment. BLM should recognize and apply the management standard for Limited Use Class lands affected by the HGLA and demonstrate which of the alternatives meet this standard. Those that do not should be identified as such in the FEIS. 1

2. Wildlife Element of the CDCA Plan – Habitat Management

In addition to the management standards for Limited Use Class lands, management of wildlife habitat and its resources under the provisions of the Wildlife Element of the CDCA Plan relies on two additional primary tools, Areas of Critical Environmental Concern (ACECs) and WHMAs. Resolution of conflicts within a Multiple Use Class relies heavily on applying the management goals and objectives contained in the Wildlife Element in general and those associated with planned management areas such as ACECs and WHMAs. As noted in our scoping comment letter, the BLM's purpose in designating the Mohave Ground Squirrel WHMA in 2006 was to "...facilitate protective management for this species and serve to prevent further declines and assist the CDFG." The two primary goals with respect to the MGS are to: 1) Ensure long-term protection of MGS habitat throughout the region, and 2). Ensure long-term viability of the MGS throughout its range. Record of Decision, West Mojave Plan, 2006.

Comment. BLM should analyze each of the alternatives to determine whether or not they are consistent with the purposes of the Mohave Ground Squirrel WHMA. Those 2
that do not should be identified as such in the FEIS.

Comment. Also noted in our scoping comments, prior to the West Mojave Plan amendments in 2006, BLM had already made commitments for conserving the Mohave Ground Squirrel in Rose Valley which includes much of the Proposed HGLA. In the CDCA Plan of 1980, BLM established the Rose Valley Habitat Management Area specifically for the Mohave Ground Squirrel. According to the CDCA Plan, this 18,000 acre was to be managed to "Protect, Stabilize and/or Enhance Wildlife Values. CDCA Plan, Table 2, Planned Management Areas for Fish and Wildlife. According to our estimate, approximately 11,000 acres of this area is within the Proposed HGLA. The Rose Valley Habitat management Area is nested within the larger Mohave Ground Squirrel management area established by BLM in 2006. These two designated management areas each have management goals and objectives which are complimentary. The Rose Valley plan was to be prepared in cooperation with the California Department of Fish and Game under provisions of the Sikes Act.

Comment. BLM should analyze each of the alternatives and determine whether or
not they are consistent with the management goals and objectives of the Rose Valley 3
Habitat Management Area. Those that do not should be identified as such in the FEIS.

Comment. The management requirements of the Mohave Ground Squirrel WHMA
include not only a one-percent cap on habitat loss, but also a compensatory habitat 4
loss requirement. The latter provision is absent from the description of the existing

regulatory environment. BLM should account for the amount of habitat loss on public lands that has occurred since 2006 and identify how much more habitat could be lost while complying with the one-percent loss threshold. Since the Mohave Ground Squirrel WHMA covers a much larger area than the Proposed HGLA, BLM needs to determine how much additional habitat loss in the Rose Valley area is appropriate considering a variety of factors including cumulative habitat loss, condition and trend and essential habitat linkages for this species. 4 (Con't)

3. Mohave Ground Squirrel Occurrence and Habitat in the Proposed HGLA

The DEIS gives brief description of the Mohave Ground Squirrel in the Rose Valley region in relationship to the Proposed HGLA. The occurrences of this species were based on literature reviews, studies and discussions with agency biologists.

Figure 3.7-1 in the DEIS is a map of "Known Areas of Mohave Ground Squirrel Occurrence." There are no occurrences indicated within the boundary of the Proposed HGLA.

Comment. In April of 1980, BLM published the "Field Ecology Technical Report on the Coso Geothermal Study Area" which was prepared under BLM contract with Rockwell International. Philip Leitner was the lead investigator and author of this report. His field studies included systematic live trapping and opportunistic sightings of the Mohave Ground Squirrel in the Coso Geothermal Study Area, some of which occurred within and adjacent to the proposed HGLA. Live trapping and sightings were reported in Rose Valley immediately east of Coso Junction, west of Highway 395 near the L.A. Aqueduct, near the NAWC boundary near the Coso Gill Station Road, and near the Pumice Mine in the far western portion of the HGLA. BLM should obtain this document and include the occurrence data for this species within the Proposed HGLA in the FEIS. 5

4. Environmental Consequences – Mohave Ground Squirrel

Impacts to the Mohave Ground Squirrel and a process for identifying possible future on-site mitigation are described in the DEIS, Chapter 4, p. 66:

"To reduce these potential impacts to this species a lease applicant shall fund, or share in the private-sector funding of, protocol level surveys for Mojave (*sic*) ground squirrel occupancy. The surveys shall follow protocol acceptable to the CDFG and BLM and shall include suitable habitat within the HGLA. If Mojave (*sic*) ground squirrels are detected, the lease Applicant shall consult with BLM and CDFG to establish additional on-site measures to protect the areas occupied by the Mojave (*sic*) ground squirrel."

Comment. Based on existing information on the occurrence of the Mohave Ground Squirrel in and around the Proposed HGLA, including the BLM-published report "Field Ecology Technical Report on the Coso Geothermal Study Area" we do not consider additional field surveys for this species are necessary or warranted. Existing information on vegetation communities and occurrence of this species in Rose Valley indicate that most of the Proposed HGLA is suitable habitat and occupied by this species. Exceptions would include rocky terrain and steep slopes.

The primary mitigation strategy should be avoidance, followed by impact minimization, and lastly, compensatory mitigation for unavoidable impacts.

Comment. Requiring a permit applicant to conduct protocol surveys for the Mohave Ground Squirrel is not a form of mitigation. Furthermore, the DEIS is vague as to whether or not any additional onsite or offsite conservation measures would be required, and any such measures that could be required in areas occupied by the species. BLM has already established that the entire Proposed HGLA is a conservation area for this species. BLM should clearly articulate how it intends to fulfill its management commitments to conserve this species in the FEIS in consultation with the California Department of Fish and Game.

Comment. Based on our recent field visits to the Rose Valley and the Proposed HGLA, we recommend that the elimination of sheep grazing be considered an effective compensatory action to offset or minimize unavoidable impacts to the Mohave Ground Squirrel and its habitat resulting from geothermal exploration and development.

Comment. Various chapters of the DEIS (e.g., Alternatives, Environmental Consequences) include a reference to "recognized Mojave (*sic*) ground squirrel core habitat." No references are given for this term although we think it is a term used by Leitner (e.g., *in* Current Status of Mohave Ground Squirrel, Trans. West Sect. Wildl. Soc. 44:2008). He delineated areas where the species appeared to persist over time based on results of live trapping surveys conducted since 1998. He cautioned that "core areas" were those geographic areas identified based on limited sampling to date and should not be considered complete or comprehensive, or applicable across the range of the species because they were not based on systematic range-wide surveys.

Comment. BLM carefully and methodically addressed Mohave Ground Squirrel occurrence and habitat suitability across the West Mojave Planning Area in support of the West Mojave Plan and CDCA Plan amendments in 2006. It considered the concept of "core areas" but rejected that in favor of a broader scale occurrence and distribution of the species based on analyses of habitat parameters, including plant composition within areas where Mohave ground squirrel occurrence had been confirmed. We recommend BLM consider and apply the information on Mohave Ground Squirrels contained in its West Mojave Plan, Appendix M, in the FEIS for the Proposed HGLA. We strongly recommend that the concept of or reference to "core areas" for this species be removed. As an alternative, such areas could be considered areas that appear to be important for persistence of the Mohave Ground Squirrel but are based on limited and incomplete data.

Comment. The USGS is working on a habitat suitability model for the Mohave Ground Squirrel under a contract from the California Energy Commission. Their report should be available in the near future. We strongly recommend BLM use this habitat model in refining development exclusion areas in the proposed HGLA proposed under Alternatives C and D.

Comment. Areas proposed for exclusion from exploration and development under alternatives C and D should be modified to include suitable habitat providing habitat linkages for the Mohave Ground Squirrel between Rose Valley and McCloud Flat. It is highly likely the species occurs in bottoms of the larger canyons in the western Coso Range that contain soils and vegetation suitable for burrowing, foraging and shelter. The forthcoming USGS habitat model should help in delineating these areas.

5. Little Lake and Wetlands

We are pleased BLM recognizes the importance and sensitivity of wetlands associated with Little Lake and that approximately 10 acres of surface water at Little Lake are in public ownership.

Comment. Under the provisions of the CDCA Plan, as amended, wetlands including riparian habitat associated with surface and groundwater, are classified as Highly

Sensitive Unusual Plant Assemblages and BLM's stated management policy and objectives for these areas is to:

A. Avoid the long-term and short-term impacts associated with the destruction, loss, or degradation of wetland and riparian areas;
B. Preserve and enhance the natural and beneficial values of wetland and riparian areas which may include constraining or excluding those uses that cause significant long-term ecological damage;
C. Include practical measures to minimize harm in all actions causing adverse impacts on wetlands and riparian areas; and
D. Retain all wetlands and riparian habitats presently under BLM administration wherever high resource values exist and adverse impacts cannot be mitigated.

We recommend that the FEIS address these management policies and objectives and reveal to what extent each of the alternatives would allow BLM to comply with these policies and objectives. Those that are consistent as well as inconsistent with these policies and objectives should be identified as such in the FEIS.

6. Water Resources

The DEIS describes the sensitivity of groundwater underlying Rose Valley and its direct relationship in maintaining Little Lake and its associated biological resources. As BLM is aware, the Hay Ranch Water Extraction and Water Delivery Project, approved in 2009 by the County of Inyo and BLM, consumes approximately 3,000 acre-feet of Rose Valley groundwater annually and is the largest single groundwater extraction operation in the valley. According to the DEIS, the current estimated groundwater recharge for Rose Valley is 5,100 acre-feet. The Hay Ranch project delivers groundwater to the Coso Operating Company's geothermal project within the Naval Air Weapons Station, approximately nine-miles to the southwest of the project's production wells. Pumping and water delivery began in late 2009 and was needed to restore water associated with the steam reservoir which had been depleted by ongoing geothermal operations, resulting in declining energy production.

The DEIS indicates groundwater recharge and extraction within the Rose Valley is nearly balanced or at steady-state, and that any additional consumptive use of groundwater would result in localized or more wide-spread draw downs in groundwater because extraction would exceed natural recharge. Such drawdown of groundwater would eventually cause significant impacts to Little Lake and its wetland resources, including dependent wildlife.

The DEIS indicates that the Reasonable Development Scenario would require groundwater consumption of approximately 20 acre-feet per year for well drilling and dust control and up to 4,680 acre-feet per year for the two geothermal plant operations.

Comment. We are pleased that BLM, in recognition of the sensitive groundwater situation in Rose Valley and public comments, has determined that it is necessary to prohibit or restrict any groundwater extraction in the HGLA for consumptive use in support of geothermal exploration, development and operations. This is especially important considering that BLM has determined that approximately 4,700 acre-feet of water would be needed annually to support geothermal development and operation in the proposed HGLA. There simply isn't enough water available to support any level of development on a sustained and environmentally acceptable basis.

Comment. Given that the Hay Ranch Water Extraction and Water Delivery Project consumes approximately 3,300 acre-feet per year of Rose Valley groundwater, we recommend BLM account for all the additional groundwater consumption in the basin to build a stronger case concluding there is little, if any, additional groundwater available for consumption based on the estimate that the total natural recharge is 5,100 acre-feet per year. According to monitoring reports from the Inyo County Water Department, 8,322 acre-feet of groundwater have been pumped from Rose Valley from 12/25/09 through 6/13/12 in support of the Coso Hay Ranch project.

Comment. Groundwater pumping that has been modeled to cause a maximum of 10% decline to the average annual amount of water flowing into the surface features at Little Lake has already been permitted under Coso Operating Company's Hay Ranch Water Extraction and Delivery Project (CUP 2007-003/Coso Operating Company, LLC). Under that CUP issued by the County of Inyo, Coso Operating Company has been granted permission to pump at their stated needed rate for a limited period of time (2 years and 8 months) at which point the projected impact to wetlands at Little Lake would reach the maximum allowable 10 percent reduction of water flow into the lake environment. Numerous background documents and monitoring reports on this subject may be found at www.inyowater.org/default.htm. In summary, existing levels of groundwater consumption in Rose Valley are already projected to cause a significant adverse impact to the wetland environment at Little Lake. The FEIS should account for this in the analysis of existing and cumulative impacts associated with groundwater consumption.

Comment. Since additional Rose Valley groundwater consumption would result in a negative balance with regard to natural recharge, we recommend that BLM clearly 6
state that under all alternatives, additional groundwater consumption would not be allowed, even for short-term uses associated with exploration, construction and dust control.

7. Cumulative Impacts

Chapter 4 of the DEIS addresses cumulative impacts to biological resources in a general way:

"Concerning listed species, the accelerated loss of habitat, combined with the increased potential for losses of burrowing or slow-moving species, such as the Mojave (*sic*) ground squirrel and desert tortoise, would represent the most significant cumulative impact from the HGLA RFD and other nearby developments. Development consistent with the proposed action, in conjunction with other projects, would diminish habitat availability and quality, and potentially result in the "taking" of these species. Stipulations, permitting requirements, and agreements between the California Department of Fish and Game and the BLM, including compliance with Section 7 of the ESA, could minimize such impacts. However, other existing and proposed developments, such as solar energy projects, typically impact and alter thousands of acres and thus can have significant impacts to local populations of listed plant and wildlife species. The increase in the associated number of roads and transmission lines would result in additional losses from collisions."

Lacking is an accounting of specific direct and indirect impacts of land uses in terms of acres of habitat lost and direct impacts to key species of concern such as the Desert Tortoise and Mohave Ground Squirrel.

Comment. BLM should provide a much more definitive cumulative impact analysis 7
for the affected region that focuses on the Rose Valley extending from Little Lake to Haiwee Reservoir and from the Coso Geothermal field to the base of the Sierra Nevada. We consider it especially important that this analysis account for public land habitat impacts and loss authorized by BLM since the West Mojave Plan amendments

were signed in 2006 establishing the Mohave Ground Squirrel WHMA, as well as those occurring on public lands within the Rose Valley Habitat Management Plan Area since the CDCA Plan was signed in 1980. It is especially important to include habitat loss associated with all of the geothermal support facilities located near Coso 7 (Con't)
Junction and the water pipeline for the Hay Ranch Water Extraction and Water Delivery Project approved by BLM in 2009. Impacts to habitat linkages through the Rose Valley area should be addressed in the FEIS.

8. Alternatives

BLM has proposed five alternatives including "No Action." Some of alternatives call for protection of lands from impacts due to geothermal exploration and development. Such protection would be achieved through "no surface occupancy" designation (Alternative C) or by designating areas "closed and unavailable for geothermal leasing" (Alternative D). Such areas, according to the DEIS, are largely based on Mohave Ground Squirrel "core areas." Alternative B would close the proposed HGLA to geothermal exploration and development and the existing three non-competitive lease applications would be cancelled.

Comment. Considering the Mohave Ground Squirrel habitat conservation requirements stemming from the Mohave Ground Squirrel WHMA in 2006 and the Rose Valley Habitat Management Area in 1980, we strongly recommend BLM develop and analyze an additional alternative that is based on meeting its management goals and objectives for conservation of the remaining habitat for the Mohave Ground Squirrel in Rose Valley including the Proposed HGLA. Conservation alternatives should not be limited to minimizing impacts but should include impact avoidance and additional measures to protect, stabilize and enhance habitat. This is especially relevant considering that BLM has continued to authorize habitat loss in support of various land use activities since 1980 and 2006, such as livestock grazing, new roads and a major water pipeline through Mohave Ground Squirrel habitat in Rose Valley.

Comment. Please expand on the nature and effectiveness of "no surface occupancy" and "closed to geothermal leasing" in the FEIS. Please explain if one is superior in providing protection of sensitive resources or if they would accomplish the same goal. 8
Also please indicate if each would prevent further loss and fragmentation of habitat

due to support facilities such as access roads, pipelines and electrical transmission lines. 8 (Con't)

Comment. Alternatives C and D do not provide protection for Mohave Ground Squirrel habitat linkages through the larger, well vegetated canyons that connect Rose Valley with Cactus Flat and McCloud Flat. These additional linkages should be identified and included in a revised description of Alternatives C and D. 9

Comment. Given there is little or no groundwater available from Rose Valley to support exploration and development of geothermal resources, we believe that Alternative B (no geothermal development) is the most realistic and reasonable one under consideration. BLM's preferred alternative (Alternative C – allow exploration and development with the provision that sensitive areas would be protected by a no surface occupancy stipulation) is inappropriate because there is insufficient water in Rose Valley to support sustained geothermal operations in the proposed HGLA.

Furthermore, given that BLM considered, but rejected air or dry cooling as infeasible under the Reasonable Development Scenario, the rationale for selecting Alternative B as the preferred alternative in any final decision is even stronger.

9. Desert Renewable Energy Conservation Plan (DRECP)

The proposed HGLA is within the DRECP area. Planning for renewable energy development on public and private lands within this area has been underway since 2009. Lead agencies in the planning process include the California Energy Commission, California Department of Fish and Game, U.S. Fish and Wildlife Service and the BLM.

The DEIS for the proposed HGLA contains a single reference to the DRECP and is limited to visual resources affected by the proposed HGLA (*see* DEIS, Chapter 3, page 96). No information is provided on planning for conservation of biological resources or how the proposed HGLA is related to or would be integrated with the decisions stemming from the DRECP once it is finalized.

Comment. The DRECP documents to date include, but are not limited to, the preliminary conservation planning framework and strategy, and associated maps showing areas of high and moderate biological resources sensitivity throughout the planning area. The proposed HGLA is located in a preliminary biological reserve for conservation due to the occurrence of high sensitivity biological resources. In addition, the entire proposed HGLA is located within the area identified for conservation and recovery of the Mohave Ground Squirrel in the DRECP Preliminary Conservation Strategy.

Comment. The planning, analysis and decision processes for the proposed HGLA and the DRECP need to be integrated. Given the importance of the DRECP in providing efficient permitting for appropriate renewable energy projects over an extended time period, we suggest that the geothermal leasing decision for the proposed HGLA could be postponed until such a time as the DRECP is finalized, and such a decision should be consistent with the DRECP. Based on preliminary planning documents under review and consideration for the DRECP, there is a strong indication that the proposed HGLA will be identified as a biological reserve intended to conserve at-risk species and their habitat, and primarily the Mohave Ground Squirrel.

This concludes our comments on the DEIS for the Proposed HGLA. Please contact us if you have questions or need clarification of any issues and our recommendations. We appreciate the opportunity to review the DEIS and provide comments.

Sincerely,

Jeff Aardahl
California Representative
Defenders of Wildlife
jaardahl@defenders.org

Sarah K. Friedman
Senior Campaign Representative
Beyond Coal Campaign
Sierra Club
sarah.friedman@sierraclub.org

LETTER C

DEFENDERS OF WILDLIFE ♦ FRIENDS OF THE PANAMINTS ♦
♦ CENTER FOR BIOLOGICAL DIVERSITY ♦

Via Electronic Mail

Jeff Childers and Peter Godfrey
HGLA Project Managers
BLM California Desert District
22835 Calle San Juan de los Lagos
Moreno Valley, CA 92553
Peter_Godfrey@blm.gov; jchilders@blm.gov

Re: Notice of Availability of the Draft Environmental Impact Statement and Draft Proposed California Desert Conservation Area Plan Amendment for the Haiwee Geothermal Leasing Area in Inyo County, CA; 77 Fed. Reg. 27478 (May 10, 2012).

Dear Mr. Childers and Mr. Godfrey,

We are writing to alert you to a significant omission and inaccuracy in the Notice of Availability for the DEIS published in the Federal Register on May 10, 2012, 77 Fed. Reg. 27478. The Notice published on May 10, 2012 references the earlier September 11, 2009 Federal Register Notice of Intent (NOI) for the Haiwee Geothermal Leasing Area (HGLA), 74 Fed. Reg. 46786, as to the lands that are affected by the action. However, the 2009 NOI did not provide notice of all the included lands, and therefore was erroneous.

The list of public lands the NOI state were being considered for geothermal leasing omits Sections 11 and 12 of Township 22S, Range 37E. These two sections are included in all descriptions of the HGLA in the DEIS, specifically:

- Figure 2.2-1 on page 2-3 of the DEIS. This is a map of the HGLA with Township, Range and Sections identified. Other maps in the DEIS that do not identify Township, Range and Sections show an identical outline of the HGLA.

- Fact Sheet, Appendix E of the DEIS, the Scoping Handouts

- The Document Scope and Leasing Area on page ES-iii of the DEIS

- The Project Overview on page 1-1 of the DEIS.

Because the Notice of Availability for the DEIS does not list the lands being considered in the DEIS but only references the erroneous Notice of Intent, the public has not been properly notified of the actual area under consideration.

To provide proper notice to the public of lands under consideration, the Notice of Availability must be re-published with the correct information regarding the area under consideration in the DEIS and BLM must restart the 90-day review process for the DEIS, to give opportunity for those who may have been misled by the omission of two sections of land affected by the proposal in the NOI to now fully participate in the public process for the action.

Sincerely,

Jeff Aardahl
California Representative
Defenders of Wildlife
jaardahl@defenders.org

Lisa T. Belenky, Senior Attorney
Center for Biological Diversity
351 California St., Suite 600
San Francisco, CA 94104
lbelenky@biologicaldiversity.org

Tom Budlong
Friends of the Panamints
tombudlong@roadrunner.com

Sophia Anne Merk
National Public Lands News
941 E Ridgecrest Boulevard
Ridgecrest, California 93555
samnplnews@yahoo.com

LETTER D

STATE OF CALIFORNIA — Edmund G. Brown, Jr., Governor

NATIVE AMERICAN HERITAGE COMMISSION
915 CAPITOL MALL, ROOM 364
SACRAMENTO, CA 95814
(916) 653-6251
Fax (916) 657-5390
Web Site www.nahc.ca.gov
e-mail: ds_nahc@pacbell.net

June 4, 2012

BLM RIDGECREST FO
7 JUN '12 PM 1:11
REC'D

Mr. Jeff Childers, Environmental Planner
United States Department of the Interior
Bureau of Land Management
300 S. Richmond Road
Ridgecrest, CA 93555

Re: SCH#2012054003; NEPA Notice; draft Environmental Impact Statement (DEIS) for the **"Haiwee Geothermal Leasing Area (HGLA) DEIS/CALIFORNIA desert Conservation Area (CDCA) Plan Project;"** located on 22,805-acres east of the Inyo National Forest , west of the China Lake Naval Air Weapons Station, south of the the South Haiwee Reservoir and north of Little Lake; southern Inyo County, California.

Dear Mr. Childers:

The Native American Heritage Commission (NAHC) is the California State 'Trustee Agency' pursuant to Public Resources Code §21070 for the protection of California's Native American Cultural Resources. The NAHC is also a 'reviewing agency' for environmental documents prepared under the National Environmental Policy Act (NEPA; 42 U.S.C. 4321 *et seq*), 36 CFR Part 800.3, .5 and are subject to the Tribal and interested Native American consultation as required by the National Historic Preservation Act, as amended (Section 106) (16 U.S.C. 470; Section 106 [f] 110 [f] [k], 304). The provisions of the Native American Graves Protection and Repatriation Act (NAGPRA) (25 U.S.C. 3001-3013) and its implementation (43 CFR Part 10.2), and California Government Code §27491 may apply to this project if Native American human remains are inadvertently discovered.

The NAHC is of the opinion that the federal standards, pursuant to the above-referenced Acts and the Council on Environmental Quality (CSQ; 42 U.S.C. 4371 *et seq*) are similar to and in many cases more stringent with regard to the 'significance' of historic, including Native American items, and archaeological, including Native American items at least equal to the California Environmental Quality Act (CEQA.). In most cases, federal environmental policy require that any project that causes a substantial adverse change in the significance of an historical resource, that includes archaeological resources, is a 'significant effect' requiring the preparation of an Environmental Impact Statement (EIS).

The NAHC conducted a Sacred Lands File (SLF) search of its Inventory determined that Native American Cultural Resources **were identified** in several of the USGS coordinates of the project area you specified in Page ES-iii; early and quality consultation with the Native American representatives on the attached list may provide detailed information of sites with which they are aware. Also note that the absence of archaeological resources does not preclude their existence, particularly at the subsurface level.

The NAHC Sacred Lands File Inventory of the Native American Heritage Commission is established by the California Legislature pursuant to California Public Resources Code §§5097.94(a) and 5097.96. The NAHC Sacred Lands Inventory is populated by submission to the data by Native American tribes and Native American elders. In this way it differs from the

California and National Register of Historic Places under the jurisdiction of the U.S. Secretary of the Interior.

The NAHC, pursuant to Appendix B of the Guidelines to the California Environmental Quality Act (CEQA) is designated as the agency with expertise in the areas of issues of cultural significance to California Native American communities. Also, in the 1985 California Appellate Court decision (170 Cal App 3rd 604), the court held that the NAHC has jurisdiction and special expertise, as a state agency, over affected Native American resources, impacted by proposed projects including archaeological, places of religious significance to Native Americans and burial sites

Culturally affiliated tribes are to be consulted to determine possible project impacts pursuant to the National Historic Preservation Act, as amended. Early consultation with Native American tribes in your area is the best way to avoid unanticipated discoveries once a project is underway. The NAHC recommends as part of 'due diligence', that you also contact the nearest Information Center of the California Historical Resources Information System (CHRIS) of the State Historic Preservation Office (SHPO) for other possible recorded sites in or near the APE (contact the Office of Historic Preservation at 916-445-7000).

Attached is a list of Native American contacts is attached to assist you; they may have knowledge of cultural resources in the project area. It is advisable to contact the persons listed and seek to establish a 'trust' relationship with them; if they cannot supply you with specific information about the impact on cultural resources, they may be able to refer you to another tribe or person knowledgeable of the cultural resources in or near the affected project area.

Lead agencies should consider avoidance, in the case of cultural resources that are discovered. A tribe or Native American individual may be the only source of information about a cultural resource; this is consistent with the NHPA (16 U.S.C. 470 *et seq* Sections. 106, 110, and 304) Section 106 Guidelines amended in 2009. Also, federal Executive Orders Nos. 11593 (preservation of cultural environment), 13175 (coordination & consultation) and 13007 (Sacred Sites) are helpful

NEPA regulations provide for provisions for accidentally discovered archeological resources during construction and mandate the processes to be followed in the event of an accidental discovery of any human remains in a project location other than a 'dedicated cemetery. Even though a discovery may be in federal property, California Government Code §27460 should be followed in the event of an accidental discovery of human remains during any groundbreaking activity; in such cases California Government Code §27491 and California Health & Safety Code §7050.5 will apply and construction cease in the affected area.

If you have any questions about this response to your request, please do not hesitate to contact me at (916) 653-6251.

Sincerely,

Dave Singleton

Cc: State Clearinghouse

Attach: Native American Contacts list

Native American Contacts
Inyo County
June 4, 2012

Big Pine Band of Owens Valley Virgil Moose, Chairperson P. O. Box 700 Big Pine , CA 93513 bigpinetribaladmin@earthlink 760- 938-2003 (760) 938-2942-FAX	Owens Valley Paiute	Ron Wermuth P.O. Box 168 Kernville , CA 93238 warmoose@earthlink.net (760) 376-4240 - Home (916) 717-1176 - Cell	Tubatulabal Kawaiisu Koso Yokuts
Bishop Paiute Tribe Chad Delgado, Chairperson 50 Tu Su Lane Bishop , CA 93514 (760) 873-3584 (760) 873-4143	Paiute - Shoshone	Bishop Paiute Tribe Brian Adkins, Environmental Mger 50 Tu Su Lane Bishop , CA 93514 (760) 873-3076	Paiute - Shoshone
Fort Independence Community of Paiute Israel Naylor, Chairperson P.O. Box 67 Independence CA 93526 Israel@fortindependence. (760) 878-5160 (760) 878-2311- Fax	Paiute	Kern Valley Indian Council Julie Turner, Secretary P.O. Box 1010 Lake Isabella, CA 93240 (661) 366-0497 (661) 340-0032 - cell	Southern Paiute Kawaiisu Tubatulabal Koso Yokuts
Timbisha Shoshone Tribe Joe Kennedy, Chairperson 785 North Main Street, Suite Bishop , CA 93514 (760) 873-9003 (760) 873-9004 FAX	Western Shoshone	Timbisha Shoshone Tribe THPO Barbara Durham, Tribal Historic Preservation P.O. Box 206 Death Valley, CA 92328 dvdurbarbara@netscape. (760) 786-2374 (760) 786-2376 FAX	Western Shoshone

This list is current only as of the date of this document.

Distribution of this list does not relieve any person of the statutory responsibility as defined in Section 7050.5 of the Health and Safety Code, Section 5097.94 of the Public Resources Code and Section 5097.98 of the Public Resources Code.

This list is applicable for contacting local Native Americans with regard to cultural resources for the proposed SCH#2012054003; NEPA Notice; draft Environmental Impact Statement (DEIS) for the Haiwee Geolothermal Leasing Area DEIS/CDCA Plan Amendment Project; located on 22,805-acres in southern Inyo County, California but north of Little Lake and west of China Lake Naval Weapons

Native American Contacts
Inyo County
June 4, 2012

Big Pine Band of Owens Valley THPO
Bill Helmer, Tribal Historic Preservation Officer
P.O. Box 700 — Paiute
Big Pine , CA 93513
amargosa@aol.com
(760) 938-2003
(760) 937-3331 - cell
(760) 938-2942 fax

Kern Valley Indian Council
Robert Robinson, Co-Chairperson
P.O. Box 401 — Tubatulabal
Weldon , CA 93283 — Kawaiisu
brobinson@iwvisp.com — Koso
(760) 378-4575 (Home) — Yokuts
(760) 549-2131 (Work)

Bishop Paiute Tribe THPO
50 Tu Su Lane — Paiute - Shoshone
Bishop , CA 93514
(520) 404-7992 - cell
(760) 873-4143 - FAX

Lone Pine Paiute Shoshone Reservation
Melvin Joseph, Chairman
P.O. Box 747 — Paiute
Lone Pine , CA 93545 — Shoshone
(760 876-1034
760-876-8302
(760) 876-8302

Lone Pine Paiute Shoshone Reservation
Kathy Bancroft, Cultural Resources Officer
P.O. Box 747 — Paiute
Lone Pine , CA 93545 — Shoshone
406-570-5289
kathybncrft@yahoo.com
760-876-8302 FAX

This list is current only as of the date of this document.

Distribution of this list does not relieve any person of the statutory responsibility as defined in Section 7050.5 of the Health and Safety Code, Section 5097.94 of the Public Resources Code and Section 5097.98 of the Public Resources Code.

This list is applicable for contacting local Native Americans with regard to cultural resources for the proposed SCH#2012054003; NEPA Notice; draft Environmental Impact Statement (DEIS) for the Haiwee Geolothermal Leasing Area DEIS/CDCA Plan Amendment Project; located on 22,805-acres in southern Inyo County, California but north of Little Lake and west of China Lake Naval Weapons

LETTER E

BOARD OF SUPERVISORS

COUNTY OF INYO

P. O. BOX N • INDEPENDENCE, CALIFORNIA 93526
TELEPHONE (760) 878-0373 • FAX (760) 878-2241
e-mail: pgunsolley@inyocounty.us

July 10, 2012

Mr. Peter Godfrey, California Desert District
Bureau of Land Management (BLM)
22835 Calle San Juan de Los Lagos
Moreno Valley, CA 92553

Mr. Godfrey,

With regard to the Haiwee Geothermal Leasing Area: Draft Environmental Impact Statement (DEIS), the Inyo County Board of Supervisors would like to thank the BLM for the opportunity to comment. Overall, the County supports the development of geothermal energy within our borders and has compiled the following comments for your use in this planning effort.

First and foremost, we are concerned about coordination pursuant to the Federal Land Policy and Management Act (FLPMA) of 1976. County staff provided comments on the Notice of Intent (NOI) for this DEIS in November, 2009. Our main concern at the time was that BLM open the coordination effort with Inyo County for this particular DEIS. To date, no one from the BLM has contacted the County and we hope that we will be hearing from someone at the BLM in the near future. After reviewing the DEIS, we have identified several items that we would like to review with BLM staff. We believe that jurisdiction to jurisdiction coordination is the perfect forum for County staff to help the BLM work through our concerns. Our comments include:

- In Section 1.5.13 (pg. 1-18) Inyo County Water Policy is addressed. In addition to this, Inyo County Code, Chapter 18.77: *Regulation of Water Transfers Undertaken Pursuant to Water Code Section 1810, Sales of Surface Water or Groundwater by the City of Los Angeles, and the Transfer or Transport of Water from Groundwater Basins Located in Whole or in Part Within*, needs to be included. 1

- In Section 3.6.1 (pg. 3-30) General Plan policies WR-1, WR-2 and WR-3 are described, in addition to these Inyo County Code, Chapter 18.77: *Regulation of Water Transfers Undertaken Pursuant to Water Code Section 1810, Sales of Surface Water or Groundwater by the City of Los Angeles, and the Transfer or Transport of Water from Groundwater Basins Located in Whole or in Part Within*, needs to be included. 2

- Section 3.7.1, (pg. 3-55) addresses Applicable Regulations and Plans, Policies/Management Goals. There is no mention of the Inyo County Agriculture Advisory Board. They should be consulted, especially with regard to 3.7.2.1 – Invasive, Non-Native Species, for related programs.

- Section 3.13, (pg. 3-106 – 3 -110) this section should include language addressing the County's General Plan chapter 8.4, Policies on Mineral and Energy Resources.

- It is unclear which parcels are privately owned from Figure 3.16-1 (pg. 3-118). It would be helpful if this illustration is made clearer and an additional illustration of the General Plan designations for each of the privately owned parcels is added. Although the actual exploration and development of geothermal resources in the area may not be conducted on the privately owned parcels, they can still be affected by these activities.

- Section 3.18.2 (pg. 3-123) states that due to the rural setting and a lack of a diverse system of roads . . . the scope of the analysis limited to US 395 and SR 190, we disagree with the lack of analysis of local roads. Please include an analysis of County roads that may be impacted, especially Coso-Gill Station road that is mentioned in 3.18.2. This analysis needs to include any road improvements that may be necessary due to exploration and development of geothermal resources in the area. 3

- In Section 3.19.3.1 (pg. 3 – 130) you can get updated population totals for the County and the CDPs from the 2010 Census. American Community Survey data is also now available for Inyo County and the CDP's. And, specifically, on pg.3-132 the reference to Inyo County's population not growing in the past decade is incorrect if you look at the actual 2000 and 2010 Censuses. Inyo County's population was 17,945 in 2000 and 18,546 in 2010 indicating the population grew 3.3% over the last decade.

- We appreciate your thorough analysis of Socio-Economics and Impacts to Public Services. However, in Chapter 4, Environmental Consequences: Impacts to Public Services, on page 4-157 it states that given the very low population impacts described for the HGLA, correspondingly low impacts on public services can be expected. We would like to point out that with a very low population, impacts, even at a low level, will be felt more greatly than if they are experienced in a densely populated area. More specifically, since Inyo County does have a low population, its public service supplies are not well equipped for increases, however small they may seem. We would like to see this issue better addressed. 4

- In Chapter 4, Environmental Consequences: Impacts to Public Revenues, page 4-158, in light of the uncertainties that have been discussed with regard to geothermal lease payments, which leads to the questionable ability of geothermal energy projects paying for themselves, how will the additional costs to Inyo County for services, including but not limited to police, fire, water and sanitary services, be mitigated? 5

Again, the Inyo County Board of Supervisors would like to thank you for the opportunity to comment. We look forward to a full coordination effort with you, and please keep us up-to-date as this planning effort moves forward. If you have additional questions please contact the County's Administrative Officer, Kevin Carunchio, at (760) 878-0292 or by email at kcarunchio@inyocounty.us

Sincerely,

Marty J. Fortney

Supervisor Marty Fortney, Chairperson
Inyo County Board of Supervisors

CC: Board of Supervisors, Inyo County
Kevin Carunchio, County CAO
Randy Keller, County Counsel
Joshua Hart, Inyo County Planning Director
Bob Abbey, BLM
Jim Kenna, BLM
Captain Lazar, China Lake Naval Weapons Center
Regional Council
California State Association of Counties

LETTER F

BIG PINE PAIUTE TRIBE OF THE OWENS VALLEY

Big Pine Paiute Indian Reservation

July 23, 2012

Attn: Peter Godfrey
California Desert District
22835 Calle San Juan De Los Lagos
Moreno Valley, CA 92553
email: Peter_Godfrey@blm.gov

RE: Comments on the Haiwee Geothermal Leasing Area Draft Environmental Impact Statement

Dear Mr. Godfrey:

Please accept these comments on the Haiwee Geothermal Leasing Area (HGLA) Draft Environmental Impact Statement (DEIS) and Draft Proposed Amendment to the California Desert Conservation Area Plan. The Big Pine Paiute Tribe of the Owens Valley (Tribe) submitted scoping comments for this DEIS on November 10, 2009. The HGLA lies within a region of great cultural importance to the Native American tribes which have occupied or used this area for thousands of years.

The Tribe recommends **Alternative B** for this project: *Close the entire HGLA to geothermal exploration, development and leasing; amend the CDCA Plan to have the HGLA closed and unavailable for geothermal exploration, development and leasing; deny authorization of all pending leases within the HGLA (DEIS, p. 2-1).* The Tribe makes this recommendation based on the long-term adverse impacts geothermal development would have on the ethnographic landscape and on the water resources of Rose Valley and the surrounding region including Coso Hot Springs. The Tribe is concerned that justifications for developing geothermal power plants overemphasize the need for the United States to develop energy alternatives and reduce dependence on fossil fuels, but underestimate the real, long-term consequences of developing such resources. The actual renewability of earth's heat is not well understood. Geothermal 1
plants typically *do* emit some of earth's sequestered carbon dioxide into the atmosphere. After geothermal production is no longer viable, scars remain indefinitely on the land and resources.

Even though specific archaeological sites could possibly be avoided with Alternative C "with no surface occupancy (NSO) in sensitive areas and Alternative D "selective closure of sensitive resource areas within the HGLA for geothermal exploration and development" p. 2-1), these Alternatives do not account for the irreversible significant impacts which geothermal development will have on the ethnographic landscape of the Rose Valley and surrounding

P.O. Box 700 * 825 South Main Street * Big Pine, CA 93513 * Office: 760-938-2003 * Fax: 760-938-2942

important cultural sites: significant multi-component sites in all directions from the HGLA, including the Stahl Site at Little Lake, Fossil Falls Archaeological District , the Sugarloaf Archaeological District, Haiwee Springs, Coso Rock Art District National Historic Landmark, 1
and Coso Hot Springs. This dense concentration of highly significant cultural sites form a (Con't)
discrete region with the HGLA within the center of this cultural landscape.

The ethnographic landscape for the HGLA should be analyzed in a "Native American Issues and Concerns" section of the EIS. The DEIS does not contain such a section which is usually included in EISs for projects in the Great Basin. There is a "*Government-to-Government Consultation with Indian Tribes*" section, but this contains no analysis and is no substitute for an 2
in-depth "Native American Issues and Concerns" section. In addition, the "*Government-to-Government Consultation with Indian Tribes*" section provides incomplete information which should be corrected in the Final EIS. Bill Helmer, Tribal Historic Preservation Officer for the Big Pine Paiute Tribe, attended the field trip to the HGLA on July 21, 2011, but is not listed in the DEIS.

The DEIS states on p. 5-9: "In the discussions noted above [two field trips to the HGLA with tribal representatives], no specific TCPs, archaeological sites, locations of important historic events, sacred sites, sources of raw material used to make tools or sacred objects, or traditional 3
hunting and gathering areas have been identified within the HGLA. In contrast, the idea that the entire landscape is sacred, was expressed. Additionally, no specific sites have been identified as eligible for listing in the NRHP."

However, Mr. Helmer expressed the need for an ethnographic or cultural landscape analysis for the area slated for geothermal development. This is very different from stating that "the entire landscape is sacred." The National Park Service defines *ethnographic landscape* in its Preservation Brief No. 36 (1994): "a landscape containing a variety of natural and cultural resources that associated people define as heritage resources. Examples are contemporary settlements, religious sacred sites and massive geological structures. Small plant communities, animals, subsistence and ceremonial grounds are often components." The National Park Service's Applied Ethnography Program provides this definition for *ethnographic landscape*: "...a relatively contiguous area of interrelated places that contemporary cultural groups define as meaningful because it is inextricably and traditionally linked to their own local or regional histories, cultural identities, beliefs and behaviors" (Michael J. Evans, et al., *Ethnographic Landscapes*: 54 CRM No 5—2001). An Ethnographic Landscape is a sub-category of the National Park Service's "Cultural Landscape," and can be eligible for listing on the National Register of Historic Places.

The EIS should include an Ethnographic Landscape analysis within an added "Native American Issues and Concerns" section. It is recommended that this analysis follow the guidelines in the ACHP's *Native American Traditional Cultural Landscapes and the Section 106 Review Process: Questions and Answers* (ACHP website, 7/11/12):

P.O. Box 700 * 825 South Main Street * Big Pine, CA 93513 * Office: 760-938-2003 * Fax: 760-938-2942

"3) How are traditional cultural landscapes identified in the Section 106 review process?

Traditional cultural landscapes, because they are often a property type such as a district or site, are identified in the same manner in the Section 106 process as other types of historic properties of religious and cultural significance to Indian tribes or Native Hawaiian organizations. The regulations at 36 CFR Section 800.4 outline several steps a federal agency must take to identify historic properties. In summary, to determine the scope of identification efforts, a federal agency, in consultation with the State Historic Preservation Officers (SHPO)/Tribal Historic Preservation Officer (THPO), must:

1. Determine and document the area of potential effect for its undertaking;
2. Review existing information; and,
3. Seek information from consulting parties including Indian tribes or Native Hawaiian organizations.

Based on the information gathered through these efforts, the federal agency, in consultation with the SHPO and any Indian tribe or Native Hawaiian organization that attaches religious and cultural significance to historic properties that may be affected by the undertaking, develops and implements a strategy to identify historic properties within the area of potential effects. Identification efforts may include background research, oral history interviews, scientific analysis, and field investigations.

A federal agency's consultation with Indian tribes or Native Hawaiian organizations is intended to ensure historic properties that may be of religious and cultural significance to them are both identified and appropriately considered in the Section 106 review process. In fact, the Section 106 regulations at Section 800.4(c)(1) require federal agencies to acknowledge the special expertise of Indian tribes and Native Hawaiian organizations in assessing the eligibility of historic properties that may be of religious and cultural significance to them."

Finally, on p. 5-8, it is stated: "Native American Tribes participating in the Scoping Process requested an opportunity for additional involvement, particularly through the Section 106 consultation process (see Section 5.3.8)," although there is no "Section 5.3.8." 4

Impacts to Regional Water Resources

Geothermal energy production involves water, and water in our desert area is precious. Geothermal wells do not last forever, but their effects on regional water resources may be long lasting. The DEIS acknowledges awareness of regional water concerns and examines some existing conditions in the Rose Valley area including current groundwater pumping and its potential adverse effects. In spite of this, the DEIS recommends an alternative allowing HGLA exploration, and potential leasing and development. It is not clear what is meant by this statement made for the preferred and other alternatives, "groundwater extraction for consumptive use would be prohibited." Geothermal energy inevitably removes and through evaporation 5

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"consumes" water from the earth. The Tribe's analysis of the Coso Hay Ranch project shows large projects involving water are inappropriate in the Rose Valley region. 5 (con't)

Potential Impacts to Coso Hot Springs not Analyzed

The Big Pine Paiute Tribe and other tribes requested an analysis of potential impacts of geothermal development in the HGLA on Coso Hot Springs. On p. 4-42 it is stated:

> "Although located more than 10 miles east-southeast from the HGLA, the Coso Hot Springs are addressed in this analysis as a result of their high cultural importance and their listing on the National Register of Historic Places. The Coso Hot Springs are surface manifestations of the Coso geothermal reservoir, although any connection between the hot springs and the reservoir, if one exists, is complex."

However complex, there needs to be an analysis of the undertaking's potential impacts on Coso Hot Springs. Instead, Coso Hot Springs is addressed with one short paragraph with no relevant references (p. 4-50):

> "With regards to the potential impacts to the Coso Hot Springs, any effects to the hot springs from the proposed action are unlikely under Alternative A (or under any of the alternatives). This is due to the distance between the Coso Hot Springs and the HGLA, the likely discontinuity between geothermal resources between the two areas, and the observed isotopic differences in the waters. Moreover, surface manifestations in such hot springs reflect natural seasonal (and sometimes diurnal) variations (Geologica 2007)."

This paragraph has no references except "Geologica 2007," which is not listed in the References section. However, Geologica is the consulting firm which prepares the Coso Hot Springs Monitoring reports for NAWS, China Lake. These reports would not analyze potential impacts to Coso Hot Springs by geothermal development in the HGLA. The statements addressing potential impacts to Coso Hot Springs by geothermal development in the HGLA are unsubstantiated and inadequate for an EIS, especially since Coso Hot Springs has already been adversely effected by nearby geothermal development.

Thank you for considering the comments of the Big Pine Paiute Tribe of the Owens Valley.

Sincerely,

Virgil Moose
Tribal Chairperson

P.O. Box 700 * 825 South Main Street * Big Pine, CA 93513 * Office: 760-938-2003 * Fax: 760-938-2942

LETTER G

STATE OF CALIFORNIA—BUSINESS, TRANSPORTATION AND HOUSING AGENCY EDMUND G. BROWN Jr., Governor

DEPARTMENT OF TRANSPORTATION
DISTRICT 9
500 SOUTH MAIN STREET
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May 24, 2012

Peter Godfrey, California Desert District
Bureau of Land Management (BLM)
22835 Calle San Juan De Los Lagos
Moreno Valley, California 92553

File: Iny-395-17.87
DEIS
SCH #: none

Dear Mr. Godfrey:

Haiwee Geothermal Leasing Area - Draft Environmental Impact Statement (DEIS)

The California Department of Transportation (Caltrans) District 9 appreciates the opportunity to review the DEIS for geothermal land leasing in southern Inyo County. We have the following comments:

- The only US 395 access noted is via Sykes Road and Gil Station-Coso Road - west and east respectively at the US 395 median crossover (post mile 17.87), both of which are County roads. It appears another possible US 395 access is at postmile 20.35 (east). This is not a County road and we find no record of an encroachment permit. If to be used, an encroachment permit, which will also ensure current standards are met, is required. Please see:

  Encroachment Permit Application:
  http://www.dot.ca.gov/hq/traffops/developserv/permits/pdf/forms/Std._E.P._Application_(TR-0100).pdf

  Encroachment Permit Instructions:
  http://www.dot.ca.gov/hq/traffops/developserv/permits/pdf/forms/encrchpermt_instruc.pdf

  For further information please contact Kurt Weierman at (780) 872-0781 or kurt_weiermann@dot.ca.gov.

- Page 4-180 states that the Inyo Regional Transportation Plan includes reconstruction of Gil Station-Coso Road. Funding for this project, which was noted to "help mitigate impacts," has been transferred elsewhere. Thus, you should consult with Inyo County regarding roadway impacts/mitigation.

Please continue to forward project information. We value a cooperative working relationship with the BLM in the high desert area. For any questions, you may call me at (760) 872-0785.

Sincerely,

Gayle J. Rosander

GAYLE J. ROSANDER
IGR/CEQA Coordinator

c: Joshua Hart, Inyo County
Mark Reistetter, Caltrans

-----Original Message-----
From: Fox, Timothy H CIV NAVFAC SW, OPDK3/242 [mailto:timothy.h.fox@navy.mil]
Sent: Friday, July 27, 2012 6:12 PM
To: BLM_CA_Haiwee_Public_Scoping
Subject: Naval Air Weapons Station China Lake Haiwee Geothermal Leasing Area DEIS Comments

Thank you for the opportunity to review the Haiwee Geothermal Leasing Area Draft EIS and provide comments. Due to the adjacency of the NAWS China Lake range and the Coso Geothermal Power Plant, we would like to provide comments concerning both mission compatibility and regarding the Coso geothermal field.

*****Mission Compatibility*****

Please consider adding under 1.5 Other Applicable Laws, Plans and Programs:

1.5.14 R-2508 Airspace Complex

The Airspace above to proposed Haiwee Geothermal Leasing Area is part of a 20,000 square mile military special use airspace complex known as the R-2508. Part of the leasing area, adjacent to the Naval Air Weapons Station (NAWS) China Lake land range, lies under airspace Restricted from the ground to unlimited. The majority of the leasing area is under a Military Operations Area which has a floor of 200 feet above ground level. Geothermal development in this area is generally considered compatible with military use of the airspace, however coordination with the military may be required. 1

****Navy Geothermal Program Office (GPO) comments*****

p.3-36, last sentence of 3rd paragraph needs to be changed to read:

The Coso Hot Springs are 1.25 miles east-northeast of the Coso geothermal field. If any connection between the hot springs and the geothermal reservoir exists, it is complex and not understood. 2
- This information is from a complication of work/studies that have been conducted for the GPO regarding the Coso Hot Springs.

p.4-42, last sentence of 1st full paragraph needs to be changed also, since it had the same original sentence, to read:

The Coso Hot Springs are 1.25 miles east-northeast of the Coso geothermal field. If any connection between the hot springs and the geothermal reservoir exists, it is complex and not understood.
- This information is from a complication of work/studies that have conducted for the GPO regarding the Coso Hot Springs.

2

(Con't)

Ground Water issues:

p.3-48, Current Ground Water:

Our concern is how will the water usage for the proposed geothermal projects be monitored in order to differentiate between impacts from the Hay Ranch Water Extraction project and this project. We do not want Hay Ranch Water Extraction project monitoring wells to be triggered by water production from this project. 3

p. 4-185, Section 4.23 Residual Impacts:

the bullet point that reads:
"Potential short-term and local impacts to ground water"
Needs to read: 4
Potential short-term and long-term, and local impacts to ground water. Other sections have both short-term and long-term stated, but this bullet does not.

Respectfully,

Tim Fox
Community Plans & Liaison Officer
NAWS China Lake, CA
(760) 939-9438

LETTER I

From: Miller, John (JFB) [mailto:John.Miller@WATER.LADWP.com]
Sent: Wednesday, August 01, 2012 3:57 PM
To: Godfrey, Peter E
Subject: Draft EIS and Proposed CDCA Plan Amendment for the Haiwee Geothermal Leasing Area in Inyo County, California

Dear Mr. Godfrey:

I am submitting this e-mail to represent the City of Los Angeles Department of Water and Power's (LADWP's) concerns with the proposed Haiwee Geothermal Leasing Area Environmental Impact Statement and California Desert Conservation Area Plan Amendment (Program) as described in the link shown at the bottom of this e-mail. I understand from the link that you are receiving public comments about the Program until August 2, 2012.

LADWP has infrastructure within or near portions of the Haiwee Geothermal Lease Area (HGLA), notably the First and Second Los Angeles Aqueducts, North and South Haiwee Reservoirs and their associated dams, and the Haiwee Power Plant (a hydroelectric generating plant). The attached right-of-way maps show some of LADWP's properties and the route of the FLAA and SLAA within the HGLA. LADWP also has fee title property in or near the HGLA that is being considered for renewable energy generation projects.

LADWP is supportive of the Program as long as the Program's developers meet LADWP's requirements for protecting LADWP's infrastructure. To meet these requirements, the developers should submit their plans for development during their early project planning phases to LADWP for review. LADWP can then issue the necessary stipulations and requirements for the developers to meet before the design phases of the developments starts. LADWP respectfully requests cooperation from the Bureau of Land Management in ensuring that this general process to protect LADWP's infrastructure is met. 1

LADWP also has a general environmental concern which BLM should be made aware of. LADWP owns an approximately 120 acre property in the northern Rose Valley, which includes three wells: two abandoned agricultural production wells, and one recently installed monitoring well. As referred to on page 163 of the Environmental Impact Statement (EIS), LADWP plans to recover seepage water from South Haiwee Reservoir using these wells and pump the seepage water back into the Los Angeles Aqueduct System. Other water gathering activities by LADWP from Rose Valley is possible in future. Page 94 of the EIS also refers to potential pumping from Rose Valley but limits the pumping to the safe yield of the basin. However, it should be understood the basin recharge is currently estimated at about 5,000 acre-feet per year and there are a number of pumping activities currently in Rose Valley. Current pumping activities include pumping by Coso Operating Company for transfer to Coso Range for geothermal projects and a number private domestic well throughout the Rose Valley. Any permitting for additional future pumping from Rose Valley should take into account current and already planned pumping from Rose Valley. Future exploratory drilling activities should take all necessary precautionary measures, along with extensive monitoring activities, to ensure that quality of the water in the aquifers of Rose Valley is not impacted. 2

Thanks for this opportunity to comment on the Program. If you have any questions, please contact me by phone at (213) 367-1035 or by e-mail at john.miller@ladwp.com.

Sincerely,
John Miller
Aqueduct Southern District Engineering, Water Operations Division,
City of Los Angeles Department of Water and Power

http://www.blm.gov/ca/st/en/fo/ridgecrest/haiwee_geothermal.html

LETTER J

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

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Peter Godfrey, Project Manager
California Desert District Office, BLM
22835 Calle San Juan De Los Lagos
Moreno Valley, California 92553

Subject: Draft Environmental Impact Statement for the Haiwee Geothermal Leasing Area Inyo County, California and the Draft Proposed California Desert Conservation Area Plan Amendment (CEQ# 20120132)

Dear Mr. Godfrey:

The U.S. Environmental Protection Agency has reviewed the Draft Environmental Impact Statement for the Haiwee Geothermal Leasing Area Inyo County, California. Our comments are provided pursuant to the National Environmental Policy Act, Council on Environmental Quality regulations (40 CFR Parts 1500-1508) and our NEPA review authority under Section 309 of the Clean Air Act.

EPA supports increasing the development of renewable energy resources in an expeditious and well planned manner. Using renewable energy resources such as geothermal energy can help the nation meet its energy requirements while minimizing the generation of greenhouse gases. While renewable energy facilities offer many environmental benefits, they are not without the potential for adverse impacts. Appropriate siting and design of such facilities is of paramount importance if the nation is to make optimum use of its renewable energy resources without unnecessarily depleting or degrading its water resources, wildlife habitats, recreational opportunities, and scenic vistas.

We have rated the preferred alternative (Alternative C) in the DEIS as *Lack of Objections - Adequate (LO)* (see enclosed "*Summary of EPA Rating Definitions*"). The EPA recommends that the Final EIS include additional clarifying information, particularly related to the mitigation measures for the potential impacts to water resources. Additionally, we recommend that the FEIS include detailed procedures for further NEPA analysis of subsequent site specific projects. Our enclosed detailed comments provide additional information regarding these concerns and recommendations.

We appreciate the opportunity to review this DEIS and are available to discuss our comments. Please send one hard copy and one CD ROM copy of the FEIS to this office at the same time it is officially filed with our Washington D.C. Office. If you have any questions, please contact me at (415) 972-3521, or contact Scott Sysum, the lead reviewer for this project, at (415) 972-3742 or sysum.scott@epa.gov.

Sincerely,

FOR

Kathleen Martyn Goforth
Manager
Environmental Review Office (CED-2)
Communities and Ecosystems Division

Enclosures:
(1) Summary of EPA Rating Definitions
(2) EPA's Detailed Comments

cc: Distribution List

SUMMARY OF EPA RATING DEFINITIONS*

This rating system was developed as a means to summarize the U.S. Environmental Protection Agency's (EPA) level of concern with a proposed action. The ratings are a combination of alphabetical categories for evaluation of the environmental impacts of the proposal and numerical categories for evaluation of the adequacy of the Environmental Impact Statement.

ENVIRONMENTAL IMPACT OF THE ACTION

"LO" (Lack of Objections)

The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

"EC" (Environmental Concerns)

The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

"EO" (Environmental Objections)

The EPA review has identified significant environmental impacts that should be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

"EU" (Environmentally Unsatisfactory)

The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. The EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the Council on Environmental Quality.

ADEQUACY OF THE IMPACT STATEMENT

Category "1" (Adequate)

The EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category "2" (Insufficient Information)

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category "3" (Inadequate)

The EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From EPA Manual 1640, Policy and Procedures for the Review of Federal Actions Impacting the Environment.

US EPA DETAILED COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE HAIWEE GEOTHERMAL LEASING AREA INYO COUNTY, CALIFORNIA AND THE DRAFT PROPOSED CALIFORNIA DESERT CONSERVATION AREA PLAN AMENDMENT, AUGUST 1, 2012

Water Resources

The Draft Environmental Impact Statement indicates that the Reasonably Foreseeable Development Scenario would require water for well drilling, dust control during construction, and makeup water to compensate for evaporative loss during plant operation if the plant designs include conventional cooling towers; however, under the preferred alternative, BLM would prohibit extraction of groundwater for consumptive use. The DEIS states that the source of the requisite water is "currently unknown" (p. 4-45). The DEIS also states that "[w]ater consumption and use would be evaluated during the NEPA process at the project level" (p. 2-53).

> *Recommendation:*
> The FEIS should identify the potential sources of water. We recommend that this discussion
> include consideration of whether it would be feasible to use sources such as wastewater for 1
> geothermal well drilling, injection and power plant operations.

Tiering and "Programmatic Like" Analysis

The DEIS states that the BLM's purpose and need for granting the pending leases is to facilitate appropriate exploration and development of geothermal resources in the HGLA, consistent with the BLM's management of other important resources in the HGLA. The BLM does not authorize any specific energy development or Federal Land Policy and Management Act right of way based on the decisions from this EIS. According to the DEIS:

> Issuance of a lease for geothermal resources lays the groundwork for future exploration and development, but does not confer the right for any activities involving ground disturbance or activities that may impact the resources of the lease area. Any future geothermal project or other energy exploration and development that may be proposed within the HGLA will be evaluated under a separate National Environmental Policy Act analysis on a site and project-specific basis (p. 1-2).

The DEIS does not, however, describe the process, screening criteria, or thresholds that would be used to determine the level of subsequent NEPA analysis.

> *Recommendations:*
> The FEIS should clarify that any subsequent site specific geothermal exploration or development
> projects would require further environmental analysis, which could be conducted through either
> an environmental assessment or an EIS that could tier to the subject FEIS and the BLM's
> Programmatic EIS for Geothermal Leasing in the Western United States (2008). 2
>
> The BLM should elaborate on the process that individual offices will use to determine whether an EA or EIS will be prepared for subsequent projects, and identify the mechanism, screening

criteria, and/or thresholds that would be used to make these decisions. We recommend that consistent standards for determining the appropriate level of NEPA review for individual projects be identified and implemented to ensure that impacts are consistently identified, analyzed and disclosed. 2 (Con't)

Stipulations, Best Management Practices, and Procedures

The extent to which groundwater may be extracted for consumptive use during geothermal operations covered by the DEIS is not clear. For example, Stipulation SA-HGLA-10 states:

> Groundwater extraction for consumptive use during geothermal project operations will be prohibited throughout the entire HGLA, except as allowed under item (c) below (p. 2-42).

The text for stipulation SA-HGLA-10 items (b), (c) and (d), however, all seem to allow consumptive use of groundwater for the exploration and development of geothermal projects.

The DEIS states, on pages 2-12, 2-17, and 2-20, that, for alternatives A, C and D, groundwater extraction for consumptive use may be allowed, with various restrictions. Elsewhere, the document states that, based on public concerns regarding the use and limited availability of groundwater, groundwater extraction for consumptive use would be prohibited under Alternatives C and D (pp. 4-51 to 4-52). These statements seem to be inconsistent. 3

The DEIS also states that, in addition to the various lease stipulations, the BLM may require a number of BMPs as conditions of any lease under the action alternatives, and that the mitigation measures and BMPs proposed in the California Renewable Energy Action Team Best Management Practices and Guidance Manual: Desert Renewable Energy Projects, September 2010 manual have been adopted for this EIS (p. 2-44). Please note that the final version of that manual is dated December 2010.

> *Recommendations:*
> The FEIS should correct any inconsistencies related to consumptive groundwater use in the text of the documents and, specifically, in the Special Administrative Stipulation SA-HGLA-10.
>
> The FEIS should ensure that the BMPs that are adopted from the Renewable Energy Action Team Best Practices and Guidance Manual reflect any changes incorporated in the December 2010 version of that document.

Biological Resources, Habitat and Wildlife

Stipulation CSU-HGLA-2, item e) states that unless otherwise agreed to in writing by the Authorized Officer, power lines shall be constructed in accordance with standards outlined in "Suggested Practices for Raptor Protection on Power lines", Raptor Research Foundation, Inc., 1996 (p. 2-32).

Recommendation:
Include, in the FEIS, the most current practices that reduce the potential for raptor fatalities and injuries from power lines. These practices can be found in the "Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006", Edison Electric Institute, Avian Power Line Interaction Committee and California Energy Commission. 4

Climate Change

Scientific evidence supports the concern that continued increases in greenhouse gas emissions resulting from human activities will contribute to climate change. A report by the California Energy Commission indicates that observed changes in temperature, sea level, precipitation regime, fire frequency, and agricultural and ecological systems reveal that California is already experiencing the measurable effects of climate change[1]. The report indicates that climate change could result in the following changes in California: poor air quality; more severe heat; increased wildfires; shifting vegetation; declining forest productivity; decreased spring snowpack; water shortages; a potential reduction in hydropower; a loss in winter recreation; agricultural damages from heat, pests, pathogens, and weeds; and rising sea levels resulting in shrinking beaches and increased coastal floods.

Recommendations:
The FEIS should discuss the potential impact of climate change on the effectiveness of proposed BMPs, lease stipulations and mitigation measures.

The NEPA analysis for each subsequent site specific project should discuss the potential impact of climate change on that project, and incorporate mitigation measures, as appropriate. The NEPA analyses for subsequent site specific projects should also assess how the projected impacts of each individual project could be exacerbated by climate change. 5

Emergency Planning and Community Right to Know Act, CAA §112(r), and California Accidental Release Prevention Program

The 2008 Geothermal PEIS provides a list of hazardous materials routinely found at geothermal plants. Hydrogen sulfide is a potential toxic gaseous pollutant that could be released during drilling, maintenance or as the result of an accident. The geothermal power plants will have to comply with CAA §112(r), and, as applicable, the Emergency Planning and Community Right to Know Act sections 303, 311, and 312, and the California Accidental Release Prevention Program. Additionally, the County's Local Emergency Planning Committee may require a facility to produce an emergency response plan whether or not such a plan is required under other regulations.

[1] Moser, Susie, Guido Franco, Sarah Pittiglio, Wendy Chou, Dan Cayan. 2009. The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2008-071.

Recommendation:
The FEIS should discuss compliance with CAA §112(r), EPCRA §§ 303, 311, & 312 and the California Accidental Release Prevention (CalARP) program, as applicable. 6

Cultural Resources, National Historic Resources and Consultation with Tribal Governments

The EPA commends the BLM for early consultation for tribal cultural resources as required under Section 106 of the National Historic Preservation Act. The DEIS states that the BLM has initiated government-to-government consultation with the Big Pine Paiute Tribe, the Bishop Paiute Tribe, the Fort Independence Paiute Tribe, the Lone Pine Paiute-Shoshone Tribe, and the Timbisha Shoshone Tribe. EPA has identified additional tribes that may have cultural ties to the project area (see Recommendations, below).

According to the DEIS, the Tribes who have been consulted are concerned about extraction of resources from the land; the benefit to the Tribes from the proposed action; impacts on spiritually important sites; impacts to Coso Hot Springs; the effects of the proposed action on the water table; the need for new transmission lines; and whether the new facilities could prohibit access to traditional lands. They have expressed the perspective that the entire landscape is sacred; that geothermal development in the leasing area could conflict with their traditional values; and that impacts on Native American values are not amenable to mitigation. Also expressed was the desire to have tribal monitors present in the event of any surface disturbing activities (p. 5-8).

Recommendations:
Consider expanding the number of tribes invited for consultation to include the Battle Mountain Band Council, Big Sandy Rancheria, Bridgeport Paiute Tribe, Cold Springs Rancheria, Goshute Business Council, Duckwater Shoshone Tribe, Elko Band Council, Ely Shoshone Tribe, North Fork Rancheria, Picayune Rancheria, Santa Rosa Indian Community, South Fork Band Council, Table Mountain Rancheria, Tule River Indian Tribes, U Tu Utu Gwaitu Tribal Council and the, Wells Band 7

Describe, in the FEIS, the process and outcome of government-to-government consultation between the BLM and each of the tribal governments within the project area, including any issues that were raised and how those issues were addressed in relation to the proposed action and selection of a preferred alternative.

Alternatives Analysis

The Haiwee Reasonably Foreseeable Development Scenario is based on a dual-flash cycle geothermal steam plant design utilizing wet cooling towers for steam condensation. According to the DEIS, the binary plant design was eliminated from further analysis because it utilizes lower temperature geothermal resources than those anticipated to occur within the HGLA. Elsewhere, however, the DEIS states that binary cycle geothermal power plants typically have lower evaporative losses (5 percent) and, to mitigate impacts associated with evaporative water losses, appropriate technologies, such as binary cycle, may be implemented (p. 2-51).

Recommendation:
The FEIS should clarify whether a binary cycle plant may be implemented vice dual-flash steam, and if so, the binary plant design should be carried forward in the analysis. Binary plants typically require less water use and use a low boiling point organic working fluid. 8

Distribution List

Chairman Michael Price
Battle Mountain Band Council

Chairperson Virgil Moose
Big Pine Paiute Shoshone Tribe

Chairperson Elizabeth Kipp
Big Sandy Rancheria

Chairperson John Glazier
Bridgeport Paiute Tribe

Chairperson Robert Marquez
Cold Springs Rancheria

Chairman Ed Naranjo
Goshute Business Council

Chairperson Virginia Sanchez
Duckwater Shoshone Tribe

Chairman Gerald Temoke
Elko Band Council

Chairperson Alvin Marques
Ely Shoshone Tribe

Chairperson Israel Naylor
Fort Independence Reservation

Chairperson Elaine Fink
North Fork Rancheria

Chairman Dale Delgado, Jr.
Bishop Tribal Council

Chairperson Melvin R. Joseph
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Chairperson Reggie Lewis
Picayune Rancheria

Chairperson Ruben Barrios
Santa Rosa Indian Community

Chairman Brandon Reynolds
South Fork Band Council

Chairperson Leanne Walker-Grant
Table Mountain Rancheria

Chairperson George Gholson
Timbisha Shoshone Tribe

Chairman Ryan Garfield
Tule River Indian Tribe

Chairperson Billie Saulque
U Tu Utu Gwaitu Tribal Council

Chairperson Paula Salazar
Wells Band Council

Debbie Flores
Battle Mountain Band Council

Sally Manning
Big Pine Paiute Shoshone Tribe

Gavin Begaye
Big Sandy Rancheria

Justin Nalder
Bridgeport Paiute Tribe

Terry Williams
Cold Springs Rancheria

Annette Harris
Duckwater Shoshone Tribe

Alfreida Jake
Elko Band Council

Cindy S. Marques
Ely Shoshone Tribe

Dennis Mattinson
Fort Independence Reservation

Christina McDonald
North Fork Rancheria

Brian Adkins
Bishop Tribal Council

Melvin Joseph
Lone Pine Community

Samuel Elizondo
Picayune Rancheria

Allen Berna
Santa Rosa Indian Community

Nicholas LaPalm
South Fork Band Council

Cliff Raley
Table Mountain Rancheria

Merv Hess
Timbisha Shoshone Tribe
P. O. Box 1779

Kerri Vera
Tule River Indian Tribe

Juanita Watterson
U Tu Utu Gwaitu Tribal Council

Aurora Aboite
Wells Band Council

LETTER K

Rose Valley Properties, LLC
9590 Prototype Court Suite 200
Reno, Nevada 89521.

Bureau of Land Management, California Desert District Office,
Attn: Peter Godfrey, Haiwee Geothermal Leasing Area
22835 Calle San Juan De Los Lagos
Moreno Valley, California 92553

Subject: Comments on the Draft EIS of the Proposed Leasing of the Haiwee Geothermal Leasing Area

Dear Mr. Godfrey:

Thank you for the opportunity to comment on the Draft Environmental Impact Statement (DEIS) of BLM's proposal to lease the Haiwee Geothermal Lease Area (HGLA) located in Inyo County, California. While Rose Valley Properties, LLC is supportive of competitive geothermal development, we are concerned with the lack of cumulative impacts within the DEIS. Rose Valley Properties, LLC is of the opinion that a competitive bidding process provides the level playing field, and allows for additional revenues to BLM to support the often-lengthy permitting processes, which typically requires additional staff resources.

Furthermore, any development of a geothermal resource in this particular area should be aware the depth of environmental concerns and existing resources that could be impacted by this project, which we have included as an attached comment matrix to this letter.

Rose Valley Properties, LLC is supportive of utilization of BLM lands for renewable energy development, as long as it is accomplished in a competitive, non-discriminatory manner and provides the best use of the renewable resource without significantly affecting other stakeholders. We believe it is incumbent upon the BLM to take in consideration the attached comments to review and address the resources that assures the best use of the land – both in terms of economics and in relation to impacts to the environment.

Sincerely,

Mark A. Casper
Rose Valley Properties, LLC

Haiwee Geothermal Leasing Area Commenting Matrix

Comment Number	Commenter	Organization (If Applicable)	Date	Page	Paragraph	Comment	
1					3	Please provide the specific leases referred to in this Section as an attachment to this EIS.	
2				ES-iii	3	Geothermal lease suitability comes from geological and hydrological studies conducted in the leasing area. It is not clear as to how the determination from this document will classify the pending lease applications suitable for geothermal development.	1
3				ES-iv	2	Please provide the responses to the comments in this section.	
4				ES-iv	5	Alternative A: This document uses the phrase that "maybe water will be allowed for some leasing applications" geothermal projects. All geothermal projects require water for exploration, construction and operation. The language should say "will need water" instead of "maybe allowed".	2
5				ES-v	4	Same comment as Alternative C above.	
6				ES-vi	1	6th line typo – Change KRGA to KGRA	
7				ES-vi	1	The KGRA is term is in wide use today and widely used by geothermal development referencing.	
8				ES-vi	1&2	The terms are Likelihood and assumptions are weak for reasonable foreseeable development.	
9				ES-vii	4	Soils: long term, there would be storm water runoff. A stipulation should be made that pads need to be constructed with a slope to the sump to prevent erosion.	3
10				ES-vii	5	Water Resources: How will water use be monitored? Will water use rely solely on produced water after the wells have been drilled?	4
11				ES-viii	1	Public Health and Safety; H_2S is a safety concern in geothermal use in this area. A plan for H_2S monitoring should be included with the possibility for the use of H_2S abatement or control.	5
12				1-7	6	Please provide a rationale for additional lands within	

						the HGLA having the potential for geothermal resources.	
13				2-9	2	The document needs to include specifics per the Geothermal Resource Operational Orders (GROs) to well spacing and well pad size for proper impacts to the environment. There needs to be a discussion on the waste generated from drilling such as drilling muds and cuttings. Drilling will result in the use of water and in the emission of pollutants that are not accounted for in this document.	6
14				2-9	4	Depending on the size of the pipeline, there could be significant amount of permanent surface disturbance to state protected Mohave ground squirrel and federal protected desert tortoise habitat from the installation of the pipeline. The EIS isn't very clear on if the pipeline will be buried along the roads or will be installed on the surface. There isn't any consideration for disturbed surface of expansion loops. Also, there should be some discussion due to the many transmission lines in the area that the pipeline will need to meet the electrical requirements for electric potential corrosion.	7
15				2-10	1	The amount of days anticipated for drilling each well seems to be estimated for a shallower well than the wells described in the EIS as having to drill deeper for the resource within the HGLA. Please include the number of days for deep well drilling as anticipated.	8
16				2-11	1	The document needs to consider the evacuation of power from the site via substation interconnects and transmission lines. Are the leases contemplated adequate for the evacuation of power from the site? The surface disturbance of the inter-connects and transmission lines must be included in the impact analyses.	9
17				2-25		Geothermal Technologies: The probability of Hydro-fracturing at the proposed depth of the wells in the HGLA should be mentioned and subsequent impacts discussed.	10
18				2-31	Known MGS	The entire HGLA is presumed MGS habitat. Mitigation would still need to be a stipulation for the approval process.	

19				2-33	Cultural	The HGLA is located within the Sugarloaf District (SL) and therefore the CRMP for SL should be followed.	
20				2-36	Biological	Section 7 consultation needs to be initiated by BLM to the USFWS for determination of a Biological Opinion for the HGLA	
21				2-36	Biological	A qualified biologist should be present during all construction projects during all times of year	
22				2-	Biological	Prevention of noxious weeds should be in this section, i.e. equipment & vehicle wash areas, etc.	
23				2-42	SA-HGLA-10	What is Inyo County's "Safe Yield"?	11
24				2-47	Air Quality	The impact analysis requires the impacts of all released pollutants through dispersion modeling. There is no consideration of the drift or the mention of air analyses studies.	12
25				2-53	Water Supplies BMPs	The EIS does not address long-term water of plant operational impacts on existing water supply.	13
26				3-7	GHG	Geothermal is exempt from Cap and Trade, however, geothermal in CA is required to report GHGs to CARB	
27				3-57	Wildlife	The CADFG might require a development of a translocation Plan for the MGS and DT prior to ground disturbance as part of the updated CDCA.	
28				3-57	Wildlife-last bullet	Should add that a biologist be on site during the entire construction period.	
29				3-59	Invasive	There is no discussion of construction equipment transporting noxious weeds into the construction areas. An equipment and vehicle wash area needs to be a stipulation.	
30				3-104	3.11-1 Table	Is the CACA 47464 Water Pipeline for Exploration or Operations?	
31				3-105	3	There needs to be a discussion on the use of BMPs for drilling wastes that are generated.	14
32				3-108	4	Deep Rose has not practiced any dust mitigation BMPs thus far during their construction of the access road and well pad. Stipulations are required for the mitigation of dust generated during construction and then ongoing for the entirety of the project.	15

33					General Comment	Please provide potential impacts and mitigation steps for private and public landholders who have mineral and water rights in areas directly surrounded by the proposed lands to be leased.	16
34					General Comment	Inyo County has evaluated the true groundwater recharge capability of the Rose Valley. No new geothermal development should occur until the recharge to the basin is better known. The county is currently evaluating projects that may have additional impacts to the basin. These impacts also need to be considered in any BLM review.	17
35					General Comment	Drilling geothermal wells within the proposed area could compromise the water quality in the Rose Valley Basin.	

LETTER L

AtoZ LAW | ARNOLD LAROCHELLE MATHEWS VANCONAS & ZIRBEL LLP

garnold@atozlaw.com

July 23, 2012

Bureau of Land Management
California Desert District Office
Attn: Peter Godfree
22835 Calle San Juan De Los Lagos
Marino Valley, CA 92553

Re: Haiwee Geothermal Leasing Area

Dear BLM:

Please address the following comments with respect to the Draft Environmental Impact Statement ("DEIS") for the Haiwee Geothermal Leasing Area ("HGLA"). We represent Little Lake Ranch, Inc. ("LLR") which is the owner of approximately 1200 acres of land located in the southerly portion of Rose Valley, including the body of water known as Little Lake. HGLA consists of approximately 22,805 of BLM administered lands. The southern most boundary of the HGLA is located approximately 7 miles north of Little Lake. A primary concern to Little Lake is the possible utilization of underground water resources within the Rose Valley Aquifer to facilitate the initial exploration for geothermal resources and perhaps later, the development and exploitation of those geothermal resources.

BLM indicates that it has received three applications for geothermal leases covering approximately 4,460 acres. (Page 1-1). Each of the three applications covers land in the northwest quadrant of the HGLA and located just east of Highway 395. (Figure 1.1-3, at page 1-5). BLM indicates that it proposes to grant each of the three leases... "to facilitate appropriate exploration and development of geothermal resources in the HGLA..." (Page 1-2). The DEIS is not entirely consistent, however, in that BLM says that the leases do not authorize any specific energy development based on the DEIS. (Page 1-2). Please describe in greater detail what the specific terms and conditions of any 1

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lease may be so that the actual authorized uses may be assessed at part of the DEIS 1
process, or better yet, a form of the leases that may be granted. (Con't)

Other than the proposed length of the leases, beginning with 10 years for exploration followed by a 40 year term for actual resource development (Page 1-10), the actual terms and conditions of any such leases are not specified other than the leases are supposed to address a variety of factors, including sanitation, water quality, wildlife, 2 cultural resource protection and reclamation. Nonetheless, none of the specific terms or the proposed protections are set forth, even in a general sense. Please provide additional details.

The HGLA is designated as a "Class L" land within the Multiple Use Class ("MUC") of the California Desert Conservation Area ("CDCA"). (Page 1-13). While geothermal generation facilities may be allowed, protection of the natural and cultural resources must be protected.

The HGLA is located in the southern part of Inyo County within the area known as the Rose Valley. Little Lake is located in the southerly portion of Rose Valley and relies on the underground water reservoir known as the Rose Valley Aquifer to supply needed water resources to preserve not only Little Lake, but all of the vegetation and wildlife that depend upon the natural springs and water flow provided by the Rose Valley Aquifer.

The DEIS notes that the BLM published a Final Programmatic EIS ("PEIS") for Geothermal Leasing in the Western United States October, 2008. (Page 1-17). We submitted comments on the draft PEIS, a copy of which is attached. All of the comments and questions raised in connection with the PEIS are equally applicable to the DEIS. Accordingly, please address the comments and questions of the attached letter.

The DEIS indicates that there were originally nine (9) general alternatives evaluated in connection with the proposed exploration and development of the geothermal resources within the HGLA. (Page 2-1). Only five alternatives were actually studied, and with little or no explanation the alternative called "Alternative Geothermal Technologies" was apparently rejected. (Page 2-2). It is peculiar, to say the least, that Alternate Geothermal Technologies would be rejected before there is even an exploration for geothermal resources or without having any knowledge whatsoever of what the nature and type of those geothermal resources might be. 3 The type of technology currently utilized by Coso Operating Company, LLC ("Coso") utilizes one of the most water wasteful technologies available for geothermal development. Yet, this is stated to be the preferred type of technology for the HGLA without seriously addressing alternate technologies that could minimize or completely eliminate the needless waste of valuable water resources. Please explain and justify this decision.

The DEIS indicates that a geothermal lease only provides a restricted or limited right of exploration <u>and development</u>. (Page 2-4). It also states that ground-disturbing 4

activities are not authorized. (Page 2-4). Please specify exactly how such activities are prohibited under the lease and what the "limited rights" to exploration and development 4
may be. What types of development activities would be permitted? (Con't)

The DEIS notes that there are no surface features associated with geothermal activity within the HGLA. (Page 2-5). The DEIS then makes some completely unsupported speculations about what type of geothermal resources may be discovered, how deep they may be, what the size of the power plant may be and what technology would be used to develop the resources. (Page 2-5). Such assumptions are nothing more than mere speculation without any evidence whatsoever to support them. The elimination of alternate technologies for geothermal development should be deferred until actual evidence is compiled through exploration activities and no technology should be eliminated without further analysis.

BLM generally outlines what it considers to be the Reasonably Foreseeable Development ("RFD") related to the HGLA. (Page 2-8). The DEIS does not, however, clearly and succinctly define what the RFD is. In particular, while there are references to exploration and construction activities, there are also many references to resource 5
development which suggest the actual exploitation of the geothermal resource and the production of electricity. The specific limitations on the proposed leases under the RFD must be clearly specified. (Page 2-8).

While the DEIS suggests that no action is currently contemplated or allowed for the development of the geothermal resources, the RFD assumes there will only be two 30-megawatt ("MW") geothermal facilities including fifteen (15) production wells and 6
seven (7) injection wells. If no development is being authorized or analyzed by the DEIS, it is unclear why the RFD would consider future development. (Page 2-8). Please explain.

It is not comforting that BLM asserts that all wells permitted by BLM would protect ground water. (Page 2-9). During the course of the environmental review by the County of Inyo ("County") and by BLM during the authorization for Coso to pump and transport nearly 5,000 acre feet of water per year from the Rose Valley Aquifer, BLM did virtually nothing to insure the protection of ground water. To the contrary, BLM made every effort possible to facilitate the approval of the Coso project to the detriment of Rose Valley and LLR. Please describe what BLM considers to be "standard review 7
methods" for protection of ground water. (Page 2-9).

Why does the RFD assume that dual-flash technology will be used, simply because that is the technology of Coso? (Page 2-10). Coso's facility was designed over 8
twenty-five (25) years ago. It should have anticipated the lack of water supplies to replenish water wasted through evaporation during the cooling process. Nonetheless, when Coso ran out of water, it pushed through a bad water pumping and delivery project based on economic reasons alone, and without any thought of the environmental costs.

Rather than suggest that binary geothermal systems "use relatively less water than dual-flash systems", (Page 2-11) identify the true differential in total water losses through evaporation compared to a fully-contained system. 9

The final environmental impact report ("FEIR") adopted by the County for the Coso project established a threshold of significance at a decline of 10% of water flowing into the surface features as Little Lake. Explain why the DEIS alters this standard by not allowing a decline of "10% or more to the <u>average annual fluctuation</u> of water flowing into the surface features at Little Lake". (Page 2-12). 10

Compare the utilization of water resources under proposed Alternative A at Page 2-12 to the use of water resources under the Preferred Alternative C at Page 2-17. The description of significant impacts set forth of Alternative A is not repeated in Alternative C. Why not? Explain why Special Administrative Stipulations SA-HGLA-10a, b and c are all eliminated in Alternative A, but remain in Alternative C. Explain why SA-HGLA-10d is eliminated in Alternative C. (Page 2-17). 11

Are the Special Administrative Stipulations described in Section 2.6 the sole measures to protect ground water resources within Rose Valley? Why do each of the proposed Alternatives which allow some geothermal leasing have differences with respect to the protection of water resources? 12

The DEIS rejects the possible use of a binary geothermal plant system before any exploration done and before any actual knowledge is obtained with respect to the characteristics of the geothermal resource in the HGLA. No legitimate reason is advanced other than Coso uses a dual-flash plant with wet cooling towers. The evaporative cooling process results in the de-watering of the geothermal resource and may, in the future, depend upon imported water to preserve the resource, much as Coso is attempting to do at present. What are of the impacts of evaporative cooling on a geothermal resource? Would the use of a binary plant, even if less efficient, prolong the life and utility of the geothermal resource? Compare the potential longevity of the power plants using a binary plant compared to dual-flash. Other than the relative proximity of Coso, what is the actual and factual data that supports the speculative premise that the geothermal resource <u>HGLA</u> will be the same or remarkably similar to Coso? (Page 2-25). 13

The DEIS further rejects with no credible evidence or analysis the use, in whole or part, of a dry cooling system. *See* the analysis provided by Ronald DiPippo submitted in connection with the Coso project, a copy of which is attached. While the efficiency of a dry cooled system is reduced in the hot summer months, (Page 2-26) it is entirely feasible and practical in the winter and colder months. No consideration has been given to a combination of dry and wet cooling facilities to materially reduce both the (a) loss of water through evaporation and the degradation of the geothermal system itself or (b) the elimination of the need for any imported water. Where is the analysis that air or dry cooling is not feasible? Nothing more than a consultant's conclusion, without any factual 14

or analytical support, is provided. BLM should take affirmative steps through the DEIS 14
to avoid any argument in the future that the operator needs to import water that would not (Con't)
otherwise be needed through the utilization of a dry cooling system. Further explain BLM's rationale.

The DEIS seems to incorporate certain unspecified standard stipulations from the PEIS and standard stipulations on Form 3200-24A to be incorporated into any leases. (Page 2-28). The DEIS should contain all proposed stipulations in a complete format and not simply refer to other documents, laws or requirements. The public should have immediate access to the stipulations upon the reading of the DEIS alone without having to resort to other documents, some of which may not be readily available.

Similarly, the reader should not forced to read PEIS Chapter 2.2.2 to determine whether BLM can or may allow for an exception, waiver or modification of the standard stipulations. This process should be replicated in full within the body of the DEIS.

SA-HGLA-10(b) should be written in the disjunctive so that consumptive use of
water is allowed <u>only if</u> such use does not exceed safe yield **<u>OR</u>** cause a decline of ten
percent (10%) or more of water flowing into the surface features at Little Lake. (Page 2-
42). Moreover, please better define what is meant by a ten percent (10%) decline of the
"annual fluctuation of water." Provide a specific example to demonstrate what water
reductions would constitute such a decline. How is the decline measured? What is the 15
beginning assumption of the amount of water flowing into Little Lake? How will BLM
determine what the annual fluctuation is? What measurement protocols will be put into
place to ascertain whether the ten percent (10%) has been reached? Why is this standard
different then the standard used in the FEIR adopted by the County?

The Authorized Officer (whoever that may be) should not have an independent ability to allow or not allow the pumping or use of groundwater. Precise standards for any allowable use should be set forth in the DEIS. If a discretionary decision can be made by the Authorized Officer, then some form of appeal or review must be provided to challenge the approval. What information or data will be required to allow the Authorized Officer to make this determination?

Please better define what is considered "development activities" with respect to
SA-HGLA-10(b). Is this limited to the construction and instillation of the power plant 16
facilities but not operation? If operations are excluded, it should be so stated.

With respect to SA-HGLA-10(c) (Page 2-42) see all of my comments above about SA-HGLA-10(b). In addition, the absolute prohibition against groundwater extraction should not be allowed by an "exception." The DEIS must describe the process and procedures to allow and approve an exception. There must also be some form of a review or appeal process. Who will be permitted to approve the exception? On what basis may the exception be allowed or granted?

The utilization of a future decision by the Authorized Officer in lieu of environmental analysis and an impact study is not permitted under NEPA. LLR and no other users of groundwater within Rose Valley should be forced to rely upon the decision of an unspecified person who may lack adequate training and expertise to act upon the requested water consumption.

Why does SA-HGLA-10(d) lack the requirement for a plan of operations together with mitigation and remediation plans as set forth in SA-HGLA-10(c)? (Page 2-43). See 17
all of my comments with respect to SA-HGLA-10(b) above, all of which are incorporated herein.

The use of the terms "water", "groundwater" and other general uses of similar terms need to be further defined. (Page 2-43). Distinctions have to be made between waters emanating from springs, surface waters, irrigation or flood waters, rain water, evaporative water and waters located in or are part of the water, steam or other moistures of the geothermal resource itself. Waters or other fluids in the geothermal recourse could also be considered as "groundwater" as defined in the DEIS. However, the more general interpretation of groundwater would be those portions of the underground aquifer, or levels of the aquifer, which may be available for consumptive use for drinking, irrigation, or other human uses at the surface once it is pumped to the ground. Thus, a better definition of the various sources of water needs to be made in the DEIS and used consistently throughout the document to avoid confusion or misinterpretation.

Similarly, the definition of "wells" needs to be refined. Geothermal production and injection wells may be drilled in connection with the exploration, development or operation of the geothermal resource, but such wells should be confined to those extracting water from the geothermal resource itself. Water wells that are drilled for the purpose of extracting groundwater that would otherwise be available for human consumption or use on the surface of the ground should be dealt with differently.

The DEIS suggests that virtually no "groundwater" will be used or available for exploration, development or operation. For the purposes of this comment letter, "groundwater" will be described as the water within the Rose Valley Aquifer that is generally available for utilization by the surface owners of land within Rose Valley and not waters that which may be contained in or part of the geothermal resource, which I will hereafter call "geothermal fluids" and may mean water, steam or any other fluid matters within the geothermal resource.

It is unclear why SA-HGLA-10(g) would be relevant to the DEIS if use of groundwater is prohibited. Will there be a completely separate and new DEIS prepared and published for comment at the time that development or operation of any geothermal resource is considered? If so, what is the relevance or need to require a "water supply assessment" as part of this DEIS. (Page 2-43). If the suggestion is that the Authorized Officer may alone approve the water supply assessment and allow for the use of groundwater, then this suggestion must be rejected as it is not consistent with the requirements of NEPA. Any consumptive use of water is clearly a potential impact upon the environmental resources of Rose Valley and must be discussed in public. The future delegation of this authority to the Authorized Officer is inappropriate and must be rejected.

SA-HGLA-10(g) suggests that a water budget shall be established. (Page 2-43). The County, as part of the Coso project, has been monitoring underground water levels, recharge and consumptive use for nearly three years. The data derived from such monitoring is entirely absent from the DEIS. While it is obviously critical for a water budget to be established, why does the DEIS ignore all of the data compiled from the
Coso monitoring? Given the amount of data already collected, why does the DEIS not 18
contain an analysis of what the current water budget may be?

SA-HGLA-10(g) further defines the term "Safe Yield" as the amount of precipitation and ground water inflow less the aggregate of surface runoff, evaporation, transpiration and ground water outflow, and that such result must be greater than or equal to zero. The time parameters for determining Safe Yield are not defined such that this formula does not refer to a single year, period of years or any other time element. As noted above, the monitoring related to the Coso project has already compiled three years of data from which it can be determined whether the Rose Valley Aquifer is already in a state of "Overdraft" which would mean that the consumptive use of water from the Rose Valley Aquifer already exceeds Safe Yield. There is no question but that the underground water levels of all of the monitored greenwells in and around the Hay Ranch have been in a steady state of decline since Coso began pumping. The underground water levels are steadily declining, indicating that Safe Yield has already been exceeded. 19

Another fallacy of the alleged water supply assessment is that there is no beginning for baseline timeframe noted. The County has dictated that Coso's pumping must cease on September 1, 2013. How will Safe Yield be defined when Coso's pumping stops? If Coso's pumping has already depleted the Rose Valley Aquifer by 5,000 acre feet per year since Coso began pumping, would be the proposed concept of Safe Yield allow any of the applicants to pump a newly-described recharge amount to prevent the recovery of the Rose Valley Aquifer? What protections are provided to allow the Aquifer to regain its historical underground water levels?

SA-HGLA-10(h) indicates that a new "water monitoring, management and mitigation plan" will be prepared, but that it must only be approved by the Authorizing Officer before the development or use of water resources. (Page 2-43). The DEIS clearly suggests that adverse impacts would arise from the use of groundwater. It is improper and ill-advised to allow the Authorizing Officer alone to approve a mitigation plan with no public comment or review. There are no standards or analysis of impacts or mitigation requirements set forth. As such, the DEIS utterly fails to address how vital resources will be protected. If such impacts, the use of water resources and mitigation measures are not presented in the DEIS, then an entirely new DEIS must be required before any use of water resources is permitted and it is impermissible under NEPA to allow a single administrative person to determine what is allowable and what is not. (Page 2-43).

SA-HGLA-10(l) purports to require the leaseholder to identify water sources and an analysis that the quality and quantity of water available are adequate. (Page 2-44). This, again, is an impermissible delegation of authority. The DEIS must, itself, identify water sources and ascertain whether they are adequate. If the utilization of water resources will cause an impact upon the environment, such impacts must be identified and mitigation measures proposed. The public is given no ability to address the adequacy of water or what effects the utilization of such water may have upon vital public 20
resources including consumptive use by others, and the impacts upon habitat and wildlife in and around the area if such water resources were depleted.

BLM continues to incorporate by reference various documents and mitigation standards that were adopted in earlier studies. (Page 2-44). The public should not be responsible to search various other published documents to determine which, if any, standards are being adopted for use in connection with the projects under review. Please see the Incorporation Statements at Page 2-45. All of the standards and requirements should be set off forth in the DEIS.

The public should not be required to speculate as to which Best Management Practices ("BMPs") will be included as part of the pending project. (Page 2-45). It does not tell us anything to suggest that some of the BMPs will be incorporated into the project requirements based upon some future environmental review. Please list which BMPs will be incorporated and which will not. If BMPs will only be incorporated after future 21
environmental review, then why are they discussed here?

The purpose of the DEIS is to identify potential environmental impacts and to adopt mitigation measures which will reduce or eliminate the impacts. There is no sufficient environmental analysis if the impacts and mitigation members are deferred to some future date, without public input. It is not permissible to delegate the authority to measure or decide which BMPs will be applied to an unnamed and undesignated staff person during so-called site-specific environmental review. (Page 2-46). The public should not need to rely upon staff determinations when the impacts could materially impact the environment and the welfare of all local residents.

The DEIS indicates that "geothermal project developers <u>are advised to incorporate</u> the general BMPs applicable to their site in project site". (Page 2-46). Environmental protection should not be subject to the mere advice by BLM as to what the developers should or should not do. If environmental protections are required, they should be spelled out and enforced through the DEIS, leading to the final environmental document.

The suggestions that flash power plants are more water friendly than binary power plants is questionable. (Page 2-50). The issue is whether the plant uses evaporative cooling processes or dry cooling processes. While dry cooling can be less efficient in

very hot weather, no mention is made of the efficiency of dry cooling in cold weather. 22
The DEIS should provide the facts of using each type of technology, and not provide a biased view against dry cooling or binary systems even though they may not produce over a typical year the same amount of total energy. The issue is whether or not such alternate systems cause less impacts on the environment and perhaps could prolong the longevity of the geothermal plant. The discussion lacks clarity and a full and honest evaluation of the alternate systems. Please clarify and provide more detail.

The entire analysis on pages 2-50 to 2-51 is circular and contradictory. At the end of this section, there is an acknowledgment that evaporative losses may vary from 5% to 33%, but the first portion of the section suggests that flash systems can satisfy 95% of their water needs. Regardless of which portion of the commentary is to be believed, the DEIS should mandate the use of little or no water resources, whether from the underground aquifer or from the geo-fluids themselves. Please explain and clarify.

The DEIS says that planning for water injection should be done in the early stages. (Page 2-52). If the injection relates to simply the geo fluids produced at the site, then there is no issue. However, if the injection philosophy suggests the importation and injection of waters outside the boundaries of the geothermal reservoir, then there is a severe impact upon local resources. Please clarify whether injection is contemplative of only the geo fluids themselves, or if there is a thought of injecting groundwater that is unrelated to the geo fluids or from imported water.

The deferral of any analysis of the use of surface or groundwater for the cooling of a geothermal facility cannot be postponed until a later date. (Page 2-53). Such usage, when considered in light of the permits already issued to Coso, must be absolutely rejected. No consumptive use of water should be permitted within the Rose Valley until
and unless an entire environmental document that discusses such use is properly 23
evaluated and analyzed in an environmental document, subject to full public review and analysis.

The suggestion that flash-steam cycle plants can minimize the use of fresh water is entirely misplaced. See the report from Ron DiPippo in connection with the Coso project. The fact is that the use of evaporative cooling will significantly deplete the water available in the geo fluids and deplete the geothermal resource over time.

We appreciate the comment that sufficient water supply must be guaranteed by an applicant before any lease is approved. (Page 2-53). Such statement, however, seems to be contrary to much of the discussion of the DEIS. How can the public be assured that such condition will be satisfied?

Given the comments for this part of the DEIS, the public can have no confidence in the statement that mitigation measures, stipulations, etc. will be monitored to ensure effectiveness and compliance. (Page 2-54). Who will ensure compliance and what will
the stipulations be? How can any member of the public know that BLM will actually 24

satisfy its stated intent? Once a lease or permits are granted, what procedures will be in place to ensure compliance? 24 (Con't)

The DEIS notes that Coso is currently re-injecting water which Coso asserts as needed for operations. (Page 3-2). The pumped water that is re-injected in Coso is depleting the Rose Valley Aquifer. What is the evidence that such re-injection processes are providing any measurable benefits to Coso? Is BLM considering a similar project in the HGLA if "water is needed" for injection? What is the evidence that any such injection will actually have a measurable benefit?

Mention is made of the Rose Spring towards the northerly boundary of Rose Valley. (Page 3-35). There has been no recent observation of a water discharge from the Rose Spring in perhaps two or more decades. As previously noted in comments to the Coso project, Rose Spring may have been directly affected by the water pumping from the Hay Ranch for agricultural purposes in the late 70s and early 80s. The Rose Valley Aquifer has been recovering ever since the termination of such pumping. Such recovery has now been interrupted by Coso's pumping. It is suggested that Rose Spring could still be an operating spring but for the excessive pumping out of the Rose Valley Aquifer.

The DEIS spends several pages reviewing the Aquifer characteristics in the Rose Valley with a final summary. (Page 3-46). It is extremely surprising that this overview did not consider any of the findings from the recently concluded study of the basin performed by the independent consultant for the County as of the end of 2010. As part of the Coso project, this study was performed by Daniel B. Stevens & Associates ("DBS") that has analyzed the Aquifer properties. The analysis of the impacts from the Coso pumping itself should be more fully analyzed and assessed in accordance with the DBS study and report. Please describe why this report has been ignored or not utilized.

The DEIS contained some inaccurate and misleading reference to the amount of water that Coso is permitted to pump and transfer it to its facilities. (Page 3-48). While Coso was permitted to transport 3,000 acre feet per year beginning in December, 2009, such limit was increased to 4,839 acre feet per year in early 2011. The amount of estimated recharge in the Rose Valley Aquifer has been estimated but is uncertain. The estimated recharge of 5,100 acre feet per year in the DEIS is probably, according to the professional estimates, in the right range, but no one knows for certain. Nonetheless, because of the permitted pumping and transportation of water by Coso, it is certain that virtually all of the recharge in the Rose Valley Basin is already designated for use by Coso, regardless of the other consumptive use of water within the Rose Valley. Thus, Coso's, pumping does not account for merely "a large fraction of the estimated 5,100 acre feet per year annual recharge, it accounts for nearly all of it, if not an excess of the recharge. As such, no further pumping or use of the underground Aquifer should be permitted under any circumstances.

The DEIS admits that the geothermal exploration results for Coso are not readily available in the public domain. (Page 3-51). Please explain why this is an adequate 25 response for the need for an adequate environmental investigation. The assumptions are nothing more than guess work and conjecture. While it is understood, in part, that Coso has proprietary information, it should not be acceptable to deny the public an adequate analysis on environmental impacts based upon the assertion of privilege or confidentiality. Coso has sole use and possession of its geothermal area. It suffers no loss of confidentiality or competitive benefits by the disclosure of its impacts upon the surrounding environment. Indeed, the governing agencies of the Coso operations, namely BLM and the USA military, should have complete access to such information in order to confirm that Coso is not adversely impacting the lands and environment within which it operates. How does the disclosure by Coso harm its profits? 25 (Con't)

The DEIS suggests that the water for the presumed geothermal resource in the HGLA is "meteoric water". (Page 3-54). For the most part, meteoric water is not recharged except over extremely long geological timeframes. As such, the loss of the meteoric water may lead to the loss of the geothermal resource itself. Please explain why the use of evaporative cooling systems should be considered or allowed. In a dual-flash geothermal facility, calculate how much geothermal fluids are produced and what percentage of such fluids are lost through evaporation. How long will it take before the geothermal resource is damaged or affected by the losses? 26

Why does the DEIS suggest that the geothermal fluids may be recharged from the much shallower aquifers within the HGLA? (Page 3-54). Is there any sampling or monitoring evidence to support the same? If not, what is the purpose for the suggestion that such recharge may exist? Provide scientific or factual proof of the assertion and the time needed for recharge.

The comment that there are no permanent "natural" surface waters may be true. (Page 3-62). However, Little Lake, which is just south of HGLA, has existed for thousands of years and is a natural of source of surface water. Fish, amphibians, mammals, birds and other wildlife depend on the existence and perpetuation of Little Lake. This, in turn, depends upon the health of the underground water basin to supply Little Lake. While the relative level of the Little Lake surface can be altered through the control system developed by LLR, it is still a natural body of water. Moreover, Little Lake and its ponds do contain a variety of fish species that depend on the water bodies for their existence. The potential loss of these water sources need to be noted in the DEIS.

The reference to the views from the Little Lake Overlook is largely correct, but perhaps misleading. (Page 3-94). While the location of the HGLA is perhaps five to six miles to the north of the Overlook, it can be easily seen from the Little Lake Overlook and the entire surroundings of the Eastern edge of Little Lake. While the exploration for geothermal resources contemplated by the DEIS would not likely impact, to a material extent, the views, the placement and operation of a geothermal facility within the HGLA certainly could impact views from the Little Lake Overlook and other locations. Perhaps a greater explanation of the view impacts would be warranted.

The DEIS states that the issuance of the three pending lease applications will not
authorize any construction or development of geothermal resources. (Page 4-2).
Nonetheless, there are a multitude of references throughout the DEIS to the
"development" of the resources. While the intent of the DEIS seems to limit its scope to
exploration activities, there is an unnecessary confusion in the document as to whether or 27
not development activities will be permitted or not. Since the form and terms of the
actual leases are not provided, more clarity is demanded. A specific limitation on what
will be allowed within the HGLA should be set forth and all references to the possibility
of future development or construction of geothermal facilities should be eliminated.

The DEIS lists Coso Hot Springs as a "key surface water resource". (Page 4-42). LLR agrees. However, the following comment that the connection between the Hot Springs and the geothermal reservoir as being complex is evasive and incomplete. The monitoring data clearly reflects an immediate and severe link between Coso and the Hot Springs. The DEIS is a continuation of BLM's refusal to acknowledge the link between the geothermal production activities at Coso with Coso Hot Springs.

The identification of groundwater impacts from the current project seem odd, given the allowable groundwater pumping and transportation related to the Coso project. (Page 4-43). Coso has already been given permission to pump all, and perhaps even more than all, of the recharge to the Rose Valley Aquifer. Any additional pumping or usage of such water will not only be substantial, but disastrous. It is further unclear why the DEIS would list an impact as the decline in the productivity of the Coso operations itself. Why is any pumping from the Rose Valley Aquifer contemplated at all. Please explain.

It is more than disturbing that the DEIS acknowledges that the source and amount of water for development and operation of any geothermal facility has not been identified or confirmed. (Page 4-44). The statement that it is unlikely for future projected water needs to come from Rose Valley is also troublesome. Similar to this statement, the environmental studies conducted prior to the development of Coso reflected the likely unavailability of water sources in Rose Valley to supply Coso. Regardless of these cautions, BLM, Navy and County supported the pumping of a huge amount of underground water resources from Rose Valley despite public opposition. No project should be approved without the identification of adequate water resources, particularly in the desert. Please explain the justification for allowing any exploration when the source and adequacy of water resources is unknown and unproven.

A statement that increased groundwater extraction is unlikely to adversely impact the springs of Rose Valley except for Little Lake is not proven. (Page 4-45). A complete inventory of the springs has not been studied nor completed. LLR has further submitted proof that the withdrawal of groundwater, even from lower levels, could well impact the functionality of springs at higher elevations. (See the reports of Andy Zdon, copies of which are attached.)

The DEIS continues to perpetrate the misrepresentation that anyone can determine
what a ten percent (10%) reduction in the current flow of water into Little Lake is. (Page
4-45). There has never been a study or report of what the amount of water flowed into
Little Lake before the Coso pumping began. If the DEIS suggests that such flow is 28
known, please provide the current analysis of what such flows were before the
commencement of Coso's pumping. How does the DEIS propose to determine what will
represent a ten percent (10%) decrease in such flow?

The DEIS suggests that make-up water will be needed to compensate for
evaporative losses during plant operations. (Page 4-45). Some, but not all, of this loss is
due to the evaporative wet cooling towers. No source of water to provide this make-up
water has been identified. Why then has the concept of the dry cooling towers been
eliminated from consideration? How can the BLM possibly consider the granting of 29
further exploration and possible development of geothermal resources when the source of
water is not known? Why are alternative technologies for the geothermal facilities
excluded from consideration?

While the DEIS suggests that the BLM will prohibit or restrict by stipulation any groundwater extraction for consumptive use (Page 4-45), such stipulation is not plainly set forth in the DEIS. Moreover, most of the stipulations are further subject to exceptions or waivers on standards that are not plainly articulated. LLR supports the absolute prohibition of groundwater extractions in Rose Valley beyond those already permitted with respect to the Coso operations. There should be no exception or contingency that could allow otherwise.

The utilization of some minimal groundwater during the exploration phase is not necessarily opposed. (Page 4-46). The amount of groundwater that may be used to drill exploration wells or to control dust during exploration is nominal. While such extremely small amounts of water (i.e. less than twenty-five (25) acre feet per year ("AFY") would not be opposed, any other consumptive use of ground water would impose significant impacts upon the environment.

The DEIS estimates of water consumption during exploration and development is confusing if not contradictory. The DEIS suggest that only ten (10) AFY of water is necessary for each of two, thirty (30) MW geothermal plants (20 AFY for 2) but the DEIS obscures the fact that more water may be necessary during operations. (Page 4-46). Please clarify this difference.

LLR questions the impartiality of the consultants providing estimates and conclusions in the DEIS. The groundwater estimates are provided by the same consultant who analyzed the water resources for the Coso project. It is odd that the exact same consultants would reference their own conclusions from prior studies to support their current conclusions. (Page 4-46). Jill Haizlip, the same consultant used in the former Coso EIR, is now estimating that as much as two thousand three hundred forty (2,340) AFY would be needed per year for a typical thirty (30) MW dual flash geothermal plant.

No such figure was reported in the former EIR when Coso was seeking over four thousand eight hundred (4,800) AFY for its two hundred seventy (270) MW dual flash plant. This estimate is also based upon the presumption that a water cooling system would be used. Such amount of water is clearly not available from the Rose Valley or any other local water source. Why does the DEIS perpetuate a logical impossibility with respect to the amount of water that may be available to operate the geothermal facility using dual flash technology? More importantly, why does BLM reject, without any study 30
whatsoever, the utilization in whole or in part of an air cooling system?

If the use of groundwater for consumptive use is prohibited (Page 4-45), where will the water come from? BLM cannot possibly approve leases which will obviously require water resources when the source of such water supplies has not been identified. The source of any needed water must be identified and confirmed before any 31
discretionary approvals are granted.

It is interesting the Jill Haizlip provides an opinion of the needed make-up water to sustain fluid pressures of two thousand three hundred forty (2,340) AFY for a typical thirty (30) MW dual flash plant. How does that compare to the Coso experience? Is the injection of water at Coso working? Is there any demonstrated proof that the water being injected by Coso is sustaining or improving electricity production? Why is Coso allowed to inject approximately four thousand eight hundred (4,800) AFY for a single one hundred eighty (180) MW power plant (six times the power that Haizlip estimates will be produced), but only uses approximately twice as much injected water as Haizlip estimated)? (Page 4-46).

If the geothermal resource is harmed through water lost through evaporative cooling, why is this process even being considered? (Page 4-46). Why are not alternate technologies being considered, such as air cooling? It has already been demonstrated in 32
other places around the world that air cooling does work, even in hot conditions at a much larger scale then proposed. (See attached reported uses of air cooling).

The injection of cool or cold water from an outside source also has the potential of seriously degrading the geothermal resource by cooling it off. What consideration has been given to this subject? Have the results obtained by Coso been studied to provide answers?

There would be no reduction in geothermal resources if all of the produced geofluids were re-injected. It is only because of the evaporative wet cooling process that there are geofluid declines using a dual flash system. Compare the total amount of energy that could be produced over a much longer period of time using different technologies compared to dual flash. Would an alternate geothermal production model substantially lengthen the expected life of the resource? (Page 4-47).

The statement in the DEIS that the Rose Valley Aquifer "is currently in a near steady-state, recharge to the valley is balanced by discharges" (Page 4-47) is simply wrong and unsupported by the Coso monitoring data. The Coso pumping is causing a net reduction in the water and storage and demonstrates that the Rose Valley Aquifer is in a state of overdraft as a result. The DEIS must present whatever facts or evidence it purports to have in order to confirm this suspected, but unfounded conclusion.

It appears that the company Geologica has produced yet another numerical groundwater flow model called Geologica 2010. (Page 4-49). Why did not Geologica ignore the monitoring data from the Coso project? Why did Geologica ignore the modeled calibration performed by Daniel B. Stevens & Associates ("DBS") that was completed in 2011?

County has already required the cessation of all Coso pumping by September, 2013 to avoid exceeding the ten percent (10%) allowed reduction in water inflows at Little Lake. Pumping cannot resume until the underground aquifer has been completely restored to its pre-pumping levels. (See DBS report and County decision allowing for the continuation of pumping attached.) What impact will this have on the proposed leases?

It is unclear why Geologica was engaged to perform impact studies. The DEIS says that groundwater will not be used for consumptive purposes or will be severely restricted. (Page 4-50). If groundwater will not be used, then there is no reason to have impact studies. Please explain.

Why does the modeling analysis in appendix G assume that there is no other groundwater extraction? (Page 4-49). The fact is that Coso already has a pumping permit. Coso will be compelled to stop pumping to avoid the exceedence of ten percent (10%) water flow reduction into Little Lake in a matter of one (1) year. Obviously, any additional pumping for the Haiwee project would be cumulative and cause an even faster reduction in groundwater flows to Little Lake and the cessation of all pumping. 33

The DEIS also appears to be contradictory. It is unclear what consumptive use is proposed, disallowed or possibly allowed. (Page 4-50). The DEIS states that it would be restricted according to the stipulations, but these stipulations themselves do not authorize a particular amount of allowable pumping or use. The DEIS concludes that any impacts from such consumptive use would be moderate, but there is no way to ascertain the accuracy of the statement. Please confirm under alternative C that no consumptive use of groundwater would be allowed under any circumstances. (Page 4-51). 34

Confirm that under alternative D, all consumptive use of groundwater would be prohibited, without exception or waiver. (Page 4-52). 35

The DEIS describes the other energy projects located in and around Rose Valley. (Page 4-168). Each of such projects uses to a greater or lesser extent groundwater within Rose Valley. Despite earlier comments that the consumptive use of groundwater from Rose Valley will be prohibited, or severely restricted, the DEIS under the cumulative impact analysis states that additional water would likely be needed to sustain operation of the RFD assumed geothermal plans during a thirty (30) year use for life. (Page 4-172). This statements appears to be completely at odds with the remainder of the DEIS and needs explanation or justification.

Coso is already utilizing all of the available recharge and more to replenish the aquifer within the Rose Valley. Coso's project alone will cause Little Lake to lose ten percent (10%) of its water inflows per the previously published numerical groundwater hydrology models ("Hydrology Model"). Thus, there is no more available groundwater to be used, regardless of what new Hydrology Models may be developed by Geological or any other hydrology consultant. All consumptive groundwater use should be absolutely prohibited from or within the Rose Valley.

If Coso were not pumping and transporting groundwater supplies, then the minor groundwater extractions suggested for exploration, construction, dust control and development likely would not cause any significant impacts on water supplies. (Page 4-173). However, The Coso pumping is not hypothetical-it exists and is continuing on a daily basis. Even minor or short term extraction projects such as suggested by DEIS could exceed the allowable pumping permitted to Coso and therefore represent an excessive use of groundwater and may further cause serious water declines at Little Lake.

This similar analysis would apply to each and all of the other projects which may arguably reply upon Rose Valley groundwater for development. By the time the DEIS was published, it was already outdated with respect to the Coso pumping and usage. The three thousand (3,000) AFY limit for Coso's maximum pumping expired one and a half years ago, and Coso has been allowed to pump at a rate of four thousand eight hundred thirty nine (4,839) AFY for a year and a half. According to the Hydrology Model, groundwater flows at Little Lake are not expected to exceed ten percent (10%), but this is based on modeling only and the Coso project is indeed expected to reduce those groundwater flows by a full ten percent (10%). Any additional pumping will exceed the ten percent (10%) limit.

It is unclear why the DEIS refers to the calculated extraction rate of seven hundred ninety (790) AFY for the Revised Groundwater Flow Model prepared by DBS ("Revised Model"). The Revised Model certainly did not suggest that an additional seven hundred ninety (790) AFY would be allowed in addition to the Coso pumping and still not exceed maximum impact levels. (Page 4-173). Please explain the implications and inconsistencies.

Update the DEIS as to the current amount of permitted extraction rate for Coso. (Page 4-173).

Why does the DEIS present simulated impact levels that assume no other extractions? (Page 4-174). The Coso project is a reality and it is occurring on a daily basis. Moreover, Coso's CUP will require it to entirely stop pumping by September 2013 to avoid exceeding the ten percent (10%) reduction threshold. No additional extractions of groundwater can be allowed or permitted without exceeding the stated maximum impact level. Please explain.

The comment that Alternate A, C or D would not degrade groundwater is at best questionable. (Page 4-187). As noted above, the alleged stipulations do not plainly prohibit groundwater extractions to any extent or degree. Without clear and absolute limitations, there is a possibility of water supply degradation. Please amend this sentence.

BLM has reached out to a number of parties seeking comments in advance of the DEIS about its scope. It is noted that many commentators, including the undersigned, requested clarification about the quantity of water that would be needed and that its source be identified. (Page 5-10). Despite these requests, the DEIS has not identified the actual source of any necessary water supplies. Why not? The DEIS is contradictory in part by describing that no consumptive groundwater used will be allowed, other sections seemed to indicate that it is possible. The DEIS generally estimates what amounts of water may be needed under different scenarios, but again fails to identify a viable source. This omission must be corrected.

The balance of this letter will deal with the contents of Appendix G which is the numerical groundwater flow modeling report attached to the DEIS ("New Model"). The New Model has been updated with monitoring data collected from November, 2007 to November, 2009. (Page G-2) It is unclear why Geologica ignored all of the monitoring data collected by County since the inception of the Coso pumping beginning in December, 2009, a period of time over 2 ½ years ago. Moreover, it is also unclear why Geologica would not have used the new data, calibration and simulation models developed by DBS as recently as early 2011. Please explain why the most recent and reliable data has not been used nor any use of the DBS model was incorporated into the New Model. The Appendix G indicates that long term monitoring data was not available at the south end of the valley. (Page G-10). This is simply inaccurate given the monitoring data readily available as part of the Coso project. Please explain and update the entire New Model based upon available monitoring data.

Another fallacy of the New Model is that there is limited groundwater extraction in the Rose Valley. (Page G-15). This totally ignores the Coso pumping and transportation project. Why did Geologica ignore the actual level of current extractions?

Why does Appendix G refer to the Draft EIR for the Coso project from 2008, rather than the final EIR for Coso? (Page G-16) 36

The conclusion reached by Appendix G that groundwater inflows equal or slightly exceeded groundwater outflows during the past five years is suspect. (Page G-17) Does this consider or ignore the Coso pumping? 37

Several references are made to a few independent pumping tests conducted over the proceeding five years, including a 6 ½ day pumping test by LADWP in March, 2009. (Page G-18 and 6-25). The largest pumping test is actually the ongoing pumping by Coso. Again, why is the data ignored or not used as part of the New Model?

The New Model perpetuates some of the same errors that were contained in the original Hydrology Model. For instance, the New Model excludes the water activity occurring beyond the south edge of Little Lake, Coso Springs, siphon well and all of the riparian wetland areas south of Little Lake. (Page G-21) No support or justification is given. Please refer to all of the criticisms of the Hydrology Model provided by Andy Zdon as part of the Coso project, copies of which are attached. Because most of these errors have not been corrected in the New Model, virtually all of the problems and observations remain with respect to the New Model. Please address the deficiencies noted by Mr. Zdon.

Without using the available data, it is no wonder that the New Model does not represent a good study of the Rose Valley Aquifer. Geologica admits as much by noting that the New Model relies upon three short pumping tests rather than all of the intensive monitoring data collected during the Coso project. (Page G-40) Given the significant amount of data now available, there is no excuse for the DEIS to utilize the New Model to assume what the impacts on water resources throughout Rose Valley will be if any or all of the projects are approved.

Geologica repeats the estimate of necessary water provided by Haizlip in 2010 using the wet cooling technology for a 30 MW dual flash power plant would 2,340 AFY. (Page G-42) The DEIS does not provide the calculations or assumptions made by Haizlip to reach this estimate. Please provide the detailed information to determine the same. Moreover, reference should be made to the actual monitoring data from the Coso project which compares the amount of fluids produced versus the fluids re-injected. (See attached.)

Geologica, as part of its hydrology analysis, continues to make unsupported and unsubstantiated claims or conclusions regarding the reduction of geothermal pressures and the ability of geothermal reservoirs to produce for years. (Page G-42) There are no facts, evidence or studies provided to support the conclusions. Moreover, this still does not address the profound question of whether the overproduction of a geothermal resource ultimately shortens the life of the reservoir on a geological scale. Would the reduction of production lead to the prolonged and virtually inexhaustible flow of energy, although producing at a reduced rate currently?

Geologica assumes, again without evidence, that pressure decline could be reduced with greater rates of an injection. Where is the proof of this analysis? (Page G-42) Moreover, would an increased rate of injection by using colder water adversely effect the heat available from the geothermal resource?

The New Model purports to describe potential impacts to existing water well supply yields and the surface features at Little Lake. All of these impacts are based upon a calibrated New Model as of November, 2009, completely ignoring the Coso pumping. (Page G-43) By ignoring the Coso pumping, the entire simulated impacts are entirely worthless because the Coso pumping is a reality and a cumulative impact. How can that possibly be ignored in the impact analysis? Please explain. The impact analysis further completely ignores the forecasted water recovery program proposed by LADWP. This would again cause additional extractions from the Rose Valley Aquifer leaving to even greater and more severe impacts.

The DEIS was released for public comment in May, 2012. It is not only odd, but irresponsible, for the DEIS to suggest that the pumping rates for Coso beginning in December, 2009 are not known or that pumping rates have not yet been established. (Page G-43) Why does anyone bother to read the New Model in light of the obvious omissions and errors?

Before addressing the conclusions reached based upon the projection, note that all of the impact studies completely ignore the actual Coso pumping and the possible pumping from LADWP. (Page G-43) If and when such cumulative consumptive use is added, the impacts from any pumping will be exacerbated to an extraordinary degree and would cause devastating results.

Regardless of the observations above, the simulated impacts nonetheless reflect severe and unacceptable draw downs in the underground water levels of nearby wells. They also reflect a clear and obvious exceedance in the maximum reduction of water flows into Little Lake. (See page G-45 and figures G-12 through G-14)

The DEIS suggests that water could be extracted from a single well at a rate of 1,000 AFY for 30 years without reducing groundwater flow to Little Lake by more than 10%. (Page G-49) No graphic analysis is included Appendix G. Where is the data and where is the proof for this statement? It still ignores the actual pumping by Coso which is well in excess of this assumed pumping rate. Oddly, the New Model suggests that such a minor amount of pumping could still reduce the underground water level at the Little Lake Ranch North Well by 3.5 feet, which is nearly ten times the allowable draw down under the Coso FEIR, as updated and revised by DBS. 38

Has any effort been made to correlate the findings of the New Model with the DBS model? If not, why not?

<u>Conclusion</u>

There is an enormous amount of work that must be done before any final EIS can be approved by BLM. All of the hydrology studies are incomplete and inconclusive. They tend to completely ignore the actual monitoring data produced in the last two and one half years from the Coso project. This is not hypothetical or simulated data, but real data related to pumping rates and the decline in the underground water levels. The data can also be of tremendous assistance in determining all of the parameters that must be considered to develop the New Model.

It is clear that virtually no consumptive use of water from the Rose Valley can or should be permitted under any circumstances. While an extremely small amount of water could probably be pumped and used for nothing more than exploratory purposes, in the range of less than 50 AFY over the life of the exploratory process, no other water usage should be allowed or permitted under any circumstances. Not only would such consumptive use exceed the threshold limits at Little Lake, but they could have a devastating impact upon the floral and fauna around the Rose Valley and Little Lake property in general.

It is submitted that the New Model must be entirely reformulated to account for the new monitoring data and resubmitted for public consideration. Moreover, the New Model must take into consideration the actual pumping being conducted by Coso at the current pumping rates over the life of the CUP issued by the County. Finally, the New Model should take into consideration the likely water reclamation project proposed by LADWP to avoid excessive pumping.

Very truly yours,

ARNOLD LAROCHELLE MATHEWS
VANCONAS & ZIRBEL LLP

Gary D. Arnold

GDA:hp

cc: Little Lake Ranch

LETTER M

TOM BUDLONG
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Thursday, July 26, 2012

Jeff Childers, Peter Godfrey
HGLA Project Managers
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Dear Mr. Childers and Mr. Godfrey,

An Aside

Reading between the lines, I suspect HGLA DEIS has been caught up in BLM's desire to reduce, and perhaps the embarrassment of, the backlog of pending geothermal leases. Ignored, perhaps, is the detail that the three pending leases are abnormal, and that their status as 'pending' is an artifact of the proponent and its lack of specific proposal, not of the BLM.

The three leases and Deep Rose have a common proponent. Deep Rose is getting to be an old issue. It proposes very expensive deep drilling with little confidence and unknown probability of success. It's a wild-cat venture with no good way to measure risk. Understandably, the proponent has not been aggressive.

The same Deep Rose people are behind the three leases. The leases are the same character and risk as Deep Rose - speculative and risky because of the probable deep resource, if any. The risk and expense explain the lack of aggressive prosecution of the leases.

Meantime, with no specific proposal from the lease applicants, BLM is paying for the HGLA DEIS process. Normally EISs are paid for by a proponent. Essentially the BLM is using BLM's scarce resources where the proponent does not have confidence to use its scarce resources. This appears unwise. Of course an underlying suspicion is that the proponent is having difficulty getting the resource to fund the EIS.

The BLM should figure a way to make the proponent propose a configuration and pay for an EIS, or postpone indefinitely until that happens. Reducing the backlog is a minor issue.

Comments on the HGLA DEIS

Please accept these comments on the Haiwee Geothermal Leasing Area DEIS, BLM/CA/ES-2012-005+1793, DOI No. 12-6.

NEPA – Rigorous Evaluation

The DEIS analyzes potential impacts from an assumed power plant configuration, not a specific configuration. Since the DEIS does not and cannot assure that an actual power plant will be the same as the assumed power plant, it cannot do a rigorous impact evaluation. In fact, data from the exploration phase of a project is used to drive the design of the production plant. Without exploration data, the assumed configuration is no more than a guess. Thus, alternatives A, C and D, which describe a fictitious development, could lead to ground disturbing activities that have not been rigorously analyzed for environmental impacts.

This presents a fundamental problem. NEPA requires rigorous evaluation, and it is impossible to perform this NEPA's requirement without a specific proposal from an applicant. A fictional design won't do.

Because BLM is responding to an assumed configuration (2 ea 30MW plants) and is not responding to an actual configuration at a specific location, the DEIS includes such statements as:

- 'In the absence of quantitative data, impacts are described based on professional judgment…'
- "This chapter identifies explicitly all impact projections based on incomplete information or best professional judgment."
  (These appear in the DEIS Incomplete or Unavailable Information section, page 4-3, section 4.1.3)
  The second quote is irrational. Incomplete information and professional judgment cannot foster explicit projections. The same paragraph points out that BLM is using the 'best available information',

which, for lack of specificity, cannot substitute for real information when making the rigorous evaluation NEPA requires. Note that unreliable information could qualify as the 'best available' information.

It's inadvisable, perhaps even reckless, to generalize several of the more important environmental aspects. A specific proposal is needed to be explicit. In fact, since the plant can't be designed / specified without exploration, the development phase should be subject to a separate or revised EIS to analyze the impacts of whatever power plant design is indicated from exploration data.

Some of the categories where impact analysis can't be rigorous without a specific site proposal:

- Water: One of the large unknowns of this project is water availability. The DEIS states the source is unknown. The aquifer is fully allocated. The plant design can be radically different depending on water availability.
- Cultural: The HGLA area is culturally rich. Cultural density is never uniform. Until a site is chosen by a proponent, the level of impact to cultural resources can't be known without analyzing all the HGLA, which would be impractical and which the DEIS does not propose. A specific site is needed for cultural impact analysis to be rigorous.
- Visual: Topography varies in the HGLA, from relatively benign near 395 to rugged mountains east of 395. Only a generalized visual impact analysis is possible without a specific site. Relevant key observation points cannot be defined and analyzed.
- Recreation: Almost the entire HGLA is appropriate for recreation, some locations more than others. A specific site proposal is needed to be rigorous about estimating impacts.

To emphasize the NEPA requirement (at the risk of stating the already well known) the pertinent text is reproduced here:

> **Sec. 1502.14 Alternatives including the proposed action.**
>
> This section is the heart of the environmental impact statement. Based on the information and analysis presented in the sections on the Affected Environment (Sec. 1502.15) and the Environmental Consequences (Sec. 1502.16), it should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public. In this section agencies shall:
>
> (a) Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.
>
> (b) Devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits.
>
> (c) Include reasonable alternatives not within the jurisdiction of the lead agency.

With no specific proposal to evaluate, an EIS based on this DEIS, if used to authorize a project in the HGLA, would violate NEPA's Section 1502.14. Note that this section is identified by NEPA as the heart of an EIS.

The DEIS acknowledges that more analysis is needed.

- Section 2.2 (page 2-4) : "If leasing is authorized, the BLM will conduct additional site and project specific environmental analysis...". The DEIS does not state the form of the additional analysis.
- Section 2.3.1, Alternative A (page 2-13) (Identical wording for Alternatives C and D), with respect to OHV route designations: "...proposed project specific changes would be analyzed in a subsequent environmental document (EA or EIS) prepared for the proposed exploration or development project.". The DEIS states the subsequent anaylsis could be either an EIS or an EA.

Comment

Selecting either alternatives A, C or D does not satisfy NEPA, since the actual disturbing activity is not defined.

To satisfy NEPA, BLM must explicitly state that specific proposed ground disturbing activities will be addressed in a separate EIS, when the specific proposal is known.

Lease Application Backlog

Paragraph 1.2.1, page 1-6 of the DEIS, identifies BLM's requirement to reduce the backlog of geothermal lease applications, especially since BLM is already two years late. This is understandable. However, the form and structure of the DEIS implies that the DEIS will be the environmental impact statement for all three project phases – exploration, development and operation . Nowhere does the DEIS state that actual ground disturbing activities, following a lease approval, will require an additional EIS.

The Environmental Consequences section on page ES-vi, confusing at best, adds to the uncertainty. This paragraph states:

- ...real impacts could occur, but would not occur until a separate BLM action authorized development following lease issuance...
- ...analysis in the DEIS addresses impacts including exploration, drilling and utilization.

These confusing sentences imply that activities on the leased property require separate authorization(s), but the DEIS analysis addresses these impacts of all three of these activities.

The final sentence in this paragraph confuses the confusion. It talks of 'additional site specific analysis', but no site specific analysis to be added to has been discussed. This contradicts the previous sentence that analysis in the DEIS addresses impacts including exploration, drilling and development.

Further, approving a lease under this DEIS apparently allows ground-disturbing activities of exploration, development and operation of a geothermal facility, as stated on Page ES-i:

> *Leasing geothermal resources by the BLM vests with the lessee an exclusive right to future exploration and to produce and use of the geothermal resources within the lease area subject to existing laws, regulations, formal orders, and the terms, conditions and stipulations in or attached to the lease form or included as conditions of approval in permits.*

Is the impact statement in this DEIS is intended to serve as the impact statement for the three phases, exploration, development and production, under the lease? If such were to happen, it would represent an 'end-run' around the purpose and intent of NEPA and its regulations, since an actual geothermal activity would not have been analyzed. It would be a clear NEPA violation. This cannot be allowed.

Comment

BLM must craft a solution to the backlog of geothermal lease applications without bypassing its NEPA responsibilities. The backlog does not trump NEPA.

Purpose and Need

Adequate Alternatives

Section 6.2 of Handbook H-1790, the National Environmental Policy Act Handbook, states: "The CEQ regulations do not differentiate the "purpose" of the action from the "need" for the action.", and "Often, the 'purpose' can be presented as the solution to the problem described in the 'need' for the action".

The need for this action is succinctly stated in the first paragraph of section 1.2.2, on DEIS page 1-7:

> *The need for action is to allocate [classify?] specific lands in the HGLA as closed, open, or open with constraints to geothermal leasing. This EIS arises from three non-competitive lease applications that are currently pending with the BLM for approximately 4,460 acres of federal mineral estate. The need for action includes making a leasing decision for each of the three applications to grant, deny, or grant with modifications. These applications were received prior to the passage of the Energy*

Policy Act of 2005, and thus are included with others in the backlog covered by the requirement mentioned above.

The same purpose is stated in section 1.2.1

The purpose also includes responding to the increasing interest in geothermal leasing opportunities on federal land by addressing three pending geothermal lease applications

This is a very narrow and well defined need.

Comment

If the need to reduce the backlog of geothermal lease applications is the primary and overriding consideration, then the alternatives presented in the DEIS are a reasonable set.

Inadequate Alternatives

In contrast to the narrow and specific purpose and need of dealing with the three non-competitive lease applications, additional purposes and needs stated in the DEIS are wide and non-specific.

- The Purpose of Action, 1.2.1, includes Executive Order 13212, citing the passage: "... agencies shall take appropriate actions...to expedite projects that will increase the production ... or conservation of energy." This directive is not specific as to technology, location or size. It does not require the energy produced be renewable. Alternatives based on conservation of energy, not production, would satisfy this directive.
- The Purpose and Need for Action (page ES-ii), and Purpose of Action (page 1-6) cite additional purpose and needs:

Purpose	Comment
1) Develop clean, renewable energy.	This could be accomplished by any of the technologies currently being implemented in the country, on or off the HGLA. Examples are wind and solar.
2) Meeting the increasing energy demands of the nation.	This could be accomplished by the same techniques and technology as 1). It could also be accomplished by increased gas and oil production and increased efficiency programs.
3) Reducing reliance on foreign energy imports.	This could be accomplished by any form of domestic energy production, including but not limited to geothermal.
4) Reducing greenhouse gas emissions.	Most forms of renewable energy are thought to do this.
5) Improving national security.	

These stated purposes are general, and are not specific to any one technology. In fact, EO 12312 does not mention why it orders expediting production and conservation of energy, and does not mention renewable energy.

According to NEPA requirements, the alternatives presented in the DEIS to satisfy these wide and non-specific purposes and needs are inadequate, since the alternatives presented are restricted to geothermal and are specific to the HGLA.

The CEQ 40 FAQs (NEPA's Forty Most Asked Questions) (http://ceq.hss.doe.gov/nepa/regs/40/40p3.htm) is specific about alternatives:

- 1a: Range of Alternatives: "...includes all reasonable alternatives, which must be rigorously explored and objectively evaluated, as well as those other alternatives, which are eliminated from detailed study with a brief discussion of the reasons for eliminating them. Section 1502.14.
- 2a: Alternatives Outside the Capability of Applicant or Jurisdiction of Agency: "Section 1502.14 requires the EIS to examine all reasonable alternatives to the proposal. ... emphasis is on what is "reasonable" rather than on whether the proponent or applicant likes or is itself capable of carrying out a particular alternative.

Comment

BLM must expand the alternatives discussed in the DEIS to other technologies and locations, to satisfy the five purposes listed on pages ES-ii and 1-6, (shown in the table above), and EO 13212.

Inapplicable Purpose and Need

- Paragraph 1.2.1.2 on page 1-7 of the DEIS cites section 222(d)(1) of the Energy Policy Act of 2005. This cite appears to be a misquote:

Document **Energy Policy Act of 2005, Aug 8, 2005** http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf	**Document** **HGLA DEIS** Page 1-7
Section SEC. 222. COMPETITIVE LEASE SALE REQUIREMENTS (d) PENDING LEASE APPLICATIONS.— (1) IN GENERAL.—	**Section** "Section 222(d)(1) of the Energy Policy Act of 2005 states,"
It shall be a priority for the **Secretary, and for the Secretary of Agriculture** with respect to National Forest Systems land, to ensure timely completion of administrative actions, including amendments to applicable forest plans and resource management plans, necessary to process applications for geothermal leasing pending on the date of enactment of this subsection.	"It shall be a priority for the **Secretary of the Interior** to ensure timely completion of administrative actions, including amendments to applicable Resource Management Plans (RMP), necessary to process applications for geothermal leasing pending on the date of enactment of this subsection."

The wording difference between the DEIS reference and the text of the EPAct/2005 above is bolded.

This section of the EPAct/2005 is not applicable to BLM. Paragraph 222(d)(1) refers to the "Secretary and for the Secretary of Agriculture…", where 'the Secretary means the Secretary of Energy. Nothing in this section directs the Secretary of the Interior or the BLM. This Section does not qualify as a purpose and need for this activity.

- Paragraph 1.2.1.2 cites section 211 of the Energy Policy Act of 2005. It directs the Secretary of the Interior to approve non-hydropower renewable energy projects of at least 10,000 MW by August 8, 2015 (ten years after passage of the EPAct of 2005).
  The approved capacity, according to data taken on June 28, 2012 from the undated BLM website: http://www.blm.gov/wo/st/en/prog/energy/renewable_energy/Renewable_Energy_Projects_Approved_to_Date.html for these categories of renewable energy is 8,437 MW. At the current high rate of approval the total will certainly exceed 10,000 MW by 2015, three years from now.
  This Section does not qualify as a purpose and need for this activity.

Comment

These purposes and needs should be removed from the EIS.

General Comment

Postpone the EIS project until the applicant/proponent shows enough interest and confidence to make a specific proposal and to pay for the environmental analysis.

Sincerely,

Tom Budlong

Tom Budlong
Voice: 310-476-1731
Fax: 310-471-7531
email: TomBudlong@RoadRunner.com

LETTER N

Childers, Jeffery K

From:	Sam Iam <samnplnews@yahoo.com>
Sent:	Friday, July 20, 2012 4:28 PM
To:	Godfrey, Peter E; Childers, Jeffery K
Subject:	Haiwee Geothermal Leasing Area

Jeff Childers and Peter Godfrey HGLA Project Managers
BLM California Desert District
22835 Calle San Juan de los Lagos
Moreno Valley, CA 92553
Peter_Godfrey@blm.gov; jchilders@blm.gov

Re: Notice of Availability of the Draft Environmental Impact Statement and Draft Proposed California Desert Conservation Area Plan Amendment for the Haiwee Geothermal Leasing Area in Inyo County, CA; 77 Fed. Reg. 27478 (May 10, 2012).

Ref: July

Dear Mr. Childers and Mr. Godfrey,

In 2008, the Geothermal Programmatic EIS was introduced however; this Known Geothermal Resource Area (KGRA) was omitted at that time. The reasons for this is not apparent by reading the whole document except to speculate that this area was not unclassified land, but rather Limited with an Area of Critical Environmental Concern at Rose Spring.

In 2009, Scoping Meetings were held for this project. However, the Haiwee Geothermal Leasing Area Draft EIS and Proposed Amendment to the CDCA Plan were not introduced until April of 2012 three years after the scoping meetings were held. There were flaws in the original description of the property in the Federal Register and the public scoping meetings were held after the public comment period time limit. BLM personnel acknowledged this, but a correction to the Federal Register notice was never initiated as promised at a public meeting in Lone Pine and recorded in this Draft.

The Public was also not notified by the procedures set forth in the California Desert Conservation Plan as noted on page 95.

"Notification of proposed amendments to or changes in the California Desert Plan will be published in the Federal Register. In addition, notices will also be published in a newspaper, or newspapers, of general circulation in the area which would be affected by the proposed amendment(s). Further a Plan amendment mailing list will be developed by BLM and will include appropriate publications, which publish material of interest to people concerned about public lands of the California Desert. All individuals, organizations, and other public agencies requesting notices of Plan amendment proposals or decisions will receive such notices. All notices and information will be published in this manner no later than 30 days prior to the first or subsequent public hearing, if one is to be held."

Regarding the specified acreage, the original Federal Register Notice September 8, 2009 stated:

"Township 21 South, Range 37 East, sections 11-14, 23-26, 35 and 36
Township 21 South, Range 38 East, sections 7-10, 15, 17-22, 27-34
Township 22 South, Range 37 East, sections 1 and 2
Township 22 South, Range 38 East, sections 5-8 within the San Bernardino and Base Meridian. Total acreage being considered for geothermal leasing is approximately **22,060** acres."

The Draft EIS states:

"Township 21 South, Range 37 East, sections 11-14, 23-26, 35 and 36
Township 21 South, Range 38 East, sections 7-10, 15, **16**-22, 27-34
Township 22 South, Range 37 East, sections 1 and 2 and **11-12**
Township 22 South, Range 38 East, sections 5-8 within the San Bernardino and Base Meridian. Total acreage being considered for geothermal leasing is approximately **22,805** acres."

A difference of 745 acres (both private and state lands) was acknowledged on October 13, 2009 at a public meeting by official transcripts by the project manager at that time.

Then when the draft came out, sections 11, 12 and 16 magically were included in the map and Notice of Intent. After including section 16 and private lands, should it not now make it an EIR, not an EIS?

At that same meeting, Inyo County Supervisor requested that air-cooling towers be assessed and only one paragraph in the Draft mentions air cooling and then dismisses it as not viable.

After looking at some notes on the final ROD on the CDCA Plan, it states that "no utility corridors should cross the Rose Valley Spring and that the KGRA is inconsistent with the BLM Bakersfield District on Coso KGRA Final EIS. Also Habitat Management Plan (W-11) is inconsistent with the wildlife element."

It also went on to say change MUC designation from Class C and L to Class M in all areas except Inyo County ERA's 40 (Rose Spring), 41 (Red Hill Cinder Cone), and 42 (Fossil Falls), which should remain Class L. It also stated that Haiwee Reservoir should become a public recreation area after completion of LA aqueduct filtration plant.

This Draft EIS ignores many tribal issues. Rose Spring ACEC was set up for Cultural Resources and is of tribal concern by at least four different tribes. In 1985 the BLM established the Rose Spring Area of Critical Environment Concern (ACEC) for scientific use and public interpretation. Portions of the Rose Spring ACEC are within the HGLA and tribal concerns voiced at several meetings asked for inclusion of monitoring of any activities.

So if this area is truly a Class L, should it not stay out of the existing KGRA's as intended by not including it in the Known Geothermal Area EIS in 2008?

This Draft EIS is long and much of the data that was initiated three years ago could use more scientific and credible data.

The seismic studies are not complete and in fact ignore the fact that there was so much damage done by a 1952 Tehachapi earthquake (7.2) to South Haiwee Dam, which borders this area to the north. The following report was completed by Donald Babbitt, M. ASCE; 1http://www.michigan.gov/documents/deq/deq-p2ca-caseismicpaper_281049_7.pdf

"Two hydraulic fill dams were damaged by the 1952 Kern County Earthquake -- Dry Canyon Dam 45 miles from the epicenter and South Haiwee 95 miles from the Epicenter (Seed et al, 1978). **The owner of the dams recognizing they were in areas of high seismicity**, hence subject to more severe shaking acted to stabilize the dams. A 120-foot wide rock fill berm was added to the upstream slope and a 100-foot wide berm to the downstream slope of 81-foot high South Haiwee Dam."

More recently, ERS radar interferometry reveals strain transient in the Eastern California Shear Zone
The data allowed us to estimate a rate of creep of 7 mm/yr on the section of the fault below the depth of 5 km. This rate is 3 times faster than the long-term geologic rate estimated on this fault and the creeping section anomalously shallow. These observations suggest that the Blackwater-Little Lake fault system is currently the locus of a transient deformation process, which has never been observed before. The article describing these results is in the November, 2001 issue of the journal Geology.
The seismic studies in the Draft seem to be picked only for what future proponents want them to say and there seems to be no connectivity to other faults as demonstrated by more geological searches.

There is lack of a complete cumulative concise water analysis. The report states that it is within the Indian Wells Valley watershed and yet the Kern County is not asked in regards to whether this will have an impact on ground water in Indian Wells Valley. It does not produce numbers regarding consumptive use of groundwater that is already being fossil water mined for other projects. It does not assess whether hydro fracking of numerous faults would impact geological and hydrological concerns. It also ignores the fact that the practice of fracking may become illegal in the state of California. It also does not contain specific environmental concerns about the usage of different chemicals in case they would use fracking.

It is our opinion that because of the significant omissions of the original documentation that had a difference in acreage and section numbers with no correction in the federal register, the disconnect of a timely document addressing all the concerns by many of the public, not mentioning why this area was excluded by the original Geothermal Programmatic EIS, whether or not this should be an EIR, and the lack of a Plan Amendment List was not kept by the BLM should predicate a longer comment period to correct these omissions in the Federal Register, Newspapers and Contact List.

There is no consistency in this document and the timeline by NEPA standards have been seriously impacted. The timeline indicated a Notice of Intent 2009, Scoping October 2009, Draft EIS and Plan Amendment with 90 day comment period Winter of 2009, Formal A public Meetings Spring 2010, FEIS Fall 2010 and ROD in winter of 2010. This time period was not kept and many of the people that responded the first time around were not notified.

Therefore, we are asking that a new time line be established for comment period of ninety days after amending the original Federal Register of September of 2009 on the acreage, waiting for the new rules on fracking, including a statement why it was not included in the KGRA of 2008, and provide adequate notification/comment period by all tribes in the immediate area, property owners, Supervisors of Inyo County, Planning Department of Inyo County and Kern County Regional Water District.

Respectfully,

Sophia Anne Merk
samnplnews@yahoo.com
National Public Lands News
941 E. Ridgecrest Boulevard
Ridgecrest, California 93555

CENTER for BIOLOGICAL DIVERSITY Because life is good.

working through science, law and creative media to secure a future for all species, great or small, hovering on the brink of extinction.

VIA ELECTRONIC MAIL

August 9, 2012

Peter Godfrey, HGLA Project Manager
California Desert District Bureau of Land Management
22835 Calle San Juan de Los Lagos
Moreno Valley, CA 92553
Via email: pgodfrey@blm.gov and jchilders@blm.gov

Re: Comments on Draft Environmental Impact Statement for the Proposed Haiwee Geothermal Leasing Area

Dear Mr. Godfrey,

The Center for Biological Diversity ("Center") is a non-profit environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 43,000 members throughout California and the western United States, including members that live and/or visit the vicinity of the proposed Haiwee Geothermal Leasing Area. These comments are submitted on behalf of our board, staff and members. The Center provides these comments on the Draft EIS for the Haiwee Geothermal Leasing Area, 77 Fed. Reg. 27478, and incorporates by reference herein our earlier scoping comments submitted on Nov. 9, 2009, and letter submitted on July 16, 2012.

The development of renewable energy generation and adequate transmission capacity for that renewable energy is a critical component of efforts to reduce greenhouse gas emissions, avoid the worst consequences of global warming, and to assist California in meeting emission reductions standards. The Center strongly supports the development of renewable energy production, and supports the generation of electricity from geothermal power, in particular, and truly necessary transmission upgrades to support that power production. However, like any project, proposed geothermal power projects must be thoughtfully planned to minimize impacts to the environment. In particular, renewable energy projects should avoid impacts to sensitive species and habitats to the greatest extent possible through careful siting, planning, and design. Only by maintaining the highest environmental standards with regard to local impacts, and effects on species and habitats, can renewable energy production be truly sustainable.

Alaska • Arizona • California • Florida • Minnesota • Nevada • New Mexico • New York • Oregon • Washington • Washington, DC

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The Center joins the comments submitted by Defenders of Wildlife, Sierra Club, and Kerncrest Audubon Society on August 2, 2012, concurs with the comments provided by Rose Valley Properties, and provides the following additional comments.

The failure to adequately addressed impacts to water resources by BLM in the DEIS renders the document inadequate under NEPA as does the BLM's failure to provide any alternative that would ensure conservation of water resources is prioritized. The proposed plan amendment which would allow for significant impacts to water resources is also inconsistent with FLPMA which requires BLM to prevent unnecessary or undue degradation of public lands. 1
43 U.S.C § 1732(b). The BLM has failed to show that it is necessary to approve either the leasing area or the pending leases at this time or that BLM has fully explored other suitable alternatives, including alternative geothermal technologies which use far less water.

The proposed plan amendment is inconsistent with FLPMA's planning provisions which require that in developing and revising land use plans, the BLM consider many factors and "use a systematic interdisciplinary approach to achieve integrated consideration of physical, biological, economic, and other sciences . . . consider the relative scarcity of the values involved and the availability of alternative means (including recycling) and sites for realization of those values." 43 U.S.C. § 1712(c). By failing to coordinate and integrate this planning process with the ongoing DRECP plan amendment process and Solar PEIS process the BLM has failed to comply with FLPMA.

In fact, the current proposal could undermine coordinated planning in the CDCA and the Center is concerned that that no effort has been made to integrate this planning process with the ongoing Desert Renewable Energy Conservation Plan process and Solar PEIS which are addressing renewable energy development throughout the California Desert Conservation Area. Both of those pending plan amendments will result in additional CDCA amendments to accommodate renewable energy and should be coordinated with this process. Coordination with the DRECP is particularly critical where, as here, the proposed leasing area and the pending leases may significantly affect species and resources that will also be significantly affected by proposed development of other renewable energy projects in the area.

The proposed plan amendment is also inconsistent with the FLPMA provisions which contemplate that BLM will prepare and maintain adequate inventory data on the resources of an area and that information be used to inform the planning process. 43 U.S.C. § 1711(a); 43 U.S.C. § 1701(a)(2). In failing to prepare and maintain an inventory of public land resources, BLM has also failed to adequately address the resources of this area in reviewing the proposed plan amendment and pending leases. *See Center for Biological Diversity v. Bureau of Land Management*, 422 F.Supp.2d 1115, 1166-67 (N.D. Cal. 2006) (discussing need for BLM to take into account known resources in making management decisions); *ONDA v. Rasmussen*, 451 F.Supp. 2d 1202, 1212-13 (D. Or. 2006) (finding that BLM did not take a hard look under NEPA by relying on outdated inventories and such reliance was inconsistent with BLM's statutory obligations to engage in a continuing inventory under FLPMA).

Given the shortcomings of the DEIS, a revised or supplemental Draft EIS is clearly needed and must be circulated to the public.

Thank you for considering these comments on the DEIS. The Center looks forward to reviewing a revised or supplemental Draft EIS.

Sincerely,

Lisa T. Belenky, Senior Attorney
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LETTER AA

BOARD OF SUPERVISORS
COUNTY OF INYO
P. O. DRAWER N • INDEPENDENCE, CALIFORNIA 93526
TELEPHONE (760) 878-0373
email: dellis@inyocounty.us

July 9, 2019

Bureau of land Management, California Desert District
Attn: Greg Miller, Assistant District Manager – Resources
22835 Calle San Juan de Los Lagos
Moreno Valley, CA 92553

Mr. Miller,

The Inyo County Board of Supervisors would like to thank the BLM for the opportunity to comment on the Haiwee Geothermal Leasing Area: Draft Supplemental Environmental Impact Statement (DSEIS). Overall, the County supports the development of geothermal energy within our borders and has compiled the following comments for your use in this planning effort. We would also like to thank the BLM for the inclusion of many of our comments on the DEIS in the DSEIS.

After reviewing the DSEIS, we have identified several items that we previously commented on that were not addressed in the SDEIS and a new one, these include:

- First and foremost, we are concerned about coordination pursuant to the Federal Land Policy and Management Act (FLPMA) of 1976. The County has consistently provided comments about the lack of coordination efforts with Inyo County for the entire span and iterations of this project and we are still hopeful that we will hear from someone at the BLM to coordinate on this Supplement to the DEIS. 1

- Section 3.7.1, (pg. 3-55) addresses Applicable Regulations and Plans, Policies/Management Goals. There is no mention of the Inyo County Agriculture Advisory Board. They should be consulted, especially with regard to 3.7.2.1 – Invasive, Non-Native Species, for related programs.

- Section 3.18.2 still does not provide an adequate analysis of County maintained roads that may be impacted by the HGLA. We would still like to see an analysis of County roads that may be impacted, especially Coso-Gill Station road. This analysis needs to include any impacts that will result in necessary road improvements due to increased use for exploration and development of geothermal resources in the area. 2

- We appreciate your thorough analysis of Socio-Economics and Impacts to Public Services. However, in Chapter 4, Environmental Consequences 4.19.1.3: Impacts to Public Services, still states that given the very low population impacts described for the HGLA, correspondingly low impacts on public services can be expected. We would like to point out that with a very low population, impacts, even at a low level, will be felt more greatly than if they are experienced in a densely populated area. More specifically, since Inyo County does have a low population, its public service supplies are not well equipped for increases, however small they may seem. We would still like to see this issue better addressed.

- In Chapter 4, Environmental Consequences: Impacts to Public Revenues, 4.19.1.4, in light of the uncertainties that have been discussed with regard to geothermal lease payments, which leads to the questionable ability of geothermal energy projects paying for themselves, we would still like to know how the additional costs to Inyo County for services, including but not limited to road improvements, police, fire, water and sanitary services, be mitigated?

- We would also like to point out that it may not be necessary for the BLM to amend DRECP designations related to sensitive resources to allow for geothermal exploration and development, by simply staying out of them and focusing on the areas that do not have these designations. Perhaps the Haiwee Geothermal Leasing Area boundary could be adjusted to include more land to the south and remove land with Areas of Critical Environmental Concern.

Again, the Inyo County Board of Supervisors would like to thank you for the opportunity to comment. We look forward to a full coordination effort with you, and please keep us up-to-date as this planning effort moves forward. If you have additional questions please contact the County's Administrative Officer, Clint Quilter, at (760) 878-0292 or by email at cquilter@inyocounty.us

Sincerely,

Rick Pucci, Chairperson
Inyo County Board of Supervisors

California Water Boards

LETTER BB

Lahontan Regional Water Quality Control Board

July 23, 2019

File: Environmental Doc Review
Inyo County

Greg Miller, Assistant District Manager—Resources
Bureau of Land Management
300 S. Richmond Road
Ridgecrest, CA 93555
blm_ca_cd_haiwee_geothermal@blm.gov

Comments on the Draft Environmental Impact Statement, Haiwee Geothermal Leasing Area Project, Inyo County

The California Regional Water Quality Control Board, Lahontan Region (Water Board) staff received a Draft Environmental Impact Statement (DEIS) for the above-referenced Project (Project) on May 2, 2019. The DEIS was prepared by the Bureau of Land Management (BLM) and submitted in accordance with the National Environmental Policy Act (NEPA) and evaluates the feasibility and potential environmental impacts of opening public lands to geothermal leasing, particularly the potential development of federally-owned geothermal resources in the Haiwee Geothermal Leasing Area in southwestern Inyo County. It is our understanding that the DEIS will function as a programmatic environmental document. Subsequent tiered environmental documents would then address project-specific environmental impacts related to the exploration or development of geothermal resources and the potential for any cumulative impacts beyond what is addressed in the DEIS. Because the State Water Resources Control Board (State Water Board) or the Regional Water Boards may need to issue permits for implementation of individual projects, we request that any subsequently issued project-specific documents comply with and satisfy the requirements of both NEPA and the California Environmental Quality Act (CEQA). In addition, Lahontan Water Board staff are concerned about the potential impacts to water quality and hydrology that such projects may present and request that BLM analyze these impacts as part of the environmental review process. 1

WATER BOARD'S AUTHORITY

All groundwater and surface waters are waters of the State. All waters of the State are protected under California law. State law assigns responsibility for protection of water quality in the Lahontan Region to the Lahontan Water Board. Some waters of the State are also waters of the United States. The Federal Clean Water Act (CWA) provides additional protection for those waters of the State that are also waters of the United States.

The *Water Quality Control Plan for the Lahontan Region* (Basin Plan) contains policies that the Water Board uses with other laws and regulations to protect the quality of waters of the State within the Lahontan Region. The Basin Plan sets forth water quality standards for surface water and groundwater of the Region, which include designated beneficial uses and narrative and numerical objectives which must be maintained or attained to protect those uses. The Basin Plan can be accessed via the Water Board's web site at http://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.shtml.

WATER QUALITY CONCERNS

We recommend the following be considered in the environmental review.

1. The DEIS states that wetlands and riparian areas will be protected and managed in accordance with all federal regulations. However, as a reminder, the Water Board has a no net loss policy for wetlands and discourage development in these areas.

2. The Haiwee Geothermal Leasing Areas is in a tectonically active transitional zone, yet the DEIS presented no analysis on the threat to groundwater should
   any geothermal well casing be compromised because of an earthquake. Staff 2
   recommend adding a paragraph to Chapter 3.6 of the DEIS to address this concern.

3. The DEIS describes water quantity in detail but briefly describes hydrologic hazards such as flooding or the impact these hydrologic hazards will have on
   geothermal facilities and water quality. Stating that geothermal facilities will not 3
   be built in flood prone areas is not sufficient. Staff recommend adding a paragraph to Section 3.6.2 of the DEIS describing the impacts that hydrologic hazards will have on the geothermal facilities and any mitigations needed to protect water quality.

4. **Appendix A – Beast Management Practices (A.3.3)** – We recommend maintaining natural drainage channels and flow paths throughout the Project site
   to avoid no net loss of function and value of waters of the state because of 4
   Project implementation.

5. **Appendix A – Beast Management Practices (A.3.6)** – Revegetating disturbed soils in the desert is challenging because of low rainfall, extreme climatic conditions, and slow growth rates, we encourage Project proponents to maintain and mow existing vegetation rather than clear and grub during construction. For those projects where native vegetation is maintained, we have observed that the need to implement temporary BMPs is greatly minimized and the costs associated with implementation and maintenance of post-construction BMPs is significantly reduced.

6. **Appendix A – Beast Management Practices (A.3.6 No. 6)** – This mitigation measure should include a statement that the use of herbicides is not permitted in waterways on the Project site.

7. The Project area is in the Rose Hydrologic Area (Indian Wells Hydrologic Unit) of the Lahontan Region. Water quality objectives and standards for waters of the State, both numerical and narrative, including those within the Rose Hydrologic Area, are outlined in Chapter 3 of the Basin Plan. Projects that have the potential to discharge to or otherwise impact groundwater or surface waters in
   the Lahontan Region, either directly or indirectly, must comply with all applicable 5
   water quality standards and prohibitions, including provisions of the Basin Plan.

PERMITTING REQUIREMENTS

Several activities associated with the proposed Project may have the potential to impact waters of the State and, therefore, may require permits issued by either the State Water Board or Lahontan Water Board. The required permits may include the following.

8. Streambed alteration and/or discharge of fill material to a surface water may require a CWA, section 401 water quality certification for impacts to federal waters (waters of the U.S.), or dredge and fill waste discharge requirements for impacts to non-federal waters, both issued by the Lahontan Water Board. All unavoidable permanent impacts to waters of the State must be mitigated to
   ensure no net loss of beneficial use and wetland function and value. Water 6
   Board staff coordinate mitigation requirements with staff from federal and other state regulatory agencies. In determining appropriate mitigation ratios for impacts to waters of the State, we consider Basin Plan requirements (minimum 1.5 to 1 mitigation ratio for impacts to wetlands) and utilize 12501-SPD Regulatory Program Standard Operating Procedure for Determination of Mitigation Ratios, published December 2012 by the US Army Corps of Engineers, South Pacific Division.

9. Land disturbance of more than 1 acre may require a CWA, section 402(p) storm water permit, including a National Pollutant Discharge Elimination System
   General Construction Storm Water Permit, Water Quality Order 7
   2009-0009-DWQ, obtained from the State Water Board, or individual storm water permit obtained from the Lahontan Water Board.

We request that the draft DEIS recognize the potential permits that may be required for the Project, as outlined above, and identify the specific activities that may trigger these permitting actions in the appropriate sections of the environmental document.
Information regarding these permits, including application forms, can be downloaded 8
from our website at http://www.waterboards.ca.gov/lahontan/. Early consultation with Water Board staff regarding potential permitting is recommended.

Thank you for requesting our consultation. If you have any questions regarding this letter, please contact me at (760) 241-7305 (tiffany.steinert@waterboards.ca.gov) or Jan Zimmerman, Senior Engineering Geologist, at (760) 241-7376 (jan.zimmerman@waterboards.ca.gov). Please send all future correspondence regarding this Project to the Water Board's email address at Lahontan@waterboards.ca.gov and be sure to include the Project name in the subject line.

Tiffany Steinert

Tiffany Steinert, GIT
Engineering Geologist

cc: California Department of Fish and Wildlife (AskRegion6@wildlife.ca.gov)

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LETTER CC

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

JUL 3 1 2019

Mr. Greg Miller
Deputy District Manager – Resources
Bureau of Land Management
California Desert District Office
22835 Calle San Juan De Los Lagos
Moreno Valley, CA 92553

Subject: Haiwee Geothermal Leasing Area Draft Supplemental Environmental Impact Statement and Draft Proposed Amendment to the California Desert Conservation Area, Inyo County, California (CEQ# 20190077)

Dear Mr. Miller:

The U.S. Environmental Protection Agency (EPA) has reviewed the Draft Supplemental Environmental Impact Statement (DSEIS) for the above-referenced document pursuant to the National Environmental Policy Act (NEPA), Council on Environmental Quality Regulations (40 CFR Parts 1500-1508), and Section 309 of the Clean Air Act.

The EPA reviewed the Draft Environmental Impact Statement (DEIS) for the Haiwee Geothermal Leasing Area (HGLA) and provided comments to the Bureau of Land Management (BLM) on July 30, 2012. In our DEIS comment letter, we recommended that BLM provide additional clarifying information regarding: potential sources of water required for development, restrictions on consumptive use of groundwater, mitigation measures for potential impacts to water resources, and the procedures for further NEPA analysis of subsequent site-specific projects. Our DEIS comments are not included in the Haiwee DEIS Public Comments document, as posted on BLM's E-Planning website;[1] therefore, we are attaching them to this letter.

We understand that the DSEIS was prepared, in part, because BLM recognized the need to conduct a more detailed study to validate projected water use by geothermal facilities should they be allowed in the HGLA. In addition, the DSEIS states that BLM needed to update the alternatives and analyses within the DEIS to reflect new land use designations approved with the Desert Renewable Energy Conservation Plan (DRECP) amendment to the California Desert Conservation Area (CDCA) Plan in September 2016.

We appreciate the opportunity to discuss this project with the BLM on July 10, 2019. Based on our review, EPA has the following recommendations for your consideration as the Final Supplemental Environmental Impact Statement (FSEIS) is being prepared.

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[1] See Internet Site: https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=dispatchToPatternPage&currentPageId=99709

Changes in Land Use Designations within the HGLA
The DSEIS frequently refers to the new CDCA Plan land use designations, including Special Recreation Management Areas (SRMAs), National Conservation Lands – which includes Areas of Critical Environmental Concern (ACECs) and California Desert National Conservation Lands (CDNCL) – and Development Focus Areas (DFAs), which are shown in Figure L-4. Implementation of the new land use designations resulted in the formation of three new ACECs (Ayers Rock, Mojave Ground Squirrel and Sierra Canyon) within the HGLA, in addition to the Rose Spring ACEC, which was established in 1985.

The Preferred Alternative, as described in the DEIS, included authorizing all pending leases within the HGLA and opening the HGLA to geothermal exploration, development and leasing – but with the requirement of no surface occupancy (NSO) allowed in sensitive areas. Much of the area that was classified as a 'sensitive resources area' within the DEIS appears, now, to have been reclassified as a DFA; while the area that was formerly 'proposed open to geothermal development' is now predominantly designated as ACECs (Figure L-4). In addition, the new Preferred Alternative, as described in the DSEIS, would allow for geothermal exploration, development and leasing throughout the entire HGLA – with no caveats providing for NSO in sensitive areas.

We understand that the new land use designations were implemented in response to the DRECP Land Use Plan Amendment (LUPA) Record of Decision (ROD); however, the DSEIS does not elaborate on why these changes were enacted except to note that there was a need to allocate a broader area of designated lands for geothermal leasing (pg. 2). ACECs have not, in fact, been designated as suitable and available for geothermal development within the DRECP LUPA. All ACECs designated in the DRECP LUPA are, supposedly, closed to geothermal leasing and development unless they overlap with a DFA where geothermal is allowed. The DSEIS states that, when they overlap, ACECs are open to geothermal leasing with an NSO stipulation (pg. 82). It is not clear why BLM has proposed geothermal leasing in the entire HGLA, including the ACECs, contrary to the DRECP LUPA, and why the new Preferred Alternative no longer includes NSO lease stipulations for sensitive areas.

Furthermore, the DSEIS does not adequately address how sensitive resources would be protected within the HGLA if geothermal resources are developed (pg. 8). Development of the Reasonably Foreseeable Development (RFD) scenario under the Preferred Alternative could, for example, increase fragmentation of Mojave ground squirrel habitat by allowing development throughout the HGLA – including within ACECs/CDNCLs specifically identified to protect Mojave ground squirrels (pg. 67). Although the DSEIS refers to Conservation Management Actions (CMAs) identified in the LUPA ROD, the DSEIS indicates that those CMAs may or may not include restrictions or stipulations necessary to protect sensitive resources from impacts associated with the development of geothermal resources in the HGLA.

Recommendations:
Revise the legend in Figure L-4 to more clearly show the SRMAs.

Revise Figure L-4 to correctly identify State lands (block 16). Discuss the status of geothermal exploration, development, and leasing on State lands (block 16), as well as additional stipulations, including NSO stipulations, or lack thereof, on these lands. 1

Clarify, in the FSEIS, the reasons why the southwestern section of the HGLA was reclassified from 'a sensitive resource area' to a DFA. Likewise, clarify why the areas that were formerly 2 'proposed open for geothermal development' have been re-designated as ACECs. Explain the reasoning behind these changes, beyond the fact that it occurred in conjunction with the DRECP LUPA ROD. 2 (con't)

Illustrate, in the FSEIS, the extent of the Mojave Ground Squirrel ACEC, including the area located within the HGLA. Describe the habitat for the Mojave ground squirrel within the HGLA, specifically noting the condition of habitat in the DFA, as compared to the rest of the HGLA. 3

Discuss, in the FSEIS, why ACECs within the HGLA should be designated, now, as suitable and available for geothermal development, in contrast to what is proposed in the DRECP LUPA ROD.

Discuss, in the FSEIS, the reasons that NSO stipulations are no longer necessary within the newly proposed DFA, the ACECs, or any remaining portion of the HGLA. Describe how sensitive resources will be adequately protected without NSO stipulations or appropriate CMAs.

Groundwater Resources
According to the DSEIS, the Haiwee RFD scenario will require water for well drilling, dust control, and operations; however, the source for this water is still unknown. The DSEIS states that long-term groundwater extraction from the local, near surface groundwater aquifer to augment geothermal reservoir fluid levels would likely have significant long-term impacts on groundwater resources in Rose Valley (pg. 63). Under the Preferred Alternative, groundwater extraction for consumptive use during exploration, development and project operations may be allowed for some leases. If consumptive water use occurs – even under specified stipulations – the DSEIS concludes that impacts would be moderate (pg. 64).

Appendix G of the DSEIS indicates that groundwater modeling simulations conclude that pumping at a reduced rate could be sustained for 30 years without reducing water flow towards Little Lake by more than 10 percent; however, the same simulations indicate that the maximum predicted drawdown at the Little Lake Ranch North well could exceed 3.5 ft – which exceeds the Maximum Acceptable Drawdown threshold of 0.4 feet established for this well. The DSEIS does not indicate if there is a lower pumping rate that would enable both sets of criteria to be met – either under simulation conditions or given ongoing pumping. 4

According to the DSEIS, the groundwater flow model did not consider the effects of other major groundwater development projects, including the Hay Ranch Groundwater Extraction and Transfer project and the Los Angeles Department of Water and Power's (LADWP) proposed Haiwee Reservoir Seepage Capture project (Appendix G). Although the effects of additional pumping are expected to be additive, they were not included in the modeling analysis. Without evaluating ongoing pumping efforts and completing a water supply assessment, it is unclear what water resources, if any, are available. 5

To better understand potential impacts of geothermal development in the HGLA, the Argonne National Laboratory (Argonne Lab) completed a study in 2016 that evaluated water usage associated with four geothermal power plant scenarios.[2] Although the DSEIS states that the Argonne Lab modeling effort supports the water use assumptions used in the groundwater flow model, the details of the study are not included in the DSEIS. According to information presented in Appendix B, the complete report 6

[2] 30 MW wet-cooled duel-flash power plant, a 49-MW wet-cooled duel-flash power plant, a 49 MW wet-cooled binary plant, and a 49 MW air-cooled binary plant

summarizing the study should be contained in Appendix J; however, Appendix J is not available on 6 (con't)
BLM's E-Planning website, nor is it listed in the DSEIS table of contents.

Recommendations:
Identify, in the FSEIS, the potential sources of water. Discuss any impacts associated with the
appropriation of this water, including impacts to wetland habitats. Discuss whether it would be 7
feasible to use other sources, such as treated wastewater, for geothermal drilling, injection and power plant operations.

Clarify, in the FSEIS, whether there is a reduced pumping rate scenario that would satisfy set restrictions on reducing water flow towards Little Lake and meet drawdown restrictions at the Little Lake Ranch well, and whether adequate groundwater resources are available, given ongoing pumping within the basin.

Describe, in the FSEIS, quantities of groundwater associated with the Hay Ranch Extraction and
Delivery System project and the LADWP's Haiwee Seepage Recovery project. Identify any 8
other sources of groundwater consumption within the basin. Incorporate these data into the numerical groundwater flow model and discuss results.

Complete a water supply assessment for the basin. Identify pumping rates over the last 10 years
within the basin. Given ongoing pumping efforts, discuss whether there is groundwater available 9
for consumption within the basin.

Given public concern about potential impacts to water resources within the HGLA, we recommend that the complete report prepared by Argonne Lab be summarized and included as an appendix in the FSEIS.

Given the limitations associated with the existing groundwater modeling simulations and ongoing pumping projects, EPA recommends that BLM consider prohibiting groundwater for consumptive use in conjunction with geothermal development.

Seismicity - Earthquakes
According to the DSEIS, the National Renewable Energy Laboratory (NREL) has developed draft evaluation guidance available for use to determine seismic risk related to geothermal development. The DSEIS acknowledges that some type of risk assessment has been conducted by BLM but does not elaborate on the results, except to note that "it is not likely to be significant" (pgs. 61-62). According to the DSEIS, the region in which the HGLA is located is one of the most seismically active in California. Given the recent seismic activity[3] near Ridgecrest, CA in July 2019, we are concerned about increased seismic risk in the HGLA.

Recommendations:
Include, in the FSEIS, the draft evaluation guidance that BLM has developed for use to determine seismic risk related to geothermal development. Clarify whether this guidance was
used by BLM in the HGLA or requires more site-specific project information. Discuss the results 10
of the risk assessment that BLM has conducted.

[3] Magnitude 6.4 Earthquake July 4, 2019; Magnitude 7.1 Earthquake July 6, 2019; and multiple aftershocks.

Discuss, in the FSEIS, ground deformation or any other impacts in the HGLA that can be attributed to the recent Ridgecrest earthquakes. 10 (CON'T)

Effective October 22, 2018, EPA no longer includes ratings in our comment letters. Information about this change and EPA's continued roles and responsibilities in the review of federal actions can be found on our website at: https://www.epa.gov/nepa/epa-review-process-under-section-309-clean-air-act.

EPA appreciates the opportunity to review this DSEIS and we are available to discuss our comments. When the FSEIS is released for public review, please send one hard copy and one CD to the address above (mail code: TIP-2). If you have any questions, please contact me at 415-947-4161, or contact Ann McPherson, the lead reviewer for this project. Ms. McPherson can be reached at 415-972-3545 or mcpherson.ann@epa.gov.

Sincerely,

Connell Dunning

Connell Dunning, Acting Manager
Environmental Review Branch

Enclosure: EPA's comments on the Haiwee Geothermal Leasing Area DEIS

CC: Patrice Copeland, R6 Lahontan Regional Water Quality Control Board
Laura Piper, Inyo County Water Department
Brandon Barrow, National Park Service

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

JUL 3 0 2012

Peter Godfrey, Project Manager
California Desert District Office, BLM
22835 Calle San Juan De Los Lagos
Moreno Valley, California 92553

Subject: Draft Environmental Impact Statement for the Haiwee Geothermal Leasing Area Inyo County, California and the Draft Proposed California Desert Conservation Area Plan Amendment (CEQ# 20120132)

Dear Mr. Godfrey:

The U.S. Environmental Protection Agency has reviewed the Draft Environmental Impact Statement for the Haiwee Geothermal Leasing Area Inyo County, California. Our comments are provided pursuant to the National Environmental Policy Act, Council on Environmental Quality regulations (40 CFR Parts 1500-1508) and our NEPA review authority under Section 309 of the Clean Air Act.

EPA supports increasing the development of renewable energy resources in an expeditious and well planned manner. Using renewable energy resources such as geothermal energy can help the nation meet its energy requirements while minimizing the generation of greenhouse gases. While renewable energy facilities offer many environmental benefits, they are not without the potential for adverse impacts. Appropriate siting and design of such facilities is of paramount importance if the nation is to make optimum use of its renewable energy resources without unnecessarily depleting or degrading its water resources, wildlife habitats, recreational opportunities, and scenic vistas.

We have rated the preferred alternative (Alternative C) in the DEIS as *Lack of Objections - Adequate (LO)* (see enclosed "*Summary of EPA Rating Definitions*"). The EPA recommends that the Final EIS include additional clarifying information, particularly related to the mitigation measures for the potential impacts to water resources. Additionally, we recommend that the FEIS include detailed procedures for further NEPA analysis of subsequent site specific projects. Our enclosed detailed comments provide additional information regarding these concerns and recommendations.

We appreciate the opportunity to review this DEIS and are available to discuss our comments. Please send one hard copy and one CD ROM copy of the FEIS to this office at the same time it is officially filed with our Washington D.C. Office. If you have any questions, please contact me at (415) 972-3521, or contact Scott Sysum, the lead reviewer for this project, at (415) 972-3742 or sysum.scott@epa.gov.

Sincerely,

FOR Connell Dunning

Kathleen Martyn Goforth
Manager
Environmental Review Office (CED-2)
Communities and Ecosystems Division

Enclosures:
(1) Summary of EPA Rating Definitions
(2) EPA's Detailed Comments

cc: Distribution List

SUMMARY OF EPA RATING DEFINITIONS*

This rating system was developed as a means to summarize the U.S. Environmental Protection Agency's (EPA) level of concern with a proposed action. The ratings are a combination of alphabetical categories for evaluation of the environmental impacts of the proposal and numerical categories for evaluation of the adequacy of the Environmental Impact Statement.

ENVIRONMENTAL IMPACT OF THE ACTION

"LO" (Lack of Objections)

The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

"EC" (Environmental Concerns)

The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

"EO" (Environmental Objections)

The EPA review has identified significant environmental impacts that should be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

"EU" (Environmentally Unsatisfactory)

The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. The EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the Council on Environmental Quality.

ADEQUACY OF THE IMPACT STATEMENT

Category "1" (Adequate)

The EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category "2" (Insufficient Information)

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category "3" (Inadequate)

The EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From EPA Manual 1640, Policy and Procedures for the Review of Federal Actions Impacting the Environment.

US EPA DETAILED COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE HAIWEE GEOTHERMAL LEASING AREA INYO COUNTY, CALIFORNIA AND THE DRAFT PROPOSED CALIFORNIA DESERT CONSERVATION AREA PLAN AMENDMENT, AUGUST 1, 2012

Water Resources

The Draft Environmental Impact Statement indicates that the Reasonably Foreseeable Development Scenario would require water for well drilling, dust control during construction, and makeup water to compensate for evaporative loss during plant operation if the plant designs include conventional cooling towers; however, under the preferred alternative, BLM would prohibit extraction of groundwater for consumptive use. The DEIS states that the source of the requisite water is "currently unknown" (p. 4-45). The DEIS also states that "[w]ater consumption and use would be evaluated during the NEPA process at the project level" (p. 2-53).

> *Recommendation:*
> The FEIS should identify the potential sources of water. We recommend that this discussion include consideration of whether it would be feasible to use sources such as wastewater for geothermal well drilling, injection and power plant operations.

Tiering and "Programmatic Like" Analysis

The DEIS states that the BLM's purpose and need for granting the pending leases is to facilitate appropriate exploration and development of geothermal resources in the HGLA, consistent with the BLM's management of other important resources in the HGLA. The BLM does not authorize any specific energy development or Federal Land Policy and Management Act right of way based on the decisions from this EIS. According to the DEIS:

> Issuance of a lease for geothermal resources lays the groundwork for future exploration and development, but does not confer the right for any activities involving ground disturbance or activities that may impact the resources of the lease area. Any future geothermal project or other energy exploration and development that may be proposed within the HGLA will be evaluated under a separate National Environmental Policy Act analysis on a site and project-specific basis (p. 1-2).

The DEIS does not, however, describe the process, screening criteria, or thresholds that would be used to determine the level of subsequent NEPA analysis.

> *Recommendations:*
> The FEIS should clarify that any subsequent site specific geothermal exploration or development projects would require further environmental analysis, which could be conducted through either an environmental assessment or an EIS that could tier to the subject FEIS and the BLM's Programmatic EIS for Geothermal Leasing in the Western United States (2008).
>
> The BLM should elaborate on the process that individual offices will use to determine whether an EA or EIS will be prepared for subsequent projects, and identify the mechanism, screening

criteria, and/or thresholds that would be used to make these decisions. We recommend that consistent standards for determining the appropriate level of NEPA review for individual projects be identified and implemented to ensure that impacts are consistently identified, analyzed and disclosed.

Stipulations, Best Management Practices, and Procedures

The extent to which groundwater may be extracted for consumptive use during geothermal operations covered by the DEIS is not clear. For example, Stipulation SA-HGLA-10 states:

> Groundwater extraction for consumptive use during geothermal project operations will be prohibited throughout the entire HGLA, except as allowed under item (c) below (p. 2-42).

The text for stipulation SA-HGLA-10 items (b), (c) and (d), however, all seem to allow consumptive use of groundwater for the exploration and development of geothermal projects.

The DEIS states, on pages 2-12, 2-17, and 2-20, that, for alternatives A, C and D, groundwater extraction for consumptive use may be allowed, with various restrictions. Elsewhere, the document states that, based on public concerns regarding the use and limited availability of groundwater, groundwater extraction for consumptive use would be prohibited under Alternatives C and D (pp. 4-51 to 4-52). These statements seem to be inconsistent.

The DEIS also states that, in addition to the various lease stipulations, the BLM may require a number of BMPs as conditions of any lease under the action alternatives, and that the mitigation measures and BMPs proposed in the California Renewable Energy Action Team Best Management Practices and Guidance Manual: Desert Renewable Energy Projects, September 2010 manual have been adopted for this EIS (p. 2-44). Please note that the final version of that manual is dated December 2010.

> *Recommendations:*
> The FEIS should correct any inconsistencies related to consumptive groundwater use in the text of the documents and, specifically, in the Special Administrative Stipulation SA-HGLA-10.
>
> The FEIS should ensure that the BMPs that are adopted from the Renewable Energy Action Team Best Practices and Guidance Manual reflect any changes incorporated in the December 2010 version of that document.

Biological Resources, Habitat and Wildlife

Stipulation CSU-HGLA-2, item e) states that unless otherwise agreed to in writing by the Authorized Officer, power lines shall be constructed in accordance with standards outlined in "Suggested Practices for Raptor Protection on Power lines", Raptor Research Foundation, Inc., 1996 (p. 2-32).

Recommendation:
Include, in the FEIS, the most current practices that reduce the potential for raptor fatalities and injuries from power lines. These practices can be found in the "Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006", Edison Electric Institute, Avian Power Line Interaction Committee and California Energy Commission.

Climate Change

Scientific evidence supports the concern that continued increases in greenhouse gas emissions resulting from human activities will contribute to climate change. A report by the California Energy Commission indicates that observed changes in temperature, sea level, precipitation regime, fire frequency, and agricultural and ecological systems reveal that California is already experiencing the measurable effects of climate change[1]. The report indicates that climate change could result in the following changes in California: poor air quality; more severe heat; increased wildfires; shifting vegetation; declining forest productivity; decreased spring snowpack; water shortages; a potential reduction in hydropower; a loss in winter recreation; agricultural damages from heat, pests, pathogens, and weeds; and rising sea levels resulting in shrinking beaches and increased coastal floods.

Recommendations:
The FEIS should discuss the potential impact of climate change on the effectiveness of proposed BMPs, lease stipulations and mitigation measures.

The NEPA analysis for each subsequent site specific project should discuss the potential impact of climate change on that project, and incorporate mitigation measures, as appropriate. The NEPA analyses for subsequent site specific projects should also assess how the projected impacts of each individual project could be exacerbated by climate change.

Emergency Planning and Community Right to Know Act, CAA §112(r), and California Accidental Release Prevention Program

The 2008 Geothermal PEIS provides a list of hazardous materials routinely found at geothermal plants. Hydrogen sulfide is a potential toxic gaseous pollutant that could be released during drilling, maintenance or as the result of an accident. The geothermal power plants will have to comply with CAA §112(r), and, as applicable, the Emergency Planning and Community Right to Know Act sections 303, 311, and 312, and the California Accidental Release Prevention Program. Additionally, the County's Local Emergency Planning Committee may require a facility to produce an emergency response plan whether or not such a plan is required under other regulations.

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[1] Moser, Susie, Guido Franco, Sarah Pittiglio, Wendy Chou, Dan Cayan. 2009. The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2008-071.

Recommendation:
The FEIS should discuss compliance with CAA §112(r), EPCRA §§ 303, 311, & 312 and the California Accidental Release Prevention (CalARP) program, as applicable.

Cultural Resources, National Historic Resources and Consultation with Tribal Governments

The EPA commends the BLM for early consultation for tribal cultural resources as required under Section 106 of the National Historic Preservation Act. The DEIS states that the BLM has initiated government-to-government consultation with the Big Pine Paiute Tribe, the Bishop Paiute Tribe, the Fort Independence Paiute Tribe, the Lone Pine Paiute-Shoshone Tribe, and the Timbisha Shoshone Tribe. EPA has identified additional tribes that may have cultural ties to the project area (see Recommendations, below).

According to the DEIS, the Tribes who have been consulted are concerned about extraction of resources from the land; the benefit to the Tribes from the proposed action; impacts on spiritually important sites; impacts to Coso Hot Springs; the effects of the proposed action on the water table; the need for new transmission lines; and whether the new facilities could prohibit access to traditional lands. They have expressed the perspective that the entire landscape is sacred; that geothermal development in the leasing area could conflict with their traditional values; and that impacts on Native American values are not amenable to mitigation. Also expressed was the desire to have tribal monitors present in the event of any surface disturbing activities (p. 5-8).

Recommendations:
Consider expanding the number of tribes invited for consultation to include the Battle Mountain Band Council, Big Sandy Rancheria, Bridgeport Paiute Tribe, Cold Springs Rancheria, Goshute Business Council, Duckwater Shoshone Tribe, Elko Band Council, Ely Shoshone Tribe, North Fork Rancheria, Picayune Rancheria, Santa Rosa Indian Community, South Fork Band Council, Table Mountain Rancheria, Tule River Indian Tribes, U Tu Utu Gwaitu Tribal Council and the, Wells Band

Describe, in the FEIS, the process and outcome of government-to-government consultation between the BLM and each of the tribal governments within the project area, including any issues that were raised and how those issues were addressed in relation to the proposed action and selection of a preferred alternative.

Alternatives Analysis

The Haiwee Reasonably Foreseeable Development Scenario is based on a dual-flash cycle geothermal steam plant design utilizing wet cooling towers for steam condensation. According to the DEIS, the binary plant design was eliminated from further analysis because it utilizes lower temperature geothermal resources than those anticipated to occur within the HGLA. Elsewhere, however, the DEIS states that binary cycle geothermal power plants typically have lower evaporative losses (5 percent) and, to mitigate impacts associated with evaporative water losses, appropriate technologies, such as binary cycle, may be implemented (p. 2-51).

Recommendation:
The FEIS should clarify whether a binary cycle plant may be implemented vice dual-flash steam, and if so, the binary plant design should be carried forward in the analysis. Binary plants typically require less water use and use a low boiling point organic working fluid.

Distribution List

Chairman Michael Price
Battle Mountain Band Council

Chairperson Virgil Moose
Big Pine Paiute Shoshone Tribe

Chairperson Elizabeth Kipp
Big Sandy Rancheria

Chairperson John Glazier
Bridgeport Paiute Tribe

Chairperson Robert Marquez
Cold Springs Rancheria

Chairman Ed Naranjo
Goshute Business Council

Chairperson Virginia Sanchez
Duckwater Shoshone Tribe

Chairman Gerald Temoke
Elko Band Council

Chairperson Alvin Marques
Ely Shoshone Tribe

Chairperson Israel Naylor
Fort Independence Reservation

Chairperson Elaine Fink
North Fork Rancheria

Chairman Dale Delgado, Jr.
Bishop Tribal Council

Chairperson Melvin R. Joseph
Lone Pine Community

Chairperson Reggie Lewis
Picayune Rancheria

Chairperson Ruben Barrios
Santa Rosa Indian Community

Chairman Brandon Reynolds
South Fork Band Council

Chairperson Leanne Walker-Grant
Table Mountain Rancheria

Chairperson George Gholson
Timbisha Shoshone Tribe

Chairman Ryan Garfield
Tule River Indian Tribe

Chairperson Billie Saulque
U Tu Utu Gwaitu Tribal Council

Chairperson Paula Salazar
Wells Band Council

Debbie Flores
Battle Mountain Band Council

Sally Manning
Big Pine Paiute Shoshone Tribe

Gavin Begaye
Big Sandy Rancheria

Justin Nalder
Bridgeport Paiute Tribe

Terry Williams
Cold Springs Rancheria

Annette Harris
Duckwater Shoshone Tribe

Alfreida Jake
Elko Band Council

Cindy S. Marques
Ely Shoshone Tribe

Dennis Mattinson
Fort Independence Reservation

Christina McDonald-
North Fork Rancheria

Brian Adkins
Bishop Tribal Council

Melvin Joseph
Lone Pine Community

Samuel Elizondo
Picayune Rancheria

Allen Berna
Santa Rosa Indian Community

Nicholas LaPalm
South Fork Band Council

Cliff Raley
Table Mountain Rancheria

Merv Hess
Timbisha Shoshone Tribe
P. O. Box 1779

Kerri Vera
Tule River Indian Tribe

Juanita Watterson
U Tu Utu Gwaitu Tribal Council

Aurora Aboite
Wells Band Council

LETTER DD

BIG PINE PAIUTE TRIBE OF THE OWENS VALLEY

Big Pine Paiute Indian Reservation
P.O. BOX 700 · 825 SOUTH MAIN STREET · BIG PINE, CA 93513
(760) 938-2003 · FAX (760) 938-2942 www.bigpinepaiute.org

JAMES RAMBEAU
TRIBAL COUNCIL CHAIRMAN

July 31, 2019

Carl Symons, Field Manager
Bureau of Land Management
Ridgecrest Field Office
300 S. Richmond Road
Ridgecrest, CA 93555
Via email to: blm_ca_cd_haiwee_geothermal@blm.gov

Subject: Comments on Haiwee Geothermal Leasing Area Draft Supplemental EIS

Dear Mr. Symons:

Please accept these comments from the Big Pine Paiute Tribe of the Owens Valley (Tribe) on the Haiwee Geothermal Leasing Area (HGLA) Draft Supplemental Environmental Impact Statement (DSEIS) and Draft Proposed Amendment to the California Desert Conservation Area Plan. The land area designated as the HGLA lies within a region of great cultural importance to the Native American tribes as these lands were occupied or used for thousands of years. The Tribe submitted comments to the Bureau of Land Management (BLM) during the scoping period for the HGLA on November 10, 2009, and during the comment period on the 2012 first draft EIS in a letter dated July 23, 2012. The Tribe feels its comments are being disregarded by the BLM, but the concerns of the Tribe remain relevant to this DSEIS.

Overall Comment

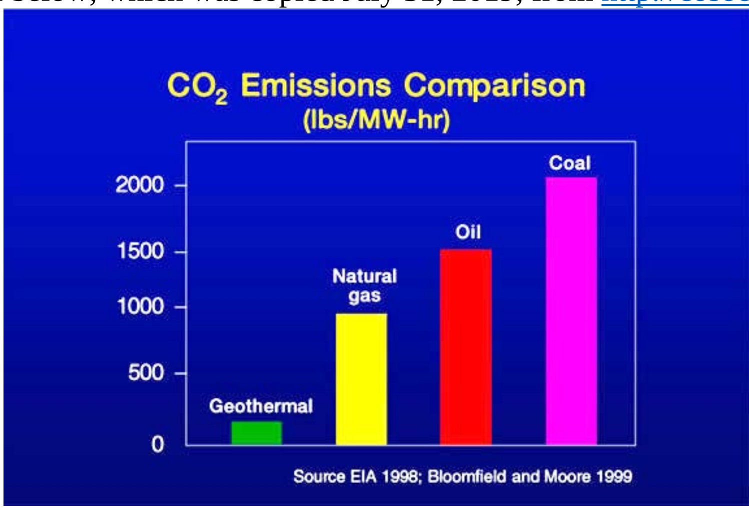
Overall, the Tribe recommends the entire HGLA be closed to geothermal exploration, development, and leasing The Tribe makes this recommendation based on the long-term adverse impacts geothermal development would have on the ethnographic landscape and on the water resources of Rose Valley and the surrounding region including Coso Hot Springs. The Tribe notes that, unlike the 2012 DEIS, there is not an alternative equivalent to Alternative B of that DEIS. The most acceptable alternative in the 2019 DSEIS is Alternative D, but this alternative does not permanently close the entire area to development because it may at a future time allow development in parts of the area. 1

Sacrificing Resource Protection for Renewable? Energy

In reviewing the DSEIS, the Tribe notes with exasperation the ease with which land management designations -- at least the designations designed to protect areas from development and resource exploitation -- may be lifted, altered, or “amended” to the point where they are no longer protective. The Federal Lands Policy and Management Act (FLPMA) in 1976 raised the importance of conservation of ecological values and called for BLM to identify and specially manage certain areas to protect, for example, riparian corridors, threatened and endangered species habitats, cultural and archaeological resources, and important landscapes. BLM accordingly established the Areas of

Critical Environmental Concern (ACEC) program. To its credit, BLM has made an effort to identify and designate ACECs, and there are many important ACECs in the Eastern Sierra. Upon reading the DSEIS, it sadly appears all too easy for BLM to go back on its designations and, despite the word "critical," lessen protection by allowing energy development, surface occupancy, hydrological alterations, and disruption to biological and cultural resources. ACEC designations highlight areas where special management attention is needed to protect and prevent irreparable damage to important historic, cultural, and scenic values; fish, plant, or wildlife resources or other natural systems or processes; or to protect human life and safety from natural hazards. Considering what modern western society has done to landscapes throughout this country, the Tribe feels the ACEC and similar land management prescriptions are not burdensome; they serve an important purpose to prevent development simply for the sake short term gain of jobs, dollars, and a few weeks of air conditioning. They must not be sacrificed when a developer comes along with a proposal. (con't)

The Tribe is concerned that very little is known about the long term consequences of geothermal power plants. Geothermal is often considered in the same renewable or green energy category as solar or wind, but it is less renewable and green than other technologies. In the short term, because fossil fuel is not burned, geothermal power may help to reduce greenhouse gas emissions. However, the Tribe notes that geothermal plants typically *do* emit some of earth's sequestered carbon dioxide into the atmosphere (see graph below, which was copied July 31, 2019, from http://cosoenergy.com/).



Also, geothermal fluid is lost in the process of producing power, so it is not truly a renewable resource. Finally, after geothermal production is no longer viable, scars remain indefinitely on the land, and resources become depleted.

Impacts to Cultural Resources

Developing geothermal within the HGLA will have irreversible significant impacts on the ethnographic landscape of the Rose Valley and the important cultural sites of the region. There are significant multi-component sites intersecting with, and in all directions from, the HGLA, including Ayer's Rock, Rose Springs, the Stahl Site, Fossil Falls Archaeological District, the Sugarloaf Archaeological District, Haiwee Springs, Coso Rock Art District National Historic Landmark, and Coso Hot Springs. This dense concentration of highly significant cultural sites form a discrete region with the HGLA located within this cultural landscape.

The Tribe is concerned that the Rose Valley area ethnographic landscape is being incrementally damaged by the progression of development projects in the region. The concern is heightened by the description in the DSEIS of the complicated path to approving a project proposed for the HGLA (Section 3.8.1 of the DSEIS). Rather than simply rejecting projects which may threaten cultural resources, the DSEIS says (p. 31), "In short, any proposed development within leases reviewed under this DSEIS require additional Section 106 review consistent with the DRECP PA. If avoidance of historic properties is not possible, the BLM will notify and invite the Advisory Council on Historic Preservation (ACHP), SHPO, Indian tribes, and all other consulting parties into consultation to resolve the identified adverse effect, consistent with 36 CFR Part 800.6."

In its previous comments, the Tribe said that the EIS is not considered complete by the Tribe without the inclusion of a "Native American Issues and Concerns" section. The DSEIS does not contain such a
section which may and should be included in EISs for projects in the Great Basin. For example, the 2
Legislative EIS for the Nevada Test and Training Range contained Appendix K: Native American Perspectives. This 152-page section was prepared by Tribal members of tribes affected by the project.

In its previous comments, the Tribe recommended BLM commission an analysis of the ethnographic landscape. The National Park Service defines *ethnographic landscape* in its Preservation Brief No. 36 (1994)[1] as: "a landscape containing a variety of natural and cultural resources that associated people define as heritage resources. Examples are contemporary settlements, religious sacred sites and massive geological structures. Small plant communities, animals, subsistence and ceremonial grounds
are often components." The National Park Service's Applied Ethnography Program provides this 3
definition for *ethnographic landscape*: "…a relatively contiguous area of interrelated places that contemporary cultural groups define as meaningful because it is inextricably and traditionally linked to their own local or regional histories, cultural identities, beliefs and behaviors" (Michael J. Evans, et al., *Ethnographic Landscapes*: 54 CRM No 5—2001)[2]. An Ethnographic Landscape is a sub-category of the National Park Service's "Cultural Landscape," and can be eligible for listing on the National Register of Historic Places.

Impacts to Regional Water Resources

The DSEIS acknowledges that geothermal exploration and development in the HGLA (pp. 62-63), "will require water for well drilling, dust control during construction, and makeup water to compensate for evaporative loss during plant operation if the plant designs include conventional, i.e., "wet", cooling towers". Considering the location of the HGLA, there are only two reliable ways to procure water: pump it from the ground or transport water to the site.

The Tribe particularly objects to further exploitation of groundwater in the Rose Valley. The Tribe has watched with dismay since December 25, 2009, as the Coso Operating Company, with permission from the County of Inyo, has drained a significant amount of groundwater out of Rose Valley. Prior to commencing pumping at the Coso Operating Company Hay Ranch, the Inyo County Water Director
created an arbitrary threshold of hydroecological significance for impacts to Little Lake, and to date, 4
this criterion has been used to allow excessive pumping in Rose Valley. Groundwater levels at monitoring wells throughout the valley, and particularly in the south where Little Lake is located and the groundwater basin naturally discharges, have dropped dramatically over the past decade (see attached graphs which are a subset of the data available at http://www.inyowater.org/projects/groundwater/coso-hay-ranch-project/). These declines have

[1] https://www.nps.gov/tps/how-to-preserve/briefs/36-cultural-landscapes.htm
[2] https://www.scribd.com/document/197896408/Ethnographic-Landscapes

occurred even though pumping at the Hay Ranch has not been at the maximum rate allowed by the county. 4 (con't)

The Tribe's analysis of data resulting from the Coso Hay Ranch Project shows unacceptable groundwater depletion, which may have consequences for Little Lake and any future water uses in Rose Valley. The Tribe has observed that Inyo County has altered its water level threshold depths over time, which in most cases has resulted in allowing more and more pumping at Hay Ranch. After pumping commenced, the Water Director has allowed water levels to drop at the key monitoring well for Little Lake beyond levels presented in the original project description. For years prior to pumping, water levels had fluctuated seasonally just north of Little Lake, but the level had not dropped below the original baseline depth (3158.88 feet above mean sea level). Now, as shown in the attached figures, groundwater levels are on a downward trajectory in this and in most other key locations in the valley. Another observation from the data is that, during times when the Hay Ranch temporarily curtailed pumping (or reduced it to near zero), groundwater levels in monitoring wells sometimes stop declining and sometimes may rise slightly (mostly in deep aquifers near the Hay Ranch). These trends give no indication that, upon cessation of pumping for the Coso Operating Company Hay Ranch project [3], the groundwater aquifer will recover fully for a long, long time. In fact, the consultants' hydrologic modeling for this project anticipated a period of 150 years of slow, gradual rising of water levels, an indication that they may never return to levels recorded prior to the pumping. (See, for example, Figure 3.2-15 in the draft Coso Operating Company Hay Ranch Water Extraction and Delivery System EIR, available on the Inyo County Water Department webpage cited above.) In summary, the changes seen in the Tribe's analysis of the Coso Hay Ranch project indicate that large projects involving water, such as development in the HGLA, are inappropriate in the Rose Valley region.

The above discussion concerns groundwater that is not "geothermal fluid"; however, geothermal wells do not last forever, and as this resource is depleted, it may have effects on availability of ground water in other parts of the aquifer system. Furthermore, as discussed below, development in the HGLA has the potential to affect resources of critical importance to the Tribe.

Potential Impacts to Coso Hot Springs not Analyzed

In previous comments, the Tribe and other tribes requested an analysis be performed regarding potential impacts of geothermal development in the HGLA on conditions in the vicinity of Coso Hot Springs. Below is a comparison of language from the 2012 DEIS as well as the 2019 DSEIS. The latter, of course, was prepared after BLM received the Tribe's 2012 comments.

2012 DEIS, p. 4-42	**2019 DSEIS, p. 22**
"Although located more than 10 miles east-southeast from the HGLA, the Coso Hot Springs are addressed in this analysis as a result of their high cultural importance and their listing on the National Register of Historic Places. The Coso Hot Springs are surface manifestations of the Coso geothermal reservoir, although any connection between the hot springs and the reservoir, if one exists, is complex."	"A key surface water resource in the vicinity of the HGLA is the Coso Hot Springs. Although located more than 10 miles east-southeast from the HGLA, the Coso Hot Springs are addressed in this analysis as a result of their high cultural importance and their listing on the National Register of Historic Places. The Coso Hot Springs are 1.25 miles east-northeast of the Coso geothermal field. If a connection between the hot springs and the Coso geothermal reservoir exists, it is complex and not understood."

5

[3] Currently permitted through May 31, 2021, but this date may be extended by the Water Director

The Tribe asserts that, regardless of complexity, there needs to be an analysis of the potential connection between the HGLA and Coso Hot Springs. Instead, in both EISs, Coso Hot Springs is addressed with one short paragraph indicating no further action on the Tribe's previous comment. 5 (con't)

2012 DEIS, p. 4-50	2019 DSEIS, p. 64
"With regards to the potential impacts to the Coso Hot Springs, any effects to the hot springs from the proposed action are unlikely under Alternative A (or under any of the alternatives). This is due to the distance between the Coso Hot Springs and the HGLA, the likely discontinuity between geothermal resources between the two areas, and the observed isotopic differences in the waters. Moreover, surface manifestations in such hot springs reflect natural seasonal (and sometimes diurnal) variations (Geologica 2007)."	"Any effects to the Coso Hot Springs from Alternative A (or under any of the alternatives) are unlikely due to the distance between the Coso Hot Springs and the HGLA, the likely discontinuity between geothermal resources between the two areas, and the observed isotopic differences in the waters. Moreover, surface manifestations in such hot springs reflect natural seasonal (and sometimes diurnal) variations (Geologica 2007)."

The Tribe is in possession of several annual Coso Hot Springs monitoring reports from the consulting firm, Geologica, which prepares the reports for Naval Air Weapons Station, China Lake. Assuming these are the reports to which the EIS refers, these reports simply present routine monitoring data, and they do not analyze for any connection between Coso Hot Springs and the HGLA. The statements addressing potential impacts to Coso Hot Springs by geothermal development in the HGLA are unsubstantiated and inadequate for an EIS. Because the data indicate Coso Hot Springs has already been adversely effected by nearby geothermal development, the Tribe remains concerned about compounding the adverse effects by commencing new geothermal development in the HGLA.

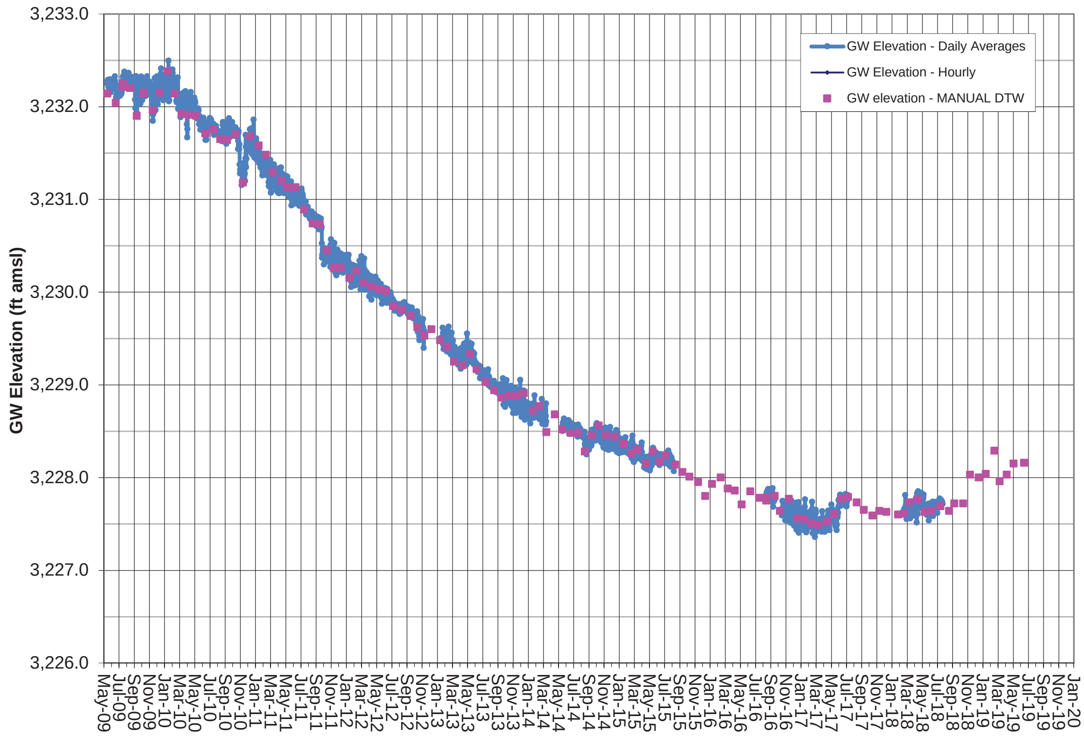
Thank you for considering these comments.

Sincerely,

James Rambeau
Tribal Chairperson

Attachment: Graphs downloaded from http://www.inyowater.org/projects/groundwater/coso-hay-ranch-project/ showing change in depth to water in select Rose Valley monitoring wells for the duration of the Coso Hay Ranch Project, 2009 to the present. The last graph labeled "RV180 - Little Lake Ranch North Well" is the key indicator for the future of Little Lake.

GROUNDWATER ELEVATION DATA - Transducer
RV090 - Coso Junction Ranch Well



Note: Transducer data (absolute pressure) adjusted by data logged from BaroTroll and correlated to Manual DTW measurements.
COC initiated Hay Ranch Project pumping on 12/25/09.
Data gaps due to approved Pressure Transducer removal.

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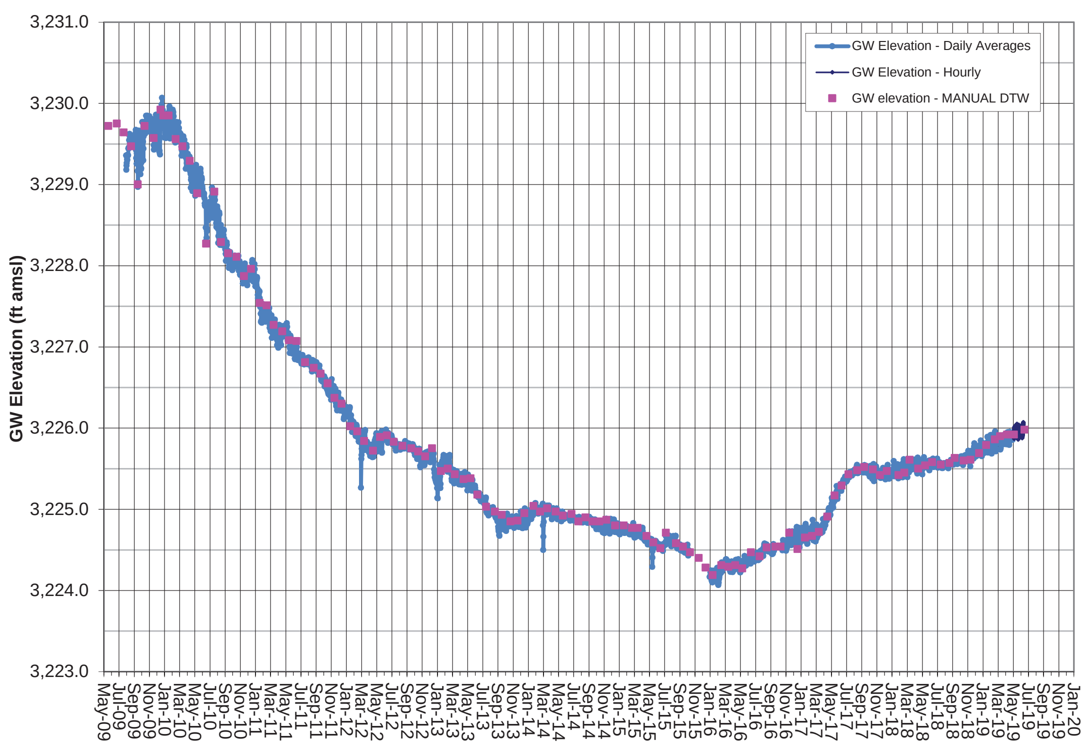
GROUNDWATER ELEVATION DATA - Transducer
RV100- Coso Junction Store#1 Well



Note: Transducer data adjusted by data logged from BaroTroll and correlated to Manual DTW.
Data gap from Oct.-Dec. due to pressure transducer malfunction.
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.

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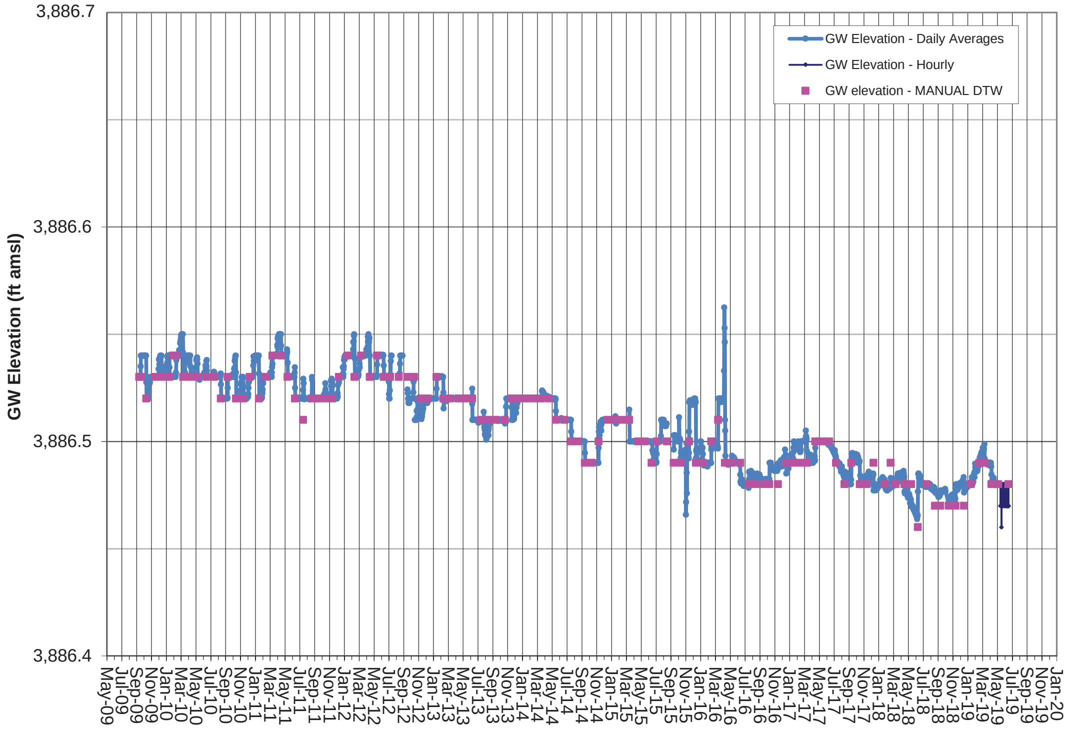
GROUNDWATER ELEVATION DATA - Transducer
RV110 - Davis Ranch North Well



Note: Vented transducer data correlated to Manual DTW measurements.
DTW measured to .01 foot; GWE calculated using approximate surface elevation.
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.

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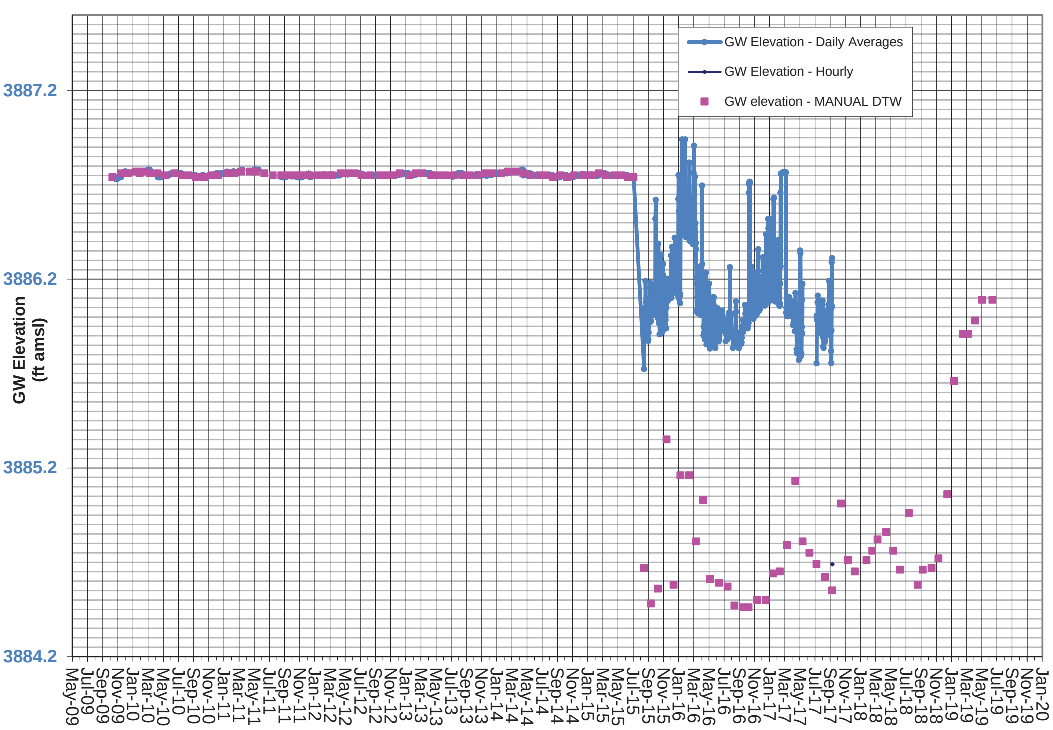
GROUNDWATER ELEVATION DATA - Transducer
RV111 - Davis Ranch South Well



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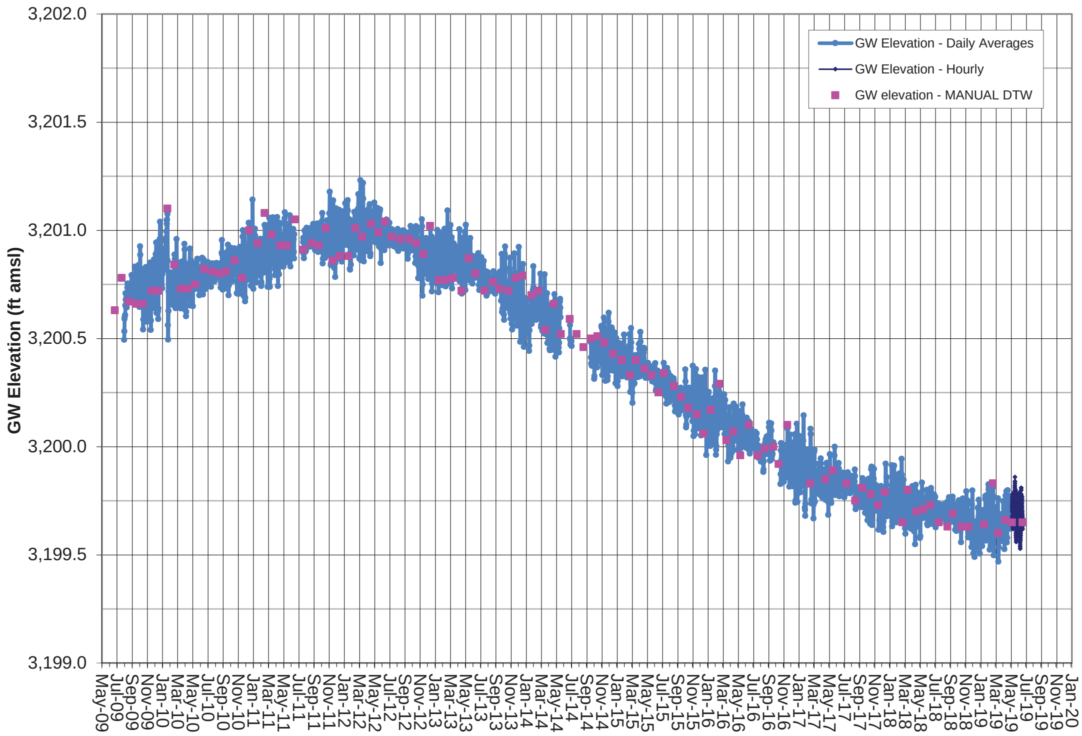
Note: Transducer data correlated to Manual DTW measurements.
Solar water supply pump installed in DR South in July 2015, which affects the accuracy of DTW correlation. Transducer removed 10/18/17.

GROUNDWATER ELEVATION DATA - Transducer
RV120 - Red Hill Well



Note: Red Hill data gap in 2011 and 2014 due to transducer malfunction. Well inaccessible in December 2018.
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.

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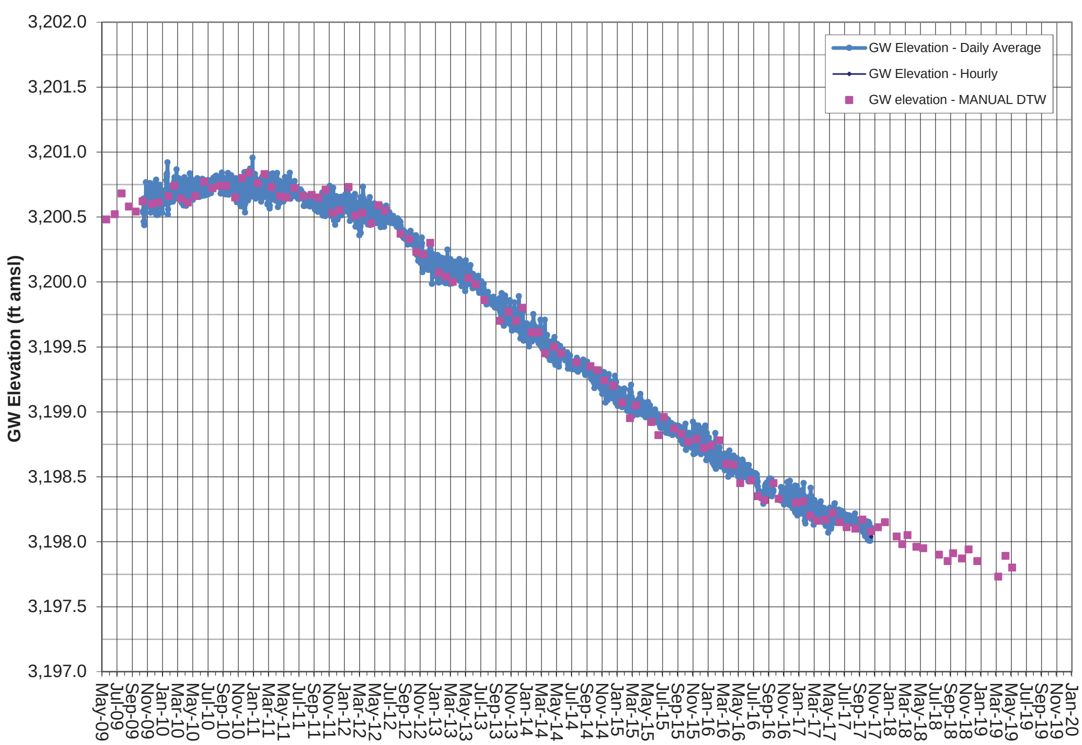
GROUNDWATER ELEVATION DATA - Transducer
RV140 - Lego Well



Note: Transducer data adjusted by BaroTroll and correlated to Manual DTW .
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.Transducer removed 11/15/17.

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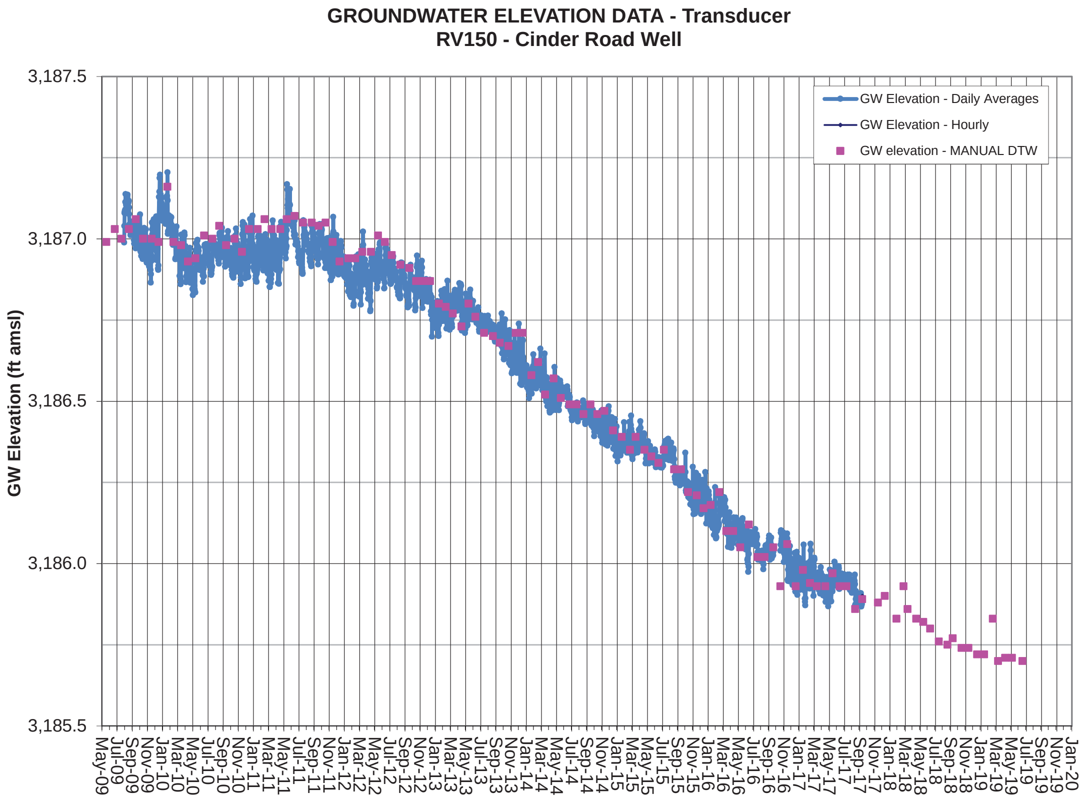

Note: Transducer data (absolute pressure) adjusted by data logged from BaroTroll and correlated to Manual DTW measurements.
Well damaged and transducer missing on Oct. 2017.
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.

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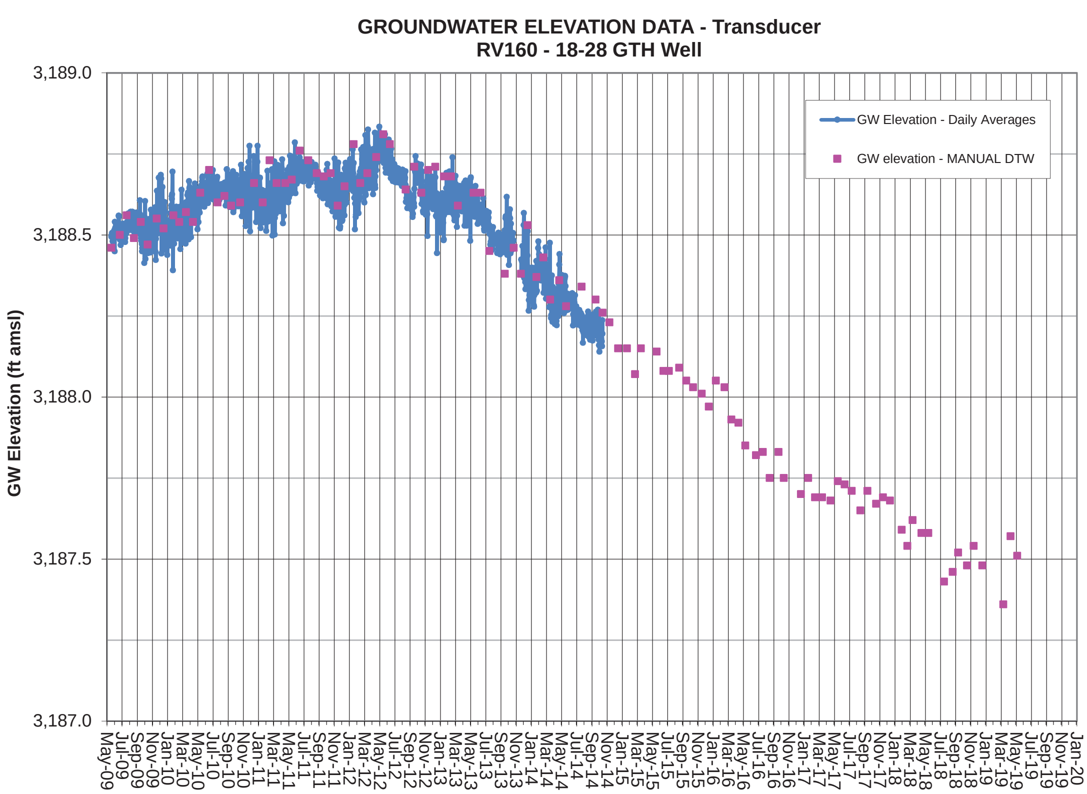

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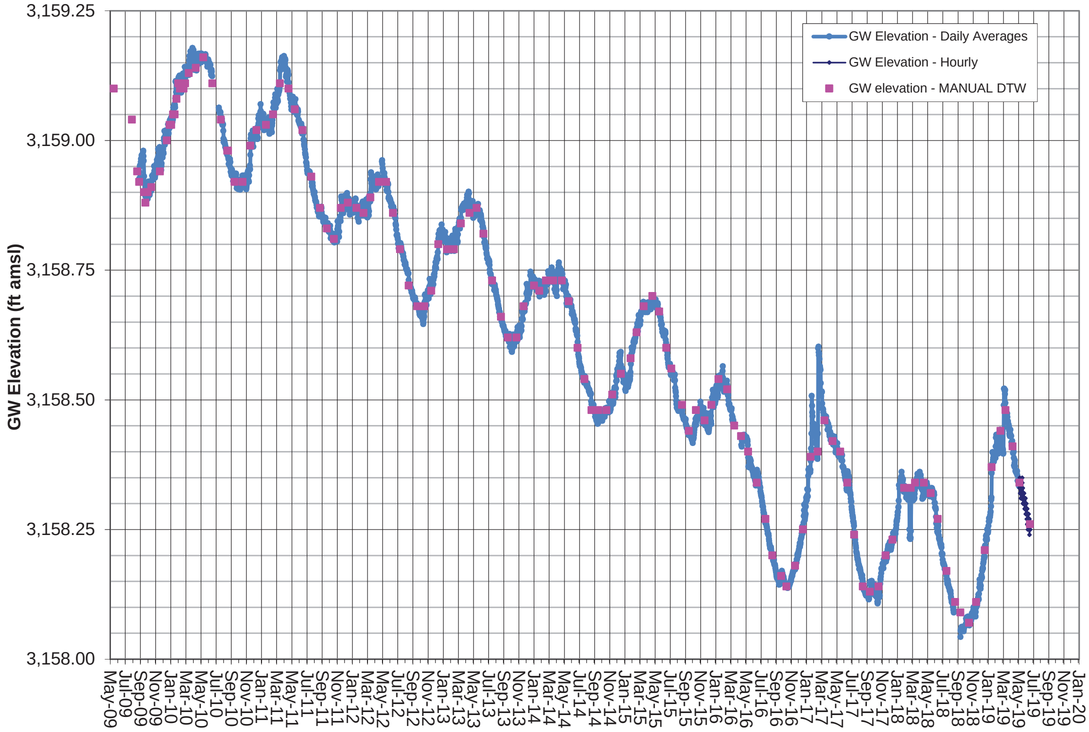
Note:
Pressure Transducer removed in 2015 as approved by ICWD.

GROUNDWATER ELEVATION DATA - Transducer
RV180 - Little Lake Ranch North Well



Note: Vented transducer data correlated to Manual DTW measurements.
Coso Operating Co. initiated Hay Ranch Project pumping on 12/25/09.
Transducer replaced on 9/20/18.

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Bishop and Mammoth Lakes, California
6/21/2019

LETTER EE

July 31st 2019

Attn: Greg Miller, Assistant District Manager – Resources
22835 Calle San Juan De Los Lagos
Moreno Valley, CA 92553

Re: Comments on Draft Supplemental Environmental Impact Statement for the Haiwee Geothermal Leasing Area (HGLA)

Dear Mr. Miller;

Thank you for the opportunity to provide comments on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Haiwee Geothermal Leasing Area (HGLA). This comment letter is submitted by: The Amargosa Conservancy, who works toward a sustainable future and responsible resource use in the Amargosa basin, a similarly groundwater dependent system in southern Inyo County, CA and Nye County, NV. The Bodie Hills Conservation Partnership, which is a coalition of organizations working toward the permanent protection of the Bodie Hills, an American treasure with exceptional scenic, historic and recreational values. The California Wilderness Coalition (CalWild), who protects and restores the state's wildest natural landscapes and watersheds on public lands. Conservation Lands Foundation (CLF), who works to protect, restore, and expand the National Conservation Lands through education, advocacy and partnerships while supporting more than 60 community-based organizations across the West. Defenders of Wildlife (Defenders) on behalf of its 1.8 million members and supporters in the U.S., including 279,000 in California. Friends of the Inyo (FOI), a Bishop, CA based non-profit with over 800 members who is devoted to the preservation of the Eastern Sierra landscapes, animals, plants and natural ecosystems. The Sierra Club, which is America's largest grassroots environmental organization, with more than 3.5 million members and supporters, including 400,000 in California. In the Eastern Sierra, the local Range of Light Group is part of the Toiyabe Chapter of the Sierra Club and consists of over 400 Sierra Club members in Inyo and Mono Counties. The Wilderness Society (TWS) which was founded in 1935 and represents over one million members and supporters. TWS's mission is to protect wilderness and inspire Americans to care for our wild places.

As detailed below, we recommend that BLM select Alternative D, which allows for leasing, exploration and development in the Development Focus Area (DFA) and does not allow leasing, exploration and development in the Areas of Critical Environmental Concern (ACECs) and California Desert National Conservation Lands (CDNCLs).

HGLA Background: The DSEIS for the HGLA evaluates alternatives for geothermal leasing on approximately 22,805 acres of BLM-administered public lands and subsurface mineral estate. Within the HGLA, approximately 21,233 acres are BLM-managed lands; the remaining 1,572 acres are split-estate where the BLM manages only the subsurface mineral rights and the surface is privately owned. Once the National Environmental Policy Act (NEPA) analysis is finalized, the Bureau of Land Management (BLM) will use the results of that analysis to determine which public lands and federal mineral estate within the HGLA will be available for geothermal leasing, exploration, and development in areas not already designated as such (i.e., DFA) in the California Desert Conservation Area (CDCA) Plan, as amended. The final decision will also consider approval of three pending geothermal lease applications within the HGLA.

Alternatives in the DSEIS include the following alternatives:

1. Alternative A (BLM-Preferred Alternative): Allow Geothermal Leasing in the entire HGLA, including approving three pending geothermal lease applications;

2. Alternative B: Allow Geothermal Leasing in the Entire HGLA with No Surface Occupancy in Sensitive Areas;

3. Alternative C: Retain current management of the HGLA, and approve pending geothermal leases outside of lands with sensitive resources;

4. Alternative D: No Action (i.e., lands within the HGLA outside of existing DFAs would not be made available for geothermal leasing, exploration and development and would remain under current management as specified in the CDCA Plan, as amended. Any proposed geothermal facilities in the DFA would be under the CDCA Plan, as amended. The current pending lease applications would be neither denied nor authorized and would be processed in conformance with the CDCA Plan, as amended. Any geothermal leasing, exploration or development proposed within existing conservation areas (i.e., ACECs and CDNCL) would not be allowed; leasing, exploration and development within the DFA would be allowed).

Our comments on the DSEIS for the HGLA are as follows:

1. **Alternatives**: Certain alternative geothermal technologies were considered as alternatives but eliminated from further analysis. Specifically, the Dry Cooling System technology (DSEIS Section 2.3.1.3) was eliminated over concern that dry cooling would decrease the overall efficiency of powerplants during the summer season when ambient air temperatures are high and electricity demand is greatest. However, this technology was considered because the HGLA is in an area with limited water sources (i.e., Rose Valley groundwater) where current groundwater pumping in support of operating geothermal powerplants in the Coso Known Geothermal Resource Area (KGRA) within the China Lake Naval Air Weapons Station is at or near the sustained yield of the groundwater basin.

Comment: We recommend that BLM analyze the Dry Cooling System technology alternative because we believe that dry cooling technology is feasible, reasonably cost effective and would conserve substantial amounts of ground water from Rose Valley. We incorporate into this letter, by reference, a comment letter from Ronald DiPippo, Ph.D. to Inyo County dated August 14, 2008 (attached) and March 16, 2009 (attached), on the Coso/Hay Ranch DEIR. 1

The Coso Operating Company that maintains and operates the existing geothermal powerplants in the Coso KGRA uses water cooling technology, which is among the most water use intensive cooling technologies. While the efficiency of a dry cooled system is reduced in the hot summer months, it is feasible during the remainder of the year when ambient air temperatures are lower, especially in the late fall through early spring seasons. Furthermore, dry cooling would eliminate the substantial waste of groundwater associated with the wet cooling technology currently used at Coso powerplants. Using air cooled steam condensing technology, while not as efficient as the current water cooled steam condensers, should not be rejected from analysis simply because it would require additional investment by Coso Operating Company and decrease their profits.

Operation of the Coso KGRA powerplants began in about 1989, initially producing about 300 MW, with powerplants fed by steam from approximately 200 production wells. Based on research study of the KGRA from 1993 – 1999 using high-resolution satellite imagery, Fialko and Simons[1] determined that ground subsidence within the Coso KGRA covering an area of approximately 50 km^2 had occurred due to the extraction of geothermal fluids that exceeded the natural groundwater recharge underlying the geothermal field. They considered subsidence in the KRGA was due primarily to reduced steam pressure in the geothermal reservoir and reduction in temperature.

Comment: BLM has a legal obligation under the Federal Land Policy and Management Act (FLPMA) to manage public lands "…on the basis of multiple use and sustained yield unless otherwise specified by law." (FLPMA, Section 102(7); and that, "the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological 2

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[1]Y. Fialko and M. Simons. 2000. Deformation and seismicity in the Coso geothermal area, Inyo County, California: Observations and modeling using satellite radar interferometry. Journal of Geophysical Research, Vol. 105, No. B9, Pages 221,781 – 21,793, September 10, 2000.

values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use." (FLPMA Section 102(8). Regarding management of public lands in the California Desert Conservation Area, FLPMA states, "(b) It is the purpose of this section to provide for the immediate and future protection and administration of the public lands in the California desert within the framework of a program of multiple use and sustained yield, and the maintenance of environmental quality." (FLPMA Section 601(b). 2 (con't)

BLM is charged with managing public lands in the HGLA under the above provisions of FLPMA, including geothermal leasing, in a manner that sustains the groundwater resource and environmental quality. BLM is obligated to not only consider, but to analyze an alternative to geothermal leasing in the HGLA that limits geothermal technology to the use of air cooled steam condensers for the purpose of conserving and sustaining groundwater for the use and benefit of current and future generations.

Background information: Due to decline of the Coso geothermal field from depletion of groundwater associated with the steam reservoir, Coso Operating Company acquired the Hay Ranch property in Rose Valley to supply groundwater for injection into the Coso geothermal field. Inyo County regulates the amount of groundwater pumping and has implemented a comprehensive groundwater management program to prevent significant impact to groundwater and groundwater-related resources.

The total amount of groundwater pumped from the Hay Ranch property from December 25, 2009 to May 8, 2019 is approximately 17,803 acre-feet (5.8 billion gallons). Coso Operating Company is allowed to pump up to 1,611 acre-feet/year from June 1, 2017 to May 31, 2019, subject to the terms and conditions of the Conditional Use Permit from Inyo County and compliance with the mitigation and monitoring plan. The allowable pumping rate has varied since it began in 2009 based on results groundwater monitoring and analysis, ranging from a high of 4,839 acre-feet/year to a low of 1,611 acre-feet/year. Authorized pumping from 2017 to 2021 is 1,611 acre-feet/year. The 2008 Final Environmental Impact Statement on the Coso Operating Company Hay Ranch Water Extraction and Delivery System[2] includes the following Response to comments (p. 2-6): The lack of substantial recharge combined with the net difference between fluid production and injection results in a net withdrawal of fluid from the Coso system. The net yearly fluid withdrawals are on the order of 2.5 million cubic meters of water. If this were spread uniformly over the Coso geothermal field (about 2 km by 5 km), this would result in a yearly water level decline of 0.25 m. (about 4 m over 15 years)." And, "The annual loss of water from the geothermal reservoir establishes the need for the proposed project; and, The proposed project would just serve to stop the decline in production."

Response to comments (p. 2-15): "The purpose of the project is to supply supplemental injection water to the Coso geothermal field, which is experiencing annual reservoir decline due to the loss of fluid through the cooling towers."

[2] http://www.inyowater.org/wp-content/uploads/legacy/INDEX_DOCS/Coso%20Hay%20Ranch_FEIR_Dec_30_08.pdf

Decline in the Coso geothermal power plants began in 2010 according to Business Wire.[3] It reported, "The increase in the decline rate has more than offset the gains expected from the Hay Ranch water injection program and an extensive capital improvement program. In aggregate, production in 2010 is forecasted to be 1,611 GWh which is approximately 26% below original production estimates in 2007 of 2,184 GWh at the same time. The average net capacity of the facility is now forecasted to be approximately 195 MW."

In addition, a 2015 article in The Sheet (Take a tour at Coso Geothermal)[4] included an overview of the Coso geothermal operation by Steve Ellis, officer with the Coso Operating Company, who stated, "... the plant produced up to 274 Megawatts (MW) at its peak and is currently running at 145 Megawatts."

2. **Status of the Rose Valley Groundwater Basin**: In 2016 the Argonne National Laboratory conducted a study of groundwater consumption for the BLM and determined that Reasonable Foreseeable Development within the HGLA would require an average of 1,830 acre-ft/year under Alternative A (BLM-Preferred Alternative). Page 95 of the DSEIS states, "Based on the calculated recharge rates and observed impacts at the Coso geothermal facilities, the combined groundwater withdrawal is predicted to cause the lowering of the groundwater table and decrease water available to wells, wetlands, and Little Lake. However, all alternatives proposed tie water consumption to the safe yield in the basin, therefore it is unlikely that any geothermal leasing will negatively impact water resources."

Pages 95-96 of the DSEIS provide additional detail regarding current and projected groundwater use and impacts, as follows: "...long-term extraction to augment geothermal reservoir fluid levels would likely have significant impact on sensitive receptors and, in particular, to surface water features at the south end of the valley on the Little Lake Ranch property. The Hay Ranch groundwater diversion project is currently operating at a permitted extraction rate of 3,000 acre-feet per year, comprising a significant fraction of the estimated 5,100 acre-feet per year annual recharge to the Rose Valley aquifer. In addition, LADWP has a proposal to extract approximately 870 acre-ft of groundwater on property they own at the north end of Rose Valley. The timeframe for the LADWP project has not been identified. As discussed above, potentially significant impacts to the groundwater resources of Rose Valley are predicted for even modest long-term pumping to augment geothermal reservoir fluid levels.

Appendix G presents a report on groundwater flow modeling analysis. Results indicate that groundwater extraction for just one or two geothermal plants would likely reduce groundwater flow to Little Lake Ranch. This extraction would exceed the 10 percent flow reduction threshold identified in the Hydrologic Monitoring and Mitigation Plan for the Hay Ranch project (MHA 2008). The analysis presented in Appendix G indicates that a 30-year pumping rate of approximately 1,150 acre-feet per year from a well located at the northern end of the HGLA could be sustained. This would not reduce groundwater flow to Little Lake by more than 10 percent. However, the analysis also indicates that the maximum predicted drawdown at the Little Lake Ranch North well, located near the north end of the Little Lake Ranch property, could exceed 3.5 ft approximately 30

[3] https://www.businesswire.com/news/home/20101116007535/en/Fitch-Downgrades-Coso-Geothermal-Power-Holdings-LLC
[4] http://thesheetnews.com/2015/12/04/take-a-tour-at-coso-geothermal/

years after the start of pumping at that rate. This would exceed the Maximum Acceptable Drawdown threshold of 0.4 feet established for this well in the Hay Ranch HMMP. Considering the Hay Ranch project, significant long-term groundwater extraction, without restraints, is unlikely to be sustained without impacting the surface water at Little Lake Ranch. However, BLM would require water production stipulations of the action alternatives (e.g. trucking water to the site) which should minimize long-term impacts from geothermal development."

Comment: The most current groundwater flow model for Rose Valley was published in 2017 by Inyo County.[5] This study concluded that the annual recharge to the Rose Valley is 3,623 acre-feet/year, significantly less than the 5,100 acre-feet/year reported by Argonne National Laboratory in its report to the BLM in 2016. Thus, the most recent estimate of sustained yield of groundwater withdrawal from Rose Valley is 3,623 acre-feet.

The most recent use of groundwater from Rose Valley by Coso Operating Company was 1,611 acre-feet/year 3
from June 1, 2017 through May 31, 2019, which is also allowed to extend to year 2021 as per the conditional use permit from Inyo County.[6] LADWP has a proposal to extract approximately 870 acre-ft of groundwater on property they own at the north end of Rose Valley, and Argonne National Laboratory estimated that 1,830 acre-feet/year would be needed to support new geothermal powerplants in the HGLA under the Reasonable Foreseeable Development scenario for Alternative A (BLM-Preferred Alternative).

Comment: Combined, the current and projected groundwater consumption totals 2,481 acre-feet/year, leaving approximately 1,142 acre-feet/year available within the sustainable yield of the basin. This amount is less than
the 1,830 acre-feet/year needed to support geothermal development under Argonne's Reasonable Foreseeable 4
Development scenario by 688 acre-feet.

Comment: BLM should update the current use of groundwater in Rose Valley by accounting for the annual amounts, in acre-feet for the following, and add the total to the analysis of current groundwater consumption:

- 30 domestic wells in the Dunmovin area that BLM reports exist and that are assumed to consume relatively small quantities of groundwater for domestic uses and small scale irrigation in the Dunmovin area.
- Coso Ranch South well, southern Coso Junction Store well (Coso Junction #2), and the Cal- trans well at Coso Junction that are regularly used by businesses in the area.
- Coso Ranch South well that provides water at a rate of 5 – 10 tanker truckload per day for the 5
  Cal-Pumice mine.
- Coso Junction Store well that supplies the general store and Coso Operating Company offices at Coso Junction.
- A well at the north end of the Little Lake Ranch property that provides water to a local cinder mine.

The DSEIS for the HGLA includes the following statement on pages 62 – 63: "The Haiwee RFD scenario realization will require water for well drilling, dust control during construction, and makeup water to

[5] http://www.inyowater.org/wp-content/uploads/2013/01/Updated-Rose-Valley-Modeling-Rpt_8-24-2017.pdf
[6] http://www.inyowater.org/wp-content/uploads/2013/01/ellis_letter_2017-07-27.pdf

compensate for evaporative loss during plant operation if the plant designs include conventional, i.e., "wet", cooling towers. The source for this water is currently unknown because each project developer would need to obtain water rights. However, based on the expressed public concern for, and limited availability of groundwater underneath the HGLA, the BLM has decided to prohibit or restrict by stipulation any groundwater extraction in the HGLA for consumptive use." 5 (con't)

Comment: Groundwater is not subject to appropriation under California law, so the statement that "...each project developer would need to obtain water rights." needs to be corrected. Please clarify what water would potentially be available given that BLM has decided to prohibit consumptive use of groundwater from Rose Valley, and how such water would be legally obtained for use in geothermal development.

6

The only alternative in the DSEIS for the HGLA that is reasonable given that BLM has decided to prohibit the consumptive use of groundwater is Alternative D (No Action), which would allow leasing and development in the DFA, but lands within the HGLA outside of existing DFAs would not be made available for geothermal leasing, exploration and development and would remain under current management as specified in the CDCA Plan, as amended. Any proposed geothermal facilities in the DFA would be under the CDCA Plan, as amended. The current pending lease applications would be neither denied nor authorized and would be processed in conformance with the CDCA Plan, as amended.

Comment: In the 2012 Draft EIS for the Haiwee Geothermal Leasing Area, the groundwater impact analysis considered the impacts of developing one and two 30-MW powerplants, each of which would require replenishment of lost geothermal fluids over the 30-year project life. The analysis found that, "...in all cases, the predicted reduction in groundwater flow exceeds the threshold of 10 percent identified as protective of Little Lake surface water features in the Hay Ranch Groundwater Extraction Project Hydrologic Monitoring and Mitigation Plan (HMMP) prepared by MHA (2008). That is, supplying groundwater for 100% injection (zero net withdrawal) requiring operation of one geothermal reservoir augmentation well for the 30 year project life would likely reduce groundwater flow to Little Lake by greater than 10 percent potentially causing adverse 7
impacts to surface water features on the property."

It is critically important to note that the above analysis did not consider the effects of groundwater pumping for the Coso Hay Ranch Groundwater Extraction and Transfer Project or the LADWP's proposed Haiwee Reservoir water seepage capture project. When added, the cumulative impact analysis would show much greater use of groundwater and adverse impacts to Little Lake.

3. **Conservation lands in the HGLA**: The CDCA Plan, as amended, established ACECs and CDNCL, as follows:

- Ayers Rock ACEC (1,564 acres) – for protection of Native American pictographs, Mohave ground squirrel habitat.
- Rose Spring ACEC (800 acres) – for protection of prehistoric cultural resources.
- Mohave Ground Squirrel ACEC (198,552 acres) – for protection of Mohave ground squirrel habitat.
- Sierra Canyons ACEC (26,405 acres) – for protection of habitat for migratory birds, nesting golden eagles, desert tortoise and winter range for the Haiwee mule deer herd.

- CDNCL – nearly 100% overlap with the Mohave ground squirrel ACEC.

Under the CDCA Plan, as amended, all the above ACECs have a 0.1% disturbance cap and CDNCLs have a 1% disturbance cap; and renewable energy development is prohibited, including geothermal.

Comment: Please indicate how many acres for each of the above conservation lands occur within the HGLA 8
boundary. Also, the CDCA Plan, as amended in 2016, prohibits renewable energy development, including geothermal, within the above conservation lands for the purpose of protecting them and their associated significant biological, cultural and scenic values. Section 202(c)(3) of FLPMA requires that the Secretary of the Interior, through BLM, "give priority to the designation and protection of areas of critical environmental concern." Alternative A (BLM-Preferred Alternative) and other alternatives that would allow any geothermal development within these ACECs is contrary to BLM's legal obligations under FLPMA. Therefore, the No Action Alternative is the only one that meets this requirement, because it would restrict leasing and development to only those lands within the DFA.

Regarding CDNCL, the Omnibus Public Lands Management Act of 2009 established the National Landscape Conservation System (now known as National Conservation Lands) and specified that BLM is to conserve, protect, and restore the outstanding cultural, ecological, and scientific values of the National Landscape Conservation System for the benefit of current and future generations. Alternative A (BLM-Preferred Alternative) and other alternatives that would allow any geothermal development within these lands is contrary to BLM's legal mandate under the Omnibus Public Lands Management Act. The only alternative that meets this requirement is the No Action Alternative.

Six years after the passage of the Omnibus, as directed by Congress, BLM chose to use a CDCA plan amendment as the process through which to identify the portions of the CDCA to add to the National
Conservation Lands, and in so doing, identified the California Desert National Conservation Lands. This plan 9
amendment clearly states the intent of the agency to fulfill its congressional mandate by identifying lands for inclusion in the CDNCLs and managing these lands consistent with other units of the System. It also acknowledges that the CMAs pertaining to the CDNCLs must be consistent with the Omnibus Act and Secretarial Order 3308, which require the BLM to ensure that National Conservation Lands are managed to protect the values for which they were designated.

Conservation standards for the system have also been outlined in Department of the Interior guidance and BLM policies. As mentioned above, Secretarial Order 3308 established a unified conservation vision for managing the National Conservation Lands 'as required by the Omnibus Act of 2009' to "conserve, protect, and restore nationally significant landscapes." In 2011, BLM released the 15-Year Strategic Plan, setting specific goals for how to manage the National Conservation Lands focused on conservation, protection and restoration. In 2012 Policy Manuals were released that interpreted the national policy and set guidance for daily management decisions.

Due to the overarching management standards essential for the agency to fulfill its conservation mandate, BLM should not allow geothermal development within ACECs and CDNCLs. Allowing for geothermal development within ACECs and CDNCLs is clearly contrary to the laws and policies outlined above. The only alternative that satisfies BLMs legal requirements is the No Action Alternative because it would restrict leasing and development to only those lands within the DFA. 9 (con't)

4. **Cultural Resources:** The pending geothermal leases and the HGLA are located within an important ethnographic (i.e., cultural) landscape. This landscape holds a number of important cultural sites including three springs, two Archaeological Districts, a National Historic Landmark, and two sites that are eligible for listing on the National Register of Historic Places.

Comment: We echo the concerns of the Big Pine Paiute Tribe of the Owens Valley set forth in their comment letter of July 23, 2012, that the approval of the pending geothermal leases and the opening of the entire HGLA to geothermal development will have irreversible and significant impacts on this ethnographic landscape and the interconnected sites located within. We also support the Tribe's call for an Ethnographic Landscape Analysis to 10
be included as part of the BLM's EIS within an added "Native American Issues and Concerns" section and that this Analysis follow the guidelines set forth by the Advisory Council on Historic Preservation on Native American Traditional Landscapes and the Section 106 Review Process.

5. **Lands with Wilderness Characteristics:** FLPMA requires BLM to inventory and consider lands with wilderness characteristics (LWC) during the land use planning process. 43 U.S.C. § 1711(a); see also Ore. Natural Desert Ass'n v. BLM, 625 F.3d 1092, 1122 (9th Cir. 2008) (holding that "wilderness characteristics are among the values the FLPMA specifically assigns to the BLM to manage in land use plans"). Lands with wilderness characteristics are identified as having the following characteristics: roadlessness, naturalness and outstanding opportunities for solitude or outstanding opportunities for a primitive and unconfined type of recreation. See, BLM Manual 6320, pp. 5-9.

Comment: As BLM acknowledges in the DSEIS, the geothermal leasing application area and the HGLA overlap a unit which BLM recently inventoried and found to have wilderness characteristics (CDCA 131-1). While the current Plan does not require BLM to manage said unit in order to protect those characteristics, it does require compensatory mitigation if wilderness characteristics are directly impacted. The required compensation is a 2:1 ratio for impacts from any activities that impact those wilderness characteristics, except in DFAs and transmission corridors and a 1:1 ratio for impacts from any activities that impact the wilderness characteristics in DFAs and transmission corridors.

6. **Protected and Sensitive Species**: Section 3.7.2.3 describes Protected and Sensitive Species within the HGLA, including the threatened desert tortoise and threatened Mohave ground squirrel.

Comment: We recommend the species occurrence description be updated to include the following:

<u>Desert tortoise</u>: The most recent observation of an adult female desert tortoise in Rose Valley was made on May 1, 2019. The specific location is on public land – T. 22S, R. 37E, Sec. 36, SE 1/4 of the NW 1/4. The observation was made by Tom Hopkins, a member of the public and the species identification was confirmed 11

by Jeff Aardahl, wildlife biologist with Defenders of Wildlife. The observation and supporting data was submitted to the California Natural Diversity Database.

Mohave ground squirrel: The range of the Mohave ground squirrel is described as extending from "Lucerne Valley to the southeast, Olancha to the northwest, and the Avawatz Mountains to the northeast." Current range maps of this species indicate its range does not extend to the Avawatz Mountains, although it does extend into portions of the National Training Center at Fort Irwin. The current range map and status of the species was reported by Leitner.[7] 11 (con't)

The Mohave ground squirrel has been documented as occurring extensively throughout Rose Valley and extending into the Coso region, so its presence in the HGLA is not simply expected, and its habitat is not simply potential as described in the DSEIS for the HGLA. We recommend updating the occurrence of the Mohave ground squirrel in the HGLA using the California Natural Diversity Database, and also the Field Ecology Technical Report for the Coso Geothermal Study Area.[8] P. Leitner conducted live trapping surveys for the Mohave ground squirrel within the Coso Geothermal Study Area, which overlaps the current HGLA. He documented the occurrence of Mohave ground squirrels in Joshua Tree Woodland, in Creosote Bush Scrub on alluvial fans, one on the east slope of the Sierra Nevada and one on the west slope of the Coso Range, Saltbush Scrub on the floor of Rose Valley and the basins and flats within the Coso Range. Leitner stated, "The present study has resulted in the capture of more Mohave ground squirrels than have been reported in all recently published surveys taken together. This was not necessarily due to unusually high population densities at our trapping sites, although that may have been a factor, especially at the Rose Valley, Sugarloaf, and Sierra Slope locations." He concluded his report with the statement, "In summary, the CGSA [Coso Geothermal Study Area] supports Mohave ground squirrel populations that are at least as abundant as any recorded to date. Since the species has been trapped at 14 sites within this relatively small area and occurs in almost all habitats, it will be very difficult to carry out geothermal exploration and development activities without causing some adverse impacts.
This is particularly true because the areas of relatively level terrain favored by these animals are also the best sites for geothermal facilities."

7. **Impact Analysis**: Section 4.7.2 of the DSEIS for the HGLA analyzes impacts on biological resources associated with each alternative. Under Alternative A (BLM-Preferred Alternative), the conservation lands (ACECs and CDNCLs) would remain in place but the prohibition on geothermal development would be lifted. This would result in habitat loss and fragmentation, especially for the desert tortoise and Mohave ground squirrel. Impact under the other action alternatives would still result in habitat loss and fragmentation although conservation lands would be given greater protection through no surface occupancy stipulations.

BLM claims that by limiting geothermal development to lands within the existing DFA, impacts to Special Status Species, especially the desert tortoise and Mohave ground squirrel, would still occur but would be reduced because development would be located in less sensitive areas.

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[7] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=15148&inline
[8] https://archive.org/details/fieldecologytech4830ock

Comment: Based on studies by P. Leitner and published in the Field Ecology Report for the Coso Geothermal Study Area in 1980, the saltbush scrub in the lower portions of Rose Valley and the creosote bush scrub west of Highway 395 had the highest number of Mohave ground squirrels among the eight study sites he sampled through live trapping. The saltbush scrub habitat in Rose Valley yielded 54 individuals and the creosote bush scrub west of Highway 395 yielded 29 individuals. Both these sites and their more extensive habitats are within the DFA. BLM should refrain from portraying the DFA as having potential for lower impact to the Mohave ground squirrel. The opposite appears to be the case given the results of live trapping by P. Leitner.

BLM states that CMAs from the DRECP amendments to the CDCA Plan would "...protect sensitive resources in all land allocation areas."

Comment: BLM's proposal to implement various CMAs may serve to minimize direct impact to these species from construction and geothermal operations, but they do not "protect" these species from habitat loss and fragmentation.

Comment: BLM should identify areas within the DFA that should be designated for no-surface occupancy
based on the presence of the desert tortoise and Mohave ground squirrel as documented through additional 12
field surveys, the California Natural Diversity Database and the results of P. Leitner's Mohave ground squirrel surveys in support of the EIS for geothermal leasing in the Coso KGRA.

8. **Off-road Vehicles:** The DSEIS at Section 3.16 states that 17 open routes are designated within the HGLA (at pg. 45). Cumulative mileage of those 17 routes is not provided. Appendix T includes an updated map and information on Recreational Use and Visitation for the Ridgecrest SRMA. However, it is unclear where the Ridgecrest SRMA is located. The CDCA Plan, as amended, identifies an Eastern Sierra Special Recreation Management Area (SRMA), which was established with the goal of offering recreational opportunities that maintain the natural character of the landscape and protect sensitive resources, while encouraging a variety of outdoor activities that provide pleasure to the user.

Comment: BLM needs to provide the cumulative mileage of the 17 routes within the HGLA.

Comment: BLM needs to include a focused analysis of the use in the area of the HGLA, particularly as it relates to off-road vehicle use. Our concern relates to the fact that current open routes could be closed if geothermal projects are constructed within the HGLA area, potentially displacing off-road vehicles into currently
undisturbed habitat. Because the Eastern Sierra SRMA's goal (stated above) focuses on maintaining the natural 13
character of the landscape, industrial development in the HGLA coupled with the potential additional routes from displacement of existing routes will degrade the experience for which the SRMA was established.
Comment: As part of the analysis requested above, BLM needs to also analyze the cumulative fragmentation of wildlife habitat that would result of industrial geothermal installations and new roads were constructed in the
area. The HGLA may fall within key wildlife connectivity areas as identified in the Desert Linkages report[9] and 14
this important issue needs to be fully addressed in the supplemental NEPA review.

[9]http://www.scwildlands.org/reports/ALinkageNetworkForTheCaliforniaDeserts.pdf

9. **Ground subsidence:** The existing Coso Geothermal Facility has caused ground subsidence that is being carefully monitored by the Facility and China Lake Naval Air Weapons Center, where the facility is located. Because of the subsidence, an effort to counteract further subsidence was put in place. The Coso Georthermal Facility acquired water rights from the Hay Ranch and built an approximately nine-mile pipeline, primarily on public lands (BLM and DoD) in order to pump and export 4,800 acre-feet per year of water from the Rose Valley to the Coso Geothermal Facility. The pipeline was completed in 2009 and required revegetation of the pipeline route. The revegetation effort, if implemented, has failed along a majority of the pipeline right-of-way. Figure 1 shows an example of the failed revegetation effort which is apparent on the left side of the Gill Station/Coso Road.

Figure 1. Failed revegetation along the pipeline route of the Hay Ranch Water Extraction and Delivery System by 2017.

Comment: BLM needs to include effective and binding revegetation obligations for all projects in the HGLA that require revegetation as part of project permitting.

Conclusion: Based on our analysis of the current status of groundwater underlying Rose Valley, existing consumption of groundwater, and the occurrence of the desert tortoise and Mohave ground squirrel, we consider Alternative D (No Action) to be most consistent with BLM's mandates under FLPMA for multiple use and sustained yield of public land resources, management of ACECs and CDNCLs, and its Special Status Species Management Policy (Manual 6840) because it would restrict geothermal leasing and development to only those lands within the DFA.

Please contact me if you would like to discuss the following organizations comments and recommendations or additional information.

Sincerely,

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LETTER FF

CENTER for BIOLOGICAL DIVERSITY   Because life is good.
Protecting and restoring natural ecosystems and imperiled species through
Science, education, policy, and environmental law

Submitted via email

August 1, 2019

Haiwee Geothermal Leasing Project
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RE: Comments on Haiwee Geothermal Leasing Area Draft Supplemental Environmental Impact Statement And Draft Proposed Amendment to the CDCA Plan BLM-CA-D050-2017-0002-EIS DOI No. 12-6, April 2019

Dear Mr. Miller,

These comments are submitted on behalf of the supporters and staff of the Center for Biological Diversity (the "Center") regarding the Haiwee Geothermal Leasing Area Draft Supplemental Environmental Impact Statement (DSEIS) and Draft Proposed Amendment to the California Desert Conservation Area Plan, BLM-CA-D050-2017-0002-EIS, DOI No. 12-6, dated April 2019. The Center is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has 1.4 million members and supporters throughout California and the United States. The Center has worked for many years to protect imperiled plants and wildlife, wildlife connectivity, open space, air and water quality, and overall quality of life for people in Inyo County. The Center previously submitted comments on the Haiwee Geothermal Leasing Area proposal on November 9, 2009 (scoping comments), July 16, 2012 (regarding the DEIS notice) and on August 9, 2012 (DEIS comments). Those comments are incorporated herein by reference.

The development of renewable energy is a critical component of efforts to reduce greenhouse gas emissions, avoid the worst consequences of global warming, and to assist California in meeting its ambitious emission reductions goals. The Center strongly supports the development of renewable energy production, and the generation of electricity from geothermal resources. We also support strategic land use planning for renewable energy including geothermal. However, like any project, proposed geothermal power planning should be thoughtfully done to minimize impacts to the environment. In particular, geothermal planning should avoid impacts to sensitive species and habitats and should be sited in proximity to existing transmission if the electricity end-use is not close-by. The planning effort should include transmission planning in order to reduce the need for extensive new transmission and the efficiency loss associated with extended energy transmission. Only by maintaining the highest environmental standards with regard to local impacts, and effects on species and habitat, can renewable energy production including geothermal be truly sustainable. BLM has undertaken extensive planning efforts across the California Desert Conservation Area that balance the need for development of renewable energy and protection of resources.

The stated goal of the Haiwee proposal as outlined in the DSEIS is to: establish a management framework and assess the potential environmental impacts of opening for lease approximately 22,805 acres of federal mineral estate for geothermal energy exploration and development in the Haiwee Geothermal Lease Area (HGLA) in the Rose Valley area of Inyo County, California; and decide whether to approve (or deny) the three pending lease applications for approximately 4,460 acres of federal lands within the proposed HGLA. Unfortunately, the DSEIS fails to adequately
address several issues including, most importantly, the inconsistency of Alternatives A and B 1
with critical resource conservation goals, the limited water availability in this area, and impacts of water use for the proposed leases on other resources.

Many significant issues are not adequately analyzed in the DSEIS for any of the alternatives. These include:

- Impacts to water resources and the lack of any reasonable justification for BLM's rejection of a requirement for dry-cooling technology in order to conserve water in this 2
arid region;
- BLM's failure to address potential for land subsidence or other changes due to 3
groundwater extraction;
- BLM's failure to ensure long term groundwater monitoring and management with effective triggers to prevent overdrafting of the already heavily utilized Rose Valley 4
aquifer, including an analysis of off-site impacts of waters that wildlife rely on;
- BLM's failure to take a hard look at the displacement of recreational activities including designated routes in the DFA if/when industrial geothermal facilities and their requisite 5
fences are constructed and lead to the creation of new unlawful routes;
- BLM's failure to adequately identify and analyze displacement of rare and threatened wildlife by geothermal development, including Mohave ground squirrel in core habitat, 6
and the fragmentation of the habitat;
- BLM's failure to identify and analyze impacts to wildlife connectivity between the Coso Range and the southern Sierra Nevada Mountains due to the construction of industrial 7
projects in the DFA; and
- BLM's failure to fully consider mitigation measures for these and other impacts 8

The DSEIS for this planning process is the appropriate place to analyze the above issues which should not be left to NEPA analysis of individual projects as they are proposed.

For example, the DSEIS fails to adequately explain why dry cooling is not required in any
alternative. Many modern geothermal facilities (including many in similar ecosystems in 9
Nevada), are closed-loop and dry-cooled. A closed-loop geothermal facility is one which pumps groundwater from the geothermal reservoir, extracts heat from the water, and then reinjects the cooled water into the geothermal reservoir. A dry-cooled facility uses air in its cooling towers, rather than water. These two features mean that modern well-designed geothermal facilities need not directly consume large amounts of groundwater. Without specific measures to reduce the amount of groundwater taken out of the system, impacts to surface and ground water resources

and the risk of ground subsidence are substantial. "Changes in surficial features and land elevations accompanying geothermal development should be viewed as the rule, rather than the exception."[1]

BLM does not appear to have fully investigated the potential impacts to surface and groundwater which can be wide-reaching. For example, good data exists on the impacts to surface thermal 10
water features of the Long Valley caldera, near Mammoth, California from development of geothermal production in this area. Monitoring of such features subsequent to the development of Casa Diablo, a geothermal facility, has shown "a cessation of spring flow at Colton Spring (2 km east of Casa Diablo) and declines in water level in Hot Bubbling Pool (5 km east of Casa Diablo)."[2] Based on water level and pressure records the study showed that development "caused a drop of 1.2 m in water level at this distance" at Hot Bubbling Pool.[3] This reveals that impacts from geothermal development may extend beyond a hyper-localized reach, which has important implications for this leasing area and the proposed leases.

Even with closed loop and dry cooled geothermal systems, impacts to surface and groundwater can occur. For example, the Jersey Valley Geothermal Project ("JVGP") in Jersey Valley, Nevada,[4] was developed by Ormat as a dry-cooled and closed-loop facility, meaning there is ostensibly no consumption of geothermal water; and JVGP, is located directly adjacent to an important thermal spring resource—the Jersey Hot Springs. According to Ormat's website,[5] JVGP went online in the first quarter of 2011, with full operation anticipated in the second quarter of 2011. Fortunately, there is reliable time-series data available for discharge from Jersey Hot Springs from the NDWR.[6] The available data show a clear declining trend in flows at the springs since the JVGP went online in 2011. From 2009-2011, the average flow rate was 0.109 cfs (48.5 gpm, 78.2 afy). In 2012 the average flow rate was 0.0775 cfs (34.8 gpm, 56.1 afy); in 2013 it was 0.05 cfs (22.4 gpm, 36.2 afy); and in 2014 it was 0.0225 cfs (10.1 gpm, 16.3 afy), with readings since then showing zero flow. While this data only shows correlation between the drying up of Jersey Hot Springs and the initiation of operations at JVGP, and no causal link has yet been established, it is a strong correlation providing sufficient reason for BLM to consider such impacts to local and regional springs and groundwater as potentially significant from geothermal development in the HGLA as well.

It is also imperative that BLM take a hard look at the potential impacts of geothermal development *before* designating the HGLA and approving any leases because post-lease or post 11
construction mitigation measures are of limited utility and have not been shown to be able to mitigate the impacts once a geothermal project is built and running. While it is important to monitor and gather data on impacts of geothermal energy development after approved, implementing a "monitoring and mitigation" program and relying on adaptive management to mitigate impacts later is unlikely to be successful. While the purpose of such a program is to

1 Sorey, M. L. 2000. "Geothermal development and changes to surficial features: Examples from the Western United States." *Proceedings World Geothermal Congress 2000*, p. 708.
2 Sorey, 2000, p. 706.
3 Sorey, 2000, p. 706.
4 . On June 4, 2010, BLM approved EA DOI-BLM-NV-063-EAO8-091, for the JVGP.
5 http://www.ormat.com/news/latest-items/ormat-technologies-brings-only-geothermal-power-plant-online-us-2010
6 Data can be accessed as follows: Obtain data at http://water.nv.gov →Mapping and Data→Spring and Stream Flow→View Spring, Stream Flow, and Site Data→Basin 132 Jersey Valley→Site Name: "132 N27 E40 29DDDB1". Data presented here captured at 12:22 PM on July 22, 2019.

detect impacts to surface and ground water as they are occurring, and to change parameters of a project to attempt to ameliorate those impacts, experience shows this *post-hoc* approach is not an effective way of minimizing impacts to water resources with respect to geothermal development.

First, monitoring of impacts is difficult and may be elusive. Since the exact pathways connecting the geothermal reservoir to the surface are not known, it is very difficult to design a monitoring regime sufficient to detect impacts. There are numerous ways that surface water is expressed from geothermal sources, which includes spring discharge but also includes evapotranspiration and seepage, two factors which are far less readily measurable than straight spring discharge. It is essentially impossible to monitor evapotranspiration or seepage in real-time. Even piezometers or other shallow wells may not be sufficient monitoring devices, as discharge at the spring complex is the result of complex interactions of deep and shallow groundwater flowing along fractured and faulted zones. Quite simply, it is not feasible to have a monitoring program comprehensive enough to detect impacts to the springs in real-time. Bredehoeft and Durbin discuss the infeasibility of groundwater monitoring and mitigation plans, and reach similar conclusions, in particular with respect to time.[7] They find that there is a temporal "lag" between the onset of impacts and the ability to detect them; and then another temporal lag between potential mitigation measures and when they actually begin to ameliorate negative impacts. While their paper is focused on large-scale inter-basin groundwater export, the points they make still hold. Where groundwater dependent resources may be significantly impacted if the surface water features dry up even briefly, the time lag between impacts onset, impacts detection, mitigation measures commencing, and impacts amelioration mean any mitigation is unlikely to be effective.

Second, even when it is feasible to detect impacts, by the time those impacts are detected, it may be too late to mitigate them. "Hydrologic systems require time to recover from stresses, meaning that drawdown continues to expand at a distance from the source of the stress. The impacts would likely become worse before they become better." [8]

Thus, even if the most extreme mitigation measure of a temporary cessation of pumping and reinjection were to be selected as mitigation as part of adaptive management, it is not clear that this would prevent impacts. It can take years or even decades for aquifers to recover from 12
depletion or significant perturbation. Since groundwater-dependent ecosystems are entirely reliant on discharge of groundwater for their life and reproductive cycles, even one season of reduced spring flows could result in catastrophic population declines for spring dependent species.

The inability of *post-hoc* mitigation to address these impacts has been evaluated on a conceptual level with regard to geothermal energy utilization by Hunt (2001): "The decline in thermal features is associated with the decline in reservoir pressure. The only way to prevent or minimize the decline of thermal features is therefore to minimize reduction in reservoir pressures. [citation omitted] At present there are no viable techniques available to do this without severely curtailing

7 Bredehoeft, J. & Durbin, T. 2009. "Groundwater development- the time to full capture problem." Groundwater 47(4), p. 8.
8 Myers, T. 2017. Technical Memorandum: Impact of Developing Dixie Meadows Geothermal Utilization Project on Springs and Surface Water. p. 9.

production."[9] Thus, as he states, there is no realistic mitigation for impacts to thermal features—such impacts are inherent in the technology.

In sum, the potential for BLM to impose a suite of marginally effective mitigation measures *after the fact* cannot be used as a substitute for adequate analysis of impacts of development in the HGLA *before* making a decision. The needed additional analysis must include analysis of at least one alternative that would both be consistent with existing planning and require measures such as dry-cooling and closed loop operations to minimize water use for all development. 12 (con't)

We appreciate that DSEIS Alternative C is compatible with many of the land use objectives identified in the CDCA Plan, as most recently amended, because the current land use management designations would remain in place. Under this alternative BLM would authorize only those portions of the three pending leases in the HGLA located within the DFA, and BLM would deny those portions of the pending lease applications located within the ACEC/NCL areas. However, unless BLM undertakes additional analysis of impacts to surface and groundwater resources and also modifies Alternative C (or considers a new alternative as suggested above) to require additional protective measures, most importantly dry cooling and closed loop operation to reduce impacts to water resources, BLM must reject all of the action alternatives in the DSEIS and choose Alternative D (no action). 13

Please feel free to contact us with any questions and keep us on the list for all notices associated with this project.

Sincerely,

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9 Hunt, T. M. 2001. "Five lectures on environmental effects of geothermal utilization." United Nations University, Geothermal Training Programme. Reports 2000, Number 1, p. 16.

References: (Attached)

Bredehoeft, J. & Durbin, T. 2009. "Groundwater development- the time to full capture problem." Groundwater 47(4).

Hunt, T. M. 2001. "Five lectures on environmental effects of geothermal utilization." United Nations University, Geothermal Training Programme. Reports 2000, Number 1.

Myers, T. 2017. Technical Memorandum: Impact of Developing Dixie Meadows Geothermal Utilization Project on Springs and Surface Water.

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Attachments

ground water

Issue Paper/

Ground Water Development—The Time to Full Capture Problem

by J. Bredehoeft[1] and T. Durbin[2]

Abstract

Ground water systems can be categorized with respect to quantity into two groups: (1) those that will ultimately reach a new equilibrium state where pumping can be continued indefinitely and (2) those in which the stress is so large that a new equilibrium is impossible; hence, the system has a finite life. Large ground water systems, where a new equilibrium can be reached and in which the pumping is a long distance from boundaries where capture can occur, take long times to reach a new equilibrium. Some systems are so large that the new equilibrium will take a millennium or more to reach a new steady-state condition. These large systems pose a challenge to the water manager, especially when the water manager is committed to attempting to reach a new equilibrium state in which water levels will stabilize and the system can be maintained indefinitely.

Introduction

This article is an issue paper, a philosophical paper that expresses our viewpoint. A discussion of our perspective will provide a road map for readers. We are concerned with the management of ground water development; we restrict ourselves to water quantity—water quality is always an issue, but it is not our concern here.

Undeveloped ground water systems are commonly found in a state of equilibrium, where, on average, equal amounts of water are recharged and discharged. Ground water systems tend to filter out higher frequency fluctuations in weather; the larger the system, the more filtering it tends to provide. The base flow of streams reflects the effects of the ground water system as a filter. In other words, the larger the ground water system, the more the equilibrium between inflow and outflow reflects long-term averaging of fluctuations in weather. Our analyses generally assume that climate is stationary; if the climate is changing, as recent evidence suggests, then the assumption of equilibrium should be questioned.

Ground water development perturbs the natural equilibrium. We are assuming that a principal objective in managing ground water development is to extend the life of the development as long as is feasible. It is possible for some ground water developments to reach a new equilibrium that includes pumping—we assume that this is desirable from a management perspective. In the new equilibrium state, pumping can be continued indefinitely. In reaching the new equilibrium, the natural state will be perturbed—there will be inevitable impacts on the natural system. Society may decide that the impacts imposed in reaching the new equilibrium are too detrimental, and they may in some way constrain the development. Our focus in this paper is the length of time that some ground water systems take to transition to a new equilibrium state that includes pumping.

Hydrogeologists predict the response time of ground water systems using models. Models provide good predictions in the near field at early times. For example, pumping test analyses give good predictions on how to size the infrastructure, well dimensions, pump size, and so forth. As predictions extend in both time and space, they become more uncertain. Much has been written about this uncertainty. We use model predictions from field situations to illustrate some of our ideas; we are aware of the many pitfalls in modeling and the resulting uncertainty associated

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with predictions (Konikow and Bredehoeft 1992; Bredehoeft 2003, 2005). Nowhere in these discussions of uncertainty did the authors argue that the predictions are not useful. Quite the contrary, we argued that predictions were worthwhile but should be used with a full awareness of the difficulties and resulting uncertainties.

We use Nevada as a prototype for our discussion. Nevada ground water law codifies some of the basic principles of ground water hydrology; for this reason, it is a nice example. Hence, we illustrate our ideas with two examples from Nevada. The most recent example is the proposal by the Southern Nevada Water Authority (SNWA) to develop a large ground water supply in eastern Nevada. The proposed SNWA development is ongoing and in the news. We present model predictions of the proposed SNWA development as an illustration of the major point of our paper. We also discuss how the water manager, in this instance the Nevada State Engineer, dealt with the model prediction that a long time would be required to reach a new equilibrium that includes the proposed pumping.

Nevada, with a few exceptions, treats each individual valley as a legally distinct ground water system. Some of the valleys are hydrologically self-contained; others are integrated by the underlying Carbonate Aquifer that underlies the region. SNWA is seeking water rights in a number of valleys. Each of these valleys requires a separate hearing and ruling by the State Engineer—granting or denying applications to pump ground water. So far there have been two hearings and ruling by the State Engineer who provided SNWA with rights to pump in Spring Valley and more recently in Cave, Dry Lake, and Delamar valleys.

The Water Budget

Meinzer (1931) elaborated on the idea of the water budget to estimate the "safe yield" of aquifers. Meinzer was not the first to express these ideas; he refers back to the earlier work of C.H. Lee from 1908 to 1911 in Owens Valley, California. According to Meinzer (1931), "Before any large ground-water developments are made, the average rate of discharge for any long period is obviously equal to the average rate of recharge." This was obvious to Meinzer and presumably his colleagues in the ground water community of the day—we have yet to find who first stated this idea. The principle establishes the reciprocal relationship between recharge and discharge in the undeveloped state and allows us to measure one as a surrogate of the other. Meinzer went on to urge the periodic inventory of the system in order to establish the elements of the budget through time.

A budget is a static accounting of the state of the system at a given time, often before the system is developed. Meinzer's idea was that the amount that could be developed depended upon the quantity of discharge from that system that could be salvaged. Nevada water law codified this idea in their definition of perennial yield:

> *Perennial yield* of a ground-water reservoir may be defined as the maximum amount of ground water that can be salvaged each year over the long term without depleting the ground water reservoir. Perennial yield is ultimately limited to the maximum amount of the natural discharge that can be salvaged for beneficial use . . . .

It follows that:

$$R_0 = D_0 \qquad (1)$$

where R_0 is the undeveloped recharge and D_0 is the undeveloped discharge. We can introduce pumping into this expression:

$$R_0 - (D_0 - \Delta D_0) - P = \mathrm{d}V/\mathrm{d}t \qquad (2)$$

where ΔD_0 is the change in the discharge created by the pumping (the salvage or capture), P is the rate of pumping, and $\mathrm{d}V/\mathrm{d}t$ is the rate of change of ground water in storage in the system.

Meinzer and others recognized that water must be removed from storage before a new equilibrium state could be reached. Again, Nevada water law codified this storage:

> *Transitional storage reserve* is the quantity of water in storage in a particular ground water reservoir that is extracted during the transition period between natural equilibrium and new equilibrium conditions under the perennial yield concept of ground water development. . . . the transitional storage reserve of such a reservoir means the amount of stored water which is available for withdrawal by pumping during the non-equilibrium period of development (i.e., the period of lowering of water levels).

At the new equilibrium state, the water budget is as follows:

$$\mathrm{d}V/\mathrm{d}t = 0 \quad \text{(by definition)} \qquad (3)$$

$$P = \Delta D_0, \quad \text{where } \Delta D_0 \leq D_0 \qquad (4)$$

and we constrain the pumping to be less than or equal to the discharge in order to allow a new equilibrium. If we allow for pumping to induce recharge, then at the new equilibrium:

$$P = \Delta R_0 + \Delta D_0 \qquad (5)$$

where ΔR_0 is the change in undeveloped recharge produced by the pumping, ΔD_0 is the change in recharge produced by the pumping, and $\Delta R_0 + \Delta D_0$ is defined as the *capture*.

Capture

Theis (1940) introduced the principle of capture. Later, the USGS in Lohman (1972) published the following definition of capture:

> Water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in recharge, or a combination of these changes. The decrease in discharge plus the increase in recharge is termed capture.

Capture is an all-important concept in managing ground water; a ground water system can only be maintained indefinitely if the pumping is equaled by the capture—a combined *decrease* in the undeveloped discharge and *increase* in undeveloped recharge. If pumping continually exceeds capture, then water levels in the system can never stabilize, and the system will continue to be depleted. In other words, if pumping exceeds the potential capture in the system, a new equilibrium state that includes the pumping can never be reached. Again, let us remind the reader that our focus in this discussion is ground water systems that, when developed, can be maintained indefinitely.

The water budget applies to the system at a given time—a snapshot in time. The usual practice is to calculate a budget for the undeveloped state and then for the final state when the system reaches the new equilibrium. In discussing the budget, or inventory idea, Meinzer (1931) drew the analogy to a surface water reservoir. One can pump anywhere from a surface water body and have a similar impact; however, where one pumps in a ground water system becomes important, as we show subsequently. While the water budget describes the state of the system at a given time, it does not inform us about the time path the system will take to reach the new equilibrium state; the time path depends upon aquifer dynamics. It should be remembered that in 1931, when Meinzer wrote his paper, Theis' (1935) seminal paper that presented a general transient ground water flow equation had not yet been published.

In 1931, hydrogeologists did not have the ability to predict the time to reach a new equilibrium state. However, we argue that the expectation of Meinzer's work, and the work of others, was that once pumping was introduced, a new equilibrium would be reached in a reasonable period of time. However, it takes some ground water systems an inordinately long period to reach a new equilibrium. The time may be so long that the fact that a new equilibrium eventually is reached becomes meaningless. It is this problem we address subsequently.

Aquifer Dynamics

Theis (1935) introduced time into ground water theory. This allowed hydrogeologists to make temporal predictions. Historically, the profession went through several phases of prediction. In the 1940s, well hydraulics blossomed. Led by Theis and Jacob, ground water hydrologists solved the boundary value problem associated with various conceptual models of the aquifer and the associated confining layers. The predictive capability associated with the solutions allowed hydrogeologists to estimate relevant parameters of the ground water system—transmissivity, storage coefficient, leakance of a confining layer, and so forth. Armed with a theoretical conceptual model, one could predict response to pumping, which in turn allowed for well design, the sizing of pumps, and well spacing, among other facets of development.

Hydrologists of the day also sought to investigate ground water systems; however, they recognized the limitations imposed by the theoretical approach. Bob Bennett and Herb Skibitski, working at the USGS in the 1950s, developed the resistor/capacitor network, analog model of ground water systems. This allowed the creation of analog models of field systems in which realistic boundary conditions and internally variable parameter distributions could be simulated. The USGS created an analog model laboratory in Phoenix in approximately 1960, where models were constructed and predictions made for several tens of ground water systems. Walton and Prickett (1963) created a similar laboratory at the Illinois State Water Survey where they built analog models of Illinois ground water systems.

By the late 1960s, digital computers had advanced to the point that realistic ground water models could be constructed and analyzed using digital methods (Pinder and Bredehoeft 1968). The technology for solving the resulting massive matrix inversion problems had been pioneered by petroleum reservoir engineers and applied mathematicians working for petroleum companies. Reservoir engineers are involved with solving the same basic flow equation that we use for ground water, and the techniques were readily adapted to ground water problems. Digital computers have become increasingly more powerful; as the computer advanced, so did the ground water modeling technology. One can now create very realistic ground water models on a PC. Techniques are available to optimize the parameter distributions within the models (Hill and Tiedeman 2007). Advances in technology now make it feasible to make predictions of the behavior of complex ground water systems. Predictions, even in the best-calibrated model, have an associated uncertainty. Our predictive capability has grown steadily since Theis (1935) used the analogy between the flow of ground water and the flow of heat and Jacob (1940), starting from first principles, showed that the analogy was correct. Hydrogeologists now routinely predict ground water system behavior.

The Time to Reach a New Equilibrium

Given our ability to predict, it is of interest how long it takes for a ground water system to reach a new equilibrium, assuming that a new equilibrium state is possible. One can envision ground water systems in which the pumping greatly exceeds any potential capture. In such an instance, the system can never reach a new equilibrium, and water levels within the system will continue to decline until the system is depleted. We are concerned here with systems in which a new equilibrium state is feasible—that is, pumping can ultimately be balanced by capture.

Hypothetical Basin- and Range-Valley-Fill Aquifer

We first examine a hypothetical system that resembles some of the valleys in the Basin and Range (Figure 1). The two streams entering the basin on the left provide on

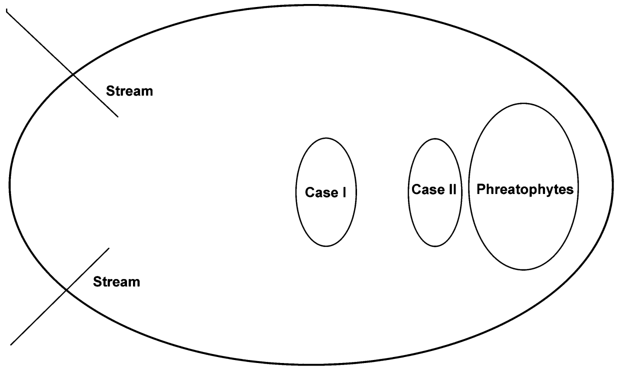

Figure 1. Plan view of a hypothetical valley-fill aquifer in the Basin and Range.

average 100 cubic feet per second (cfs) of recharge to the aquifer. The area of phreatophytes, to the right, discharges on average 100 cfs of ground water through evapotranspiration (ET) before ground water development. We consider two scenarios of ground water development located in the areas labeled case I and case II, respectively; each development pumps at a rate equal to the recharge—100 cfs.

We assume two-dimensional horizontal flow and the properties listed in Table 1. In our hypothetical system, we assume that ground water consumption by phreatophytes is diminished as pumping lowers the water table in the area containing phreatophytes. We deliberately created a ground water system in which capture of water that would otherwise be lost by ET can occur. As the water table drops between 1 and 5 feet, the consumption of ground water by ET is linearly reduced. The phreatophyte reduction function is applied to each cell in the model.

In order for this system to reach a new state of sustained yield, the phreatophyte consumption must be eliminated entirely. Using the model, we can examine the phreatophyte use as a function of time. Figure 2 is a plot of the phreatophyte use in our system vs. time since pumping was initiated. The location of the pumping makes a significant difference in the dynamic response of the system. In case II, where the pumping is close to the phreatophytes, the ET is reduced to 65 cfs in 10 years. In contrast, in case I, the ET is reduced to approximately 5 cfs in 10 years. Case I takes a long time to fully eliminate the ET; it is approximately 1000 years before the ET is totally eliminated. Even seasoned hydrologists are surprised at how long it can take an unconfined system to reach a new equilibrium state in which no more water is removed from storage.

We can also investigate the total amount of water removed from storage in our hypothetical valley-fill aquifer (Figure 3). It is important to notice that even though the two developments (case I and case II) are equal in size, the aquifer responds differently depending upon where the developments are sited. In case II, where the pumping is close to the phreatophytes, the amount of water removed from storage is approximately 50% less than that in case I. In case I, a large cone of depression must be created in order to impact the phreatophyte ET.

Table 1
Aquifer Properties for Hypothetical Basin Shown in Figure 1

Basin size	50 × 25 miles
Model cell dimensions	1 × 1 mile
Hydraulic conductivity	0.00025 ft/s
Saturated thickness	2000 feet
Transmissivity	0.5 ft^2/s (~43,000 ft^2/d)
Storage coefficient	0.1%–10%
Phreatophyte consumption	100 cfs
Wellfield pumping	100 cfs
Recharge	100 cfs

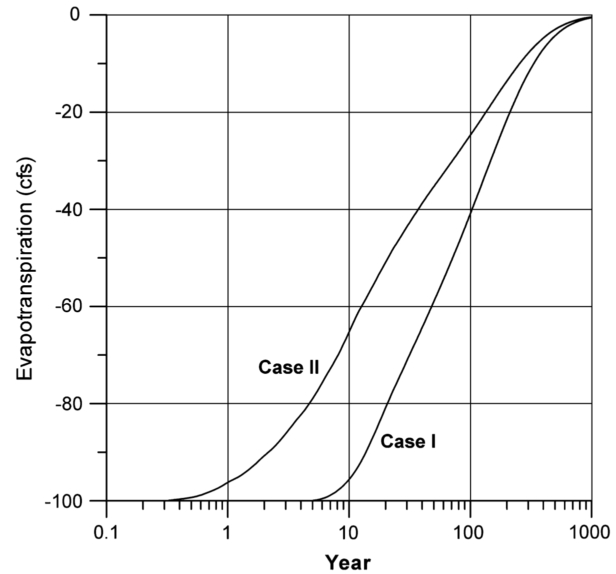

Figure 2. ET vs. time in our hypothetical valley-fill aquifer.

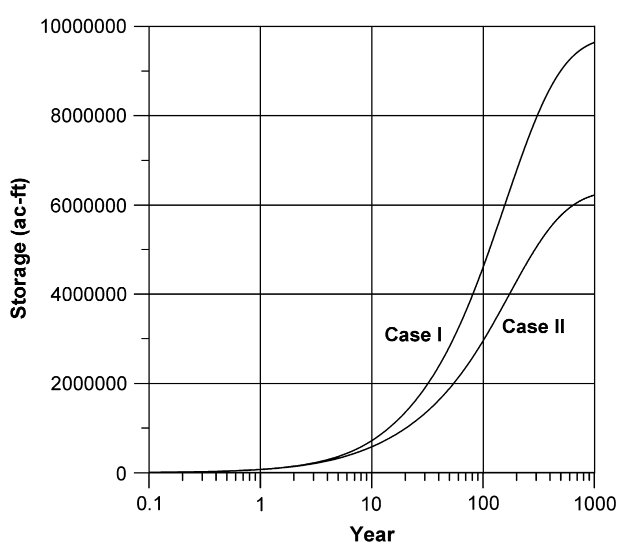

Figure 3. The volume of water removed from storage as a function of time in our hypothetical valley-fill aquifer with two developments—case I and case II (Figure 1).

This example of our rather simple Basin- and Range-valley-fill aquifer illustrates the importance of understanding the dynamics of aquifer systems. While this is a simple example, the principles illustrated apply to aquifers everywhere. In this case, it is the rate at which the phreatophyte consumption can be captured that determines how this system reaches sustainability; this is a dynamic process. Capture always involves the dynamics of the aquifer system. It makes a big difference in the response of the system where the wells are located. Thomas et al. (1989) describe the ground water hydrology of Smith Creek Valley, Nevada, where the USGS did a Regional Aquifer Systems Analysis (RASA) investigation; our simple example has many of the elements of Smith Creek Valley.

Paradise Valley

Alley and Leake (2003) explored the concept of "sustainability"; they used as their example a development in Paradise Valley in northern Nevada. The Humboldt River flows across the southern end of the valley. They used a model of ground water pumping near the southern end of the valley, not too far to the north of the Humboldt River, to examine the source of the ground water pumped vs. time (Figure 4). There are four sources of water that support the pumping: (1) water from storage; (2) capture of ET; (3) capture of surface water leaving the valley; and (4) induced recharge from the Humboldt River. Each of these sources varies with time.

The principal source of ground water in Paradise Valley during the early period is depletion of storage in the system. The storage declines to only 4% of the supply in year 300. The capture of water from ET grows from 20% in year 1 to approximately 75% of the total in year 300. The induced recharge from the Humboldt River grows from 0% in the early years to approximately 20% of the total in year 300. The capture of outflow from the valley grows to 3% in 300 years. The ground water system in Paradise Valley will take more than 300 years to reach a new equilibrium state. The time is about one-third as long as in case I in our hypothetical valley-fill aquifer explored earlier. Even after 300 years, 4% of the water pumped is still coming from storage.

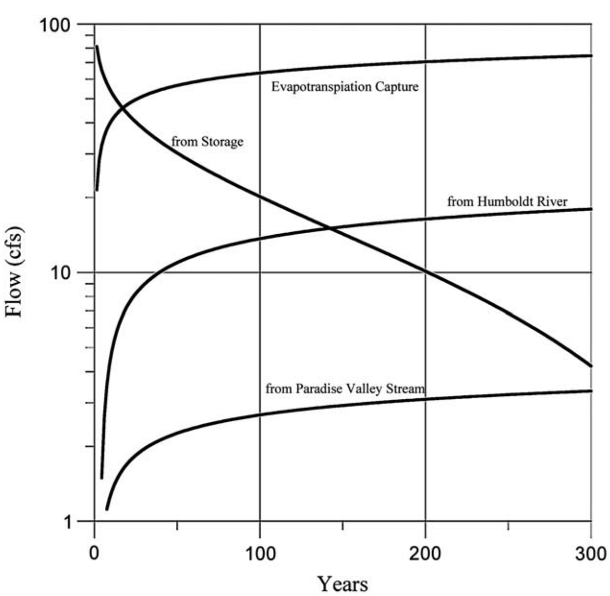

Figure 4. Computed sources of ground water to supply the pumping in Paradise Valley, Nevada (data from Alley and Leake 2003).

Both the induced recharge from the Humboldt River and the reduced outflow from the valley decrease the streamflow of the Humboldt River. This poses a potential future problem since the surface water in the Humboldt River, like most streams in the West, is overappropriated. Downstream surface water users will be hurt as this ground water development goes forward. An investigation of the undeveloped water budget for Paradise Valley would not have indicated induced recharge from the Humboldt River to be a significant source of water to the wells.

SNWA Development

The SNWA is proposing to pump 170,000 acre-feet/year of ground water just to the south of Ely, Nevada—approximately 200 miles north of Las Vegas. The water will be conveyed, via a pipeline, to Las Vegas. This will increase the water supply for Las Vegas by perhaps 40%; the fraction depends upon how much water is available in the future for Las Vegas from the Colorado River. The cost of the pipeline is currently estimated to be more than $3.5 billion.

The area under consideration for development is within the Carbonate Rock Province as defined by the USGS RASA investigation (Prudic et al. 1995), where there is a thick sequence of Paleozoic carbonate rocks. This sequence of rocks usually contains a Carbonate Aquifer that has the potential to integrate ground water flow between the valleys in the area (Eakin 1966). Analyzing ground water flow in this system entails investigating a much larger set of valleys than simply those that contain the pumping. The proposed SNWA pumping is situated mostly within the White River Regional Flow System (Figure 5).

There are several estimates of the recharge and/or discharge for portions of the ground water system pictured in Figure 5 (Eakin 1966; Las Vegas Valley Water District 2001; Welch and Bright 2007). A USGS RASA study of the system indicated that the pumping would reach a new steady state (Schaefer and Harrill 1995). The RASA, while calculating the impacts of a new equilibrium that included the pumping, did not estimate the time to reach the new state, other than to indicate that it was more than 200 years.

We realize that uncertainties associated with models and model predictions place confidence bounds around predicted values. However, we present single-valued graphs of predicted results to illustrate our points; we recognize that this oversimplifies the results. Figure 6 is a model prediction of the expected drawdown of the water table at the new equilibrium state that includes the

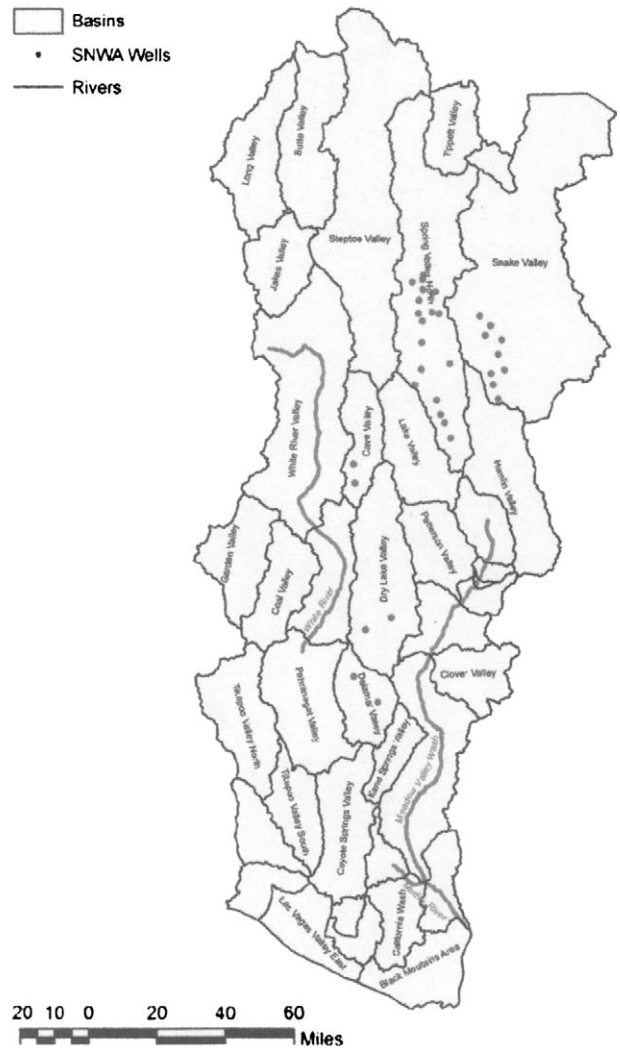

Figure 5. Map of the valleys in Nevada impacted by the proposed SNWA development. The proposed pumping wells are indicated.

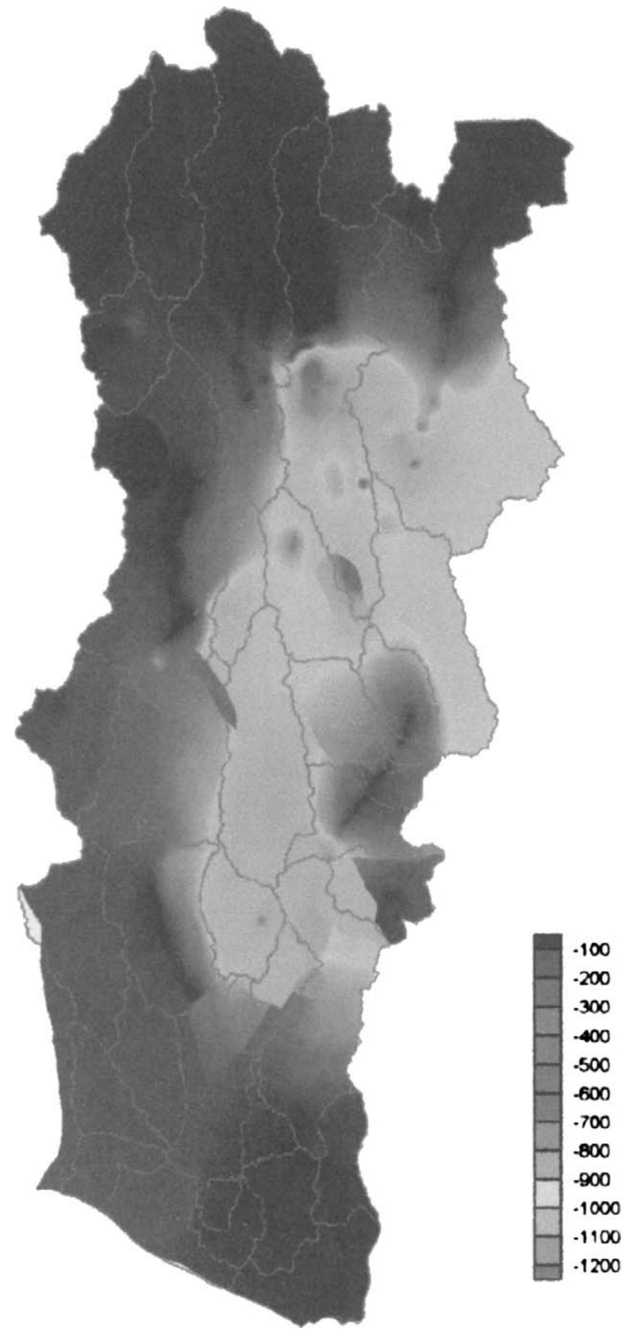

Figure 6. Computed expected drawdown in the water table at the new equilibrium state that includes the proposed SNWA pumping—predicted steady-state model.

proposed SNWA pumping. There is a very large area where the drawdown exceeds 700 feet. The deeper Carbonate Aquifer has similar drawdowns. Of particular interest is how long this system takes to reach the new equilibrium. Figure 7 is a plot of the change in storage in the system vs. time.

This figure is especially telling. The storage should level out and reach a stable level as the system reaches a new equilibrium (as in Figure 3), but this system is not close to reaching a new equilibrium state after 2000 years of projected pumping. A plot of the predicted ET vs. time (Figure 8) shows that the system has not reached a new equilibrium in 2000 years.

Combining Figures 7 and 8, we see that at 500 years, approximately 32% of the water pumped is coming from the depletion of storage and 65% from capture of ET. At 1000 years, 23% is coming from storage and 74% from capture of ET. At 2000 years, 14% is still coming from storage, while 82% is from capture of ET.

Nevada water law has only an implied reference to time; it only requires that the system reaches a new equilibrium state at some undetermined future time. The law was written before the tools were available to predict the future dynamics of ground water developments. The fact that the model predicts times more than 2000 years to reach a new equilibrium should change one's perspective on ground water management of this system.

Monitoring to Control Impacts

A strategy known as adaptive management relies on preventing impacts by monitoring the ground water

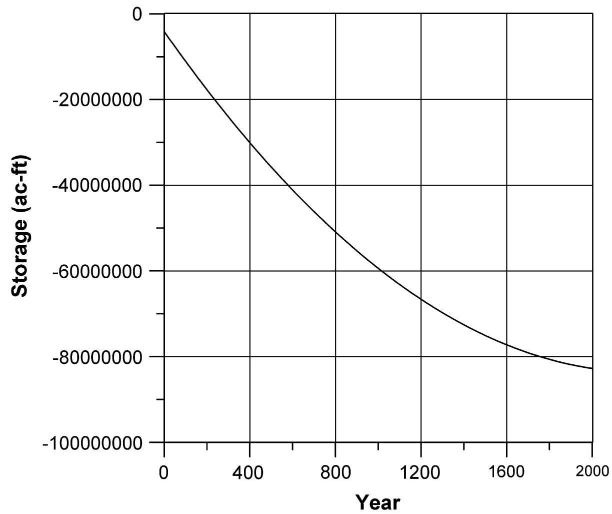

Figure 7. Predicted change in storage with proposed SNWA pumping.

system and changing the pumping stress when an undesirable impact is observed. The federal government entered into such agreements with SNWA before withdrawing their objections to the project. However, long-term monitoring also suffers from a prediction problem associated with the response time of the ground water system. We illustrate the monitoring problem with our hypothetical aquifer (Figure 1). We will examine a situation where we are attempting to maintain a spring at the lower end of our valley. Let us imagine that rather than having an area of phreatophytes discharging ground water, we have a single spring that discharges at 100 cfs before development. Our objective is to maintain the spring flow. We now start the case I ground water development that also pumps at 100 cfs.

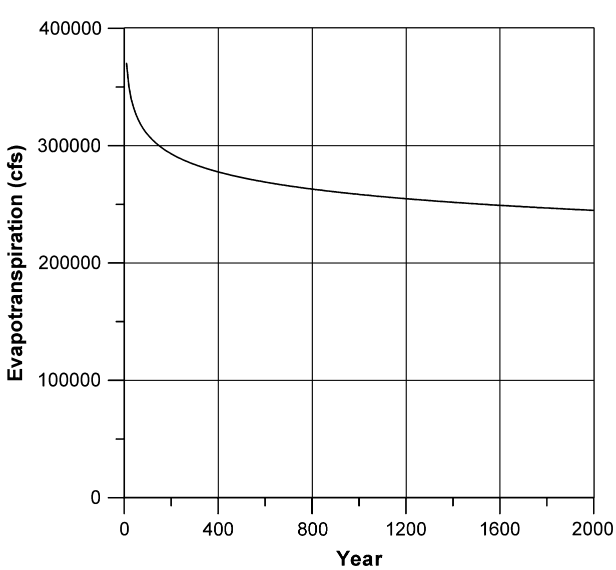

Figure 8. Computed plot of ET vs. time.

Let us further suppose we impose a monitoring and control strategy on the system. We monitor the spring with the intent that once the spring flow drops below 90 cfs (a 10% decline in flow), we will stop pumping ground water; in other words, our intent (as stated earlier) is to preserve the spring flow. We will use a 10% drop in flow as an observable signal that indicates that pumping is impacting the spring; smaller drops in flow could be ambiguous. (We are not arguing that this is a rational policy; rather we are illustrating a point.) Figure 9 shows the discharge of our spring vs. time; pumping stopped in area 1 in approximately 50 years when the spring discharge dropped to 90 cfs. The minimum spring flow occurs at approximately 75 years, 25 years after we stopped pumping. The reduction in flow is 13 cfs—larger than what it was when we stopped pumping. The maximum drawdown at the spring, created by the pumping, takes 25 years after pumping stops to work its way through the system.

We also see that the system does not recover readily to its predevelopment state even though the spring discharge equaled the recharge and was 100 cfs. Perhaps this is best understood if we look at the water removed from storage by the pumping and the rate at which it is replenished. During the period of pumping, the spring flow drops more or less linearly from 100 to 90 cfs. The amount of water removed from storage during this period averages approximately 95 cfs. The reduction in spring discharge averaged 5 cfs over the 50-year period—the capture of spring discharge averaged 5 cfs over the period. In other words, 95% of the ground water pumped during the 50 years of pumping came from storage. During the remaining 250 years since pumping stopped, the spring discharge averaged approximately 90 cfs. During that period, we are putting back in storage, on average, 10 cfs. This means that during the 250 years since the pumping ceased, we have restored just more than 50% of the water that was removed from the storage during the pumping period. You can easily see that this simple system will take approximately 500 years to return to its original state.

This hypothetical model illustrates the monitoring problem. If the monitoring point is some distance removed from the pumping, there will be (1) a time lag between the maximum impact and the stopping of pumping and (2) the maximum impact will be greater than what is observed when pumping is stopped (unless one has reached a new equilibrium state during the pumping period). The time for full recovery of the system will be long, even in the case where one has not reached the new equilibrium.

The real world is more complex. Those that advocate monitoring seldom envision totally stopping the pumping; rather, they imagine changes in the development that minimize damages. Stopping the pumping is a management action of last resort and we showed that it has problems. Less stringent management actions have a correspondingly lesser beneficial impact and even more problems.

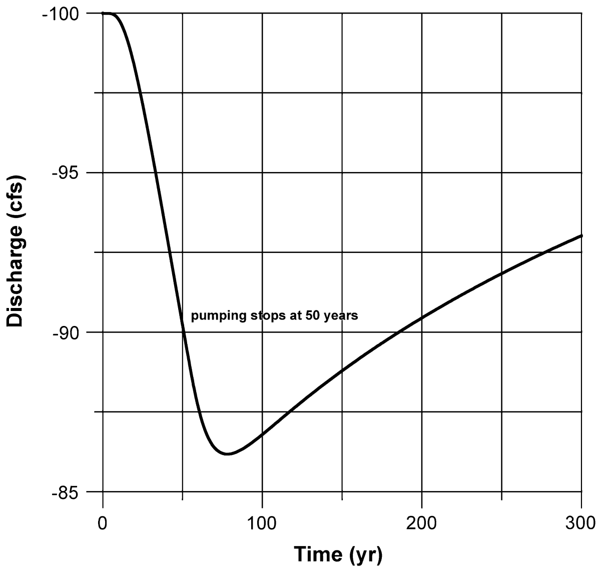

Figure 9. Predicted spring flow from a hypothetical aquifer (Figure 1 with phreatophytes in area 1 replaced by a spring). Pumping ceases after 50 years when the spring flow drops to 90 cfs.

Discussion

We do not think that the SNWA development in Nevada is all that unique nor do we think that this is typically only a western problem. Large aquifer systems exist throughout the country and the world. The response time problem is typical of large systems; there are other developments where the hydrologic boundaries where capture can take place are far from the pumping. Long times will be involved before the system can reach a new equilibrium—assuming that a new equilibrium is feasible. When the time to reach, or even approach, a new equilibrium exceeds a millennium or more, one has to ask—"Is the fact that the system will ultimately reach a new equilibrium meaningful?" It may be too distant in the future to have much meaning—too much can happen, civilizations change, the climate itself may change, and so forth. The bottom line is—it is important to predict the time trajectory of ground water systems, especially if one hopes to manage the system. Hydrogeologists have the tools to make these predictions.

The more vexing problem faces the water managers. For example, the SNWA development in Nevada can, given thousands of years, reach a new equilibrium. The question for the water manger, in this case the State Engineer, is how to deal with a system that takes so long to reach the new state—clearly, the law did not anticipate such long times.

Monitoring for control also has fundamental problems. The maximum impacts are larger than those observed at the time pumping stops, and they occur some time after the pumping stops. This is especially true if the monitoring is some distance away from the pumping. In addition, ground water systems will be very slow to recover to their predevelopment state once pumping is stopped.

In the case of SNWA's recent applications to pump in Cave, Dry Lake, and Delamar valleys, the Nevada State Engineer (2008) dealt with the problem as follows:

> The State Engineer finds that there is no dispute that the basins of the White River Flow System are hydrologically connected, but that does not mean that isolated ground-water resources should never be developed. The State Engineer finds he has considered the hydrologic connection and is fully aware that there will eventually be some impact to down-gradient springs where water discharges from the carbonate-rock aquifer system, but the time frame for significant effects to occur is in the hundreds of years.

> The State Engineer finds that a monitoring-well network and surface-water flow measurements will be part of a comprehensive monitoring and mitigation plan that will be required as a condition of approval and will provide an early warning for potential impacts to existing rights within the subject basins and the down-gradient basins of White River Flow System. The State Engineer finds that if unreasonable impacts to existing rights occur, curtailment in pumping will be ordered unless impacts can be reasonably and timely mitigated.

Conclusions

Some ground water systems in which a new equilibrium state that includes pumping can be achieved may take a long time to reach the new equilibrium. This is especially true where the discharge from the system that can potentially be captured by the pumping is a long distance away from the pumping center. Such a system may take more than a millennium, some more than two millennia, to reach the new equilibrium state.

This can pose a problem for the water manager, especially if the manager seeks to achieve a new equilibrium that will allow the pumping to persist for a prolonged period—essentially indefinitely.

One strategy, adopted by the State Engineer in Nevada, is to allow a large amount of pumping, more that can be sustained by a new equilibrium, while monitoring the system for adverse impacts. This strategy poses two problems: (1) a large ground water system creates a delayed response between the observation of an impact and its maximum effect and (2) there is a long time lag between changing the stress and observing an impact at a distant boundary.

If a water manager allows more pumping than the pumping can capture, then sooner or later the pumping must be curtailed or a new equilibrium can never be reached and the system will be depleted.

Acknowledgments

The authors wish to thank the editor and reviewers for their helpful suggestions.

Disclaimer

In fairness to the reader, we need to state that both authors of this paper acted as consultants on issues related to proposed ground water development in eastern Nevada. We consulted on opposing sides—Durbin for SNWA and Bredehoeft for the environmental coalition that opposes the development. Durbin's model of the proposed development for SNWA was documented, including its calibration, in a public document presented to the Nevada State Engineer at a hearing on SNWA's application for permits to pump ground water in Spring Valley, Nevada. Both authors presented the results of Durbin's model analysis in a public statement to the Nevada State Engineer at a hearing on SNWA's application to pump ground water in Cave, Dry Lake, and Delamar valleys, Nevada. The results are presented here as an example of model predictions; the predictions reflect all the caveats stated earlier.

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The United Nations University

GEOTHERMAL TRAINING PROGRAMME
Orkustofnun, Grensásvegur 9,
IS-108 Reykjavík, Iceland

Reports 2000
Number 1

FIVE LECTURES ON ENVIRONMENTAL EFFECTS OF GEOTHERMAL UTILIZATION

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Lectures on environmental studies given in September 2000
United Nations University, Geothermal Training Programme
Reykjavík, Iceland
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PREFACE

Geothermal energy is generally regarded as benign to the environment. The exploitation of geothermal energy has, however, to be conducted in a sustainable way. New Zealand is one of the world´s pioneer countries in the development of high-temperature geothermal resources. Dr. Trevor M. Hunt, geophysicist at the Wairakei Research Centre of the Institute of Geological and Nuclear Sciences in Taupo, has been one of the key people in the exploration and the monitoring of the exploitation of the geothermal fields in New Zealand. He gave the lectures presented here as the UNU Visiting Lecturer at the UNU Geothermal Training Programme in Reykjavik in September 2000.

In his lectures, Dr. Trevor M. Hunt gives a detailed account of the environmental changes that have been caused by the operations of the geothermal power stations in Wairakei and Ohaaki in New Zealand. He demonstrates very clearly the importance of regular monitoring of geothermal fields both prior to and during exploitation and points out how the environment can best be protected and the effects of exploitation mitigated. We are very grateful to him for writing up his lecture notes and thus making the lectures available to a much larger audience than those who were so fortunate in attending his lectures in Reykjavik. The experience of Dr. Trevor M. Hunt and his colleagues in New Zealand is very valuable to the world geothermal community and will certainly help in promoting the sustainable use of geothermal resources in the world.

Since the foundation of the UNU Geothermal Training Programme in 1979, it has been customary to invite annually one internationally renowned geothermal expert to come to Iceland as the UNU Visiting Lecturer. This has been in addition to various foreign lecturers who have given lectures at the Training Programme from year to year. It is the good fortune of the UNU Geothermal Training Programme that so many distinguished geothermal specialists have found time to visit us. Following is a list of the UNU Visiting Lecturers during 1979-2000:

1979 Donald E. White	United States	1990 Andre Menjoz	France
1980 Christopher Armstead	United Kingdom	1991 Wang Ji-yang	China
1981 Derek H. Freeston	New Zealand	1992 Patrick Muffler	United States
1982 Stanley H. Ward	United States	1993 Zosimo F. Sarmiento	Philippines
1983 Patrick Browne	New Zealand	1994 Ladislaus Rybach	Switzerland
1984 Enrico Barbier	Italy	1995 Gudm. Bödvarsson	United States
1985 Bernardo Tolentino	Philippines	1996 John Lund	United States
1986 C. Russel James	New Zealand	1997 Toshihiro Uchida	Japan
1987 Robert Harrison	UK	1998 Agnes G. Reyes	Philippines/N.Z.
1988 Robert O. Fournier	United States	1999 Philip M. Wright	United States
1989 Peter Ottlik	Hungary	2000 Trevor M. Hunt	New Zealand

With warmest wishes from Iceland,

Ingvar B. Fridleifsson, director,
United Nations University
Geothermal Training Programme

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LECTURE 1

GEOTHERMAL AND THE ENVIRONMENT

1. INTRODUCTION

For tens of thousands of years mankind has functioned as an integral part of the environment, and until recently has had no greater impact than any other animal species. However, as our technological skills have increased, especially in the last century, so has our capacity to cause environmental changes. Such changes, in themselves, are not necessarily a problem, but it is the fact that so many of the changes have been unpredictable and irreversible in the short term that has caused problems. This is in part due to our poor understanding of the environment and of environmental processes at a time when our ability to alter the environment has never been greater. For example, let us consider what is possibly the greatest environmental problem at present – that of global warming. Scientific measurements show that there has been a 12% increase in the carbon dioxide content of the atmosphere since 1880, and this has been linked to various meteorological changes which have occurred in the latter part of the 20 th century. However, there is still a great deal of scientific debate about the processes involved. Current thinking favours the theory that much of this increase in carbon dioxide is associated with increased energy use, and in particular with the burning of fossil fuels combined with reduction of forest areas that are carbon "sinks".

Geothermal energy is generally accepted as being an environmentally benign energy source, particularly when compared to fossil fuel energy sources. Geothermal developments in the last 40 years, however, have shown that it is not completely free of adverse impacts on the environment. These impacts are becoming of increasing concern, and to an extent which may now be limiting developments. History shows that hiding or ignoring such problems can be counterproductive to development of an industry because it may lead to a loss of confidence in that industry by the public, regulatory, and financial sectors. A good example of the consequences of ignoring problems is the nuclear power industry. If our aim is to further the use of geothermal energy, then all possible environmental effects should be clearly identified, and countermeasures devised and adopted to avoid or minimise their impact.

1.1 What is the "Environment" ?

Firstly it may be worthwhile to consider what is the "environment," and why it should be preserved or protected. Some dictionary definitions are:

1. The Oxford dictionary (Brown, 1993) defines environment as *"the set of circumstances or conditions … in which a person or community lives, works, develops, etc, or a thing exists or operates; the external conditions affecting the life of a plant or animal"*.

2. The Encyclopaedia of environmental science (Parker, 1980) considers it is *"the sum of all external conditions and influences affecting the life and development of organisms"*.

3. The Merriam Webster Collegiate dictionary (Internet) defines it as:
   a: *"The complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival."*
   b: *"The aggregate of social and cultural conditions that influence the life of an individual or community."*

The term environment is therefore generally used in a broad sense to encompass not only the physical conditions, but also the cultural and spiritual conditions of people living nearby.

1.2 What is the geothermal environment?

Natural thermal features

A major component of the geothermal environment is the beautiful natural thermal features which vary in colour and form. Their environmental importance is increased because they are rare on a world-wide basis, and often fragile. The main types of natural features are:

- Geyser – hot spring which periodically erupts a jet of hot water and steam;
- Fumarole – vent from which steam is emitted at high velocity;
- Hot spring and pool – a vent from which hot water flows, or depression into which hot water collects; often ebullient. Edges may be raised by precipitation of silica or calcium carbonate;
- Silica sinter terrace – terrace formed of opaline silica precipitated from waters of geysers and hot springs. Where the waters originate in calcareous rocks (limestones) the mineral precipitated will be travertine (calcium carbonate). Travertine terraces are rare, but splendid examples are found in Yellowstone National Park (USA) and at Pamukkale (Turkey);
- Thermal area – area of heated ground. It is often bare, or has only stunted, heat-tolerant vegetation;
- Mud pool – hot pool in which adjacent rock or soil has been dissolved to form a viscous mud, usually sulfurous and often multi-coloured;
- Algal mat – mat of coloured algae found in hot flowing streams carrying water away from geysers or hot pools. Colours range from white (hottest water) through orange and green to black (coolest water);
- Thermophyllic plant – plant which tolerates or thrives in hot ground. These may be found elsewhere but only in much warmer climates.

Cultural significance

- Myths and legends – thermal features are often associated with myths and legends in native peoples culture. For example, the native Maori people of New Zealand have a legend that the thermal areas of NZ were formed when fire gods, summoned from far away and travelling underground, surfaced looking for the person who called them;
- Spiritual – many societies which use geothermal energy incorporate it into their ceremonies. For example, in Beppu (Japan) they hold a Hot Spring Festival every year.

Cultural uses

- Bathing in hot pools – bathing in hot pools is common in most countries where geothermal waters are available. Bathing in geothermal waters is often claimed to have special medicinal properties, and in New Zealand geothermal waters are used in the government hospital at Rotorua for the treatment of arthritis and skin diseases;
- Washing – clothes are washed in warm streams;
- Cooking – boiling hot pools are used for cooking. Food is placed in a woven basket and lowered into the hot pool. This is still done in Japan and New Zealand, but mainly for tourists;
- Minerals – in primitive native societies, ochre formed from hydrothermal alteration of rocks was used to paint the face and body. At present time, sulfur and zeolite minerals are collected from fumarolic areas.

Economic uses

- Tourism – because of their relative rarity, many thermal areas containing beautiful natural thermal features are tourist destinations;
- Low impact use – in many places where there is warm or hot geothermal water it is used for low-impact agricultural or industrial purposes; for example: fruit and crop drying, heating greenhouses, and fish farming. Small communities often develop around these places.

1.3 Why preserve the environment?

The most compelling reasons why we should try and preserve the environment are:

Self respect
Most human cultures value their surroundings, even to the extent of significantly modifying them to enhance their beauty or desirability. It is generally recognised that the destruction of beautiful natural thermal features such as geysers, hot springs and silica terraces is unacceptable. The famous American philosopher Thoreaux (1860) said: *"What is the use of a house if you have not got a tolerable planet to put it on?"*

Self-preservation
Few advanced living organisms will significantly alter or destroy their surroundings because this is likely to threaten their continued existence as a species.

Maintaining our heritage
The natural environment is a heritage, passed to us by preceding generations, and it is our responsibility to pass it undamaged to future generations.

Economic
Changing the environment can have negative economic effects. In the case of geothermal development, the destruction, loss or modification of beautiful natural thermal features can badly affect tourism which is often a major source of revenue and employment. For example, in New Zealand, international tourism is the third largest source of overseas income, and the natural thermal features are prime tourist destinations. For this reason many geothermal areas with thermal features which have tourist potential have been designated as scenic reserves by the New Zealand government and no geothermal developments are allowed in them.

To meet national and international obligations
In most countries, industrial development (including geothermal) is contingent on the developer obtaining a permit (from a regulatory authority) which involves assessing the impact the development may have on the environment. In many countries the permitting process involves public submissions and hearings, and permits are extremely difficult to obtain if significant environmental effects are predicted.

Preservation of the environment is not merely a local issue but an international concern: Of 27 Principles proclaimed by the 1992 United Nations Conference on Environment and Development (Earth Summit), 21 refer specifically to the environment. This conference was held, at Rio de Janeiro, Brazil (June 3-14, 1992), to reconcile world-wide economic development with protection of the environment. It was the largest gathering of world leaders in history, with 117 heads of state and representatives of 178 nations attending. Through treaties and other documents signed at the conference, most of the world's nations nominally committed themselves to the pursuit of economic development in ways that would protect the Earth's environment and its non-renewable resources.

The main documents agreed upon at the Earth Summit were:

The Convention on Biological Diversity
This is a binding treaty requiring nations to take inventories of their plants and wild animals and protect their endangered species.

The Framework Convention on Climate Change, (Global Warming Convention)
This is a binding treaty that requires nations to reduce their emission of carbon dioxide, methane, and other "greenhouse" gases thought to be responsible for global warming. However, the treaty stopped short of setting binding targets for emission reductions.

The Declaration on Environment and Development, (Rio Declaration)
This laid down 27 broad, non-binding principles for environmentally sound development.

Agenda 21
This outlined global strategies for cleaning up the environment and encouraging environmentally sound development.

The Statement of Principles on Forests
This non-binding statement aimed at preserving the world's rapidly vanishing tropical rainforests, and

recommended that nations monitor and assess the impact of development on their forest resources and take steps to limit the damage done to them.

The Earth Summit was hampered by disputes between the wealthy industrialised nations of the North (*i.e.,* western Europe and North America) and the poorer countries of the South (*i.e.,* Africa, Latin America, the Middle East, and parts of Asia). In general, the countries of the South were reluctant to hamper their economic growth with the environmental restrictions urged upon them by the North unless they received increased financial aid, which they claimed would help make environmentally sound growth possible.

2. BENEFITS OF GEOTHERMAL DEVELOPMENT

2.1 Energy savings

According to Lund (2000) the total geothermal electricity produced in the world is equivalent to saving 12.5 Mt (million tonnes) of fuel oil per year (assuming 0.35 efficiency factor). The total direct-use and geothermal heat pump energy use in the world is equivalent to savings of 13.1 Mt of fuel oil per year (0.35 efficiency factor). If the replacement energy for direct-use was provided by burning the fuel directly, then about half this amount would be saved in heating systems (35% vs. 70% efficiency). If the savings in the cooling mode of geothermal heat pumps is considered, then this is equivalent to additional savings of 1.2 Mt/yr of fuel oil (Table 1).

TABLE 1: Fuel oil and carbon savings (annual) from geothermal energy production; taken from Lund (2000)

Fuel oil (10^6)		**Carbon (10^6 t)**		
Barrels	**Tonnes**	**Natural gas**	**Oil**	**Coal**
179.1	26.7	5.56	23.80	27.64

2.2 Reduced greenhouse gas emissions

Electricity generation from geothermal resources involves much lower greenhouse gas (GHG) emission rates than that from fossil fuels. According to the International Atomic Energy Agency (IAEA), replacing one kilowatt-hour (kWh) of fossil power with a kilowatt-hour of geothermal power reduces the estimated global warming impact by approximately 95%. This estimate includes emissions from the "full energy chain," which includes all of the upstream and downstream processes necessary for power generation. At first reading this may seem an exaggeration but the extraction, refinement, and transport of fossil fuels can entail substantial greenhouse gas emissions. For example, methane, the main component of natural gas, is a potent greenhouse gas, so leakage from systems (pipelines, tankers) which transport natural gas may considerably increase the global warming impact of natural gas-fired power generation.

Most geothermal power plants release a small amount of carbon dioxide (CO_2), which is contained in the fluid. The full-energy-chain emissions from geothermal power generation had been estimated in three studies reviewed by the IAEA. A 1989 study estimated emissions equivalent to 57 grams of carbon dioxide per kWh of net electricity generation, while two 1992 studies estimated 40 and 42 grams per kWh. For power generation from fossil fuels, the IAEA estimated greenhouse gas emissions equivalent to 460-1290 grams of CO_2 per kWh (Fig. 1). However, the literature on full-energy-chain GHG emission rates is scant and imperfect, so the values developed by the IAEA and shown in Figure1 should not to be considered definitive.

According to Lund (2000), the equivalent savings in the production of CO_2 from geothermal electricity production from fuel oil is 40.2 Mt and from direct-use 42.0 Mt. The corresponding figures for natural gas and coal are 9.5 and 46.9 Mt for electricity, and 9.9 and 49.0 for direct-use (at 35% plant efficiency). Similar numbers for natural gas, oil and coal can be determined for sulfur oxides (SO_x) and nitrogen oxides (NO_x) at 0, 0.25 and 0.26 Mt and 2.2, 7.6 and 7.6 kt (thousand tonnes) respectively for electricity, and 0, 0.26 and 0.28 Mt and 2.3, 7.9 and 7.9 kt respectively for direct-use. For direct-use, the values would be approximately half if the heat energy was used directly.

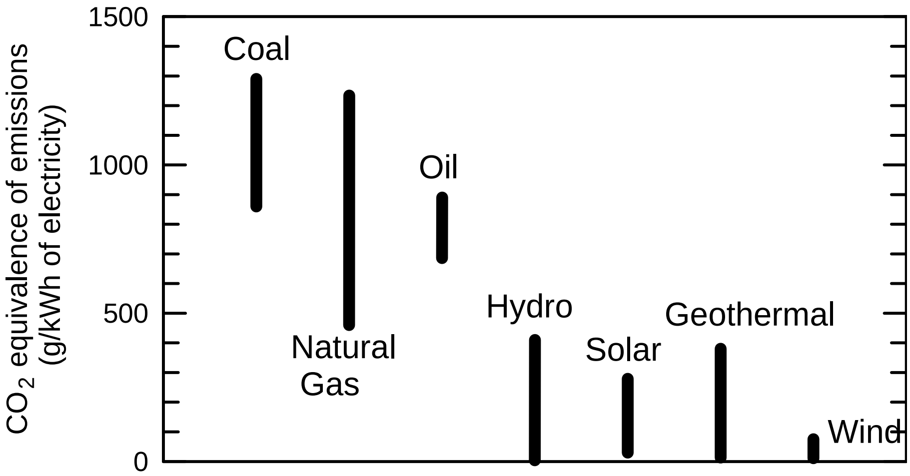

FIGURE 1: Relative amounts of greenhouse gas emissions from various types of electricity generation methods, data expressed as CO_2 equivalents; taken from Geothermal Energy News (May 1998), and geothermal data adjusted on basis of data from ETSU (1998)

In total, the savings from present worldwide geothermal energy production, both electric and direct-use, are summarised in Tables 1 and 2.

TABLE 2: CO_2, SO_x and NO_x savings (annual) from geothermal energy production; taken from Lund (2000)

CO_2 (10^6 t)			**SO_x (10^6 t)**			**NO_x (10^6 t)**		
Natural gas	Oil	Coal	Natural gas	Oil	Coal	Natural gas	Oil	Coal
19.4	82.2	95.9	0	0.51	0.54	4.5	15.5	15.5

2.3 Reduced sulphur gas emissions

The amount of sulphur gases (mainly H_2S) emitted from a geothermal power station (average 0.03 g/kWh) is less than 2% of that emitted from equivalent size coal- and oil-fired power stations (9.23 and 4.95 g/kWh, respectively).

3. ENVIRONMENTAL IMPACTS

Geothermal energy does have some environmental impacts, most of which are associated with the exploitation of high-temperature geothermal systems. In Table 3 the possibilities of environmental effects of geothermal development both for low-temperature areas and high-temperature areas are summarised.

3.1 Drilling operations

Exploitation of both low-temperature and high-temperature systems involves drilling wells to depths of 500-2500 m; this requires large drilling rigs and may take several weeks or months. For high-temperature systems the location of the drilling site is important, although directional drilling techniques have reduced this in recent times. The main environmental effects of drilling are shown here below.

TABLE 3: Possibilities of environmental effects of geothermal development

	Low-temperature systems	High-temperature systems	
		Vapour-dominated	Liquid-dominated
Drilling operations:			
Destruction of forests and erosion	●	● ●	● ●
Noise	● ●	● ●	● ●
Bright Lights	●	●	●
Contamination of ground-water by drilling fluid	●	● ●	● ●
Mass withdrawal:			
Degradation of thermal features	●	● ●	● ● ●
Ground subsidence	●	● ●	● ● ●
Depletion of groundwater	O	●	● ●
Hydrothermal eruptions	O	●	● ●
Ground temperature changes	O	●	● ●
Waste liquid disposal:			
Effects on living organisms			
surface disposal	●	●	● ● ●
reinjection	O	O	O
Effects on waterways			
surface disposal	●	●	● ●
reinjection	O	O	O
Contamination of groundwater	●	●	●
Induced seismicity	O	● ●	● ●
Waste gas disposal:			
Effects on living organisms	O	●	● ●
Microclimatic effects	O	●	●

O No effect ● ● Moderate effect
● Little effect ● ● ● High effect

Impact of access and field development
The construction of road access to drilling sites can involve destruction of forests and vegetation which, particularly in tropical areas with high rainfall (Indonesia, Philippines), can result in erosion. Such erosion can result in large amounts of silt being carried by the streams and rivers draining the development area, This silt can affect fish in the river and may even affect fish in coastal waters near the mouth of the river. The silt may also deposit on the river bed where the gradient (flow rate) is less, causing the bed of the river to be raised and make the adjacent land more likely to be flooded during periods of high rainfall.

Effects of drilling operations
Drilling creates noise, fumes and dust which can disturb animals and humans living nearby. Typical noise levels (in approximate order of intensity) are:

- Air drilling – 120 dBa (85 dBa with suitable muffling);
- Discharging wells after drilling (to remove drilling debris) – up to 120 dBa;
- Well testing – 70-110 dBa (if silencers used);
- Heavy machinery (earth moving during construction) – up to 90 dBa;
- Well bleeding – 85 dBa (65 dBa if a rock muffler is used);
- Mud drilling – 80 dBa;

- Diesel engines (to operate compressors and provide electricity) – 45-55 dBa if suitable muffling is used.

The characteristics of the site (e.g. its topography) and meteorological conditions will also have an influence. To put the above noise levels into context, 120 dBa is the pain threshold (at 2-4000 Hz), noise levels in a noisy urban environment are 80-90 dBa, in a quiet suburban residence about 50 dBa and in a wilderness area 20-30 dBa (DiPippo, 1991; Armannsson and Kristmannsdottir, 1993). Noise is attenuated by distance travelled in air; there is approximately 6 dB attenuation every time the distance is doubled, but lower frequencies are attenuated less than higher frequencies. Thus, low rumbling noises from drill rigs and silencers carry much further than high frequency steam discharge noises.

Continuous drilling involves the use of powerful lamps to light the work site at night which can disturb local residents, domestic and wild animals.

Disposal of waste drilling fluid
In the past it was common practice to discharge waste fluids into nearby waterways.

3.2 Mass withdrawal

Large-scale exploitation of liquid-dominated high-temperature geothermal systems involves the withdrawal of large volumes of geothermal fluid. For example, between 1958 and 1991 more than 1700 Mt of fluid were withdrawn from the Wairakei geothermal field (New Zealand); assuming an average temperature of 200°C this represents nearly 2 km^3 of fluid (Hunt, 1995). In geothermal power schemes where the fluid withdrawn is reinjected, the reinjection wells are generally located away from the production wells to reduce the chances of the cooler reinjected water returning to the production wells and reducing the temperature of production fluids. Even if all the waste liquid is reinjected, there may be a large mass loss (up to 30% of that withdrawn) associated with discharge of water vapour into the atmosphere from the power station. A major consequence of the mass loss from parts of the field is the formation of a 2-phase (steam + water) zone in the upper part of the reservoir, and as production continues this zone increases in size and the pressures (both in and below this zone) decrease. At Wairakei, the deep (liquid phase) pressures declined by about 0.5 MPa (5 bar) during exploratory drilling, and a further 1.7 MPa (17 bar) during the first ten years of production, although subsequent pressure declines have been less than 0.5 MPa (Figure 2). Pressure declines in the reservoir, as a result of mass withdrawal and net mass loss, are an important cause of environmental changes at or near the surface.

Degradation of thermal features
In their natural, unexploited state many high-temperature geothermal systems are manifested at the surface by thermal features such as geysers, fumaroles, hot springs, hot pools, mud pools, sinter terraces and thermal ground with special plant species. Often these features are of great cultural significance, as well as being important tourist attractions. The thermal features result from the (upward) leakage of

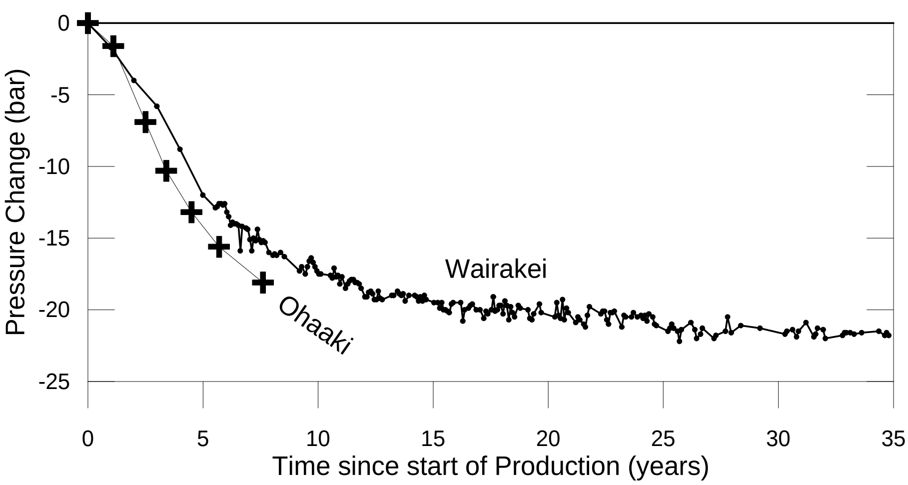

FIGURE 2: Deep reservoir pressure changes since start of production at the liquid-dominated, high-temperature geothermal fields of Wairakei (1958) and Ohaaki (1988), in New Zealand; note the rapid decline in pressure during the first 10 years of production

boiling geothermal fluid from the upper part of the reservoir, through overlying cold groundwater, to the surface.

Historical evidence shows that natural thermal features have been affected, often severely, during the development and initial production stages of most high-temperature geothermal systems. At Wairakei (New Zealand), nearly all the thermal features in the Waiora and Geyser Valleys (including more than 20 geysers) have died. At Ohaaki (New Zealand), the level and temperature of water in the Ohaaki Pool have declined since exploration drilling and reservoir testing began. Such effects are not confined to liquid-dominated systems. At Larderello (Italy) where the original natural activity consisted of numerous steam and gas jets, activity has now largely ceased, and at The Geysers (USA) there has been a decrease in the flow from hot springs since exploitation began.

Scientific evidence shows that the decline in thermal features is associated with the decline in reservoir pressure. As the pressure declines, so also does the amount of geothermal fluid reaching the surface and hence the thermal features decline in size and vigour. If pressures fall further then the features may die and the flow may reverse with cold groundwater flowing down into the reservoir; once this situation has occurred there may be little hope of resurrecting the features, at least within a human lifetime.

Depletion of groundwater
Most high-temperature geothermal systems are overlain by a cold groundwater zone. If exploitation of the system results in a large pressure drop in the reservoir, this groundwater may be drawn down into the upper part of the reservoir in places where there are suitable high-permeability paths (such as faults); such a situation is called a *cold downflow* (Bixley, 1990). If the lateral permeability of the rocks in the groundwater zone is low then a downflow may result in a drop in the groundwater level. For example, at Wairakei, a localised drop of more than 30 m in groundwater level has occurred associated with a cold downflow.

Downflows, and groundwater level changes, may also occur as a result of breaks in the casing of disused wells (Bixley & Hattersley, 1983).

Ground deformation
Withdrawal of fluid from an underground reservoir can result in a reduction of formation pore pressure which may lead to compaction in rock formations having high compressibility and result in subsidence at the surface. Subsidence has also been observed in groundwater and petroleum reservoirs. Horizontal movements also occur. Such ground movements can have serious consequences for the stability of pipelines, drains and well casings in a geothermal field. If the field is close to a populated area, then subsidence could lead to instability in dwellings and other buildings; in other areas, the local surface watershed systems may be affected.

The largest recorded subsidence in a geothermal field (15 m) is in part of the Wairakei field (New Zealand) This subsidence has caused:

- Compressional and tensional strain on pipelines and lined canals;
- Deformation of drill casing;
- Tilting of buildings and the equipment inside;
- Breaking of road surfaces;
- Alteration of the gradient of streams and rivers.

Ground movements have been recorded in other high-temperature geothermal fields in New Zealand, at Cerro Prieto (Mexico), Larderello (Italy), and The Geysers (USA). Subsidence in liquid-dominated fields has been greater than in vapour-dominated fields, because the former are often located in young, relatively-poorly compacted volcanic rocks and the latter are generally in older rocks having lower porosity.

Ground temperature changes
The formation and expansion of a 2-phase zone in the early stages of exploitation of a liquid-dominated geothermal system can also alter the heat flow. Steam is much more mobile than water; it can move through small fractures that are impervious to water and can move much more quickly through larger fractures. The generation and movement of steam can therefore result in increased heat flow and increased ground temperatures so that vegetation becomes stressed or killed.

At Wairakei, heat flow from natural thermal features was about 400 MW prior to the start of exploitation in 1958, increased to a peak of nearly 800 MW by the mid 1960s, and has since declined to about 600 MW (Allis, 1981). Most of this increase was associated with increased thermal activity in the Karapiti thermal area, which is situated 3 km south-west of the main production borefield. These changes have been attributed to steam rising to the surface through fissures that were previously impervious to water.

3.3 Waste liquid disposal

Most geothermal energy developments bring fluids to the surface in order to mine heat contained within them. In high-temperature liquid-dominated geothermal fields the volumes of resultant liquid waste involved may be large: at Wairakei, a medium-sized power station (156 MW), it is currently about 5800 m^3/hr. For vapour-dominated systems it is less, and for low-temperature systems it is very much less: at Chevilly-Larue (France) it is only about 3 m^3/hr. The waste fluid is disposed of by putting it into waterways or evaporation ponds, or reinjecting it deep into the ground. Surface disposal causes more environmental problems than reinjection.

Environmental problems are due not only to the volumes involved, but also to the relatively high temperatures and toxicity of the waste fluid. For example, at Wairakei the waste water has a temperature of about 140°C. The chemistry of the fluid discharge is largely dependent on the geochemistry of the reservoir, and the operating conditions used for power generation and will be different for different fields (Webster, 1995). For example, fluids from the Salton Sea field (USA), which is hosted by evaporite deposits, are acidic and highly saline (pH <5, [Cl] = 155 000 ppm). At the other extreme, those of the Hveragerdi field (Iceland) are alkaline and of very low salinity (pH >9, [Cl] <200 ppm). Most high-temperature geothermal bore waters include high concentrations of at least one of the following toxic chemicals: lithium (Li), boron (B), arsenic (As), hydrogen sulfide (H_2S), mercury (Hg), and sometimes ammonia (NH_3). Fluids from low-temperature reservoirs generally have a much lower concentrations of contaminants.

Most of the chemicals are present as solute and remain in solution from the point of discharge, but some are taken up in river or lake bottom sediments, where they may accumulate to high concentrations. The concentrations in such sediments can become greater than the soluble concentration of the species in the water, so that re-mobilisation of the species in the sediment, such as during an earthquake or flood, could result in a potentially toxic flush of the species into the environment. Chemicals which remain in solution may be taken up by aquatic vegetation and fish (Webster & Timperly, 1995), and some can also move further up the food chain into birds and animals residing near the river. For example, in New Zealand, annual geothermal discharges into the Waikato River contain 50 kg mercury, and this is regarded as partly responsible for the high concentrations of mercury (often greater than 0.5 mg/kg of wet flesh) in trout from the river and high (greater than 200 μg/kg) sediment mercury levels.

Effects on living organisms
If hot waste water from a standard steam-cycle power station is released directly into an existing natural waterway, the increase in temperature may kill fish and plants near the outlet. Release of untreated waste into a waterway can result in chemical poisoning of fish, and also birds and animals which reside near the water because some of the toxic substances move up the "food chain".

Effects on waterways
Release of large volumes of waste water into a waterway may increase erosion, and if uncooled and untreated there may be precipitation of minerals such as silica near the outlet surface disposal

Contamination of groundwater
Release of waste water into cooling ponds or waterways may result in shallow groundwater supplies becoming contaminated and unfit for human use

Induced seismicity
Most high-temperature geothermal systems lie in tectonically active regions where there are high levels of stress in the upper parts of the crust; this stress is manifested by active faulting and numerous earthquakes. Studies in many high-temperature geothermal fields have shown that exploitation can result in an increase (above the normal background) in the number of small magnitude earthquakes (microearthquakes) within the field. It is believed the increase is caused by reinjection because when reinjection is stopped the number of small earthquakes decreases, and when it is restarted the number increases (Sherburn et al., 1990). High wellhead reinjection pressures increase the pore pressure at depth particularly in existing fractures, which allows movement to suddenly release the stress and resulting in an earthquake. This phenomenon occurs in both liquid- and vapour-dominated fields, but has not been observed in low-temperature fields. Detailed studies show that the induced microearthquakes cluster (in space) around and below the bottom of reinjection wells and so the effects at the surface are generally confined to the field (Stark, 1990). To date no serious damage has been caused by such earthquakes, but they do frighten people.

3.4 Waste gas disposal

Gas discharges from low-temperature systems do not usually cause significant environmental impacts. In high-temperature geothermal fields, power generation using a standard steam-cycle plant may result in the release of non-condensable gases (NCG) and fine solid particles (particulates) into the atmosphere (Webster, 1995). In vapour-dominated fields in which all waste fluids are reinjected, non-condensable gases in steam will be the most important discharges from an environmental perspective.

The emissions are mainly from the gas exhausters of the power station, often discharged through a cooling tower. Gas and particulate discharges during well drilling, bleeding, cleanouts and testing, and from line valves and waste bore water degassing, are usually insignificant. The concentration of NCG varies not only between fields but can also from well to well within a field, thus changes to the proportion of steam from different wells may cause changes in the amounts of NCG discharged.

Gas concentrations and compositions cover a wide range, but the predominant gases are carbon dioxide (CO_2) and hydrogen sulphide (H_2S).

Carbon dioxide
Carbon dioxide occurs in all geothermal fluids but is most prevalent in fields in which the reservoir contains sedimentary rocks, and particularly those with limestones. Carbon dioxide is generally the most abundant NCG. It is colourless and odourless, and is heavier than air and can thus accumulate in topographic depressions where there is still air. It is not highly toxic (c.f. hydrogen sulfide) but at high concentrations it can be fatal due to alteration of pH in the blood. A 5% concentration in air can result in shortness of breath, dizziness, and mental confusion. At 10% a person will normally lose consciousness and quickly be asphyxiated. Exposure standards range from 5000 to 30,000 ppm (for 10 min.). There is some evidence that in high-temperature fields the amount of CO_2 discharged (per unit mass withdrawn) decreases with time as a result of de-gassing of the deep reservoir fluid and a decline in heat transfer from the formations occurs.

Hydrogen sulphide
H_2S is characterised by a “rotten egg odour” detectable by humans at very low concentrations of about 0.3 ppm. At such concentrations it is primarily a nuisance, but as the concentration increases, it may irritate and injure the eye (10 ppm), the membranes of the upper respiratory tracts (50-100 ppm), and lead to loss of smell (150 ppm). At a concentration of about 700 ppm it is fatal. Because H_2S is heavier than air it can accumulate in topographic depressions where there is still air, such as well cellars and the basements of buildings near the gas exhausters. The disappearance of the characteristic smell at concentrations greater than 150 ppm is especially dangerous because it leads to people failing to recognise potentially fatal concentrations. Exposure standards range from 10 to 50 ppm (10 min.). In sparsely populated areas, H_2S emissions may not prove a problem, and at many sites, there are already natural emissions from fumaroles, hot springs, mudpots etc. H_2S emissions can vary significantly from field to field, depending on the amount of H_2S in the geothermal fluid, and the type of plant used to exploit the reservoir (Table 4).

H_2S dissolved in water aerosols, such as fog, reacts with atmospheric oxygen to form more oxidised sulphur-bearing compounds; some of these compounds have been identified as components of "acid rain", but a direct link between H_2S emission and acid rain has not been established. U.S. Occupational Safety & Health ceiling level for H_2S is 14 mg/m^3, but an ambient air quality standard of 0.042 mg/m^3 is used in California.

TABLE 4: H_2S emissions from some geothermal plants; taken from ETSU (1998)

Field	H_2S emission (g/kWh)	Reference
Wairakei, NZ	0.5	Barbier, 1991
The Geysers, USA	1.9	Barbier, 1991
Lardarello, Italy	3.5	Barbier, 1991
Cerro Prieto, Mexico	4.2	Barbier, 1991
Krafla, Iceland	6.0	Armannsson and Kristmannsdottir, 1992
Ohaaki, NZ	6.4	Barbier, 1991

Other gases
Geothermal power stations do not emit oxides of nitrogen (NO_x), which combine photochemically with hydrocarbon vapours to form ground-level ozone which harms crops, animals and humans. However, geothermal gases may contain ammonia (NH_3), trace amounts of mercury (Hg) and boron (B) vapour, and hydrocarbons such as methane (CH_4). Ammonia can cause irritation of the eyes, nasal passages and respiratory tract, at concentrations of 5 to 32 ppm. Inhalation or ingestion of mercury can cause neurological disorders. Boron is an irritant to the skin and mucus membranes, and is also phytotoxic at relatively low concentrations. but these metals are generally emitted in such low quantities that they do not pose a human health hazard. The metals may also be deposited on soils and, if leached from there, they may contribute to groundwater contamination.

Binary plants use low-boiling point fluid, commonly iso-pentane, which may escape from the plant over a period of time. The gas phase may be recognised in the steam, and values of up to 4000 ppm have been recorded.

Effects on living organisms
The impacts of H_2S discharge will depend on local topography, wind patterns and land use. The gas can be highly toxic, causing eye irritation and respiratory damage in humans and animals, and has an unpleasant odour. Boron, NH_3, and (to a lesser extent) Hg, are leached from the atmosphere by rain, leading to soil and/or vegetation contamination (Webster, 1995). Boron, in particular, can have a serious impact on vegetation. Contaminants leached from the atmosphere can also affect surface waters and affect

aquatic life. Details of biological impacts of these gases are given by Webster & Timperley (1995).

Microclimatic effects
Even in geothermal power schemes which have complete reinjection, a considerable amount of gas (mainly steam) may be lost to the atmosphere. For example, at Ohaaki, of 70 Mt of fluid withdrawn (1988 - 1993) about 20 Mt (nearly 30%) was discharged to the atmosphere. Such discharges of warm water vapour may have a significant effect on the climate in the vicinity of the power station, depending on the topography, rainfall, and wind patterns. Under certain conditions there may be increased fog, cloud or rainfall. Microclimatic effects are mainly confined to large power schemes on high-temperature fields; exploitation of low-temperature geothermal systems does not cause significant microclimatic effects.

3.5 Landscape impacts

Land use
Power plants must be built on the site of geothermal reservoirs because long fluid transmission lines are expensive, and they result in losses of pressure and temperature. At the site, land is required for well pads, fluid pipelines, power station, cooling towers and electrical switchyard. The actual area of land covered by the total development can be significantly higher than the area required for these components. For example at Cerro Prieto field (Mexico) the area covered by the well pads (12 ha) is only 2% of the total area (540 ha) encompassing all the wells and the 180 MWe power station.

In many cases, the land between the well pads and pipes may continue to be used for other purposes, although at some sites the nature of the development may make this impracticable. For example, at Wairakei, where the development is located in a relatively narrow valley, there are a lot of individual pipelines, separation plants, steam discharges and surface hot water drains which effectively divide the land up into very small parcels. This precludes the land being used for anything else, although it is unlikely the land would have had another productive use. In contrast, the development at nearby Ohaaki (Broadlands) field, the design of the development has resulted in much larger parcels of land between the pipelines and the road system so the land will continue to be used. Areas previously used for stock and arable farming are now used mainly for sheep farming, and land which was mainly self sown pine scrub is worked as a productive forest.

The impact on land use depends on the type of development, and the original use of the land.

Visual intrusion
A geothermal plant must be located close to the resource, so there is often little flexibility in the siting of the plant. Geothermal plants generally have a low profile, and need not have a tall stack like coal and oil fired power plants. However, their visual impact may still be significant, as geothermal fields are often situated in areas of outstanding natural beauty. Any associated natural thermal features (e.g. geysers and hot pools) may be a tourist attraction or of historical and cultural significance. Visual impact may be particularly high during drilling due to the presence of tall drill rigs.

3.6 Catastrophic events

Like any large engineering development, catastrophic events may occur during the construction and operation of a large-scale geothermal power scheme.

Landslides
For schemes in areas of high relief and steep terrain, landslides are a potential hazard. Landslides may be triggered either:

a) Naturally, by heavy rain or earthquake; or
b) As a result of construction work, which may have removed the "toe" of the slide.

Such events are relatively rare but the result may be severe, such as for the landslide on 5 January 1991 in Zunil field (Guatemala), when 23 people were killed (Goff & Goff, 1997).

Hydrothermal eruptions

Although rare, hydrothermal eruptions (also called "hydrothermal" or "phreatic explosions") constitute a potential environmental hazard in high-temperature liquid-dominated geothermal fields (Bixley and Browne, 1988; Bromley & Mongillo, 1994). Eruptions occur when the steam pressure in near-surface aquifers exceeds the overlying lithostatic pressure and the overburden is then ejected, generally forming a crater 5-500 m in diameter and up to 500 m in depth (although most are less than 10 m deep).

A hydrothermal eruption occurred on 13 October 1990 in the Agua Shuca fumarole area of Ahuachapan field (El Salvador) which killed or injured people living nearby (Goff & Goff, 1997). At Wairakei field, hydrothermal eruptions began (or significantly increased) in the Karapiti thermal area after development of the field began. At least 15 eruptions have occurred here but fortunately nobody has been killed or injured.

4. SUMMARY

- Use of geothermal energy has low environmental impact, particularly when compared with fossil fuels.
- Most environmental impacts are associated with the exploitation of high-temperature systems, particularly in liquid-dominated fields (Table 3).
- Exploitation of low-temperature systems rarely has any significant environmental effects.

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LECTURE 2

EXAMPLES OF ENVIRONMENTAL CHANGES

No significant development of a high-temperature geothermal field has taken place without some environmental changes having occurred. Some well-documented examples are given here.

1. CHANGES AT WAIRAKEI GEOTHERMAL FIELD (NEW ZEALAND)

Wairakei field is situated in the central volcanic region of New Zealand. Exploration began in 1949, and the first exploration drillhole was drilled in 1950. Initial exploration holes were shallow (<300 m) but successfully encountered high temperatures which led to more and deeper holes being drilled. By December 1958, 69 prospecting holes had been drilled and test discharged. During this "Test discharge period", mass withdrawal increased to about 20 Mt/yr. The Wairakei power station (original installed capacity 192.6 MWe) was progressively commissioned from November 1958 to October 1964, during which time the annual mass withdrawal increased to 75 Mt/yr, after which it declined and has remained at about 45 Mt/yr since 1975 (Figure 3). The time since November 1958 is referred to as the "Production period".

Prior to development of the field, the reservoir was liquid-dominated with fluid generally at or near boiling point for depth and a thin 2-phase zone existed in the upper part. Over-lying the reservoir is a zone of cold groundwater, locally heated by fluids escaping upwards to supply natural thermal features at the surface.

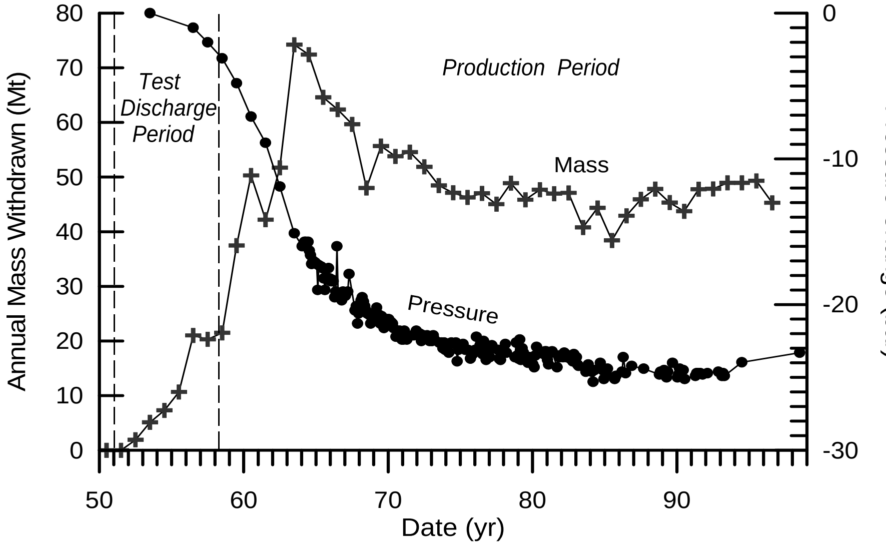


FIGURE 3: Mass withdrawal and pressure changes at Wairakei field, pressure is on average at -152 m a.s.l.; taken from Hunt & Glover (1996) and updated

Until the late 1990's, all the fluid withdrawn was discharged into the nearby Waikato River (99.95%) or into the atmosphere (0.05%), except for about 5 Mt reinjected during tests. Fluid withdrawn is 2-phase; on average about 80% (by weight) at the wellhead is liquid.

At the time of its planning and exploration, environmental concerns were regarded as relatively unimportant and no serious environmental problems were foreseen. However, during the late stages of construction some environmental issues arose, but by that time there had been a large capital expenditure, a large labour force was working, and the reasons for the environmental changes were equivocal so development proceeded. In later years the environmental effects and their causes have become clearer.

1.1 Pressure changes

Withdrawal during the test discharge period resulted in deep-liquid pressures decreasing by about 3 bar

(0.3 MPa). However, this value must be treated with caution because some of the data were not obtained by direct down-hole measurements but calculated from well head pressures in wells standing shut and full of water. During the early stages of production (1960's), large pressure decreases extended across most of the field leading to the expansion (both vertical and horizontal) of the 2-phase zone, followed by the formation of a vapour-dominated region in the upper part of this zone. By the mid-1970's deep-liquid pressures had settled at about 25 bar (2.5 MPa) below pre-production values (Figure 3).

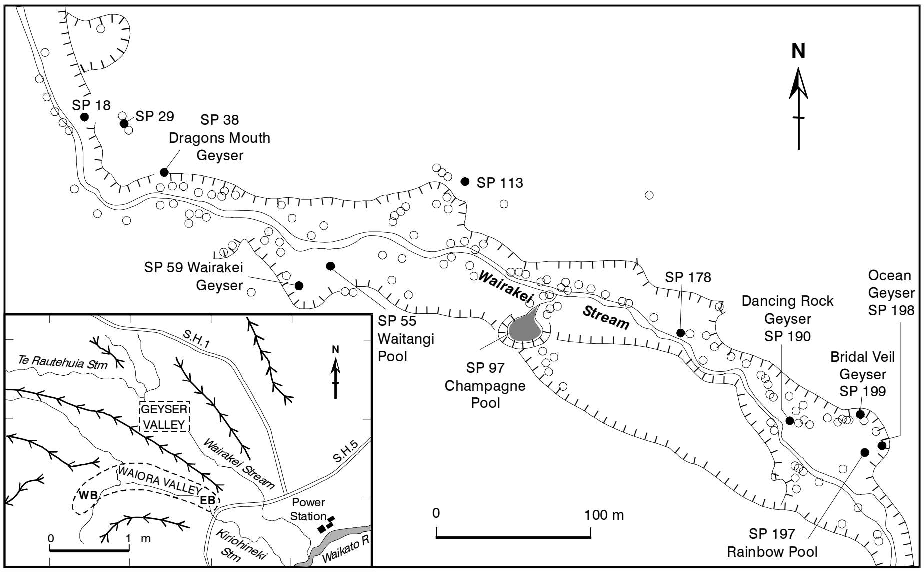


FIGURE 4: Location of thermal features in Geyser Valley, Wairakei; inset map shows the location of Geyser Valley relative to Eastern (EB) and Western (WB) borefields

1.2 Changes to natural thermal features

Prior to development, Wairakei was a major tourist attraction noted for a wide variety of natural thermal features which included geysers, fumaroles, hot springs, hot pools, and sinter slopes. Most of these features were located in two adjacent valleys: Geyser Valley (Wairakei Stream) and Waiora Valley (Kiriohinekei Stream) (Figure 4). Exploratory drilling began in the Waiora Valley, and it was here that most production wells were located; no wells have been drilled in the Geyser Valley.

Regular observations and measurements (flow rate, chloride content and temperature) of selected thermal features did not begin until November 1952, *after* exploratory drilling and well discharges had begun. Initially, the effects of mass withdrawal on the natural features were small and isolated, and were thought at that time to be caused by natural climatic variations. This was, in part, because the data showed that although some features changed during the testing period, others did not show any change. Following the large increase in mass withdrawal after commissioning, most features in Geyser Valley died and those that did not were severely reduced. This rapid decline of the thermal features came as a surprise to many people.

Measurements made during the test discharge period and early part of the production period show that the main changes to the natural thermal features before their death were the following.

Decrease in flow rate from hot springs and pools
Measurements show that there were large decreases in the flow rate from many hot springs and pools in Geyser Valley during the test discharge period. Examples are shown in Figure 5. At Waitangi Pool (SP55) in Nov. 1953 the outflow rate was about 1.2 l/s, which decreased to about 0.2 l/s in late 1957. Another example is Spring 29, in Nov. 1952 this discharged periodically, but in October 1953 the periodicity ceased, and the rate of discharge steadily declined until April 1954 when the discharge ceased. The water level then decreased until it was 1.5 m below the edge, at which point measurements could no longer be made (Figure 5). These changes occurred as a result of pressure drop of less than 3 bar (0.3 MPa) in the

reservoir.

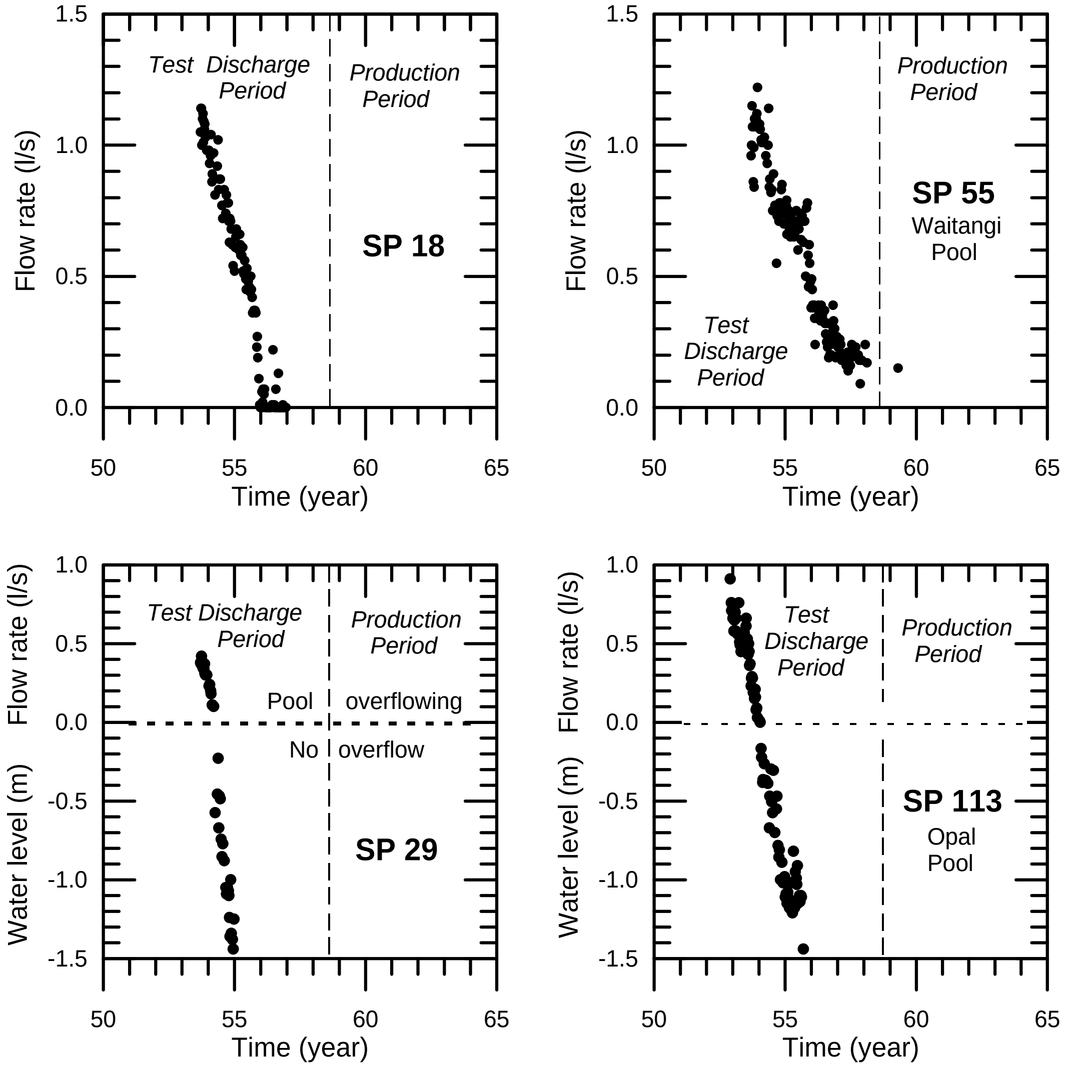


FIGURE 5: Examples of changes with time in overflow rate and water level for thermal features at Wairakei geothermal field resulting from development; note the rapid and linear declines in flow rate. Taken from Glover & Hunt (1996)

Decrease in chloride content of springs

Prior to exploitation, fluids in the upper part of the Wairakei reservoir had a chloride content of about 1680 ppm (265°C, enthalpy 1160 kJ/kg; Brown et al., 1988) which, after adiabatic steam loss, would have a content of about 2506 ppm (99°C) at the surface. Most fluids emerging from natural features at Wairakei had a chloride content of about 1600-1700 ppm, indicating some dilution by warm (150°C) near-surface groundwater containing about 300 ppm chloride (Brown et al., 1988).

Many springs in Geyser Valley showed rapid decreases in chloride content during the test discharge period and early part of the production period (Figure 6). The largest (measured) decreases in the test discharge period were at Springs 18 and 38 (Dragon's Mouth Geyser), where the chloride content declined from about 1800 ppm in 1951 to about 700 ppm in 1957 (Figure 6); i.e. a decrease of more than 50%. In general, the highest (topographically) springs showed the earliest change. Springs which were at lower elevations, and had larger flow rates, had the smallest change during the test discharge period. For example, in Waitangi Pool (Spring 55) the chloride decreased by only about 20% during the test discharge period (Figure 6), but during the early 1960s the chloride content decreased from about 1500 ppm to about 500 ppm in 3 years.

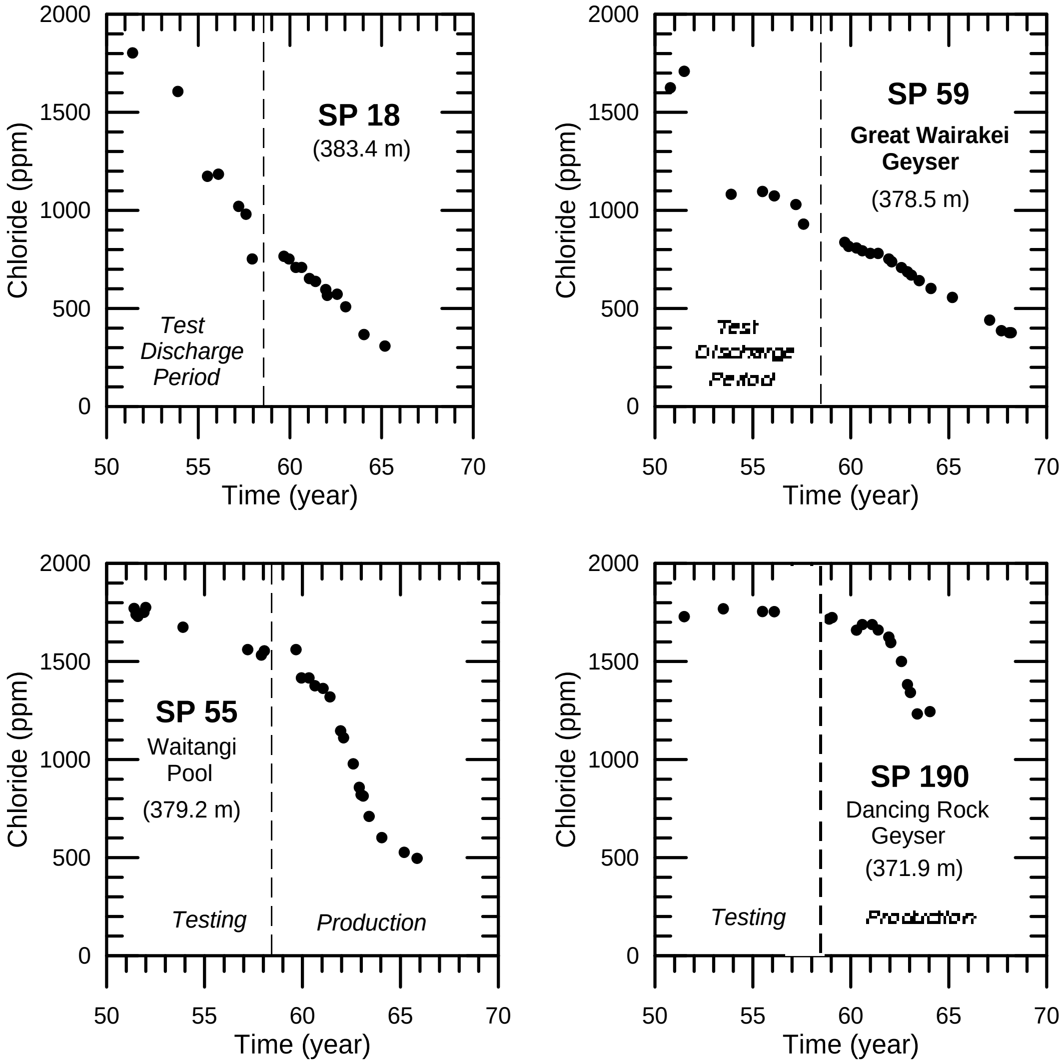


FIGURE 6: Changes with time in chloride content of water in thermal features at Wairakei geothermal field, as a result of development; taken from Glover & Hunt (1996)

Increase in eruption period of geysers

Little quantitative data are available about the decline of the geysers at Wairakei. It is known that the eruption period (time between start of successive eruptions) of two geysers increased during the Test discharge period, before geysering ceased. The eruption period of Bridal Veil Geyser (Spring 199) increased from about 38 min. in Nov. 1952, to about 55 min. in Dec. 1953, to about 65 min. in Dec. 1954 (Figure 7). Another example is the Great Wairakei Geyser (Spring 59): during the test discharge period the eruption period increased from about 12 to more than 30 hrs, before the feature stopped geysering in 1954 (Figure 7). Comparison of the eruption period data with rainfall measurements (Figure 7) shows that the increases in period were not caused by a decrease in rainfall. Similarly, the reductions in flow rate from springs could not have been caused by changes in rainfall.

Decrease in temperature of springs and pools

Some hot springs and pools at Wairakei showed outflow temperature declines of up to 30°C during the Test discharge period: these included SP18 and SP178 (Figure 8). However, the temperatures of some other features in Geyser Valley showed little change: these included Rainbow Pool (SP197) and Ocean Geyser (SP198) (Figure 8). These features maintained temperatures near boiling, while flow rates decreased significantly, because the upflowing geothermal fluids were diluted by warm (>100°C) groundwater.

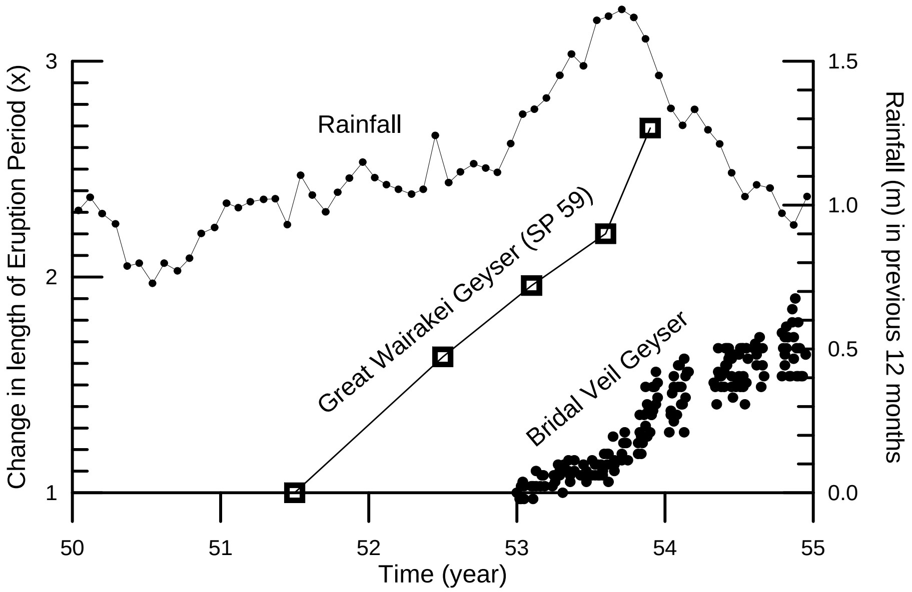


FIGURE 7: Changes in length of eruption period (T/T_0) of geysers in Geyser Valley at Wairakei during the test discharge period; periods are normalised to T_0 = 12.5 hours for Great Wairakei Geyser, and 39 min for Bridal Veil. Rainfall data are monthly running totals of rainfall in previous 12 months. Note the steady increase in length of eruption period with time

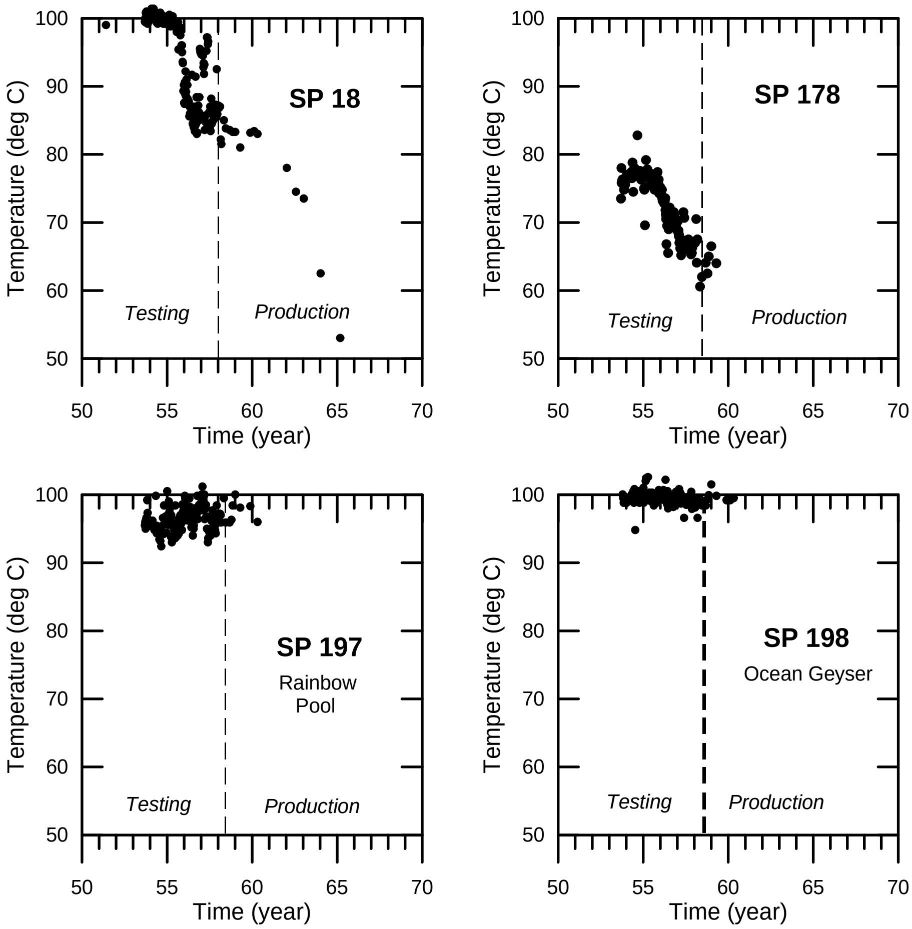


FIGURE 8: Changes with time in temperature of water in thermal features at Wairakei geothermal field, as a result of development; note the different behaviours – the temperature in some features remained near-constant, while in others it fell; taken from Glover & Hunt (1996)

1.3 Groundwater level changes

A cold groundwater zone overlies the reservoir, and extends from near the surface (5-30 m) to several hundred metres depth. The zone consists of several aquifers (some perched) in which water may be flowing laterally in response to topographic relief or geological control.

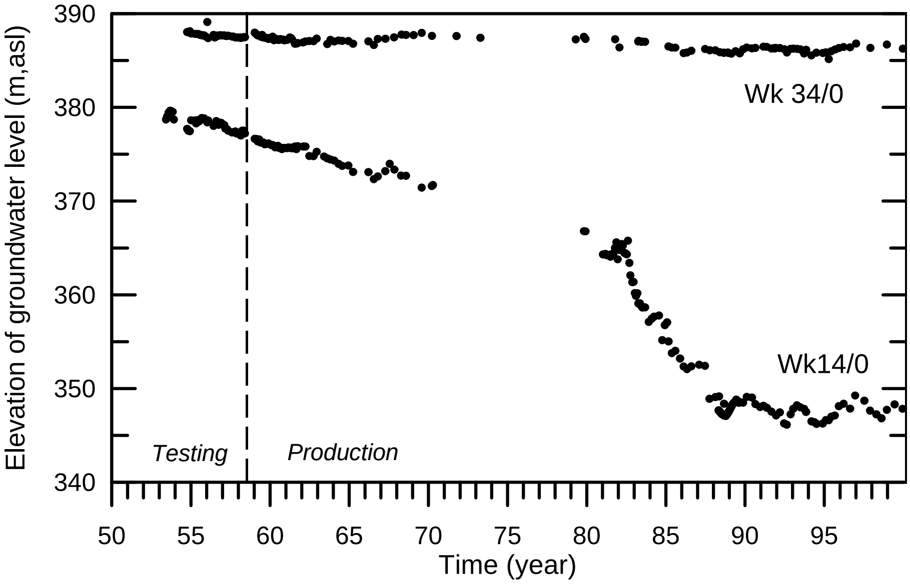


FIGURE 9: Examples of changes in shallow groundwater level in monitor holes at Wairakei

Groundwater levels have been monitored in shallow (20-50 m depth) holes since 1953. In most places the water level has varied by about ±1 m in response to seasonal variations in rainfall (for example 34/0, Figure 9). However, in monitor holes in an area adjacent to the Western borefield the levels have fallen significantly. These holes are situated near a region of cold water invasion, and it is believed that a large part of the cold downflow consists of water from the groundwater zone. The largest and best-documented change has been at hole 14/0, where the level is now about 30 m below that in 1953 (Figure 9). In the late 1970's it was realised that a significant part of the downflow was associated with vertical flows in non-producing wells that had damaged or broken casing. These breaks were sealed off, reducing the downflow from about 200 to about 100 kg/s.

1.4 Groundwater temperature changes

The temperature of water in the groundwater monitor holes (at or near the groundwater surface) has been measured since the mid-1950's, but not as frequently as the levels. Temperature measurements are less reliable and more variable than level measurements because of difficulties inherent in measuring temperature, water level changes and steam heating effects, as well as short-term climatic effects.

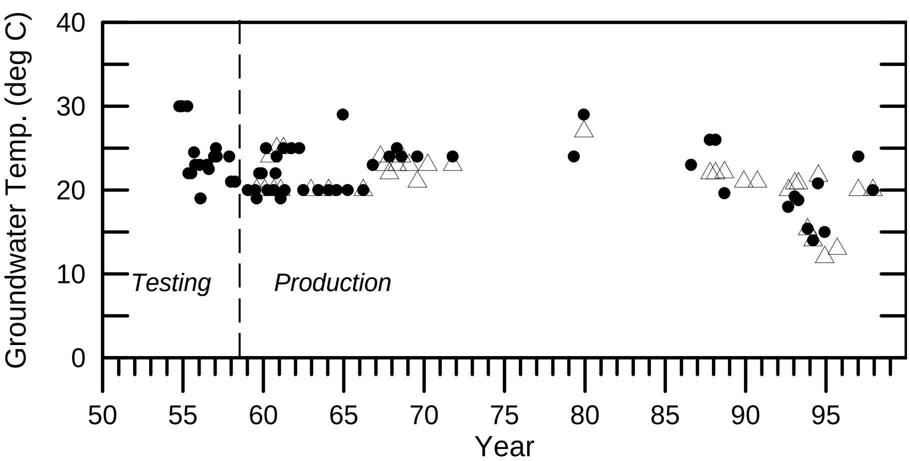


FIGURE 10: Plot of groundwater temperatures in monitor holes outside the production area at Wairakei; note the lack of any significant changes

In monitor holes away from natural thermal features and outside production areas, the groundwater temperature has remained cold (Figure 10).

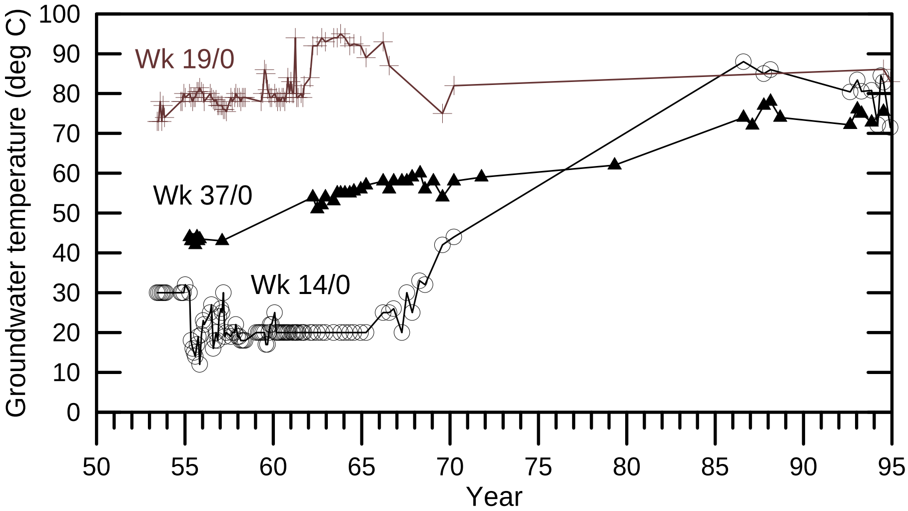


FIGURE 11: Plot of groundwater temperatures in monitor holes in part of the production area at Wairakei; note the increase in temperature in some holes

Before production started, groundwater temperatures in the main part of the Eastern borefield varied from ambient to about 75°C (Figure 11). After production began, the temperatures in wells near the centre of groundwater decline rose by up to 60°C (Wk 14/0; Figure 11) due to steam heating and groundwater level decline. In wells further away from the centre of decline (e.g. Wk 37/0), the temperature rise was correspondingly less. Since the 1980's, groundwater temperatures here have remained constant at around 70-80°C.

1.5 Changes in surface heat flow

At Wairakei, there have been large but localised changes in surface heat flow associated with exploitation (Allis, 1981). Changes, both increases and decreases, occurred during the test discharge and production periods. In Geyser Valley the heat flow reaching the Wairakei Stream from springs and geysers decreased steadily from 52 MWt in 1952 to 30 MWt in 1958, and to 5 MWt in 1966 when measurements ceased; this decrease reflecting the decline of the natural thermal features. In the Karapiti thermal area, an outbreak of fumarolic activity and hydrothermal eruptions began in 1954, and the heat flow increased from 40 (1950) to 90 MWt (1958). Measurements at Karapiti showed that after production began the heat flow there increased rapidly to a peak of 420 MWt (1964) then declined to about 220 MWt (1979-88) (Figure 12). This increase resulted in an expansion of the area of thermal ground, which caused trees and other temperature-sensitive vegetation to die. However, it also allowed some rare species of thermophilic vegetation (mosses, shrubs) to capitalise on the expansion of thermal area. Hydrothermal eruptions from craters of up to 25 m diameter occur spasmodically every 1-2 years (Figure12), and fumarolic activity continues. The centres of thermal activity appear to migrate randomly. The area is now a major tourist attraction, but the thermal features are insignificant compared with that of Geyser Valley before production began.

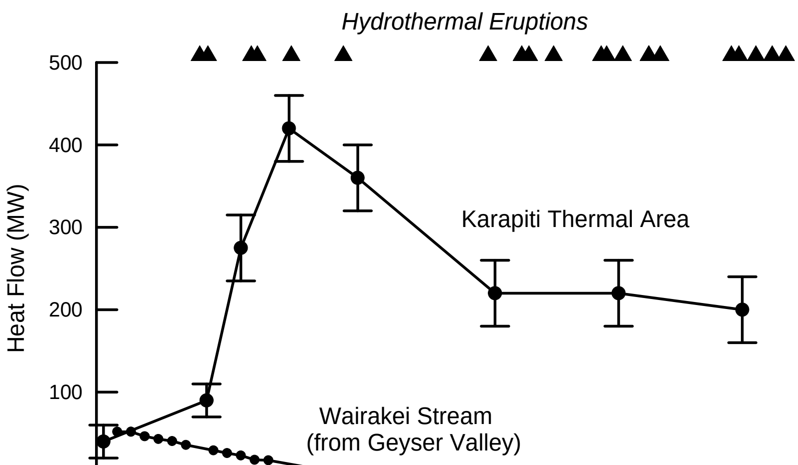


FIGURE 12: Changes in heat flow from the major thermal areas of Wairakei field; taken from Hunt et al. (1998)

1.6 Ground movements

Ground movements have occurred at Wairakei as a result of mass withdrawal. Vertical movements, in the form of subsidence, have been the largest and are amongst the greatest induced subsidences in the world.

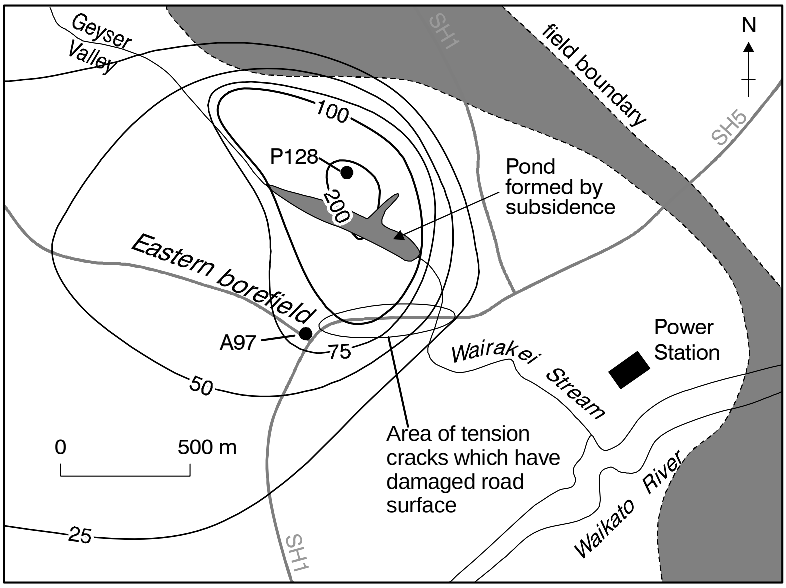


FIGURE 13: Subsidence rates in the main subsidence bowl at Wairakei, rates are in mm/yr for the 1990's; note that the maximum subsidence does not coincide with the borefield. Taken from Allis (2000)

Vertical movements
At Wairakei, subsidence was first detected in 1956, and led to the installation and regular relevelling (to 2nd order standard) of a network of benchmarks. The relevelling data have shown that subsidence has occurred over most of the production field but is greatest in the eastern part of the field where it is centred about 500 m northeast of the Eastern borefield (Figure 13). The subsidence rate in the centre reached about 480 mm/yr in the 1970's but has since declined to about 215 mm/yr, and the total subsidence there now exceeds 15 m (Allis, 2000). The longest record is for benchmark A97, situated in the Eastern borefield, where subsidence is now about 4 m. The data (Figure 14) shows that subsidence began during the test discharge period, but did not exceed 25 mm/yr until after commissioning when it rapidly increased to about 145 mm/yr. Although the pressure decline stabilised in the mid-1970s, the subsidence rate did not start to show a reduction until the late 1970's. The maximum subsidence in the main subsidence bowl is predicted to increase to about 20 m by the year 2050 (Allis & Zhan, 2000)

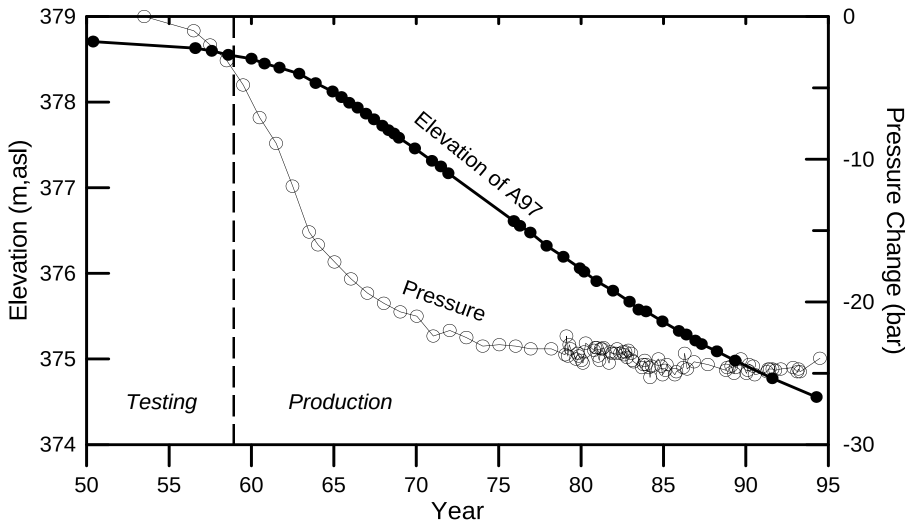


FIGURE 14: Change in elevation (subsidence) of benchmark A97 compared with deep liquid pressure changes at Wairakei, note that the subsidence has continued despite stabilisation of pressure since late 1970's. Data from Hunt & Glover (1996)

The principal environmental effect of the subsidence has been a change to the profile of the bed of the Wairakei Stream as a result of differential subsidence: once a fast flowing narrow stream, it now has a pond in the area of maximum subsidence. This pond is up to 6 m in depth, and the bottom is filling with silt. Trees that have been flooded have died; but the pond has become a popular habitat for water birds. The subsidence has caused casing damage in wells closest to the main subsidence area: compressed joints and breaks occur at 140-270 metres depth, which defines the vertical section of compaction (Bixley and

Hattersley, 1983). There has been no casing protrusion because the wells are adequately cemented near the surface, and so the compression is manifested at depth by casing deformation.

Horizontal movements
At Wairakei, horizontal ground movements were first suspected in 1964, and this was confirmed early in 1965 by measurements along the main steam lines. Subsequent measurements have shown horizontal movements of more than 100 mm/yr and tilting rates of more than 1 microradian/yr (Allis, 1990).

Data suggest that in the area of greatest subsidence there is a zone of compressional strain (buckling of pipes) which is surrounded by an annulus of tensional strain (ground surface cracking). Fissures have opened up in some of the surrounding fields, but are soon filled with soil carried in by heavy rainfall. Tensional cracking has damaged the surface along a 500 m section of nearby state highway 1 (Figure 13), necessitating rebuilding and resurfacing. The horizontal strains have also necessitated mounting pipelines on sliding foundations and insertion and removal of sections of pipelines in the Eastern borefield.

2. CHANGES AT OHAAKI GEOTHERMAL FIELD (NEW ZEALAND).

2.1 Development history

At Ohaaki, drilling began in 1965, and in the following 6 years 25 deep wells were drilled. From the middle of 1967 until the start of 1972, test discharges were conducted during which time the annual mass withdrawal increased to about 10 Mt/yr (Figure 15). During this "Test discharge period" all the fluid withdrawn was discharged into the Waikato River or the atmosphere; there was no reinjection. In the following 16 years, a further 18 holes were drilled but no extensive testing was done; the average mass discharge was only 1.5 Mt/yr and did not exceed 3.5 Mt/yr. This time is known as the "Recovery period". Commissioning of the Ohaaki power station (116 MWe installed capacity) began in August 1988 and was completed in November 1989. Mass withdrawal rose to 16.2 Mt in 1990, and has remained at similar values since then (Figure 15). Since commissioning, most of the waste fluid has been reinjected (mainly around the periphery of the production areas) and net mass loss has been about 6 Mt/yr.

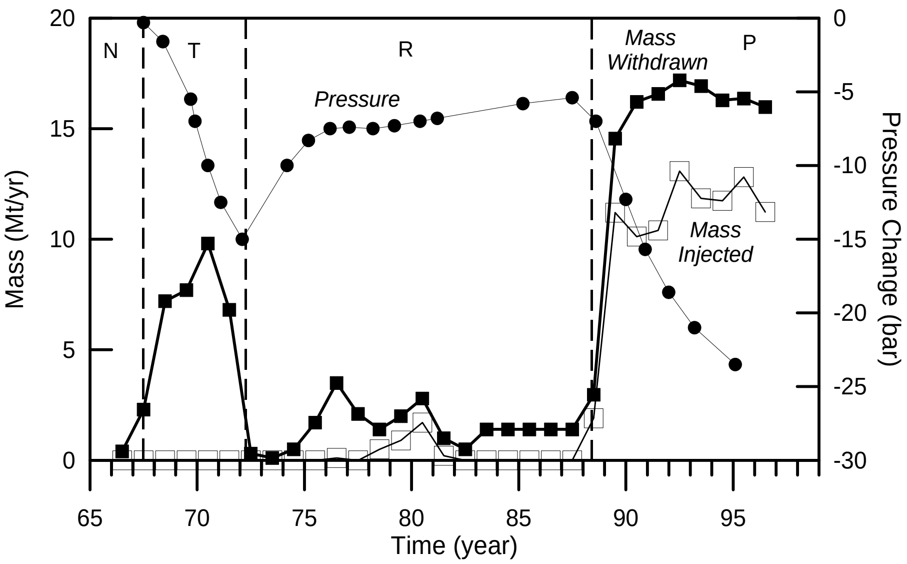


FIGURE 15: Variation of mass withdrawal (solid squares), reinjection (open squares), and deep liquid pressure (solid dots) with time at Ohaaki geothermal field. N = Natural state, T = Test discharge period, R = Recovery period, and P = Production period; taken from Glover et al. (2000)

Prior to development of the field, the reservoir was liquid-dominated with fluid generally at or near boiling point for depth, similar to Wairakei.

2.2 Pressure changes

At Ohaaki, deep-liquid pressures decreased by about 15 bar (1.5 MPa) during the test discharge period, but recovered by about 10 bar (1 MPa) in the recovery period before decreasing again after production began (Figure 15). Considering the test periods at each field, the pressure changes at Ohaaki were much greater (15 bar) than at Wairakei (3 bar), despite the mass withdrawal rates at Ohaaki being smaller than at Wairakei (10, 20 Mt/yr, respectively).

2.3 Changes to natural thermal features

Information obtained from Wairakei during the 1960's and 1970's led to a better understanding of the relationship between surface features and the geothermal reservoir. It was recognised that the thermal features were fed by fluids escaping from the upper part of the reservoir, along faults or fissures. During the planning stages of the Ohaaki Power Scheme, it was acknowledged that environmental effects might occur, but an Environmental Impact Report was not prepared until 1977, *after* the test discharge period. In this report the effects of chemical and gas discharges, noise, and thermal pollution on the climate, natural waterways, flora and fauna, were assessed and steps proposed to mitigate the effects. However, the possible effects of exploitation on natural thermal features were not mentioned in the Impact Report, despite the fall in water level in the Ohaaki Pool during the test discharge period and the changes that were known to have occurred at Wairakei.

Prior to exploitation the Ohaaki Field had few natural thermal features (cf. Wairakei); the largest and most significant feature being the Ohaaki Pool, a boiling pool with a surface area of about 850 m^2. This pool has cultural significance for the local Maori people, and is noted for its beautiful fretted sinter lip and surrounding sinter apron.

Changes in flow rate and water level from Ohaaki Pool

The presence of an extensive sinter apron around the pool indicates that it has overflowed for a long time. Measurements made in a shallow canal from the pool, prior to the test discharge period suggest that normally the flow rate was about 9 l/s. However, it is known that sudden changes in flow rate and water level had occurred in past times. For example, on 25 March 1957 the pool suddenly ceased to overflow, and by 2 April 1957 the water level was about 0.73 m below the overflow channel. On 18 April 1957, the pool was reported to be overflowing again. When visited on 24 April, not only was the discharge flowing down the canal, but water was also spilling over the lip all round and flowing away across the sinter terrace. The total flow rate was estimated to be at least 23 l/s. At this time there was also increased activity (including geysering) in other nearby springs. The increased flow slowly declined, but by 5 June 1957 was still greater than normal. It was considered that the unusual recession was due to mechanical causes; probably the feeding channels becoming blocked by earth movements, and later clearing themselves as pressure increased below the blockage.

Measurements have shown that the overflow rate and water level in the Ohaaki Pool were strongly influenced by the operation of nearby bores (Figure 16). During the test discharge period, when nearby bores were discharged the flow rate decreased until overflow ceased, and then the water level receded. When discharge decreased and was temporarily stopped in 1968, the water level rose, the pool began to overflow, and the flow rate increased to about 8 l/s. Soon after the discharges recommenced, the flow rate stopped increasing for a short period then again decreased rapidly until the pool ceased to overflow. The water level then fell, reaching a level of 1.8 m below the channel on 14 February 1969. About this time it was noticed that some parts of the overhanging edge had collapsed, possibly due to loss of buoyancy support by the water and/or thermally-induced fracturing associated with exposure to the air. No further water level data were collected until 1 October 1971, when the water level was 9.5 m below overflow (Figure 17). During the remainder of 1971 the water level rose reaching a (temporary) maximum of 4.5 m in July 1972, before again declining to 6.4 m in April 1973. There was another gap in the data from then until May 1974 when the water level was at 5.7 m, after which time the level quickly rose to 3.1 m by November 1974, and then more slowly until the middle of 1976 (Figure 17). There was little discharge from nearby bores during this period and the reason for the temporary drop in level between July 1972 and November 1974 is not known. During the remainder of the recovery period a number of discharge and interference tests were conducted which resulted in perturbations (up to 4 m) to the water level in the pool. The data suggest that, except for these perturbations, the water level generally rose and the pool began intermittently overflowing in October 1981 due to injection of separated water from a nearby bore. From then until August 1988 (start of the production period) the pool overflowed intermittently at rates of up to 2 l/s. During the production period, the water level in the pool has generally been sufficient to result in overflow.

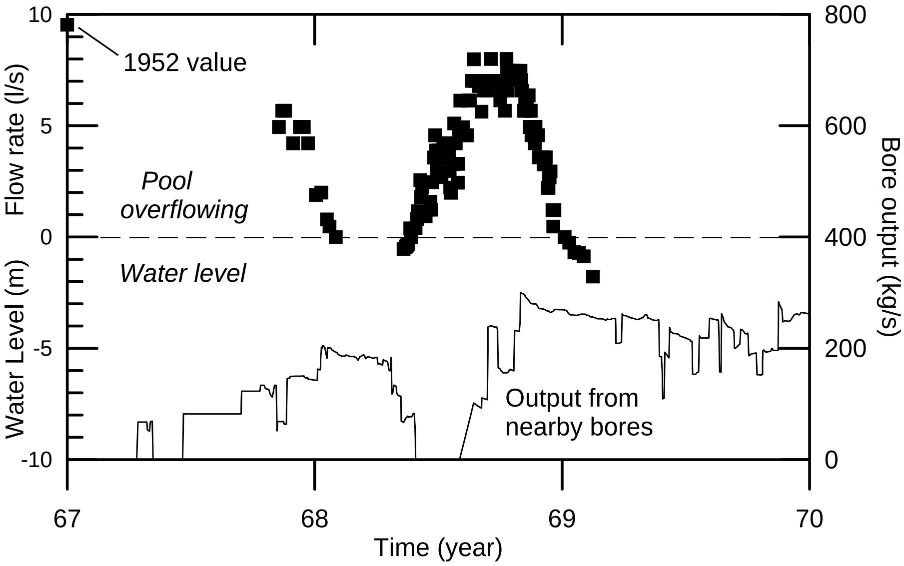


FIGURE 16: Plot showing variation of flow rate and water level in Ohaaki Pool during the early part of the test discharge period at Ohaaki field; note the rapid response of flow rate to changes in output from nearby bores being test discharged. Taken from Glover et al. (2000)

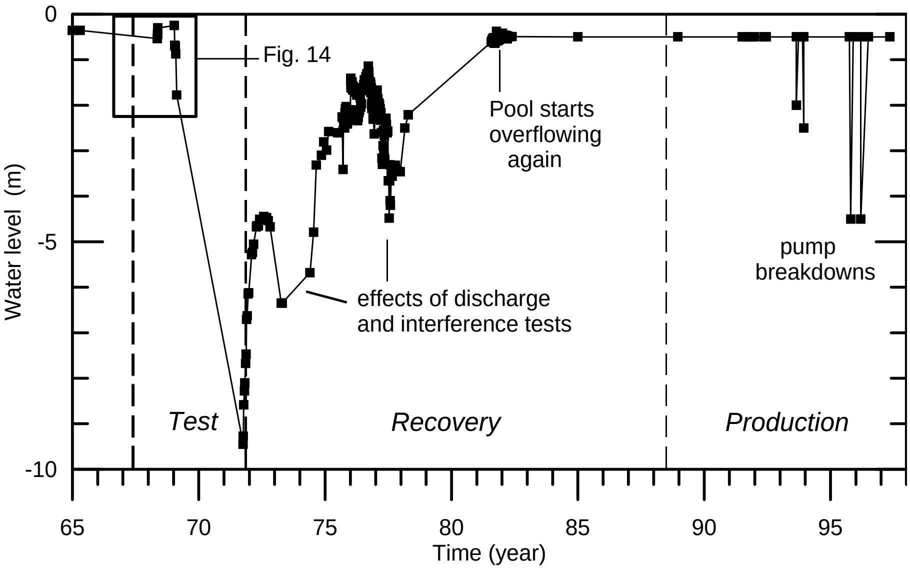


FIGURE 17: Plot showing variation of water level in Ohaaki Pool with time; note the rapid recovery of water level after end of the test discharge period. Taken from Glover et al. (2000)

Changes in temperature of Ohaaki Pool

Temperature data are not as detailed as for flow and water level, but show that the temperature of water in the Ohaaki Pool was also influenced by operation of nearby bores. Measurements made prior to well testing (Figure 18) suggest that the water was not always boiling, but surface temperatures were in excess of 85°C. During the initial part of the test discharge period, temperatures decreased to about 65-75°C, but may have recovered in the later part. In the recovery period, temperatures were generally greater than 90°C except when discharges were made from bores in the Western steamfield at which time they decreased to about 75°C.

No measurements were made during the early part of the production period (1989-1992), but the temperature had decreased to about 30-50°C by mid 1992. The temperatures now vary, depending on the amount of bore fluid being injected into the pool.

Changes in chemistry of Ohaaki Pool

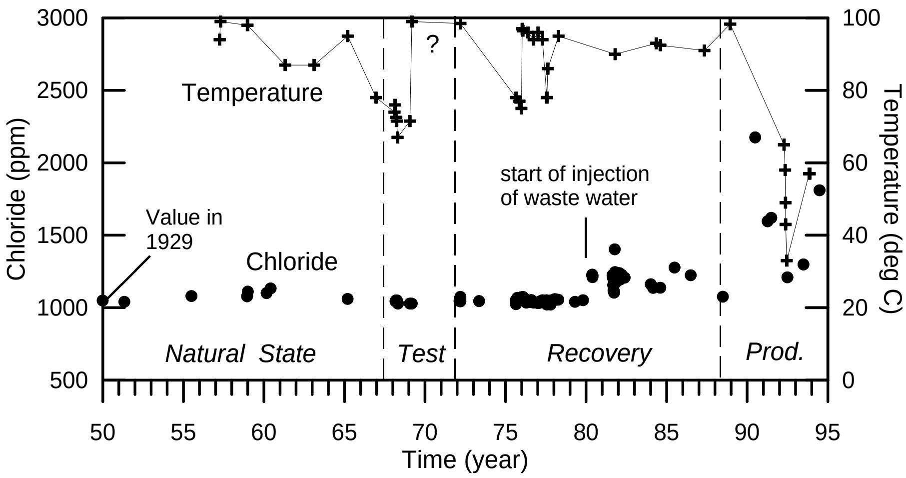


FIGURE 18. Changes in temperature and chloride concentration in Ohaaki Pool; note the lack of change in chloride concentration until after injection of waste water began. Taken from Glover et al. (2000)

The earliest recorded chloride concentration, 1049 mg/kg, was measured in 1929 but no further measurements were made until May 1951. After that date, measurements were made more frequently and show that there were no significant changes in chloride concentration when the pool was in its natural state, during the test discharge period, and early part of the recovery period. The water in the pool was a mixture of a deep parent fluid which had undergone boiling and dilution with a steam-heated (140°C) water. The calcium and magnesium concentrations were 5 and 10 times higher in the pool water than in the deep drillhole waters; this supports the inference that a shallower cooler component had mixed with the deep parent fluid.

Some time between October 1979 and May 1980, the chloride concentration increased by about 150 mg/kg; the increase was probably due to the discharge of bore fluid into the pool. The large variations in chloride, over short periods between May 1980 and May 1987, are likely to have been caused by changes in the amounts of bore water entering the pool.

All samples collected during the test discharge and early part of the recovery periods were taken when the pool had no visible outflow; i.e. no overflow. The fact that evaporation from the surface did not cause increased concentration suggests that subsurface outflow was occurring. Hochstein and Henrys (1988) calculated mass flows for a time when the pool had no visible surface outflow; they obtained an evaporative steam flow of 6.7 kg/s and a subsurface outflow of 30-41 kg/s, i.e. a total mass flow of 37-48 kg/s.

In 1988, a water right was obtained to inject up to 300 t/h (83 kg/s) into the pool to provide overflow. After that time, large-scale discharge of bore water was made into the pool. The average chloride concentration in the pool water increased to 1390 ppm due to the high chloride concentrations in bore water (1620 ppm, at atmospheric pressure). There were also large changes in the chloride concentration during this period as a result of the large variations in inflow, and varied conditions in the permeability of the base of the pool. The low value of 1075 ppm probably indicates no inflow of bore water, and the high of 2175 ppm was probably due to evaporation at a time when leakage and overflow was minimal.

Changes to other thermal features

Before development began, more than 20 thermal features of lesser significance were present at Ohaaki (Figure 19). These included: boiling mud pools (up to 12×6 m), warm pools (up to 80×40 m), and thermal ground.

The surveys showed that in the north-eastern part of the field many of the warm pools and mud pools had dried up and become weakly steaming from vents in the base, and for the remainder there were temperature decreases of up to 38°C. Some patches of thermal ground decreased in area, but others were unaffected (especially in the south-eastern part of the field).

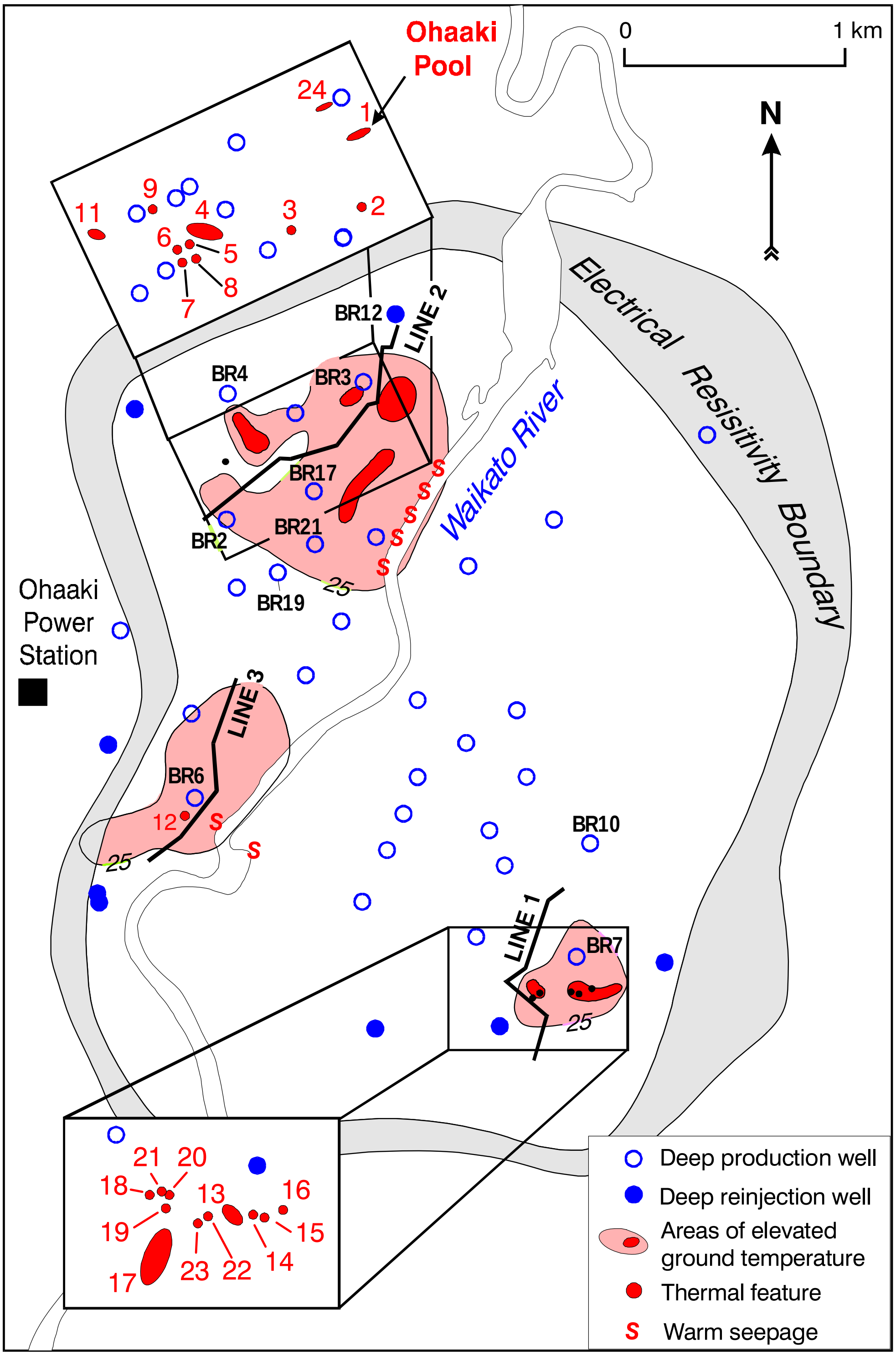


FIGURE 19: Map of Ohaaki geothermal field showing location of thermal features and ground temperature survey lines; taken from Hunt & Bromley (2000)

2.4 Ground movements

Pressure drawdown in the reservoir during the test discharge period and since production began has led to compaction within a rock unit above the reservoir, resulting in deformation of the ground surface over a kidney-shaped area in the north-western part of the field (Clotworthy et al., 1995; Allis et al., 1997) (Figure 20). The deformation is associated with draining of fluid from a compressible lacustrine mudstone unit of limited areal extent, but up to 250m thick.

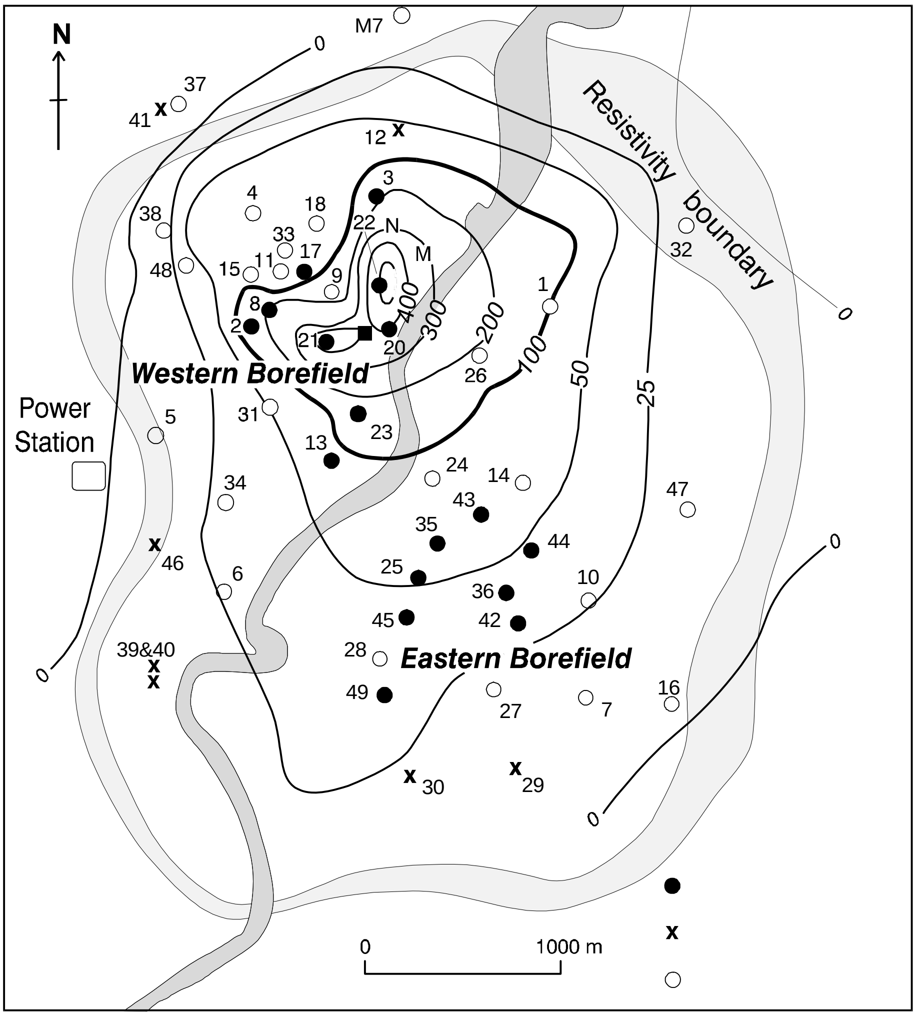


FIGURE 20: Map of Ohaaki geothermal field showing ground subsidence rates during the production period; numbers indicate well numbers; rates are for the period 1993-95. Note the kidney shape of area of greatest subsidence rate. Taken from Allis et al. (1997)

Subsidence monitoring shows that during the test discharge period the centre of the area subsided by 0.15-0.20 m. There was little subsidence during the recovery period, but it restarted at the beginning of the production period and by January 1995 had exceeded 1.2 m (Figure 21). The subsidence has resulted in tilting which has caused water in the Ohaaki Pool (when full) to overflow from the south-western part of the pool in addition to the drainage channel.

Compressional strain has occurred near the Ohaaki Pool at the rate of up to 100 mm/yr, and has been manifested in the form of buckling of the sinter apron south of the pool. Here, the sinter has been upthrust about 20 cm along several $\wedge$-shaped, sub-parallel ridges extending for up to 100 m. These ridges were first noticed in 1994. It is possible that the compressional strain has fractured the base of the Ohaaki Pool, allowing fluid to drain away. Compressional strain has also caused buckling of some steam pipelines, necessitating removal of sections. Tensional strain has occurred around the edges of the subsidence area, resulting in cracks up to 2 cm wide at the ground surface.

Numerical modelling suggests that the subsidence is likely to last for several decades, and that it is non-recoverable, even if reservoir pressures were returned to their pre-development values (Allis et al., 1997).

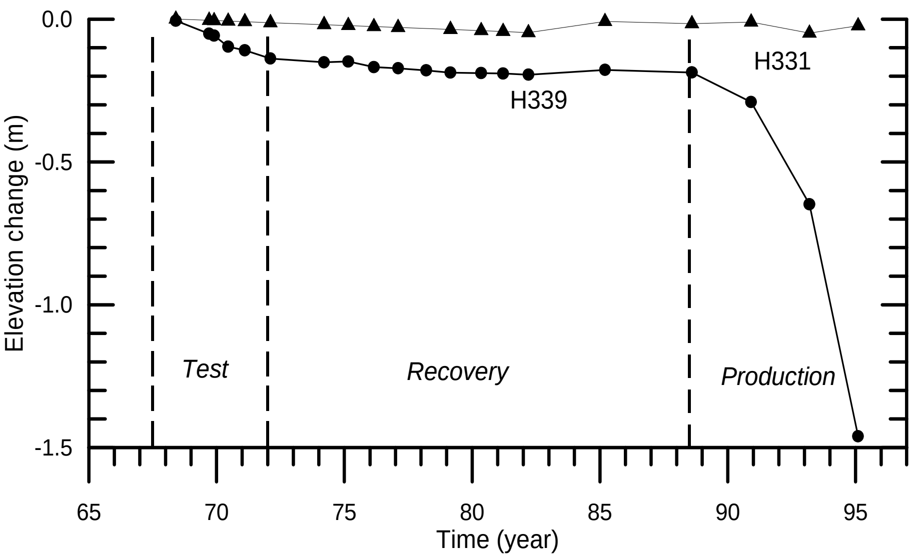


FIGURE 21: Elevation changes at selected benchmarks in Ohaaki field, benchmark H331 (triangles) lies outside the field, and H339 (solid dots) is near the centre of the subsidence bowl. Note that subsidence stopped soon after end of test discharge period, and recommenced shortly after start of the production period. Taken from Glover et al. (2000)

2.5 Ground temperature change

Shallow (1 m deep) ground temperature measurements made in 1967 (prior to test discharge period), showed that temperatures exceeding 10°C above ambient occurred over most of the north-western part of the field. Additional measurements made in 1983 (recovery period) indicated the approximate area and location of the thermal anomalies was similar to that in 1967. In Dec. 1988, during the commissioning of the power station, a set of 1 m ground temperature monitoring points was established at 25 m intervals along 3 lines across the thermal anomalies (Figure 19). The measurements were repeated in April 1996, and the data corrected for seasonal temperature changes.

Comparison of data from the 1988 and 1996 surveys (Hunt & Bromley, 2000) shows that there were no significant temperature differences on Line 1 through the south-eastern thermal anomaly (Figure 22). On Line 2, there were temperature *decreases* (10-45°C) over distances of about 200 m; at these places the ground temperatures in 1988 had been 40-70°C above ambient. There was an *increase* of up to 75°C near BR17; and there ground temperatures are now in excess of 90°C. However, additional measurements suggest these high temperatures are very localised. The area near BR17 lies in a zone of tensional strain associated with ground subsidence and there are numerous cracks in the ground surface. It is probable that the high ground temperatures measured are associated with localised heating of the ground by steam rising through these cracks. Evidence for this is that, on cold mornings during the 1996 survey, steam could be seen rising from the cracks, and grass on the edges of the cracks was observed to be dying. On Line 3, there have been no significant changes, except at three points (Figure 22) where ground temperatures have *decreased* by 10-20°C (from 44-48 in 1988, to 27-36°C in 1996).

Repeat TIR imagery has also shown the development of numerous narrow, linear thermal anomalies in the north-eastern part of the field, particularly in the vicinity of BR 9. These anomalies are coincident with the tension cracks associated with ground subsidence.

The data indicate that over most of the field, shallow (1 m depth) ground temperatures have not changed since production began in 1988.

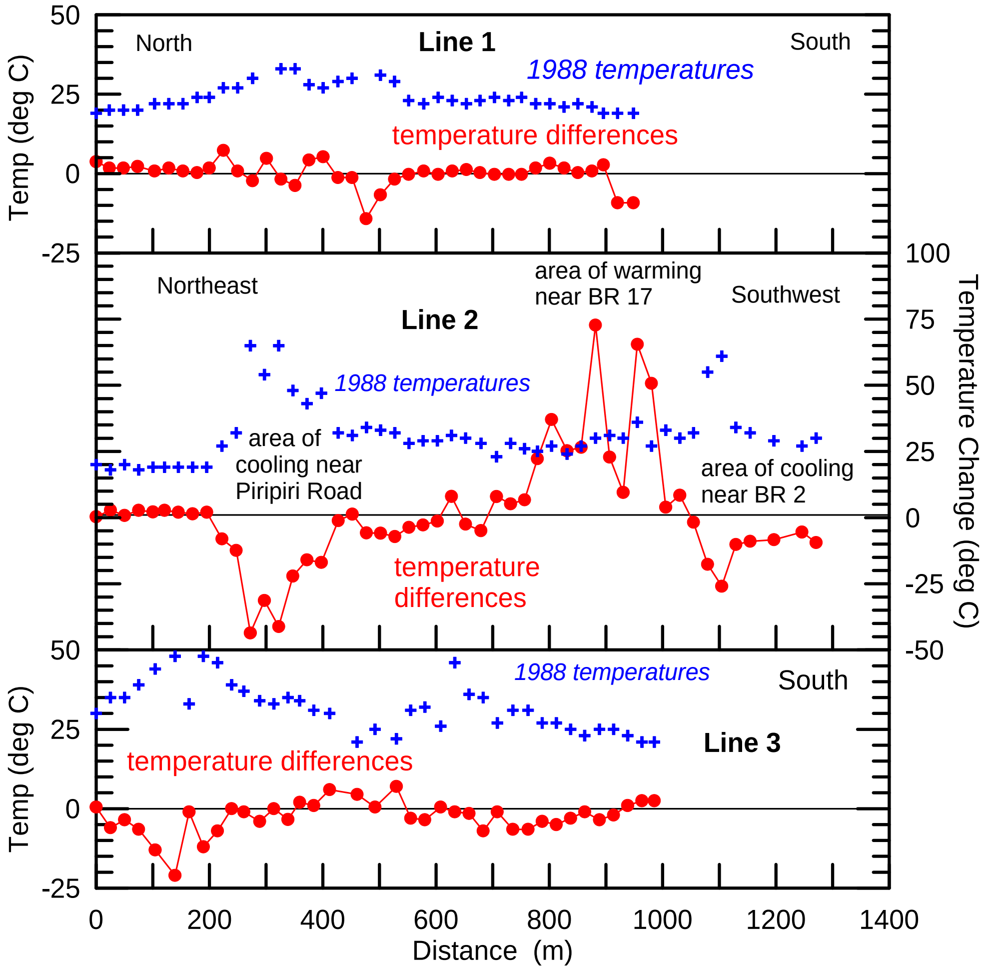


FIGURE 22: Changes in shallow ground temperatures at Ohaaki field, temperature differences are for the period 1988-1996, and cover the first 8 years of the production period. The differences have been adjusted for seasonal differences; location of the survey lines are shown in Figure 19. Taken from Hunt & Bromley (2000)

2.6 Groundwater level changes

Groundwater levels have been monitored regularly since 1967; at present there are 35 shallow (<50 m deep) and 10 deep (250 m) monitor wells. The data indicate that groundwater levels have generally been unaffected by discharge testing or production. However, in local areas near thermal features groundwater levels have declined by several metres (e.g. BR 3/0, BR 4/0 Figure 23). Data from some very shallow wells indicate the presence of localised pockets of steam- and rainwater-recharged water, which are perched above the principal groundwater aquifer. The water levels in such perched aquifers are more variable.

2.7 Groundwater temperature changes

The temperatures at, or near the water surface, have been measured; in 13 shallow groundwater monitor holes since the test discharge period. Subsequently, more monitor holes have been drilled, and at present measurements are made in 46 monitor holes. Over most of the field the groundwater is cold (ambient temperature 10-25°C), but in two areas which surround known areas of thermal ground the groundwater temperature is warm (25-75°C) or hot (75-100°C).

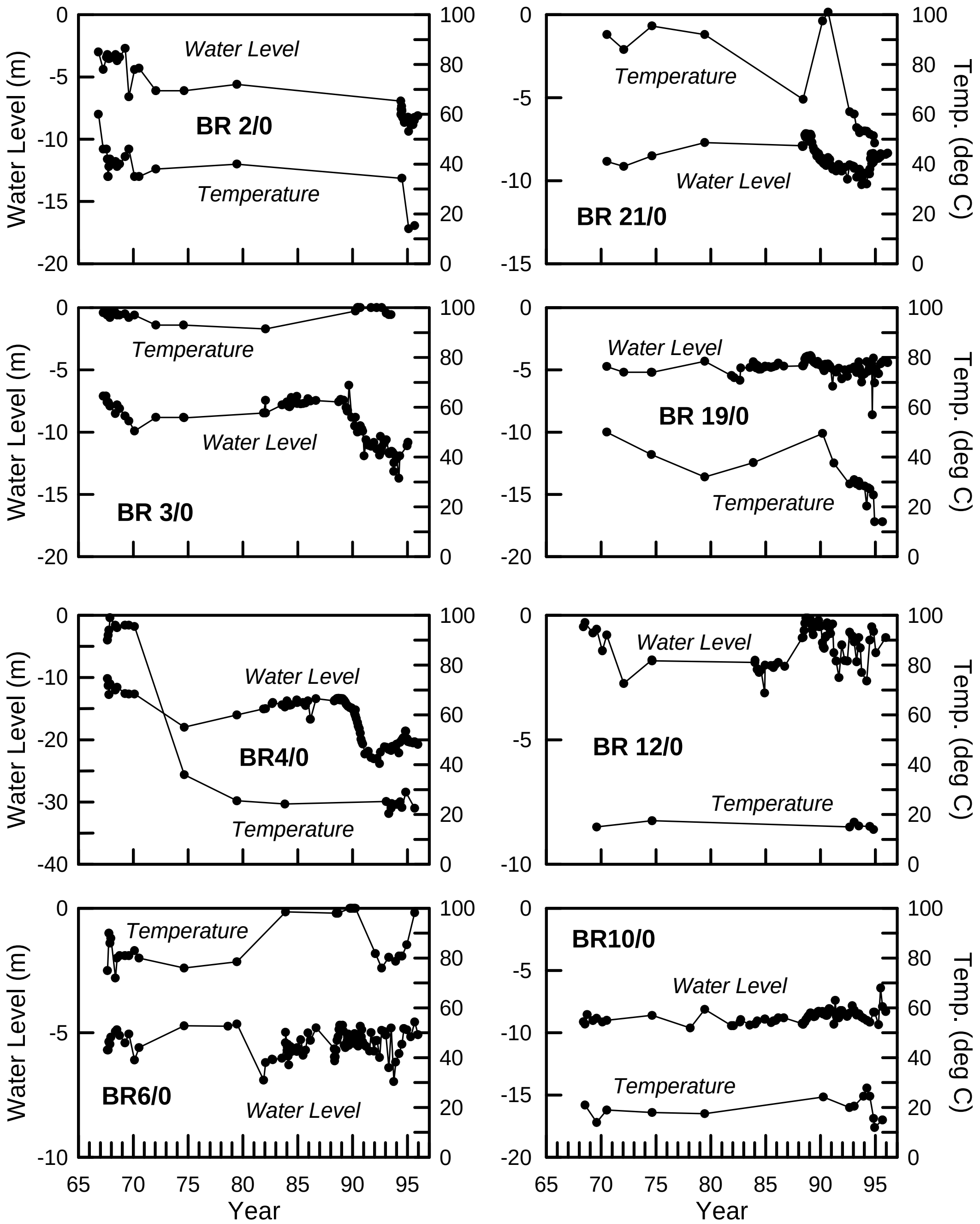


FIGURE 23: Graphs of change with time in shallow groundwater level and groundwater temperature at Ohaaki field; taken from Hunt & Bromley (2000)

The monitoring has shown that generally the test discharges had no effect on shallow groundwater temperatures, either hot (e.g. BR3/0,BR6/0; Figure 23) or cold (e.g. BR10/0; Figure 23). One clear exception, however, was in BR4/0: between August 1967 and February 1970, the groundwater was near boiling (90-100°C), but between then and August 1974 the temperature decreased by about 60°C and has remained at 20-25°C since June 1979 (Figure 23). This decrease in water temperature may reflect the onset of a localised cold downflow associated with the pressure drop that occurred during the test discharge period. As the hot water drained downwards it was replaced by cold groundwater which moved in laterally.

There were no significant changes in groundwater temperature during the recovery and production periods. Water in monitor holes that was hot or boiling at the start of the periods has remained hot, or decreased in temperature by less than 20°C (e.g. BR3/0; Figure 23). Similarly, water in monitor holes that were cold, has remained cold (e.g. BR10/0; Figure 23).

However, there have been exceptions. In BR21/0, at the start of the production period the water temperature was 66°C, but in March and September 1990 the temperature had risen to 97.5 and 101°C respectively (Figure 23). By August 1992, the temperature had returned to 61°C, and all subsequent measurements have shown a steady decline in temperature from that value to about 50°C in late 1994. Except for the two measurements in 1990, the groundwater temperature in this monitor hole has decreased steadily from about 90°C in the early 1970's to about 50°C in 1995. A similar temperature peak, but of smaller magnitude, also occurred in nearby BR19/0 followed by a decrease of about 30°C in the early 1990's (Figure 23). Both these monitor holes are in the vicinity of thermal features and the rapid pressure drawdown in the reservoir may have temporarily induced an increased flow of steam to the surface along conduits feeding these features, which in turn may have heated groundwater in the vicinity.

2.8 Seismic activity

Continuous seismic monitoring was carried out for 5 years during the latter part of the recovery and the early stages of the production periods. Seismic activity was low in and around the field prior to commissioning of the power plant and during the first 3 years of production no induced seismicity was detected, even though injection pumping pressures temporarily reached 40 bar (4 MPa) (Sherburn et al., 1993). This behaviour is different from that at Wairakei, where similar pumping pressures in well Wk 301 induced seismic activity. It has been suggested (Sherburn et al., 1990) that the absolute value of wellhead pressure during injection is not the critical factor for inducing seismicity, but instead it is the formation overpressure. At Ohaaki, the injection wells prior to injection were full of fluid and had a slight artesian pressure, so the formation overpressure is almost equal to the wellhead pressure (20-25 bar). At Wairakei, before injection the water level in Wk 301 was at 240 m depth (due to production-induced drawdown) so that during injection the formation overpressure was 44-54 bar (24 bar from filling the well, plus 20-30 bar of pumping pressure).

3. CHANGES AT ROTORUA GEOTHERMAL FIELD (NEW ZEALAND)

Rotorua geothermal field is recognised internationally for the geysers and hot springs at Whakarewarewa thermal area (Figure 24). Geysers are rare natural phenomena world-wide, and Pohutu Geyser at Whakarewarewa is one of New Zealand's two largest surviving examples. In the early 1950's, about 220 geysers existed in New Zealand, but by 1990 only about 55 remained; most of the losses being directly attributable to human interference with the geothermal systems.

In the early 1960's and again in the mid-1970's, mass flows from Rotorua wells increased sharply as additional wells were drilled (Figure 25), as a result of national electricity shortages (1950 and 1960's) and oil shortages in the (1970's). During these times the level of natural hydrothermal activity in Rotorua declined, to reach an all-time recorded low by the mid-1980's (Cody and Lumb, 1992). During the early 1980's, public sensitivity to the intrinsic and tourism values of New Zealand's few remaining geysers increased, as geysers and hot springs in Rotorua progressively failed due to extraction of geothermal fluids. These concerns, together with a realisation that there was no quantified estimate of the volume of fluid extracted in Rotorua, or adequate records of the changes in the surface activity, led to establishment of the Rotorua Geothermal Monitoring Programme in 1982. By 1985, this programme had established that the winter daily mass discharge from all wells was around 31 kt/d, which represented about 40% of the natural deep upflow of the system. In 1986, central government initiated a bore closure programme and a punitive charging regime for remaining well discharges.

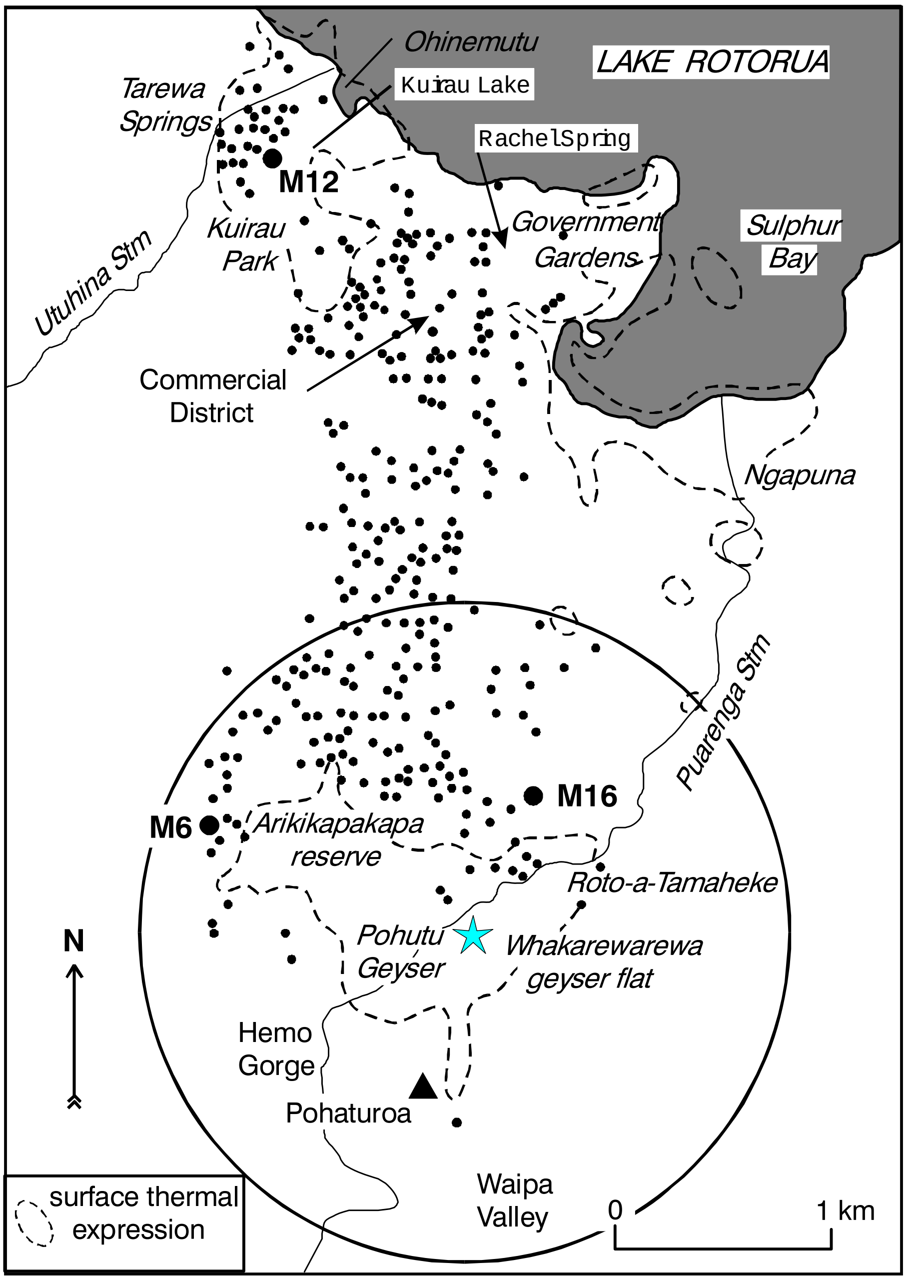


FIGURE 24: Distribution of geothermal wells in Rotorua City in 1985 (solid dots), monitor wells and thermal areas (outlined by broken lines); circle shows area in which all geothermal wells were closed. Taken from Scott & Cody (2000)

3.1 Exploitation and management history

Many Rotorua residents have taken advantage of the underlying geothermal fluids by drilling shallow wells (20-200 m deep) to extract hot water for both domestic and commercial heating. The first geothermal wells in Rotorua were drilled during the 1920's, by 1944 there were at least 50 wells in use, and by early 1998 over 1150 wells had been drilled. However, many of these were replacement, standby or reinjection wells, so the actual number of producing wells reached a maximum of around 500 in 1985. At that time the total well discharge was estimated to be 25 kt/d (290 kg/s) during summer, rising to 31 kt/d (360 kg/s) during winter (Figure 25).

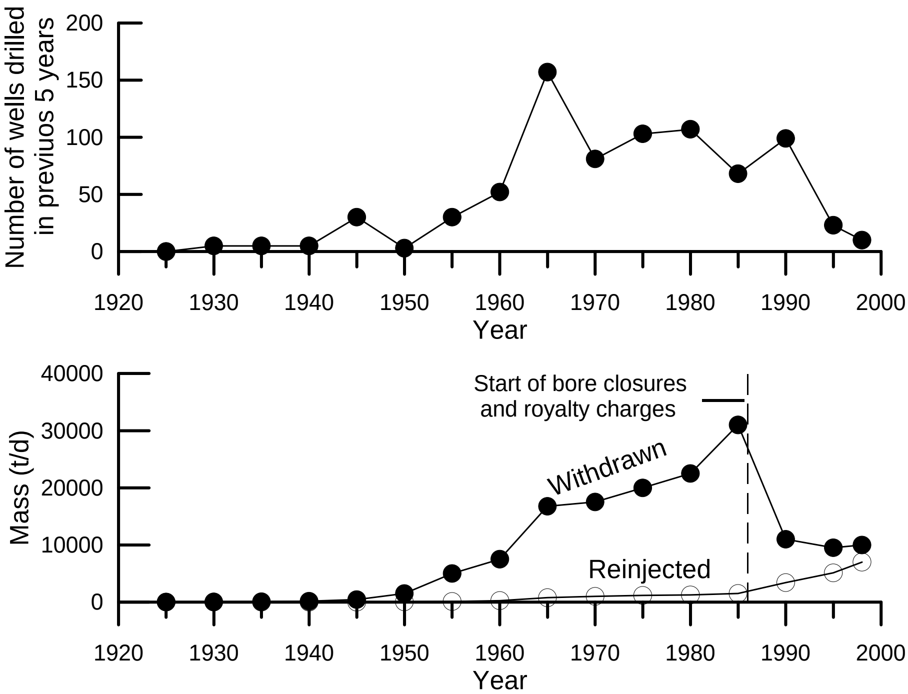


FIGURE 25: History of wells drilled in Rotorua, and the amounts of fluid withdrawn and reinjected; note the rapid decrease in mass withdrawn and increase in mass reinjected following the start of bore closures and imposition of royalty charges. Data from Scott & Cody (2000)

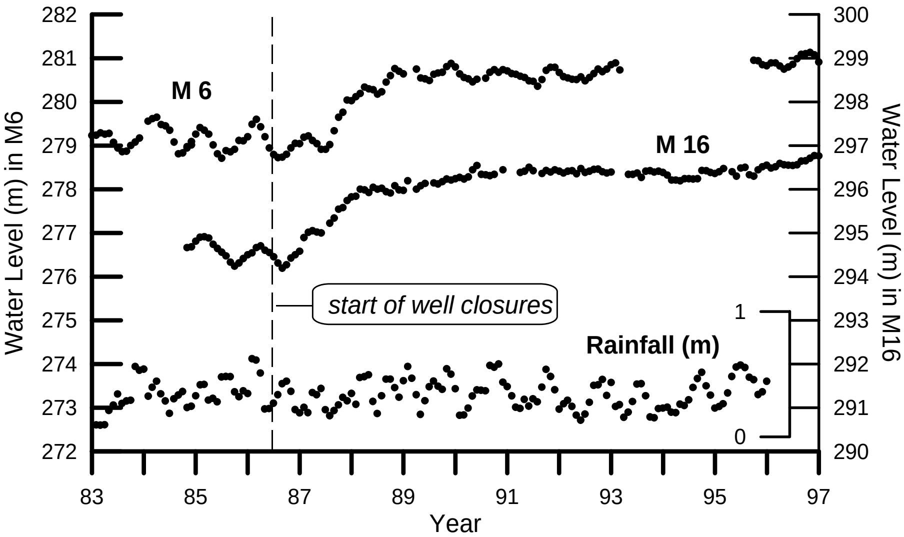


FIGURE 26: Changes in water level in some monitor wells in Rotorua City; location of the wells is shown in Figure 24. Note the rise in water level following start of bore closure programme. Data from Scott & Cody (2000)

In 1985 only about 5% of well discharge fluids were reinjected back to the production aquifer (typically 20-200 m depths), with most waste waters being discharged into shallow soak holes (<20 m depth). Approximately half the fluid extracted was for residential use and half for commercial use. A bore closure programme in 1987-88 resulted in 106 wells within 1.5 km of Pohutu Geyser (Figure 24) being cemented shut. This, together with the punitive royalty charging regime for all remaining wells, resulted in a further 120 wells outside the 1.5 km radius of Pohutu Geyser being shut. The effect of both forced closures and the royalty charges was a reduction of total well discharge to about 30% of 1985 levels by 1989. Average summer drawoff in 1990 was estimated to be 10.28 kt/d (118 kg/s), increasing in winter by 1.04 kt/d (12 kg/s) to a total of 11.32 kt/d (130 kg/s). The commercial sector then accounted for 68% of the total discharge, and the mass reinjected had risen to 31% of total well discharge.

Net mass withdrawal from the field in 1990 had decreased to near 20% of the amount in 1985. By late 1992 the 141 wells in use were producing 9.5 kt/d, with 5.1 kt/d being reinjected. In 1997, well production was still around 10 kt/d, but of this about 7 kt/d was being reinjected back to source.

3.2 Changes in field pressure and water level

A network of 24 monitor (M) wells (typically 80-180 m deep) was established in 1982. During late 1987, all M-wells showed a sudden water level or pressure rise of 1-2m (0.1-0.2 bars, 0.01-0.02 MPa pressure), with ongoing gradual recoveries to date totalling 2-2.5 m. M 16 is typical of wells into ignimbrite aquifers, and M6 is typical of wells into rhyolite aquifers (Figure 26).

3.3 Changes to surface thermal features

Discharges from thermal features at the surface in Rotorua are generally alkaline, high chloride-low sulphate waters, similar to the geothermal waters found in neighbouring shallow wells. No precise early measurements of total natural outflow are available, but estimates are that all hot springs and geysers at Whakarewarewa produced about 34 kt/d prior to any exploitation, and 25 kt/d in 1967. The geysers and most large flowing hot springs have shown responses to the sudden reduction of well drawoff in 1987: at Whakarewarewa, the springs produced about 8.39 kt/d in 1982, which increased to about 9.24 kt/d in 1989-90. The changes in outflows from hot springs show an inverse relationship to bore discharge, and are consistent with more geothermal fluid now being available for natural spring outflows as a consequence of reduced well drawoffs.

Springs and geysers
At present, geyser activity in Rotorua is confined to Whakarewarewa, where at least 65 extinct geyser vents are recognised. On Geyser Flat there are seven intimately connected and interactive geysers, such that data from any single one are not indicative of overall trends of Geyser Flat activity. Natural changes are also occurring which compound the problems of interpreting geyser changes through time.

At Geyser Flat, qualitative historical data from the 1890's, and later instrumental and visual records from the 1950's, present a clear picture of declines in outflows and failing geyser activity during 1950's-1980's, but with a pronounced recovery since 1987 to present day (Figure 27).

Pohutu Geyser: Full column eruptions of Pohutu (largest geyser on Geyser Flat) typically reach up to 21 m height, and occur 10-60 times each day, historically averaging 30-60% of any day in eruption (Figure 27). During the 1960's-1980's, Pohutu showed a pronounced shift to more frequent but shorter duration eruptions, possibly because of reduced aquifer pressures, but its total daily eruption times showed no significant change. In late 1986, it underwent a period of several months with no strong full column eruptions but many long episodes of dry steam emission, a phenomenon unseen before or since then. Eruptions of Pohutu have not shown any changes conclusively related to the well closures of 1986-87, except for the disappearance of dry steaming emissions. At present, it continues to have numerous short eruptions (2-5 minutes), but recordings from December 1997 to February 1998 show a shift to longer duration eruptions, with about 20% now lasting 30-50 minutes (Figure 27).

Te Horu Geyser: Until about 1972, this geyser used to erupt 2-7 m high with about 100 l/s outflows which occurred as frequently as 10-15 times each day, but after that time eruptions and boiling ceased. In January 1998, water began rising in the vent, then in December 1998, minor overflows occurred, followed in March-April 1999 by stronger overflows.

Wairoa Geyser: This last erupted naturally in December 1940 after which its water level fell to >4.5 m below overflow and the water became acidic. However, in early 1996, its water level rose to 3.2 m below overflow, with continuous powerful boiling and it remains so to date.

Kereru Geyser: Eruptions 10-15 m high, several times a week, occurred up until about 1972; after which time no large natural eruptions are known until they resumed in January 1988. Since then, moderate-large eruptions have occurred every few days or weeks, and occasionally up to seven per day have been observed in daylight hours. It remains active to date, with an exceptionally long eruption (about 5 minutes) occurring on 12 November 1997.

Papakura Geyser: This geyser stopped erupting in March 1979, after a 90 yr period during which it was known to have faltered very briefly only three times. The cessation of eruptions from Papakura was directly responsible for initiating the Rotorua Monitoring Programme in 1981. Papakura has not recovered to date, although in October 1997 the fluid in the vent had heated to about 60°C and become clear and alkaline once more, although still without any boiling or eruptions since 1979.

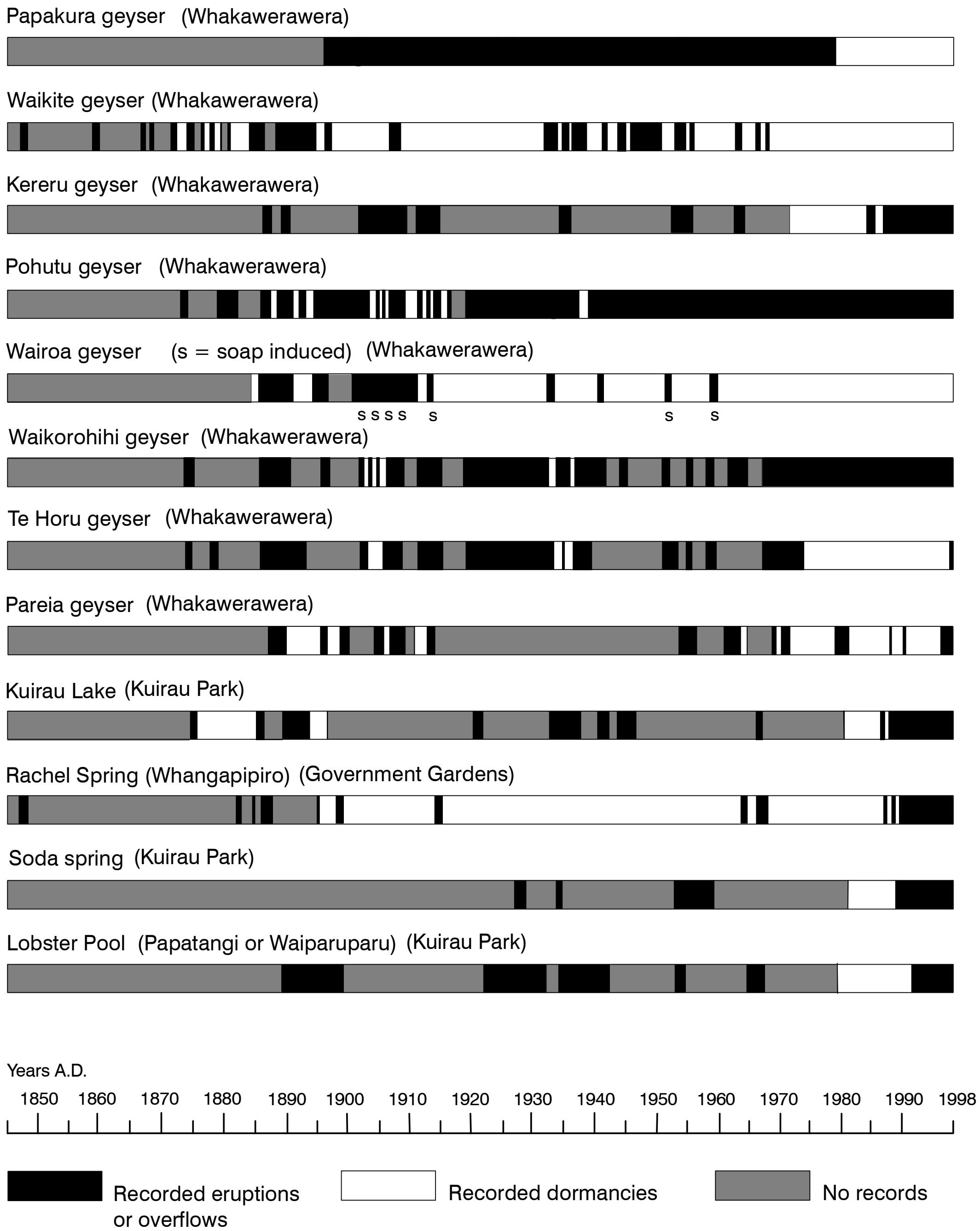


FIGURE 27: Histograms showing historic changes in activity for some major spring and geysers in Rotorua City; taken from Scott & Cody (2000)

Waikite Geyser: This last erupted in March 1967, since then the vent has remained dry and weakly steaming. In June 1996, its previously 8.5 m deep and dry vent suddenly filled with boiling water which rose to within 2.3 m of overflow. In June 1997, its water levels retreated suddenly to >8m depth, but returned in late 1998 to about 3m below overflow. An analysis of waters collected in 1996 showed very low chloride and high sulphate concentrations, confirming an absence of deep geothermal waters.

Okianga Geyser: During the late 1970's and early 1980's no eruptions were observed, but since about 1992 it has been reliably erupting every 25-35 minutes to about 7 m high.

Parekohoru Spring: In 1985-86, this spring ceased overflowing for several days each winter; the first such stoppages known in historical times. Since 1988 there have been no further cessation of flows. Boiling surges with large overflows recommenced in 1995, similar to reports of earlier this century, and continues to date.

Rachel Spring: This is the sole remaining boiling and flowing alkaline spring in the Government Gardens. Prior to 1987, the last recorded overflowing and boiling episode was in 1967. From then until 1987 its water level had remained at 1.2-1.7 m below overflow, and the temperature at 70-80°C. However, since late 1988 it has been continually boiling and flowing at 7-12 l/s. It still has brief cessation of overflow, but these stoppages last only a few days and since 1988 its water level has never fallen more than 0.1 m below overflow.

Kuirau Lake: From late 1940's -1987, the water was warm (about 45–50°C), acidic, low chloride and there was little or no overflow. However, from 1988 until November 1997, Kuirau Lake consistently overflowed at 40-60 l/s and 70-80°C, with high chloride and low sulphate alkaline waters. The rise and heating of Kuirau Lake since 1988 has killed all of the vegetation surrounding its shores; including trees up to 5m high and 20-30 years old, which had grown since the lake cooled in the late 1940's. Since December 1997, outflow has fluctuated between about 25 and 50 l/s

Tarewa Springs: Over the last 14 years, water levels have typically been about 1.5 m below overflow. In March 1998, several of the larger Tarewa springs, within Kuirau Park, commenced boiling once more and in some cases their water levels rose to overflow. In July 1998, geysering activity occurred in three of the springs. Two features had been infilled or built over while inactive, and their reactivation has created considerable problems.

Hydrothermal eruptions

Since records began in 1845, at least 91explosive hydrothermal eruptions have occurred. The frequency and distribution of these appear to show a correlation with larger scale disturbances of the field imposed by both human and natural activity. The 1886 volcanic eruption of Mount Tarawera (about 20 km east of Rotorua) caused pronounced changes to thermal activity throughout Rotorua, with many previously extinct or passively flowing springs suddenly boiling, erupting and overflowing. New geysers erupted at Whakarewarewa, and many hydrothermal eruptions and resumed hot spring overflows also occurred in the weeks and months following the volcanic eruption

An area of high steam flow occurs at the southern end of Lake Rotorua, and spectacular large hydrothermal eruptions were common there in the 1890's-1900's. At that time the lake level was uncontrolled, but since the lake level has been controlled the eruptions have become less frequent.

In the early 1890's a railway line was built into Rotorua. The construction works resulted in extensive drainage of previously swampy, peaty ground. Writers at that time attributed several hydrothermal eruptions there to the effects of the recent drainage works.

There was also an increase in the number of hydrothermal eruptions during the 1950's-1960's when there was increased well drilling and hot water drawoff.

4. CHANGES IN TONGONAN GEOTHERMAL FIELD (PHILIPPINES)

The Bao-Banati thermal area is located in the southwest part of the Greater Tongonan Geothermal Field (GTGF), approximately 2 km from the Malitbog reinjection sink, and 4 km from the Mahiao-Sambaloran reinjection sink and Tongonan I power plant. The thermal area contains the largest and most impressive thermal manifestations within the field and includes numerous hot springs, fumaroles and steaming vents which discharge neutral-pH chloride waters. The hot springs are distributed along the Bao River and the Banati Creek, and fumaroles and steaming vents occur near the confluence of the Bao and Malitbog rivers.

The chemistry of the Tongonan thermal springs was first determined in 1965. Surveys were also conducted in 1973 and 1979 prior to exploitation. After six years of drilling and discharge testing an assessment of the response of the thermal springs was made, but no significant changes in discharge chemistry of the springs was found. In 1983, a monitoring programme to measure any effects of exploitation on the thermal features in the GTGF was started.

In the early 1970's, thermal activity in the area included geysering and steaming features. The most prominent features were hot springs no. 1, 4, and 36. Hot spring no. 1 is popularly known as "Orasan", which means clock in the local vernacular, due to its periodic geysering activity. Hot spring no. 4 has one of the greatest mass flowrates (20 kg/s), and hot spring no. 36 has the highest chloride concentration (3600 mg/kg).

Prior to development, the springs discharged neutral-pH chloride waters with 2500-4000 mg/kg of Cl, l50-180 mg/kg HCO_3, and 40-80 mg/kg SO_4. The major cations include Na (650-1400 mg/kg), K (42-107 mg/kg) and low Ca (12-48 mg/kg). Trace amounts of Mg and Fe are also present in less than 1.0 mg/kg. Assuming maximum steam loss at 100°C, the quartz geothermometer predicts temperatures of 160 -180°C for the reservoir feeding the springs. The chemistry suggests the Bao-Banati springs mark the outflow sector of the field.

4.1 Flowrate changes

After commissioning of the Tongonan 1 power plant in 1983, a significant decline in the activity of the Bao-Banati thermal springs was observed. Most notable was the cessation of geysering activity, with a corresponding decline in mass flowrate from hot spring no. 1. Hot springs no. 4 and 36 showed a decline in mass flowrate, and eventually ceased discharging in 1985. Other hot springs in the area exhibited a similar declining trend in mass flowrate. The total flow was approximately 85 kg/s in 1983, which reduced to 55 kg/s in 1984, and to 10 kg/s in 1992. Most of the springs dried up or became reduced to non-flowing pools. For example, hot spring no. 16 declined in mass flowrate from 8.8 kg/s in 1982 to 1 kg/s in 1987, and ceased discharging in 1989 (Figure 28).

In December 1982-January 1983, a noticeable increase in mass discharge of the springs was observed coincident with 65 kg/s reinjection into well situated about 2 km from the springs. A similar change occurred again in May-August 1996, coinciding with the further use of reinjection well 5R1D at a higher reinjection rate of 224 kg/s. At both times there was an increase in the measured mass flowrate of hot springs no. 1, 7, and 8. Hot spring no. 3, on the northwest bank of the Bao River displayed more frequent and vigorous geysering during the height of this reinjection. Hot springs no. 4 and 36, which had dried up in 1985, re-appeared during the height of reinjection but both features disappeared again after the reinjection stopped.

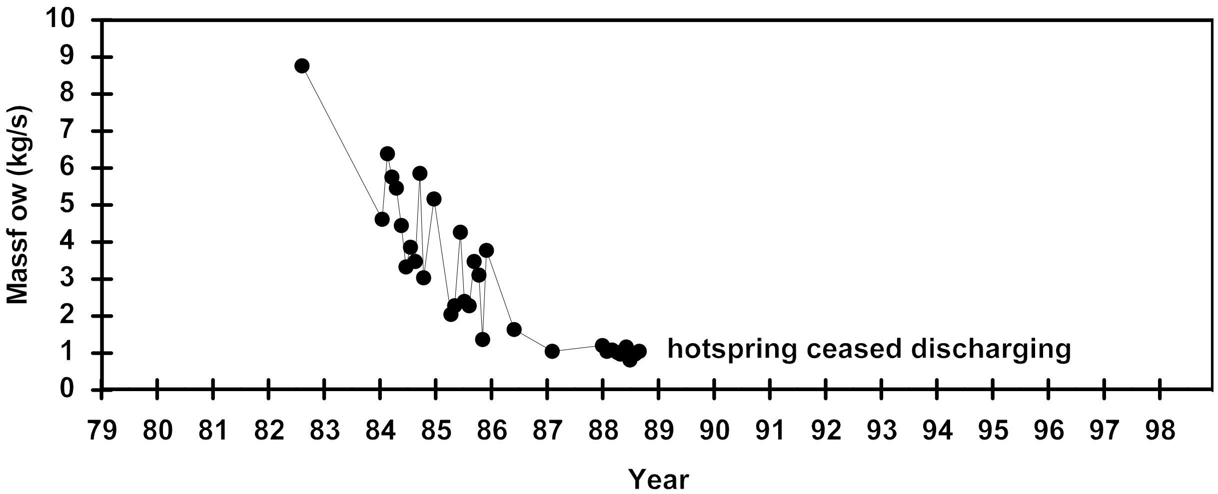


FIGURE 28: Changes in mass flowrate of hot spring no. 16 with time, Tongonan, Philippines; taken from Bolanos & Parilla (2000)

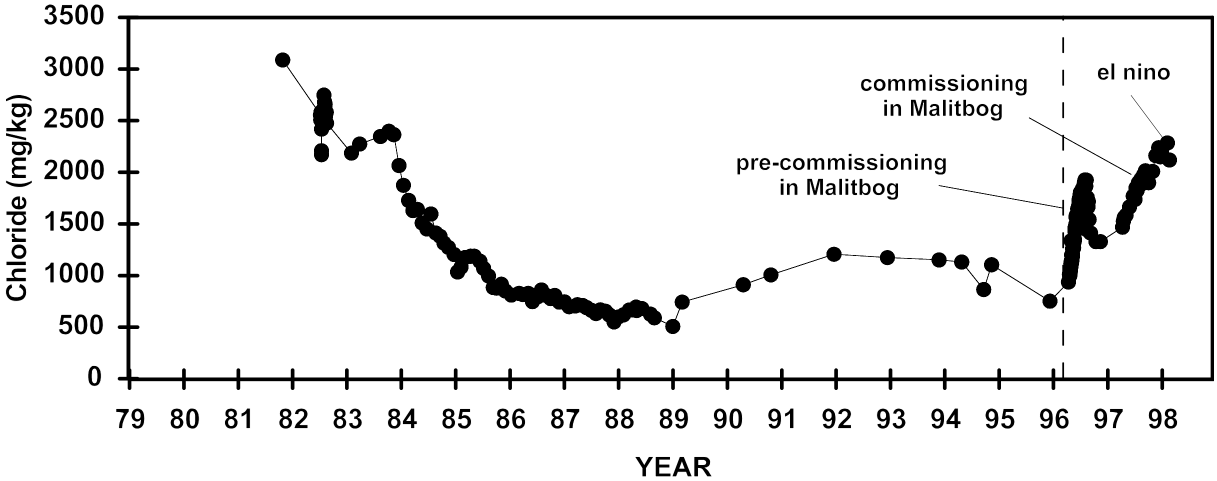


FIGURE 29: Changes in chloride concentration in hot spring no. 1 with time, Tongonan, Philippines; taken from Bolanos & Parilla (2000)

4.2 Chemistry changes

In 1981-1982, the chloride concentration of the Bao-Banati springs was 2500-3500 mg/kg, similar to that of nearby exploration wells. After exploitation began in 1983 the chloride concentration of the springs steadily declined to a low of 500-1500 mg/kg in 1989 (Figure 29). The decline in chloride was due to the decrease in reservoir pressures, associated with mass extraction from the reservoir (Figure 30) which caused a reduction in the contribution of fluid from the deep geothermal reservoir.

During 1990-1995, a temporary increase in chloride concentration of the springs was observed. This can be attributed to the increase in brine reinjection at Tongonan 1 as a consequence of declining well enthalpies and increasing generation during the period. The increase in reinjection temporarily increased reservoir pressures, and effectively increased the contribution of deep geothermal fluids to the spring discharges. However, in 1995 chloride concentrations in spring waters appear to have declined as reinjection in Tongonan decreased. This suggests the absence of reinjection fluid breakthrough coming from the Mahiao-Sambaloran reinjection sink, which had chloride concentrations of 12500-16000 mg/kg.

During the pre-commissioning activities in the Malitbog Sector in May-August 1996, an increase in

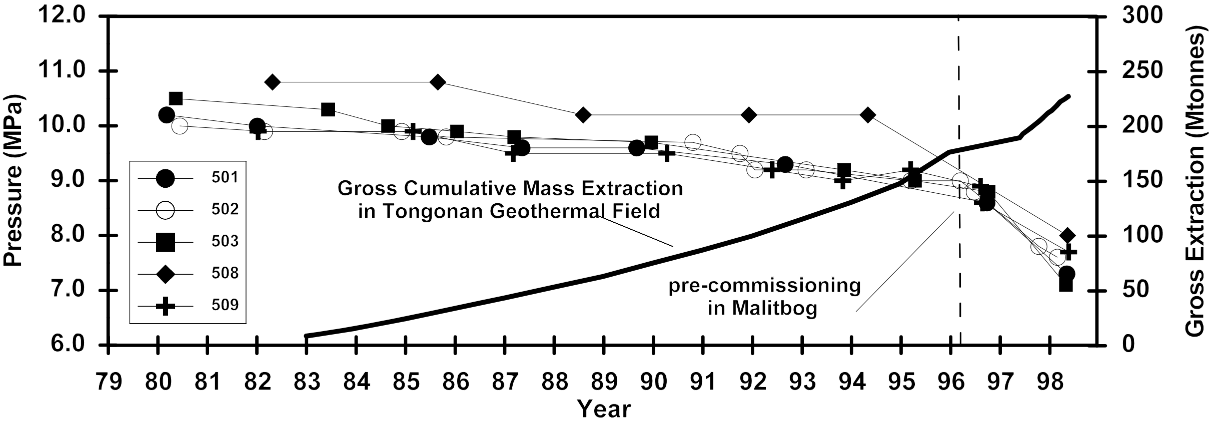


FIGURE 30: Deep pressure changes in nearby Malitbog wells (symbols) and cumulative gross mass extraction from Tongonan geothermal field (solid line); pressure changes are at reference depth of -1000 m RSL. Taken from Bolanos & Parilla (2000)

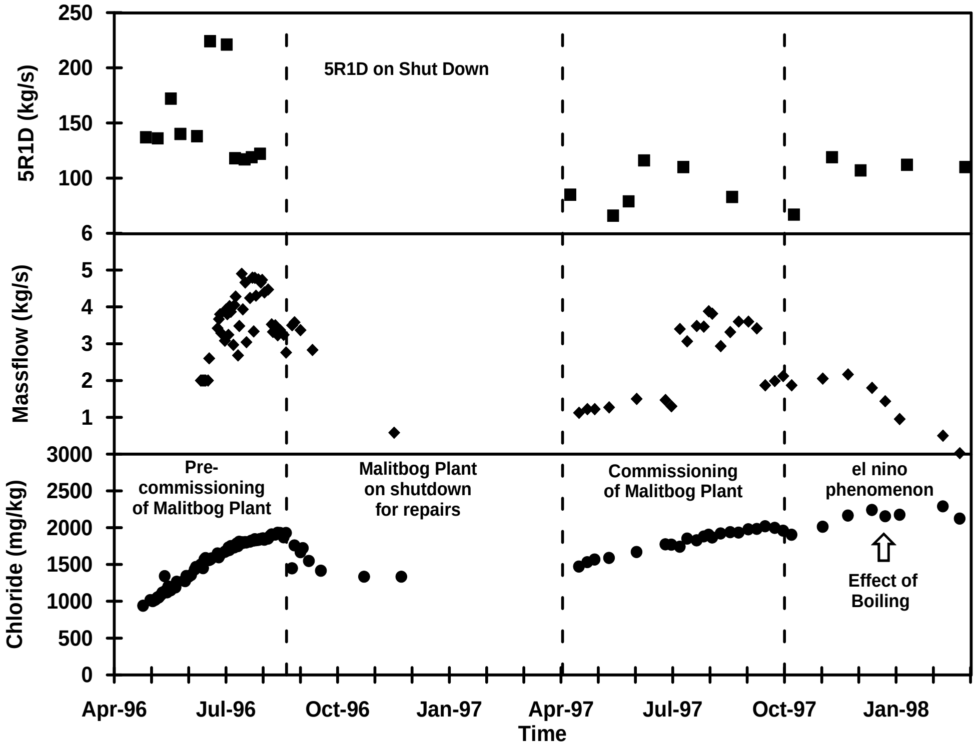


FIGURE 31: Relation between rate of reinjection into well 5R1D, and changes in massflow rate and chloride of hot spring no. 1; taken from Bolanos & Parilla (2000)

chloride concentration was observed in the hot springs. At this time, about 140-220 kg/s of brine was being reinjected into reinjection well 5R1D (Figure 31). With conclusion of the Malitbog plant pre-commissioning activities on 14 August 1996, reinjection into 5R1D was stopped. Chloride concentrations then declined from a peak of 1900 mg/kg in mid-August 1996 to 1300 mg/kg in November 1996 (Figure 30), which indicated breakthrough of reinjected fluids from 5R1D to the Bao-Banati springs had previously occurred. This was later confirmed by tracer testing. Full operation of the Malitbog Plant commenced in April 1997 and 5R1D was put back on line at a reduced reinjection rate of 66-119 kg/s. An increase in mass flow and chloride of the springs was again observed (Figure 31).

In late 1997 and early 1998, hot spring no. 1 showed an increase in chloride (2200 mg/kg) which surpassed previous levels (1900 mg/kg) in 1996-1997. However, flow from this spring declined from 3.88 kg/s in August 1997 to 0.02 kg/s in March 1998. The increase in chloride, but decline in mass flowrate, cannot be associated with the breakthrough of reinjection fluid from well 5R1D, as was the case in May-August 1996. Probable causes are: a long drought which effectively reduced the contribution of near surface groundwaters to the spring discharges; and a shift in the direction of flow of reinjection fluid towards the Malitbog production sector in the northeast, rather than towards the natural outflow in the southwest. This shift is shown by the increasing chloride concentration in production wells near the Malitbog reinjection sink (5R1D, 5R4 and 5RB wells). In well 515D (northeast of well 508D), chloride increased from 7500 mg/kg in June 1997 to 9500 mg/kg in March 1998.

4.3 Changes in quartz geothermometer temperatures

There was a decline in quartz geothermometer temperatures, which is consistent with decreased contributions from deep geothermal fluids and increased dilution by shallow ground waters (Figure 32). However, the quartz geothermometer temperatures temporarily recovered in 1996 during the pre-commissioning activity in Malitbog, after which they resumed the decline, only to increase again in April 1997 during commissioning of Malitbog. The increases in quartz geothermometer temperatures during these periods provide additional evidence of the breakthrough of reinjected fluid from 5R1D to the hot springs.

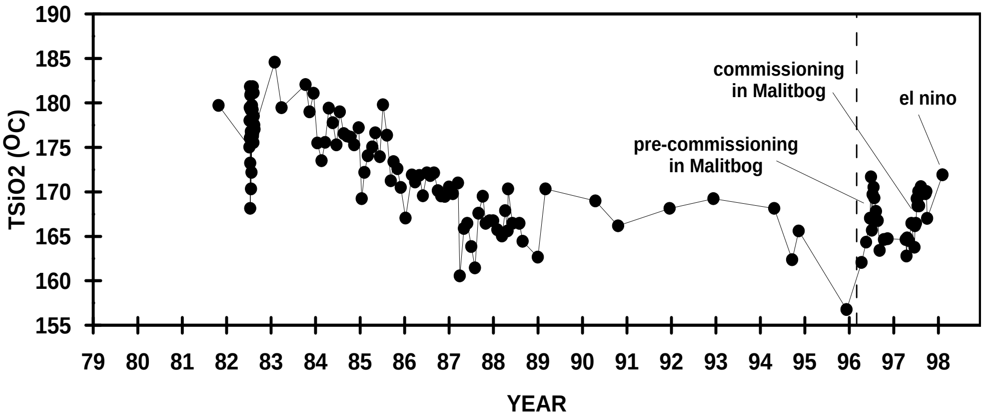


FIGURE 32: Changes in quartz geothermometer temperatures of hot spring no. 1

Monitoring of the Bao-Banati thermal springs during operation of Tongonan 1 Power Plant shows there have been:

a) Significant declines in the flow rates from the springs;
b) A demise or reduction in the character of some springs to non-flowing pools;
c) A decline in the chloride concentration of the waters;
d) Declines in quartz geothermometer temperatures.

The changes are similar to those observed in thermal springs at Wairakei and Ohaaki geothermal fields in New Zealand, and are attributed to the decrease in reservoir pressures which have caused a reduction in the contribution of deep geothermal fluids to the waters emerging from the springs.

During reinjection of waste brine into well 5R1D (Malitbog sector) as part of pre-commissioning trials and after commissioning of the Malitbog Plant, there were increases in flowrate, thermal activity, and mineralization of the springs. These changes are interpreted as being caused by breakthrough of reinjected fluid from this well to the springs.

5. CHANGES AT PAMUKKALE (TURKEY)

One of the most spectacular natural geothermal features in the world is the travertine terraces at Pamukkale, in south-western Turkey. In 1993, a joint project was started involving Hacettepe University (Ankara) and the Ministry of Culture of Turkey, aimed at conserving the terraces. This on-going project is also supported by UNESCO, which has declared the area a World Heritage Site. The need for this project arose after intensive tourist activity had caused environmental pollution in the area.

The pure white travertines have become darker, yellowish and brownish after establishment of tourist sites and hotels in the area above the terraces, and this is especially noticeable at the end of the summer tourist seasons. These hotels take the hot water directly from the spring outlets or by open channels to swimming pools, after which it is released onto the travertine. This procedure has several adverse effects.

- Outgassing of CO_2 from water in the pools decreases its travertine depositing capacity;
- Swimmers in the pools leave organic relicts which cause a rapid growth of algae, which cause a change in colour of the travertines.

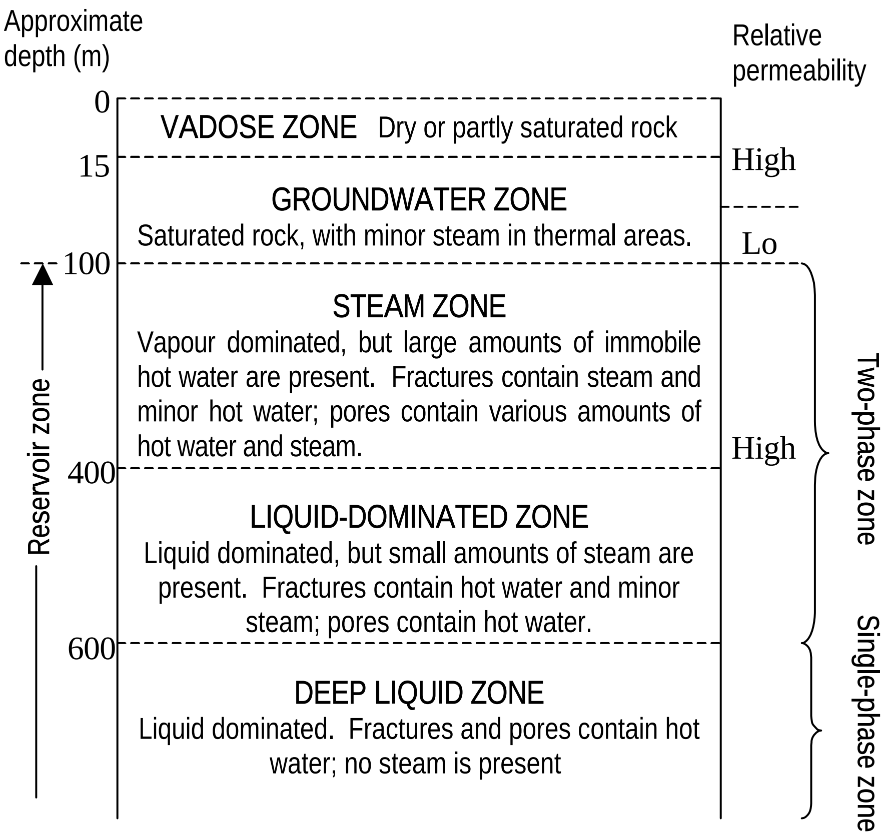
The lack of a sewage system is another major source of pollution. Each hotel has a septic tank dug into the travertine and, although lined with cement, they leak waste water which emerges at the bottom of the terraces. There are large amounts of algae in these places because the leaked water is rich in nutrients. To prevent this pollution, protection areas have been delineated, based on geological and hydrological information.

A further problem is mechanical damage to the surface of the terraces caused by people or animals walking on the travertines; this deforms the calcite crystals and deters their formation. To prevent this occurring, a program has been developed to enhance travertine deposition and for their protection against pollution. This includes (Simsek et al., 2000):

- Construction of about 4.7 km of new concrete channels from the four main springs to the travertines, to prevent loss of thermal water by leakage along the water path. These channels are covered with concrete lids to reduce outgassing before the water reaches the travertine area. The lids also serve to stop sunlight reaching the water, thus deterring growth of algae in the channels;
- Building intake structures at the springs for better management of the hot waters;
- Construction of fences around the springs and water outlets to the travertine terraces;
- Prohibiting walking on the white travertine area;
- The old asphalt road crossing the travertines has been closed, and replaced by new terraces constructed to imitate the natural morphology of the area;
- Removal of septic tanks and their replacement by portable toilets;
- Moving the hotels and other tourist facilities from above to below the travertine terraces.

APPENDIX I

Vertical distribution of water in the borefield area several years after the start of production at Wairakei geothermal field, New Zealand; taken from Allis & Hunt (1986).



The United Nations University
GEOTHERMAL TRAINING PROGRAMME

Hunt, T.M.: Five lectures on environmental effects of geothermal utilization
Reports 2000
Number 1, 51-60

LECTURE 3

MONITORING

1. REASONS FOR MONITORING

1. To obtain data on which rational and informed resource management decisions can be made by developers and regulatory authorities;
2. To verify that management decisions are having the desired outcomes;
3. To enable the public to have confidence in the environmental management process;
4. To assist in building up a knowledge of geothermal systems and how to develop them in an environmentally responsible way.

2. PRINCIPLES OF MONITORING

2.1 Basic principles

- Monitoring needs to *begin before development starts* so that a good baseline can be obtained. It is not possible to go back in time, so many different eventualities need to be considered and a *fully integrated monitoring programme needs to be developed* and begun well before large scale productions starts.
- Monitoring should be conducted at a *frequency sufficient to enable natural variations to be distinguished* from exploitation-induced changes.
- The data collected needs to be interpreted and *regularly compared with pre-determined "trigger points"*. "Zero change" is just as important as a change, and is not a valid reason for stopping monitoring, although the frequency of measurement may be reduced after a long period of no change.
- *Data needs to be reliable.* Equipment should be calibrated regularly and operated by a competent person.

2.2 Monitoring programme planning

In setting up a monitoring programme it should be recognised that:

- The programme is likely to extend for several years and/or even decades, therefore all observations and measurements need to thoroughly documented in a suitable archive.
- During this time there will probably be staff changes and therefore there needs to be a written set of instructions about how and when measurements will be made, so that measurements are compatible with each other
- The programme is likely to need revision from time to time

2.3 General requirements

Important factors in monitoring are:
- Care needs to be taken in making the measurements to obtain the greatest accuracy. Instruments should be calibrated before each survey, and the measurements must be made by a competent

operator who is fully aware of the reasons for making the measurements.

- Where possible, the same instruments and observation techniques should be used in all the surveys to minimise errors.
- If possible, the person interpreting the measurements should have made the measurements or have been involved in the surveys.
- Monitoring sites need to be clearly marked and monitoring facilities (e.g. groundwater monitor wells) need to be maintained.

3. MONITORING OF NATURAL THERMAL FEATURES

Natural thermal features are rare and often have significant cultural and economic value. Furthermore, experience of changes to natural thermal features as a result of geothermal developments has shown that they can be very fragile.

3.1 Geysers

The activity of a geyser is generally quantified by the *eruption period*, which is the length of time between the start of successive eruptions. For many geysers this is relatively uniform over periods of weeks or months; in one famous geyser, Old Faithful Geyser in Yellowstone National Park (USA), the eruption period has been stable for at least 150 years. For most geysers however the eruption period will change with time due to rainfall and supply of water. During the time of exploration drilling and discharge testing of drillholes in Wairakei field (1950-1958) the eruption period of Bridal Veil Geyser (Spring 199) in nearby Geyser Valley increased from about 38 min. in Nov. 1952, to about 55 min. in Dec. 1953, to about 65 min. in Dec. 1954 (Figure 5). During the test discharge period the eruption period of Great Wairakei Geyser (Spring 59) increased from about 12 to more than 30 hrs, before it stopped geysering in 1954 (Figure 5). Comparison of the eruption period data with rainfall measurements (Figure 5) showed that these increases in eruption period were not caused by a decrease in rainfall (Glover & Hunt, 1996).

A common method of reliably measuring eruption period is to install a water temperature sensor (thermocouple) in the outflow channel from the geyser apron, connected to a data logger with an internal clock. Eruption of the geyser soon causes water to flow in the channel. The sensor in the channel detects this water, and a signal is sent to the data logger. The sampling frequency of the data logger can be matched to the eruption period; for geysers with long eruption periods (> 1 day) a sample may be only every 10 minutes, but for those with a shorter period a sample every minute may be necessary. The data may be corrupted by periods of splashing prior to full eruption, but this can be minimised by careful selection of the site of the sensor. Setting up such a recording device may involve some trial and error placement of the sensor(s) and the selection of an appropriate sampling interval. Such equipment is readily available commercially and costs about US$1000-2000 depending on the degree of sophistication, inclusion of software, and number of sensors. The equipment is easily portable and requires only dry-cell or automobile batteries.

Length or duration of play can also be measured with the above equipment, but this is often more difficult to determine because for most geysers the cessation of eruption is not a sharp event; eruptions generally die away gradually.

Eruption height can also be measured, but this may be difficult because the liquid in the eruption column can be obscured by steam clouds. Generally, eruption height is measured by vertical triangulation using a theodolite. Sophisticated equipment such as a recording infra-red camera which enable the steam cloud to be penetrated are not necessary for the purposes of geothermal development monitoring, but are used for studies of geyser eruption processes. For geothermal monitoring purposes a set of (say) 5 measurements of eruption height, every 1-3 months would be adequate.

Another indication of geyser activity is volume of water discharged in each eruption, but in practise this is often difficult to measure unless all the water drains away from the geyser apron through a single channel.

Data from New Zealand suggests that indicators of geysers being affected by geothermal developments are:
1. Increase in eruption period, by more than about 20% (natural variation);
2. Increase in duration of eruptions;
3. Reduction in eruption height.

However, it should be clearly recognised that the characteristics of a single geyser, or groups of geysers, can change naturally with time. Such changes may occur slowly over a period of several years and be associated with changes in rainfall, or may be sudden if associated with earthquake activity that alters the plumbing system of the geyser.

3.2 Hot springs

Parameters of hot springs which indicate the state of health of a spring are:

1. *Flow rate*. This is generally measured using a permanently fixed V-notch in the overflow channel. If the spring does not overflow then the *water level* in the pool is an alternative parameter that can be measured. In both cases corrections may be needed for leakage into the surrounding soil if the edges of the pool are not sealed.
2. *Chemistry* of the fluid emerging. Samples (approx. 250 ml) are collected from the overflow channel and taken to the laboratory for analysis of chloride content. Analyses of boron (B), magnesium (Mg), silica and sulphate (SO_4^-) may also be made and can prove useful.
3. *Temperature*. This is generally measured using a thermocouple, but it is important to take the measurement at the same point each time, especially if the spring discharges into a pool because local atmospheric conditions can affect the temperature near the water surface.

3.3 Thermal ground

Many natural thermal features lie within areas of thermal ground where the near surface (<1 m depth) ground temperatures are above ambient. Lateral variations in the temperature of thermal ground are often manifested by differences in vegetation species and the in the health (thermal stress) of individual species. Geothermal development may cause changes in the distribution and temperature of thermal ground, however, changes may have complex origins. It has been found that, in hot thermal ground, the near-surface temperatures are influenced more by groundwater depth than by groundwater temperature (Allis & Webber, 1984). This is thought to be due to the upward movement of steam and water vapour above a boiling or near-boiling groundwater surface (convection), which increases ground temperatures above that expected from a purely conductive temperature gradient. This effect, however, appears to be limited to about 10-20 m above the groundwater surface. If the boiling groundwater surface is deeper, then the near-surface temperatures are controlled more by thermal conduction. Thus, changes in the depth and temperature of the groundwater can affect the near-surface ground temperature.

Ground temperature can be monitored in several ways as seen below.

Thermal infra-red (TIR) imaging (Mongillo & Bromley, 1992)
Generally TIR imagery is obtained using a special camera mounted vertically in a low-flying (approx. 500m a.g.l.) helicopter or fixed–wing aircraft. An optical-mechanical scanning system in the camera focuses the TIR radiation emitted from the ground onto mercury-cadmium-telluride detectors, which give an electrical signal proportional to the intensity of radiation. The signals are recorded on standard

VHS video cassette for later analysis. The data are calibrated either internally (via an inbuilt reference) or externally (by measuring the temperature of identifiable water bodies during the survey). The survey is conducted on a grid pattern, with navigation by interactive GPS backed up by a visual record obtained from a vertically mounted video camera. To ensure that the effects of solar radiation are minimised, surveys are generally conducted after sunset. Such surveys require a high degree of skill and understanding by the operators to ensure that reliable data are obtained. After the survey, a large amount of computer processing of the data is needed to improve the information content in the images and to compile a TIR map. The equipment is capable of detecting temperature differences of about 0.2°C, but in practise differences of about 1-2°C are the best than can be determined between repeat surveys. The ground resolution depends on the height of the survey above ground surface, but generally a resolution of about 2x2 m is obtained. The results are often enhanced by pseudo-colouring and are easily incorporated into GIS archiving systems. Similar imagery can also be acquired by satellites but the present resolution of 15-30 m is not sufficient for monitoring purposes.

Problems: The main problems likely to be encountered are weather and ground conditions which may be unsuitable for long periods of time resulting in logistic and scheduling delays.

Advantages of this method are:
a) Complete coverage of a field or thermal areas can be acquired, thus quantitative determinations of areas of change can be obtained and changes to small-scale or inaccessible features can therefore be determined;
b) Information about the state of thermal stress to vegetation may also be obtained;
c) There is no need to obtain land occupier permission;
d) No ground based operations such as farming etc are disturbed.

Disadvantages of this method are:
a) Sophisticated and expensive equipment is required;
b) Highly skilled people are needed to perform the survey and for processing of the data;
c) Results cannot be obtained quickly because processing is required; thus unusual results cannot be easily checked.

Ground temperature measurements (Hunt & Bromley, 2000)
Shallow ground temperature measurements can be made quickly and cheaply at selected sites. The measurements must be made at 1 m depth, or greater, to minimise daily and seasonal temperature variations. In most cases the measurements will be confined to soil in the Vadose zone. The measurements are generally made with a thermocouple inserted in a wooden rod, connected to a hand-held display unit. A hole is first made in the ground with a steel rod or auger, and then the thermocouple rod inserted. Care is needed to ensure that the thermocouple is in good contact with the sides of the hole, and a few minutes taken for the measurements to stabilise. A survey may be in a grid pattern or at specific intervals along profile lines through the thermal ground.

Problems: The main problems likely to be encountered are:
a) Difficulty in exact reoccupation of the site measured in previous surveys due to vegetation growth, recent engineering works, or poor recording or marking of the site. Installation of a permanent marker helps to overcome this problem.
b) Large lateral changes in ground temperature due to steam heating. This is common in areas of high ground temperature (>50°C). In such cases it is desirable to make several measurements, about 1 m apart, at such sites to gauge the amount of lateral variation.
c) Variations due to seasonal ambient temperature changes. Surveys made in summer will generally result in greater measured temperatures than those made in winter. A correction for such effects can be obtained if the survey extends sufficiently far outside thermal ground and into ground having “normal” temperatures, thus providing a “base value” that can be used to put all repeat survey data on the same base.
d) Effects of rainfall. Heavy rainfall before a survey may quench the soil and cause a reduction in

the measured temperatures. To avoid this, surveys should not be made immediately after a period of heavy rainfall.

Advantages of this method are:
a) Low cost, especially where labour to cut paths through vegetation is cheap;
b) No sophisticated equipment is required;
c) Results can be obtained very quickly, even in the field during the survey;
d) Unusual results can be quickly checked.

Disadvantages of this method are:
a) The number and distribution of data points are limited;
b) In certain areas there may be danger to field staff from being burned or scalded;

4. MONITORING GROUND DEFORMATION

Experience has shown that both horizontal and vertical (subsidence, inflation) components of ground deformation (strain) occur together, although subsidence is the greatest. All data available indicate that exploitation-induced deformation is continuous in both space and time, i.e. there are no tares or asperities, except where tension cracks and compressional buckling occur at the ground surface. Generally each component is determined separately using different techniques.

4.1 Vertical deformation (Gabriel et al., 1989; Massonet et al., 1997)

Ground subsidence and inflation can be measured by repeat *levelling* using traditional optical survey techniques. Permanent survey marks (benchmarks) are installed in the ground or on permanent structures such as concrete pipeline supports. The elevation of these is then measured, relative to a base station outside the field, using standard 2nd or 3rd order techniques along closed loops. Temporary intermediate points are generally needed. In areas of high subsidence rate (>100 mm/yr) the levelling needs to be completed quickly to avoid introducing errors caused by ground movement between the start and closure of a loop. The frequency of surveys will depend on the rate of subsidence and the location of the subsidence area. At Wairakei field (New Zealand) the main steam lines are levelled every 6 months, the production area every 2 years, and the whole field about every 10 years.

Advantages of this method are:
a) Tradition technique, well known in all parts of the world;
b) Provides high-precision data if standard routines are correctly applied.

Disadvantages of this method are:
a) Slow (and hence expensive), especially in severe topography;
b) Information is restricted to survey lines;
c) Can be badly affected by atmospheric conditions in hot climates.

Vertical deformation can also be determined using *Synthetic Aperture Radar (SAR) Interferometry*. The technique involves interferometric comparison of radar imagery (commonly C-band with wavelength of 56.6 mm) obtained from satellites at different times. Imagery may be from the same or a different satellite, but if it is from a different satellite then more corrections and processing of the data are needed. Corrections for changes in atmospheric radar propagation delay are made, based on known or estimated variations in water vapour content of the troposphere. Corrections also need to be made for topography and are usually made from digital terrain data. Comparison of radar images taken at different times provides interferometric fringes corresponding to contours of equal change in satellite-to–ground distance. Each fringe corresponds to a change in distance of half a wavelength, which corresponds, to a vertical displacement of about 25 mm. Spatial resolution is typically 10 m. In practise, SAR interferometry is best when combined with some levelling profiles to provide ground truthing.

Advantages of this method are:
a) A complete map of displacement may be quickly obtained.

Disadvantages of this method are:
a) Precision is not as high as for levelling;
b) The method is not suited to high-rainfall areas with significant vegetation or forest;
c) Suitable imagery needs to be available for the area;
d) Sophisticated software and processing are needed, including digital terrain data.

4.2 Horizontal deformation

Horizontal deformation can be determined from repeat measurements of *horizontal angles* between reference points using a theodolite. Generally the reference points are permanent markers specifically installed for the purpose. At Ohaaki field (New Zealand), these consist of a concrete post made from a concrete drainage pipe (approx. 600 mm diameter), mounted vertically, set in a concrete pad and filled with concrete. A threaded pipe is set in the upper surface of the post to allow a theodolite, or a target, to be mounted on the post. Alternatively, a concrete pad can be installed with a brass or stainless steel pin to enable exact reoccupation of the site at future times. It is important that the reference points extend well outside the field. Standard first order triangulation survey techniques are then used to measure the angles between all visible reference points, and the network is connected to any national triangulation network. After a repeat survey (2-10 yr), the changes in angles are then used to compute the relative motions of the reference points. However, if a full determination of relative movements is to be obtained then observations of astronomical azimuths and distances between survey marks are required, in addition to angles. The main problems encountered with horizontal deformation surveys in New Zealand has been growth of vegetation and trees, necessitating the cutting of sight lines through forest which is expensive.

Advantages of this method are:
a) Equipment requires no batteries, and is more robust than elctromagnetic distance measuring equipment (EDM) (below);
b) Standard measurement techniques are used.

Disadvantages of this method are:
a) More time-consuming than use of EDM;
b) Precision not as high as for EDM

Horizontal deformation can also be determined from repeat measurements of *horizontal distances* between reference points using electromagnetic distance measuring equipment (EDM). Such equipment uses either laser light or microwave radiation. Similar reference points to those described above can be used, and both the transmitter/receiver and the reflectors are mounted on the threaded pipe. Surveys are best carried out at night to minimise the effects of differential expansion of the pillars by sunlight.

Advantages of this method are:
a) Quick;
b) Easy to use.

Disadvantages of this method are:
a) Equipment is not as easily portable as a theodolite;
b) Electronics are susceptible to breakdown requiring return to factory.

5. MONITORING GROUNDWATER CHANGES

5.1 Groundwater level (Driscoll,1986)

Variations in water level in the shallow unconfined groundwater aquifer can be easily measured in shallow monitor holes. These holes are about 3-5 cm diameter and generally drilled vertically using a small truck mounted auger. The depth of the hole depends on the depth of the water table, and needs to extend 5-10 m deeper than the natural water table. The hole should not be situated in a topographic hollow that might become flooded, close to roads, or within the grout screen area of a deep production well. The holes should be solid cased (PVC or similar) in the Vadose Zone, and slotted or screened casing used from the water table to the bottom. In places where the ground temperature is less than about 50°C then plastic (PVC or ABS) casing can be used, but for ground temperatures greater than this value steel casing should be used. The open area of the screened casing should approximate the natural porosity of the rock formation, and the slots should widen inwards to minimise plugging of the slots by fine formation material. A record should be kept of the casing pattern, and the position and elevation of the hole should be established by surveying. It is likely that over a long period of time, fine silt and debris will migrate through the screened casing and be deposited in the bottom of the hole. The casing should extend 10-20 cm above the ground surface and the top closed by a locking cap to prevent children dropping stones etc. into the hole or people using it as a water well. In fields with high gas content, there should be a small hole in the cap to allow escape of gas entering the well through the screened casing. The wellhead also needs to be indicated by a marker post and protected from damage by vehicles or animals. Where possible, the well should be at or close to a gravity monitoring benchmark.

Measurement of water level can be made using a simple electric circuit device powered by a small battery. Alternatively, a water level recorder can be installed which comprises a pressure transducer coupled to a data-logger set to record every hour.

5.2 Groundwater temperature

The temperature of groundwater can easily be measured in groundwater monitor holes using a digital thermometer and a probe. Where possible, the temperature should be measured not only at the water surface but also deeper in the monitor hole, to enable a temperature profile in the water to be obtained. The same equipment should be used for all measurements and the wires between the thermocouple sensor and the instrument should not contain any joints.

5.3 Groundwater chemistry (Ellis and Mahon, 1977; Glover and Stewart, 1996)

Samples for laboratory analysis are best obtained from groundwater monitor holes (above) after water level and temperature measurements have been made. Samples should not be taken from stale and stagnant water in these holes; only after 5-10 well-bore volumes of water have been removed and naturally replaced should a sample be collected. Removal of stagnant water and collection of the sample are generally done using a small portable electric pump.

Important parameters that should be measured are:
pH, chloride, lithium, sodium, potassium, magnesium, sulphate (SO_4), total silica (SiO_2), total bicarbonate (HCO_3) and fluoride. In addition, measurements of stable isotopes $\delta^{18}O$, $\delta^{2}H$, and tritium are worthwhile making.

6. MONITORING RESERVOIR MASS CHANGES

Generally developers routinely measure the amount of mass withdrawn from, and reinjected into the field. However, these measurements do not provide information about natural mass losses from thermal features or natural recharge. Changes in mass can be determined from microgravity monitoring at selected points. This method is described later.

7. MONITORING RESERVOIR CHEMISTRY CHANGES

Withdrawal of deep reservoir fluid generally induces recharge which may alter the chemistry of the alkali-chloride fluid, especially if a significant proportion of the recharge water has a very different chemistry. However, the situation may not be simple mixing because the recharge fluid may be one or more of the following:

a) Unmineralised, non-geothermal groundwater;
b) Acid-sulphate waters formed by condensation of geothermal gases in near surface oxygenated groundwater;
c) Bicarbonate waters formed by condensation of steam containing carbon dioxide and hydrogen sulphide in poorly-oxygenated, near-surface groundwater;
d) Seawater.

If the recharge fluid is unmineralised non-geothermal groundwater, or acid-sulphate water and bicarbonate waters that are low in chloride, then a reduction in chloride content of the reservoir liquid may occur in the discharge from wells in areas near where the invasion occurs. Monitoring of the dilution trends can provide information about the rate of lateral movement of the invasion front. However, if the field is adjacent to the ocean and seawater is drawn in (such as at Tiwi field, Philippines) then the chloride concentration may increase. From a suite of chemical species it is generally possible, using a mixing diagram, to determine the amount of mixing of the various components.

Samples can easily be obtained for analysis by sampling the weir box associated with a wellhead separator, sampling a 2-phase pipeline from the well, sampling from a weir box, or using a downhole sampler. Details about sampling procedure, corrections needed, and analysis techniques are given in standard textbooks (Ellis & Mahon, 1977; Henley et al., 1984; Nicholson, 1993).

8. MONITORING CLIMATIC CONDITIONS

In order to assess the influence of variations in climatic conditions on thermal features, and groundwater temperatures and levels it is necessary to also measure rainfall, air temperature and air pressure. These can generally be obtained from a weather observatory installed near the power station. In the early stages of development it is generally necessary to install several small weather observatories, in and around the geothermal field, to collect information which will enable various air discharge scenarios for the power station to be modelled.

9. INTERPRETATION OF MONITORING DATA

Generally, the process of collecting monitoring data is relatively straightforward. However, correct interpretation of the results may be difficult. Often the first problem in interpretation is separating natural variations from those induced by exploitation of the field. Further complexities may be introduced by other human activities. For example, the removal of trees, pumping of water supply wells, and diversion or damming of rivers in and near the field may cause groundwater level changes. The effects of these may be difficult to measure or even estimate. Monitoring results are often field or region-specific. For example, in New Zealand geothermal fields the natural ground water level changes have a seasonal variation of about $\pm$1 m, but in some geothermal fields in Japan the variation is 10 m. Furthermore, each set of monitoring results needs to be interpreted in relation to other results. For example, changes in ground temperature need to be analysed together with changes in groundwater level and groundwater temperature.

10. USE OF MONITORING RESULTS

10.1 Review panel

The monitoring data and interpretations need to be actively used, and not merely filed away. A common problem is that regulatory authorities rarely (at least in NZ) have scientific or engineering staff with the appropriate qualifications and experience to assess the monitoring data. To overcome this problem in New Zealand, the monitoring results are initially examined by a Review Panel. Each developed field has a separate Panel. The panels are composed of 3 geothermal experts who are independent of the developer, and often contain retired geothermal professionals and university staff. The panels meet twice yearly for the first two years of development, then annually after that, to examine the results of the monitoring programme which are prepared by the developer and given to panel members prior to the panel meetings. The formal meetings last about one day, and the costs are paid by the developer. The Panel then prepares a report to the regulatory authority, which may then recommend changes to the way in which the development proceeds and any further monitoring that might be needed. Data and interpretations provided by the developer to the panel, and the panel reports are considered to be public information and can be requested by any member of the public, except that the developer may request that certain information which might be of commercial value be kept secret.

10.2 Permitting

In New Zealand, all geothermal developers must apply every 10-20 years to the regulatory authority for their permits (Resource Consents) to be renewed. The permitting process in New Zealand will be described later.

10.3 Common failures in monitoring

Experience has shown that few monitoring programmes are adequately planned and executed. Regulatory authorities must beware that this may be a deliberate policy or subconscious action of developers in order to obscure or make worthless any embarrassing data while still appearing to comply with the regulations. Common problems are:

- Failure to start measurements well before production begins, so that a good baseline is not obtained;
- Failure to extend measurements, particularly ground deformation and microgravity, outside the field, resulting in poor or ambiguous results;
- Failure to make measurements at a sufficient number of points to ensure that the inevitable loss of some points does not cripple the monitoring programme;
- Failure to use trained staff, resulting in poor data being obtained and leading to doubt that true comparisons can be made;
- Failure to adequately document the monitoring data;
- Failure by regulatory authorities to check that monitoring is being carried out when required and

to the specified precision.

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LECTURE 4

PROTECTING THE ENVIRONMENT

1. PROTECTION THROUGH MANAGEMENT PRACTISES

Prime responsibility for protecting the environment during a geothermal development rests with the developer, and specifically with the engineers and managers of the project. This responsibility cannot be shifted to the scientists, the regulatory authorities, the company shareholders, the government, or the workers.

Some general principles for protecting the environment are:
- *Monitor the environment.* Having good information is essential to enable problems to be identified and corrective action taken before they become serious and irreversible.
- *Rely on scientists to recognise the problems, but not to remedy them.* The training in their discipline often heavily influences the judgement of specialist scientists, but important decisions involving the environment requires understanding of many disciplines.
- *Act before scientific consensus is achieved.* Scientists rarely agree that something is absolutely certain. Calls for additional research may be delaying tactics or made to extend funding.
- *Confront uncertainty.* Do not believe that science or technology can provide a solution to every environmental problem. Effective management policies are possible under conditions of uncertainty, but they must take uncertainty into account. Favour actions that are robust to uncertainty and are reversible.
- *Include human motivation.* Short-sightedness and greed are often responsible for environmental problems, and this should be recognised in management practises. Resist pressure for short-term gains at the risk of environmental problems.
- *Take a precautionary approach.* Do not take actions for which there is doubt about the environmental outcome.
- *Be prepared for worst case scenarios.*

2. PROTECTION THROUGH ENGINEERING PRACTISES

2.1 Minimising impact of access and field development

Destruction of forests and vegetation resulting from construction of road access to drilling sites can be minimised by *careful planning* to reduce the number of steeply-sloping exposed banks. Remedial action can be taken to reduce erosion such as *planting fast-growing trees* which bind the soil, and *planting grass, crops, or low vegetation* beneath and alongside pipeline routes to increase surface run-off and minimise scouring of unprotected soil (Hunt and Brown, 1996). It is also important to consult with local people to ensure that places of cultural importance are not damaged or destroyed.

2.2 Reducing the effects of drilling operations

Noise inevitably occurs during the exploration drilling, construction and production phases of development. Air drilling is the most noisy (120 dBA) due to the "blow pipe" where the gases exit. *Suitable muffling* can reduce this to around 85 dBA (Brown, 1995). Mud drilling is quieter at around 80 dBA. Diesel engines operating the compressor and electricity supplies can also produce a resonant sound that carries for long distances; this noise can be constrained, to less than 55 dBA during the day and 45 dBA at night, by *suitable muffling* and *constraining noisy operations* (such as tripping or cementing) *to* *the daytime hours. Construction of screens of sound-absorbing material*, such as vegetation, can also reduce the impacts of drilling noise.

Following drilling, a well is usually discharged to remove drilling debris. Such vertical discharges are very noisy (up to 120 dBA). After this, there is normally a period of well testing; this can be suitably muffled by the *use of silencers,* but even then the noise is still significant (70-110 dBA). The well is then put on "bleed" where the noise is around 85 dBA reduced to 65 dBA if the "bleed" is led to a rock muffler (Brown, 1995).

The effects of using powerful lamps to light the work site at night may be reduced by *temporary screens and careful placement of the lamps.*

To reduce noise associated with the use of heavy machinery there must be *suitable muffling on the exhausts of the earth moving equipment.*

2.3 Disposal of waste drilling fluid

Discharge of waste fluids into nearby waterways is no longer acceptable. Modern drilling techniques involve *using minimal amounts of fluid and recycling* as much as possible.

2.4 Reducing possibility of degradation of thermal features

The decline in thermal features is associated with the decline in reservoir pressure. The only way to prevent or minimise the decline of thermal features is therefore to *minimise reduction in reservoir pressures* (Hunt and Brown, 1996). At present there are no viable techniques available to do this without severely curtailing production. The only possible technique would be to alter the way in which the energy is used, such as by not removing the fluid but instead only mining the heat using heat exchangers. However, with current technology, this would involve a large reduction in the amount of energy that could be extracted, and necessitate drilling more wells.

2.5 Avoiding depletion of groundwater

If exploitation of the system results in a large pressure drop in the reservoir, the groundwater may be drawn down into the reservoir along high-permeability paths. If the lateral permeability of the rocks in the groundwater zone is low then the downflow may result in a drop in the groundwater level. Downflows may also occur as a result of breaks in the casing of disused wells, and cause groundwater level changes.

The best ways of preventing changes in groundwater level are to *maintain reservoir pressure,* and *promptly repair damaged wells* (Hunt and Brown, 1996).

2.6 Changes in ground temperature

The only way to prevent increased heat flows is to minimise the extent of the 2-phase zone by *maintaining reservoir pressures* (Hunt and Brown, 1996). However, experience suggests the areas of high heat flow and ground temperatures are usually localised and do not cause significant environmental problems.

2.7 Ground deformation

Ground movements have been recorded in most high-temperature geothermal fields in New Zealand, at Cerro Prieto (Mexico), Larderello (Italy), and The Geysers (USA), and have led to:

a) Compressional and tensional strain on pipelines and lined canals;
b) Deformation of drill casing;
c) Tilting of buildings and the equipment inside;
d) Breaking of road surfaces;
e) Alteration of the gradient of streams and rivers.

Little can be done to prevent the effects of ground deformation, except to *maintain reservoir pressure*. Experience suggests that subsidence is difficult to reverse by increasing reservoir pressure because of the great weight of rock overlying the formation that has compacted. The effects of deformation on pipelines can be reduced by *mounting the pipelines on rollers*, but experience at Wairakei shows that even with such assistance sections of pipe need periodically to be removed or installed to maintain the pipeline network. Equipment that is sensitive to level should be *mounted on an adjustable base.*

2.8 Hydrothermal eruptions

Hydrothermal eruptions cannot at present be reliably predicted, however three separate causes have been identified to increase the likelihood of an eruption (Bromley and Mongillo, 1994). The first mechanism assumes an expanding 2-phase zone in the reservoir due to exploitation which increases steam flow to the surface. Near the surface, aquicludes may restrict the flow of steam and pressures can increase. During long dry periods, the thickness of the near-surface aquifer is reduced and further increased heating and steam flow occurs. If a period of heavy rainfall then occurs, the permeability of the ground is reduced so that the steam cannot escape and pressures can be further increased to the point where an eruption happens. The second mechanism involves hydraulic fracturing allowing a release of non-condensable gases to decrease the boiling point close to the surface. The third mechanism is a reduction in the lithostatic pressure by removal of the overburden, either naturally by landslides or by man-made excavations.

There are no countermeasures available apart from *maintaining reservoir pressures* to minimise steam formation and the concomitant increase in heat flow, and *refrain from building on or excavating in active thermal ground.*

2.9 Mitigating the effects of waste liquid disposal on living organisms

Release of hot waste water from power station directly into an existing natural waterway, may increase the temperature sufficiently to kill fish and plants near the outlet. Temperatures can be reduced by cooling the waste water prior to release using either forced- or natural-draft cooling towers, or natural cooling in open ponds. Alternatively, the heat can be used to generate more power by using a binary-cycle plant, and then "cascaded" further, through heat exchangers, for use in industrial or agricultural processes.

Release of untreated waste into a waterway can result in chemical poisoning of fish, and also birds and animals which reside near the water because some of the toxic substances move up the "food chain". Some effluent treatment processes exist to remove minerals from the waste water, but these are generally uneconomic, although research is currently underway in this area to develop more commercially feasible solutions where minerals are extracted for use in industrial processes (e.g. silica for whitening paper). Ponding, (which reduces the temperature of water and encourages the minerals to precipitate and sediment out) can assist.

The best way of mitigating the impacts of waste water disposal is to ensure that all waste water and condensate are collected and *reinjected in deep wells* at the edge of the field.

2.10 Avoiding effects of waste liquid contaminating groundwater

Release of waste water into cooling ponds or waterways may result in shallow groundwater supplies becoming contaminated and unfit for human use. Also, ponding may lead to contamination of groundwater if the pond lining is not impermeable or becomes accidentally broken. The best means of avoiding this is to *reinject all waste liquid.*

2.11 Minimising induced seismicity

Reinjection may cause an increase in the number of small magnitude earthquakes (microearthquakes) within the field. The increase is caused by high wellhead reinjection pressures increase the pore pressure at depth, particularly in existing fractures, which allows movement to suddenly release the stress and resulting in an earthquake.

The only effective countermeasures are to *reduce reinjection pressures to a minimum, and to ensure that all structures in the field are earthquake resistant.*

2.12 Minimising the effects waste gas disposal on living organisms

Standard countermeasures are based on minimising the release of gases into the atmosphere by *reinjecting all waste fluids, designing power stations to minimise gas discharges*, and *employing active monitoring systems* to enable the power plants to be shut down or generation reduced if the amounts of gas discharged exceed set levels. Hydrogen sulfide emissions can be reduced using a variety of techniques. Once the gases have been discharged there are no ways in which they can be controlled.

2.13 Reducing microclimatic effects

Even in geothermal power schemes which have complete reinjection, a considerable amount of gas (mainly steam) may be lost to the atmosphere. For example, at Ohaaki, of 70 Mt of fluid withdrawn (1988 - 1993) about 20 Mt (nearly 30%) was discharged to the atmosphere. Such discharges of warm water vapour may have a significant effect on the climate in the vicinity of the power station, depending on the topography, rainfall, and wind patterns. Under certain conditions there may be increased fog, cloud or rainfall. Microclimatic effects are mainly confined to large power schemes on high-temperature fields; exploitation of low-temperature geothermal systems does not cause significant microclimatic effects.

Countermeasures include *adequate investigation and planning of the power scheme before construction, design of the power station to minimise discharges***,** and *active monitoring and control of discharges* when the plant is in operation.

3. PROTECTION THROUGH REGULATIONS

Although the adverse effects of geothermal development can be avoided or minimised through the methods described above, it is generally recognised that geothermal developments need to be controlled and monitored by independent regulatory authorities through enforceable regulations. Experience in other natural resource operations suggests, regrettably, that if a developer is allowed unfettered access to a resource the environment often suffers. In most countries these authorities are central, regional or local government, and they issue (to developers) permits or consents which ensure that the best environmental practises are followed (Hietter, 1995; Goff, 2000). This is not entirely altruistic because if severe environmental damage occurs it is generally government that has to take ultimate responsibility for the problem. The permitting process varies from country to country, but generally involves:

a) Preparation of an Environmental Impact Report (EIR);
b) Consideration of that report by officials, experts and the public;
c) Granting of permits subject to restrictions;
d) Setting up of a monitoring programme and measurements taken regularly;
e) Periodic review of the monitoring data and renewal of the permits.

Some countries also require that a geothermal development be "sustainable", and this often leads to semantic arguments.

3.1 Permitting in New Zealand

New Zealand has several Acts of Parliament that work together to regulate and guide environmental use in a sustainable and integrated way. These acts work in accordance with the internationally accepted principles of Integrated Resource Management, which seeks to ensure that international environmental goals are achieved through locally appropriate practices with the agreement and participation of local communities and other stake-holders. Management of much of this process is devolved from central government to regional and to local government (Luketina, 2000).

The principal act which affects geothermal developments is the *Resource Management Act* 1991 (*RMA*) which sets out how people are to use air, land, and water (including geothermal fluid). Others include the Hazardous Substances and New Organisms Act and the Biosecurity Act. The RMA devolves management of these resources to regional councils (regional government).

The RMA sets out restrictions on the use of geothermal water and heat. No person may take, use, dam, or divert water or geothermal heat unless allowed by a rule in a *regional plan*, or by a *resource consent* issued by the relevant regional council, or unless the activity is for reasonable domestic use or for communal traditional use by the local Maori (the indigenous people of New Zealand).

Other sections that are relevant to geothermal use place restrictions on the discharge of contaminants to the environment, and on land uses such as drilling.

The RMA separates resource use activities into several classes:
1) *Permitted activity* is a small-scale activity with minimal potential for adverse environmental effects. It is allowed by a regional plan without a resource consent if it complies with certain conditions set down in the regional plan.
2) *Controlled activity* requires a resource consent, and has minor potential for adverse environmental effects. The resource consent will be granted if the activity meets certain conditions set down in the regional plan. The application for the consent is unlikely to be notified for public submission, and is generally decided by council staff.
3) *Discretionary activity* is a large-scale activity requiring a resource consent. The application will likely be publicly notified. If submissions against it are received, it will be decided by councillors after a public hearing.
4) *Non-complying activity* means an activity which contravenes a rule in a plan and requires a resource consent. The application will likely be publicly notified.
5) *Prohibited activity* means an activity which the regional plan expressly prohibits and for which no resource consent shall be granted.

Regional plans and policy statements: The RMA requires each regional council to put in place a regional policy statement and a regional plan. The regional policy statement sets the policy, “by providing an overview of the resource management issues of the region and policies and methods to achieve integrated management of the natural and physical resources of the whole region”. The regional plan provides the rules to implement the policy and to “assist a regional council to carry out any of its functions in order to achieve the purpose of this act”.

There is a set procedure for developing the policy statement or plan:
1) Preparation;
2) Consultation;
3) Public notification of proposed policy statement or plan;
4) Submissions;
5) Public notification of submissions;
6) Further submissions;
7) Hearing by the regional council;
8) Notification of regional council’s decision;
9) Reference (submissions) to the *environment court;*
10) Environment court hearing;
11) Amendment of the proposed policy statement or plan;
12) Approval;
13) Policy statement or plan made operative.

3.2 Waikato regional council regional policy statement

The geothermal section of the Waikato regional council’s regional policy statement identifies the major geothermal management issues as being the following:

1) Maintaining the variety of characteristics of the regional geothermal resource; and
2) Ensuring efficient take and use of the geothermal resource.

For geothermal resources there are several considerations in terms of sustainable management which form the Waikato regional council policies.

Sustainable production: Ensuring that users, such as large geothermal power developments, do not take geothermal fluid from the earth faster than it can be replaced.

Biodiversity: Ensuring that the biodiversity of geothermal micro-organisms, plants and animals is maintained for its own intrinsic value and for possible use in industrial processes and medical applications.

Preservation of features: Ensuring that geothermal features that people value for their cultural, amenity, and scientific values such as geysers, mud pools, and silica terraces are maintained for future generations to enjoy and learn from.

Efficient use: Ensuring that when geothermal resources are used, they are used efficiently.

Maori values: Ensuring that Maori traditional values are recognised and provided for.

3.3 Waikato regional council regional plan

The regional plan sets out the rules for achieving the aims and objectives of the regional policy statement. In the geothermal chapter of this plan there are several broad concepts from which the rules derive:

Classification of systems: The geothermal systems of the region are classified into development, protected, or unclassified systems. System boundaries are defined according to electrical resistivity contours and other survey information. Classifications and boundaries can be changed through a formal process by providing sufficient evidence that a change is warranted.

Protected systems: Takes and discharges of geothermal water from and to land (other than those lawfully established prior to notification of the plan) on protected systems will be prohibited.

Unclassified systems: New takes and discharges from unclassified systems will be a discretionary activity. Existing uses lawfully established prior to notification of the plan will be a permitted activity in unclassified systems.

Development systems: The take from and discharge to land of less than 30 t/d of geothermal fluid will be permitted (under certain conditions). Other takes and discharges up to 500 t/d will be discretionary or controlled activities. The take and discharge of more than 500 t/d will be a discretionary activity.

Significant geothermal features: The regional plan contains a list of significant geothermal features in the region, ranked in order of importance based on rarity, resilience, and viability. They are found on many of the geothermal systems mentioned above, including development systems. Resource consents are needed to do anything in or around a significant geothermal feature.

3.4 The resource consent process

Assessment of environmental effects: According to rules set down in the RMA, a resource consent application must be accompanied by an assessment of any actual or potential effects that the activity may have on the environment and the ways in which any adverse effect on the environment may be mitigated.

Consultation: An application for a resource consent must include evidence that all reasonable steps have been taken by the applicant to engage in adequate consultation with interested parties. These parties may include adjacent landowners and occupiers of land, local iwi (native tribes), the Department of Conservation, the relevant district council, environmental groups and special interest groups such as fishing and hunting clubs.

Notification: A resource consent application must be publicly notified, and served on such persons who are likely to be directly affected by the application. This is done by placing advertisements in papers and sending letters to affected and interested parties. Notification is not required if all affected parties provide their approval.

Submissions: Submissions can be made in support, in opposition, or neutral to the application. If anyone submits in opposition to the application, the application and submissions have to be heard in a formal hearing process by a hearings committee.

Prehearing meetings: Prehearing meetings can be held between the applicant and submitters in order to address the concerns of the submitters. They can range from a brief meeting between the parties to a formal public meeting with an independent facilitator or chairman.

The decision: If there were no submissions against the application, the decision is made by council staff. If there were submissions against the application a hearing is held. The hearing committee is usually made up of three elected council members. At the hearing, the applicant, the submitters, and council staff present evidence, as if in a law court. Then the committee make their decision based on the evidence, stating whether the consents are to be granted, their duration, and what the conditions are.

Appeals: If the applicant does not agree with the decision made by council staff, they may appeal to the council. In the case of a decision made by hearings committee, the applicant or any of the submitters may appeal to the environment court. The environment court is presided over by a judge and operates in the manner of a full judicial court. Applicants to the court need lawyers, and the winner may have to pay all the costs of the loser. A decision of the environment court may be appealed in the High Court, but only on a question of law.

Costs: The costs associated with obtaining a Resource Consent depend on several factors such as
- How detailed the applicant's Assessment of Environmental Effects needs to be;
- How long Council staff spend assessing the application;
- Whether the application needs to be notified;
- Whether there are submitters against the application, which leads to a hearing;
- Whether the consent decision is appealed in the Environment Court.

3.5 Resource consent conditions

Resource consent conditions fall into three main types:

- *Physical conditions* limiting the physical details of what the consent allows, e.g. volume of take or discharge, location of take or discharge;
- *Monitoring conditions* requiring environmental monitoring and reporting;
- *Standard conditions* relating to such administrative matters as site access, opportunity to review conditions, and consent-holder charges.

Recently Waikato regional council has adopted a policy of requiring developers wishing to drill a deep geothermal well to provide a $200,000 bond to cover "abandonment" costs in the event of the company being unable or unwilling to close in the bore at the end of its useful life. Closure must be to the standards of the Code of practice for deep geothermal wells.

All consents except the bore permits carry an annual charge. The charge is in the range US$30-1000. Most geothermal power stations have about 15 consents costing about US$700 each, per annum, to cover administration, general environmental information gathering, state of the environment reporting, and development of policy and plans.

The RMA requires regional councils to monitor consents. Each year in the Waikato region, theconsents for geothermal developments are examined to see whether monitoring and reporting conditions have been complied with. The site is visited by council staff, who also look for unauthorised activities and potential hazards. Compliance monitoring reports are then sent to the developer setting out the consent conditions which have not been complied with (if any), and any issues of concern to council staff.

From time to time people make complaints regarding various activities of geothermal power stations. Examples include discharging pollutants to a river, dumping asbestos into geothermal features, discharging to air without a consent, H_2S odour nuisance, steam nuisance across a road, taking more steam than their consent allows, and diverting a stream without a consent. All complaints are investigated. A staff member will usually go to the site and take samples, photos, and other evidence where appropriate, interview people on site, and interview the complainant. If the complaint is justified, prosecution may ensue but usually it is enough to threaten to prosecute. Regional councils are able to recover all costs for a justifiable complaint.

If a developer contravenes a regulation or resource consent, the council can issue a legally enforceable *abatement notice* ordering them to stop. The developer can appeal to the environment court against the abatement notice. If they do so, they can continue with the activity until the case is heard. In order to make sure that the person has no right of appeal, the council can apply to the environment court for an *enforcement order*. This takes effect once the case is heard. To make sure that the person stops the activity immediately the council can apply to the district court or the environment court for *an interim enforcement order*. If granted, this will remain in force until the *enforcement order* is heard, or until it is cancelled.

A developer can be prosecuted for contravening those sections of the RMA which impose duties and restrictions in relation to land, subdivision, the coastal marine area, the beds of certain rivers and lakes, water, and discharges of contaminants, any enforcement order or abatement notice, and a range of other provisions. Penalties include imprisonment for up to 2 years and fines of up to US$100,000 plus a further fine of up to US$5,000 for every day that the offence continues.

Some regional councils have set up a *review panel* for each development, consisting of 3-5 geothermal experts (scientists and engineers)who are independent of the developer, to advise council about the development. Each year the developer has to submit a report about its operations to the panel, which then considers the report and gives its opinion to council about the state of the resource and makes suggestions about how the developer could improve the use of the resource and protection of the environment. The review panel may meet for 1-3 days each year, and the cost of the panel is borne by the developer. The use of a review panel minimises the need for council to have experts on its staff.

3.6 Case study: Consents for Ohaaki power station

In 1997 Contact Energy Ltd started liasing with Environment Waikato regarding renewal of resource consents for the Ohaaki geothermal power station. Several meetings were held and in late 1997 a draft application was presented to Waikato Regional Council for comment. In the meantime, Contact Energy Ltd were preparing their technical appendices and engaging in consultation meetings with affected parties including the local Maori tribe (on whose land the station was built by the government) and other local landowners.

A formal application was received from Contact Energy Limited in April 1998 for 15 resource consents to:

- Take and use up to 60,000 t/d of geothermal water;
- Take and use up to 71,000 t/d of water from the Waikato River for cooling ;
- Divert stormwater and to take and/or divert groundwater;
- Discharge up to 54,000 t/d of separated geothermal water via reinjection wells;
- Discharge stormwater onto and into land;
- Discharge up to 147,000 t/d of stormwater to the Waikato River;
- Discharge up to 2,000 t/d of geothermal water to the Waikato River;
- For the discharge of cooling water onto or into land) in the event of an emergency;
- Discharge antiscalants into land via wells (including circumstances where they may enter water);
- Discharge sewage into land and underground water through septic tanks;
- Discharge up to 2,400 t/d of separated geothermal water to the Ohaaki Pool;
- Discharge geothermal water from the Ohaaki Pool to the Waikato River;
- Discharge debris to the Waikato River associated with the cleaning of the water intake screens;
- Construct and upgrade structures in, on, under, and/or over the bed of the Waikato River;
- Excavation, well drilling, metal extraction, earthworks, roadwork's, less than 5 metres from the bed of the Waikato River.

The application requested a term of 25 years. The application was a 150-page document accompanied by a set of technical appendices of several hundred pages.

The application was publicly notified in local newspapers, and nine submissions were received. Six were in opposition, one was neutral, and two were in support subject to conditions of consent. Land subsidence was a major issue for the local Maori people whose sacred sites and buildings were subsiding into the Waikato River.

A *hearings committee* comprising of councillors conducted a four-day hearing for the purpose of enquiring into the application and submissions thereto. A site visit was held as part of the hearing, including a visit to sites of spiritual significance to local Maori.

The *hearing* was adjourned in September 1998 for a period of four weeks following a request from a submitter for the committee to seek legal advice regarding whether the committee was able to call an adjournment for a year in order to give the applicant time to satisfy the concerns of the submitter.

The hearing was closed in October 1998. The committee had received legal advice that an adjournment of one year was not allowed for in the RMA. The committee recommended that the application be granted and that a term of 15 years be applied as:

- Predictions beyond 15 years are difficult to provide with accuracy;
- Significant effects have occurred over a period of 10 years;
- Most submitters had relevant concerns about a longer term including effects, changes in technology, economic stability, and site management of owners, new or otherwise.

In November 1998 a landowner of part of the Ohaaki land appealed to the environment court against the decision, on the grounds that the decision would result in further land subsidence. On the same day Contact Energy Ltd filed an appeal against the decision on the grounds that the term should be for 25 years. Contact Energy also applied to the court to have the appeal struck out on the grounds that the person had not himself submitted to the application, and therefore had no status before the court.

The landowners appeal was subsequently struck out by the judge, who found that the person was not a beneficial landowner, although his father was. Contact Energy's appeal against the term was then withdrawn and the consents granted.

3.7 Results of the RMA process

The public hearing process has generally worked well for members of the public because they have the opportunity to directly voice their environmental concerns to the regulatory authorities in an informal setting. Furthermore, information about a development and the results of monitoring becomes public knowledge.

However, the developer has more financial resources than individual members of the public and if the resource consents are not obtained, or obtained with what the developer considers are onerous conditions, then an appeal is often made to the environment court. Defending such an appeal may be very costly, and few individuals can risk losing such a case. The cost and publicity of legal action also can intimidate councils.

An unexpected outcome of the RMA process has been its use by one developer to stop or hinder a competitor. Each developer opposes granting of resource consents to competitors on environmental grounds. Since they both have the financial resources to hire lawyers and scientists to argue their respective cases, the hearings and court cases become extended. An additional, and unfortunate, outcome of this has been that developers have concentrated on the legal battles to the detriment of other activities that might improve the environment, and have reduced monitoring to the minimum required because it may be used in evidence against them.

4. PROTECTION THROUGH ECONOMIC MEASURES

4.1 Royalty or user charges

Rotorua provides a good example of how economic measures can be used to protect the environment, and how these may in some circumstances be superior to regulations (O'Shaughnessy, 2000).

The Rotorua City Geothermal Empowering Act 1967 (RCGEA) gave the Rotorua district council (local government) control of all geothermal use within the city. However, despite the requirement by this act to issue licences, no licences were issued during the 19 years the act was in force. This was, in part, because the act focussed on safe exploitation of geothermal energy, with no regard for sustainability of the resource or protection of surface thermal features. In 1979, when Papakura Geyser ceased erupting, public and scientific concern resulted in the Rotorua district council imposing a moratorium (in 1980) on any new wells being drilled (Figure 33) within a 1.5 km radius of Pohutu Geyser. However, replacement of existing wells was allowed in this zone, with often farcical consequences. For example, a property with a house would be bought by a company and re-developed as a motel complex, the small shallow well on the property was then alleged to have "failed", and replaced by a deeper and larger diameter well from which a much greater quantity of hot water and steam was drawn. Extraction of geothermal water within 1.5 km of Pohutu Geyser was therefore allowed to increase significantly under that policy. This lack of effective management contributed to central government revoking the RCGEA in 1986, and forcing the closure of all wells within 1.5 km of Pohutu Geyser. The district council may secretly have welcomed this intervention by central government, because it removed from them any need to enforce locally unpopular management conditions.

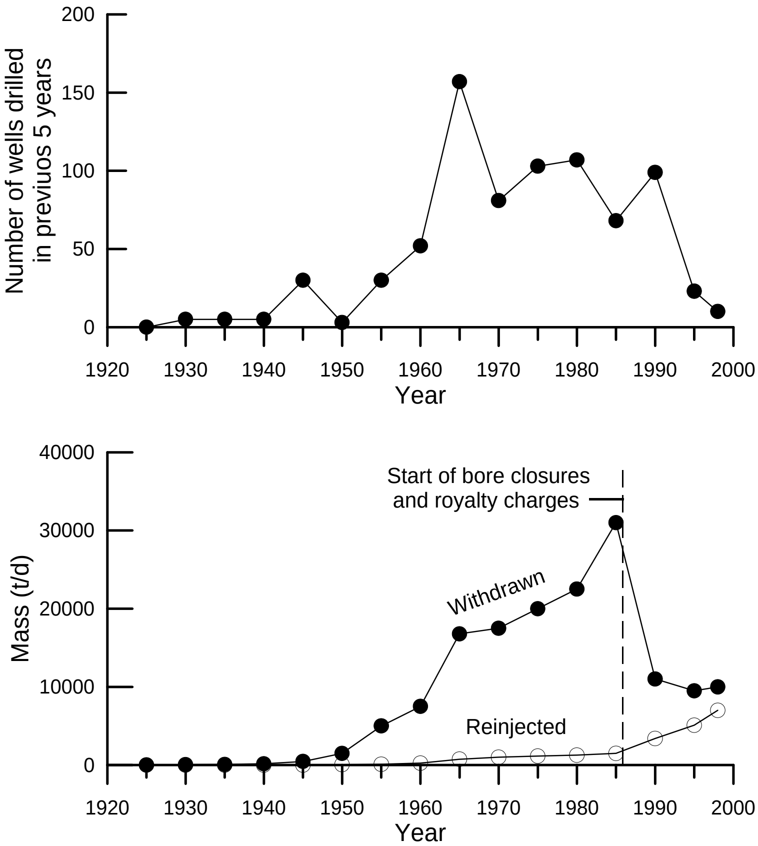

FIGURE 33: Graphs showing the number of new wells drilled and mass of fluid withdrawn and reinjected at Rotorua City; note the decrease in number of new wells drilled and increase in the amount of fluid reinjected following imposition of economic measures

A punitive annual royalty charge was also imposed on all remaining wells, starting from 1 April 1987. These were deliberately set at a high level and were calculated on the maximum possible well discharge and temperature, regardless of actual use. Depending on which part of the city a well was located, this led to many anomalies; i.e. a single pensioner could have incurred royalty fees of US$7,000 per year, whereas a large motel with a low-pressure/low-temperature well might have paid only US$300 per year. However, these royalty charges were very efficient in further reducing total well draw-off during 1987-1992. At the start of this period, many people took advantage of an opportunity for free closure by cement grouting to escape the annual royalty charges. This resulted in a greater reduction of well draw-off (approximately 125 wells closed) than did the enforced closures of wells.

4.2 Bonds

Another economic measure which can be effectively used to protect the environment is the requirement for a developer to deposit a large refundable bond that is forfeited if environmental damage occurs. Interest on the bond money, less an amount to cover taxes and inflation, would be returned annually to the developer. Although the damage may not be able to be rectified by money, the potential loss of a large amount of money may keep a developer more focussed on the environment and the consequences of his actions. Such a system is particularly effective when there is the suspicion that a development company will not be able to meet its obligations either through lack of expertise or financial problems. Another situation where this is effective is for a public company where the profits, share value, and bonuses of the managers may be adversely affected by loss of the bond.

5. SUMMARY

Effective countermeasures are available to minimise most impacts. These include:

- Careful planning to reduce impacts of access and site development;
- Muffling of equipment to reduce drilling and operational noise;
- Maintaining reservoir pressures to lessen the chances of natural thermal features and groundwater supplies being affected, and ground subsidence occurring;
- Reinjecting all waste liquids deep into the ground to avoid potentially toxic fluids affecting living organisms and contaminating shallow groundwater aquifers;
- Minimising reinjection pressures to reduce the chances of inducing small earthquakes;
- Designing power stations to minimise gas discharges.

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LECTURE 5

MICROGRAVITY MONITORING

1. GRAVITY

1.1 Fundamental concepts

Gravity is a fundamental, attractive, force *(f)* which acts between all bodies of matter, and is given by Newton's Universal Law of Gravitation.

$$f = -G\left(\frac{M_1 M_2}{r^2}\right)$$

where G is the universal gravitational constant (6.673 x 10^{-11} m^3 kg^{-1} s^{-2}), M_1 and M_2 are the masses of the bodies, and r is the distance between them. Rearranging this equation

$$f = M_1\left(\frac{-GM_2}{r^2}\right) = M_1 g_2$$

Newton's 2nd Law of Motion states that force is the product of mass and acceleration, hence g_2 represents an acceleration. If M_1 is free to move, it will be drawn towards M_2 at a speed which constantly increases (accelerates) at a rate g_2. The term g_2 is the value of gravity of M_2 at distance r, thus *gravity is the capacity of a body to accelerate other objects*. In practice, for geophysicists, it is the force which causes unsupported objects near the Earth's surface to move towards the centre of the Earth.

The force of gravity exerted by a body is pervasive and acts on all other bodies in the universe. It is a potential field, and has no gaps or discontinuities. The force of gravity at a point can be represented by a vector whose magnitude and direction are the sum of the attraction of all bodies in the universe. In practice, however, the main component of gravity at points on the Earth's surface is from the Earth itself (99.9999%), with secondary components from the Sun and Moon. The gravity effects (at the Earth's surface) of other celestial bodies (planets, stars) are negligible, despite what astrologers might say.

1.2 Units

A gravitational field may be characterised in two equivalent ways: by the acceleration produced on a body placed in the field or by the force produced per unit mass. These lead, in the S.I. (System International) to the dimensionally equivalent units of metre per second squared (m/s^2) and Newton per kilogram (N/kg) respectively. However, a common unit of gravity used in geophysics is the *gal* (named after the astronomer Gallileo), and derived from the old cgs system of units:1 gal = 1 cm/s^2 = 10^{-2} m/s^2. In microgravity work this unit is too large and a sub-multiple, the *microgal*, is generally used:

$$1 \text{ microgal } (\mu\text{gal}) = 10^{-8} \text{ m/s}^2$$

The term *microgravity* is generally used to distinguish data in the range 1-500 microgal (0.001-0.5 milligal) from those in geophysical prospecting (Bouguer anomalies) which usually lie in the range 500-100,000 microgal (0.5-100 milligal). Microgravity measurements are therefore 1- 2 orders of magnitude smaller than those normally encountered in geophysical prospecting. Values of gravity on the Earth's surface are about 9.8 m/s^2 (9.8 x 10^8 microgal), hence one microgal represents about 1 part in 1000 million of the Earth's field.

2. EARTH'S GRAVITY FIELD

2.1 Components of the gravity field

Gravity at points on the Earth's surface has two principal components:

a) *Mass component* - caused by the direct attraction of the mass of the Earth itself (including its atmosphere) and of the Sun and Moon. This is oriented inwards towards the centre of the Earth:

$$f_m = \frac{GM}{r^2}$$

where G = Universal gravitational constant;
M = Mass of the Earth; and
r = Distance of the point from the centre of mass.

b) *Centrifugal component* - that caused by the effects of the diurnal (daily) rotation of the Earth. This is oriented perpendicular to the axis of rotation (line joining the geographical poles) and is outwards:

$$f_c = w^2 d$$

where w = Angular velocity of rotation; and
d = Distance from the axis of rotation.

The value of gravity at a point on the Earth's surface is the vector sum of these two components, however, the mass component is much larger than the centrifugal component.

2.2 Variation with position

Because of the Earth's rotation and finite rigidity the Earth is not a perfect sphere but an ellipsoid, and so the mass component (f_m) varies from place to place depending on the distance from the centre of the Earth. At the equator the centrifugal component is at a maximum, and at the geographic poles it is zero.

Gravity at points on the Earth surface varies with position due mainly to: change in the centrifugal component with latitude, non-spherical (ellipsoidal) shape of the Earth, and local variations of density within the Earth.

Gravity varies with respect to:
Height above sea level - by about 300 microgal/m
Latitude - by 0 (poles) to about 0.8 microgal/m (at about 45°S)
Longitude - by < 0.01 microgal/m

2.3 Variations with time (Longman, 1959; Broucke et al., 1982; Melchior, 1983; Torge, 1989)

For relatively short periods of time (< 100 years) the rate of rotation of the Earth, and hence the centrifugal component at a point, is constant, although over geological time periods the rate of rotation (angular velocity) may have slowly decreased due to frictional drag of water in the oceans.

The mass component at a point changes with time, due mainly to changes in position of the Sun and Moon relative to the Earth. The maximum amplitude of the gravity changes is 240 microgal, and the maximum rate of change is about 50 microgal/hour. Changes due to motion of other celestial bodies are negligible (< 1 microgal).

Since the relative paths of the Earth, Moon and Sun are well known from astronomical observations, the gravitational effect at any point of the Earth's surface at any time can be predicted. These gravity changes are called the Earth-tide effect. The effect is periodic, being produced by the same force that produces the ocean tides.

Gravity variations associated with the exploitation of geothermal fields are similar in amplitude to the Earth-tide effect, and so the latter must be corrected for in order to isolate exploitation induced variations. Corrections using standard tidal prediction tables or computer programs are usually of sufficient accuracy. Three complicating factors need to be addressed when applying a tidal correction to gravity data in which variations of less than 10 microgal are being investigated:

a) The predicted tidal effect on a spherical solid Earth needs to be multiplied by the *amplification factor* to give a closer approximation to the effect on a real (elastic) Earth. The magnitude of the elastic contribution is determined by the distribution and tidal redistribution of mass below the surface, and is also latitude dependent because of the Earth's oblateness and the Coriolis force. The average value of the gravimetric factor is 1.16, with a normal range of 1.155 - 1.165.

b) *Phase differences* or *phase lag* of -6° to + 3° between observed "elastic Earth" and the predicted "solid Earth" tides result from the non-instantaneous response of the oceans (due to inertial and sea-bottom topography effects).

c) The *ocean loading effect* is caused by a combination of tilting of tectonic plates as the water mass distribution in the oceans varies tidally, and variation in the gravitational attraction of this varying water mass. Together, these may account for up to 4% of the *observed* Earth tide, in coastal regions, i.e. up to 10 microgal.

Each of these factors can be quantified, for a particular location, by recording gravity continuously for a period of 3-12 months and comparing the observed combined tidal amplitudes and phases with the predicted solid Earth-tide Effect. In general, however, it is adequate for most microgravity surveys in geothermal fields to take the predicted tide, multiplied by the standard gravimetric factor (1.16), in order to calculate the Earth-tide correction.

In terms of errors introduced by incorrect tidal corrections, timing is the most critical since tidal gravity varies by as much as 1 microgal/min. Errors in the tidal correction due to poorly specified station locations (latitude, longitude and elevation) are less important, provided elevations are known to a few hundred metres and horizontal coordinates to a few kilometres. With suitable attention to these factors (particularly timing) the error in the tidal correction can be reduced to be less than 1 microgal.

It is important when comparing the results of different surveys over the same geothermal field, that the surveys have been reduced using the same parameters to avoid introduction of a bias.

2.4 Changes in position of mass in the Earth

Such changes can occur over time periods ranging from several minutes to several years and may result from:

- *Mass changes* in geothermal or petroleum reservoirs as a result of exploitation.
- *Atmospheric pressure variations* associated with weather; i.e. the lateral movement of high- and low-pressure air masses. Air pressure changes during or between surveys generally do not exceed 10 hPa (10 mbar), and are commonly less than 5 hPa, so these effects are rarely more than about 2 microgal in amplitude.
- *Variations in shallow groundwater level.*
- *Variations in soil moisture*. Rainfall can also cause an increase in saturation of the aeration zone as fluid percolates down from the surface. During a long dry period there may be a decrease in saturation due to evaporation from the ground surface, evapo-transpiration from plants, or simple downward percolation of fluid under gravity.

- *Active volcanism.* Emplacement of magma at shallow depths, or changes in the degree of vesiculation of magma in shallow magma bodies. Gravity changes of up to 400 microgal have been reported.
- *Mining operations.* Removal of mineral ore, coal, and rock from underground mines will cause gravity changes at the ground surface above the area of excavation.
- *Topographic changes.* Changes in surface topography, such as associated with road or canal construction, can cause local, but significant, gravity changes.
- *Ground subsidence* as a result *of fluid withdrawal.*

Movement of people or vehicles do not cause measurable changes in gravity because their mass is too small, although they may cause ground vibrations which influence gravity measurements.

3. GRAVITY MEASUREMENTS

The small magnitude of the gravity changes of interest for microgravity surveying require high-precision instrumentation, together with careful field practice and analysis techniques

3.1 Types of gravity meters

There are two types of instruments used for measuring gravity in the field (c.f. laboratory):

a) Absolute instruments - these measure the absolute value of gravity at a point.
b) Relative instruments - these measure differences in gravity between points.

Absolute gravity measurements are generally based on the determination of the fundamental quantities of acceleration (distance and time) from the free movement of a sensor in the Earth's gravity field. Currently, the free-fall method is commonly used; pendulum methods have largely ceased. The best absolute instruments can measure gravity with an error of about ±10 microgal, which is sufficient for microgravity work in geothermal systems, but such instruments are not portable. At present, semi-portable instruments can reach an accuracy of ±50 microgal, but they are large and slow to set up and use. Absolute instruments currently available are therefore unsuitable for microgravity surveys in geothermal systems. For further details of absolute instruments see Torge (1989).

Relative instruments such as those manufactured by LaCoste & Romberg (LCR) and Scintrex are the only readily available ones with the portability, ruggedness and precision suitable for microgravity surveys. The LaCoste & Romberg D- and G-type gravity meters are astatic meters which function like a long-period seismograph. A mass on the end of a beam is held in place at one end by a supporting beam, and is balanced by a stretched metal spring. The spring is set up in such a way that its extension is equal to the distance between the points at which its ends are fixed. It behaves as a "zero-length" spring because its length, which is defined as its real (unstretched) length minus its extension is zero. In reality it does not shrink away to nothing when no force is put onto the beam, because the spring is always under stress since it is coiled. When the torque on the mass (from the force of gravity) is perfectly balanced by the torque from the spring, the net torque on the mass becomes zero. In this case, the mass exhibits simple harmonic motion, but the period tends to infinity and the equilibrium is said to be unstable. Readings are taken visually by nulling a beam to a zero-point.

The Scintrex CG-3M instrument is a microprocessor-based automated gravity meter (Budetta and Carbone, 1997; Bonvalot et al., 1998). The gravity sensor consists of a proof mass suspended by a quartz spring, and there is a capacitive displacement transducer feedback system to move the mass back to a null position. Measurements are begun by pressing a key and readings are automatically made for a specified time or number. Readings are displayed on an LCD unit and stored in a digital memory, which allows each reading to be compared with the average of those already taken and stored or rejected. The Scintrex CG-3M instrument also has automatic corrections for tilting during the measurement sequence and drift.

Scintrex instruments are easier than LaCoste & Romberg for inexperienced operators to use, but suffer more from instrumental drift and calibration problems.

3.2 Tares

A tare is a sudden (< 1 s - 1 min) apparent jump in instrument reading (Torge, 1989). This may range in amplitude from a few microgal (limit of detection) to several milligal, and is an important and serious source of error in microgravity surveys using spring-type relative gravity meters. Both LaCoste & Romberg and Scintrex CG-3M gravity meters are subject to tares but the LCR instruments are much more susceptible to these. A tare is basically a jump in the zero point of the meter, and the change can be in either direction (increase or decrease in reading). There are two main types of tare:

a) **Thermal tares -** these occur when the thermostat and heater in the meter are unable to adjust the internal temperature to rapid external temperature changes. Such effects are likely to occur when the meter is removed from the carrying case into a cold environment, or conversely. To minimise the chances of this happening, the inside of the transport vehicle should be kept at a similar temperature to that outside (i.e. do not use heater or air-conditioner). Other causes of thermal tares can be poor battery contacts and damaged power supply cable. Even a drop of a fraction of a degree in temperature inside the instrument, for only a few minutes, will cause the apparent reading to drift for several hours and may result in a thermal tare.

b) **Mechanical tares -** these occur when a LaCoste & Romberg meter is knocked or jolted, either in a "clamped" or "unclamped" state; knocks to the meter when "unclamped" will result in larger tares than for similar knocks when "clamped". Special care must be taken, when removing or returning the meter to the carrying case, not to knock the legs (levelling screws) against the case (or its lid). Another common cause of a mechanical tare is dropping an object (pen, glasses, field book) on to the top of the meter during a reading.

It is very important that any incidents which might cause a tare, and the time at which they occur, are recorded to enable adjustments to be made during reduction of the data. Field experience suggests there is not necessarily a direct relationship between the size of the knock and the size of the tare induced; a small knock may induce a large (>50 microgal) tare, but a large knock will almost certainly induce a large tare. Tares can be minimised by careful field technique, but it is unusual for a survey of more than a few days to be completed without a tare occurring. If the meter is knocked then further (repeat) readings should be made as soon as possible at survey points recently occupied; this greatly assists in the accurate determination of the size of the tare.

3.3 Instrument drift

In spring type gravity meters, the readings at a point (corrected for the Earth-tide effect) will change slowly with time as a result of ageing of the springs in the meter, and this is called instrument drift. It can be considered as a slow and regular change of the zero point of the instrument. It is determined for each meter from the change in gravity at repeated points, after correcting for the effects of earth-tides and tares. Drift is generally assumed to be linear with time. La Coste & Romberg instruments may have drift rates of 50 microgal/day when new, but this reduces to less than 5 microgal/day after a few years. Scintrex instruments have much larger drift rates which are automatically compensated for during the (internal) reduction of the data., however, field experience shows that for microgravity work it is best to determine the drift independently of the microprocessor and apply a correction to each set of observations.

If preliminary calculations show that there is a large apparent drift rate (>100 microgal/day) then the observations and their residuals should be examined closely for tares. If the apparent drift rate exceeds 500 microgal/day, consideration should be given to repeating the observations. If consistently high drift rates occur then it is probable that the meter needs repairing. It is therefore desirable to use older meters for microgravity surveys, provided they have been well maintained.

3.4 Calibration

Relative gravity meters do not give a direct measurement of gravity, or gravity difference. For LaCoste & Romberg meters the instrument (dial) readings are converted to values of gravity, or strictly differences in readings to differences in gravity, by way of a calibration scale unique to each meter. A calibration scale is provided with each new meter by the manufacturer and is determined in the factory by temporarily adding small weights to the beam, and measurement of gravity at two absolute gravity stations. For LCR Model-G meters the calibration scale consists of a table of dial readings and gravity values, at 100 counter unit intervals (approx. 100 mgal). For LCR Model-D meters, the calibration scale is a single number. A plot of counter units against gravity value approximates a straight line. For most geophysical uses, such as making Bouguer anomaly surveys, this scale is sufficiently accurate and can be used for many years. However, this is insufficient for microgravity surveys, where very small differences are being sought, because the calibration varies with time as a result of ageing of the moving parts. One of the effects of ageing is to alter the slope of the calibration line. This effect can be corrected for by multiplying the gravity values in the calibration scale by a constant (at any one time), known as the Calibration correction factor (*f*), which has a value close to 1.00. This factor can be determined by making a survey along a calibration interval consisting of two (or more) points of accurately known gravity or gravity difference. Generally these points are incorporated in, or have been linked to, stations in the International Gravity Standardisation Net (IGNS 71).

Although the calibration line approximates a straight line, precise measurements show that in detail it is a wriggly or corrugated line (non-linear), unique to each meter. Most of the corrugations in the line are repetitive, and are the result of minor imperfections (eccentricities) in the manufacture of the gear wheels, in the measuring screw (micrometer), and in the levers connecting the screw to the beam. Experiments show that for G-meters (> G458) the non-linearities have periods of 1.00, 7.33, 36.67, 73.33 counter units, and for D-meters 0.1, 0.722, 1.625, 3.250 counter units. Errors arising from these imperfections are called periodic errors; they can be determined by rigorous measurements over a very accurately known gravity range, or by intercomparison with other gravity meters whose periodic errors have been determined. In some meters these errors may exceed 20 microgal. For most repeat surveys in geothermal fields the effects of periodic errors can be neglected, but those of changes in calibration with time cannot. Failure to account for the change in calibration with time (between surveys) may result in spurious gravity changes of more than 100 microgal. Before each survey the meter(s) should be run over a calibration interval (Δg_i) whose range of gravity values include those in the area of the geothermal field.

$$\textit{Calibration correction factor } (f) = \frac{\Delta g_i}{\Delta g_m}$$

Where Δg_m is the gravity difference measured over the interval assuming the manufacturers calibration scale (i.e. $f = 1$).

3.5 Reading procedure

In microgravity work it is very important that the same reading procedure is used at each point, and during each survey. No attempts should be made to hurry, or "short-cut", the reading procedure, and the observer should be kept free of physical distractions such as biting insects, radio music, uncomfortable reading positions. Experience has shown that measurements taken during poor weather conditions (rain, snow, extreme heat) are generally of poor quality and often need repeating.

4. SURVEY PROCEDURES

The aim of microgravity surveys is to precisely measure the value of gravity (g) at a point (x, y, z) at a specific time (t). This involves the precise measurement of gravity and removal or correction for spurious temporal effects that change the value of gravity. Survey procedures are used which maximise these requirements.

4.1 Network design

The principal aim of microgravity surveys in geothermal fields is to measure temporal gravity changes associated with exploitation. It is therefore important that the survey (measurement) points extend well beyond the area in which measurable exploitation-induced gravity changes occur. Assuming that any mass changes are confined to the field, then from simple calculations (finite plate) using mass extracted values, the extent of the points beyond the field can be estimated. For the Wairakei field (New Zealand), where most of the mass changes occur at depths of 100-500 m, such calculations show that the gravity effects of likely mass changes are undetectable (< 10 microgal) at distances of more than 2 km from the field. For geothermal fields in which exploitation causes significant mass changes at greater depths it is necessary to extend the survey points to greater distances beyond the field boundaries. In fields where it is known (or suspected) that production (or reinjection) causes mass changes outside the field then it is necessary to extend the survey points even further. Design of the network should ensure that about 20% of the survey points lie in places where there will be no measurable gravity changes. This is important because it allows for the position of the zero change contour to be well established; this is important for determining values for net mass change using Gauss's theorem (described later).

Survey points should be free from the effects of mechanically- or culturally-induced vibrations; away from main roads, pumps and other machinery. Survey points should not be on production/reinjection wellheads or well cellars (because they suffer from vibration and thermally-induced elevation changes), but experience has shown that some steam transmission pipeline supports are satisfactory. There should be easy road access to the survey points; so that the distance of hand-carrying the instrument is small. This not only minimises the chances of tares but ensures that the survey can be undertaken in the shortest possible time. Photographs and diagrams of each survey point should be made, and notes taken of the easiest and quickest way to get to the point.

During the development of a field (up to 30 years), engineering constructions (new pipelines, additional wells, and new roads) are added which result in the destruction of survey points. It is therefore important that in critical places, there is sufficient redundancy of survey points such that loss of some points does not significantly affect the usefulness of the microgravity programme. Construction engineers should be made aware of this problem so that, where necessary, new points can be established and gravity measurements made *before* destruction of old survey points. Ideally, the gravity difference between the old and new points should be measured before destruction of the old point.

Additional survey points should be positioned near places where gravity (mass) changes are likely to occur such as in areas of greatest mass production or reinjection, surface geothermal activity, and ground subsidence.

4.2 Survey points

It is of critical importance that survey points allow reoccupation of the point with a precision of ±0.5 cm vertically and ±1 cm horizontally, or better. The points should therefore be on permanent, concrete structures or benchmarks, and clearly identified by a pin and identification plate. The surface around the pin should be flat and horizontal, and made of concrete or other stable material; wooden steps or bare ground surfaces are unsuitable. To minimise the chances of damage to the survey point during construction work it is desirable to bury the survey points within a small, concrete-lined chamber.

4.3 Reference station

When computing (reducing) the gravity values from the instrument readings it is convenient to place all observations in terms of a reference or base station. Often this station will also be used to help determine instrument drift. Ideally, this reference station will be:

a) Easily accessible at the start and end of a day's observations;
b) Outside the field and in an area not affected by mass changes within the field, or shallow groundwater level fluctuations;
c) In a position unlikely to be damaged by engineering construction work;
d) In a position where it can easily be incorporated in levelling surveys associated with the geothermal field.

The possibility of the gravity values at the reference station changing with time (and hence systematic gravity differences at other survey points) can be checked by examining the gravity differences at other survey points distant from the field. Gravity changes at these points should be close to zero; if they are not then a base correction, obtained by averaging the differences at distant stations, can be applied.

4.4 Observation procedures

When using relative gravity meters, certain observation procedures are used to maximise the precision of calculating instrument drift and any tares which might occur, and to minimise the chances of measurement error.

- To improve determination of instrument drift, we assume that the drift rate can change (both in magnitude and direction) between successive days of observation, and after a tare. It is therefore important that at least two observations are made at most survey points during a day's work. However, a simple reversal of the measurement order should not be done. Experience suggests a near-random sequence is best. To improve the linkage between successive day's observations, it is important that each day's measurements contains observations at two or more survey points occupied the previous day.
- To improve determination of the magnitude of tares, when a tare is recognised or suspected during the survey then re-observations should be taken at one or (preferably) two survey points made immediately before the tare.
- To minimise the chances of measurement error influencing the results, at least three observations should be made at each survey point.
- It is customary, but not absolutely necessary, to start and finish one day's observations with readings at the reference station.

Measurements should be temporarily suspended if:

a) Long period seismic waves from an earthquake (teleseisms) make readings difficult. For large distant earthquakes these may continue for several hours.
b) The power supply to the gravity meter fails; this will cause the instrument to go "off-heat", and give erroneous readings. After reconnection to a stable power source, several hours should be allowed after the meter has re-established its operating temperature before observations are restarted. In reduction of the data, a power loss should be treated as a tare.
c) The gravity meter suffers (or is suspected to have) a large tare such as might result from it being dropped, or the transport vehicle is involved in a serious accident.

To avoid reader bias, the same observer and the same technique should be used throughout a survey. Experience has shown that the best results are obtained when a survey is carried out in a single, set of continuous daily observations. Breaks of several days or more during a survey generally result in poorer results (higher standard errors and residuals). Experience also shows that if the gravity meter has not been used for a long time before the start of the survey, then the first days observations may not be satisfactory and will need to be repeated.

To reduce the time between observations it is best if as many as possible of the survey marks are visited and prepared (vegetation and rubbish removed) before the measurement start. The measurements should be reduced as soon as possible, so that if remeasurements are required then the time gap between the main survey and the remeasurement survey is small.

4.5 Errors and blunders

Mistakes will occur during any set of gravity observations, and are called *blunders*. Few microgravity surveys are free from blunders, such as: occupation of the wrong survey point; transposition of numbers when recording the readings, forgetting to record all the data required (e.g. time), incorrect entry of data into the computer. Blunders are generally discovered during initial reduction of the observational data, and corrected using the redundancy of data available.

Errors are deviations from the correct or accurate measurement and are inherent in any set of observational data. Observations commonly have a normal or Gaussian distribution about the "true" value, and are random. However, some errors are consistently in one direction, and are known as bias.

A list of the main causes of errors is given in Table 5; most of these can be minimised (but not eliminated) by careful survey practices. If these practices are used, the main cause of large errors is that of tares. During reduction of the data, tares (both recognised and suspected) can be corrected for (see later) but those with an amplitude of less than about 20 microgal are difficult to determine and are generally neglected; in this case their effect is absorbed into the drift correction. Good estimates of the error of a gravity value at a survey point are given by the size of the residuals (differences between an individual observation and the mean at that point) and the standard error determined during reduction of the observational data. In a good survey these should be 5-10 microgal; a residual >20 microgal suggests a poor reading and may be discarded.

A good estimate of the error of gravity changes (differences in gravity between surveys, corrected for elevation and groundwater variations etc.) can be obtained from the standard deviation of the mean of changes at survey points located well outside the geothermal field. However, care must be taken to exclude data from survey points known or suspected to be located near any areas from which recharge fluid may have been withdrawn or reinjected fluid may have been deposited. Also excluded, must be data at points where a blunder has occurred, such as failure to reoccupy the same point.

5. INFRASTRUCTURE AND ORGANISATIONAL REQUIREMENTS

Conducting microgravity surveys require similar organisational support to other large geophysical surveys using advanced equipment (eg. MT, CSAMT, aeromagnetics). Good results will rarely be obtained from individuals working alone, or with inadequate support, or using gravity meters which have not been carefully used and maintained (eg. commercially hired instruments used extensively on prospecting surveys). Basic requirements are listed below.

TABLE 5: Summary of external, instrumental and reading errors associated with use of LaCoste and Romberg model G gravity meter (from Rymer, 1989)

Cause	Comments	Approx. size of error	
		maximum	**minimum**
External			
Earth tide amplification factor	Value ranges from 1.155 to 1.165 depending on Love numbers and latitude	< 2 μgal	< 1 μgal
Phase lag	Observed and predicted tides may be out of phase by -6° to +3°	Unknown but small	(< 1 μgal)
Ocean loading	Caused by tilting the shoreline and the gravitational attraction of mass of water in the oceans	< 10 μgal	1 μgal
Noise	Low frequency (< 1 Hz) disturbances caused by wind, surf, and distant earthquakes cause beam to swing: also produce tares	< 50 μgal	1 μgal
Reading			
Leg length	Height of meter is varied by changing leg lengths, gravity varies according to the free air gradient of -3 $\mu Gal\ cm^{-1}$	10 μgal	< 1 μgal
Sensitivity and levelling	Sensitivity can be varied manually, but it drifts with time. Failure to level, especially along the long level, effective-ly changes the reading line and changes the sensitivity.	< 20 μgal	
Dial movements	Slack (backlash) in the gears will cause errors unless the reading is approached from the same side each time	< 40 μgal	< 1 μgal
Timing	Provided the reading is steady, there is no evidence that there is an advantage in waiting before making a reading	Negligible	-
Instrumental			
Movement of instrument	The rms deviation about the mean reading when the gravity meter is moved between readings is greater than if it is not moved between readings		
Meter calibration	Polynomials and Fourier series can be used to model the calibration features. There are periodic terms due to the way the LCR is constructed, but over small ranges the effect can be kept down to a few microgals.	500 μgal in 500 mgal or 0.1%	< 1 μgal
Thermally-induced tares	Low battery power or a sudden change in external temperature may cause a thermal shock to the measuring system unless a secondary thermostat is fitted. If the internal temperature is allowed to fall to room temperature the effect is much larger.	~ 10 mgal	
Shock-induced tares	Hysteresis effects in the spring and physical jolting of the system can cause tares of almost any magnitude	~ 10 mgal	< 1 μgal
Total		50 μgal to several mgal	< 10 μgal

5.1 Field staff

Staff should be trained in the use of high precision gravimetry, and understand the principles involved. Although experience in making Bouguer anomaly type of gravity surveys is helpful, this is not sufficient training because of the increased care and knowledge needed for microgravity measurements. Field staff should be meticulous in making and recording the data. Staff should be encouraged to immediately report or record all mistakes; it should be made quite clear to them that this is important and that no punitive action will result from unintentional mistakes. During the survey, staff must be under no pressure to complete work by a specific time or date. The taking of gravity measurements must be the prime, and only job, being carried out. New staff should serve an "apprenticeship" with an experienced person.

5.2 Equipment

The gravity meter should be one which has been carefully maintained and whose history is known. Meters rented from commercial geophysical supply companies are not suitable; their maintenance history is not known (seals may be defective; magnetic shielding may have been reduced) and they are likely to have been used in severe operating conditions. Whenever possible, the same instrument, and the same operator, should be used in successive surveys. Equipment should be transported in a well-maintained 4-wheel drive vehicle, preferably fitted with a sprung carrying box for the instruments. The vehicle should not be driven at high speed over rough roads; the driver should be aware that jolting during transport is a major cause of poor results (tares) and will result in repeat measurements having to be made. Good maps and survey point location diagrams are needed.

5.3 Office staff and facilities

Staff involved in reduction of the gravity data should be experienced in gravity data and its collection; this is important because it enables them to recognise and correct simple mistakes made in the field (e.g. transposition of numbers during recording of field data). Reduction of data should take place during or immediately after the survey. This enables dubious or unusual data to be checked or remeasured as quickly as possible.

6. REDUCTION OF GRAVITY OBSERVATIONS

To determine the value of gravity at a survey point (observed g) the meter readings must be converted into gravity values (using calibration data), and corrections made for short-term temporal effects (Earth-tide, instrument drift, and tares). A number of computer programs are available to do this.

In New Zealand, a program is used in which the whole set of observational data for a survey is taken and the values of relative gravity (at each point) are calculated using the Least squares method. The readings themselves, and not the differences between successive readings, are used for the observation equations. Using this program for reduction of the observational data, to provide values of observed gravity (or strictly gravity difference with respect to an arbitrary base value) is an iterative process which involves subjective judgements by the person running the program. The first step is to locate mistakes in the input data file caused by (in approximate order of likelihood): mistakes in entering the field data into the computer, mistakes in recording the field data, malfunction of the gravity meter. The program is first run, with large values adopted for the blunder rates (say 0.1) and standard errors (say 0.5). Such mistakes will quickly become apparent and be signalled by very large residuals (>20 microgal), high daily drift rates (>500 microgal/day), or failure of the program to complete the calculations. The next step is to start progressively reducing the values for blunder rates and expected standard errors, and begin searching for unrecognised (in the field) tares. Such tares show as sudden changes in the sign and amplitude of residuals, and by the presence of high drift rates. At this point it may also be decided to remove certain individual observations which do not appear to be in error, but they have large (>30 microgal) residuals. However, it is unlikely that more than 1% of the observations in a survey will fall into this category. Finally, we begin weighting the iterative process, starting with limits of 0.5 and progressively reducing to 0.01, or until the values of observed g do not change significantly (< say 2 microgal) between runs. At this stage a "satisfactory solution" has been obtained

7. GRAVITY DIFFERENCES

Gravity values at a point in a geothermal field often differ between surveys. These differences (apart from instrumental and reading errors) may result from (in approximate order of magnitude):

- Mass changes in the geothermal reservoir (what we seek to determine);
- Vertical ground movements (subsidence or inflation);
- Changes in groundwater level;
- Changes in saturation (soil moisture content) in the aeration zone;
- Local topographic changes;
- Horizontal ground movements;
- Changes in gravity at the base station.

Gravity values may also vary with time as a result of deep-seated regional mass movements (active volcanism) but because geothermal fields generally occupy a relatively small area, and the difference in time between surveys is relatively short, the gravity effects of such movements are usually small and can be neglected.

The gravity effects of mass movements in the geothermal reservoir, called *gravity changes* (or "corrected gravity differences"), are obtained by correcting the observed gravity differences for the effects of ground movements, and changes in groundwater level and soil moisture.

7.1 Vertical ground movements

Exploitation of a geothermal system often causes vertical ground movements; generally subsidence in or near to production areas, and sometimes inflation near to reinjection wells. The size and location of these movements are not predictable, and can only be determined by repeat levelling surveys. The largest movements are generally ground subsidence; in one area of the Wairakei field, subsidence (over a 30 year period) has exceeded 15 m, but inflation has been less than 0.01 m.

Assuming (initially) that there are no mass changes involved, the effect of ground movement at a point is to move the gravity meter through the Earth's gravity field: Subsidence will result in the instrument being brought closer to the centre of mass of the Earth thus increasing the apparent value of gravity, and conversely inflation will decrease the value of gravity. The size of this increase or decrease (Δg_v) will be governed by the *vertical gravity gradient* (*dg/dz*) in the vicinity of the point.

$$\Delta g_v = \frac{dg}{dz}\Delta h$$

where Δh is the amount of subsidence or inflation, and Δh is small (i.e. changes in the gradient can be neglected). As a first approximation, the vertical gradient can be determined from the gravity field of the reference ellipsoid derived from world-wide gravity measurements. This yields a value of -308.6 microgal/m (at sea level, lat. 45°); this is the value commonly employed as the *free-air correction* in Bouguer anomaly surveys.

However, the vertical gradient varies from place to place (by up to 10%) depending on the latitude and elevation of the point, and on the mass distribution (topography and geology) near the point. Values for the vertical gradient can be determined by making gravity measurements at two (or more) different heights at a place. To obtain values for the gravity gradient with sufficient precision it is generally necessary to have a vertical separation of 1 m (or greater) between the upper and lower measurement points.

Note that in correcting the observed gravity differences it is assumed that there is no mass change involved in the subsidence or inflation; the gravity effects of such mass change will therefore be incorporated or remain in the gravity change value determined and may need to be accounted for in interpretation of that change. Simple calculations, using reasonable models for mass changes during exploitation, indicate that the effects of exploitation have negligible effects on the value for the vertical gravity gradient at the surface; the value of the gradient is dominated by the mass attraction effect of the rock and immobile water.

7.2 Groundwater level changes

In many geothermal fields the hot reservoir is overlain, near the surface, by a cold groundwater system which in turn is overlain by a zone of aeration (vadose zone). Pores and fractures in rocks within the groundwater system are saturated with cold water, generally originating from percolation of rainfall (meteoric water) down through the aeration zone or lateral flow of groundwater.
In many places the groundwater level (i.e. boundary between groundwater and aeration zone) varies with time. Percolation of rainfall or snow melt downwards through the aeration zone may cause the groundwater level to rise. During periods of low rainfall, drought, or pumping from shallow wells (for irrigation purposes) the groundwater level may fall. In places with strongly seasonal rainfall the groundwater level may vary by 5-10 m over periods of a few weeks or months. The gravitational effects of such variations need to be corrected for.

The gravity effect (Δg_w), at a point on the ground surface, of a change in groundwater level (Δh) is given (Allis and Hunt, 1986; Torge, 1989) by:

$$\Delta g_w = 2\pi G\rho\varphi(1-S)\Delta h$$

where G = Gravitational constant (6.673×10^{-11} m^3 kg^{-1} s^{-2});
ρ = Density of the water (kg m^{-3});
φ = Effective porosity of the rock (dimensionless); and
S = Saturation (fraction of pore volume with liquid) in the aeration zone prior to the change (dimensionless).

In rocks with high permeability, S will generally approximate the residual saturation or specific retention; in rocks with low permeability, S will approximate the field capacity.

Ideally, groundwater level changes would be known from measurements in shallow wells alongside each survey point. However, drilling and monitoring of such a large number of wells is too costly. Instead, data from a smaller number of wells scattered throughout the geothermal field are used, and the value of groundwater level change is obtained by interpolating values from a map of water level change obtained by contouring this data.

7.3 Changes in saturation in the aeration zone

Rainfall or snow melting can result in an increase in saturation of the aeration zone (soil moisture content) as the fluid percolates down. During a long dry period there may be a decrease in saturation due to evaporation from the ground surface, evapo-transpiration from plants, or simple downward percolation of fluid under gravity. These effects can lead to significant mass changes with the aeration zone, and hence gravity changes at the surface.

The gravity effect (Δg_a), at a point on the ground surface, of a change in saturation (ΔS) in an aeration zone of thickness (d), is given by:

$$\Delta g_a = 2\pi G\rho\varphi\Delta S d$$

Few studies have been made which quantify the changes in saturation with time in this zone. Makinen and Tattari (1991) measured gravity changes of about 12 microgal amplitude over periods of several months, associated with changes in soil moisture content of sand and silt at several places in Finland. Here, the amplitudes of the gravity changes were similar to those associated with changes in groundwater level. Ideally, therefore, measurements of soil moisture should be taken regularly, at the same time as depth of groundwater level. However, this is not a trivial matter, and requires use of Time Domain Reflectometry (TDR) equipment to measure changes in water saturation. A first approximation for the gravity effect would be to multiply the gravity effect of the (much more easily determined) groundwater level change, by a simple factor determined from TDR measurements at a few points.

7.4 Local topographical changes

Mass changes adjacent to one, or a few, survey points may occur as a result of engineering construction work in the geothermal field. Common situations are cutting or filling of road embankments, digging of drainage channels, and excavation of building sites. Generally, the gravity effects of these are negligible unless the construction is very large or very close (few metres) to the survey point. A correction value (Δg_t) can be estimated using terrain correction tables in standard geophysical prospecting text books, or using simple 2-D or 3-D computer programs.

7.5 Horizontal ground movements

Large vertical ground movements (subsidence) associated with exploitation may also be accompanied by horizontal ground movement. At Wairakei, horizontal movements of up to 1 m have been measured. Field tests suggest that the gravity effects of horizontal movements are negligible (< 1 microgal) because the nearby topography moves with the survey point. However, this is quite different from failure to accurately reposition the gravity meter over a survey point close to a topographic feature. In this case, large apparent gravity differences may occur because the instrument has been moved through a large horizontal gravity gradient associated with the nearby topography: such a case would be when the survey point is on top of, and near the edge, of a pier or pipeline support.

7.6 Base changes and correction

It is usual, when computing values of observed gravity from relative gravity meter data, to place the values in terms of a base or reference station having a fixed value which is assumed to be constant during the survey (apart from Earth-tide effects which are computed and accounted for). This assumption is generally valid because the time period for the survey is relatively short, and the base station is outside the geothermal field (and so not affected by temporal mass changes within the field or ground subsidence). However, the gravity value at the base may change between different surveys, due to a local variation in groundwater level. If this happens, and the same base value is used in the data reduction, then the gravity differences at all other stations will be changed by this amount; i.e. the differences will be biassed. One way of checking and correcting for this bias is to examine the gravity differences at survey points well outside the geothermal field. If there has been no gravity change at the base, then the mean of gravity changes at these points should be zero, or less than the standard error of the gravity differences (generally < 5 microgal). If the mean value exceeds the standard error then a base correction should be applied such that the mean becomes zero.

7.7 Calculation of gravity change

The gravity change, at a point, is obtained using the equation:

$$\Delta g = (g_2 - g_1) + (dg/dz)h + \Delta g_w + \Delta g_a + \Delta g_t + b$$

where g_1,and g_2 are the values of observed gravity for survey times t_1, and t_2; (dg/dz) is the vertical gravity gradient; Δh is elevation change; Δg_w is the gravity effect of local groundwater level changes; Δg_a is the gravity effect of changes in soil moisture; Δg_t is the gravity effect of local topographic changes; and b is the base correction.

The values of gravity change (Δg), for the period $(t_2\text{-}t_1)$ are the prime quantities involved in microgravity analysis of exploitation-induced changes.

8. GRAVITY CHANGES

The main causes of gravity changes, associated with exploitation of a liquid-dominated geothermal reservoir are:

- Liquid (pressure) drawdown in the 2-phase zone;
- Saturation changes in the 2-phase zone;
- Changes in liquid density due to temperature changes.

These three physical causes of mass change combine to produce most of the gravity changes observed during exploitation of liquid-dominated geothermal systems. Note, however, that these are not independent of each other.

The gravity effects of pressure-induced liquid density changes, pore compaction, and mineral precipitation are generally insignificant (< 10 microgal), and can be neglected (Allis and Hunt, 1986).

8.1 Liquid drawdown

A primary effect of withdrawing fluid from a geothermal reservoir is the formation of a 2-phase zone near the top of the reservoir, and subsequent drawdown of the deep liquid level (Allis and Hunt, 1986). Downhole pressure and temperature measurements, and gravity change data, together with numerical simulation modelling (Hunt & Kissling, 1994), indicate that during initial exploitation this 2-phase zone quickly expands laterally and vertically, although the greatest vertical expansion is likely to be in the vicinity of the production bores.

If S_o is the residual saturation after drawdown, φ is the connected porosity, ρ_s is the steam density, ρ_w is the liquid water density, and G is the Universal gravitational constant, then the gravity change (Δg) due to drawdown of the deep liquid level is:

$$\Delta g = -2\pi G \varphi (\rho_w - \rho_s)(1 - S_o)h$$

where h = Thickness (or change in thickness) of the 2-phase zone.

This 1-d equation, derived by Allis and Hunt (1986), is valid provided, the lateral extent of 2-phase zone is large compared with its depth, connected porosity and saturation change are uniform, and temperature is uniform in the zone.

The main uncertainties which might affect the calculation are likely to be in the values adopted for φ, Δ*S*, and *h*. Values for connected porosity (φ) may vary by 10 or even 20% within and between adjacent rock units. Saturation changes are also likely to vary both laterally and vertically within the 2-phase zone (Hunt, 1988), but the maximum value will be set by the residual saturation (S_o).

$$\Delta S_{(max)} = (1 - S_o)$$

Data from Wairakei suggest that here S_o is likely to be about 0.5; note the large amount of immobile water this value represents. The value of h is difficult to determine because the deep liquid level (the point at which no vapour is present in the interstices): ($S = 1$) is difficult to locate. Indeed, there may be no point at which this occurs because steam may be present in large fractures to considerable depth. Despite these limitations, calculations using "best estimate" values for these parameters at Wairakei provided results consistent with other data. For example, taking $\varphi = 0.3$, $\rho_w - \rho_s = 850$ kg/m^3, $\Delta S = 0.5$, and $h = 100$ m, the expected gravity change is about -550 microgal, similar to that observed during the early stages of exploitation (Allis and Hunt, 1986).

8.2 Saturation changes

Data from well bores suggests that as exploitation proceeds, pressures in the 2-phase zone vary (increase or decrease) both in time and space as a result of:

a) Steam loss due to boiling (dry-out), which causes saturation to decrease, which involves mass decrease and hence gravity decreases;
b) Cooling and condensation resulting from inflowing water, which causes saturation to increase, which involves mass increase and hence gravity increases.

Experience suggests that saturation in the 2-phase zone will decrease over a wide area as exploitation proceeds, and will gradually approach residual saturation (S_o). However, in places, the pressure decrease will cause inflows of replacement water which are cooler and may result in local increases in saturation.

The gravity changes associated with a saturation change are given, as a first approximation, by

$$\Delta g = 2\pi G\varphi(\rho_w - \rho_s)\Delta S\, h$$

8.3 Changes in liquid density due to temperature changes

If the density of water in an aquifer changes due to a temperature change and no saturation change results (i.e. the aquifer is confined and the liquid volume remains constant), the resulting gravity change will be

$$\Delta g = 2\pi G\varphi\Delta\rho h$$

where $\Delta\rho$ = Average density change; and
h = Average aquifer thickness with changed temperature ΔT.

At about 200°C, the volumetric coefficient of thermal expansion for water is almost 2 orders of magnitude greater than that of rock, so the effects of changes in volume of rock can be ignored. For temperatures between 180 and 230°C, $\Delta\rho = 1.3 \times 10^{-3}\,\Delta T$. Taking $\varphi = 0.3$, the gravity effect is

$$\Delta g(microgal) = 0.015\,\Delta T h$$

where *h* is in metres, and Δ*T* is in °C. If the temperature of a 500 m thick aquifer decreases by an average 10°C in the temperature range 180-230°C, gravity will increase by about 75 microgal.

The uncertainties with this calculation are whether the aquifer is confined, and whether saturation changes could have occurred because of change in the vertical pressure gradient over some portion of the liquid column. If an increase in density due to a temperature decrease causes the water level (or a steam-water interface within the aquifer) to fall, then the calculated gravity increase will be overestimated. The amount of overestimation will be proportional to the value of $(1 - S_o)$ in the unsaturated zone above the changing water level.

The extent to which temperature changes cause changes in water level depends upon the permeability in the upper portion of the liquid-dominated zone. If there is a region of relatively high permeability near the water surface, then the pressure within this zone will control the height of the water surface. Pressure changes due to deeper temperature changes will be restricted to greater depth. Similarly, if there is low permeability near the water surface, then the underlying liquid column tends to be confined and there may be no changes in water level. The only circumstances favouring changes in water level are when there is good vertical permeability through the liquid column and when pressure in the column is controlled by good horizontal permeability beneath the zone of decreased temperature.

9. ANALYSIS OF GRAVITY CHANGE DATA

9.1 Determination of local areas of net mass loss/gain

Visual examination of a contour map of gravity changes for a period of time during which exploitation has occurred may show places where gravity has increased (net mass gain), decreased (net mass loss), or where there has been no change (at least not significantly greater than the error of the measurements). This map, when compared with a map showing the locations and amounts of mass withdrawal, may provide some useful information:

1. During the early stages of exploitation, when there may be formation and expansion of a 2-phase zone, the extent of gravity decreases will indicate the (minimum) extent of the 2-phase zone. This data can be very important where it provides information in areas of the field in which there are no drillholes. Indeed, microgravity data are probably the only surface measurements that will provide such information which is important in setting up, or verifying, numerical reservoir simulation models.

2. Comparison of gravity change and mass withdrawal maps may indicate, in a qualitative sense, the location of
   (a) places where fluid withdrawn has been completely recharged; here there will be no significant gravity changes despite mass withdrawal;
   (b) places distant from the borefield where fluid has been mined; here there will be significant gravity decreases;
   (c) places where reinjected fluid has moved to, and the path of that movement; here there will be significant gravity increases.

Such data, although strictly qualitative, quickly helps to give a picture of the mass movements that have occurred as a result of exploitation, and confirm or refute models derived from well-bore measurements which may be confined to only a small part of the field.

A good example is at Wairakei. Maps of gravity changes for various periods during development of the field are given in Figure 34, and a map showing the total measured changes up to 1994 is shown in Figure 35.

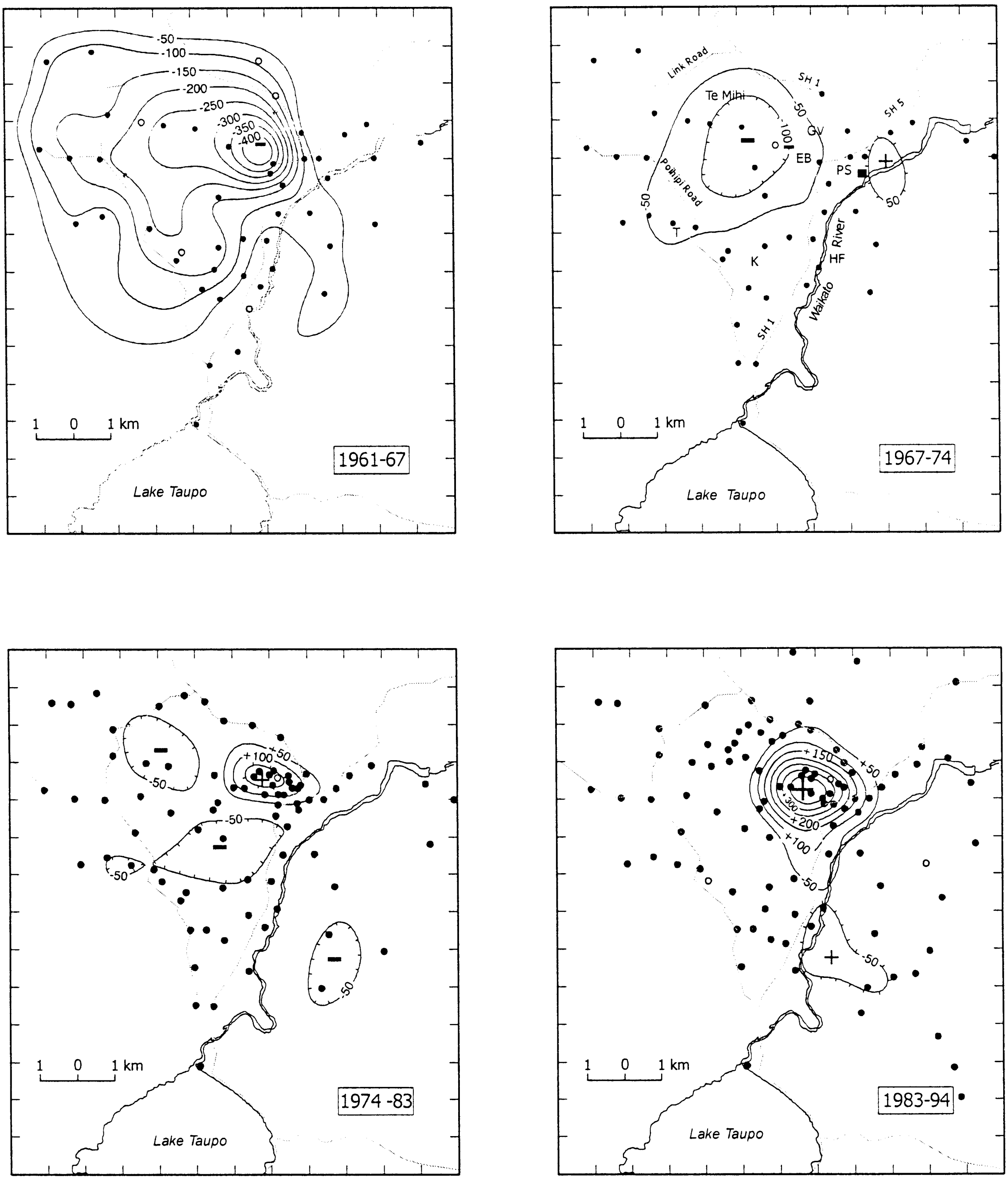

FIGURE 34: Gravity changes (corrected for ground subsidence) for various periods during the production period at Wairakei geothermal field, New Zealand. Contour values at 50 microgal intervals; zero contour has been omitted for clarity; solid dots are measurement used in contouring, open circles indicate measurements discarded. PS = Power station, EB = Eastern borefield, GV = Geyser valley, K = Karapiti thermal area, T = Tukairangi thermal area (Hunt, 1995 and updated)

9.2 Determination of recharge

The relation between the mass (M) of a body and its gravity effect is given by Gauss's theorem (Hammer, 1945; La Fehr, 1965):

$$M = \frac{1}{2\pi G} \iint_P g \, da$$

where G = Universal gravitational constant; and
g = The gravity value associated with an element of area a, over the plane of measurement P.

This formula is often used in mining geophysics to determine the (anomalous) mass associated with a Bouguer (or residual) anomaly. This formula can be extended (Hunt, 1970) to the case of a mass change (ΔM) and associated gravity changes dg:

$$\Delta M = \frac{1}{2\pi G}\iint dg\, da$$

To evaluate this integral, the simplest way (and sufficient considering the errors involved in the measurements) is to approximate the integral by a summation:

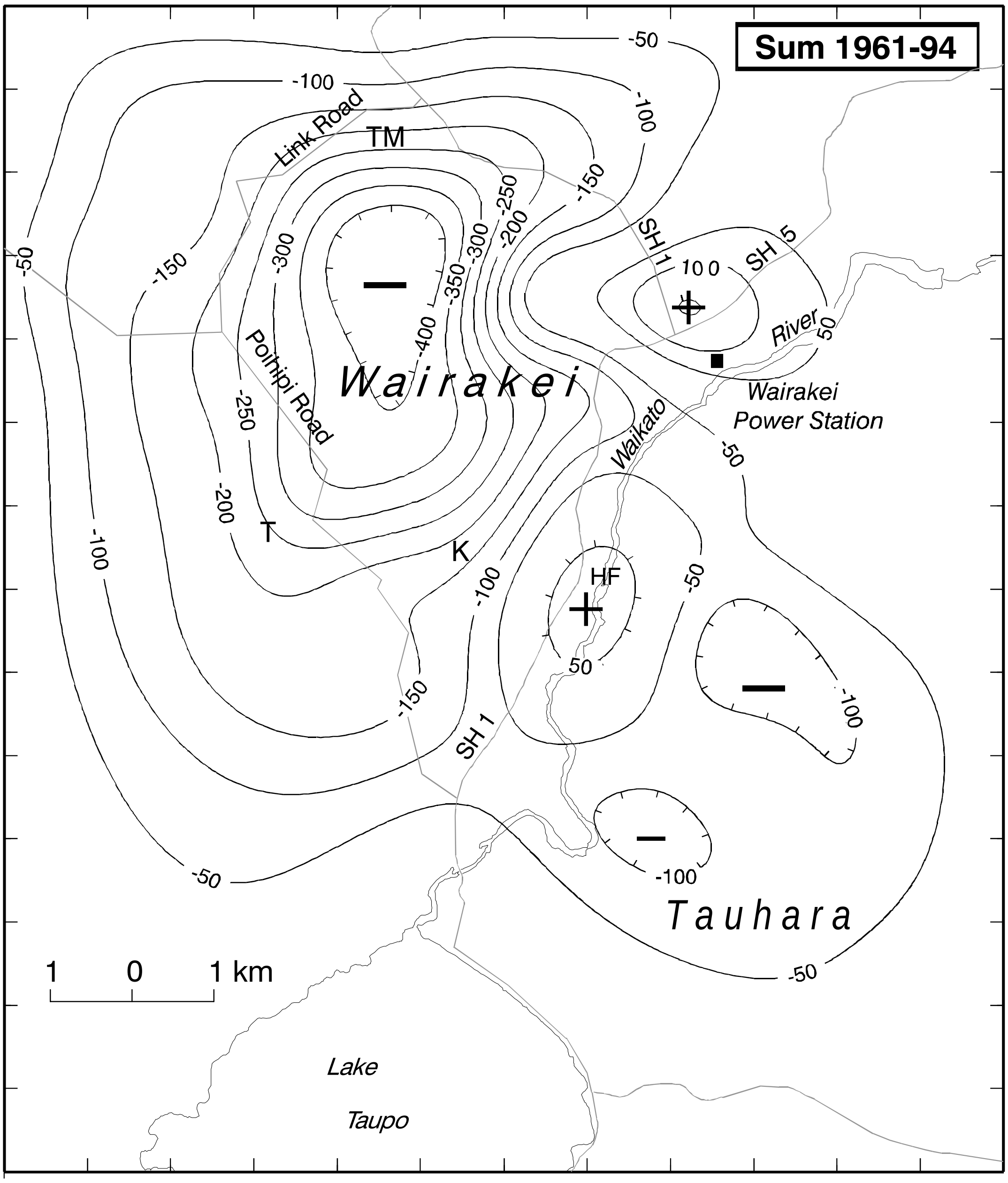

FIGURE 35: Sum of measured gravity changes from 1961 (first survey) to 1994 (last field- wide survey) at Wairakei geothermal field, New Zealand. Contour values at 50 microgal intervals; zero contour has been omitted for clarity. Map has been constructed by summation of 500 m grid values obtained from the maps in previous figure

$$\Delta M = \frac{1}{2\pi G}\sum \Delta g\, \Delta a$$

where Δg = Average gravity change in a small element of an area Δa, and the summation is extended over a wide area.

In practice, the summation can be made numerically using a computer program, or more commonly by gridding the gravity change map, estimating the average gravity change in each grid square, and summing these values to obtain $\Sigma\ \Delta g \Delta a$. In doing this it is important that the gravity data extends well beyond the region of measurable gravity changes associated with the field, and the area of each element is sufficiently small that the error in the estimate of Δg in the element is about the same as that of the measurement (and contouring) of Δg.

The value of ΔM obtained is the net mass loss/gain for the whole field for the period between the gravity surveys. *This method of determining the mass change is very powerful because it is completely independent of any assumptions about fluid density, depth of production, permeability, or porosity.* Its accuracy is limited only by the precision of the gravity measurements, and errors inherent in contouring and summing the data.

If the amount of mass withdrawn from the field by the wells (M_w), and any natural loss from surface discharge features (M_t) is known then the overall amount of mass recharge (R) can be determined

$$\Delta M = (M_w + M_t) - R \qquad \textit{and hence} \qquad R = (M_w + M_t) - \Delta M$$

During production, the mass withdrawn by the wells is usually much greater than that lost from the surface features, however the latter needs to be monitored because it may change with time. For example, at Wairakei natural loss before production was about 13 Mt/yr, but after 20 years of production had decreased to about 6 Mt/yr. Values for mass discharge and recharge for Wairakei, calculated by summation of the gravity changes, are given in Table 6 and have an estimated uncertainty of about 15%.

TABLE 6: Mass discharge and recharge values for Wairakei, MB is the mass withdrawn (M_t), MN the natural mass discharged, MT the total mass loss (MB+MN) is the integrated sum of gravity changes (N m^2/kg), MC the net mass change (M_t), and MR the mass recharge (M_t) (Hunt, 1995)

Period	MB	MN	MT	IS	MC	MR
1950-61	145	125	270	na	-100?	170
1961-67	360	55	415	-71	-235	180
1967-74	400	60	460	-13	-35	425
1974-83	390	45	435	0	0	435
1983-91	375	40	415	+19	+45	460

9.3 Testing numerical reservoir simulation models

Gravity change data can be used to discriminate between two (or more) numerical reservoir simulation models for exploitation of a field. The models predict development of a 2-phase zone and subsequent changes in saturation which involve assumptions about the geometry of the field, various reservoir properties, and behaviour of the field during exploitation. The models are generally developed progressively.

Prior to production, little information is available about response of the field to exploitation and generally only that resulting from test discharges can be used to set up the models. Under such circumstances it is likely that several different models can be devised which fit the data. If there has been sufficient mass withdrawal to cause gravity changes during the pre-production period it may be possible to test the models by calculating the predicted gravity effects and comparing them with measured gravity changes.

Discrepancies between the theoretical (model-derived) and measured gravity changes may indicate that assumptions made in setting up the models are wrong. Comparison of the theoretical and measured gravity changes should focus on the lateral extent and amplitude of the gravity changes. Large measured changes at points further away from the test discharge area may indicate values assumed (in the model) for permeability are too low, or for porosity are too high. This application of the microgravity technique may be particularly useful in the situation where the test wells are confined to a small part of the field.

The most favourable situation is where there is a period of field-wide test discharge, followed by a period of no (or limited) discharge so that any recovery can be monitored. Several gravity surveys during the discharge and recovery periods may provide sufficient information for discrimination between different simulation models. However, it should be recognised that the gravity changes are likely to be much smaller than those which may occur during the production period and consequently the precision of the gravity surveys, may need to be greater than for later surveys. This, in turn, may necessitate using fewer survey points, carefully chosen to maximise discrimination between the models. Natural discharges may be greater than the test discharges, and so need to be known accurately.

The technique was used to test initial models for the Broadlands (Ohaaki) field. It was found that changes in vapour saturation in the test discharge area were over-estimated, and their lateral extent was under-estimated (Hunt et al., 1990a). This led to the conclusion that the upper part of the production zone may be shallower, thinner, have greater porosity, and extend further than considered in the initial models.

9.4 Determination of saturation changes

Liquid saturation changes in a 2-phase zone as a result of boiling (dry out) or cooling and condensation during production can be determined for areas of the field if other variables (temperature change, liquid drawdown, and thickness) are known using the following basic 1-d equation:

$$\Delta g = 2\pi G \varphi (\rho_{w-s}) \Delta S\, h$$

However, saturation changes are best determined by using numerical reservoir simulation models, and varying the saturation change in appropriate blocks, until a match is obtained between the calculated and observed gravity changes.

9.5 Tracking the path of reinjected fluid

Reinjection involves the continuous transfer of waste liquid, generally back into the reservoir, and usually into a different part of the field from where it was withdrawn (production area). There is thus a transfer of mass from one place to another, and hence we might expect to observe a gravity increase in the vicinity of the reinjection wells. However, experience (tracer tests, pressure and temperature measurements) suggests that the reinjected liquid rarely remains in the vicinity of the reinjection wells. There are many scenarios for what happens to the reinjected fluid. Taking two simple cases:

1. *Reinjection into the 2-phase zone*
   The liquid is cooler and hence denser than the liquid present, and tends to sink towards the bottom of the zone. The process is complex: the cooler liquid will cause steam to condense, thus increasing the saturation in pores. Generally the rocks do not have isotropic permeability and so the liquid will move more rapidly along paths of high permeability and in response to any pressure gradients that might be present.

   The pattern of gravity increases associated with this process will therefore generally be non-uniform, and will reflect the directions of increased permeability and/or pressure gradients. Furthermore, by examination, and quantitative analysis of the gravity data from several repeat surveys it may be possible to determine the rate of flow of the reinjected fluid in particular directions. While the reinjected liquid remains in the 2-phase zone there will be a relatively large gravity signal because the liquid will be replacing vapour in the pores or fractures and hence there will be a large density change.

2. *Reinjection into the deep-liquid zone*
   Reinjection of relatively cool liquid into a hot, single-phase (liquid) zone beneath a 2-phase zone is more complex, and the effects will depend on the depth of reinjection below the deep-liquid level, the permeability (both vertical and horizontal) of the rocks, and the pumping pressure. Two extreme situations are:

   (a) The depth of reinjection is well below the deep-liquid level and vertical permeability is low. The reinjected liquid then flows out of the reinjection wells and displaces pore liquid horizontally. Although the reinjected fluid is cooler and hence denser than the displaced liquid, the density change is unlikely to be large enough to cause significant gravity changes at the surface. For example: if the reinjected water has a temperature of 150°C and completely displaces water at 250°C in the pores of a rock with porosity 0.3, then the density change is $(917 - 799) \times 0.3 = 35$ kg/m^3. Compare this with 150°C water displacing a similar volume of steam at 250°C: $(917 - 19) \times 0.3 = 269$ kg/m^3.

   Liquid water is (in this situation) incompressible, and so the displaced water must go somewhere. The most likely place for it to move to is laterally into the 2-phase zone; i.e. it will cause a lateral movement of the boundary of the 2-phase zone, some distance from the reinjection wells. At this point, liquid will replace steam in the pores and there will be a significant gravity change signal at the surface. The amplitude of the gravity changes will depend not only on the geometric situation, but also on what other changes are occurring in the reservoir in the vicinity of the 2-phase/1-phase boundary. However, the presence of localised gravity increases adjacent to (but not in) a reinjection area might signal the lateral flow of reinjected fluid from the reinjection wells to that point. Movement of such local gravity increases, between successive surveys, will reflect the direction of movement of the reinjected fluid.

   (b) The depth of reinjection is below the deep liquid level, and vertical permeability is relatively high. In this case the reinjected fluid will displace pore liquid vertically and the deep-liquid level will be displaced upwards in a cone of impression (this is the reverse of a cone of impression commonly found in groundwater surfaces around a pumped well). Generally the permeability of the rocks in and around the reinjection area will be anisotropic, and so the reinjected fluid will not flow symmetrically out from the reinjection area. This permeability anisotropy will cause the cone of impression to be similarly asymmetrical, indicating directions of greater and lesser permeability. At Wairakei, a cone of impression formed by such reinjection, was crescent-shaped, indicating increased flow in two, near-perpendicular directions (Hunt et al., 1990b).

3. *Injection outside the field*
   If the liquid is injected into or outside the field boundary then the liquid may not interact with the geothermal system. The ability for significant amounts of fluid to be injected outside the field indicates the presence of porous formations capable of absorbing the liquid. Such formations are likely to be highly porous and have low saturation; the injected fluid will replace air in the interstices and hence there will be a large density change (even neglecting cooling effects). Gravity changes (increases) in the vicinity of the reinjection area will therefore indicate the presence (location) of injected liquid, and changes in location between successive surveys will indicate migration of the injected liquid.

In the above cases, note that as the plume of injected fluid moves, the gravity changes will be associated only with the pores that have been saturated since the last survey; in previously saturated pores there will be no significant density change and hence no gravity change.

Quantitative analysis of the gravity data can be made using standard 3-d gravity modelling programs, provided values are known (or can be assumed) for: porosity, initial saturation, liquid density, and the geometry of the situation (depth or initial position of deep liquid level).

9.6 Determination of reservoir properties

Exploitation of a liquid-dominated geothermal system generally results in a transfer of mass (from one part of the field to another), which may cause measurable gravity changes. In some cases, the *rate* of mass transfer is controlled by the properties of the rock in the reservoir (e.g. permeability), hence the *rate* of gravity change with time is related to those properties. In such cases values for the properties can be determined from repeat microgravity measurements using numerical reservoir simulation models. Two such cases are the following:

1. *During formation and expansion of a 2-phase zone in the initial stages of production*
   Analysis of gravity changes at Wairakei geothermal field using simple radially symmetrical models and the MULKOM simulator showed that, for survey points near the centre of the production area, the size of theoretical changes soon (< 3 years) differs greatly (> 50 microgal) for different values of permeability (Hunt and Kissling, 1994). For example, after only 12 months the gravity change in the centre of the borefield is predicted to be -330 microgal for a permeability of 50 md and -180 microgal for a permeability of 200 md. Good estimates of permeability may be obtained by comparing the measured gravity changes with theoretical curves of gravity change calculated for different permeabilities, using a simple plot of gravity change against time. The analysis for Wairakei suggested that the gravity changes are most sensitive to differences in reservoir permeability at points close (< 1 km) to the production area (i.e. area of greatest liquid drawdown), but elsewhere are more model dependent (in particular to radius of the model). Application of this technique therefore depends on sufficient information being available to construct a realistic numerical simulation model, and a simulator which can generate theoretical gravity changes.

2. *During reinjection which causes displacement of the deep liquid level*
   As outlined above, reinjection may cause displacement of the deep-liquid level (vertically or laterally). Taking the case of vertical upward displacement of the deep liquid level, the shape of the cone of impression and its rate of growth (or decay, if reinjection stops) is controlled by the permeability of the rocks in that area. Note that the gravity signal reflects mainly the resaturation of the pores in the 2-phase zone; the effect of mass increase due to the denser (cooler) reinjected water at depth is small. By measuring the rate of change of size and shape of the cone of impression from several gravity surveys, and modelling this using a numerical simulator in which the permeability is adjusted until the measured and calculated gravity changes are in agreement, values for permeability (vertical, horizontal) can be determined. If the horizontal permeability is anisotropic, values for permeability in different directions may be calculated. Successful application of this technique will depend on the availability of adequate gravity change data in the vicinity of the reinjection well(s), including one or more baseline surveys to enable corrections to be made for other (more extensive) changes that might be occurring (such as a general rise or fall in the deep liquid level).

This technique was used at Wairakei during a reinjection test into an older part of the borefield. Using an analytical model (Theis or line source solution), values of 18.2 and 5.4 dm were obtained for permeability-thickness (kh) assuming anisotropic permeability (Hunt and Kissling, 1994). The modelling also provided a value of 8.7×10^{-6} m/Pa for storativity (φch).

10. CASE HISTORIES

Microgravity surveys have been made at more than 10 producing geothermal fields: *Wairakei, Ohaaki* and *Kawerau* in New Zealand; *Bulalo, Tiwi,* and *Tongonan* in the Philippines; *Larderello* and *Travale* in Italy; *Hatchobaru, Takigami* and *Yanaizu* in Japan. They have also been tried at *The Geysers* and *Heber* fields in USA, and at *Cerro Prieto* in Mexico, but apparently abandoned due to political considerations and lack of funding. It is rumoured that they have also been made in some other fields, but abandoned for a variety of reasons (chiefly poor measurement techniques and failure to install adequate survey marks) which have resulted in spurious results when the gravity changes between the first and second surveys have been calculated. However, this is exactly what happened at Wairakei in the early 1960s (Hunt, 1995), and it should not discourage use of the technique.

10.1 Wairakei (New Zealand)

Wairakei is a liquid-dominated field, located in the central part of the North Island. Test drilling began in 1950, and commissioning of the power station began in 1958 and continued until 1962, at which time the installed capacity was 193 MW (gross). There has been no significant reinjection; all waste water is discharged into the nearby Waikato River.

The technique of using repeat microgravity measurements to investigate the effects of exploitation of a geothermal field was developed using data from Wairakei. During nearly 40 years of production, 13 repeat surveys have been made. The first survey, however, was not made until 1961 (3 years after production began), and although carefully made, was not done to the now accepted requirements of precision or redundancy. Furthermore, few measurements of elevation or groundwater level change were made at that time. However, by the early 1970s significant improvements in gravity measurement and reduction techniques had been made, and monitoring programmes had been implemented. Early interpretations of the gravity change data clearly showed that the largest changes occurred during the early stages of development of the field and that during this time there was little natural recharge of fluid - the reservoir was being mined of fluid. The results of the 1961-67 and 1967-74 survey periods (Figure 34) showed the necessity for a comprehensive baseline survey to be made before production began. During the early 1980s, the microgravity results obtained at Wairakei, in conjunction with the reservoir engineering data enabled the various causes of gravity changes to be understood (Allis and Hunt, 1986).

The largest gravity changes have been in the Eastern borefield which formed part of the main production area during the early stages of development. Between 1961 and 1974, gravity values decreased by up to 560 microgal, but have subsequently increased by about 440 microgal (Figure 36). The decrease was caused by expansion of the 2-phase zone and dry-out of the upper part of this zone which has become vapour-dominated (Allis and Hunt, 1986). The subsequent increases have been attributed to re-saturation of the lower part of the 2-phase zone by downflows of cold groundwater; i.e. the deep liquid level has risen. In the late 1980s, environmental concerns necessitated a study of reinjection and a long-term (13-month) test was undertaken during 1988-89 in part of the borefield which had the greatest pressure decrease. Initial theoretical calculations suggested that there might be little gravity change associated with the reinjection and so a full study was not undertaken; instead gravity measurements were made only before and immediately after the test, and not during the test. This proved to be a mistake. There was a significant gravity change (+120 microgal) associated with the reinjection which on analysis showed that the reinjected fluid had flowed in two directions away from the reinjection bore (Hunt et al., 1990b). This led to an improved understanding of some of the physical processes involved in the 2-phase zone, and the realisation that in certain (but not unusual) circumstances the gravity changes could be related to physical properties of the reservoir and in particular permeability-thickness (kh) and storativity (φch) (Hunt and Kissling, 1994). If a more detailed gravity monitoring programme had been undertaken it might have been possible to better determine anisotropic values for kh. The results of the surveys during the reinjection trial also led to the concept that the permeability could be determined from gravity

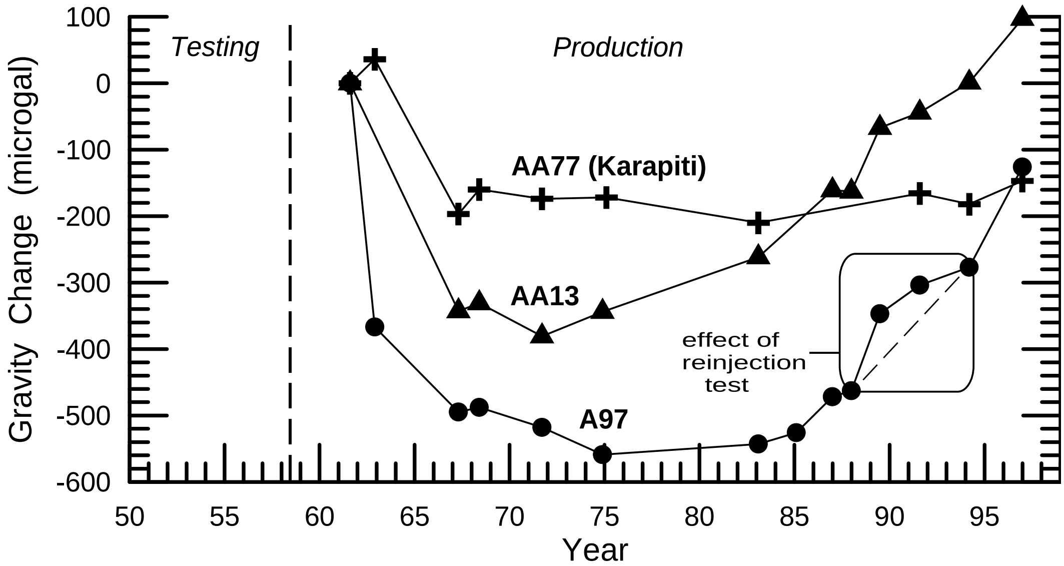

FIGURE 36: Gravity changes at selected benchmarks in Wairakei geothermal field, New Zealand. Benchmarks AA13 and A97 are in the Eastern borefield. Note the gravity decreases during the early stages of production as the 2-phase zone expanded, followed by the gravity increases as the deep water level in the Eastern borefield rose as the rocks became re-saturated as a result of cold downflows

measurements during the early stages of expansion of the 2-phase zone. Unfortunately, insufficient measurements had been made during these stages at Wairakei or Ohaaki fields; one measurement at Wairakei indicated a permeability of 100 md (Hunt and Kissling, 1994). We must now wait for sufficient measurements to be made in another field to fully test this concept.

10.2 Ohaaki (New Zealand)

Ohaaki (Broadlands) is a liquid-dominated field, situated 25 km north-east of Wairakei. Development of the field was unusual; a 4 year period (1967-1971) of large-scale test discharges (without reinjection) was followed by 16 years (1972-1988) of relatively minor discharges which allowed recovery of the field, before full-scale production (and reinjection) for a 116 MW (gross) power station was started in 1988. During the test discharge period deep-liquid pressures decreased by about 15 bar, but subsequently recovered by about 10 bar during the recovery period, before decreasing again when production began.

Seven, field-wide gravity surveys have been completed to date which span the test discharge, recovery and production periods. Gravity changes (max. -165 microgal) during the test discharge showed that there was little or no recharge during this period, and the field was effectively mined (Hunt, 1987). During the recovery period there were positive gravity changes within the field (up to +65 microgal) which indicate that natural recharge exceeded the small amount of mass withdrawn. Gravity change data for the drawdown and recovery periods were used to test 3 numerical reservoir simulation models for the field prior to production beginning (Hunt et al., 1990a). The models predicted changes in vapour (or liquid) saturation with time, and hence changes in density from which changes in gravity could be easily calculated. The results showed that none of the models adequately explained the microgravity data, suggesting that the upper part of production zone was shallower, thinner, had greater porosity, and extended further than considered by the models. This allowed the models to be refined before production began.

Since production began, large gravity changes (up to -200 microgal) have occurred in the central part of the field. The distribution of negative gravity changes within the field is similar to the temperature

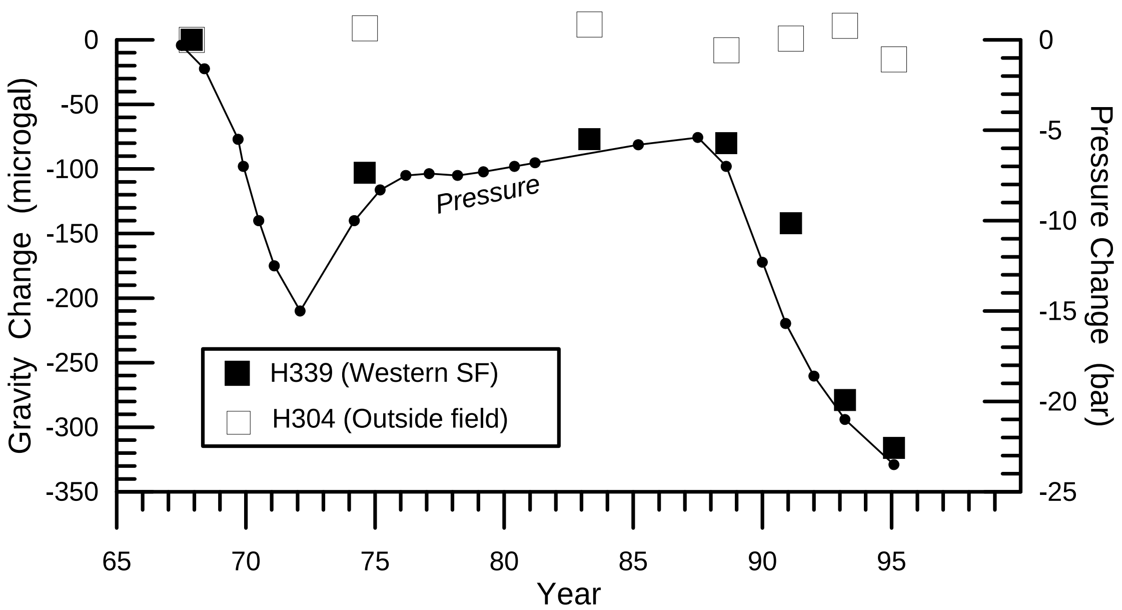

FIGURE 37: Gravity changes at benchmarks inside and outside the Ohaaki geothermal field. Note how the gravity changes at benchmark H339 (near centre of Western steamfield) follow the reservoir pressure changes

distribution at depth, and probably reflects mainly the extension (both horizontally and vertically) of the 2-phase zone in the reservoir, and reduction in saturation (dry-out) within this zone. This explanation is consistent with the gravity changes at benchmarks in the area of greatest change, which follow the trend in deep-liquid pressure declines in the production area (Figure 37). Despite 70 Mt having been reinjected around the edges of the field there have been no positive gravity changes in these areas indicating that the reinjected water has laterally displaced fluid near the reinjection wells. Analysis of the data (Hunt, 1997) indicates that natural recharge has been only about 5 Mt of the 31 Mt mass lost to the atmosphere (Figure 38).

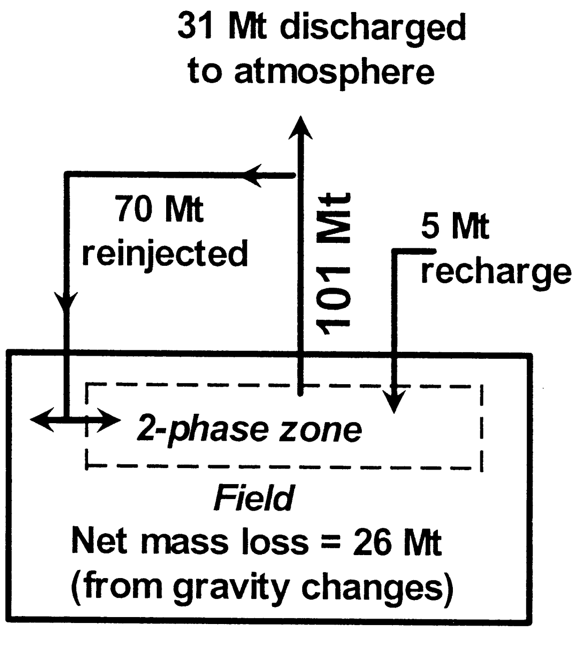

FIGURE 38: Block diagram summarising mass changes in the Ohaaki field during 1989-96, determined from microgravity measurements

10.3 Tongonan (Philippines)

This is a large, liquid-dominated field, located in Leyte Island. Development began in 1983 with the commissioning of a 37.5 M power station (Tongonan I). Since then a further 118 MW (Upper Mahio, in 1996) and 77 MW (Malitbog) have been added. Annual withdrawal rates increased from 5 Mt/yr in 1983 to 15.8 Mt/yr in 1994. By March 1995, a cumulative total of 131 Mt had been withdrawn of which 62 Mt had been reinjected.

Five microgravity surveys have been conducted (1980, 1981, 1982, 1985, 1995) at about 100 survey points. The most extensive and reliable data are for the 1981 and 1995 surveys. Erroneous levelling data precluded the interpretation of 1981-95 data, but if there was no ground subsidence then the gravity changes have been less than 50 microgal over all the field except in the Mahio area where changes of up to -75 microgal were measured (Apuada & Hunt, 1996).

10.4 Bulalo (Philippines)

Bulalo is a liquid-dominated field, located 70 km south-east of Manila. Production began in 1979 with an installed capacity of 110 MW, increased to 220 MW in 1980, 330 MW in 1984 and 426 MW in1996.

Fieldwide gravity and levelling surveys have been conducted every 1-3 years since 1980, and cover an area of about 36 km^2. The gravity measurements were initially made at 87 benchmarks, and the network has subsequently been increased to 120 measurement points (San Andres and Pedersen, 1993; Protacio et al., 2000). Bi-monthly gravity monitoring at six stations (1986-1987) indicated that the uncertainty due to non-reservoir causes is ±20 microgal, which is attributed to variations in rainfall and groundwater level. Surveys were usually conducted during the dry months of March, April and May to minimise the effects of rainfall. Selected benchmarks (up to 7 km from the centre of production) were used as fixed references for datum shift (base change) adjustments. Ground subsidence of up to 0.5 m has occurred, centred on the production area.

Between 1980 and 1991, gravity changes exceeded -250 microgal, and the maximum rate of change was -26 microgal/yr at a point near the centre of production. The cumulative gravity changes (1980-1999) have now reached almost –600 microgal in the central part of the production area. This sector has high excess steam indicating widespread on-going change from brine to steam. The smallest cumulative change in the production area is now more than –250 microgal. The gravity decreases within the production area have been near-uniform with time.

Mass discharges predicted by recent reservoir simulation modelling have generally matched those inferred from the observed gravity data. According to simulation studies, no recharge occurred between 1980 and 1984. The mass recharge between 1984 and 1991 was estimated to be 30% of net fluid withdrawal during the same period, equivalent to an average rate of 175 kg/s (630 t/hr). Calculations indicate that there has been about 42% recharge of the 374 Mt net mass loss since 1980 (Protacio et al., 2000).

10.5 Tiwi (Philippines)

Tiwi is liquid-dominated field situated 250 km south-east of Manila. Production began in 1979 with an installed capacity of 110 MW which was raised to 220 MW in 1980 and then to 330 MW in 1982. Total mass withdrawal peaked at about 38 Mt/yr in 1983, but by 1990 had fallen to 22 Mt/yr; reinjection began in 1983 and from then until 1990 has been about 9 Mt/yr.

Microgravity surveys began in 1979, and subsequent surveys were made in 1980, 1982, 1984, 1986, 1988 and 1990 (San Andres, 1992). Surveys have been made regularly since 1990 but the results have not been published.

The gravity data (San Andres, 1992) delineated areas of decreasing gravity over the production area, which were caused mainly by development of a steam zone. Initially, large gravity decreases were observed in the eastern Naglagbong area which provided most of the geothermal production. At the same time, significant gravity decreases also were observed in the Kap-Mat area in the west. This behaviour is consistent with a shallow hydraulic connection between these two areas. In the Kap-Mat area the general trend in gravity has been linear rate of decrease with time, consistent with expansion of the steam zone and increasing in vapour saturation. The initial rapid gravity decline in Naglagbong from 1979 to 1984 was followed by minor gravity decreases from 1984 to 1990 due to declining local production and cold water influx. Mass recharge at Tiwi was estimated to be a minimum of 50% of net withdrawals between 1979 and 1990.

10.6 Larderello (Italy)

Larderello was the first geothermal field to be commercially exploited: production began in 1921. The field is vapour-dominated. Total production is currently about 800 t/hr (7 Mt/yr) of which about 200 t/hr (1.8 Mt/yr) is reinjected.

Microgravity surveys began in 1986, and since then a further 5 surveys have been made: 1987, 1988, 1989, 1991, 1993 (Dini et al., 1995). Gravity changes during the whole of this period have been very small. The largest changes have been similar to the "environmental noise" (15 microgal), indicating there has been almost complete mass recharge. Consistent, positive gravity changes in the main reinjection area, however, suggest that some of the reinjected water is being accumulated.

10.7 Travale-Radicondoli (Italy)

Travale field is located about 15 km southeast of Larderello. It is also a vapour-dominated geothermal system, and the average production rate is 100 kg/s (3.15 Mt/yr). Reinjection is insignificant.

Microgravity measurements were first made in 1979, and since then 7 further surveys have been made. Only small (<30 microgal) gravity changes have been measured. Analysis of the data shows about 97% of the fluid withdrawn between 1979 and 1991 has been replaced, indicating that (for this period of time) the field has been in a quasi-equilibrium state with respect to mass changes (di Filippo et al., 1995).

10.8 The Geysers (United States of America)

The Geysers is a vapour-dominated field, located in northern California, and is the largest field in the world both with respect to lateral extent and power produced. Production began in 1960 with an 11 MW plant and by 1993 the field was producing 1193 MW, however, since the late 1980s there has been considerable decline in the supply of steam. Information about the field has been restricted by commercial confidentiality, but Denlinger et al. (1981) state that between 1974 and 1981 about 20% of the mass withdrawn was reinjected, and the net mass produced was about 26 Mt/yr.

Microgravity measurements were made in 1974, and repeated in 1977. The maximum gravity change was -120 microgal, near the centre of the production region, and analysis suggested that recharge was small (Isherwood, 1977). The data was also analysed by Allis (1982) who showed that the ratio of gravity change to ground subsidence may be a useful indicator of the rate of fluid depletion in vapour-dominated systems because it was independent of reservoir thickness, pressure drop, and porosity. The ratio for that part of the field with greatest production was about -14 microgal/cm corresponding to a recharge of about 55%, but in some parts of the field the recharge was less than 25%. No published reports of gravity change measurements have been made after 1977, except for a brief (38 day) test of a cryogenic gravimeter in 1979 (Olson and Warburton, 1979). However, calculations (Allis et al., 2000) suggest that there will have been an average gravity decrease of up to 60 microgal/y, peaking about 1987, and the cumulative gravity change at The Geysers has been about 1000 microgal.

Recently, injection of water from outside the field has begun at several places in the field: the Southeast Geysers Effluent Pipeline project (SEGEP). Calculations (Allis et al., 2000) show that the gravity effects of this reinjection will be in the range 1-4 microgal year, and microgravity measurements may be useful in tracking the path of the injected water.

10.9 Cerro Prieto (Mexico)

Cerro Prieto is a liquid-dominated field situated in the north-western part of Mexico. Production began in 1973 with an output of about 69 MWe, which has been progressively increased to about 570 MWe in 1995.

Microgravity measurements of 70 survey points were started in 1978, and repeat surveys were made annually until 1983 (Grannell et al., 1984) but no significant results have been reported and it is believed the measurement programme ceased in 1983.

10.10 Hatchobaru (Japan)

Hatchobaru is a liquid-dominated field, situated in central Kyushu. A 55 MW power station was opened in June 1977 (No. 1 unit) and a further 55 MW added in June 1990 (No. 2 unit). The combined production rate is now about 1325 t/hr of liquid and 590 t/hr steam; there are 21 production and 10 reinjection wells in use. The main production is from depths of 1-2.5 km, and reinjection is at depths of 1-1.5 km.

Nineteen microgravity surveys, involving 44 survey points, have been made between 1990 and 1997 (Ehara et al., 1997; Nishijima et al., 2000). Gravity decreases of up to 250 microgal have been measured in the production area. In the reinjection area, gravity values at one point increased rapidly by up to about +80 microgal, and have since gradually decreased. Mass changes, calculated by integrating the gravity changes, suggest that between 1991 and 1993 of 32.4 Mt withdrawn, 16.7 Mt was discharged to the atmosphere, 15.7 was reinjected and about 16.3 Mt of natural recharge occurred (Nishijima et al., 2000).

10.11 Takigami (Japan)

Takigami is a liquid-dominated field, situated in Kyushu. A 25 MW power station began production in November 1996; there are 4 production and 9 reinjection wells.

Eleven microgravity surveys were conducted between May 1991 and March 1993 (Ehara et al., 1995); these surveys span a 4 month period of pre-production and reinjection testing (3 Mt withdrawn, 2 Mt reinjected) conducted between November 1991 and February 1992. Gravity changes of up to -150 microgal were measured, but most of the changes were found to be due to large seasonal variations in shallow groundwater level. Takigami lies in a mountainous area with an annual rainfall of 2.6 m, most of which occurs in the summer months. After correction for the gravity effects of these variations, gravity changes of up to +30 microgal were determined for the reinjection area and up to -40 microgals in the production area (Ehara et al., 1994, 1995).

Since then, efforts have concentrated on better determination of the correction for groundwater level changes using a multivariate regression model (Nishijima et al., 1999; Fujimitsu et al., 2000). A comparison between precipitation and gravity shows that there are phase lags of 3-8 months between rainfall and groundwater level changes. The accuracy of the gravity changes obtained after removal of the groundwater changes determined in this manner is estimated to be 10 microgal. Published data (Fujimitsu et al., 2000) show that in the production area there were gravity decreases of up to 30 microgal immediately prior to production (1995-1996), and increases of up to 40 microgal after production (1996-1997). There appears to have been no gravity changes in the reinjection area since production began.

10.12 Yanaizu-Nishiyama (Japan)

Yanaizu - Nishiyama is a liquid-dominated field, situated in central Honshu. A 65 MW power station was commissioned in May 1995. The production rate is 71 t/hr water and 525 t/hr steam from 15 deep wells (1.56-

2.70 km). There are 3 reinjection wells (1.5 km deep).

Microgravity measurements were started at 83 survey points in September 1994; annual surveys have been conducted since then and the survey network expanded to 138 points (Takemura et al., 2000). Since 1998, monitoring surveys have been carried out three times a year to determine if seasonal gravity variations occur. Near one gravity station, a weather monitoring station and soil moisture measuring equipment have been installed. At the weather station, barometric pressure, air temperature and rainfall are measured at 30 min. intervals. Shallow groundwater monitoring wells have been installed adjacent to 10 gravity survey points, and changes in water level monitored at 30 min. intervals.

11. LESSONS LEARNED

Microgravity measurements began at Wairakei geothermal field nearly 40 years ago, and since then the techniques of measurement and interpretation have been developed, and we have learned:

1. It is important that a good baseline data set is obtained before exploitation begins.

2. The gravity surveys need to be accompanied by surveys to monitor ground subsidence and groundwater level changes.

3. The measurement points need to extend well beyond the field boundaries to locate areas where reinjected fluid may be going, to determine the significance level of the measurements, and to check that gravity changes have not occurred at the base station.

4. The largest gravity changes occur in the early stages of exploitation and are associated with development of a two-phase zone: surveys at this time need to be more frequent.

5. The greatest benefits are achieved when the gravity change data are used in conjunction with numerical reservoir simulation models.

6. Predictions (of gravity change) are often wrong, and should be treated only as a rough guide to planning the microgravity surveys.

7. We have never regretted obtaining more (extra) microgravity data; we have often regretted not taking more. It is not possible to go back in time to collect extra data.

12. FUTURE TRENDS

Although the microgravity technique has been well developed over the last decade, some improvements can still be made. The following are suggestions of what can be done.

12.1 Determination of the effects of groundwater and soil moisture variations

At present few studies have been made of the gravity effects of changes in shallow groundwater level and changes in saturation in the Vadose zone. In porous formations, such as occur near the surface in active volcanic regions, variations of several metres can cause gravity changes of about 10 microgal/m of groundwater level change. Seasonal variations in water storage in the Vadose Zone are also likely to be important; changes of about 12 microgal have been recorded in Finland (Makinen and Tattari, 1991).

12.2 Improvements in measuring and determining the effects of ground subsidence

In some fields, such as Wairakei and Ohaaki, significant ground subsidence has occurred as a result of pressure drawdown in the reservoir and needs to be corrected for in determining gravity changes associated with mass variations in the reservoir.

Values for subsidence at the survey marks are usually obtained by optical levelling surveys; generally to 2nd order standard. This traditional technique is time-consuming and therefore costly. New techniques are emerging which may replace optical levelling; these include (differential) GPS surveys (Nunnari and Puglisi,1994) and Synthetic Aperture Radar interferometry (Massonnet et al., 1997). At present these methods cannot provide the required precision quicker than optical levelling, except in regions of high topographical relief and poor access, but it is anticipated that improvements will occur in the near future.

To obtain an accurate correction for the gravity effect of subsidence it is also necessary to know the vertical gravity gradient at each survey mark. For some microgravity surveys the standard theoretical "free air" correction value of -308.6 microgal/m has been used for all measurements, and in other surveys an average of several measured values has been used: -302 (±5) microgal/m for Wairakei and -295 (±8) microgal/m for Ohaaki. Further studies are needed to measure and incorporate local variations of gradient into the calculation of the gravity effects of subsidence, and so reduce the uncertainty in the gravity change values.

12.3 Borehole gravimetry

Currently, all microgravity surveys in geothermal fields have been made at the ground surface, but the amplitude of the measured gravity changes would be greater if the measurements could be made closer to, or within, the regions of mass change. This has been suggested for monitoring depletion of hydrocarbon reservoirs (Schultz, 1989), however the temperature in geothermal wells is much higher than in oil and gas wells. Some borehole gravimeters (BHGM) have been developed for use in the mining and petroleum industry (Robbins, 1989; Popta et al., 1990), but currently the maximum environment temperature limit for such instruments is about 260°C, they require a 7 inch diameter hole, which must not deviate more than 14° from the vertical. Improvements in temperature limitations and reduction in the size of the instrument would be required to make this technique feasible for geothermal field operation. In addition, a technique would need to be developed to ensure accurate repositioning of the meter in the hole in repeat surveys.

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July 24, 2017

Technical Memorandum

Prepared for: Center for Biological Diversity

Subject: Impact of Developing Dixie Meadows Geothermal Utilization Project on Springs and Surface Water

This technical memorandum reviews the potential for geothermal development at the Dixie Meadow Geothermal Utilization Project, as described in the Environmental Assessment (DOI-BLM-NV-C010-2016-0014-EA, for the Orni 32, LLC, Dixie Meadows Geothermal Utilization Project (EA)), to cause a significant change to the hot springs that support the Dixie Meadows. The Dixie Meadows are part of the Dixie Valley geothermal system (DVGS) which extends along the Stillwater fault from the currently-producing Dixie Valley Producing Field (DVPF) south to the Dixie Hot Springs, which support the Dixie Meadows (Figure 1). Deleterious impacts to the wetlands and springs, that will be considered in this memorandum, include:

- A significant change in the rate of flow that discharges from the springs,
- Changes in the water quality or temperature of those springs
- Damages caused by a hydrocarbon spill induced by drilling into an artesian aquifer that hosts hydrocarbons (oil).

This memorandum describes a conceptual flow model (CFM) for the Dixie Valley flow system and a localized CFM describing flow to the hot springs. As part of the localized CFM, the memorandum considers details of the geothermal reservoir including flow around the faults, the direction of fractures, and how the geothermal fluid disperses through the fractures and provides flow to the surface springs. The proposed geothermal power system is described, although there are few details known about the proposal for Dixie Meadows. Considered with the localized flow system, the ways and likelihood that aspects of the development could affect the spring flow is also assessed.

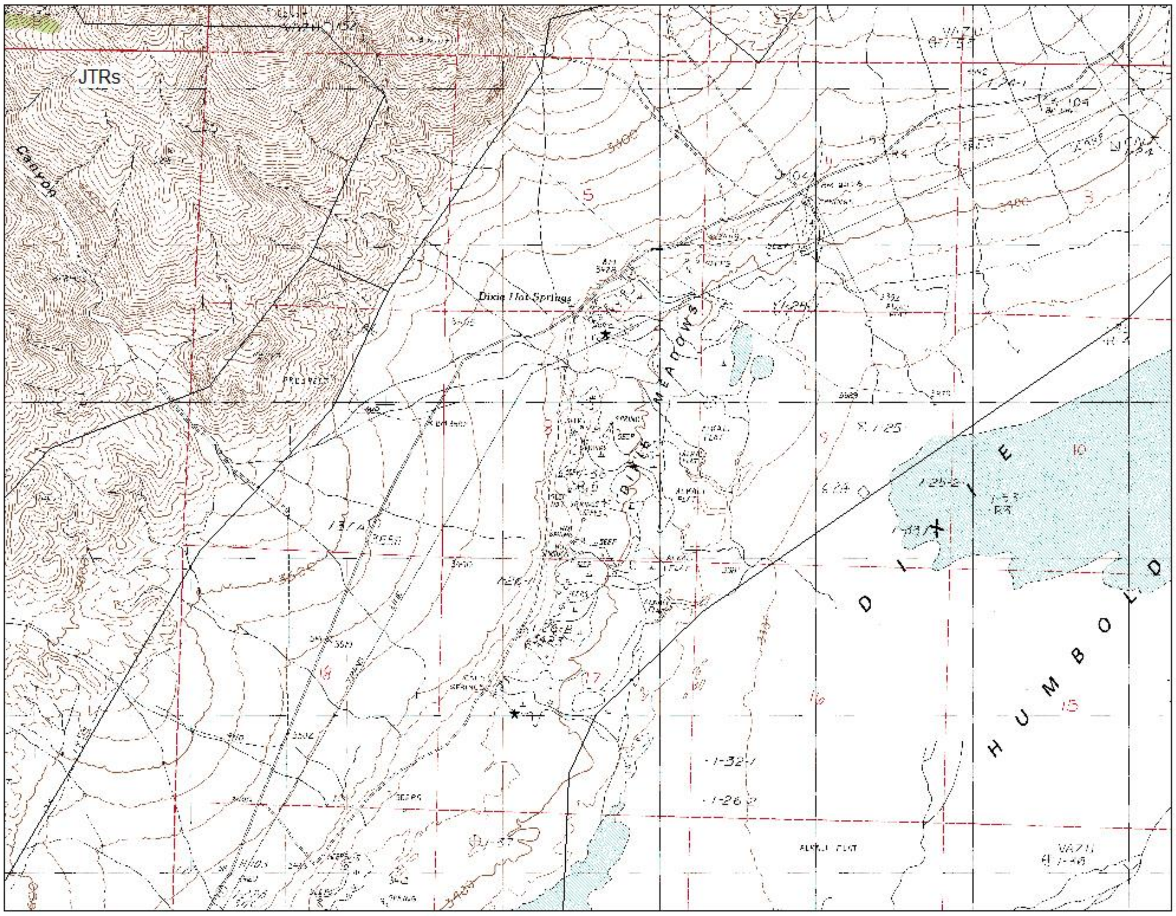

Figure 1: Topographic map showing the Dixie Meadows area. Contour interval is 40 feet, with intermediate contours of 10 feet. Base map is USGS 1:24K Dixie Hot Springs.

Conceptual Flow Model

Dixie Valley is the terminal end of a flow system that includes the surrounding Fairview, Stingaree, Jersey, Cowkick, Eastgate, and Pleasant Valleys (Huntington et al. 2014). By terminal, Dixie Valley is the valley into which groundwater from the surrounding valleys flows as interbasin flow and from which most of the groundwater discharges as groundwater evapotranspiration and spring flow (Huntington et al. 2014). The overall flow system is topographically closed. Interbasin flow from Fairview and Jersey Valleys ranges from 700 to 1300 and from 1800 to 2300 acre-feet per year (afy), respectively. Groundwater discharge estimates, based on ET from wetland vegetation and the playa, range from 17,000 to 28,000 afy (Harrill and Hines 1995).

Groundwater flows from the mountains surrounding the valley into the valley, where it discharges in springs and wetlands near the edge of the playa (Huntington et al. 2014). There are three primary aquifers – the fractured rock aquifers in the mountains, the basin fill aquifer between the base of the mountains and the playa, and the playa. The alluvial aquifer and playa aquifer can be distinguished by the difference in water quality, with the playa having extremely high salinity, and difference in transmissivity, with the playa being much less transmissive due to silt in the formation (Id.).

Dixie Meadows has numerous springs, ranging along a scarp forming the downhill end of the alluvial fans, from section 4, northeast of the labeled Dixie Hot Springs, to Cold Springs on the west side of section 17, which is about two miles just west of due south from the Dixie Hot Springs. The springs all lie just east of the end of the alluvial fan, which appears as an eroded scarp that may coincide with a near-vertical fault that extends upward from the Stillwater fault (Figure 2). The map (Figure 1) also has labeled a short fault in its northeast portion.

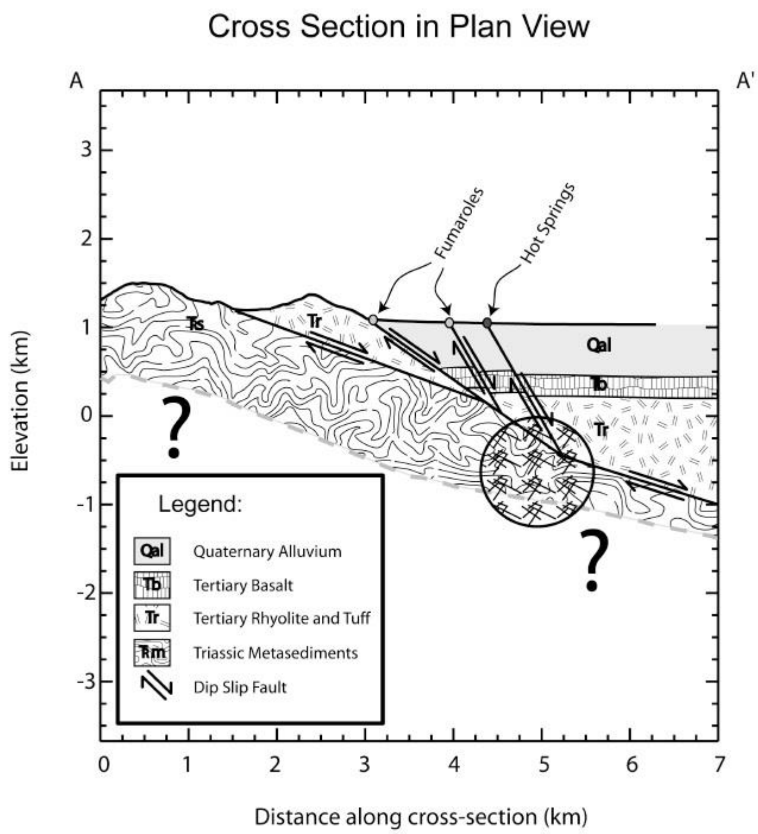

Figure 2: Figure 5 from Kennedy-Bowdoin (2004) showing a geologic cross-section along the Stillwater fault.

Reportedly, there are about 35 seeps and springs, with the hot springs discharging from unconsolidated Quaternary lacustrine sediments with temperatures ranging from cold to 182°F (Benoit 2011). The hottest springs occur in an area about ¼ square mile in size (Id.). Total discharge is about 50 gallons per minute (gpm), but it is very difficult to measure (Id.).

A simple description of the geothermal flow system is that recharge into bedrock outcropping in the Stillwater Mountains circulates deeply where it gains heat. As it flows downgradient toward the valley discharge points, the Stillwater Fault acts as barrier which impedes the flow and causes it to flow to the surface where it discharges into springs and wetland seeps. The vertical flow is probably through the damage zone caused by the fault rather than directly up through the fault. However, it is more complicated than can be explained by just one low angle fault (Figure 2). Evidence of upward flow of hydrothermal fluids within the fault zone includes the observed decrease in silica between 3 and 2.3 km bgs, due to its precipitation within the fractures (Hickman et al. 1998b). Silica deposition would seal the fractures, but the fact the fractures remain highly conductive show the faults remain active (Id.).

Isotopes from sampled groundwater indicates that most had recharged during cooler climatic conditions (Huntington et al. 2014, p 31). This indicates that water discharging through the warm springs could be decreasing due to a long-term decrease in recharge.

Two conceptual models have been proposed to explain the hot springs and fumaroles at Dixie Meadows (Benoit 2011). One is that a series of faults that parallel the range front allows thermal fluids to rise up generally beneath the thermal features. Kennedy-Bowdoin et al. (2004) provide more detail and show a cross-section through the range-front fault that shows the parallel faults dip more steeply, to the southeast, and intersect the Stillwater Fault (Figure 2). These intersections would cause an agglomeration of fractures that could allow hot water under the Stillwater fault to rise through it and along fractures associated with the steeper faults to the surface.

Benoit's (2011) second conceptual model is that thermal fluid rises along the Stillwater fault and then flows laterally downhill to the east until it intersects the ground surface near the playa. Benoit provides no references or data to support this description, but does imply this would explain steam present along the range front (causing the fumaroles) and allow hot water to be present some distance from the fault. No springs occur far from the faults in the Dixie Meadows area, but occur along a trend a couple miles long. This would be unlikely if they were the intersection of a water table aquifer with the ground surface. It would seem more likely that it corresponds to a fault line intersecting the larger Stillwater fault (Figure 1).

The main geothermal reservoir occurs in fractured rocks, mostly of Jurassic age, within the hanging wall of the Stillwater fault (Lutz et al. 1997). The hanging wall is the downthrust block, which for the Stillwater fault is the graben side of the fault, which has displaced downward on the east side of the Stillwater fault. The graben is the block that thrusts downward, which in Dixie Valley has caused a thick basin fill east of the fault. The geothermal system is much more complicated than circulation around the damage zone of a single normal fault. Northwest-southeast trending faults, some not exposed at the surface, intersect the Stillwater fault providing a concentrated fracture zone which likely allows water that recharged west of the Stillwater fault to flow through the fault in discrete locations. The "concept of a complex series of faults (both synthetic and antithetic) separating the Stillwater Range from Dixie Valley allows for the possibility that the geothermal circulation encompasses multiple faults both inboard and outboard of the range-front fault" (Smith et al. 2001, abstract). This means the faults, and associated fractures, create a complex mix of flows on both sides of the primary Stillwater fault.

It also explains the presence of geothermal zones identified several miles from any range-bounding fault, such as within the middle of the Dixie Valley basin (Benoit 2011).

Mixing between the basin fill and geothermal aquifers is apparent by the fact that the basin fill contains 10 to 20 percent geothermal water (Huntington et al. 2014). However, some of the basin-fill wells and springs, based on lithium concentrations, had as much as 46% geothermal water (Huntington et al. 2014, p 42). If the pathway for geothermal water to reach the surface is not impervious to flow entering or leaving it, there could be mixing with geothermal water entering the basin fill and basin fill water entering the pathway. The direction of flow across the bounds of the pathway would depend on gradient across the boundary, meaning that if the pressure in the conduit exceeds that in the surrounding basin fill, flow would be from the conduit to the basin fill.

As noted, many springs occur within 0.2 miles of the fault. Several studies have documented the fractures near the fault (Barton et al. 1998, Hickman et al. 1998a and b). Fractures parallel the faults, and some very small fracture zones are highly transmissive. They are also very heterogeneous. The presence of springs exemplifies the heterogeneity of the fractures, because each spring likely discharges flow from discrete fracture zones.

Analysis of permeability within productive wells shows that a small number of fractures intersecting the well and striking parallel to the local trend of the fault dominate the productivity (Barton et al. 1998). The permeability was found to be high only when individual fractures and the overall Stillwater fault zone are optimally oriented and stressed for frictional failure (Id.). Figure 3, a histogram of fracture directions, shows the general northeast to southwest trend direction of the significant permeable fractures. The wells on the left side of Figure 3 are the higher producers. Well 45-14, on the lower right, shows fractures in various directions, but the well was not a good producer suggesting the fractures were limited or that nearby fracturing limited the length of fractures.

The productive wells had fractures along their wellbore, often ranging from 0.5 to 3 fractures per meter (from Table 1 in Barton et al. 1998), but the fluid entry zones were often spaced much less frequently (Barton et al. 1998). Relatively few fractures dominate the flow. The most permeable fractures parallel the faults (Id.). The fact that productivity along the fault is highly variable is evidence the fractures are very heterogeneous.

Modeling shows that a geothermal system requires a unique set of permeability values, both in the fracture zones and in the bulk formations away from the fractures (McKenna and Blackwell 2004). High permeability values allow substantial flow to the surface, but also allow rapid heat loss so that the geothermal system may not be productive for a long time, at least on a geologic scale (Id.). If the permeability is low, the fluid loses heat before it reaches the surface (Id.). Geothermal systems are transient, at least on a geologic time scale. Permeability often increases after an earthquake along the fault, as occurred along the Stillwater fault in 1954 (McKenna and Blackwell 2004). This suggests that events such as earthquakes may reset the system.

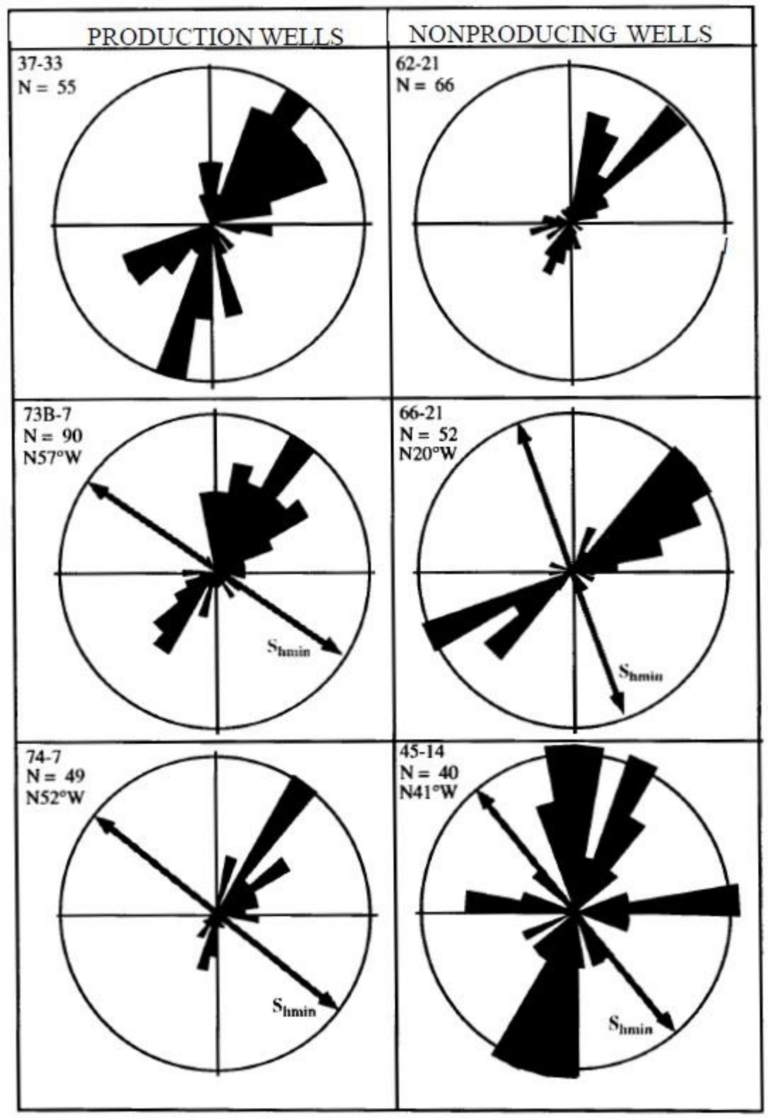

Figure 3. Histograms showing the subset of fractures from Figure 2 that are hydraulically conductive from the producing (left column) and nonproducing (right column) wells at Dixie Valley. The orientation of S_{hmin} is from Hickman et al. (this volume).

Figure 3: Figure 3 from Barton et al. (1998) showing a histogram of fracture directions.

Proposed Geothermal Development

The proposal is for a closed-loop geothermal system, in which geothermal fluids are pumped from depth (unspecified in the EA) to the surface and through heat exchangers before being reinjected into the geothermal reservoir at a lower temperature. Because the system is proposed to be closed, it would not consumptively use any water, unless there is a leak. The EA does not provide the actual proposed flow of geothermal fluid but states that other facilities have produced about 14,000 gallons per minute (gpm) with each well ranging from 2000 to

3000 gpm (EA, p 2-10). The EA claims that the amount of water withdrawn from the geothermal reservoir would be reinjected without loss and the only change in flow being due to a decrease in water temperature from 300 to 150 degrees F. At a similar facility in nearby Jersey Valley, the same company stated there would be 17 geothermal production wells and 7 geothermal injection wells[1].

Typically, removing geothermal water would decrease the discharge rate to springs by reducing the pressure. Reducing the pressure would allow groundwater from surrounding formations to enter the pathway, thereby changing its temperature and chemistry. Geothermal development would affect spring flow in several ways.

Similar facilities have circulated as much as 14,000 gpm, which should be compared with the 50 gpm that naturally circulates. Based simply on pumping rates, the geothermal development could overwhelm the natural system. As described above, the natural system involves natural recharge circulating deeply probably along the damage zone of the Stillwater Fault (Figure 2) with flow through the fault occurring at points where other faults intersect the Stillwater Fault. The geothermal reservoir would be the fracture damage zone along the Stillwater fault with intermittent pathways to the surface provided by the other faults. The discrete discharge points exemplify the heterogeneity of the system

If the geothermal project circulation could extract and reinject the flow evenly along the fault system so that it did not cause pressure gradients, it is possible to minimize the impacts. But, the system would have a few collection and injection wells, so there would point sources and sinks for water in the system rather than being spread along the faults. The 17 production wells and 7 injection wells at Jersey Valley would be spread over several miles (see Figure 4 in the Jersey Valley EA[2]). The production wells would pull water from the natural discharges to the springs because pumping causes a drawdown in the potentiometric surface (a pressure gradient). Injection would create zones of pressure that would be higher than the background, as necessary to assure fluids flow into the fractures. Much of the injected flow would follow similar pathways as occurred before development because those pathways are most transmissive, but the limitation of the existing fractures would require higher pressure to force the fluid through the fractures. This would result in a substantial amount leaking off into other fractures or the bulk media, which would cause a net loss of flow.

It is also possible that reinjection would not occur into the same fracture zones as the water removed for geothermal development. As described above, the most permeable fractures are few, and due to heterogeneity, there is no certainty that permeable fractures in the injection wells would intersect the permeable fractures in the collection wells. This would cause reinjected water to be lost to the circulation, especially if reinjection reaches fractures that are transverse to the general fracture trend found in the fault system (Figure 3).

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[1] Jersey Valley Geothermal Development Project, Pershing and Lander Counties, Nevada, Environmental Assessment DOI-BLM-NV-063-EA08-091, Battle Mountain BLM, May 2010. P 11

[2] Id., Figure 4.

Therefore, there are two ways that recirculation could lose water – by leaking off into bulk media or by reinjection to fractures not connected to the collection wells.

Reinjection of water would locally increase the pressure. If the pressure increase is near one of the pathways upward to the springs, it could increase the amount of geothermal water in the mix of shallow and geothermal water discharging to the surface. This discharge could therefore have higher temperatures or more briny water due to a higher proportion of geothermal water.

Another hazard for the surface springs, and associated ecosystems, would be the potential for the wells hitting oil under artesian pressures (Hulen et al. 1999). In Dixie Valley, oil has been found with geothermal water, and although there have been no spills, the geothermal development is limited. At a nearby site, Kyle Hot Springs, an artesian aquifer yielded oil that discharged about 500 barrels from a well into an ephemeral stream channel.

There is a local analog to development of the Dixie Hot Springs, the Jersey Valley Geothermal Development Project, the environmental assessment for which acknowledged that "the geothermal production and injection operations could alter the pressures in the hot spring thermal reservoirs sufficiently to cause the flow of the hot springs to increase, diminish, or even cease"[3]. Spring flow data collected since 2011, and subsequent to development of the geothermal plant, show there has been a significant decrease in flow (Figure 4). While considering whether to grant water rights to the Jersey Hot Spring, the Nevada State Engineer found that the spring had gone completely dry.

> The measurement taken on August 1, 2014, indicates that the flow from the spring had ceased, with the residual pool approximately 2 feet below the normal water mark. By January 30, 2015, the spring site was observed to be completely dry. Based upon the record of flow measurements, the State Engineer finds that the flow of Jersey Hot Spring has, over the last four years, declined to a point where it no longer generates an active flow. (Nevada State Engineer Ruling 6305, p 2, 3)

It is likely that the flow decreases in Jersey Valley are related to the geothermal development in that valley.

[3] Id., P 69.

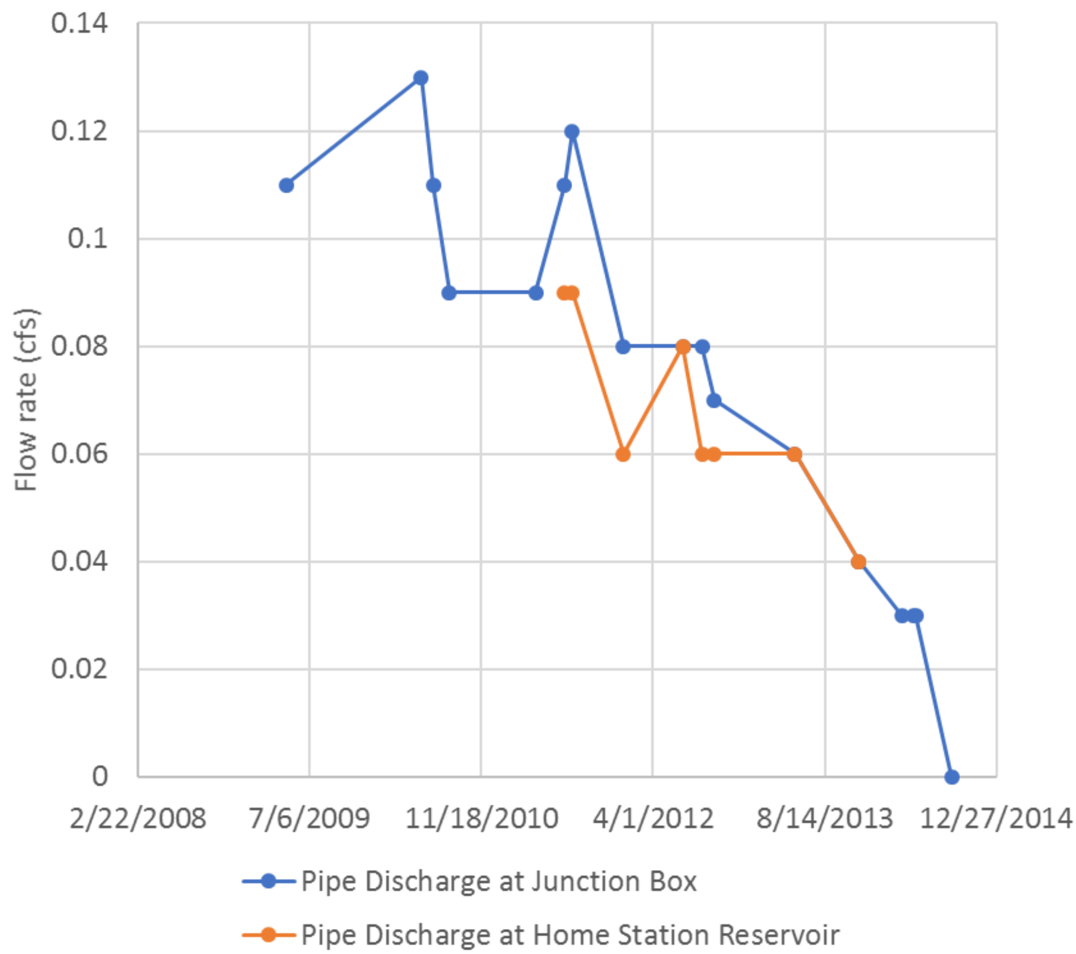

Figure 4: Measured flows at two stations in Jersey Valley associated with the Jersey Valley geothermal plant. Data from the Nevada State Engineer (http://water.nv.gov/SpringAndStreamFlow.aspx)

Monitoring, Management and Mitigation Plans

The EA indicates there would be 3M plan designed to prevent deleterious impacts due to the development. It does not provide details that can be assessed in detail, but there are reasons why it is unlikely that any 3M could be successful.

- The pathways connecting the geothermal reservoir with the surface are not well-enough known to allow monitoring.
- Even if there is monitoring on the correct pathways, it is unlikely that management could make changes that would protect the resources. Hydrologic systems require time to recover from stresses, meaning that drawdown continues to expand at a distance from the source of the stress. The impacts would likely become worse before they become better.
- Mitigation involves replacing the water. That would be very difficult, especially since chemistry and temperature is critical and would be part of the mitigation.

Conclusion

This memorandum has identified three conceptual models describing how geothermal development at Dixie Meadows could affect the flow to springs in the Dixie Meadows areas. Reinjected water could leak off into surrounding formation or it could be reinjected into fractures not associated with the geothermal circulation. In my opinion, there is a substantial likelihood that this effect would occur. Considering the small amount of spring flow as compared to the amount of water that would undergo geothermal development, there is a high likelihood that the development could cause the spring flow to be significantly diminished.

The changing pressures also make it likely that the mixture of briny geothermal water and shallow freshwater in the springs will change. In my opinion, the geothermal development will cause the water quality in the springs to contain more brine, and to potentially become hotter, at least until the reinjection of cooled geothermal water cools the springs. Additionally, drilling into artesian aquifers presents a small chance that hydrocarbons could mix with groundwater or otherwise discharge through the wells to the surface and contaminate the surface or spring waters.

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GEOTHERMAL DEVELOPMENT AND CHANGES IN SURFICIAL FEATURES: EXAMPLES FROM THE WESTERN UNITED STATES

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Key Words: geothermal development, hot springs, impacts, monitoring

ABSTRACT

Changes in surficial thermal features and land-surface elevations can accompany development of geothermal reservoirs. Such changes have been documented to varying extents at geothermal fields in the Western United States, including Long Valley caldera, Coso Hot Springs, and Amadee Hot Springs in California, and Steamboat Springs, Beowawe, Dixie Valley, and Brady Hot Springs in Nevada. The best-documented cases are for the Casa Diablo area in Long Valley caldera, California and for Steamboat Springs, Nevada where hydrologic monitoring programs have delineated some combination of declines in thermal-water discharge, increases in fumarolic steam discharge, and subsidence. At other areas noted above, similar types of changes have occurred but existing monitoring programs do not permit the same level of analysis of cause-and-effect relationships between such surficial changes and contributing factors.

1. INTRODUCTION

In most respects, geothermal energy offers considerable advantages over other forms of electrical and direct-use energy development in terms of minimizing adverse environmental effects. However, exploitable geothermal reservoirs are commonly associated with surficial thermal features such as hot springs and fumaroles, and some level of change in such features can be expected to accompany subsurface pressure changes associated with the production and injection of reservoir fluids. Geothermal reservoir pressure and temperature declines can also result in subsidence of the land surface. Perhaps the best-documented examples are from the Wairakei and Broadlands geothermal fields in New Zealand (Allis, 1981; Glover et al., 1996).

Most areas of existing or potential geothermal development in the Western United States include natural thermal features such as hot springs, geysers, spring-fed thermal pools, and steam-heated features such as fumaroles and hot pools. The extent that these features may be impacted by geothermal development depends on many factors, including both the properties of the subsurface and the details of the development (production and injection) scheme. The hydrologic and mechanical properties of the subsurface are usually not sufficiently known before development begins to predict the distribution and magnitude of surficial changes. Ideally, a hydrologic monitoring program should be in operation before and during development in order to delineate changes from both natural and man-made influences. For a variety of institutional, economic, and engineering reasons, this ideal is rarely met. Even when monitoring data are available, it is often difficult to quantify the relative effects of different factors that can influence surficial conditions, e.g. variations in precipitation and groundwater recharge, pumpage of groundwater aquifers, and crustal unrest (earthquakes and deformation).

The following list (see Figure 1 for locations) includes areas for which some degree of documentation exists for changes in surficial thermal features and land-surface elevations, followed by references to background information.

- Amadee Hot Springs, California: Land subsidence (Unpublished consultant's reports available from Lassen County Planning Department and California Division of Oil, Gas, and Geothermal Resources)
- Beowawe, Nevada: Cessation of geyser discharge (Layman, 1984; Faulder et al., 1997)
- Brady Hot Springs, Nevada: Cessation of hot-spring discharge and onset of boiling and steam upflow from shallow aquifers (Garside and Schilling, 1979)
- Coso Hot Springs, California: Increased activity of steam-heated features (Combs and Rotstein, 1975; Moore and Austin, 1983)
- Dixie Valley, Nevada: Increased activity of steam-heated features and subsidence (Benoit, 1997; Bergfeld et al., 1998)
- Long Valley caldera, California: Increased steam discharge in the well field, decreased thermal-water discharge at sites downstream from the well field, and subsidence (Sorey and Farrar, 1998)
- Steamboat Springs, Nevada: Cessation of geyser discharge (Sorey and Colvard, 1992)

In this paper, we describe the hydrologic monitoring program and the evidence for changes in surficial features associated with ongoing geothermal development in the Casa Diablo area of Long Valley caldera. We also compare and contrast the Long Valley development experience with that at Steamboat Springs, Nevada, and comment on situations at the other development areas listed above.

2. LONG VALLEY CALDERA, CALIFORNIA

2.1 Geothermal Development

The geothermal system in Long Valley involves upflow from a source reservoir in the west moat of the caldera and lateral outflow of thermal water in a generally west to east direction (Sorey et al., 1991). Reservoir temperatures range from 214°C beneath the west moat, to 170°C at Casa Diablo, and 110°C near Hot Creek gorge in the east moat of the caldera (Figure 2). Hot springs discharge primarily within Hot Creek gorge. Geothermal development currently consists of three binary power plants on a combination of private and public lands located at Casa Diablo. The plants produce a total of about 40 MW from wells that tap the shallow, 170°C, reservoir at depths of ~150 m. Plant MP-1 has been in continuous operation since 1985; plants MP-2 and PLES-1 began operations in 1991. In this single-phase, closed system, cooled geothermal water at ~80°C is reinjected in the well field at depths of about 600 m. Total flow rate through the plants is about 900 kg/s.

Inadvertent leaks of isobutane working fluid into the injection wells at Casa Diablo have provided a useful chemical tracer within the geothermal system. Isobutane has been detected in fumaroles at and near Casa Diablo and in the Hot Bubbling Pool 5 km to the east. Fluorescein tracer tests and isobutane data indicate that less than 10% of the fluid injected at Casa Diablo moves into the production zone. Instead, most of it flows away from the well field within the injection reservoir. The appearance of isobutane at distant thermal features, however, indicates a higher degree of connection between these two zones outside the well field.

2.2 Hydrologic Monitoring Program

The Long Valley area, which includes the resort town of Mammoth Lakes, has numerous features of geologic, hydrologic, and recreational significance. Concerns over possible impacts of geothermal and water-resources developments on surficial thermal features led to establishment of the Long Valley Hydrologic Advisory Committee (LVHAC) in 1987. LVHAC membership includes the U.S. Bureau of Land Management, U.S. Forest Service, U.S. Geological Survey (USGS), Mono County, California State Department of Fish and Game, Mammoth Community Water District, geothermal developers, and various environmental organizations. As described by Farrar and Lyster (1990), the purpose of the LVHAC was to implement a hydrologic monitoring program focused on early detection of changes in surficial features that could be influenced by water-resource developments within the caldera. The LVHAC provides information to permitting agencies on such changes and recommends mitigation alternatives for specific development projects. The committee is advisory and as such its recommendations do not create legal obligations. The USGS, as a non-voting member of the LVHAC, is responsible for collecting and compiling hydrologic monitoring data, and has on occasion been requested to prepare interpretive reports based on these data.

In addition to the hydrologic monitoring program conducted by the USGS, each resource developer is required to monitor conditions in and around their well fields. Thermal and nonthermal subcommittees of the LVHAC meet with specific developers to discuss both public and proprietary monitoring and development data and interpretive analyses of such information. Findings and/or recommendations are conveyed to the LVHAC. Experience has shown that this full and open disclosure and discussion of public and proprietary monitoring data has allowed a more complete understanding of changes accompanying development and promoted an attitude of trust that has helped to avoid litigation. One example of this process is the planning and completion of a numerical model of the response of the geothermal field to development. The modeling was funded by the developer and carried out by one of its consultants, but input and review were sought from members of the thermal subcommittee.

The LVHAC monitoring program includes thermal springs east of Casa Diablo (Figure 2), streamflow measurement sites along Mammoth and Hot Creek, and both thermal and nonthermal wells (e.g. CH10B, and M-14, respectively). Areas of environmental concern include thermal springs at the Hot Creek Fish Hatchery and in Hot Creek gorge. The Hatchery springs discharge at a composite temperature near 16°C, considered optimum for trout-rearing operations. These springs contain a small (~5%) component of thermal water. Springs in Hot Creek gorge discharge at temperatures up to boiling (93°C), and provide a popular environment for bathing in heated creek water.

2.3 Changes in Surficial Features

Geothermal development at Casa Diablo has resulted in declines in reservoir pressure and temperature over the 1985-1998 period. As exemplified by data from observation well 65-32 on the edge of the well field (Figure 3), a cumulative pressure change of 0.1 Mpa between 1985 and 1990 was followed by an additional drop of 0.25 Mpa during 1991 in response to increased production and deepening of injection wells. Between 1991 and 1999, reservoir pressures have declined by about 0.1 Mpa, for a total decline of 0.45 Mpa (4.5 bars). The reduction in reservoir temperature amounts to 10-15°C, compared with localized reductions of ~80°C in the deeper injection zone. Boiling conditions in the heated groundwater system above the production reservoir have resulted in significant steam occurrences at and near the land surface, including fumaroles occupying former hot-spring vents, steam collecting beneath building foundations, and steam flowing upward through the roots of trees.

Data from the USGS monitoring program outside the Casa Diablo area (Sorey and Farrar, 1998a, b) show cessation of spring flow at Colton Spring (2 km east of Casa Diablo) and declines in water level in Hot Bubbling Pool (HBP, 5 km east of Casa Diablo). The water-level record for thermal well CW-3 adjacent to HBP correlates with the pressure record from well 65-32, indicating that the 0.25 Mpa pressure decline in the well field in 1991 (equivalent to a water-level drop of 25 m) caused a drop of 1.2 m in water level at this distance.

At the Hot Creek Fish Hatchery, chemical-flux measurements show that the thermal-water component in the springs has declined by some 30-40% since 1990. However, temperatures in the Hatchery springs have changed mainly in response to variations in the nonthermal component caused by seasonal and annual variations in groundwater recharge. The apparent lack of observable response in spring temperature accompanying the decline in thermal-water component suggests a moderating influence of conductive heating from rocks within and adjacent to the shallow flow zone containing a mixture of thermal and nonthermal fluids.

Total thermal-water discharge at Hot Creek gorge is calculated from chemical flux measurements at gaging sites on Hot Creek upstream and downstream from the thermal springs. Within a measurement error of ~15%, no decrease in thermal-water flow has been detected over the 1988-1998 period and the presence of isobutane has not been detected in the gorge springs. It appears from this that the current level of geothermal development has not caused detectible hydrologic changes beyond distances of about 5 km from the well field.

Leveling data collected along Highway 395 show subsidences in the vicinity of Casa Diablo beginning in 1986, superimposed on a general pattern of uplift that began in 1980 in response to crustal unrest (Sorey and Farrar, 1998; Sorey et al., 1995). Since 1988, benchmarks at Casa Diablo have subsided approximately 25 cm relative to benchmarks on the resurgent dome, which have risen approximately 20 cm. This perhaps represents a unique situation in that subsidence induced by geothermal fluid withdrawal has allowed the actual land surface elevation to remain relatively constant, while intermittent intrusive activity has cause significant uplift of the surrounding region.

3. STEAMBOAT SPRINGS, NEVADA

3.1 Geothermal Development

The geothermal system beneath the Steamboat Hills, located about midway between Reno and Carson City, Nevada, is currently being developed by two well fields and associated power plants (Figure 4). To the south, the higher-temperature Caithness Power Incorporated (CPI) development involves single-stage steam flash and residual liquid injection. To the north, the lower-temperature Far West Capital (FWC) project involves production and injection of pressurized single-phase liquid and binary power plant conversion. Electrical production totals about 15 MW at the CPI plant and 85-90% of produced fluids are reinjected north of the production well field. The generating capacity of the FWC plants totals about 40 MW and 100% of produced fluids are reinjected in wells adjacent to the production well field.

Between the two development areas is a silica terrace through which hot springs and geysers discharged until 1987, when sustained testing of geothermal wells began and water levels in the spring vents began falling (Sorey and Colvard, 1992; Collar and Huntley, 1990; Collar, 1990). Analyses of available hydrologic and geochemical data have led various authors to conclude that a single, interconnected, geothermal system exists in the Steamboat Springs area (Sorey and Colvard, 1992; Mariner and Janik, 1995, and White, 1968). Hot water flows upward beneath the Steamboat Hills and then laterally toward the north and northeast. In addition to the main terrace described above, the ultimate point of discharge of thermal water under pre-development conditions was Steamboat Creek.

3.2 Hydrologic Monitoring Program

Regulation and monitoring activities at Steamboat have tended to be more complex and difficult to pursue than at Long Valley. Although there are multiple regulatory jurisdictions involved at each area, the absence of an entity such as the LVHAC at Steamboat has made it more difficult to conduct adequate monitoring and to provide for interpretive studies of changes associated with development. This situation still exists today, in spite of the fact that part of the silica terrace and adjacent areas to the west were designated an Area of Critical Environmental Concern by the Bureau of Land Management (Sorey and Colvard, 1992).

Each developer has been responsible for monitoring conditions in and around their well field. A set of wells drilled for testing and monitoring exists in the FWC well field; in the CPI well field wells drilled for stratigraphic information are monitored. A network of wells drilled into the nonthermal groundwater system surrounding the Steamboat Hills is included in the monitoring program carried out by FWC.

3.3 Changes in Surficial Features

Data on pressure changes in the developed well fields are either not publicly available or are difficult to interpret. Pressures declines in both fields appear to be minimal (~0.05 Mpa, or 0.5 bars). This indicates high reservoir transmissivity and pressure support from injection wells. Indeed, tracer tests at the FWC show that most of the injected water remains within the well field (Rose et al., 1999). This is in contrast to the situation at Long Valley described above.

By the time monitoring programs began in earnest in 1986, the geysers and springs were in decline and by 1987, liquid discharge on the main terrace had stopped. Monitoring of water levels in some spring vents continued through 1989, when water levels in the silica-lined spring conduits fell beyond the reach of measuring equipment. Two measurements were also made in 1989-1990 of thermal-water discharge in Steamboat Creek, using chloride flux techniques, for comparison with similar estimates made in the 1950-1960 period (Sorey and Colvard, 1992). These data suggest declines in total discharge of about 40%.

The analysis by Sorey and Colvard (1992) concluded that declines in hot-spring activity and thermal-water discharge at Steamboat Springs resulted from a combination of (1) successive years of below-normal precipitation and groundwater recharge, (2) groundwater pumpage in the South Truckee Meadows (north of the Steamboat Hills), and (3) geothermal fluid production. It was not possible at that time to adequately determine the relative impacts of each factor. However, precipitation has returned to normal or above-normal levels since 1994 and monitoring records show that groundwater levels have risen significantly since that time and are now at nearly the same levels as in the late 1980's. Although no recent measurements have been attempted of water levels in the spring vents on the main terrace, there is no evidence of any renewed spring flow.

4. OTHER AREAS OF GEOTHERMAL DEVELOPMENT

The scale and type of geothermal development at other noted areas in the Western United States vary widely, ranging from a small binary-electric power plant supplied by two production wells and no injection wells at Amadee Hot Springs in northeastern California to the ~250 Mwe steam-flash power plants at Coso Hot Springs in eastern California (Figure 1). In all but one case, all or most of the development area and surficial thermal features are privately owned. The exception is the Coso Hot springs area south of Long Valley in eastern California, where most of the land under development is part of the federally operated China Lake Naval Weapons Center. Thermal features at Coso Hot Springs, located adjacent to the well field, are traditionally utilized by local Native Americans. Environmental agreements between the Navy, the U.S. Bureau of Land Management, and Native American organizations call for mitigation in the event that geothermal development causes changes that negatively effect future use for religious and ceremonial purposes (Bureau of Land Management, 1980).

In cases where geothermal reservoirs and associated surficial thermal features are on privately owned land, regulations governing geothermal development are usually specified by state or county agencies, rather than federal agencies. Monitoring programs may not include observations of thermal features, so that information about changes in thermal features or land elevations is usually anecdotal or unpublished and often not sufficiently detailed to provide adequate documentation of cause-and-effect relations. Even when thermal features are on public lands, hydrologic monitoring may be deemed unnecessary where expected changes in thermal features or land-surface elevations are judged a-priori to be either mitigatable or insignificant.

A common aspect of changes induced by development of hot-water reservoirs is the reduction of liquid discharge in springs and geysers and the increase in steam discharge in fumaroles and other steam-heated features. Available information indicates that such changes have occurred at Long Valley, Steamboat, Beowawe, Amadee Hot Springs, and Brady Hot Springs, while at Coso Hot Springs and Dixie Valley naturally occurring steam discharge has increased during development. At Amadee Hot Springs, Brady Hot Springs, Dixie Valley, and Long Valley, reductions in reservoir pressure have also induced significant levels of land subsidence and ground cracking. As pointed out previously, documentation of such changes and determinations of the influence of various factors on the thermal features is adequate only for Long Valley. At Beowawe and Steamboat Springs, reductions and cessation of geyser activity accompanied the pre-development testing of production wells in the 1970's, at a time when monitoring efforts were inadequate. Some of the previously cited references contain information on thermal features at the "other" areas of geothermal development discussed in this section; additional pertinent references are listed below:

- Beowawe: Zoback (1979); White (1998); Layman (1984); Olmsted and Rush (1987)
- Brady Hot Springs: Ettinger and Brugman (1992); Harrill (1970), Osterling (1969); Olmsted et al. (1975)
- Coso Hot Springs: Monahan and Condon (1991a,b); Erskine and Lofgren (1989); Fournier et al. (1980); Fournier and Thompson (1982)
- Dixie Valley: Williams et al. (1997); Waibel (1987)

5. CONCLUSIONS

Changes in surficial thermal features and land elevations accompanying geothermal development should be viewed as the rule, rather than the exception. This follows from the nature of geothermal reservoirs within flow systems that commonly include discharge of fluids at the land surface. In the absence of fluid injection in locations proximal to such discharge areas, reductions in reservoir pressure will cause some degree of reduction in fluid upflow feeding the thermal features. Natural geyser activity should be expected to be most sensitive to such changes because of the unique combination of processes and characteristics typically required for geyser discharge. Where hot fluids occur at relatively shallow depths, either within a developed reservoir or in the overlying groundwater system, pressure reduction can also induce boiling conditions that result in increases in steam discharge at the land surface.

Factors other than pressure reductions in geothermal reservoirs can influence the temperature and flow rate of surficial thermal features. Information gained from hydrologic monitoring in and around the developed well fields, both during and prior to the development period, can allow quantification of the timing and magnitude of cause-and-effect relations between various factors that affect surficial thermal discharge and guide attempts to mitigate any adverse impacts caused by development.

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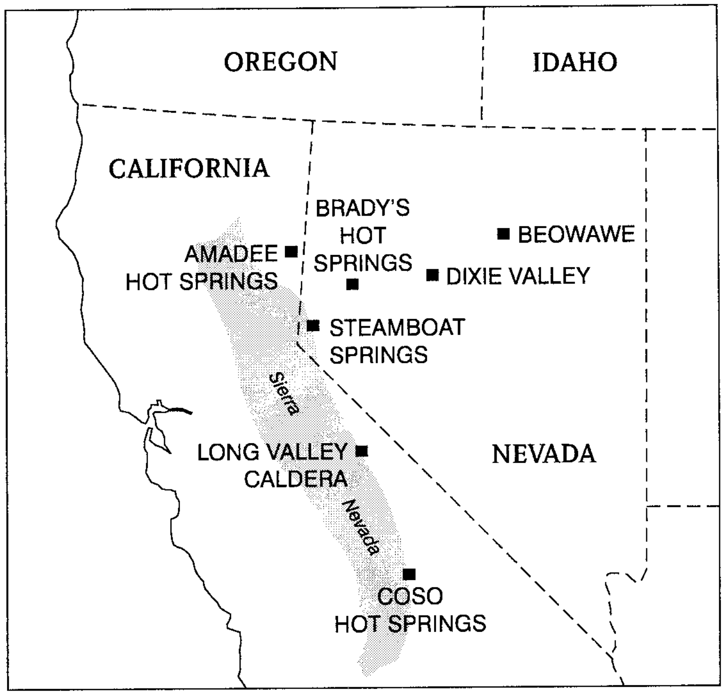

Figure 1. Locations of some geothermal fields where development has been associated with changes in thermal features and/or land subsidence.

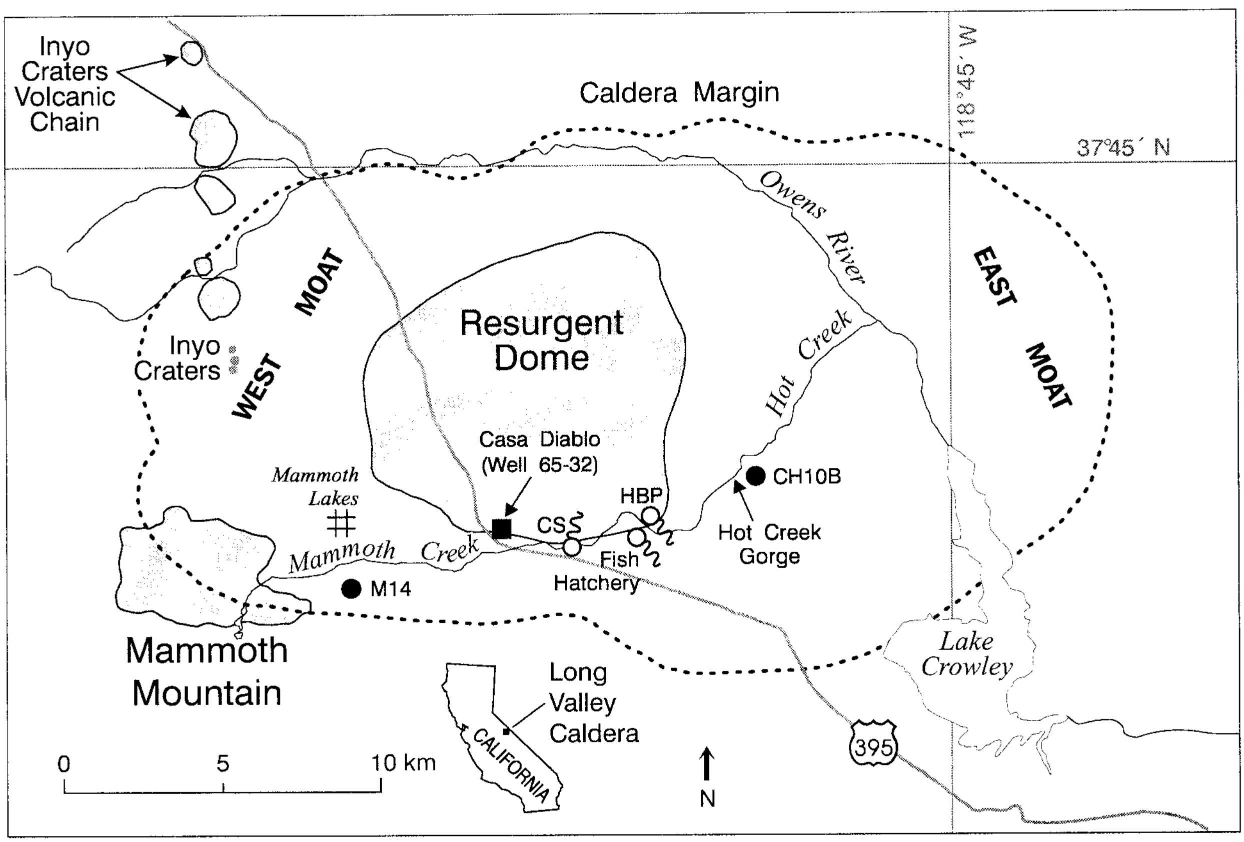

Figure 2. Map of Long Valley caldera showing various geologic and cultural features, and key sites in the hydrologic monitoring program directed by the Long Valley Hydrologic Advisory Committee.

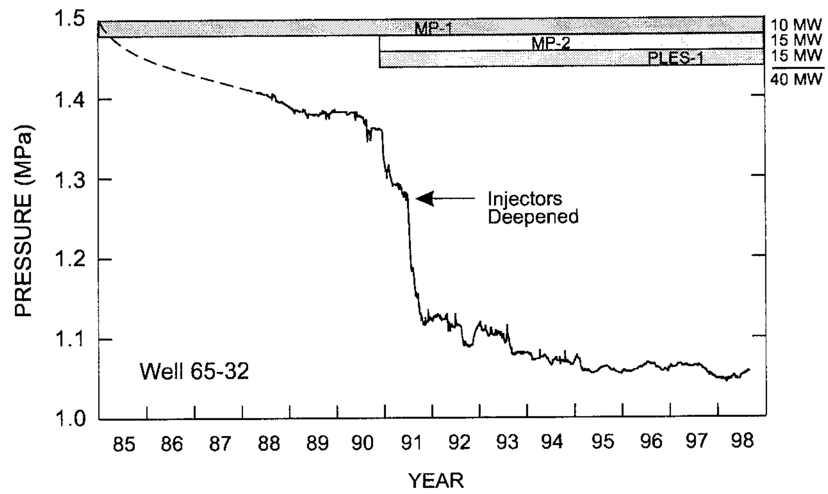

Figure 3. Pressure history in observation well 65-32, located on the edge of the geothermal well field at Casa Diablo, and periods of operation of three geothermal power plants.

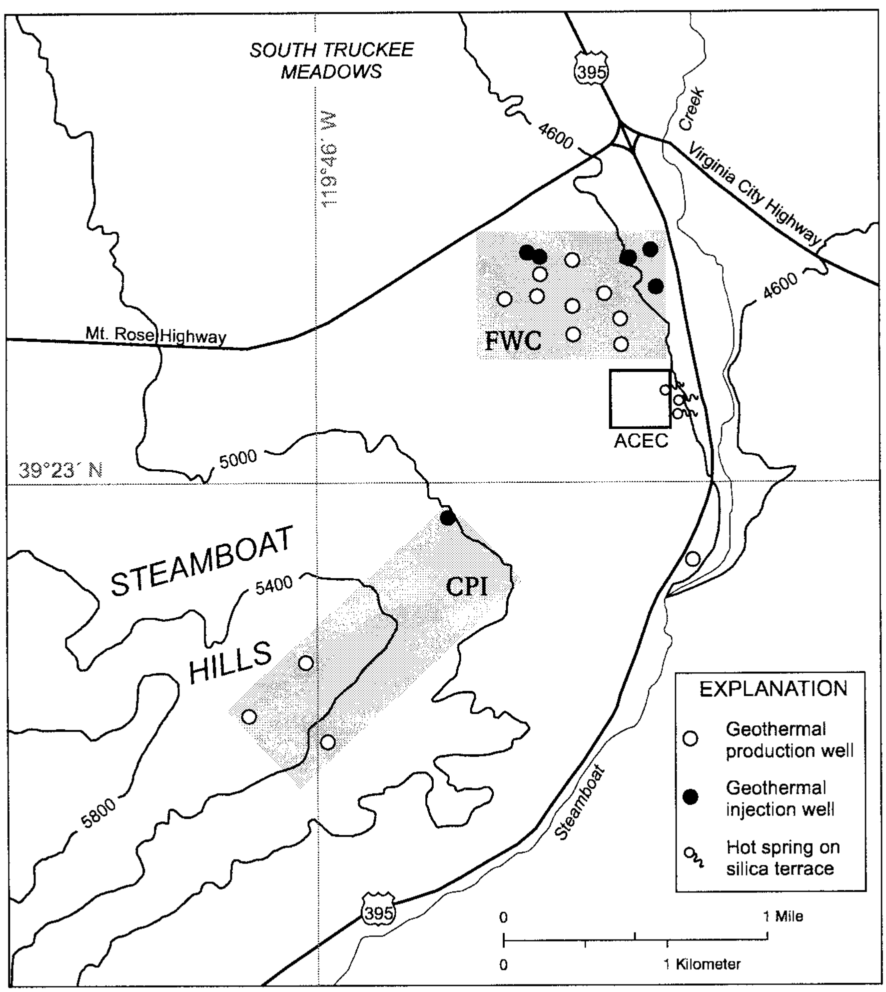

Figure 4. Map of the Steamboat Hills and surrounding region showing approximate wellfield areas for the Caithness Power, Incorporated (CPI) and Far West Capital (FWC) geothermal developments, locations of most of the production and injection wells, some of the vents on the main silica terrace that formerly included active hot springs and geysers, and the outline of the Area of Critical Environmental Concern (ACEC) designated by the Bureau of Land Management.

LETTER GG

Basin and Range Watch

July 30th, 2019

To: Greg Miller, California Desert District office Email sent to blm_ca_cd_haiwee_geothermal@blm.gov

Re: Comments on the Haiwee Geothermal Leasing Area and Draft Supplemental Environmental Impact Statement - BLM-CA-D050-2017-0002-EIS DOI No. 12-6

Basin and Range Watch is a 501(c)(3) non-profit working to conserve the deserts of Nevada and California and to educate the public about the diversity of life, culture, and history of the ecosystems and wild lands of the desert. Federal and many state agencies are seeking to open millions of acres of unspoiled habitat and public land in our region to energy development. Our goal is to identify the problems of energy sprawl and find solutions that will preserve our natural ecosystems, open spaces, and quality of life for local communities. We support energy efficiency, better rooftop solar policy, and distributed generation/storage alternatives, as well as local, state and national planning for wise energy and land use following the principles of conservation biology.

Purpose and Need:

The Purpose and Need Statement cites Executive Order 13783, dated March 28, 2017, which promotes "clean and safe development of our Nation's vast energy resources, while at the same time avoiding regulatory burdens that unnecessarily encumber energy production, constrain economic growth, and prevent job creation."

This is simply an insulting statement and contradicts the BLM's legal requirements to adequately review a potential impact on public lands. Under the National Environmental Policy Act. Even if it is one of Donald Trump's orders, it is not relevant to this review and should be removed from the Final EIS. We are offended that our concerns may be written off as "Regulatory Burdens".

The BLM is required to consider a full range of alternatives under the National Environmental Policy Act. Since this review specializes in geothermal energy, we believe the No Action Alternative is the most appropriate.

A No Action Alternative can be justified by BLM because there are less environmentally destructive ways to utilize renewable energy than to approve this kind of energy.

Distributed generation in the built environment should be given more full analysis as a completely viable alternative. This project will need just as much dispatchable baseload behind it, and also does not have storage. But environmental costs are negligible with distributed generation, compared with this project. Distributed generation cannot be "done overnight," but neither can large transmission lines across hundreds of miles from remote central station plants to load centers. Most importantly, distributed generation will not reduce the natural carbon-storing ability of healthy desert ecosystems, will not disturb biological soil crusts, and will not degrade and fragment habitats of protected, sensitive, and rare species.

Germany is a distributed generation success story and has installed 22 GW of renewable energy in 2012, about 80 percent of which is in the built environment. This alternative is viable and can be integrated into the grid. In-Depth: Germany's 22 GW Solar Energy Record Read more at http://cleantechnica.com/2012/05/31/in-depth-germanys-22-gw-solar-energyrecord/#XJfxt6OcUUkdvr3S.99

Development Focus Areas in the Desert Renewable Energy Conservation Plan (DRECP).

The EIS would allow geothermal to be partly built in a DRECP Development Focus Area. While the purpose of the DRECP was to concentrate the development in the DFA's, the cumulative impacts of the project would impact not only the lands in the DFA, but adjacent lands as well. Impacts to groundwater, wildlife connectivity (bighorn sheep), visual resources and cultural landscapes would all extend outside of the DFA.

California Desert Conservation Area: (CDCA)

The development of 3 geothermal projects on over 4,000 acres of public lands would not be consistent with the CDCA. The CDCA protects the following elements:

(1) the California desert contains historical, scenic, archeological, environmental, biological, cultural, scientific, educational, recreational, and economic resources that are uniquely located adjacent to an area of large population;

(2) the California desert environment is a total ecosystem that is extremely fragile, easily scarred, and slowly healed;

(3) the California desert environment and its resources, including certain rare and endangered species of wildlife, plants, and fishes, and numerous archeological and historic sites, are seriously threatened by air pollution, inadequate Federal management authority, and pressures of increased use, particularly recreational use, which are certain to intensify because of the rapidly growing population of southern California;

(4) the use of all California desert resources can and should be provided for in a multiple use and sustained yield management plan to conserve these resources for future generations, and to provide present and future use and enjoyment, particularly outdoor recreation uses, including the use, where appropriate, of off-road recreational vehicles;

(5) the Secretary has initiated a comprehensive planning process and established an interim management program for the public lands in the California desert; and

(6) to insure further study of the relationship of man and the California desert environment, preserve the unique and irreplaceable resources, including archeological values, and conserve the use of the economic resources of the California desert, the public must be provided more opportunity to participate in such planning and management, and additional management authority must

Be Under the Federal Lands Policy Management Act, the CDCA was established to be provided by the Secretary to facilitate effective implementation of such planning and management. https://www.blm.gov/or/regulations/files/FLPMA.pdf

The Haiwee Geothermal Area would be inconsistent with the management actions required in the CDCA.

The area contains hydrologic resources that are unique as well as cultural and biological resources.

The development of 3 geothermal projects would not be consistent with allowing multiple use while conserving the resources for future generations.

Since the desert is easily scarred, these projects would leave lasting impacts.

The Purpose and Need Statement should state more about the conservation requirements of the Land Use Plans that must be amended to approve this plan.

Alternatives

We oppose allowing any disturbance in the Mojave Ground Squirrel, Ayres Rock, Rose Spring and Sierra Canyon ACEC's. Areas of Critical Environmental Concern were established to protect a variety of resources, not develop the areas that were established to protect them. Any geothermal development would compromise all cultural landscapes and would degrade the integrity of the cultural ACEC's.

The Mohave ground squirrel has long been listed as Threatened under the California Endangered Species Act. In spite of its protected status, little is known of its habitat needs or even where it still occurs. In many areas within its historic range, there are no recent records. This information is essential to the development of a conservation strategy for the species.

The factors that are the basis for making a listing determination for a species under section 4(a) of the Act (16 U.S.C. 1531 et seq.), which are:
(a) The present or threatened destruction, modification, or curtailment of the species' habitat or range;
(b) Overutilization for commercial, recreational, scientific, or educational purposes;

(c) Disease or predation;
(d) The inadequacy of existing regulatory mechanisms; or
(e) Other natural or manmade factors affecting its continued existence.

Development of any of this habitat is not appropriate. The Mojave Ground Squirrel has a limited habitat and is very vulnerable to disturbance. Industrial energy projects are not appropriate in its habitat.

The EIS does not review a dry cooling only alternative. Dry-cooling can be the difference between a couple hundred acre feet of water and thousands of acre feet of water. In an arid 1
region like this, this should be the only alternative considered.

"Cooling tower is an integrated part of any geothermal power plant because waste heat from turbine exhaust steam must be continuously rejected to make the plants operate. According to the heat dump choice, the cooling system can be classified as wet cooling and dry cooling. Dry cooling towers conduct heat transfer through air-cooled heat exchanger that separates the working fluid from the cooling air. In a dry cooling tower, air can be introduced by either mechanical draft fans or by natural draft tall tower to move the air across the air-cooled heat exchangers. Ambient condition has significant effect on the performance of dry cooling towers. Most geothermal power plants, especially the geothermal power plants using Enhanced Geothermal Systems (EGS) technology, have unique ambient conditions and applications. The Queensland Geothermal Energy Centre of Excellence (QGECE) developed natural draft dry cooling towers (NDDCTs) and steel cooling tower technologies for geothermal power plants…."
https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119066354.ch32

Affected Environment/Environmental Consequences:

Potential hydrologic impacts could be:

Degrading surface water quality by increasing erosion and sedimentation, or altering spring discharged water chemistry, it could alter water quantity by reducing spring discharge rates, 2
decreasing groundwater supply, or interfering substantially with groundwater recharge, it could alter surface or geothermal water temperatures.

Biological Resources:

The project would potentially impact 33 rare or sensitive plants, desert tortoise and the Mojave ground squirrel.

3

Also this species list does not include the possibility of the Panamint alligator *lizard (Elgaria panamintina)* inhabiting the area. There is a confirmed Panamint alligator lizard sighting from Haiwee Springs, in the Coso Range, not far from the proposed project site. Panamint alligator lizards are BLM sensitive species and the sighting occurred in 1993. It can be referenced here: https://www.fws.gov/cno/Science/Review%20PDFs/2017/comments/panamint_alligator_lizard_SSA_2017-11_comments.pdf 3 (con't)

Visual Resources:

The Visual Resources analysis fails to provide good Key Observation Points. In fact, the supplemental provides absolutely no KOP's.

Large geothermal plants are complex and have several components that will altar the visual landscape.

The project should not even be considered on VRM Class II lands. The objective of VRM Class II is: To retain the existing character of the landscape. Allowed Level of Change: The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer.

Geothermal projects cannot maintain this objective. They are quite large, require new roads, and must be illuminated all night for security and operational reasons. Geothermal plants also release common steam plumes which are also a visual impact. 4

This kind of development would also be inconsistent with VRM Class III Objectives which are to partially retain the existing character of the landscape. Allowed Level of Change: The level of change to the characteristic landscape should be moderate. Management activities may attract attention, but should not dominate the view of the casual observer.

The size of these projects completely alter the view. There would be no partial maintaining of the VRM Class.

Land use plans must always be amended to accommodate such huge visually disturbing projects.

Downgrading a Visual Class can have economic impacts. The area in question is within or near popular recreation areas.

The SEIS fails to provide us with any good Key Observation Points and these must be included. KOP's from the Coso Wilderness, Hwy 395 and areas in the Sierra should be considered and included. The SEIS should also include a dark skies KOP and this would help provide an idea of how much of an impact a fully illuminated geothermal plant can have.

Conclusion:

Basin and Range Watch supports the No Action Alternative for this supplemental EIS. While renewable energy is an important element of our future, it must be planned in a way that fully minimizes environmental impacts and BLM has failed to do this in this EIS. The region targeted for impacts includes important biological resources, cultural resources, hydrologic resources and visual resources. Because there are plenty of renewable energy alternatives to this project, the impacts are simply not necessary.

Thank you,

Kevin Emmerich

Co-Founder

Basin and Range Watch

P.O. 70, Beatty, NV 89003