APPENDIX A
TYPICAL GEOTHERMAL RESOURCE DEVELOPMENT AND TRANSMISSION TOOLS

GEOTHERMAL INTRODUCTION

The term *geothermal* comes from the Greek *geo* meaning "earth" and *thermal* meaning "heat." As such, geothermal energy is energy derived from the natural heat of the earth. Geothermal resources are typically underground reservoirs of hot water or steam created by heat from the earth, but geothermal resources also include subsurface areas of dry hot rock. In cases where the reservoir is dry hot rock, the energy is captured through the injection of cool water from the surface, which is then heated by the hot rock and extracted as fluid or steam. Geothermal steam and hot water can naturally reach the earth's surface in the form of hot springs, geysers, mud pots, or steam vents. Geothermal reservoirs of hot water are also found at various depths beneath the Earth's surface. Geothermal resources can also be accessed by wells (**Figure A-1**).

Figure A-1: Geothermal Flow Chart

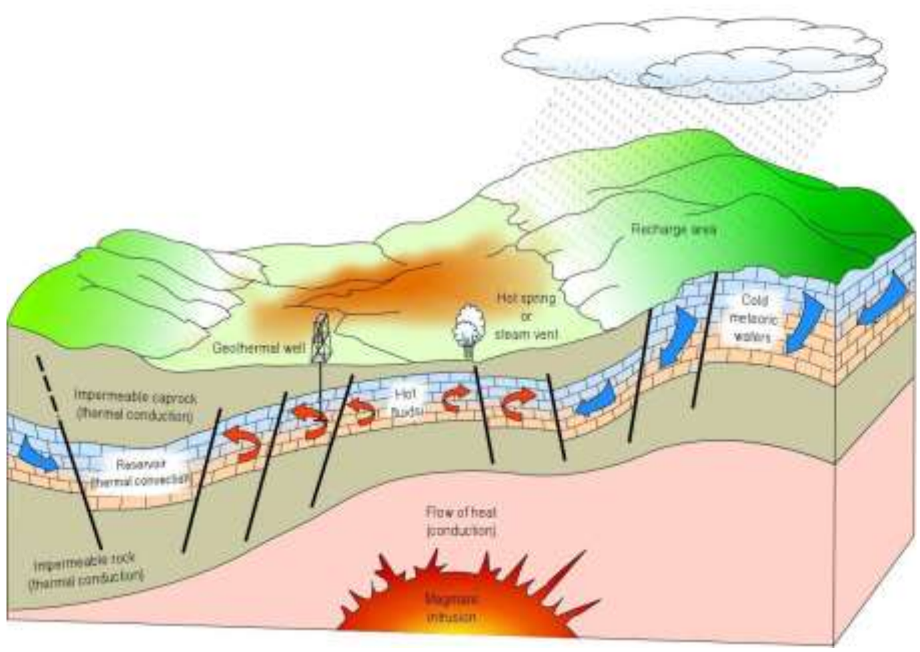


Table A-1 identifies the typical facilities required to generate electricity from geothermal resources.

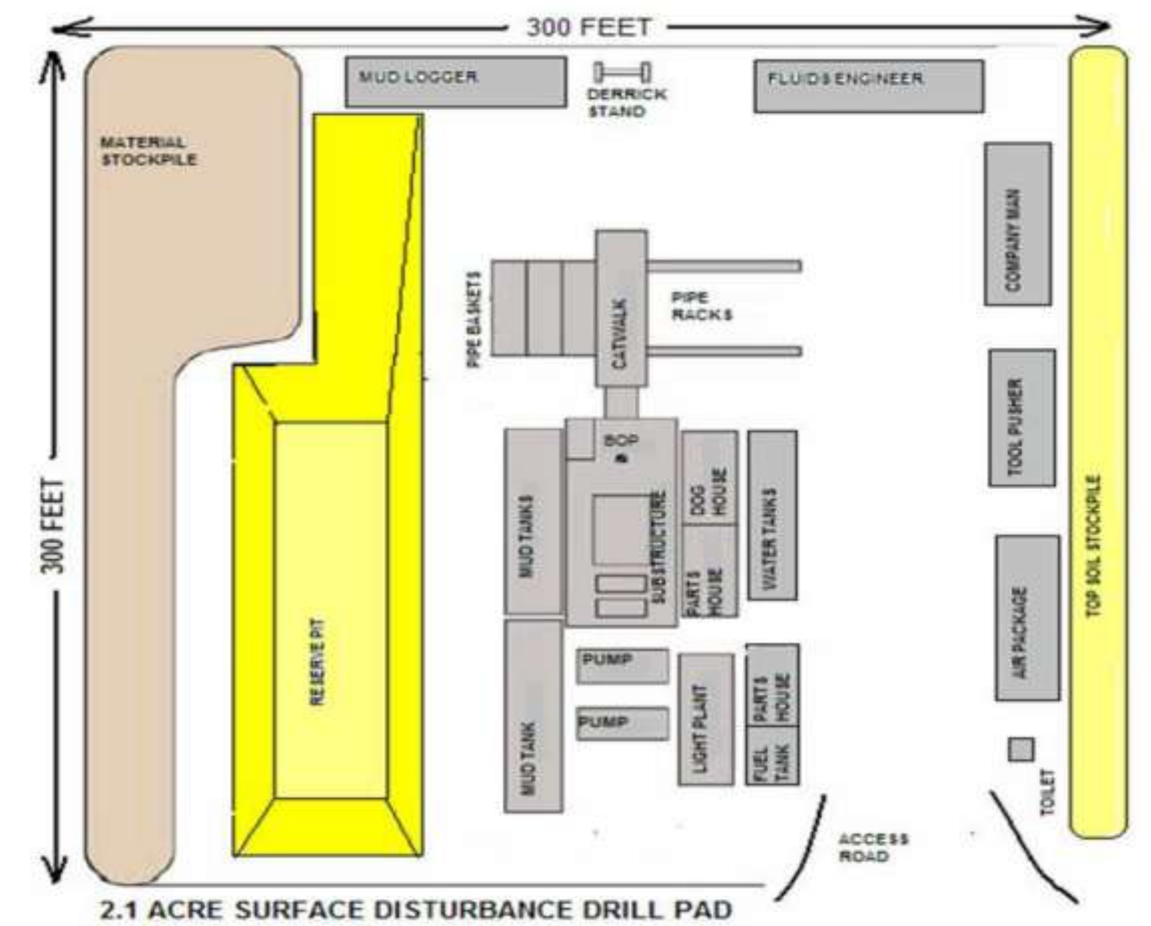
Table A-1
Typical Geothermal Development Facility Functions

Structure	Function
Well Pad Access Roads	Access roads are used during development to construct the production wells and install equipment. During utilization, access roads are used for accessing wells for maintenance.
Well Pads	Well pads include all the equipment necessary to operate a well. During development, any additional drilling would occur from the well pads. Well pads also include reserve pits for testing of new wells.
Production Wells	Production wells flow geothermal fluid to the surface that is then piped to the power plant to generate electricity.
Injection Wells	Injection wells are used to inject geothermal fluid from the power plant back into the geothermal reservoir. Injection ensures the longevity and renewability of the geothermal resource.
Observation Wells	The observation well is used to monitor the geothermal resource. Water samples and downhole pressure data are gathered from the observation well.
Geothermal Fluid Collection Pipeline	A pipeline that collects produced geothermal fluids and transports them to the plant.
Injection Pipeline	Injection pipeline moves geothermal fluid from the power plant to the injection well, where it is returned to the geothermal reservoir.
Power Plant	The power plant produces electricity using either binary, flash steam or some combined geothermal power plant technology.
Substation	The substation converts electricity produced at the power plant to the proper voltage in order to transfer this electricity along a transmission line to the power system.
Transmission Line	The transmission line transmits the electricity generated to users.

Well Pads

Well pads are constructed to perform temperature gradient and geothermal exploratory drilling. The layout of a typical well pad is shown in **Figure A-2**.

Figure A-2: Typical Geothermal Well Pad Layout.



SOURCE: Ormat Nevada 2007

Well pad facilities and equipment needed for the development phase include a drill rig and ancillary equipment, such as generators, support trailers, and well testing equipment. Each production well pad will be equipped with a small metal equipment building (approximately 15 feet by 15 feet) that will be located on the well pad so as to not interfere with drilling or workover operations.

The building will house:

- Auxiliary systems
- Motor switch gear
- Controls

- Sensors
- Transmitters

Drilling

Exploratory drilling determines if the geothermal resource is viable to be used in energy generation. Each exploration well is drilled with a large rotary drill rig. During drilling, the top of the drill rig mast could be as much as 178 feet above the ground surface, and the rig floor could be 20 to 30 feet above the ground surface. **Figure A-3** shows example drill rigs.

Figure A-3: Example Drill Rigs

Typical Exploration Well (178 feet tall)

Typical Slim Well Rig (50 feet tall)

SOURCE: Ormat Nevada 2007

Blow out prevention equipment (BOPE) is used during drilling to protect the natural and human environment surrounding the operation. BOPE is installed on a wellhead to prevent the escape of pressure either in the annular space, between the casing and the drill pipe, or in an open hole (i.e. hole with no drill pipe) during drilling and well completion operations. **Figure A-4** depicts a schematic of a well with BOPE installed. If a resource is not viable, an exploration well is sealed and capped, if the resource is found to be viable, the well site could be used for production. Well drilling for production wells is the same as for exploration wells. Production wells are similar to exploration wells;

however, they are usually a little bigger and deeper. **Figure A-5** shows a typical production well cross section.

Production wells bring the geothermal fluid to the surface where it can be piped to a geothermal power plant to generate electricity.

Injection wells will also be drilled to inject used geothermal water back into the geothermal reservoir. The injected water will be reheated, and assist in maintaining pressure as well as sustaining the reservoir. Injection wells have the same construction as exploration and production wells.

Well logging

Well logs and surveys are typically run during the drilling of any production wells to:

- Identify any groundwater aquifers which may be present,
- Determine lithology and geologic structure,
- Identify zones suitable for production and injection, and
- Gather data on formation properties during well tests.

Well testing

A well test is conducted in order to evaluate economic production capability of each well. The long term test would consist of pumping the geothermal fluids from the well for approximately 30 to 90 days, through on-site test equipment. Geothermal fluids produced from the well would flow through various testing apparatus, including a weir box to measure the volume of fluid flow, and accumulate in the well-pad reserve pit. The fluid would then either evaporate or be transferred, by temporary piping, for injection in an injection well in the development area. All surface test equipment and temporary pipelines would be removed at the completion of testing.

Figure A-4: Typical Blow Out Prevention Equipment.

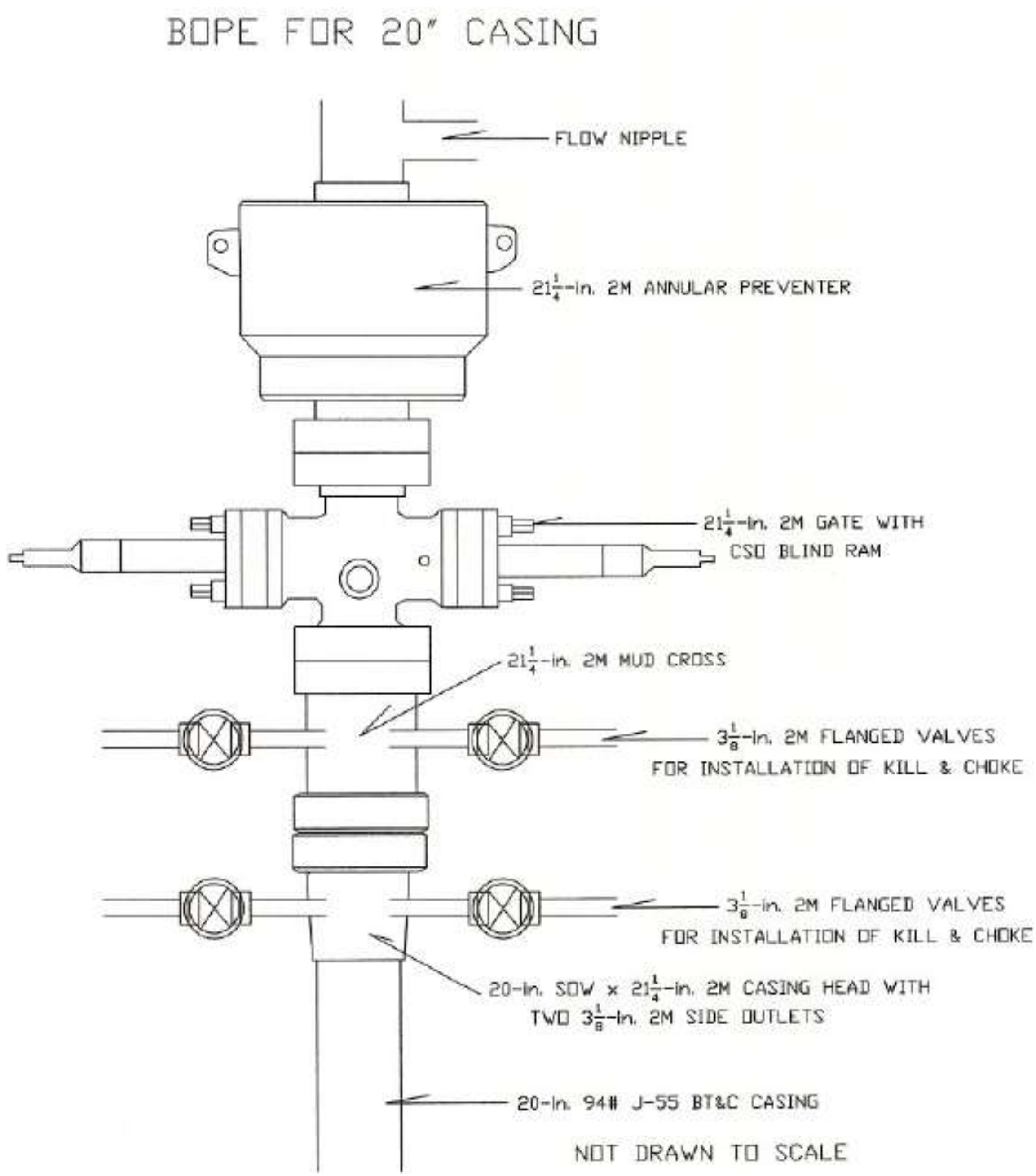
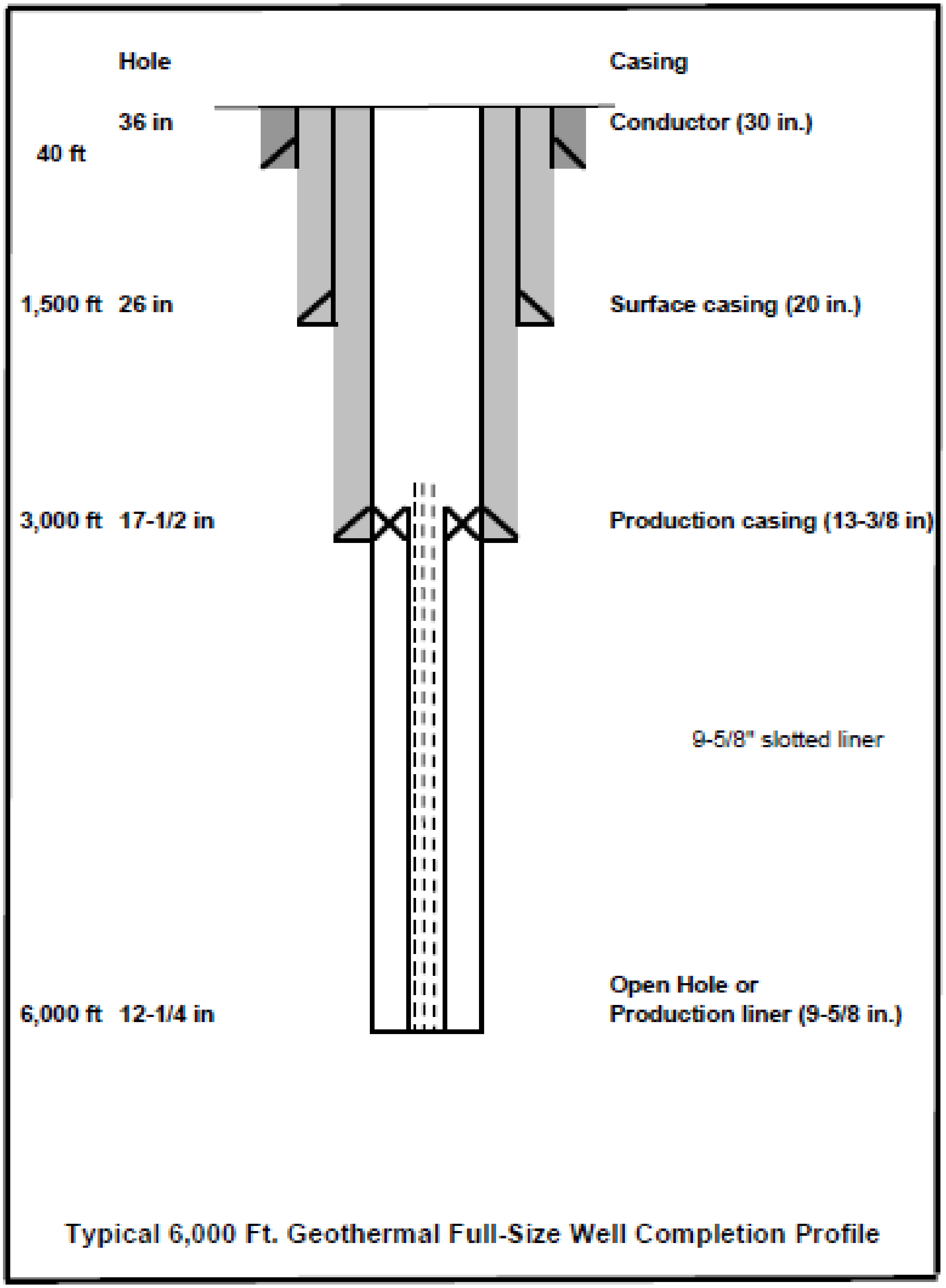


Figure A-5: Typical Production Well Schematic



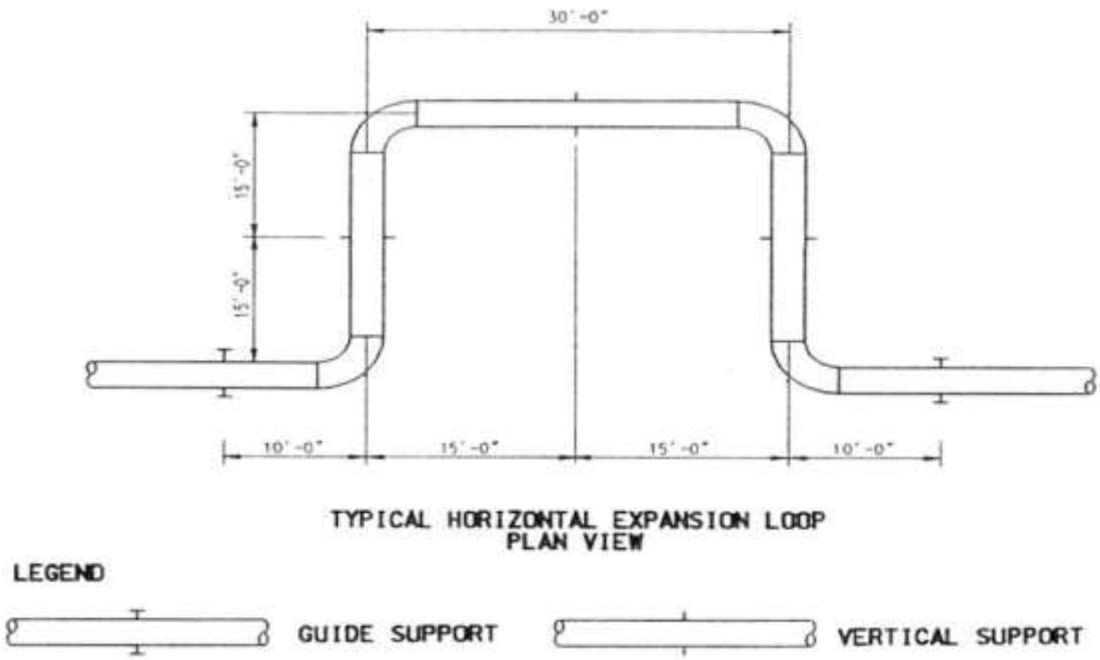
Pipelines

Pipelines, consisting of seamless steel pipe and including insulation, will vary in diameter from 12 to 30 inches depending upon individual well productivity (**Figure A-6**). In general, the pipeline will be located 5 feet from one edge of a 20-foot right of way, with the remaining 15 feet reserved as a pathway for construction equipment and inspection traffic. Horizontal expansion loops (typically a square bend in the pipeline approximately 30 feet by 30, as shown in **Figure A-7**, will be constructed every 300 to 450 feet along the pipeline route to allow for thermal expansion. Vertical expansion loops may be desirable at specific locations such as the power plant pad and at road crossings and livestock or wildlife. The top of pipes are typically 3 feet above the surface except for terrain undulations or areas where livestock or wildlife crossings are desired.

Figure A-6: Actual Geothermal Pipeline

The pipeline will be located above ground level on a series of sliding pipe supports (sleepers), and would be colored to blend in with the terrain. Surface piping infrastructure for plant operations stands off the ground 18 to 36 inches on "T" shaped stands placed 40 feet apart. Electrical and controls conduits are run in a small catwalk immediately adjacent to the pipe.

Figure A-7: Typical Pipeline loop.



TYPICAL PHASES IN GEOTHERMAL DEVELOPMENT

Geothermal resource use involves four sequential phases: (1) exploration, (2) drilling, (3) utilization, and (4) reclamation and abandonment. The success or failure of each phase affects the implementation of subsequent phases, and, therefore, subsequent environmental impacts. Development of geothermal resources is unique to the industry, but many activities are similar in scope to other fluid minerals (e.g., oil and gas), such as surveying, drilling, site-development (well pads and roads), and reclamation and abandonment.

Federal geothermal leasing regulations (43 CFR 3200) require, prior to commencement of surface disturbing activities related to any drilling operations on a federal geothermal lease, the operator on the ground shall be covered by a bond. A bond is a written contract to guarantee the lands disturbed from fluid mineral activities will be reclaimed. A surety or personal bond may be posted by the lessee, sublessee (owner of operating rights) or operator. These bonding obligations also need to transfer to new owners should the operator decide to sell. In addition, the state agency in charge of mineral management may also require its own set of bonding requirements. **Table A-2** provides the estimated acreages of land disturbance for each phase in geothermal development for a typical power plant. The actual area of disturbance varies greatly depending upon site conditions and the type and size of power plant being constructed; therefore, a range is provided. Acreages are not provided for the Reclamation and Abandonment phase since this phase involves the return of previously disturbed lands to their existing conditions. The total potential amount of area disturbed under the utilization phase includes development activities. Much of the land would be reclaimed after the initial exploration, drilling, and construction; therefore, the actual amount of land occupied during operation, would be less. A typical development generally requires several leases or the use of private or other adjacent lands. The details of each phase of development are described below.

Table A-2
Typical Disturbances by Phase of Geothermal Resource Development

Development Phase	Disturbance Estimate per Plant
Exploration	**2 – 7 acres**
Geologic mapping	negligible
Geophysical surveys	30 square feet[1]
Gravity and magnetic surveys	negligible
Seismic surveys	negligible
Resistivity surveys	negligible
Shallow temperature measurements	negligible
Road/access construction	1– 6 acres
Temperature gradient wells	1 acre[2]
Drilling Operations and Utilization	**51 – 350 acres**
Drilling and well field development	5 – 50 acres[3]
Road improvement/construction	4 – 32 acres[4]
Power plant construction	15 – 25 acres[5]
Installing well field equipment including pipelines	5 – 20[6]
Installing transmission lines	24 – 240[7]
Well workovers, repairs and maintenance	negligible[8]
TOTAL	**53 – 367 acres**

[1] Calculated assuming 10 soil gas samples, at a disturbance of less than three square feet each.
[2] Calculated assuming area of disturbance of 0.05 to 0.25 acre per well and six wells. Estimate is a representative average disturbance of all well sites. Some wells may require a small footprint (e.g., 30x30 feet), while others may require larger rigs and pads (e.g., 150x150 feet).
[3] Size of the well pad varies greatly based on the site-specific conditions. Based on a literature review, well pads range from 0.7 acres up to 5 acres (GeothermEx 2007; FS 2005). Generally a 30MW to 50 MW power plant requires about five to 10 well pads to support 10 to 25 production wells and five to 10 injection wells. Multiple wells may be located on a single well pad.
[4] One-half mile to nine miles; assumes about ¼ mile of road per well. Estimates 30-foot wide surface disturbance for an 18 to 20 foot road surface, including cut and fill slopes and ditches.
[5] 30-MW plant disturbs approximately 15 acres; 50 MW plant disturbs approximately 25 acres.
[6] Pipelines between well pad to plant assumed to be ¼ or less; for a total of 1½ to seven miles of pipeline in length, with a 25-foot-wide corridor
[7] Five to 50 miles long, 40-foot-wide corridor.
[8] Disturbance would be limited to previously disturbed areas around the well(s).

Phase One: Geothermal Resource Exploration

Before geothermal resources are developed, a geothermal resource developer explores for evidence of geothermal resources on leased or unleased land. Exploration includes ground disturbance but does not include the direct testing of geothermal resources or the production or utilization of geothermal resources. Exploration operations include, but are not limited to, geophysical operations, drilling temperature gradient wells, drilling holes used for explosive charges for seismic exploration, core drilling or any other drilling method, provided the well does not reach the geothermal resource. It also includes related construction of roads and trails, and cross-country transit by vehicles over public land. Exploration involves first surveying and then drilling temperature gradient wells. It generally takes between one and five years to complete exploration.

Surveying includes conducting or analyzing satellite imagery and aerial photography, volcanological studies, geologic and structural mapping, geochemical surveys, and geophysical surveys of leasable areas that could support geothermal resource development. The surveys consist of collecting electrical, magnetic, chemical, seismic, and rock data. For example, water samples from hot springs could be used to determine the subsurface characteristics of a particular area. Once the data is compiled, geologists and engineers examine the data and make inferences about where the higher temperature gradients may occur. High temperature gradients can indicate the location of potential underground geothermal reservoirs capable of supporting commercial uses.

Surveys may require creating access using four-wheel drive vehicles, or by helicopters or on foot to areas with no roads or very poor roads. Cutting of vegetation may be required in some areas to facilitate access. In some cases, gas collectors may be installed to measure soil gases. These collectors have partially buried sensors and may disturb small areas of less than three square feet (BLM 2007b).

While not widely used for geothermal surveys, seismic surveys have the greatest survey impact on the local environment. These surveys typically involve setting up an array of geophones and creating a pulse or series of pulses of seismic energy. The pulse is created either by detonating a small charge below the ground surface (requires drilling a narrow “shot hole”) or by a vibroseis truck that is driven through the survey area. Data is transmitted from the geophones to a central location. The geophones may be installed on the ground’s surface, in small excavations made specifically for burying the geophones, and/or in existing wells. These surveys are typically undertaken over the course of a few days. In areas where there is a lot of natural seismic activity, longer term installation of geophones may be undertaken to record naturally occurring earthquakes. Such cases do not involve a vibroseis truck (BLM 2007b).

Resistivity surveys include various methodologies from laying out long cables (up to 1,000 feet or more) on the land surface, or setting up equipment repeatedly in small areas (a few tens of square feet at the most for each measuring site). Minor, temporary disturbances are associated with each site for the burial of sensors (BLM 2007b).

The second step of the exploration phase is to drill temperature gradient wells on leased or unleased land. This process confirms a more precise location of high temperature gradients. Temperature gradient wells can be drilled using a truck-mounted rig and range from 200 feet to over 4,000 feet deep. The number of gradient wells also varies, depending on the geometry of the system being investigated and the anticipated size of power development. Geologists examine either rock fragments or long cores of rock that are brought up from deep within the well. Water samples are taken from any groundwater encountered during drilling. Also, temperatures are measured at depth. Both well temperatures and the results of rock sample analyses are used to determine if additional exploration is necessary to identify the presence and characteristics of an underground geothermal reservoir. After collecting the desired materials and data, the wells are completed with sealed, water-filled tubing from surface to bottom, often with cement around the tubing (BLM 2007b).

Most temperature gradient wells are drilled with a small rotary rig (often truck-mounted) similar to that used for drilling water wells, or a diamond-coring rig, similar to that used for geologic sampling in mineral exploration and civic works projects. Neither rig of this size requires construction of a well pad or earth moving equipment unless the site is sharply graded. Support equipment is needed, including water trucks, tanks for mixing and holding drilling fluids, personnel and supply transport vehicles, and sometimes a backhoe for earth-moving activities is needed to prepare the drilling site. A temperature gradient drilling operation can be run by about three on-site personnel and others traveling to the site periodically with materials and supplies (BLM 2007b).

Temperature-gradient well drilling requires road access. Whenever possible, a driller would access the temperature gradient well site using existing roads. When existing roads are not available, new access roads may need to be constructed for the truck-mounted rig to reach the site; this could require one to six acres of disturbance.

Preparing the site for drilling could include leveling the surface and clearing away vegetation. Several temperature gradient wells are usually drilled to determine both the areal extent of the temperature anomaly and where the highest temperature gradient occurs. Each drill site could disturb approximately 0.10 acres, and the drill rig could be approximately 60 feet tall. During exploration, a driller is not permitted to produce any fluids out of, or inject any fluids into, the well; therefore, the site may also host a sump or tanker truck. Additionally, a diesel generator may also be used at the site to power equipment. The well site itself involves excavation of a small cellar (typically less than three feet square and less than three feet deep) to allow the conductor casing to be set beneath the rig. Drilling may last for several weeks.

Temperature gradient wells are not intended to directly contact the geothermal reservoir, and therefore produce no geothermal fluids. In areas of known artesian pressures, any drilling expected to penetrate the groundwater table would include BOPE. In cases where a temperature gradient well does penetrate a geothermal zone, any release of geothermal fluids at the surface is likely to be minimal due to the small well diameters and the use of BOPE (BLM 2007b).

Drilling fluids may include drilling mud (bentonite clay, activated montmorillonite clay and crystalline silica-quartz), drilling mud additives (caustic soda, sodium bicarbonate, and anionic polyacrylamide liquid polymer), cement (Portland cement and calcium chloride), fuel (diesel), lubricants (usually petroleum-based) and coolants. The specific fluids and additives depends on a variety of factors, including the geologic formations being penetrated and the depth of the well. Releases of drilling muds are not permitted; a sump and a tanker truck are required to capture all fluids. The risk of spills of other fluids is similar to that of any other project involving the use of vehicles and motorized equipment (BLM 2007b).

All surface disturbances would be reclaimed to the satisfaction of BLM. If a temperature gradient well was unsuccessful, it would be abandoned, and the drill site would be reclaimed. Abandonment includes plugging, capping, and covering the wells. Reclamation includes removing all surface equipment and structures, regrading the site to predisturbance contours, and replanting native or appropriate vegetation to facilitate natural restoration.

Phase Two: Drilling Operations

Once exploration has confirmed a viable prospect for commercial development and necessary leases have been secured, the drilling of exploration wells to test the reservoir can proceed. Drilling Operations include flow testing, producing geothermal fluids for chemical evaluation or injecting fluids into a geothermal reservoir. This would also involve the construction of sumps or pits to hold excess geothermal fluids. It could involve development of minor infrastructure to conduct such operations.

Drilling is an intense activity that requires large equipment (e.g., drill rig) and can take place 24 hours a day. A drilling operation generally has from 10 to 15 people on site at all times, with more people coming and going periodically with equipment and supplies. Getting the rig and ancillary equipment to the site may require 15 to 20 trips by full-sized tractor-trailers; with a similar amount for de-mobilizing the rig. There would be 10 to 40 daily trips for commuting and hauling in equipment (BLM 2007b).

If a reservoir is discovered, characteristics of the well and the reservoir are determined by flow testing the well. If the well and reservoir were sufficient for development, a wellhead, with valves and control equipment, would be installed on top of the well casing. Excess geothermal fluids are stored in temporary pits or sumps, generally lined with plastic (small sumps) or clay (large sumps). The water is left to evaporate and any sludge is removed and properly disposed.

Phase Three: Utilization

Utilization and production is the next phase after a viable reservoir is determined and includes the infrastructure needed for commercial operations, including access roads, construction of facility structures, building electrical generation facilities, drilling and developing well fields, and installing pipelines, meters, substations, and transmission lines. The utilization phase could last from 10 to 50 years and involves the operation and maintenance of the geothermal field(s) and generation of electricity.

The type of development utilization that occurs is based on the size and temperature of the geothermal reservoir. Geothermal resources can be classified as low temperature (less than 90°C, or 194°F), moderate temperature (90°C to 150°C, or 194 to 302°F), and high temperature (greater than 150°C, or 302°F). Only the highest temperature resources are generally used for generating electrical power; however, with emerging technologies and in colder climates such as Alaska, even the lower temperature resources are proving usable for electrical generation.

High temperature reservoirs are suitable for the commercial production of electricity. Three types of power plants that harness geothermal resources are dry steam plants, flash steam plants, and binary-cycle plants. Occasionally a hybrid between flashed steam and binary system is also used. Dry steam power plants use the steam from the geothermal reservoir as it comes from the wells and route it directly through turbine/generator units to produce electricity. Flash steam power plants use water at temperatures greater than 182°C (360°F). Water is pumped under high pressure to the generation equipment at the surface, the pressure is suddenly reduced, allowing some of the hot water to convert, or "flash," into steam, and the steam is used to power the turbine/generator units to produce electricity. Binary-cycle power plants use water from the geothermal reservoir to heat another "working fluid." The working fluid is vaporized and used to turn the turbine/generator units. The geothermal water and the working fluid never come in contact with each other. Binary-cycle power plants can operate with lower water temperature 74°C to 182° C (165°F to 360°F) and produce few air emissions.

Development of the lease would involve the following construction and operations:

- Access roads—New access roads to accommodate the larger equipment associated with the development phase could be constructed. In general, a plant can require ½ mile to nine miles of roads in order to access the site, well pads, and power plant. Depending on the type and use-intensity of the road, the areas of surface disturbance is about 30-feet wide for an 18 to 20 foot wide road surface, including cut and fill slopes and ditches.

- Drill site development—Multiple wells may be drilled per lease. Production-size wells can be over two miles (10,560 feet) deep. The number of wells is dependent upon the geothermal reservoir characteristics and the planned power generation capacity. For example, a 50MW (net) power plant could require up to 25 production wells and 10 injection wells. It is common that multiple wells would be installed on a well pad. The size of the well pad is dependent upon site conditions and on the number of wells for the pad, but they are typically about one to five acres, including minor cut and fill. In order to drill these deep holes, a large drilling rig or derrick would be erected. Various temporary support facilities may be located on site, including generators, mud tanks, cement tanks, trailers for the drillers and mud loggers, housing trailers, and storage sheds. As appropriate, facilities can be painted to blend in with the surrounding environment. Drilling operations can occur 24 hours a day.
- Wellfield equipment—A geothermal power plant is typically supported by pipeline systems in the plant's vicinity. The pipeline systems include a gathering system for produced geothermal fluids, and an injection system for the reinjection of geothermal fluids after heat extraction takes place at the plant. Pipelines are usually 24 to 36 inches in diameter, but can be as small as 8 inches depending on the type of pipeline. Pipelines transporting hot fluids or steam to the plant are covered with insulation, whereas injection pipelines are generally not. When feasible, they would parallel the access roads and existing roads to the destination of the geothermal resource's steam or water. Pipelines are typically constructed on supports above ground, resulting in little if any impact to the surrounding area once construction is complete and the corridor has been revegetated. The pipelines typically have a few feet of clearance underneath them, allowing small animals to easily cross their path. The pipelines are typically painted to blend in with the surrounding environment. In general, plants have about 1½ to seven miles of pipes with a corridor width of about 25 feet.
- Power plant—A 50 MW plant would utilize a site area of up to 20 to 25 acres to accommodate all the needed equipment, including the power plant itself, space for pipelines geothermal fluids and reinjection, a switch yard, space for moving and storing equipment, and buildings needed for various purposes (power plant control, fire control, maintenance shop, etc.) The power plant itself would occupy an estimated 25 percent of this area for a water-cooled plant, or about 50 percent for an air-cooled plant. Where topography permits, the power plant could be situated so as to be

less visible from nearby roads, trails, scenic vistas or scenic highways. The site of the plant requires reasonable air circulation to allow for efficient operation of the plant's condensers. A smaller 20-MW plant would typically require approximately five to ten acres for the entire complex.

- Electric transmission lines—Transmission lines may range in length from 5 miles to 50 miles with a corridor width of approximately 40 feet. Wooden poles most likely support them, and about 5 acres could be disturbed per mile of transmission line.
- Reclamation—When a production well is successful, a wellhead with valves and control equipment is installed on top of the well casing. If a production well is unsuccessful, the production well would be plugged and capped, and the site would be reclaimed.

The number of personnel required during construction varies significantly, but at any one point there may be a few hundred laborers and professionals on site with attendant vehicle traffic. The number of people required for routine operation of a power plant is typically three per shift; however, additional personnel (as many as 12 total, depending on plant size) may be on site during the day for maintenance and management (BLM 2007b)

Activities associated with operation and maintenance and energy production would involve managing waste generated by daily activities, managing geothermal water, landscaping, and the maneuvering of construction and maintenance equipment and vehicles associated with these activities.

Phase Four: Reclamation and Abandonment

This phase involves abandoning the well after production ceases and reclaiming all disturbed areas in conformance with BLM standards. Abandonment includes plugging, capping, and reclaiming the well site. Reclamation includes removing the power plant and all surface equipment and structures, regrading the site and access roads to predisturbance contours, and replanting native or appropriate vegetation to facilitate natural restoration.

Geothermal Fluid Production and Associated Waste

Geothermal fluid production and associated waste production is likely to occur for short periods as wells are tested to determine reservoir characteristics. If geothermal fluids are discovered in commercial quantities, development of the geothermal field is likely. The rate of fluid production from a geothermal reservoir is unknown until the development testing phase is completed. During the initial stages of testing, one well is likely to be tested at a time. If testing is successful and the well and reservoir are sufficient for development, wellheads, valves, and control equipment would be installed on top of the well casing.

Using data from other areas of geothermal development, it appears that production of geothermal fluids can be expected to vary widely from one to six million gallons per well, per day. Assuming five million gallons per day, per well as an average production figure, a lease with two producing wells would produce 10 million gallons of fluid per day.

The production of hot geothermal fluid from each lineshaft turbine pump will be flow-rate controlled. Downhole pumps in the production wells will deliver the geothermal fluid to the plant via a pipeline gathering system at about 230 pounds per square inch, gauge.

Most geothermal fluids produced are reinjected back into the geothermal reservoir, via reinjection wells. In flash steam facilities about 15 to 20 percent of the fluid can be lost due to flashing to steam and evaporation through cooling towers and ponds. Binary power plants utilize a closed loop system, therefore, well production and reinjected operate with no fluid loss. Fluids can also be lost due to pipeline failures or surface discharge for monitoring/testing the geothermal reservoir.

The routinely used chemicals for a binary geothermal plant include the hydrocarbon working fluid (such as iso-butane or n-pentane) and the lubricating oil used in the downhole pumps. If a well's pressure falls below the "bubble point," if it possible that downhole scaling might occur. This requires either a mechanical clean-out with a drilling rig or a coiled-tubing unit, or an "acid job," during which acid (typically hydrochloric acid or less commonly hydrogen fluoride) is injected into the wellbore to dissolve the scale. If scaling is persistent, the operator may choose to adopt routine injections of a scale-inhibitor chemical, such as polymaleic anhydride or polyacrylic acid, used in dosages of one to 10 parts per million (BLM 2007b).

Geothermal Commercial Electrical Generation

Commercial electrical generation from geothermal resources is also called *indirect use*. Electrical generation uses geothermally heated fluid to turn a turbine connected to a generator. As discussed above, the fluid may be the naturally occurring steam or water in the geothermal reservoir or another fluid which has the geothermal heat transferred through a heat exchange system.

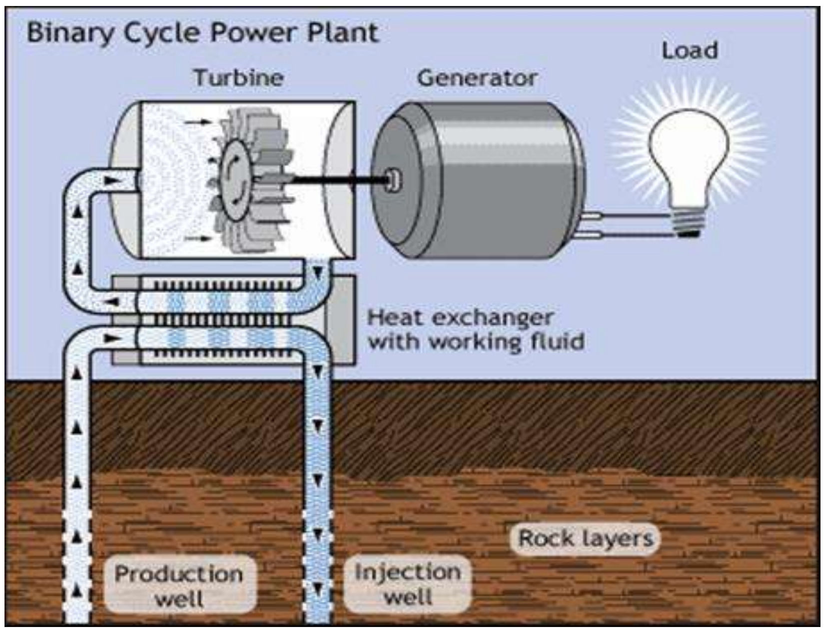
Geothermal power plants can be small (300 kilowatts), medium (10 to 50 megawatts) and large (50 megawatts and higher) (Nemzer et al. 2007). Generation capacity is guided by the number of turbines within a plant. In general, commercial electrical generation requires hot geothermal reservoirs with a water temperature above 200°F (93°C); however, new technologies have proven that lower-temperature water (e.g., 165°F [74°C]) can also be used for electrical generation.

The two types of geothermal plant systems brought forth in this proposal are binary-cycle and flash steam power plants.

Binary Cycle Power Plants

Binary-cycle power plants typically use cooler geothermal fluids than flash steam plants (165 to 360°F [74 to 182°C]). The hot fluid from geothermal reservoirs is passed through a heat exchanger, which transfers heat to a separate pipe containing fluids with a much lower boiling point. These fluids, usually iso-butane or iso-pentane, are vaporized to power the turbine (**Figure A-8**, Binary-cycle Power Plant). The advantage of binary-cycle power plants is their lower cost and increased efficiency. These plants also do not emit any excess gas and, because they use fluids with a lower boiling point than water, are able to use lower-temperature geothermal reservoirs, which are much more common. Most geothermal power plants planned for construction in the US are binary-cycle.

Figure A-8 Binary Cycle Power Plant



Typical Binary power plant equipment includes:

- Shell and tube heat exchangers
- Three turbo-expander generators
- Condensers
- Pentane accumulators (23,000 gallon storage vessels)
- Pentane transfer and feed (circulating) pumps
- Air compressors
- Vapor recovery unit
- Lubricant coolers
- Firewater storage tank and diesel-powered firefighting pump

- Diesel-fueled emergency generator and potentially a Zero demand generator
- Transformers
- Electrical room and operations office

The turbo-expanders will be located outdoors. A typical turbine generator skid consists of two turbines directly coupled to one generator, approximately 20 feet high and 40 feet long by 20 feet wide.

The layouts of a Binary power plant sites proposed by Ormat and Vulcan are shown in **Figures A-9 and A-10**.

Figure A-9: Air Cooled Binary Power Plant Schematic Proposed by Ormat Industries.

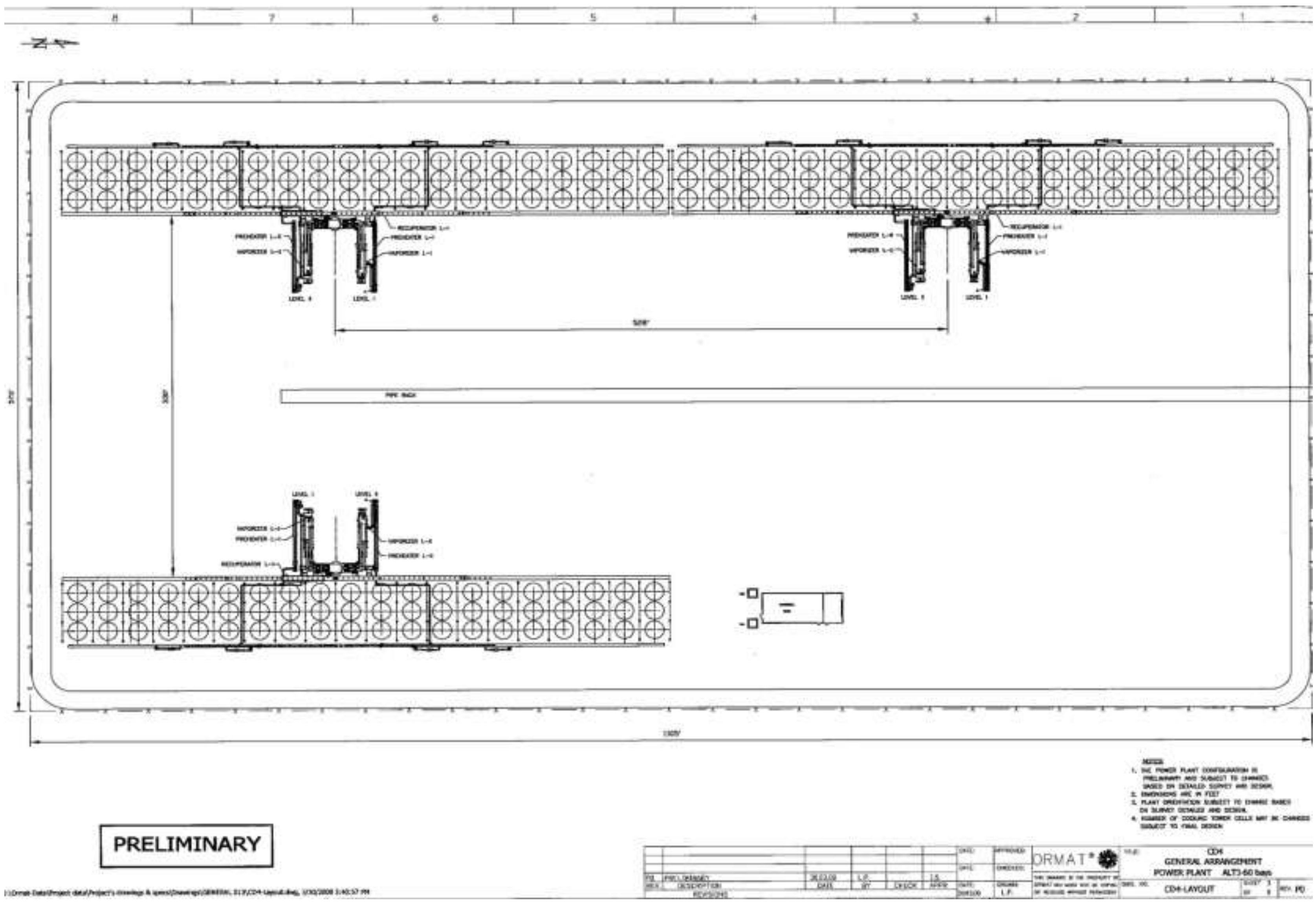
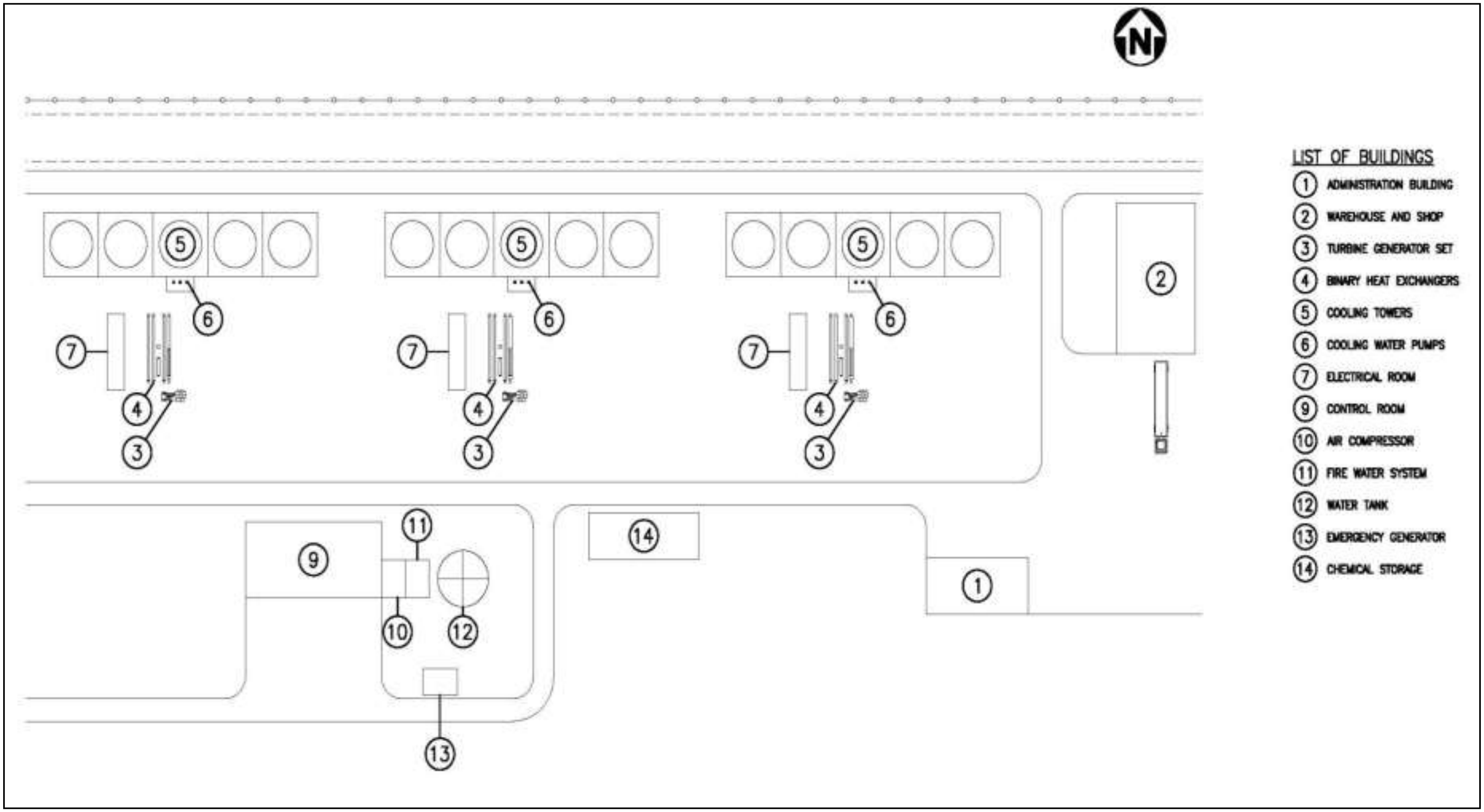


Figure A-10: Wet Cooled Binary Power Plant Schematic Proposed by Vulcan Power.



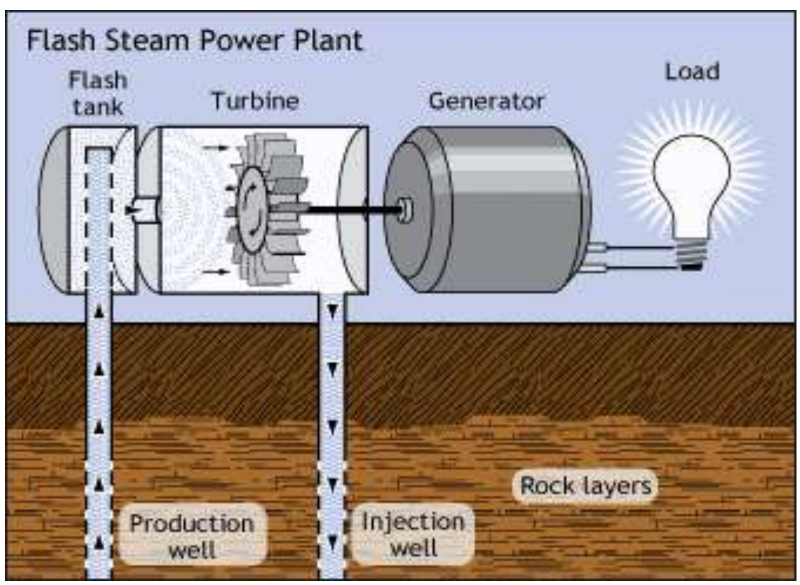
Flash Steam Power Plants

Flash steam power plants use hot water above 360°F (182°C) from geothermal reservoirs. The high pressure underground keeps the water in the liquid state, although it is well above water's boiling point at standard atmospheric pressure. As the water is pumped from the reservoir to the power plant, the drop in pressure causes the water to convert, or "flash," into steam to power the turbine (**Figure A-11**, Flash Steam Power Plant). Any water not converted into steam is injected back into the reservoir for reuse. Flash steam plants emit small amounts of gases and steam. Flash steam plants are the most common type of geothermal power generation plants currently in operation .

The cooling water and condensate mixture collects in the hot well section of the condenser. Hot well pumps would take suction from the lower hot well section of the condenser and deliver the water to the top of the cooling tower. The majority of the water would be cooled and then circulated back to the condenser.

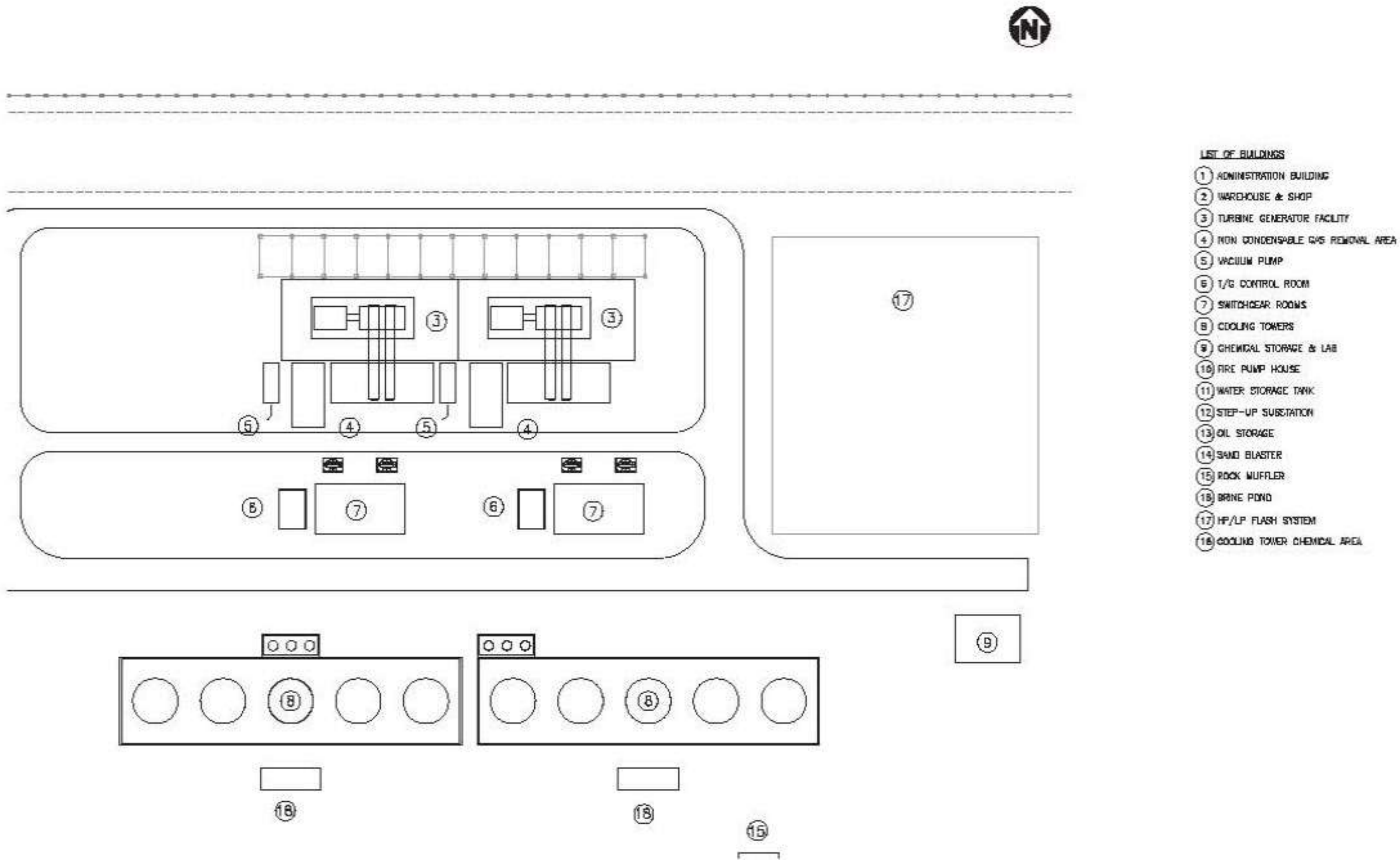
The main circulating water pumps would take water from the cooling tower basin to a direct condenser where the water would be used to condense the steam discharged from the turbine by means of direct contact. Alternatively, the condenser may be installed below grade so that the cooling water could flow by gravity from the cooling tower basin to the condenser. This option eliminates costly pumps that require a significant amount of power.

Figure A-11 Flash Steam Power Plant



Typical equipment used at a flash power plant is similar to that used in a Binary system. The typical layout of a flash steam power plant site is shown in **Figure A-12**.

Figure A-12: Proposed Flash Steam Schematic by Vulcan Technologies



Other types of technologies that harness geothermal energy include direct use, dry-steam plants and enhanced geothermal systems. None of these technologies are proposed in this EIS and are therefore not described in further detail.

Geothermal Power Plant Cooling Systems

A cooling system is essential for the operation of any modern geothermal power plant. Cooling towers prevent turbines from overheating and prolong facility life. Most power plants, including most geothermal plants, use water cooling systems. Water cooled systems generally require less land than air cooled systems, and are considered overall to be effective and efficient cooling systems. The evaporative cooling used in water cooled systems, however, requires a continuous supply of cooling water and creates vapor plumes in climatic conditions where the ambient temperature drops, wind is minimal and humidity increases. Usually, some of the spent steam from the turbine (for flash- and steam-type plants) can be condensed for this purpose.

Air cooled systems, in contrast to the relative stability of water cooled systems, can be extremely efficient in the winter months, but are less efficient in hotter seasons when the contrast between air and water temperature is reduced, so that air does not effectively cool the organic fluid. Air cooled systems are beneficial in areas where extremely low emissions are desired, or in arid regions where water resources are limited, since no fluid needs to be evaporated for the cooling process. **Figure A-13** shows an Air-Cooled Geothermal Power Plant, and **Figure A-14** shows a Dry/Wet Geothermal Binary Plant.

Air cooled systems are preferred in areas where the viewshed is particularly sensitive to the effects of vapor plumes, as vapor plumes may be emitted into the air by wet cooling towers and not air cooling towers. Most geothermal air cooling is used in binary facilities.

TRANSMISSION

Once power is generated, it would be routed to the main transformer from the motor control center of the geothermal power plant. There the voltage would be stepped up to the appropriate transmission line voltage (230 kilovolts [kVs]) and would be connected to the electrical interconnect substation. The substation connects the power plant to the distribution grid via a 230-kV transmission line. An overview of the transmission system is as follows:

The three main structural elements that make up an electrical distribution system are: (1) transmission lines, which convey high voltage electricity from power generation facilities; (2) substations, which reduce the voltage in the transmission lines to distribution levels; and (3) distribution lines, which convey the electricity to customers. (The Proposed Action evaluated in this EIS involves construction of transmission lines and substations).

Figure A-13: Air Cooled Geothermal Power Plant cooling fans and pipelines.

Figure A-14: A photo of a dry/wet cooled Geothermal Binary Power Plant.

Transmission Lines

Transmission lines are high-voltage lines (60-kV or greater) that convey bulk power from remote power sources to the electrical service area. These lines may be overhead or underground; underground transmission lines are discussed separately below. Overhead high-voltage conductors are approximately an inch in diameter and are made of aluminum strands or a mixture of aluminum and steel strands. The lines are isolated electrically by the surrounding air and are not wrapped with insulation material.

Support structures for overhead transmission lines range from single wood or metal poles and H-frame towers between 50 and 90 feet tall for lower voltage lines (i.e., 60-kV and 120-kV), to metal H-framed or lattice frame towers between 75 and 130 feet tall for higher voltage lines (i.e., 345-kV). As described in Chapter 2 of the EIS, SPPC proposes to use steel or wood H-frame tangent structures, steel or wood three-pole dead–end heavy-angle structures, steel single-pole heavy-angle dead-end structures, and steel single-pole staggered structures (**Chapter 2, Figures 2-3 to 2-6**). SPPC's transmission system consists of approximately 4,000 miles of high-voltage power lines.

It is not desirable for circuits that serve the same substation to be located or double circuited in close proximity to each other (e.g., in the same corridor or on the same pole). This results in less reliability because both circuits could be compromised by the same event (e.g., wind storm or lighting strike). In addition, safety issues would increase from maintenance activities, including working on energized lines, because one circuit would always have to be carrying power. In cases where the circuits are serving separate substations, double circuit configurations would not have the same reliability issues provided that they are each serving other load centers and there is existing redundancy built into the distribution system.

In some cases, these circuits can be located on the same structure. Transmission lines, including those constructed by SPPC, are designed in accordance with requirements of the National Electrical Safety Code, which address design issues such as the following:

- Clearances between the lines and other features, such as ground or water surfaces, roadways, railways, other conductors or communication wires, and buildings;
- Use of shield wires along the top of the transmission line to shield the conductors from lightning strikes;
- If an energized line falls to the ground, high-speed relay equipment will sense this condition and actuate breakers that would de-energize the line in a tenth of a second to half a second;

- Connection of metallic parts to an electrode in the ground (grounding) in order to safeguard employees and the public from the hazard of electric potential; and
- Standards for mechanical and structural design, selection of materials, and construction practices to ensure that towers, conductors, and insulators are strong enough to withstand normal and unusual loads, such as ice and wind, to ensure that pole spans are adequate to prevent conductor or structure failure, and to ensure that adequate clearances are maintained.

Substations

Because electricity in the transmission lines is at voltages greater than what the customer can use, the transmission lines are first directed through substations, which regulate or reduce the electric voltage to levels that can be conveyed to the customer. Substations generally consist of a control building and steel structures that support the necessary electrical equipment, including the terminals to receive transmission lines and transformers that convert power to a different voltage. The substation contains the high-voltage disconnects and protective relays used to separate the geothermal facility from the utility transmission line if a problem exists in either system.

Each substation consists of a 13.8-kV circuit breaker, a 13.8-kV/230-kV transformer, a 230-kV potential and current transformers for metering and system protection, and a 230-kV circuit breaker to protect the substation. A typical substation is shown in **Figure A-15** and a cross section of a typical geothermal substation is located in **Figure A-16**.

Distribution Lines

Electricity from substations is conveyed to the customer through medium voltage 25-kV distribution lines. Because distribution lines carry lower voltages, they require less substantial lines and support structures than transmission lines. Distribution conductors are generally half an inch to an inch in diameter and are supported by wood poles approximately 40 feet tall. Because distribution lines are most prevalent in highly developed areas and they operate at lower voltages, distribution lines are more easily and frequently placed underground. Because distribution lines serve all electrical customers, they are the largest component of the electrical system. SPPC's distribution system consists of approximately 13,500 miles of overhead and underground lines.

Underground Transmission Lines

Underground construction of transmission lines generally involves placing the transmission line beneath the ground in a concrete encased polyvinyl chloride conduit system. Underground construction is an effective technique to avoid certain potential hazards associated with overhead lines, such as downed lines or interference with aircraft (**Table A-3**). It is also effective in avoiding certain

Figure A-15: A typical substation.

Figure A-16: A cross section of the typical geothermal power plant substation.

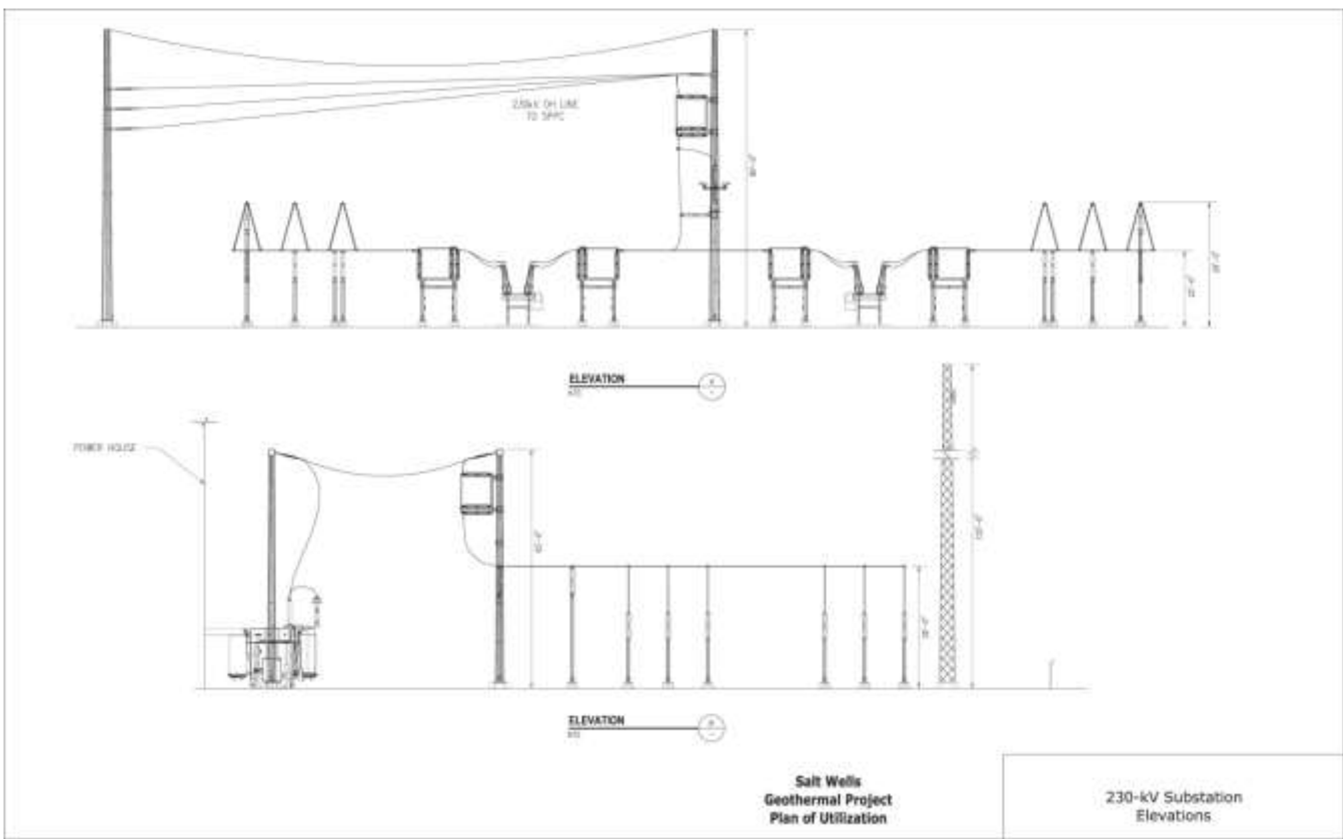


Table A-3
Relative Reliability of Overhead and Underground Transmission Lines

Failure Type	Overhead	Underground
	Frequency of Failure	
Insulation failure	Lower	Higher
Splice failure	Lower	Higher
Termination failure	Lower	Higher
Dig-in	None	Higher
Tree contact	Higher	None
Vehicle accident	Higher	None
Fire and smoke	Higher	Lower
Storm (high wind)	Higher	None
Storm (lightning)	Higher	Lower
Moisture/Erosion Damage	None	Higher
Bird contact	Higher	None
	Time to Address Failure	
Locate fault	Faster	Slower
Repair fault	Days	Weeks
Temporary fix (if required)	Faster	None

Source: SPPC 2002, 2004

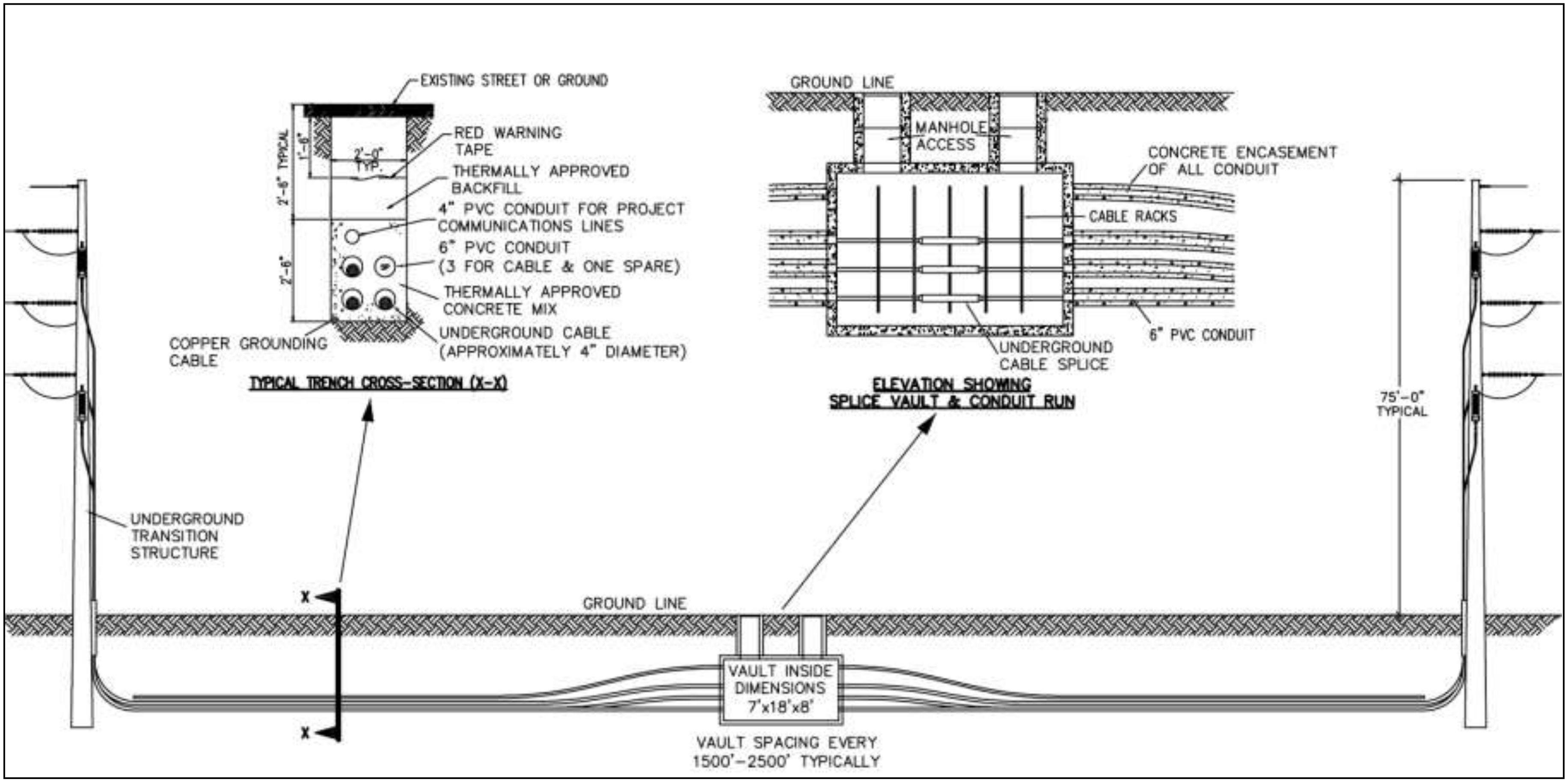
impacts associated with overhead power lines, such as visual impairment. Underground construction does have certain associated impacts that are greater than aboveground construction due to the amount of ground disturbance associated with trenching.

An underground transmission system consists of the electrical cable, cable duct bank systems (conduits), splice vaults, and transition structures (**Figure A-17**).

Underground Conductor
A 120-kV underground cable consists of an aluminum or copper conductor wire covered with insulating and protective materials approximately four inches in diameter, which is larger than overhead cables of comparable capacity. Unlike overhead conductors, underground cables must be covered with electrical insulation and a moisture impervious sheath for electrical properties and to protect them from moisture intrusion or other physical contact.

Cable Duct Bank Systems
Cable duct bank systems are plastic conduits that house the underground cable. For a 120-kV transmission line, a duct bank system would typically consist of four 6-inch conduits, three for the cable and an unused conduit for emergency repair or replacement, and one 4-inch conduit for project or other communication purposes. The conduits are encased in thermally engineered concrete and are backfilled with soil that meets prescribed thermal properties.

Figure A-17: Typical underground 230-kV transition system



The ground surface above the trench is restored to preexisting conditions (typically street pavement or native vegetation).

Splice Vaults

Splice vaults are compartments approximately 8 feet wide, 9 feet deep, and 19 feet long that provide access for installing and splicing cable. Splice vaults are generally located every 1,500 to 2,500 feet along the line, depending on the length of the cable to be installed and the availability of a suitable location for the facility.

Transition Structures

There is a common misconception that "undergrounding" entails directing lines underground straight off of an aboveground transmission line. However, in order to run a line underground, a transmission line must first travel through a transition structure. Also referred to as riser poles or termination structures, transition structures are poles located at each end of the underground cable section to transition the underground cable to overhead lines or substation equipment. Transition structures are about the same height as poles on an overhead section of line (approximately 75 feet) and are highly visible to surrounding receptors (**Figure A-18**). Termination structures are made of self-weathering steel, are set in a concrete foundation, and are installed in much the same way as other overhead transmission line poles. For visual comparison **Figure A-19** simulates a 120-kV overhead transmission line wood pole in the same location as Figure A-18.

Underground construction trenches are typically two feet wide and five feet deep, although the trench must often be deeper or wider to avoid existing utilities. Approximately 25 feet of ground disturbance on either side of the trench (or 50 to 60 feet total) is also required, in flat terrain, to permit use of equipment along the trench and for placing excavated material. Width requirements can be reduced to between 20 and 30 feet if the excavated materials are hauled offsite. The area under construction at any one time is typically 300 feet long. Traffic control is required for construction within city or county streets.

Figure A-18: View of a typical underground transition structure

Figure A-19: Simulated view of a 120-kV pole in the same location as an underground transition structure.