Throughout this Application, all references to Federal Power, Federal Power Avenal, LLC, and Federal Power Avenal refer to Avenal Power Center, LLC.

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5.0 ALTERNATIVES ANALYSIS

This chapter considers whether reasonable alternatives to the Project exist that offer substantial environmental advantages compared to the Project, while still being able to feasibly attain Federal Power's basic Project objectives. As described in Chapter 2.0 - Project Description, Federal Power's basic Project objectives are to:

- Provide environmentally sound, efficient and reliable power generation for California's restructured energy market.
- Use a location that has existing nearby infrastructure (i.e., existing transmission lines, water supply and gas supply) with available capacity and supply to support the Project.
- Develop a site consistent with community planning and existing zoning, at a location that is supported by the local community.
- Minimize the impacts on environmental resources.

The selected Site was chosen based on its physical, environmental and land use characteristics consistent with the above objectives. It is a flat piece of property located in an active farming region and in proximity to supporting infrastructure (natural gas, electric transmission, water supply). The Site and surrounding lands are frequently and intensively disturbed by agricultural activities (e.g., ripping, plowing, fertilizing, planting, irrigating, harvesting), so there will be no disturbance to natural habitat as a result of the Project. The Site is within the City of Avenal in an area that is zoned as an industrial park and is a distance of approximately 6 miles from the City's residential and business districts. As a result, there will be minimal environmental impact from Project construction and operation. Other considerations include support for the Project by the City of Avenal and by Kings County.

5.1 INTRODUCTION

The Commission's power plant siting proceeding is a certified functional equivalent process to the environmental review required by CEQA. The alternatives analysis required by Commission regulations in CCR, Title 20, Appendix B, is similar to the CEQA requirement to analyze alternatives. Thus, CEQA provides further guidance regarding the appropriate level of alternatives analysis to include in this AFC.

The selection of alternatives for consideration in this analysis is governed by the rule of reason, which requires an environmental document to "set forth only those alternatives necessary to permit a reasoned choice" (CCR Title 14, Section 15126.6[f]). The key issue is whether the

selection and discussion of alternatives fosters informed decision-making and public participation based on the various economic, environmental, social and technological factors involved. An environmental document need not consider an alternative where the effect cannot be reasonably ascertained and where implementation is remote and speculative (CCR Title 14, Section 15126.6[f][3]). For purposes of this analysis, the reasonable range of alternatives considered is: (1) the "no project" alternative; (2) power plant site alternatives; (3) cooling alternatives; (4) transmission interconnection alternatives and (5) technology alternatives. Guidance relevant to the scope of this alternatives analysis includes Public Resources Code Section 21002 and California Code of Regulations Title 14, Section 15126.6.

Alternatives considered in this analysis are described and evaluated in the sections below. A comparative analysis of alternatives follows the separate evaluations and is summarized in Table 5.1-1.

5.2 NO PROJECT ALTERNATIVE

The "no project" alternative is defined as the Project not being developed. The Site would remain in its existing condition and would be available for continued agricultural use or another proposal for an industrial facility consistent with the City's industrial park development.

With the recent growth in California's economy, and the continued population growth in California, the Commission has determined that California will need a substantial amount of additional generation capacity over the next several years. The Project will serve to fill part of the identified need. The Project will provide competitively priced power to the California electricity market to help meet the state's growing demand for electricity and to help replace less efficient generation resources retired due to age or cost of producing power. The "no project" alternative would not meet this objective.

It is reasonable to predict that additional power generating capacity will be built in California and, consequently, that the net effect of implementing the "no project" alternative is that future electrical generating capacity will be delayed and likely displaced to other sites. Federal Power is committed to constructing the Project in an expedient manner. The "no project" alternative could substantially delay the development of an adequate capacity of modern, efficient, power generation in the State and continue to place the regional demand for electricity on older fossil fuel-fired steam/electric power plants and simple-cycle gas turbine peaking plants. These plants

TABLE 5.1-1

COMPARATIVE ANALYSIS OF ALTERNATIVES

ALTERNATIVES	FEASIBILITY CRITERIA			ENVIRONMENTAL IMPACT CRITERIA																
	Commercial Availability	Implementability	Cost Effectiveness	Air Quality	Geology Hazards	Agriculture and Soils	Water Resources	Biological Resources	Cultural Resources	Paleontological Resources	Land Use	Socioeconomics	Traffic and Transportation	Noise	Visual Resources	Waste Management	Hazardous Materials	Public Health	Worker Safety	Transmission System Safety and Nuisance
THE PROJECT																				
• Proposed Configuration Using Combined-Cycle Technology	High	High	High	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low to Moderate	Low	Low	Low	Low	Low
NO PROJECT	High	High	Low	●	❍	❍	❍	❍	⊗	⊗	⊗	●	❍	❍	❍	❍	❍	❍	❍	❍
ALTERNATIVE SITES																				
• Site A	Low(1)	Low(1)	Low(1)	⊗	⊗	⊗	⊗	⊗(3)	⊗(3)	⊗(3)	⊗	⊗	⊗	●	●	⊗	⊗	⊗	⊗	⊗
• Site B	Moderate(2)	Moderate(2)	Moderate(2)	⊗	⊗	●	⊗	⊗(3)	⊗(3)	⊗(3)	●	⊗	⊗	●	⊗	⊗	⊗	⊗	⊗	⊗
COOLING ALTERNATIVES																				
• Wet Cooling	High	Low	High	❍	⊗	⊗	●	⊗	⊗	⊗	❍	⊗	⊗	⊗	❍	●	⊗	⊗	⊗	⊗
ALTERNATIVE TRANSMISSION LINE ROUTES																				
• Route A	Moderate(2)	Moderate(2)	Moderate(2)	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	●	⊗	⊗	⊗	⊗	⊗
• Route B	Moderate(2)	Moderate(2)	Moderate(2)	⊗	⊗	●	⊗	⊗	⊗	⊗	●	⊗	⊗	⊗	●	⊗	⊗	⊗	⊗	●
ALTERNATIVE TECHNOLOGIES																				
• Natural Gas																				
- Conventional Boiler Steam Turbine	High	Moderate	Low	●	⊗	⊗	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗	●	⊗	●	⊗	⊗	⊗
- Supercritical Boiler Steam Turbine	High	Moderate	Low	●	⊗	⊗	●	⊗	⊗	⊗	⊗	⊗	⊗	⊗	●	⊗	●	⊗	⊗	⊗
- Simple Cycle Combustion Turbine	High	High	Low	●	⊗	⊗	❍	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
- Kalina Combined Cycle	Low	Low	Moderate	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• Fuel Cells	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• Coal																				
- Conventional Furnace/Boiler Steam Turbine Generator	High	Low	Moderate	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Atmospheric and Pressurized Fluidized Bed Combustion	Moderate	Low	Moderate	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Integrated Gasification Combined Cycle	Low	Low	Moderate/ Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Direct and Indirect Fuel Combustion Turbines	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Magnetohydrodynamics	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• Nuclear Reactions	Moderate	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)

ALTERNATIVES	FEASIBILITY CRITERIA			ENVIRONMENTAL IMPACT CRITERIA																
	Commercial Availability	Implementability	Cost Effectiveness	Air Quality	Geology Hazards	Agriculture and Soils	Water Resources	Biological Resources	Cultural Resources	Paleontological Resources	Land Use	Socioeconomics	Traffic and Transportation	Noise	Visual Resources	Waste Management	Hazardous Materials	Public Health	Worker Safety	Transmission System Safety and Nuisance
• Water																				
- Hydroelectric	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Geothermal	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Ocean Energy Conversion	Low	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• Biomass	High	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• Solar Radiation																				
- Solar Thermal	Moderate	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Solar Photovoltaic	Moderate	Moderate	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
- Wind Generation	Moderate	Low	Moderate	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
ALTERNATIVE NO_X CONTROL																				
• XONON™	NA(4)	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
• $SCONO_X$™	NA(4)	Low	Low	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)	--(5)
ALTERNATIVE INLET AIR COOLING																				
• Evaporative Cooling	High	Moderate	Moderate	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
• Inlet Fogging	High	Moderate	Moderate	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗

LEGEND: ❍ = Less Impact; ⊗ = Same or Similar Impact; ● = Greater Impact.

(1) Land not available. See Section 5.3.1.
(2) Land availability and commercial terms not determined.
(3) Presence or absence of sensitive resources not determined for alternative sites. It is expected that impacts at the alternative sites would be similar to or greater than at the selected Site.
(4) Not available at the scale of a 7FA turbine.
(5) Environmental Impact Criteria not rated since this alternative was determined not practical based on Feasibility Criteria evaluations.

have less efficient technology than the Project with more fuel required and more air emissions per unit of power generated.

As a merchant power plant, the business risk associated with construction and operation of the Project will be borne entirely by the applicant. No ratepayer or public monies will be placed at risk. The "no project" alternative would not serve to insulate ratepayers or taxpayers from risk, but instead could harm ratepayers by decreasing competition and thereby increasing electricity prices. In addition, with the "no project" alternative, projected socioeconomic benefits related to Project construction and operations employment, local expenditures, and additional sales and property taxes would not occur.

As described in Section 5.3, the Site has been selected, in part, to minimize impacts of development on the environment. The "no project" alternative would likely displace needed future power development to a different site that would have environmental impacts at least as great as the Project.

The "no project" alternative would not serve the growing needs of California's residents and businesses for economic, reliable and environmentally sound power resources.

5.3 POWER PLANT SITE ALTERNATIVES

The Site was selected for the Project in part because the Site can be developed with minimal environmental impacts. Key characteristics considered during the Site selection process that are most relevant to minimizing environmental impacts include:

- The Project is consistent with the City's industrial land use zoning and industrial park.
- The Site is located distant from existing communities, and development of the Project at the Site is supported by the City.
- The Site is located proximal to necessary infrastructure. The short infrastructure tie-ins that will be required can be constructed and operated with no disturbance to natural habitat.
- The Site is located such that views from most receptor locations are muted by distance and land configuration (e.g., Project facilities from most receptor locations will not modify the skyline).
- There are no threatened or endangered species known to inhabit the Site.

In addition to the selected Site, two other locations were considered to see if their use instead of the selected Site could substantially reduce impacts of the Project. These alternative site locations are provided in Figure 5.3-1 and are described further in the following subsections. The alternative sites analyzed were selected by screening lands in the region to identify parcels that typify at least some of the favorable characteristics of the Site, to maximize the assurance that sites that might reduce impacts of the Project, if present, would be identified.

5.3.1 ALTERNATIVE SITE A

Alternative Site A is located within the City of Avenal near the Kettleman compressor station. This site consists of the majority of a quarter section bounded on the west, north and east by unimproved dirt roads (34 1/2 Avenue alignment, Pueblo Avenue and 34th Avenue, respectively) and on the south by Plymouth Avenue. This site is also within the City's industrial park, where development of a power plant would be consistent with existing land use designations. In addition, this site is located distant from developed communities and close to necessary infrastructure. Site A has been extensively disturbed by agriculture and could be developed without impacting native habitat. There are no California Natural Diversity Data Base (CNDDB) occurrences on Site A.

Because of the similar site conditions and similar magnitude of disturbance that would be required, it is expected that environmental impacts of the Project at Alternative Site A would be similar compared to the selected Site. Electrical transmission and natural gas interconnections would be shorter, but water is farther away. Federal Power was not able to obtain site control for Site A. There are no identifiable environmental benefits to Site A compared to the selected Site.

5.3.2 ALTERNATIVE SITE B

Alternative Site B is located approximately 3 miles north of the selected Site in Fresno County, near the Gates substation. Site B is almost a complete quarter section, bordered on the south by Jayne Avenue and on the west by Lassen Avenue (Route 269). Site B is zoned agricultural and is actively farmed. Site B is about 1 mile from the Gates substation and about 1-1/2 miles from PG&E's large natural gas transmission line. The San Luis Canal is approximately 2 miles east of Site B. Site B has been extensively disturbed by agriculture and could be developed without impacting native habitat. There are no CNDDB occurrences on Site B.

Site B is a similar distance to the PG&E gas line, but considerably further from the canal, which is the closest known potential source of water. Site B is located approximately the same distance from regional transportation routes, and in a similar topographic setting as the selected Site, so visual effects would be approximately the same as with the Project. Site B is not zoned industrial like the selected Site in Avenal so there would be a greater land use impact. Site B would reduce the amount of new transmission line by approximately 5.0 miles compared to use of the selected Site. Because the transmission line from the selected Site will have not have significant impacts, there is no justification to seek rezoning of Site B from Agricultural to Industrial.

5.4 COOLING TECHNOLOGY ALTERNATIVES

There are two general cooling technology alternatives that are technically feasible for rejecting heat from the steam turbine: dry cooling and wet cooling. Dry cooling requires an air-cooled condenser (ACC) and is the technology proposed for the Project. Wet cooling can utilize a circulating cooling water system with an evaporative cooling tower for heat rejection, or once-through cooling water flow. Wet cooling with an evaporative cooling tower is considered in this analysis, but once-through cooling is not considered because it is unlikely to be acceptable to regulatory agencies and the public for a new power plant. Hybrid wet/dry cooling utilizes both an evaporative cooling tower and an air-cooled condenser. Hybrid cooling also is not analyzed herein, because its benefits and drawbacks compared to the proposed dry cooling technology are the same as those for wet cooling described below, but less extreme, since it is simply the combined use of both technologies.

With the dry cooling technology proposed for the Project, exhaust steam from the steam turbine is cooled and condensed in an ACC, which is a large external heat exchanger that uses atmospheric air as the cooling medium. Large, electric motor-driven fans move large quantities of air across finned tubes (similar in principle to an automobile radiator), through which the exhaust steam is flowing. Heat transfer from the hot steam to the air cools the steam, which condenses and is returned to the steam cycle. The ACC for the proposed Project will have dimensions of approximately 260 feet x 280 feet and will be approximately 140 feet high. The ACC requires substantial power to operate the motor-driven fans. The primary advantage of the dry cooling technology is that water is not needed for cooling. For the proposed 600 MW plant, dry cooling is expected to save more than 2,000 AFY in water demand compared to using wet cooling.

For the wet cooling technology alternative, the heat rejection system for condensing steam from the steam turbine exhaust would consist of a surface condenser, a circulating cooling water system, and a wet cooling tower. The warm circulating water would be directed through a mechanical draft cooling tower, which would be approximately 400 feet long by 50 feet wide by 45 feet high. The warm circulating water would cascade from the top of the tower, through the tower, where it would contact surfaces designed to maximize air-to-water contact. Fans draw air through the tower to further increase air-to-water contact. Cooling occurs primarily through partial evaporation of the falling water (similar to operation of a "swamp" cooler) and contact cooling of the water by the cooler air. The cooled water collects in a large basin beneath the tower, and circulation pumps return the water back to the condenser and other equipment to repeat the cycle. The primary advantages of wet cooling technology include:

- The plant would consume less natural gas per unit of net power output, thereby providing more efficient use of non-renewable fossil fuel and reducing fuel burning emissions per unit of net power generated.
- Construction costs for a wet cooling system are considerably less than for a dry cooling system.
- The plant would have less visual impact with a wet cooling system, since the cooling tower would be approximately 45 feet high compared to the ACC that will be approximately 140 feet high.

Dry cooling technology was selected for the Project because CEC policy related to the use of water for power plant cooling, as set forth in the CEC's 2003 *Integrated Energy Policy Report*, results in an estimated low probability that wet cooling would be permitted by CEC for this facility.

5.5 ELECTRICAL TRANSMISSION LINE INTERCONNECTION ROUTE ALTERNATIVES

The Project electrical transmission line interconnection route is shown in Figure 5.5-1, and the interconnection is described in detail in Section 2.4. The route was selected for the Project in part because it minimizes environmental impacts. Key characteristics considered in conjunction with the electrical interconnection route selection process that are most relevant to minimizing environmental impacts include:

- The selected route is located away from developed roads so that views from most receptor locations are muted by distance. It will cross developed roads only where it follows the existing PG&E transmission line corridor between the Site vicinity and the Gates substation.

- The selected route is located to leave the south side of the Site, away from Avenal Cutoff Road and, consequently, will not interfere with the road frontage as the City's industrial park is developed. It will cross Avenal Cutoff Road only where it follows the existing PG&E transmission line corridor.
- The selected route traverses land that is exclusively used for agriculture, and there are no developments in proximity to the selected route. There is one farm house that will be displaced by transmission line construction, since the farm house occurs near the edge of the existing PG&E transmission line right-of-way. There are no other residences near the transmission line route.
- The selected route traverses intensively disturbed lands, so no disturbance to natural habitat or threatened or endangered species will occur.

In addition to the selected route, alternative electrical interconnection routes were considered to see if their use could substantially reduce impacts of the Project. These alternative routes are shown in Figure 5.5-1 and described further in the following sections.

5.5.1 ROUTE A

Route A would exit the northwest corner of the Site and traverse due west across Avenal Cutoff Road, and then merge with the selected line route where it parallels the existing transmission lines to the Gates substation. Use of Route A would require approximately 1.4 miles less transmission line construction between the Site and the Gates substation compared to the selected route. Route A would be entirely on lands that have been extensively disturbed by agriculture and are generally similar to the lands traversed by the selected route. Route A would cross Avenal Cutoff Road at a location where there currently are no high voltage electric transmission structures or wires and, therefore, would increase visual impacts compared to the proposed route. Therefore, this route was rejected.

5.5.2 ROUTE B

Route B would exit the northwest corner of the Site and traverse northwest across Avenal Cutoff Road and agricultural fields to Jayne Avenue. Similar to Route A, use of Route B would require approximately 1.4 miles less transmission line construction between the Site and the Gates substation compared to the selected route. Route B would be entirely on lands that have been extensively disturbed by agriculture and are generally similar to the lands traversed by the

selected route. Route B would result in increased disruption to local farmers because it would not be located adjacent to the existing PG&E transmission lines. Instead, it would result in a separate transmission line corridor approximately 0.4 mile apart from the existing PG&E corridor. The two separate transmission corridors would also incrementally increase visual impacts of the Project compared to a single corridor. Therefore, Route B was rejected.

5.6 OTHER TECHNOLOGY ALTERNATIVES

A wide variety of technology alternatives were studied to determine the most appropriate configuration for the Project. The Project will be a merchant plant and, as such, will be providing electricity in a deregulated market. The ability of the Project to operate efficiently in a deregulated market is paramount to the success of the venture, so the generating technology proposed has been carefully selected. The following sections include a discussion of power generating technologies, fuel technology alternatives, combustion turbine alternatives, NO_x control alternatives and inlet air cooling alternatives. Cooling technology alternatives are addressed in Section 5.4.

5.6.1 SELECTION METHODOLOGY

Technologies considered were primarily those that could provide base load or load-following power as opposed to those that would provide peaking or intermittent power. The reason for using this screening criterion was that the operating efficiency of the facility is interrelated with the substantial investment in its design.

The selection methodology included a stepped approach, with each step containing a number of criteria. The selected technology would have to pass Steps 1 and 2 and provide the lowest or near lowest cost in Step 3. The steps are:

- **Step 1 - Commercial Availability** - The technology had to be proven commercially practical with readily available, reliable equipment.
- **Step 2 - Implementable** - The technology had to be implementable; that is, it must meet environmental, public safety, public acceptability, fuel availability, financial and system integration requirements.
- **Step 3 - Cost-Effective** - The technology had to be incrementally cost competitive, not only with existing generating units, but also with units that will probably enter the market during the early commercial operation period of the Project. Incremental cost considerations include

capital as well as operation and maintenance (O&M) costs, which would translate into a bus bar cost represented in cents per kilowatt-hour.

This methodology was applied to a number of base load and load-following technologies as described in the following sections.

5.6.2 ALTERNATIVE NATURAL GAS-FIRED TECHNOLOGIES

Selection of the power generation technology focused on those technologies that can utilize natural gas. These technologies include conventional boiler-steam turbine units, combustion turbines in various configurations, and fuel cells.

5.6.2.1 Combined-Cycle (Selected) Generating Technology

This technology integrates combustion turbines and steam turbines in a combined cycle to achieve higher efficiencies compared to simple-cycle technologies. The combustion turbine drives a generator and the exhaust gases from the combustion turbine are used to produce steam that drives an additional generator, instead of being released to the atmosphere as they would under a single-cycle configuration. The resulting efficiency of the system is 50 to 54 percent, considerably above most other alternatives. This efficiency results in relatively low air emissions per kilowatt-hour generated. In addition, natural gas fuel emits little sulfur dioxide and little particulate matter. For these reasons, the system is considered the benchmark against which all other base load technologies are compared. Combined-cycle technology is commercially available and can be implemented. Because of its high efficiency and relatively low cost of generation, this technology is cost effective. This technology is the one selected for the Project, as well as most other new base load and load-following units being developed in the United States.

5.6.2.2 Conventional Boiler Steam Turbine

In conventional boiler steam turbine technology, fuel is burned in a furnace/boiler to create steam, which is passed through a steam turbine that drives a generator. The steam is condensed and returned to the boiler. This is an aging technology that is able to achieve a maximum thermal efficiency on the order of 35 to 40 percent. Applying the review methodology, the technology is commercially available and can be implemented. However, due to its relatively low efficiency, it tends to emit a greater quantity of emissions per kilowatt-hour generated

compared to more efficient technologies. Furthermore, its cost of generation is higher than the selected combined-cycle technology. This technology therefore does not satisfy Step 3 and was eliminated from further consideration.

5.6.2.3 Supercritical Boiler-Steam/Turbine

This technology is basically the same as the conventional boiler-steam/turbine except it utilizes considerably higher pressures. Plants using this type of technology are more expensive to construct per unit of power generated compared to conventional boiler-steam/turbine plants. Higher construction costs are generally offset by increased efficiency, so cost of power produced is about the same as a conventional boiler steam turbine plant. Applying the review methodology, the technology is definitely commercially available and could probably be implemented. However, because it is not as efficient as the combined-cycle technology, it would emit a greater quantity of emissions per kilowatt-hour compared to the Project. Based on the lower efficiency compared to the selected combined-cycle technology, this technology does not satisfy Step 3 and was eliminated from consideration.

5.6.2.4 Simple Cycle Combustion Turbine

This technology uses a combustion turbine to drive a generator. Air is compressed in the compressor section of the combustion turbine, and then passed into the combustion section where fuel is added and ignited. The resulting hot combustion gases pass through a turbine, which drives a generator. The combustion turbines have a relatively low capital cost and have efficiencies approaching 40 percent in the larger units. Because they are fast-starting and have a relatively low capital cost, they are used primarily for meeting high peak demand and have relatively low efficiency compared to combined-cycle technology. Applying the review methodology, this technology is commercially available and could be implemented. However, due to its lower efficiency compared to the selected combined-cycle technology, this technology would result in more air emissions per kilowatt-hour generated. Also, the incremental cost of generation, if it were base-loaded, would be relatively high. The technology, therefore, does not satisfy Step 3 and was eliminated from consideration.

5.6.2.5 Kalina Combined Cycle

This technology is similar to the conventional combined cycle except water in the heat recovery boiler is replaced with a mixture of water and ammonia. Overall efficiency is expected to be increased 10 to 15 percent. However, this technology is still in the testing phase. Applying the review methodology, the technology fails to pass Step 1, since it is not commercially available. It was therefore eliminated from consideration.

5.6.3 FUEL ALTERNATIVES

Technologies based on fuels other than natural gas, such as fuel cells, coal and oil, nuclear, solar and water, are described in the following sections.

5.6.3.1 Fuel Cells

This technology uses an electrochemical process to combine hydrogen and oxygen in order to liberate electrons, thereby providing a flow of current. Types of fuel cells include phosphoric acid, molten carbonate, solid oxide, alkaline and proton exchange membrane. With the exception of the phosphoric acid fuel cell and possibly the molten carbonate fuel cell, none of these technologies is commercially available on the scale of a commercial power plant. Therefore, they fail Step 1. The phosphoric acid fuel cell has operated in smaller size units, and the molten carbonate fuel cell has completed testing. At this time, however, neither of these technologies is cost competitive with conventional combined-cycle technology. Therefore, fuel cells fail Step 3 of the review methodology.

5.6.3.2 Coal

The technologies that use coal for fuel include: conventional furnace/boiler steam turbine generator; fluidized bed steam turbine generator; integrated gasification combined-cycle; direct-fired combustion turbine; indirect-fired combustion turbine; and magnetohydrodynamics.

Conventional Furnace/Boiler Steam Turbine Generator

Using this technology, coal is burned in the furnace/boiler, creating steam that is passed through a steam turbine connected to a generator. The steam is condensed in a condenser, passed through a cooling tower and returned to the boiler. Designs include stoker, pulverized coal and cyclone. The efficiency of this technology is equivalent to a conventional gas fired steam

turbine generator unit (35 to 40 percent) and, because of the usually lower price of coal compared to natural gas, the technology can be cost competitive under most conditions. However, the air emissions are greater per kilowatt-hour generated compared to conventional combined-cycle technology because of its lower efficiency, resulting in more fuel consumed per kilowatt-hour. Applying the review methodology, the technology is commercially available (Step 1). The technology should be implementable, except for a possible adverse public perception that large coal-fired units have unacceptably high levels of air emissions (untrue with modern units). In addition, coal would have to be imported from outside California (resulting in increased truck and/or train traffic), and the time to construct a facility would probably be about twice that for a conventional combined-cycle unit. The technology may therefore not pass Step 2. In addition, the generation cost of the technology could be greater than for a combined cycle (Step 3). Due to the potential problems under Step 2 and the potentially higher cost in Step 3, the technology was eliminated from consideration.

Atmospheric and Pressurized Fluidized Bed Combustion

Both of these technologies burn coal in a hot bed of inert material containing limestone that is kept suspended or fluidized by a stream of hot air from below. Water coils within the furnace create steam that drives a steam turbine generator. Efficiencies of atmospheric fluidized bed combustion (AFBC) units are on the order of 35 to 40 percent; pressurized (pressurized fluidized bed combustion [PFBC]) units are between 40 and 45 percent. The technology is commercially available for the AFBC technology, at least up to the 160-MW size. The PFBC technology is not commercially available. Applying the review methodology, the AFBC may pass Step 1, but the PFBC is eliminated from consideration. Implementation of the AFBC technology in California is possible, particularly for cogeneration applications (several units have been constructed in recent years). Coal would have to be imported from outside California, increasing train and/or truck traffic. The technology should pass Step 2, although possibly not for the 600-MW size that the applicant has planned. The generation cost of the technology, however, could be greater than for a combined cycle (Step 3). Due to the lack of a commercially proven unit in the 600-MW range, and the potentially higher cost, the AFBC technology was eliminated from consideration.

Integrated Gasification Combined-Cycle

Integrated gasification combined-cycle (IGCC) technology gasifies coal to produce a medium Btu gas that is used as fuel in a combustion turbine, which exhausts to an HRSG that supplies steam to a steam turbine/generator. The coal gasifier is located at the same site as the combustion turbine, HRSG and steam turbine generator. It is sized to supply the combustion

turbine and is integrated with it and the rest of the equipment to provide an integrated generating system. While a 100-MW unit has been fully tested in California, the technology is probably not fully commercially available. Applying the review methodology, the IGCC will not pass Step 1. Implementation of the IGCC technology in California is possible, except that coal would have to be imported from outside California (resulting in increased truck and/or train traffic). The generation cost of the technology could be competitive with a conventional gas-fired combined cycle (Step 3), but this is a relatively unknown factor. Due largely to the probable lack of full commercial availability, particularly in the 600-MW range, IGCC technology was eliminated from consideration.

Direct- and Indirect-Fired Combustion Turbines

Direct-fired units burn finely powdered coal directly in the combustion chamber of the combustion turbine. Indirect-fired units burn the coal in a fluidized bed or other combustor. Both use a heat exchanger to transfer the heat from the combustion gases to air, which is then expanded through the turbine. Neither of these units is commercially available. Therefore, they both fail to pass Step 1 of the selection methodology and were eliminated from consideration.

Magnetohydrodynamics

High temperature (3,000ºF) combustion gas is ionized and passed through a magnetic field to directly produce electricity. This technology is not commercially available. Therefore, it fails to pass Step 1 of the review methodology and was eliminated from consideration.

5.6.3.3 Nuclear Reactions

Nuclear technology includes nuclear fission and nuclear fusion. Nuclear fission breaks atomic nuclei apart, giving off large quantities of energy. For nuclear fission, pressurized water reactors (PWRs) and boiling water reactors (BWRs) are commercially available. California law prohibits new nuclear plants until the scientific and engineering feasibility of disposal of high-level radioactive waste has been demonstrated. To date, the Nuclear Regulatory Commission has been unable to make the findings of disposal feasibility required by law for this alternative to be viable in California. Nuclear fission would also require very large quantities of fresh water for cooling, a resource that is not readily available. The technology therefore is not implementable and fails to pass Step 2 of the review methodology. It was therefore eliminated from consideration.

Nuclear fusion forces atomic nuclei together at extremely high temperatures and pressures, giving off large quantities of energy. Nuclear fusion is not available commercially, and it is not clear if or when it will become available. The technology, therefore, fails to pass Step 1 of the review methodology and was eliminated from consideration.

5.6.3.4 Water

These technologies use water as "fuel." They include hydroelectric, geothermal and ocean energy conversion.

Hydroelectric

This technology uses falling water to turn turbines that are connected to generators. A flowing river or, more likely, a dammed river, is required to obtain the falling water. This technology is commercially available. However, most of the sites for hydroelectric facilities have already been developed in California, and any remaining potential sites face formidable environmental licensing problems. There are no large bodies of water near the Avenal Energy Project Site that can be used for hydroelectric power. Therefore, it would fail to pass Step 2 of the review methodology. It was therefore eliminated from consideration.

Geothermal

These technologies use steam or high-temperature-water (HTW) obtained from naturally occurring geothermal reservoirs to drive steam turbine/generators. There are vapor dominated resources (dry, superheated steam) and liquid-dominated resources that use a number of techniques to extract energy from the HTW. Geothermal energy electric power generation utilizes commercially available technology. However, geothermal resources are limited, and most, if not all, current resources have been discovered and developed in California. Geothermal development is not viable at the Project location. It was, therefore, eliminated from consideration.

Ocean Energy Conversion

A number of technologies use ocean energy to generate electricity. These include: tidal energy conversion, which uses the changes in tide level to drive a water turbine/generator; wave energy conversion, which uses wave motion to drive a turbine/generator; and ocean thermal energy conversion, which employs the difference in water temperature at different depths to drive an ammonia cycle turbine/generator. While all of these technologies have been made to work at a

research scale, they are not commercially available. Even if they were commercially available, they are considerably more costly than conventional combined-cycle technology and so would fail Step 3 of the review methodology. They were therefore eliminated from consideration.

5.6.3.5 Biomass

Major biomass fuels include forestry and mill wastes, agricultural field crop and food processing wastes, and construction and urban wood wastes. Several techniques are used to convert these fuels to electricity, including direct combustion, gasification and anaerobic fermentation. While these technologies are available commercially on a limited basis, their cost tends to be high relative to a conventional combined-cycle unit burning natural gas. This technology, therefore, does not pass Step 3 of the review methodology and was eliminated from consideration.

5.6.3.6 Solar Radiation

Solar radiation (sunlight) can be collected directly to generate electricity with solar thermal and solar photovoltaic technologies, or indirectly through wind generation technology in which the solar energy causes thermal and pressure difference in the atmosphere, creating wind. Wind generation and two types of solar generation, thermal conversion and photovoltaics, were considered as alternative technologies to the combined cycle. These are described in the following subsections.

Solar Thermal

Most of these technologies collect solar radiation, then heat water to create steam to power a steam turbine generator. The primary systems that have been used in the United States capture and concentrate the solar radiation with a receiver. The three main receiver types are mirrors located around a central receiver (power tower), parabolic dishes and parabolic troughs. Another technology collects the solar radiation in a salt pond and then uses the heat collected to generate steam and drive a steam turbine generator. While one of these technologies might be considered to be marginally commercial (parabolic trough), the others are still in the experimental stage. All require considerable land for the collection receivers and are best located in areas of high solar incidence. In addition, power is only generated while the sun shines, so the units do not supply power when clouds obscure the sun or between early evening and late morning. Gas-fired backup generation for the evening hours is necessary to support continuous power output and to provide steam to support solar operations. The Avenal area does not have sufficient year

round sunshine to be favorable for commercial solar power generation. The land use impact of the large area required for collection receivers would also be significant. Considering these factors, this technology may not be implementable. Hence, solar thermal was eliminated from consideration.

Solar Photovoltaic

This technology uses photovoltaic "cells" to convert solar radiation directly to direct current electricity, which is then converted to alternating current. Panels of these cells can be located wherever sunlight is available. This technology is commercially available, since panels of cells can theoretically be connected to achieve any desired capacity. The cost is higher than the selected combined-cycle technology. This technology fails Step 3, cost-effectiveness, and was therefore eliminated from consideration.

Wind Generation

This technology uses a wind-driven rotor (propeller) to turn a generator and generate electricity. Only limited sites in California have an adequate wind resource to allow for the installation of wind generators, and most of these sites have already been developed or are remote from electric load centers and have limited or no transmission access. Even in prime locations the wind does not blow continuously, so capacity from this technology is not always available. In California, the average wind generation capacity factor has been 25 to 30 percent. In addition, depending on the site and/or season, the technology cannot be depended upon to be available at system peak load since the peak may occur when the wind is not blowing. The technology is commercially available. Land consumption and effects on visual resources and avian species are a concern that may inhibit implementability. The cost of generation is above the cost of the selected combined-cycle technology. Due to the lack of availability of good sites, limited dependability, and relatively high cost, this technology was eliminated from consideration.

5.6.3.7 Conclusion

Using the selection methodology identified in Section 5.6.1, alternative fuels were eliminated from consideration. The availability of natural gas, the environmental and operational advantages of natural gas fuel technology, and the proven performance and commercial benefits of natural gas make this the selected choice for the Project.

5.6.4 ALTERNATIVE NOX CONTROL TECHNOLOGIES

To minimize NO_x emissions from the Project, the CTGs will be equipped with dry low NO_x combustors, and the HRSGs will be equipped with post-combustion selective catalytic reduction (SCR), using aqueous ammonia as the reducing agent. Alternative NO_x control technologies are analyzed in Appendix 6.2-5 and summarized in this section.

The following combustion turbine NO_x control alternatives were considered:

- Steam injection (capable of 25 to 42 ppm NO_x)
- Water injection (capable of 25 to 42 ppm NO_x)
- Dry low NO_x combustors (capable of 9 to 25 ppm NO_x)

Dry low NO_x combustors were selected because they provide for lower NO_x emissions and lower HRSG makeup water requirements.

Three post-combustion NO_x control alternatives were considered:

- SCR
- XONON™
- $SCONO_x$™

SCR is a proven technology and is used frequently in combined-cycle applications. Ammonia is injected into the exhaust gas upstream of a catalyst. The ammonia reacts with NO_x in the presence of the catalyst to form nitrogen and water and significantly lower emissions.

The XONON™, manufactured by Catalytica Combustion System, is a relatively new technology. XONON™ achieves NO_x as well as CO and VOC emission control through the combustion process using a catalyst to limit the combustor temperature to below the temperature where NO_x is formed. The XONON™ can produce the same amount of heat energy as a conventional combustor, but with lower temperature, thus reducing the formation of NO_x. The material of the catalyst is platinum and/or palladium. The XONON™ module is attached directly within the gas turbine combustor. The XONON™ combustor installed in the 1.5 MW Kawasaki gas turbine, which began operation in June 2000, has not yet produced sufficient operating data to determine that this level of control can be achieved over the long term. It still has not been tested on large-scale gas turbines. GE Power Systems, which has a collaborative agreement to commercialize the XONON™ system for GE gas turbines, indicated they are not planning to actively develop XONON™ technology for their products for at least 2 years. XONON™ was therefore eliminated from further review for the Project.

The $SCONO_x$™ is also a relatively new technology and has been installed on a 25-MW combined-cycle plant and the 49 MW City of Redding Unit 6 simple-cycle gas turbine. $SCONO_x$™ consists of an oxidation catalyst, which oxidizes CO to CO_2 and NO to NO_2. The NO_2 is adsorbed onto the catalyst, and the catalyst is periodically regenerated. Although a potentially promising technology, $SCONO_x$™ has not been commercially demonstrated on a larger gas turbine such as the 7FA proposed for Avenal Energy. There are several technological and commercial issues remaining to be resolved prior to application of this new technology to the class of large combustion turbines selected for the Project.

The following reducing agent alternatives were considered for use with the SCR system:

- Anhydrous ammonia
- Aqueous ammonia
- Urea

Anhydrous ammonia is suitable for use, but its handling and storage are of more concern than is the use of aqueous ammonia. The aqueous ammonia (19 percent ammonia, 81 percent water solution) has been used in many combined-cycle facilities and has been selected for the Project. Urea has not been commercially demonstrated for use with SCR on gas turbines attempting to meet the extremely low NO_x levels proposed for the Project. Therefore, this technology was eliminated from consideration.

5.6.5 ALTERNATIVE INLET AIR COOLING TECHNOLOGIES

Combustion turbine output and efficiency both increase as inlet air temperature decreases. Ambient air temperatures for the Project are sufficiently high for a large portion of the year to warrant some form of inlet air cooling. Three available forms of combustion turbine inlet air cooling are evaporative cooling, inlet fogging and air chilling.

Both evaporative cooling and inlet fogging are capable of cooling to temperatures near the ambient wet-bulb temperature. Air chilling, on the other hand, is capable of cooling CTG inlet air to temperatures significantly below ambient wet-bulb temperatures (chilled air temperature is typically 48°F) over a wide range of ambient conditions resulting in substantial net output gains. Air chilling uses mechanical or absorption refrigeration to produce a cold fluid for cooling of the inlet air and can be designed to operate continuously.

Based on temperature profiles at the Site, mechanical inlet air chilling was selected to eliminate output reduction at high ambient temperature conditions and result in substantial net output gains.

5.7 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section presents a comparative analysis of the alternatives presented. Since the purpose of this analysis is to evaluate if there are feasible alternatives that could avoid or lessen adverse environmental impacts of the Project, the following criteria are used:

- Feasibility - This criterion includes consideration of commercial availability, implementability and cost.
- Environmental Impacts - The anticipated environmental effects are comparatively reviewed to determine if impacts would be less than, the same as or similar to, or greater than the Project.

The comparative analysis is presented in Table 5.1-1. The top row of the table shows the feasibility criteria and environmental criteria for operation of the Project. Subsequent rows in the table show the comparative analysis of feasibility and environmental impact criteria for each of the alternatives analyzed. The feasibility criteria reflect independent evaluations of commercial availability, implementability and cost-effectiveness of each alternative. Criteria for these alternatives are not absolute, but are as they would be compared to the Project. Environmental Impact Criteria for technology alternatives are evaluated only for those technologies with a rating of Moderate or High for all three Feasibility Criteria.

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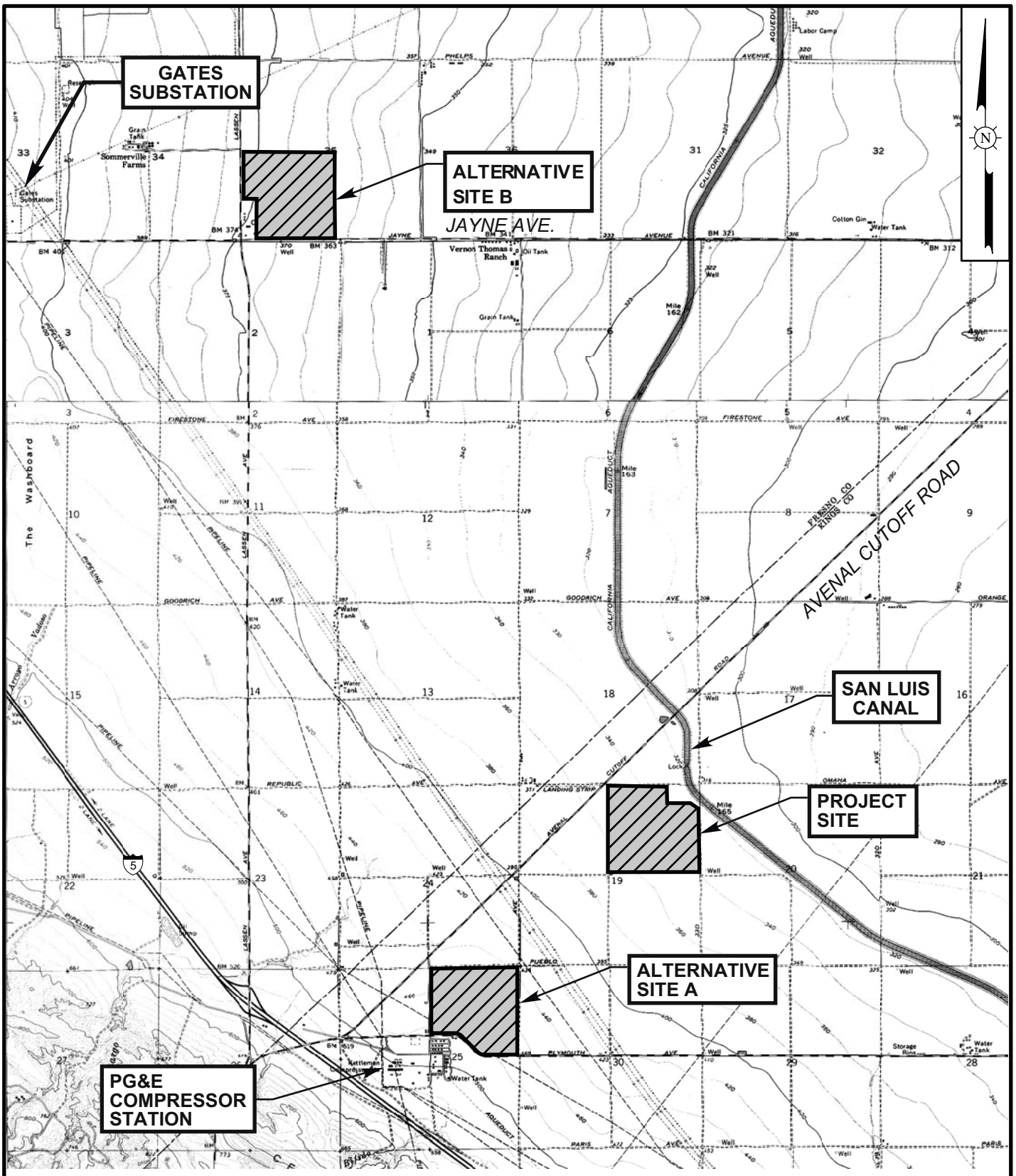

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SCALE

REFERENCE: U.S.G.S 7.5 MINUTE TOPOGRAPHIC SERIES MAPS OF HURON, CALIFORNIA, DATED 1971 AND LA CIMA, CALIFORNIA, DATED 1978.

ALTERNATIVE SITE LOCATIONS

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 5.3-1**

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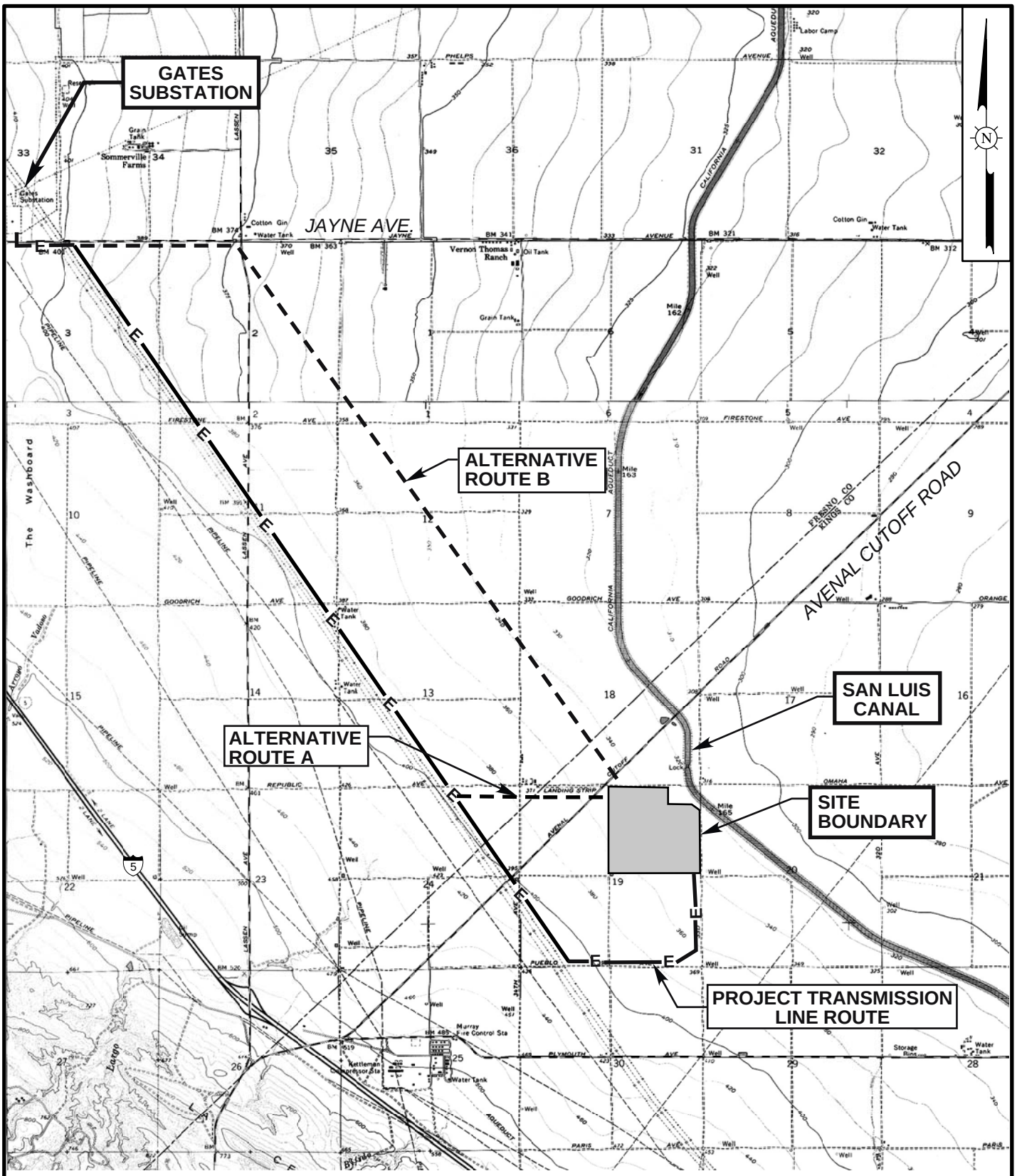

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TRANSMISSION LINE ALTERNATIVES

FEDERAL POWER AVENAL, LLC

AVENAL ENERGY | **FIGURE 5.5-1**