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4.3 GEOLOGY, SOILS, AND SEISMICITY

This section provides information regarding hazards for Project facilities in relation to unstable slopes, surface traces of active faults, areas susceptible to liquefaction, and areas with potential for earthquake-induced groundshaking. The potential for injection of reclaimed water at the geysers to induce seismicity is evaluated. To provide a basis for this evaluation, the setting section provides information on regional geology, including a description of major geologic units and locations of faults. The general geologic conditions at each reservoir site and within the geysers area are presented. Mechanisms of geologic instability are discussed, with particular reference to Project facilities. Soil types are characterized, including an evaluation of hazards such as expansiveness, corrosivity, and erosion potential. Regulations intended to minimize geologic hazards are summarized, including requirements for building and grading permits, erosion control, and dam design.

IMPACTS EVALUATED IN OTHER SECTIONS

The following items are related to the Geology, Soils, and Seismicity section but are evaluated in other sections of this document.

- Topographic Alterations. Construction of dams, reservoirs, and the geysers pipeline would involve substantial excavation and filling and would permanently alter topography. Potential impacts that would result from topographic alterations are discussed in Section 4.14, Visual Resources.
- Mineral Resources. Construction of a dam and reservoir at the Two Rock and Adobe Road sites could affect aggregate reserves in the vicinity. Potential impacts to mineral resources are discussed in Section 4.1, Land Use.
- Flooding Due to Dam Failure. Potential impacts from dam failure and inundation are discussed in Section 4.19, Inundation from Dam Failure.
- Soil Erosion. Soil erosion related to agricultural irrigation is discussed in Section 4.2, Agriculture. Sedimentation of waterways is discussed in Section 4.6, Surface Water Quality.
- Groundwater. Potential environmental impacts that could affect the quantity and quality of groundwater are addressed in Section 4.5, Groundwater.
- Streambank Erosion. Erosion within streams and rivers due to changes in flows is discussed in Section 4.4, Surface Water Hydrology.

AFFECTED ENVIRONMENT (SETTING)

Geology

The Project area, which includes most of Sonoma County and adjacent northern Marin County, is immediately east of the San Andreas Fault zone (Figure 4.3-1). The northwest-trending San Andreas Fault zone is the junction between two crustal plates: the North American plate, which forms the land mass to the east, and the Pacific plate, which is mostly under water in the vicinity of the Project area. The movement between these two plates, over many millions of years, has produced the northwest-trending ridges and valleys present in Sonoma County and throughout the Coast Ranges. The plate boundary is defined by many nearly parallel faults, which, together with the San Andreas Fault, are the main sources of seismic activity in the vicinity of the Project.

The geologic units that underlie the Project region are depicted in the Santa Rosa Quadrangle geologic map of the California Division of Mines and Geology Regional Geologic Map Series (Wagner and Bortugno 1982) and described in the geology of the Santa Rosa Quadrangle (Wagner and Bortugno 1983). The oldest geologic units in the vicinity of the Project east of the San Andreas Fault are the Franciscan Complex, which is Jurassic to Early Cretaceous in age and the Great Valley Group which is Early Cretaceous. The Franciscan Complex consists of folded and faulted sandstones, shale, conglomerate, chert, greenstone, and serpentinite rocks. In some areas these rocks occur as large intact blocks, and in others may occur as melange (meaning a mixture of rocks).[1] The Great Valley Group consists of marine mudstones, sandstones, and conglomerates. Much younger Miocene to Pliocene sedimentary rocks, including the Wilson Grove Formation[2] (marine sandstone, conglomerate, and tuff) and the Petaluma Formation (mostly non-marine claystone, mudstone, and siltstone) were deposited on top of the Franciscan Complex. During Pliocene time, volcanic activity occurred and resulted in the widespread deposition of the Sonoma Volcanics (basalt, andesite, rhyolite, tuff, and other volcanic rocks) in the eastern portion of the County. Pleistocene to Holocene alluvium, including the Glen Ellen Formation, in northwest-trending valleys constitutes the youngest geologic unit in the area.

South County

Proposed South County reservoir sites are located in the western foothills of the Sonoma Mountains where they border Petaluma Valley. The main geologic formations in this part of the Project region are the Petaluma Formation and the Sonoma Volcanics, both of Pliocene age. However, some relatively small areas are underlain by Franciscan Complex rocks which are in fault contact with the Pliocene rocks. The following description of site specific geologic conditions is based on the *Geotechnical Assessment of Alternative Reservoir Sites and Pipeline Alignments* (Rust Environment & Infrastructure 1995). All reservoir geology figures are found together at the end of this discussion.

Tolay Extended and Tolay Confined Reservoir Sites

The Tolay Creek main dam site is located on a relatively narrow constriction of Tolay Creek, immediately downstream of the broad, flat-floored valley of Tolay Creek. At the main dam site maximum slopes are about 1.5:1 (horizontal to vertical[3]) with elevations ranging from 180 to 300 feet above mean sea level.

The reservoir site is underlain by rocks of the Petaluma Formation (claystone and sandstone), Sonoma Volcanics (andesite, rhyolite, and tuff), and Franciscan Complex. Franciscan Complex rocks are found at higher elevations at the reservoir site and consist of melange (Figure 4.3-2). Alluvial deposits occur in the flattest portions of the valley floor and range in thickness from 25 to 30 feet.

The main dam site is underlain by claystone of the Petaluma Formation and rhyolites of the Sonoma Volcanics. Thick old landslide deposits consisting of rocks from these two formations have been interpreted based on results of subsurface exploration at the main dam site. The north saddle dam is underlain entirely by claystone and sandstone of the Petaluma Formation. The west saddle dam is underlain by claystone of the Petaluma Formation on the north abutment and

[1] A chaotic mixture of intact sandstone, greenstone, blueschist, silica-carbonate, and chert in a sheared or crushed matrix of shale.
[2] This unit was formerly known as the Merced Formation and is currently referred to as the Wilson Grove Formation.
[3] Throughout this report slope gradients will be reported in a ratio of horizontal distance to vertical distance.

old landslide deposits on the south abutment. The back dam, which crosses the broad valley, is underlain by silty clay to clayey sand material.

Few landslides were mapped at these reservoir sites during site reconnaissance. Rocks of the Petaluma Formation and soil-like units of the Sonoma Volcanics are prone to landsliding. However, because of the gentle slopes surrounding the valley floor the risk of landsliding at this site is moderate (Rust Environment and Infrastructure 1995).

The Tolay Fault trends northwesterly through the proposed main dam, back dam, and west saddle dam. This fault is not considered to be active based on the California Division of Mines and Geology fault evaluation (discussed in the Fault section below).

Adobe Road Reservoir Site

The Adobe Road dam site is located in a broad valley that contains an incised creek. Elevations at the site range from approximately 275 to 375 feet above mean sea level. Maximum slopes at the dam site are about 2:1.

The entire site is underlain by sedimentary rocks of the Petaluma Formation consisting of claystone and siltstone with interbeds of sandstone and pebbly conglomerate (Figure 4.3-3). Bedding orientation is variable possibly as a result of folding and landsliding; however, the general orientation of bedding is northwest with moderate to steep dips to both the northeast and southwest.

Numerous recent landslides exist within and above the reservoir area. The landslides range in size from 10 feet wide to 300 feet wide. Geotechnical investigations at the site suggest that older landslides are deeper and more extensive at this site than at other reservoir sites (Figure 4.3-5). Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is high (Rust Environment and Infrastructure 1995).

Sears Point Reservoir Site

The Sears Point dam site is located in the broad, flat-floored valley of Tolay Creek. Maximum slopes on the abutments of the dam site are about 4:1. Elevations at the Sears Point site range from approximately 30 feet to 155 feet above mean sea level.

Most of the reservoir site is underlain by soft, friable, and massive claystone of the Petaluma Formation. Minor outcrops of limestone, andesite, and tuff occur throughout the site (Figure 4.3-4). Alluvium, consisting mainly of clay and clayey sand, underlies the flat valley floor and ranges in thickness from about 30 to 40 feet. Several springs were mapped during field reconnaissance.

Numerous recent and old landslides are present at the site and are associated with the expansive Petaluma Formation claystone (Figure 4.3-4). Some of these slides are up to 400 feet wide and extend downslope as much as 1,000 feet. Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is moderate (Rust Environment and Infrastructure 1995). Thicker and more extensive landslide deposits are present in the western portion of the reservoir site.

Lakeville Hillside Reservoir Site

The Lakeville Hillside dam site is located in a broad flat valley that has relatively steep side slopes, especially in tributary channels. Elevations at the Lakeville Hillside site range from approximately 140 to 200 feet above mean sea level. Maximum slopes at the dam site are about 2:1.

The entire site is underlain by sedimentary rocks of the Petaluma Formation, consisting of claystone and siltstone with interbeds of sandstone and pebbly conglomerate (Figure 4.3-5). Bedding orientation is generally northeast with moderate dips to both the west and the east.

Several recent landslides are present within and above the reservoir area. The landslides range in size from 10 feet wide to 500 feet wide (Figure 4.3-5). Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is high (Rust Environment and Infrastructure 1995).

West County

The West County region includes the hilly areas bounded by the Santa Rosa Plain to the east and Bodega Bay to the west. The predominant geologic formation is the Pliocene-age Wilson Grove Formation, which consists mostly of marine sedimentary rocks. The Wilson Grove Formation underlies a relatively extensive area of this portion of the Coast Ranges which is underlain by older bedrock units of the Franciscan Complex and the Great Valley Group.

Two Rock Reservoir Site

The Two Rock dam site is located in a broad steep-sided canyon about 400 feet wide. Elevations at the site range from approximately 150 to 360 feet above mean sea level. Maximum slopes at the dam site are about 2:1.

The entire reservoir site is underlain by rocks of the Franciscan Complex, consisting of a melange (Figure 4.3-6). The Wilson Grove Formation occurs as a cap on the Franciscan Complex bedrock and is found on ridges surrounding the proposed reservoir. Surficial deposits overlying the bedrock include alluvium along the creek channel and colluvium on lower slopes.

Few landslides were mapped at the Two Rock reservoir site. Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is low (Rust Environment and Infrastructure 1995).

The Dunham Fault trends northwesterly through the eastern portion of the reservoir. The Bloomfield Fault is located about 2,000 feet southwest of the Two Rock dam site. Neither of these faults is considered to be active based on the California Division of Mines and Geology fault evaluation (discussed below).

Bloomfield Reservoir Site

The Bloomfield dam site is located in a narrow valley with flat to gently sloping sides. Elevations at this site range from 80 to 280 feet above mean sea level. Maximum slopes at the dam site are about 2:1.

The major bedrock unit at the reservoir site is the Wilson Grove Formation, consisting predominantly of massive, soft, weakly cemented siltstone to very fine sandstone (Figure 4.3-7). Franciscan Complex bedrock consisting of sheared shale and sandstone occurs north of the Bloomfield Fault, in the northern portion of the reservoir. Alluvial deposits blanket the flat, narrow valley floor and the broader valley floor at the northern portion of the site.

A few minor landslides are present at this site and a few erosional features, such as gullies and rills, are mapped (Figure 4.3-7). Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is low (Rust Environment and Infrastructure 1995).

The Bloomfield Fault trends northwesterly through the northern portion of the reservoir. This fault is an Early Quaternary fault and is not considered to be active based on the California Division of Mines and Geology fault evaluation (discussed below).

Carroll Road Reservoir Site

The Carroll Road dam site is located in a relatively narrow valley. Maximum slopes at the site are about 3:1. Elevations range from approximately 80 feet to 265 feet above mean sea level.

Most of the reservoir site is underlain by the Wilson Grove Formation, consisting of soft, friable, massive sandy siltstone to silty sandstone (Figure 4.3-8). Franciscan Complex bedrock occurs in a small area in the northern portion of the reservoir site. Bedding at the site is mostly flat lying to gently dipping. Alluvium ranging in thickness from about 25 to 30 feet occurs in the flat portions of the valley floor.

Most of the landslides mapped within the Carroll Road site are small and can be attributed to erosion or the presence of springs. Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is low (Rust Environment and Infrastructure 1995).

Valley Ford Reservoir Site

The Valley Ford dam site is located in a broad valley with flat to gently sloping sides. Maximum slopes in the dam site area are about 3.5:1. Elevations at the Valley Ford site range from approximately 30 to 160 feet above mean sea level.

The entire reservoir site is underlain by the bedrock of the Wilson Grove Formation consisting of massive, soft, weakly cemented sandy siltstone and siltstone (Figure 4.3-9). Bedding is typically close to horizontal. Alluvial deposits consisting of clay, sand, and silt overlie bedrock in the stream channel and are about 16 feet thick. The lower and flatter slopes of the valley are covered with several feet of clayey sand colluvium.

Numerous gullies are present in the Wilson Grove Formation indicating that the bedrock is potentially erodible, particularly in areas of concentrated surface water flow. A few minor landslides occur at this site and most are associated with incised erosion scars that follow steep drainage courses (Figure 4.3-9). Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is low (Rust Environment and Infrastructure 1995).

Huntley Reservoir Site

The Huntley reservoir site is located within a broad valley with gentle slopes. Maximum slope gradients at the site are approximately 2:1. Elevations at the site range from 100 to 260 feet above mean sea level.

The Huntley dam and reservoir site is underlain by Franciscan melange and the Wilson Grove Formation (weakly cemented sandstone and siltstone) (Figure 4.3-10). The older Franciscan Complex rocks occur in the valley floor and lower slopes. The younger Wilson Grove Formation occurs in depositional contact with the Franciscan and is found at the upper portions of slopes and on ridges. The contact between the Wilson Grove Formation and Franciscan Complex appears to dip gently toward the north Creek bank slumping, and minor shallow earth flows were observed at the site during field reconnaissance. However, no evidence of large, deep-seated landsliding or major slope instability was observed. Evaluation of existing landslides, topography, and geologic materials indicates that the risk of landsliding at this site is low (Rust Environment and Infrastructure 1995).

The Geysers Geothermal Resource Area

The geysers geothermal resource area is located in the Mayacmas Mountains in the northeastern most portion of Sonoma County and a smaller adjoining portion of Lake and Mendocino counties (Figure 4.3-11). This highland area is made up of a series of rugged northwest-trending ridges and valleys. The central ridge of the northwest-trending Mayacmas Mountains forms the boundary between Lake County on the east and Sonoma County on the west and extends into Mendocino County. Topography at the geysers is steep and rugged. Elevations range from just over 1,000 feet in the base of Big Sulphur Creek to a maximum of about 3,600 feet along the ridge near the Lake County line.

The main ridge of the northwest trending Mayacmas Mountains is a prominent drainage divide. Creeks on the west side of the ridge flow toward the northwest joining the Russian River near Cloverdale. Creeks on the east side flow both northeastward toward Clear Lake and southeastward into Lake Berryessa.

Throughout the geysers area, bedrock consists predominantly of the Franciscan Complex, which includes marine sandstone, shale, volcanic rocks, and serpentinite. The Franciscan rocks in this area are intensely fractured and degraded by hydrothermal (hot water) alteration due to infusion with hot, mineral-rich water. At the geysers, soil cover is generally thin and bedrock lies at or near the surface. Bedrock of other formations is scarce within the geysers area. Pyroclastic (erupted volcanic material) and flow rocks of the Pleistocene Clear Lake Volcanics occur east of the Project area at Cobb Mountain, Boggs Mountain, and Mt. Hannah. Deep magma chambers such as those responsible for the Clear Lake Volcanics are presumed to contribute the heat that generates steam at the geysers.

Unusual geologic conditions at the geysers, including open fractures in bedrock at great depth and heat from probable shallow magma chambers, produce natural steam. The steam was first used in the 1920s for generating electricity for a resort hotel along Big Sulphur Creek. Commercial development for power production began in 1955, and increased in the 1960s when twelve wells began to supply steam to an 11-megawatt power plant built by Pacific Gas and Electric. In 1966, power production increased to 51 megawatts, and by 1978 approximately 95 wells delivered steam to eleven power plants, with a total capacity of 502 megawatts. Power production reached a peak in the late 1980s.

Beginning in 1969, water discharge limitations set by the Regional Water Quality Control Board required that the effluent water (water that had condensed after steam production) be disposed of by re-injection. Currently a limited amount of water from Big Sulphur Creek is diverted and injected on a seasonal basis to enhance steam production. Injection of water from the Lake County Sanitary District into portions of the steamfield has been approved and is included as a Cumulative Project.

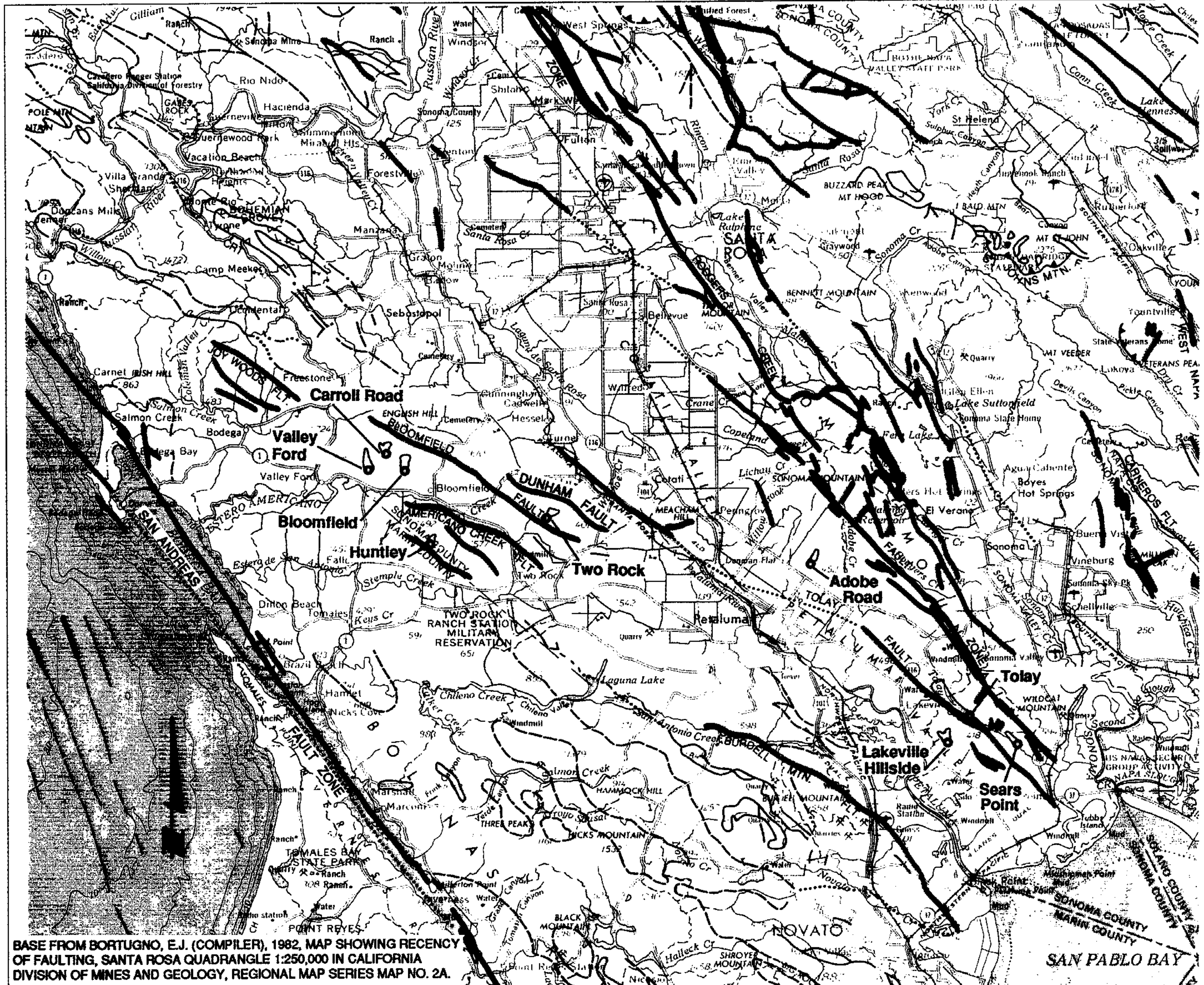
The structural grain of the geysers area is controlled by generally northwest oriented faults of several generations. The bedrock in the geysers area is intensely faulted and fractured. Older apparently inactive faults are abundant and cross-cut by younger faults. Faults in the geysers are further discussed under Historical Seismicity, below.

The Geysers Pipeline Alignment

The discussion of the geologic setting along the geysers pipeline alignment is divided into four segments according to topographic characteristics and bedrock type. Geologic and seismic hazards along pipeline routes are shown in two figures, the Southern Project Area (Figure 4.3-12) and the Northern Project Area (Figure 4.3-13). The description of this portion of the project is based on the *Geotechnical Assessment of Alternative Reservoir Sites and Pipeline Routes* (Rust Environment and Infrastructure, Inc. 1995).

Delta Pond near Santa Rosa Creek to the Pleasant Avenue/Chalk Hill Road Intersection east of Windsor

This gently sloping area is underlain by alluvium along Santa Rosa, Mark West, and Windsor creeks between Windsor and Santa Rosa. The alluvium is underlain by the Pleistocene Glen Ellen Formation which consists of older deposits of



BASE FROM BORTUGNO, E.J. (COMPILER), 1982, MAP SHOWING RECENCY OF FAULTING, SANTA ROSA QUADRANGLE 1:250,000 IN CALIFORNIA DIVISION OF MINES AND GEOLOGY, REGIONAL MAP SERIES MAP NO. 2A.

Source: Rust Environment & Infrastructure

Geologic Time Scale			Years Before Present (Approx.)	Fault Symbol	Recency of Movement	DESCRIPTION ON LAND
Quaternary - Potentially Active	Late Quaternary	Historic	200	~		Displacement during historic time (e.g. San Andreas Fault 1906). Includes areas of known fault creep.
		Holocene	10,000	~		Displacement during Holocene time.
			700,000	~		Faults showing evidence of displacement during late Quaternary time.
	Early Quaternary	Pleistocene	2,000,000	~		Quaternary (undifferentiated) faults - most in this category show evidence of displacement during the last 2,000,000 years; possible exceptions are faults which displace rocks of undifferentiated Plio-Pleistocene age.
Pre-Quaternary - Inactive		Pliocene	5,000,000	~		Fault showing evidence of no displacement during Quaternary time or faults without recognized Quaternary displacement.
		Miocene				

FAULT MAP SYMBOLS

ON LAND

Solid where well located; dashed where approximately located or inferred; dotted where concealed by younger rocks, lakes or bays; queried where continuation or existence is uncertain. Barbs indicate thrust fault (barbs on upper plate). Arrows indicate relative or apparent direction of movement.

Two Rock — ALTERNATIVE RESERVOIR STORAGE SITE

SCALE

0 5 10 MILES

1:250,000

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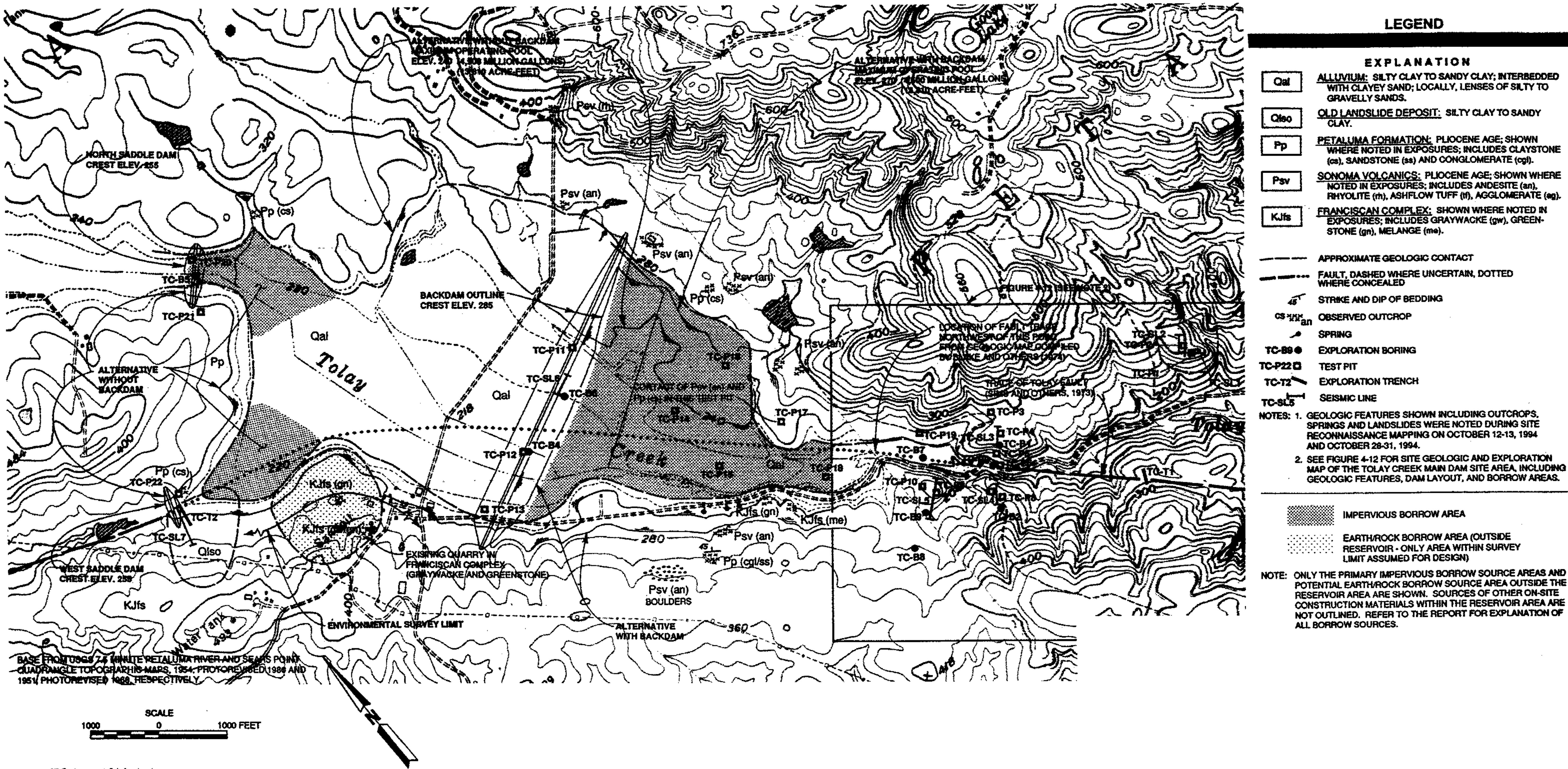
REGIONAL FAULTS

Figure 4.3-1



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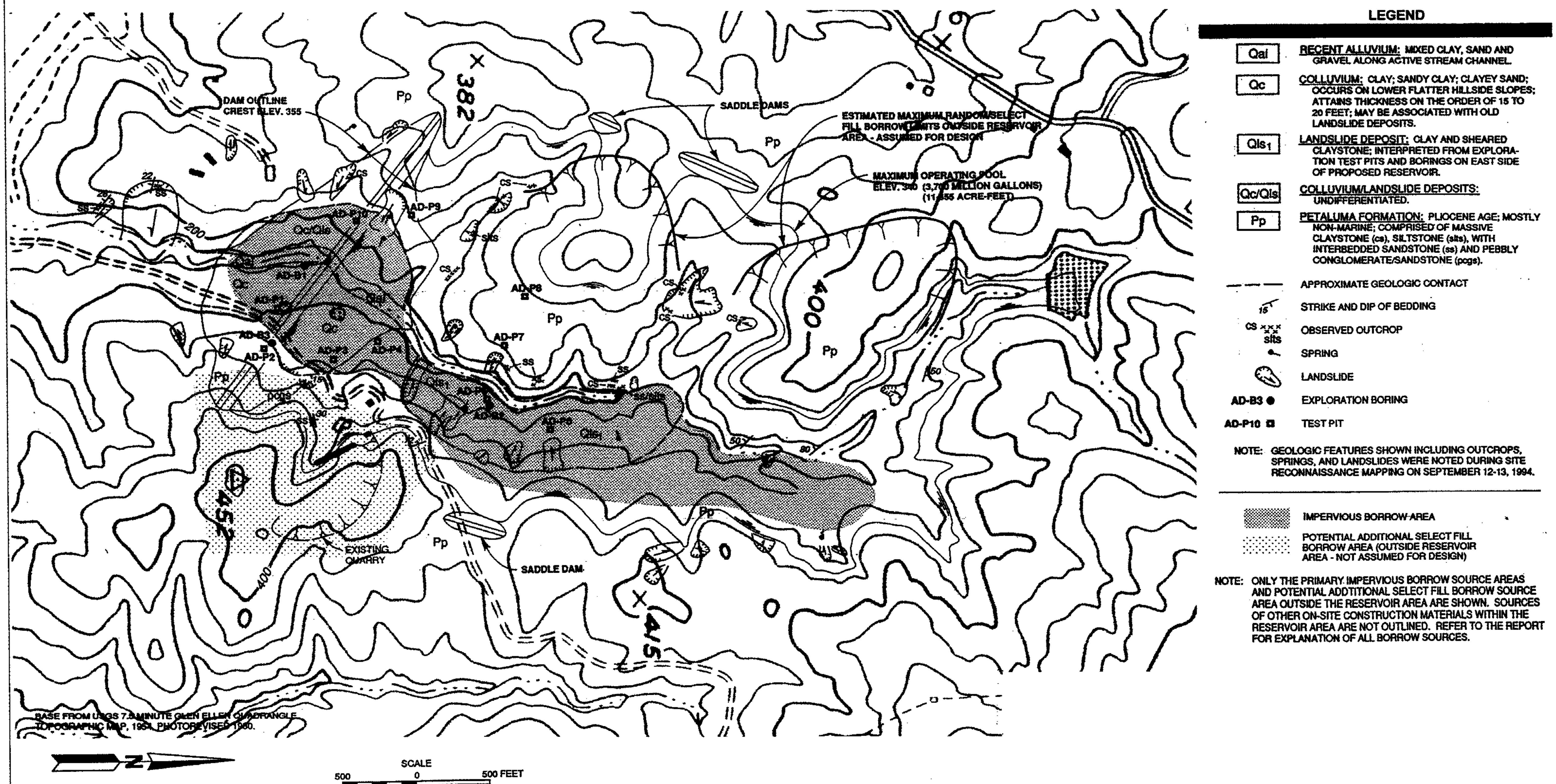
GEOLOGY of the TOLAY RESERVOIR SITE

Figure 4.3-2



Source: RUST Environment & Infrastructure

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Figure 4.3-3

GEOLOGY of the ADOBE ROAD RESERVOIR SITE

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Figure 4.3-4

GEOLOGY of the SEARS POINT RESERVOIR SITE

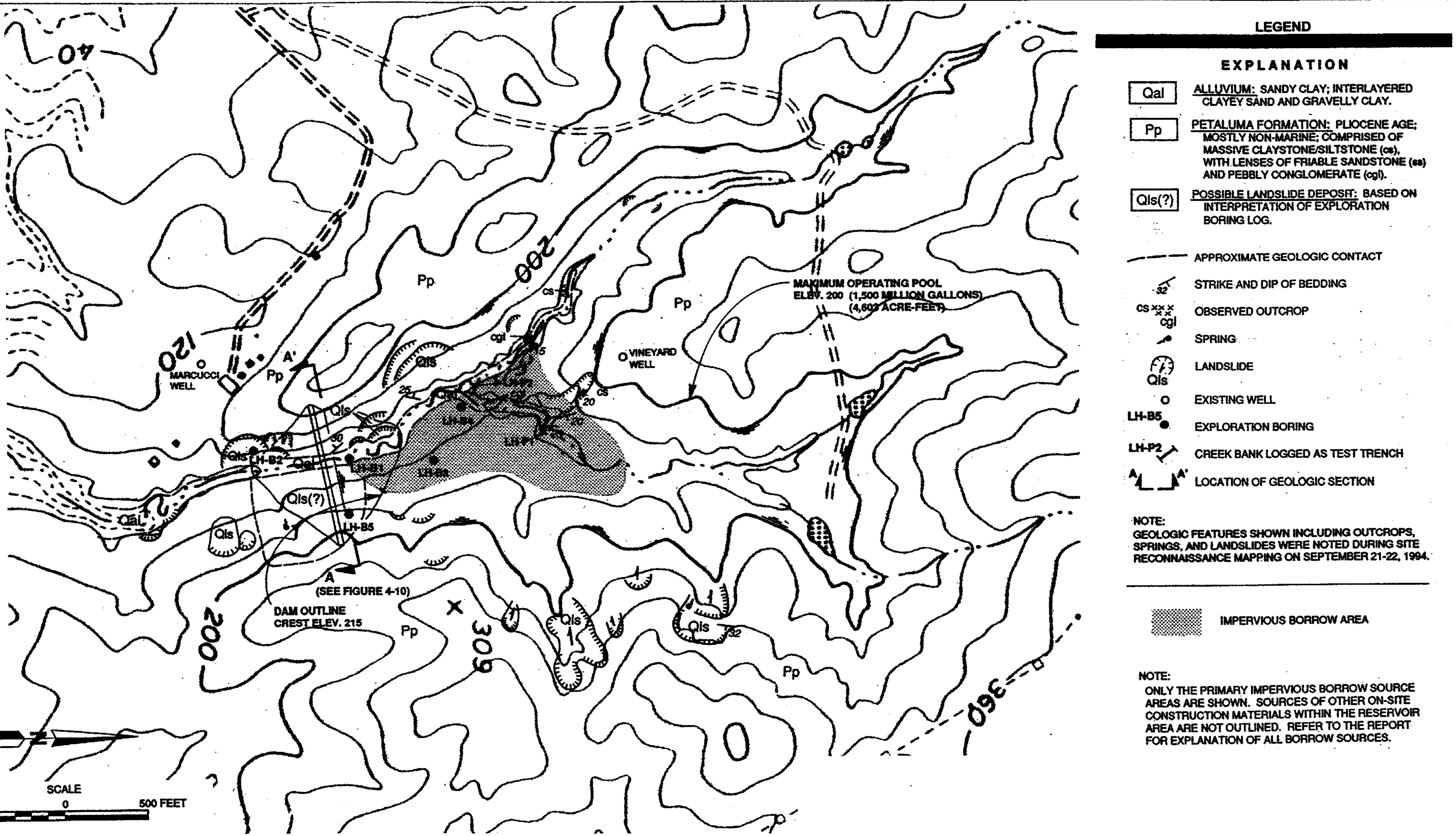

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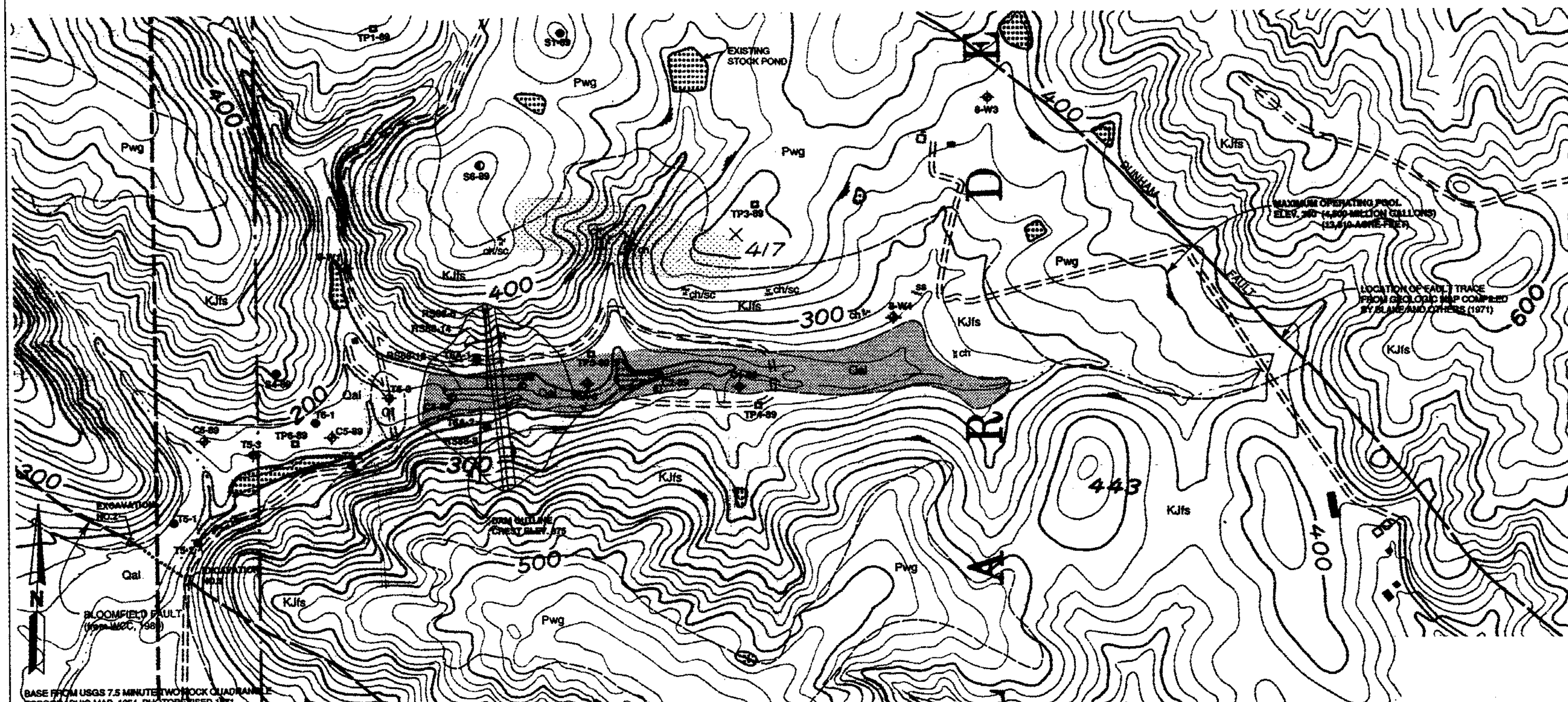
Figure 4.3-5

GEOLOGY of the LAKEVILLE HILLSIDE RESERVOIR SITE



LEGEND

EXPLANATION

- **Qf** — FILL: MIXED CLAY, SILT, SAND, GRAVEL ASSOCIATED WITH EARTH DIKES.
- **Qal** — ALLUVIUM AND COLLUVIUM: MIXED CLAY, SILT, SAND AND GRAVEL.
- **Pwg** — WILSON GROVE FORMATION (FORMERLY MERCED FORMATION): SANDY SILTSTONE, SILTSTONE; MASSIVE; FINE GRAINED; SOFT.
- **KJfs** — FRANCISCAN COMPLEX: MELANGE MATERIAL CONSISTING OF SHEARED, CRUSHED SHALE AND FRACTURED SANDSTONE; INCLUDES RESISTANT MASSES OF CHERT (ch), SILICA CARBONATE (sc), GREENSTONE AND GRAYWACKE SANDSTONE (ss).

- APPROXIMATE GEOLOGIC CONTACT
- FAULT, DASHED WHERE UNCERTAIN, DOTTED WHERE CONCEALED
- ch ××× sc — OBSERVED OUTCROP

NOTE: GEOLOGIC FEATURES SHOWN INCLUDING OUTCROPS WERE NOTED DURING SITE RECONNAISSANCE MAPPING ON OCTOBER 21, 1994.

PREVIOUS EXPLORATION BY WOODWARD-CLYDE CONSULTANTS (WCC):

- T6A-1 — CORE HOLE
- C3-89 — AUGER BORING
- T6A-3 / S-W4 — AUGER BORING WITH PIEZOMETER
- TP4-89 — TEST PIT
- RS88-8 — SEISMIC LINE

- IMPERVIOUS BORROW AREA
- POTENTIAL HARD ROCK BORROW AREA (OUTSIDE RESERVOIR - NOT ASSUMED FOR DESIGN)

NOTE: ONLY THE PRIMARY IMPERVIOUS BORROW SOURCE AREAS AND POTENTIAL HARD ROCK SOURCE AREA OUTSIDE THE RESERVOIR AREA ARE SHOWN. SOURCES OF OTHER ON-SITE CONSTRUCTION MATERIALS WITHIN THE RESERVOIR AREA ARE NOT OUTLINED. REFER TO THE REPORT FOR EXPLANATION OF ALL BORROW SOURCES.

SCALE
500 0 500 FEET

Source: RUST Environment & Infrastructure

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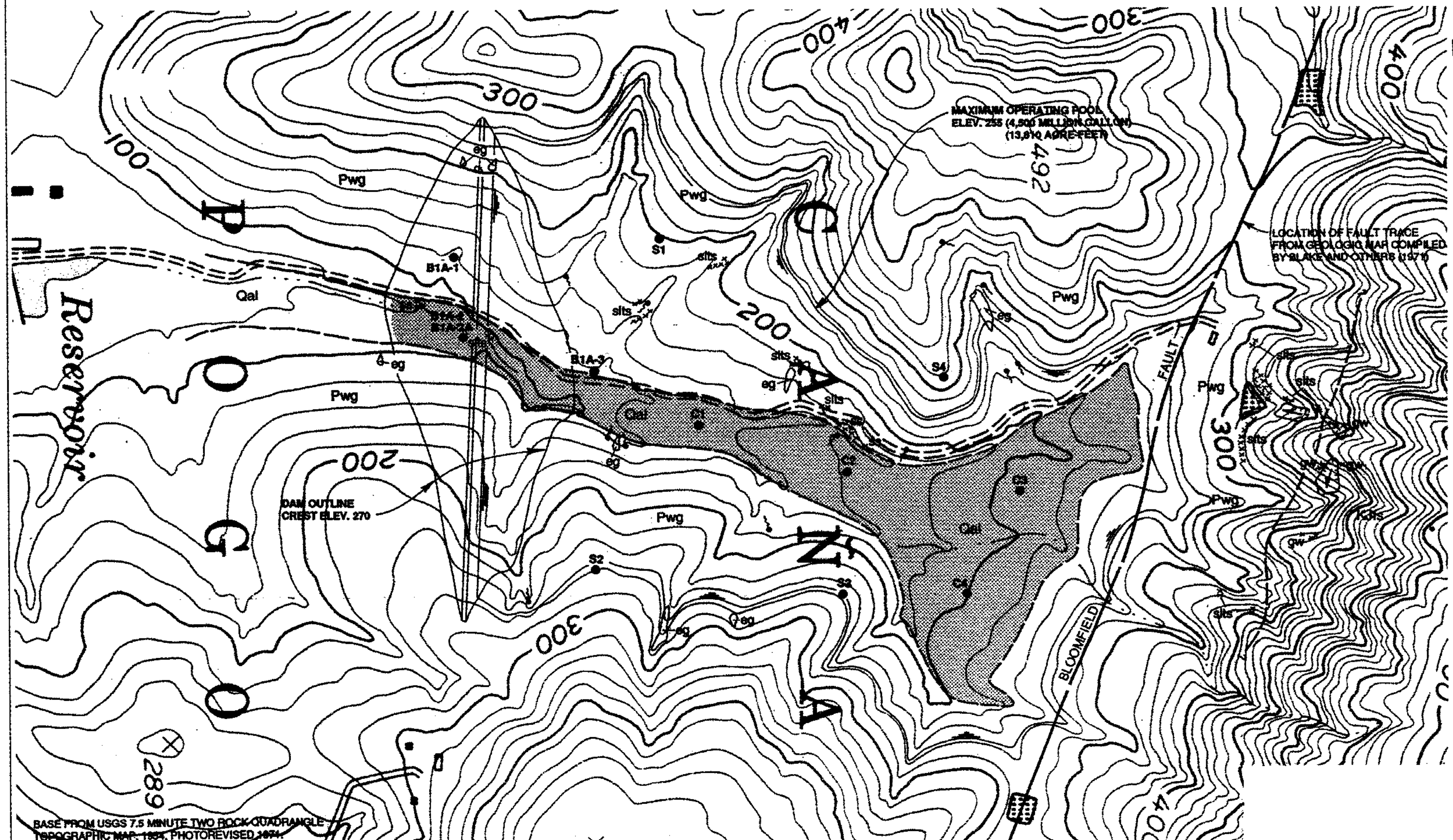
Figure 4.3-6

GEOLOGY of the TWO ROCK RESERVOIR SITE



LEGEND

Qal	ALLUVIUM: SANDY CLAYS, SILTY SANDS, SANDY SILTS.
Pwg	WILSON GROVE FORMATION (FORMERLY MERCED FORMATION: SANDY SILTSTONE, FINE SANDSTONE, OCCASIONAL CLAYSTONE; BEDDING NOT DISCERNABLE; SOFT IN HARDNESS; STRONG; APPEARS TIGHT.
KJfs	FRANCISCAN COMPLEX: INCLUDES GRAYWACKE, SHEARED SHALE AND SILTSTONE.

- APPROXIMATE GEOLOGIC CONTACT
- FAULT, DASHED WHERE UNCERTAIN
- OBSERVED OUTCROP: WILSON GROVE FORMATION SILTSTONE (slts); FINE SANDSTONE (ss); FRANCISCAN COMPLEX GRAYWACKE (gw)
- SPRING
- eg — EROSION GULLY OR SCAR
- LANDSLIDE

NOTE: GEOLOGIC FEATURES SHOWN INCLUDING OUTCROPS, SPRINGS, EROSION GULLIES, AND LANDSLIDES WERE NOTED DURING SITE RECONNAISSANCE MAPPING ON OCTOBER 6-7, 1994.

PREVIOUS EXPLORATION BY WOODWARD-CLYDE CONSULTANTS (WCC):

- B1A-1 ● EXPLORATION BORING (1988)
- S1, C1 ● EXPLORATION BORING (1989)

IMPERVIOUS BORROW AREA

NOTE: ONLY THE PRIMARY IMPERVIOUS BORROW SOURCE AREAS ARE SHOWN. SOURCES OF OTHER ON-SITE CONSTRUCTION MATERIALS WITHIN THE RESERVOIR AREA ARE NOT OUTLINED. REFER TO THE REPORT FOR EXPLANATION OF ALL BORROW SOURCES.

N

SCALE
500 0 500 FEET

Source: RUST Environment & Infrastructure

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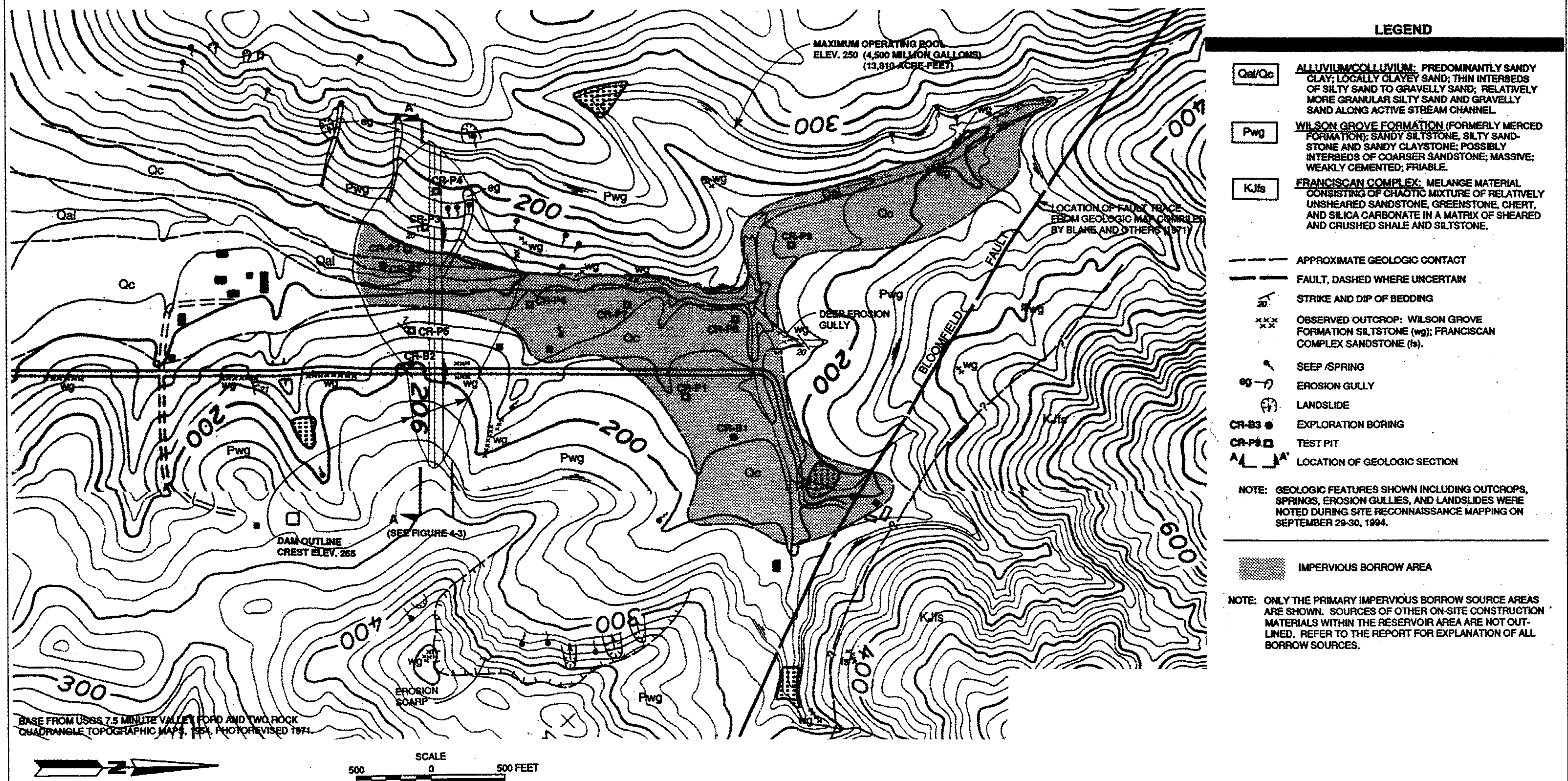
Figure 4.3-7

GEOLOGY of the BLOOMFIELD RESERVOIR SITE



Source: RUST Environment & Infrastructure

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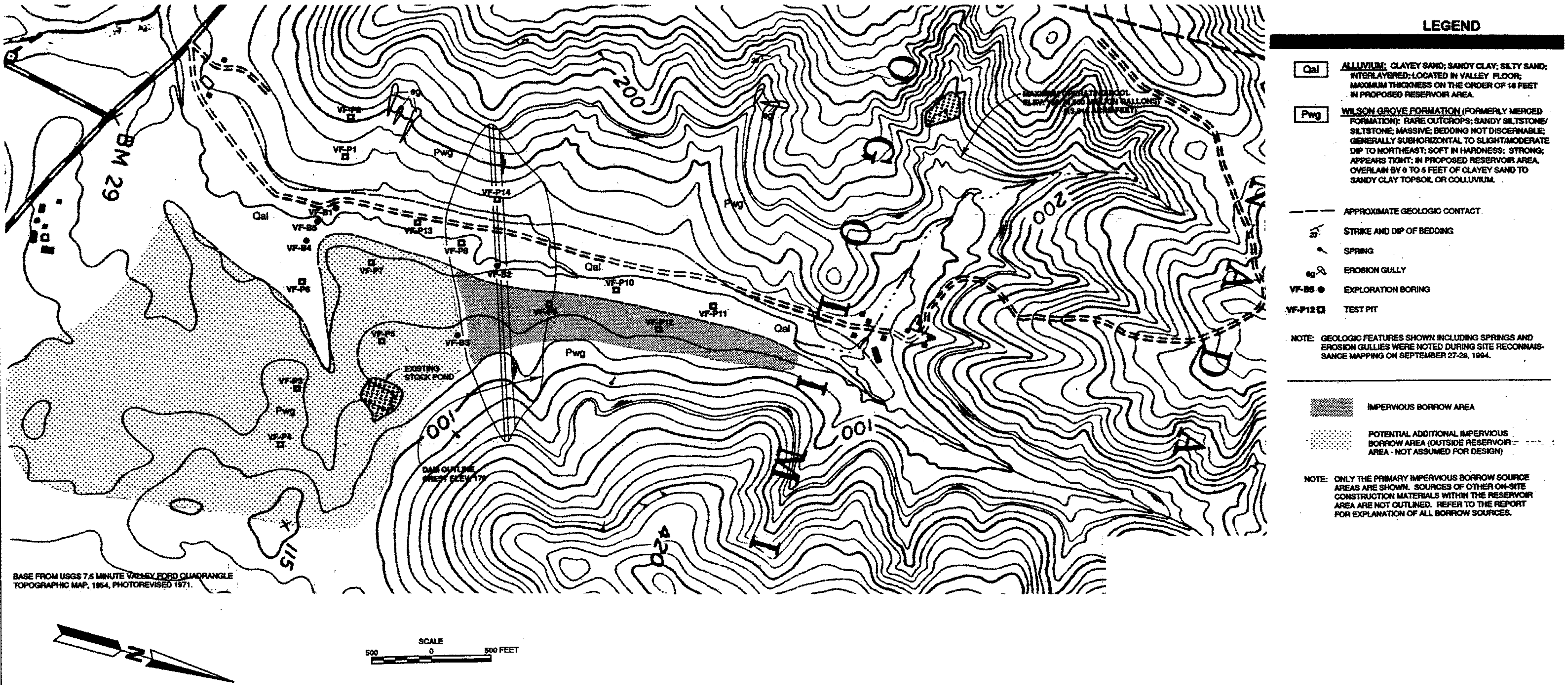
Figure 4.3-8

GEOLOGY of the CARROLL ROAD RESERVOIR SITE



Source: RUST Environment & Infrastructure

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Figure 4.3-9

GEOLOGY of the
VALLEY FORD RESERVOIR SITE

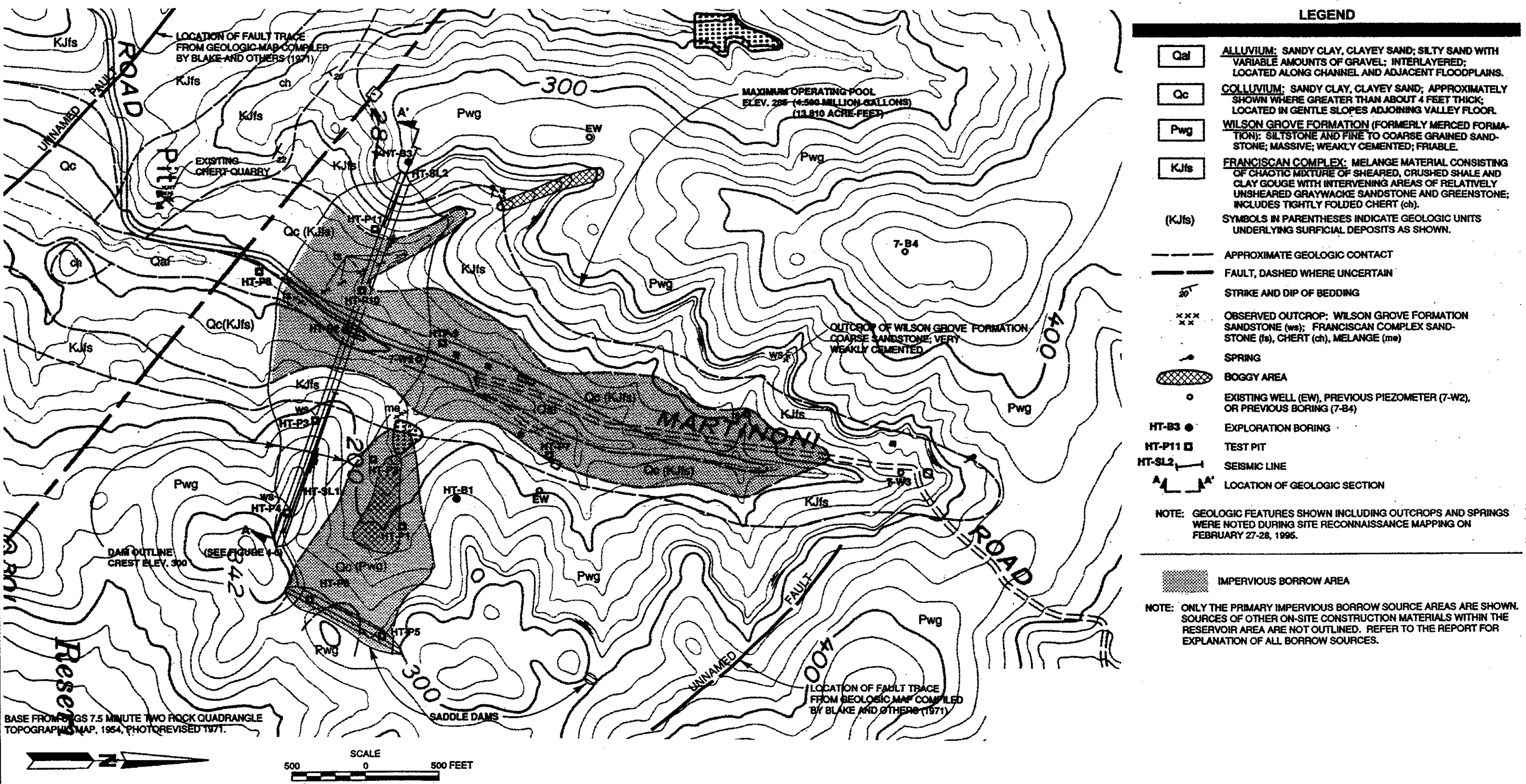

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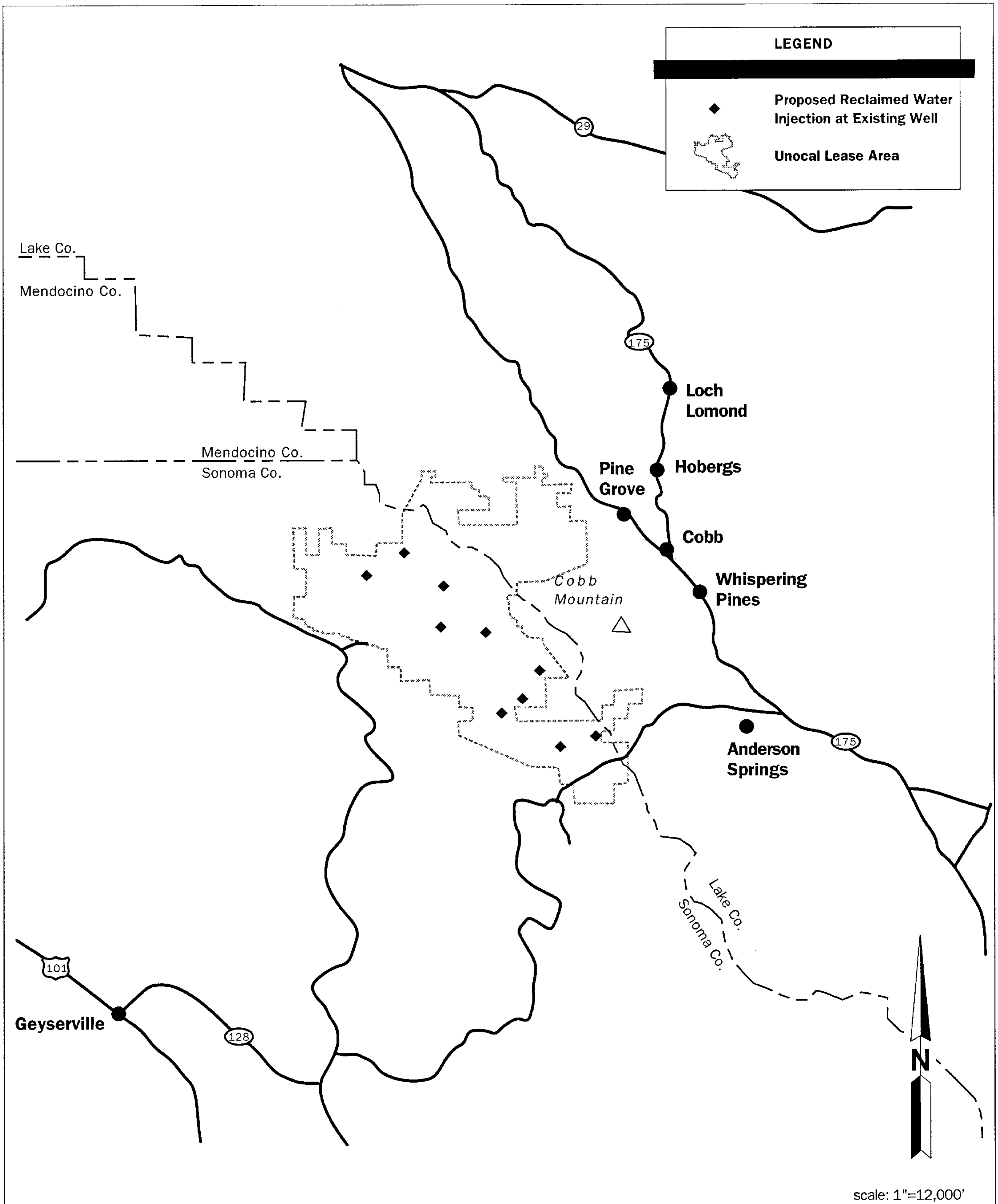
Figure 4.3-10

GEOLOGY of the HUNTLEY RESERVOIR SITE



Source: Parsons Engineering Science

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Santa Rosa
Subregional Long-Term Wastewater Project

GEYSERS LOCATION MAP

Figure 4.3-11

gravel, silt, sand, and clay with minor interbedded tuff. The pipeline route is principally in slightly elevated areas within the Glen Ellen Formation.

Chalk Hill Road from Pleasant Avenue to SR 128 in the Southern Alexander Valley

This segment consists of hilly terrain with intervening valley areas along Brooks and Maacama creeks. The Glen Ellen Formation underlies the southernmost and northern area; shales, siltstones, and sandstones of the Great Valley Group are found in the central portion of this segment. The pipeline alignment crosses these formations and areas underlain by serpentinite and alluvium. The active Healdsburg Fault crosses the alignment in the southern portion of this segment (Figure 4.3-13).

SR 128 from Chalk Hill Road to Alexander Valley Road

This gently sloping area of the Alexander Valley is underlain by alluvium, alluvial fan deposits, and older deposits of gravel, silt, sand, and clay with minor interbedded tuff of the Glen Ellen Formation.

Pine Flat Road from Alexander Valley Road to the Geysers Geothermal Steamfield

This portion of the alignment is located in the Mayacmas Mountains. The pipeline alignment is within Pine Flat Road, which is steep and winding. The area is underlain by Franciscan melange. Coherent blocks of greenstone, chert, serpentine, and sandstone have been mapped along the route.

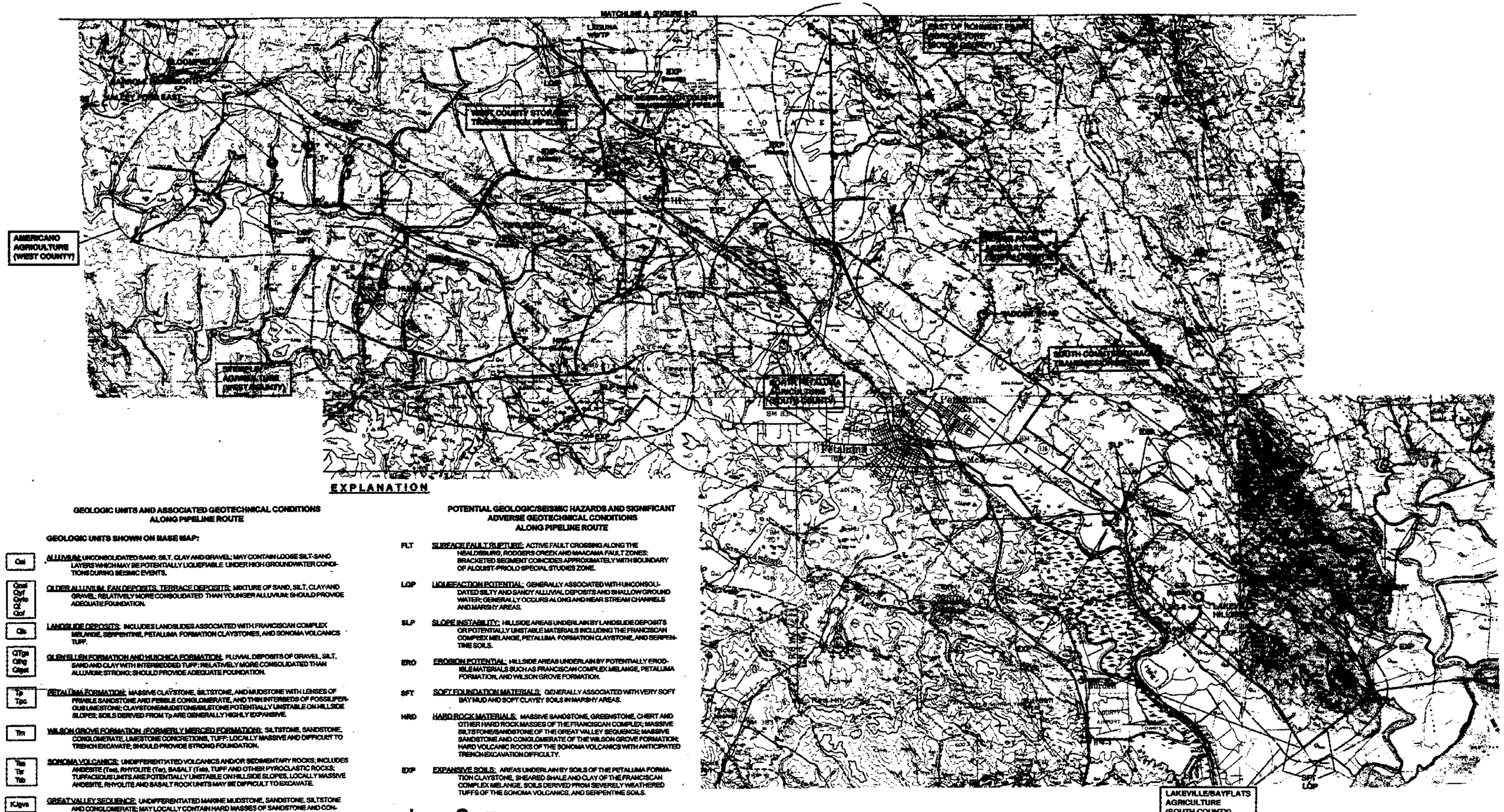
Several small to large landslides have been mapped along the pipeline alignment and are associated with Franciscan melange and serpentinite. Extensive areas of landslide deposits occur along Pine Flat Road. Disruption of the road pavement by settlement, cracking, scarps, and washouts in several locations is evidence of widespread slope instability in the area. The Pine Flat Road segment of the geysers pipeline route is considered to have a high potential for slope instability (Rust Environment and Infrastructure 1995).

Seismicity

Historical Seismicity

The Project area is located in a seismically active region and earthquakes are a common occurrence. Since the mid-nineteenth century, hundreds of earthquakes have been felt in Sonoma County. A few of these earthquakes were strong enough to cause damage in the Project region.

In the 1800's five moderate earthquakes shook the Santa Rosa area. Three of these earthquakes caused localized minor damage such as broken chimneys in



EXPLANATION

GEOLOGIC UNITS AND ASSOCIATED GEOTECHNICAL CONDITIONS ALONG PIPELINE ROUTE

GEOLOGIC UNITS SHOWN ON BASE MAP:

Qal	ALLUVIUM: UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL; MAY CONTAIN LOOSE SILT-SAND LAYERS WHICH MAY BE POTENTIALLY LIQUEFIABLE UNDER HIGH GROUNDWATER CONDITIONS DURING SEISMIC EVENTS.
Qoal, Qyf, Qyfo, Qt, Qof	OLDER ALLUVIUM, FAN DEPOSITS, TERRACE DEPOSITS: MIXTURE OF SAND, SILT, CLAY AND GRAVEL; RELATIVELY MORE CONSOLIDATED THAN YOUNGER ALLUVIUM; SHOULD PROVIDE ADEQUATE FOUNDATION.
Qls	LANDSLIDE DEPOSITS: INCLUDES LANDSLIDES ASSOCIATED WITH FRANCISCAN COMPLEX MELANGE, SERPENTINE, PETALUMA FORMATION CLAYSTONES, AND SONOMA VOLCANICS TUFF.
QTge, QHg, Qgst	GLEN ELLEN FORMATION AND HUICHICA FORMATION: FLUVIAL DEPOSITS OF GRAVEL, SILT, SAND AND CLAY WITH INTERBEDDED TUFF; RELATIVELY MORE CONSOLIDATED THAN ALLUVIUM; STRONG; SHOULD PROVIDE ADEQUATE FOUNDATION.
Tp, Tpc	PETALUMA FORMATION: MASSIVE CLAYSTONE, SILTSTONE, AND MUDSTONE WITH LENSES OF FRIABLE SANDSTONE AND PEBBLE CONGLOMERATE, AND THIN INTERBEDS OF FOSSILIFEROUS LIMESTONE; CLAYSTONE/MUDSTONE/SILSTONE POTENTIALLY UNSTABLE ON HILLSIDE SLOPES; SOILS DERIVED FROM Tp ARE GENERALLY HIGHLY EXPANSIVE.
Tm	WILSON GROVE FORMATION (FORMERLY MERCED FORMATION): SILTSTONE, SANDSTONE, CONGLOMERATE, LIMESTONE CONCRETIONS, TUFF; LOCALLY MASSIVE AND DIFFICULT TO TRENCH EXCAVATE; SHOULD PROVIDE STRONG FOUNDATION.
Tsa, Tsr, Tsb	SONOMA VOLCANICS: UNDIFFERENTIATED VOLCANICS AND/OR SEDIMENTARY ROCKS; INCLUDES ANDESITE (Tsa), RHYOLITE (Tsr), BASALT (Tsb), TUFF AND OTHER PYROCLASTIC ROCKS; TUFFACEOUS UNITS ARE POTENTIALLY UNSTABLE ON HILLSIDE SLOPES, LOCALLY MASSIVE ANDESITE, RHYOLITE AND BASALT ROCK UNITS MAY BE DIFFICULT TO EXCAVATE.
KJgvs	GREAT VALLEY SEQUENCE: UNDIFFERENTIATED MARINE MUDSTONE, SANDSTONE, SILTSTONE AND CONGLOMERATE; MAY LOCALLY CONTAIN HARD MASSES OF SANDSTONE AND CONGLOMERATE THAT MAY BE DIFFICULT TO EXCAVATE; SHOULD PROVIDE STRONG FOUNDATION.
KJfs, KJfss, KJfm	FRANCISCAN COMPLEX: INCLUDES MELANGE, A CHAOTIC MIXTURE OF FRAGMENTED ROCK MASSES IN A SHEARED SHALY MATRIX; INCLUDES COHERENT BLOCKS OF SANDSTONE, SHALE, CONGLOMERATE, CHERT (ch), GREENSTONE (gs), SERPENTINIZED ULTRAMAFIC ROCKS (sp), METAGRAYWACKE AND BLUESCHIST; ASSOCIATED WITH EXTENSIVE LANDSLIDING IN THE GEYSERS AREA; POTENTIALLY UNSTABLE ON HILLSIDE SLOPES; INCLUDES HARD ROCK MASSES IN MELANGE THAT MAY BE DIFFICULT TO EXCAVATE.

SURFICIAL DEPOSITS NOTED DURING SITE RECONNAISSANCE:

Qc	COLLUVIUM: THICK SOIL (CLAY-SILT-SAND-GRAVEL) AT BASE OF HILLSIDE SLOPES AND AT THE EDGES OF ALLUVIAL VALLEYS; SHOULD PROVIDE ADEQUATE FOUNDATION.
Qf	FILL: MOSTLY THICK ROAD EMBANKMENT FILL.

POTENTIAL GEOLOGIC/SEISMIC HAZARDS AND SIGNIFICANT ADVERSE GEOTECHNICAL CONDITIONS ALONG PIPELINE ROUTE

FLT	SURFACE FAULT RUPTURE: ACTIVE FAULT CROSSING ALONG THE HEALDSBURG, RODGERS CREEK AND MAACAMA FAULT ZONES; BRACKETED SEGMENT COINCIDES APPROXIMATELY WITH BOUNDARY OF ALQUIST-PRIOLO SPECIAL STUDIES ZONE.
LQP	LIQUEFACTION POTENTIAL: GENERALLY ASSOCIATED WITH UNCONSOLIDATED SILTY AND SANDY ALLUVIAL DEPOSITS AND SHALLOW GROUND WATER; GENERALLY OCCURS ALONG AND NEAR STREAM CHANNELS AND MARSHY AREAS.
SLP	SLOPE INSTABILITY: HILLSIDE AREAS UNDERLAIN BY LANDSLIDE DEPOSITS OR POTENTIALLY UNSTABLE MATERIALS INCLUDING THE FRANCISCAN COMPLEX MELANGE, PETALUMA FORMATION CLAYSTONE, AND SERPENTINE SOILS.
ERO	EROSION POTENTIAL: HILLSIDE AREAS UNDERLAIN BY POTENTIALLY ERODIBLE MATERIALS SUCH AS FRANCISCAN COMPLEX MELANGE, PETALUMA FORMATION, AND WILSON GROVE FORMATION.
SFT	SOFT FOUNDATION MATERIALS: GENERALLY ASSOCIATED WITH VERY SOFT BAY MUD AND SOFT CLAYEY SOILS IN MARSHY AREAS.
HRD	HARD ROCK MATERIALS: MASSIVE SANDSTONE, GREENSTONE, CHERT AND OTHER HARD ROCK MASSES OF THE FRANCISCAN COMPLEX; MASSIVE SILTSTONE/SANDSTONE OF THE GREAT VALLEY SEQUENCE; MASSIVE SANDSTONE AND CONGLOMERATE OF THE WILSON GROVE FORMATION; HARD VOLCANIC ROCKS OF THE SONOMA VOLCANICS WITH ANTICIPATED TRENCH EXCAVATION DIFFICULTY.
EXP	EXPANSIVE SOILS: AREAS UNDERLAIN BY SOILS OF THE PETALUMA FORMATION CLAYSTONE, SHEARED SHALE AND CLAY OF THE FRANCISCAN COMPLEX MELANGE, SOILS DERIVED FROM SEVERELY WEATHERED TUFFS OF THE SONOMA VOLCANICS, AND SERPENTINE SOILS.

ALTERNATIVE RESERVOIR STORAGE SITE

PIPELINE ROUTE

SLP - HAZARD/CONDITION OCCURRING ALONG APPROXIMATE BRACKETED PIPELINE SEGMENT

G-1, SC-1 SEGMENT MARKER (DISCUSSED IN TEXT)

PS-G4 PUMP STATION (DESIGNATIONS SHOWN ONLY FOR GEYSERS TRANSMISSION PIPELINE)

AMERICANO AGRICULTURE (WEST COUNTY) — PROJECT SEGMENT (DISCUSSED IN TEXT)

BASE FROM PRELIMINARY GEOLOGIC MAP OF WESTERN SONOMA COUNTY AND NORTHERNMOST MARIN COUNTY, BLAKE AND OTHERS, 1971; PRELIMINARY GEOLOGIC MAP OF EASTERN SONOMA COUNTY AND WESTERN NAPA COUNTY, FOX AND OTHERS, 1973; PRELIMINARY GEOLOGIC MAP OF MARIN AND SAN FRANCISCO COUNTIES AND PARTS OF ALAMEDA, CONTRA COSTA, AND SONOMA COUNTIES, BLAKE AND OTHERS, 1973; PRELIMINARY GEOLOGIC MAP OF SOLANO COUNTY, AND PARTS OF NAPA, CONTRA COSTA, MARIN AND YOLO COUNTIES, SIMS AND OTHERS, 1973.

SCALE
6000 0 6000 FEET

NOTES:
1. PIPELINE ALIGNMENTS PROVIDED BY PARSONS ENGINEERING SCIENCE.
2. ONLY PROPOSED ALTERNATIVE TRANSMISSION PIPELINE ALIGNMENTS ARE SHOWN. EXISTING PIPELINES WHICH SUPPLY SOME OF THE PROPOSED PIPELINES ARE NOT SHOWN.
3. POTENTIAL HAZARDS AND GEOTECHNICAL CONDITIONS SHOWN ARE BASED ON REVIEW OF AVAILABLE PUBLISHED DATA AND SITE RECONNAISSANCE CONDUCTED ON OCTOBER 4-5, 1995.

Source: RUST Environment & Infrastructure

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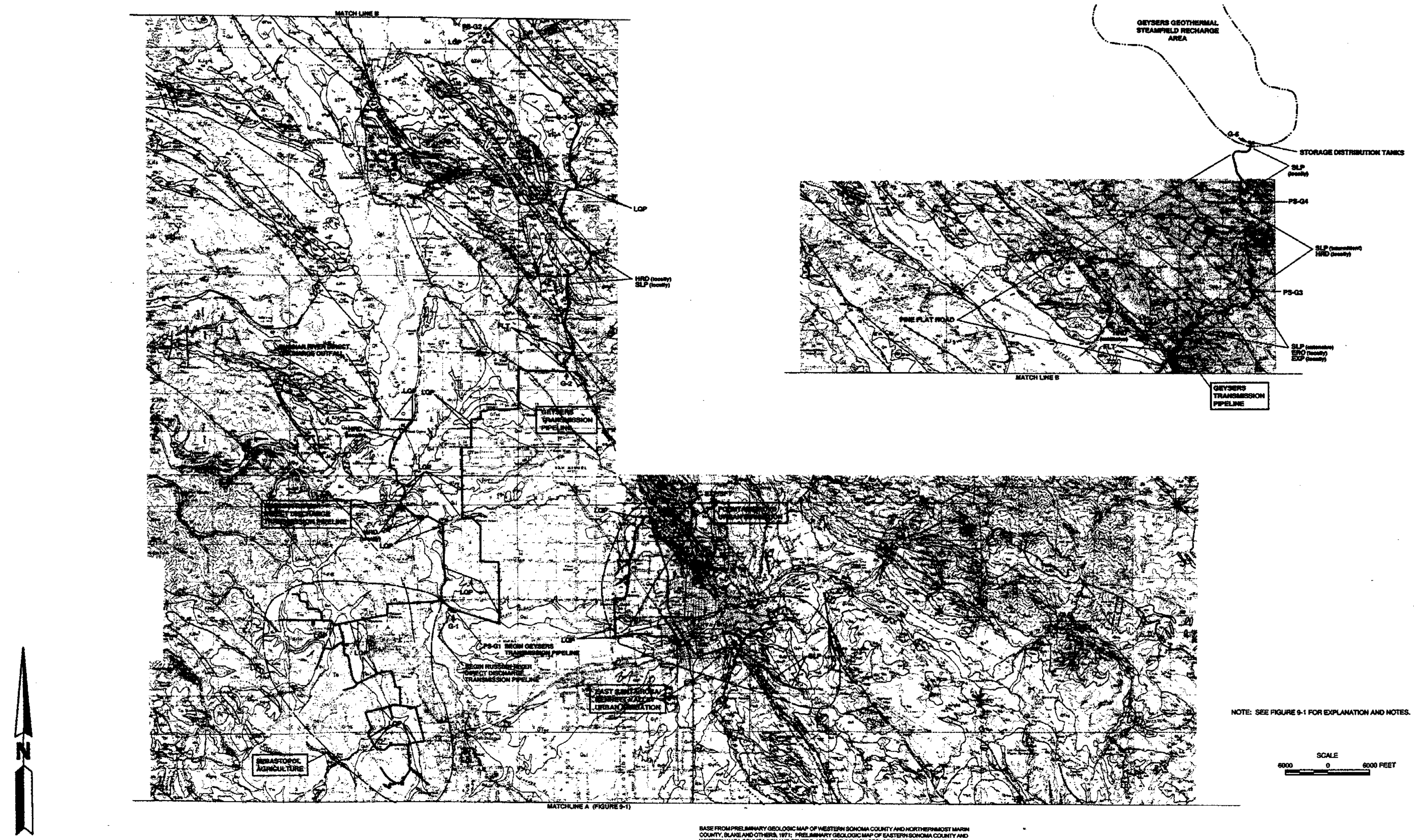
GEOLOGIC and SEISMIC HAZARDS GEYSERS PIPELINE ROUTE SOUTH

Figure 4.3-12



NOTE: SEE FIGURE 9-1 FOR EXPLANATION AND NOTES.

SCALE
6000 0 6000 FEET

BASE FROM PRELIMINARY GEOLOGIC MAP OF WESTERN SONOMA COUNTY AND NORTHERNMOST MARIN COUNTY, BLAKE AND OTHERS, 1971; PRELIMINARY GEOLOGIC MAP OF EASTERN SONOMA COUNTY AND WESTERN NAPA COUNTY, FOX AND OTHERS, 1973; PRELIMINARY GEOLOGIC MAP OF MARIN AND SAN FRANCISCO COUNTIES AND PARTS OF ALAMEDA, CONTRA COSTA, AND SONOMA COUNTIES, BLAKE AND OTHERS, 1973; PRELIMINARY GEOLOGIC MAP OF SOLANO COUNTY, AND PARTS OF NAPA, CONTRA COSTA, MARIN AND YOLO COUNTIES, SIMS AND OTHERS, 1973.

Source: RUST Environment & Infrastructure

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Santa Rosa Subregional Long-Term Wastewater Project

GEOLOGIC and SEISMIC HAZARDS GEYSERS PIPELINE ROUTE NORTH

Figure 4.3-13

Santa Rosa in 1865, 1893, and 1899. These earthquakes ranged in magnitude from less than 4 to 5.1. The first two epicenter locations were inferred to be in Bennett Valley and the third in Santa Rosa based on detailed analysis of historical accounts and newspaper records (Toppozada, Real, and Parke 1981). In 1891 a magnitude 5.5 earthquake centered near Napa caused minor damage in Santa Rosa and in 1898 a strong earthquake (magnitude 6.2) centered east of the southern end of the Rodgers Creek Fault, severely damaged buildings at Mare Island Naval Shipyard and caused structural damage in Petaluma and Santa Rosa.

The great San Francisco earthquake (18 April 1906) on the San Andreas Fault had an estimated magnitude of 8.3 on the Richter scale. The geology, geophysics, and damage reports of this earthquake were reported by the State Earthquake Investigation Commission (Lawson 1908). The following description is based on Lawson's report *California Earthquake of April 18, 1906*

> The 1906 earthquake caused extensive damage in San Francisco and in other communities in the Bay Area. Santa Rosa, Sebastopol, and Fort Bragg sustained relatively more damage than most other places in California during the earthquake. In Santa Rosa strong ground shaking and a fire in the downtown area resulted in extensive property damage in the business district. Approximately 61 people were killed in Santa Rosa (Lawson 1908).

Ground shaking intensity effects from the 1906 earthquake varied throughout the project area. The extent of damage was influenced by geologic conditions, the design and workmanship of building construction, and other factors. Damage reports from Santa Rosa and Sebastopol of collapsed buildings and ground cracking indicate ground shaking intensities of IX to X on the Modified Mercalli Scale (see Table 4.3-1).

Table 4.3-1

Modified Mercalli Intensity Scale

I.	Not felt except by a very few under especially favorable circumstances.
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended object may swing.
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.
V.	Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes notices. Pendulum clocks may stop.
VI.	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.

Table 4.3-1

Modified Mercalli Intensity Scale

VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.
IX.	Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X.	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.

[1] Abridged Modified Mercalli Intensity Scale (1956 version)

Some of the extreme damage in this area was attributed to poor building construction. In Valley Ford and Bloomfield reports indicate that ground shaking intensities were about IX on the Modified Mercalli Scale. In Valley Ford walls fell from brick buildings, houses were shifted off foundations, and chimneys collapsed. Ground cracking was reported in the valley floor. In Bloomfield reports indicate that "two brick buildings, two stores and a dwelling were wrecked" and that several frame buildings were shifted from their foundations. No reports of damaged pipes or visible surface waves were recorded. Damage reports from Petaluma and Lakeville of substantial cracking in plaster, fallen chimneys and damage to brick buildings indicate ground shaking intensity of about VIII on the Modified Mercalli Scale (Lawson 1908).

The October 1969 magnitude 5.6 and 5.7 earthquakes on the Healdsburg Fault caused several million dollars of damage in Santa Rosa and the vicinity. Numerous breaks in the water pipeline system occurred in the eastern part of Santa Rosa. More recently, the magnitude 4.9 earthquake along the Hayward Fault (26 January 1986) and the magnitude 7.1 Loma Prieta earthquake on the San Andreas Fault (17 October 1989) were felt in the County, but no damage was reported to major pipeline facilities.

Numerous instances of ground failure and liquefaction effects were recorded after the 1906 earthquake and again in 1969. These soil failures occurred predominantly in marshy ground and areas near the trace of the Healdsburg-Rodgers Creek Fault in central Santa Rosa. In 1969 ground cracking was common along the banks of Matanzas Creek and Santa Rosa Creek (Youd and Hoose 1978).

In 1990 the U.S. Geological Survey estimated the probability of large earthquakes occurring on major active faults in the San Francisco Bay Area. The 30-year probability of a magnitude 7 earthquake occurring on the Rodgers Creek Fault was estimated at 22 percent (U.S. Geological Survey 1990). There is a 67 percent probability of one or more large earthquakes occurring in the greater Bay Area within the same period of time (U.S. Geological Survey 1990)[4].

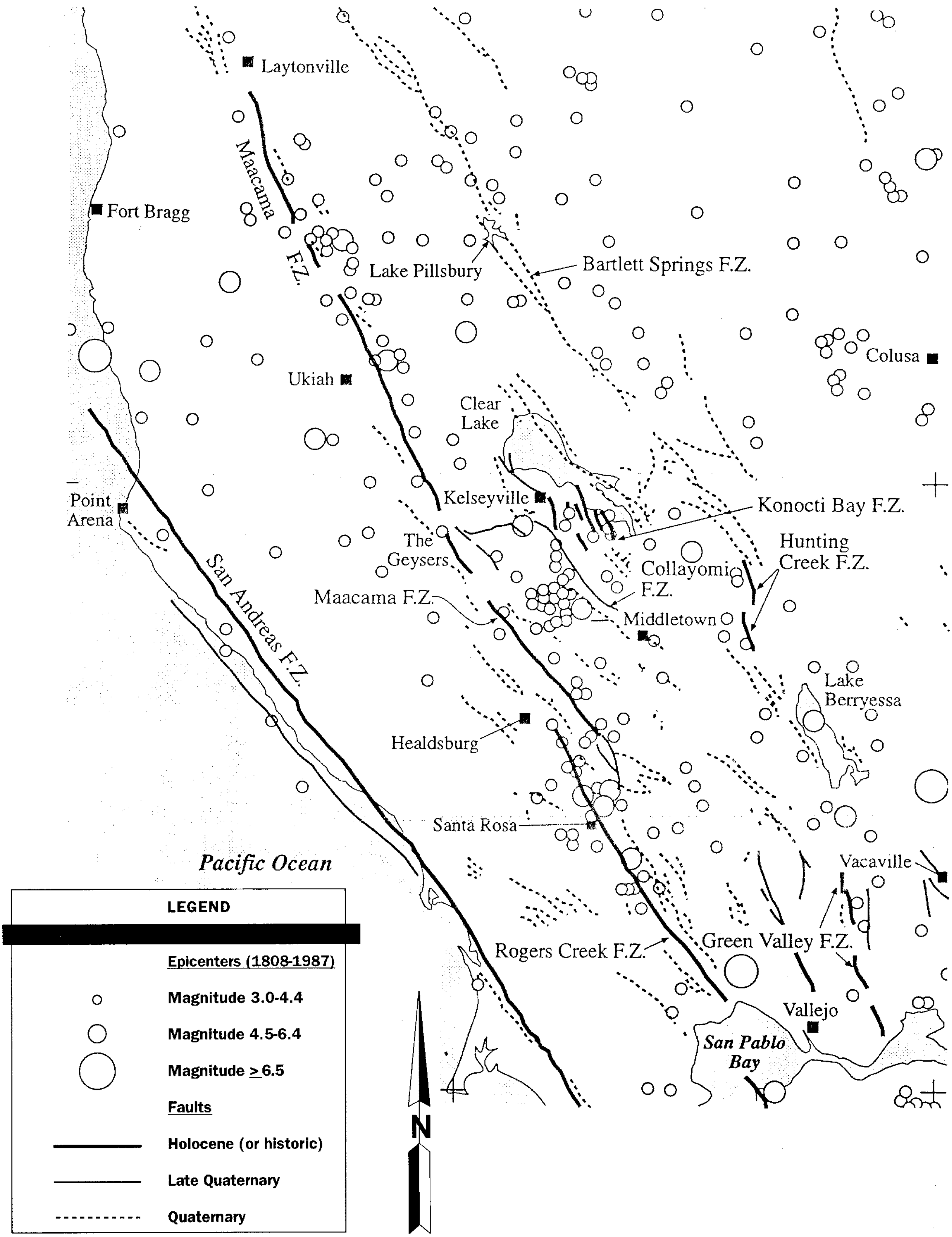
Geysers Seismicity

The northern portion of the geysers area (Unocal lease area) is extremely active seismically (Figure 4.3-14). Earthquakes occur at apparently random intervals rather than in related groups or swarms and generally have epicenters less than 20,000 feet deep. Seismic monitoring has demonstrated that the rate of earthquake occurrence increased as steam development increased from the 1960s to the 1970s. Studies have revealed a correspondence between production wells, episodes of water injection, and earthquakes (Stark 1991, Greensfelder 1993). Both steam production and injection of water to restore production may induce seismic activity.

Baseline seismicity at the geysers, before geothermal development began, is not well documented. It appears that the currently high rate of seismicity in the vicinity of the geysers geothermal area began in the early 1960s, shortly after initiation of commercial steam power generation. Studies of induced seismicity in the geysers area began in 1971 and by 1972 regional seismographic monitoring capabilities were established. At that time numerous small earthquakes with epicenters in the geysers geothermal area began to be routinely reported. Since 1975 more that 20,000 earthquakes with magnitudes ranging from 0.7 to 3.0 and

Figure 4.3-14 Geysers Regional Faults and Seismicity

[4] Because these estimates are based on the estimated recurrence interval of earthquakes on each fault and five years has elapsed since the analysis without a major earthquake, current probabilities would be slightly higher than those reported in 1990.



Source: Greensfelder and Associates, 1995

GEYSERS REGIONAL FAULTS and SEISMICITY

Figure 4.3-14

about 300 larger earthquakes (magnitudes ranging from 3.0 to 4.6) have been reported to originate at the geysers. In the period from 1975 to 1985, 21 were reported felt in Cobb (Greensfelder and Parsons 1995). Felt earthquakes reported from Cobb during this 10-year period ranged in intensity from II to V on the Modified Mercalli Scale with three of the 21 reported events classified as Modified Mercalli V (earthquakes in May 1982, June 1983, and September 1984).

Based on the documented parallel increase of seismicity rates and geothermal development, including steam production and water/steam condensate injection, it has been established that these activities cause earthquakes (Greensfelder 1993). It is generally accepted that injection can generate earthquakes in the vicinity of wells by increasing water pressure on pre-existing fracture planes in the reservoir rock. This pressure reduces resistance to shearing and permits the release of natural tectonic stress and strain. However, the detailed mechanism of the release of natural elastic energy is not completely understood.

Static stress modeling calculations indicate that the small earthquakes induced at the geysers do not contribute to the risk of larger earthquakes on nearby faults (Greensfelder and Parsons 1995).

Faults

There are several fault zones within Sonoma County that could affect Project facilities (Figure 4.3-1). These include active faults, which are faults that may have been historically active (during the last 200 years) or active in the geologically recent past (about the last 11,000 years, usually referred to as Holocene in the geologic time scale). Faults that have been active at some time during the Quaternary geologic period (the last two million years) are classified as potentially active.

The San Andreas, Healdsburg-Rodgers Creek, Maacama, Konocti Bay, West Napa, Green Valley, and Bartlett Springs Fault zones are all Holocene in age and considered active (Table 4.3-2). Portions of some of the major fault zones have been classified as Quaternary because they do not display evidence of Holocene movement, but displace geologic units of Quaternary age (last two million years). Regional faults that are classified as Quaternary age are the Tolay, Americano Creek, Bloomfield, Dunham, Collayomi, Geyser Peak, and Cobb Mountain Fault zones (Wagner and Bortugno 1982). Characteristics of faults that could affect project facilities are listed in Table 4.3-2. Faults not listed in Table 4.3-2 would not affect Project facilities because of their age, distance, or seismic potential. Refer to the Geotechnical Evaluation of Alternative Reservoir Sites and Pipeline Routes (Rust Environment and Infrastructure, Inc. 1995) for detailed discussion of fault activity and relationship to Project structures.

Faults near Reservoir Sites

The southeastern segment of the Tolay Fault (Table 4.3-1 and Figure 4.3-2) was zoned as an Alquist-Priolo earthquake fault zone in 1976[5], but was removed from the zone in 1982 on the basis of Fault Evaluation Report 140 (Hart 1982). The fault was removed from the earthquake fault zone[6] because it did not meet the criteria for zoning under the California Division of Mines and Geology fault evaluation program, that is, “only those faults considered active (Holocene) and well defined as surface structures are zoned." Trenching across the postulated trace of the Tolay Fault in the west saddle dam area and downstream of the main dam site revealed landslide deposits that did not show evidence of faulting. Because the age of the landslide deposits is not

[5] In January 1994, state law renamed this the Alquist-Priolo Earthquake Fault Zoning Act
[6] These zones are nowreferred to as earthquake fault zones

known the trench investigation does not provide conclusive information about the age of the fault (Rust Environment and Infrastructure, Inc. 1995).

The Tolay Fault is classified as a Quaternary-age fault because evidence of displacement within the last 2 million years has been documented. According to Hart (1982), if the Tolay Fault is active in the Holocene then such activity is minor, distributive, and restricted to the southeastern segment of the fault where it is in proximity to the well-defined and active Rodgers Creek Fault. Although the Tolay Fault does not meet the criteria for an earthquake fault zone under the Alquist-Priolo Act and is not considered to be a surface rupture hazard, the fault is considered to be capable of producing a magnitude 6.5 earthquake and could produce strong ground shaking (Wesnousky 1986).

The Dunham, Bloomfield, and Americano Creek Faults are mapped as Quaternary faults and therefore are considered potentially active, according to the Division of Mines and Geology definition discussed above (Table 4.3-2). These faults separate Franciscan Complex rocks from Wilson Grove Formation rocks in the West County.

The Dunham Fault is about four miles long, sub-parallel to the northwest segment of the Tolay Fault. Bortugno (1982) classifies the Dunham Fault as a Quaternary fault, however, this designation does not preclude the possibility that Holocene movement may have occurred. No evidence of Holocene displacement was identified during geotechnical investigations in the vicinity of Two Rock by Woodward-Clyde Consultants (1989).

The Bloomfield Fault was previously studied by Woodward-Clyde Consultants (1990) as part of earlier geotechnical investigations of a proposed dam in the Two Rock area. Their investigation consisted of interpretation of aerial photographs, geologic reconnaissance, and two shallow excavations. The fault zone is up to 11 feet wide and consists of fractures, shears, and gouge. Alluvial deposits of possibly late Quaternary-age have not been displaced by the fault. Based on these data, Woodward-Clyde concluded that the Bloomfield Fault does not show evidence of Holocene or late Quaternary activity.

The Americano Creek Fault is considered to be Quaternary in age and potentially active. However, the short length of the fault suggests that it would not be capable of generating a major earthquake.

Geysers Faults

The Maacama Fault is a recognized Holocene Fault that is located about four miles southwest of the geysers geothermal area (Table 4.3-2). The Green Valley Fault, also Holocene, extends from Suisun Bay 55 miles northeast along the west side of Lake Berryessa and has recently been extended north to connect with the Hunting Creek Fault (Figure 4.3-13). These active faults are zoned under the Alquist-Priolo Earthquake Fault Zoning Act.

The Bartlett Springs Fault, located 20 miles east of the Maacama Fault, has displaced Holocene alluvium in several segments, and alignments of seismicity suggest that the fault is active. The largest earthquake magnitudes associated with this Bartlett Springs Fault have been about magnitude 5.

The Konocti Fault is a Holocene fault that may be responsible for three historic earthquakes. In 1954, a magnitude 4.4 earthquake caused slight damage at Lakeport. Two other earthquakes occurred near Kelseyville in 1955 and had magnitudes of 3.6 and 4.6 to 5.0. The first of these broke chimneys and windows at Lower Lake and the second had similar effects and was felt over a 1,700 square mile area.

The Collayomi Fault is located about 10 miles northwest of the Maacama Fault and is mapped as late Quaternary (Jennings et al. 1994). The Big Valley Fault, located just northeast of the geysers geothermal area, is considered to be a prominent splay of the Collayomi Fault.

The Geyser Peak and Cobb Mountain Faults have been mapped in the vicinity of the geysers. These faults are classed as early Quaternary (700,000 years to 2 million years old) and are considered to be inactive. Numerous other pre-Quaternary faults are present in the vicinity of the geysers. These older faults generally are related to the coastal thrust belt or the Coast Ranges thrust fault. They were active tens of millions of years ago, but have not shown evidence of activity during the last two million years.

Table 4.3-2

Faults that Could Affect Project Facilities

Fault	Location (refer to Figures 4.3-1 and 4.3-14)	Age	Method of Estimating Activity Level	Maximum Credible Earthquake (Magnitude - Richter Scale)	Alquist-Priolo Earthquake Fault Zone (Yes / No)
Americano Creek	From Two Rock, northwest along Americano Creek for about six miles	Quaternary	Refer to Faults text, above	Not available	No
Bartlett Springs	20 miles east of the Maacama Fault, from east of Clear Lake to south of Covelo in Mendocino County	Holocene	Displaced alluvium in several segments and alignments of seismicity	7 (Lake County Sanitation District, 1994)	No
Bloomfield	Extends for about nine miles and is two miles northeast of Bloomfield	Quaternary	Refer to Faults text, above	Not available	No
Collayomi-Big Valley	Northeast of the geysers geothermal area and 10 miles northwest of the Maacama Fault	Quaternary	Refer to Faults text, above	6.6 (Wenousky 1986)	No
Dunham	Extends for about four miles and is located one to two miles south of the Tolay Fault	Quaternary	Refer to Faults text, above	Not available	No
Green Valley	Extends 55 miles from Suisun Bay to south of Clear Lake	Holocene	Measured creep of 4 mm/year and associated seismicity	6.9 (Wenousky 1986)	No
Green Valley	Extends from Suisin Bay 55 miles northeast along the west side of Lake Berryessa	Holocene	Fault creep and aligned seismicity	6.9 (Wenousky 1986)	Yes
Healdsburg-Rodgers Creek	From the Bay portion of Sonoma County, through Santa Rosa and Healdsburg	Holocene	Historic damaging earthquake	7 (CDMG 1994)	Yes

Table 4.3-2

Faults that Could Affect Project Facilities

Fault	Location (refer to Figures 4.3-1 and 4.3-14)	Age	Method of Estimating Activity Level	Maximum Credible Earthquake (Magnitude - Richter Scale)	Alquist-Priolo Earthquake Fault Zone (Yes / No)
Konocti Bay	Southern portion of Clear Lake	Holocene	A complex arrangement of short faults associated with abundant small earthquakes (magnitudes less than 4.4). One fault has caused a 3-foot high offset in lake bottom sediments	7 (Lake County Sanitation District, 1994)	No
Maacama	Extends 90 miles from east of Healdsburg (forms the base of the Mayacmas Mountains) to Laytonville	Holocene	Measured slip rate of 2 to 5 millimeters per year	7.6 (Wenousky 1986)	Yes
San Andreas	Along the Mendocino/Sonoma County coast line (through Tomales Bay) and off-shore	Holocene	Historic surface rupture and damaging earthquake	8.3 (CDMG 1982)	Yes
Tolay	From Sears Point for 22 miles to a location about 6 miles southwest of Santa Rosa	Quaternary	Refer to Faults text, above	6.5 (Wenousky 1986)	No
West Napa	South and West of Napa near the Napa River	Holocene	Holocene fault displacement	6.5 (Wenousky 1986)	No

Source: Jennings, 1994; Wenousky , 1986; Lake County Sanitation District, 1994; ABAG, 1995; CDMG, 1990.;

Geologic Hazards

Major geologic hazards that may be present within the region range from unstable geologic conditions to potential seismic activity. This section discusses some of the mechanisms of geologic instability. Geologic conditions at specific alternative sites are discussed in the appropriate setting section, above.

Slope Instability

Landsliding is a natural process in the Coast Ranges and is a common occurrence in certain types of geologic materials. Geologic materials rich in clay minerals have a great capacity to absorb water, resulting in reduction of shear strength. The force of gravity can cause landslides when saturated clays reduce the shear strength of a rock below its minimum stability threshold. Among the potentially unstable geologic formations in the Project region are the clay-rich Petaluma Formation and the sheared and fractured shale matrix of the Franciscan Complex. Another unstable configuration may occur where the angle of dip of bedding planes and the cut slope result in daylighting of bedding or bedding planes that are parallel to the surface of the ground. In these cases the potential exists for rock units to slip along a weakened plane.

The steepness of a slope is a major factor in slope stability. Human modifications of topography and drainage such as road cuts, surface runoff diversion, or impounding water can reduce the natural shear strength of slopes and generate landsliding, even in areas of normally low susceptibility.

Several other conditions can cause, or contribute to, slope instability. Heavy rains can saturate slopes, reduce shear strength, and result in failure. Stream cuts along the base of a slope can undermine the slope and possibly induce sliding. Chemical and mechanical weathering can break down rock materials, and the seepage from high groundwater levels can increase water concentration, thus reducing strength.

Slope stability hazards at the reservoir sites were evaluated during geotechnical investigations at each reservoir site (Rust Environment and Infrastructure, Inc. 1995). Three slope instability hazard categories for landsliding risk potential (low, moderate, and high) were established based on the abundance of existing landslides, slope gradients, and strength of the underlying geologic material.

Two Rock, Bloomfield, Carroll Road, Valley Ford, and Huntley reservoir sites are considered to have low landsliding risk, based on the limited extent of existing slope instability and the presence of generally stable geologic materials of the Wilson Grove Formation and the Franciscan Complex. Moderate landsliding risk exists at the Tolay and Sears Point reservoir site where slope gradients are moderately steep and bedrock consists of the less stable Petaluma Formation. The Adobe Road and Lakeville Hillside sites are considered to have high landsliding risk based on the presence of numerous and large landslides that occur in the underlying Petaluma claystone and because of steep slope conditions.

Earthquake-induced Slope Instability

Bedrock formations and unconsolidated deposits (soils) respond differently to seismically induced ground shaking. As a general rule, the severity of ground shaking increases with proximity to the epicenter of the earthquake. However, given similar location and seismic energy output, the least amount of damaging vibration would occur on a site that was entirely underlain by bedrock. A site underlain by a major thickness of alluvium would experience considerably more damaging vibration because of the unconsolidated material's tendency to deform to a greater degree than the bedrock.

Earthquake-induced landsliding of steep slopes can occur in either bedrock or unconsolidated deposits. Firm bedrock can usually support steeper, more stable slopes than slopes cut in unconsolidated or poorly consolidated material. However, rock type, grain size, degree of consolidation, and bedding angle all contribute to the strength or weakness of a bedrock hillside. Shales and deeply weathered rocks are very susceptible to slope failures during strong seismic ground shaking. Project component sites that have a moderate to high risk of landsliding would also be at risk for earthquake-induced slope failure.

Seismic Hazards

Seismic hazards include ground shaking, surface rupture along active faults, and liquefaction. Strong ground shaking can damage structures, their foundations, and contents. Strong ground shaking may also trigger secondary effects such as liquefaction or ground settlement in some areas. Ground shaking intensity of IX on the Modified Mercalli Scale (Table 4.3-1) could damage well built structures and rupture pipes.

Damage due to surface rupture is limited to the actual location of the fault-line break, unlike damage from ground shaking that can occur at great distances from the fault. Surface rupture could damage buried pipelines that have not been adequately protected where they cross fault traces. In the Project region the Healdsburg-Rodgers Creek Fault and the Maacama Fault are active faults with potential forsurface rupture that could affect Project facilities.

A common hazard related to severe ground shaking in loose saturated sandy soils is liquefaction. This transformation from a solid to a liquid ("quicksand") state can cause ground settling, landsliding, and lateral spreading[7]. Alluvial areas adjoining streams and in valleys and shorelines are areas where liquefaction can occur if specific conditions exist such as loose sandy deposits and high groundwater conditions. If loose granular soils (predominately silt and fine sand) are present and seasonal maximum groundwater levels are within 20 feet of the ground surface there is a high potential for liquefaction (California Division of Mines and Geology 1974). If groundwater levels in liquefaction prone soil are between 20 feet and 50 feet of the ground surface there is a moderate potential for liquefaction to occur (California Division of Mines and Geology 1974). Liquefaction in sediment where the groundwater is more than 50 feet below the ground surface does not generally result in surface ground failure. Portions of the study area that could be affected by liquefaction are shown in figures 4.3-12 and 4.3-13.

Soils

The following description of soils in the Project area is based on soil surveys of Sonoma County and Marin County prepared by the U.S. Soil Conservation Service (1972 and 1985). The soils of Sonoma County belong to two major groups which are subdivided into 15 associations (Table 4.3-3). The major soil groups are related to the substrate on which the soils have developed. Soils in the basins and on tidal flats, flood plains, terraces, and alluvial fans were developed on the unconsolidated deposits of the valleys and shores. Soils of the high terraces, foothills, uplands, and mountains generally were developed on bedrock terrain or on bedrock thinly overlain by unconsolidated material.

Soils of the Huichica-Wright-Zamora Soil Association have developed on low terraces and alluvial fans in the Cotati-Petaluma Valley. West of the Laguna de Santa Rosa, the majority of the soils belong to the

[7] Lateral spreading may result if liquefaction occurs in material that makes up a slope, particularly a free-face, such as along river banks.

Hugo-Josephine-Laughlin association, which occurs on the mountainsides east of the Pacific Coast. Soils of the Goldridge-Cotati-Sebastopol Association are used for apple orchards near Sebastopol. In the vicinity of the geysers, various soil associations including the Spreckels-Felta, Yorkville-Suther, and Hugo-Josephine-Laughlin have developed on steeply sloping terraces and uplands. The Stemple/Americano Creek area contains two associations: the Steinbeck-Los Osos association in the uplands and the Pajaro Association along creeks. The Russian River Valley from Alexander Valley (Jimtown) to Cloverdale consists of the Yolo-Cortina-Pleasanton Association, which developed on the nearly level or moderately sloping valley floor. From Santa Rosa southeast to San Pablo Bay, soils of the Clear Lake-Reyes and Haire-Diablo Associations dominate. A summary description of each soil association is provided in Table 4.3-3, and their characteristics are listed in Table 4.3-4.

Table 4.3-3

Soil Associations

Soil Association	Description
Clear Lake Reyes	Principally occur along Laguna de Santa Rosa and cover much of the area from Rohnert Park-Cotati downstream to San Pablo Bay. Poorly drained, consisting of nearly level to gently sloping clays and clay loams. Used mainly for irrigated pasture. Correspond to the Reyes-Novato soils in Marin County.
Haire-Diablo	Occur from the south end of the Santa Rosa plain to near San Pablo Bay. Moderately well-drained to well drained, gently sloping to steep fine sandy loams to clays. Used mainly for dry land pasture, with some hay cropping.
Huichica-Wright-Zamora	Cover most of the Santa Rosa plain. Somewhat poorly drained to well drained, nearly level to strongly sloping, loams to silty clay loams. Principal use of soils is for pasture and hay.
Pajaro	Occur along Green Valley Creek (west of Sebastopol), along Estero Americano (south of Bodega), and between Petaluma and Two Rock. Somewhat poorly drained, nearly level to gently sloping, fine sandy loams to clay loams. Principal use for dry farming or irrigated pastures and hay.
Yolo-Cortina-Pleasanton	Occur along the Russian River north of Healdsburg, west of Healdsburg, and along some creek valleys near the Sonoma-Napa county line. Well drained to excessively drained, nearly level to moderately sloping, very gravelly sandy loams to clay loams. Used mainly for pasture. Generally excellent farming soils capable of supporting grapes, row crops, orchards, or pasture.
Spreckels-Felta	Occur in the foothills in the east central portion of Sonoma County. Well drained, gently sloping to very steep, very gravelly loams to clay loams. Used as range and pasture land.
Yorkville-Suther	Occur in the foothills of the Mayacmas and other mountains of the Coast Ranges in the northern part of Sonoma County. Moderately well drained, moderately to very steeply sloping loams and clay loams. Used primarily for pasture and range.
Gounding-Tommes-Guenoc	Occur along the Russian River east of the Mayacmas and throughout the Sonoma Mountains. Well drained, gently to very steeply sloping clay loams. Used mainly for range, pasture, and watershed.
Kidd-Forward-Cohasset	Occur along the Sonoma-Napa county line. Excessively drained to well drained, moderately sloping to very steep, gravelly and stony loams. Used for range, watershed, and some recreation and timber.
Los Gatos-Henneke-Maymen	Occur in the Mayacmas Mountains in the northeast corner of Sonoma County. Well drained to excessively drained, moderately to very steeply sloping loams, gravelly loams, and gravelly sandy loams. Used primarily as watershed and for wildlife habitat.

Table 4.3-3

Soil Associations

Soil Association	Description
Hugo-Josephine-Laughlin	Occupy about one-third of Sonoma County, occurring in the Mayacmas and throughout the ridges of the Coast Ranges from Sebastopol to the Sonoma-Mendocino county line. Well drained, gently to very steeply sloping gravelly loams and loams. Used for commercial timber production as well as pasture and range for sheep.
Steinbeck-Los Osos	Occur in the southwestern portion of Sonoma County. Moderately drained to well drained, gently sloping to steep loams and clay loams. Used mainly for range and pasture.
Goldridge-Cotati-Sebastopol	Occur in the southwestern part of Sonoma County. Moderately well drained to well drained, gently sloping fine sandy loams and sandy loams. Primary use is for apple orchards.
Kneeland-Rohnerville-Kinman	Occur along the Pacific Coast north of Bodega Bay. Well drained to moderately well drained, nearly level to steeply sloping loams and clay loams. Primarily used as range or pasture.
Empire-Caspar-Mendocino	Occur along the South Fork Gualala River, in the northwest corner of Sonoma County. Well drained to moderately well drained, strongly to steeply sloping sandy loams and sandy clay loams. Used mainly as timberland.

Source: U.S. Soil Conservation Service 1972

Table 4.3-4

Soil Association Characteristics

Soil Association	Percolation Rate[1]	Expansion Potential[2]	Erosion Hazard[2]	Liquefaction Potential[2]	Soil Strength[3]
Clear Lake Reyes	S	H	L	VL	P
Haire-Diablo	S	M-H	M-H	VL-L	P-F
Huichica-Wright-Zamora	VS-MS	H	L-M	VL-L	F-P
Pajaro	MS	L	L	M	F
Yolo-Cortina-Pleasanton	MS-VR	L	L	L-M	F-G
Spreckels-Felta	S-M	L-H	H	VL-L	F
Yorkville-Suther	VS-S	H	H	VL-L	F-P

Table 4.3-4

Soil Association Characteristics

Soil Association	Percolation Rate[1]	Expansion Potential[2]	Erosion Hazard[2]	Liquefaction Potential[2]	Soil Strength[3]
Gounding-Tommes-Guenoc	M	M	H	VL-L	F-P
Kidd-Forward-Cohasset	M-R	L-M	H-VH	L	F
Los Gatos-Henneke-Maymen	MS-M	L-M	H-VH	L-M	F
Hugo-Josephine-Laughlin	M	M-L	H-VH	L	F
Steinbeck-Los Osos	M-S	M-H	H-M	VL	F-P
Goldridge-Cotati-Sebastopol	S	M-L	H-M	VL-M	F-P
Kneeland-Rohnerville-Kinman	S-MR	L-H	M-H	VL-M	F-P
Empire-Caspar-Mendocino	M-MS	M	M	L-M	F

Source: U.S. Soil Conservation Service 1972

1 VR = Very Rapid; R = Rapid; MR = Moderately Rapid; M= Moderate; MS = Moderately Slow; S = Slow; VS = Very Slow.

2 VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low.

3 G = Good; F = Fair; P = Poor.

Soil Hazards

Soil permeability conditions affect suitability of the land for irrigation, for construction of dam embankments, or for lining reservoirs. Soils with very slow to moderate percolation rates (which dominate the Project area) have low to moderate permeability. Soils that have low permeability are potential sources of clay lining for ponds or the impervious corezone for dam embankments.

Expansiveness, or the potential to swell and shrink with repeated cycles of wetting and drying, is another common characteristic of many of the soils in the Project area. Expansiveness can cause distress to structure foundations. Expansive soils tend to be weak and compressible, and they may not provide adequate support for foundations unless they are specially treated. Sometimes they must be removed entirely and replaced with engineered backfill. If left in place, these weak soils can cause unacceptable amounts of settlement and may require special foundation designs.

Erosion potential is variable throughout the Project region. Silty soils are generally readily erodible whereas sandier soils are less susceptible to erosion. Excessive erosion in the vicinity of building and pipeline structures can result in the loss of foundation support. Excessive erosion could also contribute to reservoir siltation (i.e., the reservoir filling up with silt).

Regulatory Framework

Building Permits

Project structures would be constructed in numerous local jurisdictions. Each city and county has adopted building codes, typically based on the Uniform Building Code, that specify design and construction standards and require that an approved building permit be obtained prior to construction. Local jurisdictions also require that a building inspector review plans and inspect the construction site and grant final approval upon completion of construction. Building permits would be required for pump stations. Dam construction requires special permits issued by the state, discussed below.

Grading Ordinance

Construction or installation of project facilities would require grading of land located in numerous jurisdictions. Some cities and counties in the study area have adopted grading ordinances to regulate grading and to minimize environmental impacts associated with construction grading. Grading ordinances typically require setbacks from property lines, erosion and sediment control, soil stockpile management methods, and inspection procedures. A grading permit may be required, depending on local jurisdiction ordinance specifications, for pipeline installation, road construction, transmission line construction, or other earth works.

National Pollutant Discharge Elimination System Permit

The federal Clean Water Act regulates the discharge of stormwater from construction sites. The State Water Resources Control Board has obtained a General Permit (No. CAS000002) for discharge of stormwater runoff associated with construction activities. Construction activities include clearing, grading, or excavation that results in soil disturbance of at least five acres of total land area. Construction activities that result in soil disturbance of less than five acres require a permit if the construction activity is part of a larger common plan of development. Therefore, the owner of the land where construction would occur is responsible for obtaining coverage under the state-wide General Permit and is required to file a Notice of Intent for each construction activity prior to commencement of construction.

The General Permit requires development and implementation of a Storm Water Pollution Prevention Plan and identification of a monitoring program and reporting requirements. Sediment control measures that shall be included in the General Permit (from State Water Resources Control Board Fact Sheet) are as follows:

a) A description of soil stabilization practices. These practices shall be designed to preserve existing vegetation where feasible and to revegetate open areas as soon as feasible after grading or construction. In developing these practices, the discharger shall consider: temporary seeding, permanent seeding, mulching, sod stabilization, vegetation buffer strips, protection of trees, or other soil stabilization practices. At a minimum, the operator must implement these practices on all disturbed areas during the rainy season.

b) A description or illustration of control practices which, to the extent feasible, will prevent a net increase of sediment load in stormwater discharge. In developing control practices, the discharger shall consider a full range of erosion and sediment controls such as detention basins, straw bale dikes, silt fences, earth dikes, brush barriers, velocity dissipation devices, drainage swales, check dams, subsurface drain, pipe slope drain, level spreaders, storm drain inlet protection, rock outlet protection, sediment traps, temporary sediment basins, or other controls. At a minimum, sandbag dikes, silt fences, straw bale dikes, or equivalent practices are required for all significant sideslope and downslope boundaries of the construction area, The discharger must consider site-specific and seasonal conditions when designing the control practices.

c) Control practices to reduce the tracking of sediment onto public or private roads. These public and private roads shall be inspected and cleaned as necessary.

d) Control practices to reduce wind erosion.

Division of Safety of Dams

Since 1929, the State of California has supervised the construction and operation of dams to prevent failure to safeguard life and protect property. The California Department of Water Resources, Division of Safety of Dams supervises the construction, enlargement, alteration, repair, maintenance, operation, and removal of dams and reservoirs. The Division of Safety of Dams has jurisdiction over all non-U.S. owned dams in the State that are 25 feet or higher (regardless of storage capacity) and dams with a storage capacity of 50 acre-feet of water or greater (regardless of height). Dams six feet or less in height (regardless of storage capacity) or dams with a storage capacity of 15 acre-feet or less (regardless of height) are not under the Division's jurisdiction (California Water Code, Division 3).

When reviewing permit applications the Division of Safety of Dams evaluates the safety of dams and reservoirs by assessing the potential for seepage, earth movement, and other conditions that may occur in the vicinity of a dam or reservoir. The Division requires that data concerning subsoil, foundation conditions, availability of construction materials, and geologic hazards be gathered to review the design, construction, and operation of dams and reservoirs. Investigations usually include exploratory pits, trenches, drilling, coring, geophysical surveys, tests to determine leakage rates, and physical tests to measure properties of foundation materials. Staff at the Division of Safety of Dams performs an independent evaluation of the dam engineer's design to ensure that the design meets or exceeds required standards. Special conditions may be attached to the Division of Safety of Dams permit approval, and design and construction plans may be modified by the Division at any time after approval to insure safety.

During the construction or repair of any dam or reservoir, the Division of Safety of Dams is required to make continuous and periodic inspections to verify that construction is proceeding in accordance with approved plans.[8] No foundations or abutments may be covered until the Division's field engineer has inspected and approved them. The Division of Safety of Dams permit approval may be revoked whenever the dam or reservoir constitutes a danger to life and property.

A discussion of historical dam failure, dam surveillance and monitoring, and evaluation of dam inundation are provided in Section 4.19, Inundation from Dam Failure.

Geology, Soils, and Seismicity Goals, Objectives, and Policies

[8] Under the police power of the State representatives of the Division of Safety of Dams may enter private property to make investigations or inspections.

Table 4.3-5 identifies goals, objectives, and policies which provide guidance for development in relation to geology, soils and seismicity in the Project area. The table also indicates which evaluation criteria in the Geology, Soils, and Seismicity Section are responsive to each set of policies.

Table 4.3-5

General Plan Goals, Objectives, and Policies - Geology, Soils, and Seismicity

Adopted Plan Document	Document Section	Document Numeric Reference	Policy	Relevant Evaluation Criteria[1]
Sonoma County General Plan	Public Safety Element	Goal PS-1 Objective PS-1.1 Objective PS-1.2 Policy PS-1f	Prevent unnecessary exposure of people and property to risks from earthquakes, landslides and other geologic hazards and regulate new development to reduce risks from known geologic hazards to acceptable levels	1-8
Sonoma County General Plan	Public Safety Element	Policy PS-1j	Encourage strong enforcement of state seismic safety requirements for dams	5
Sonoma County General Plan	Public Safety Element	Policy PS-1k	Incorporate measures to mitigate identified geologic hazards to acceptable levels	1-8
Santa Rosa General Plan	Noise and Safety Element	Goal S-2 Objective S-2b	Minimize potential earthquake impacts and assure provisions of the Alquist-Priolo Special Studies Zone Act are met	2,3,4,5
Santa Rosa General Plan	Noise and Safety Element	Goal S-3 Objective S-3a	Identify and mitigate geologic and soils hazards	1-8
Petaluma General Plan	Community Health and Safety Element	Objective (h) Policy 14 Policy 15 Policy 16	Minimize injury and property damage resulting from landslides and mass movements including areas prone to slope instability erosion and mass movement	1,3,6
Petaluma General Plan	Community Health and Safety Element	Objective (g) Policy 11 Policy 13	Minimize risks associated with seismic activity and avoid placement of critical facilities in areas prone to ground failure during an earthquake	2,3,4,5
Petaluma General Plan	Community Health and Safety Element	Objective (t)	Decrease the loss of topsoil and the deterioration of water quality that results from erosion and sedimentation	6

Table 4.3-5

General Plan Goals, Objectives, and Policies - Geology, Soils, and Seismicity

Adopted Plan Document	Document Section	Document Numeric Reference	Policy	Relevant Evaluation Criteria[1]
Sebastopol General Plan	Conservation, Open Space and Parks Element	Goal 4 Policy 10 Program 10.1	Protect and preserve soil as a natural resource and control soil erosion	6
Sebastopol General Plan	Safety Element	Goal 2 Policy 3 Program 3.1	Minimize risk resulting from slope instability, unstable land areas susceptible to liquefaction and settlement or containing expansive soils	1,3,7
Windsor General Plan	Environmental Resources Element	Policy C1.6	Require that development minimize discharge of sediments into waterways	6

Source: Harland Bartholomew and Associates, Inc., 1995

1. Evaluation Criteria can be found in Table 4.3-6.

EVALUATION CRITERIA WITH POINT OF SIGNIFICANCE

According to the CEQA Guidelines, exposure of people or structures to major geologic hazards is considered a significant impact. Geologic hazards within the Project area include slope instability, strong ground shaking, fault rupture, liquefaction, and other processes that could affect soil stability.

Table 4.3-6

Evaluation Criteria with Point of Significance

Evaluation Criteria	As Measured by	Point of Significance	Justification
1. Will Project facilities be located within an area of unstable slope conditions?	Geotechnical assessment of landslide risk potential	Overall rating of Moderate to High	The rating system takes into consideration slope gradient, existing slope instability, rock types and geologic structure. In general, steeper slopes underlain by the weak Petaluma Formation claystone are less stable than gentler slopes and sites underlain by Wilson Grove and Franciscan Complex rocks. Landslides and other slope failure could occur in areas with Moderate to High risk. "Low"

Table 4.3-6

Evaluation Criteria with Point of Significance

Evaluation Criteria	As Measured by	Point of Significance	Justification
			risk areas are expected to have stable slope conditions.
2. Will Project facilities be subject to ground rupture due to location near a surface trace of an active fault?	Location of facilities within an Alquist-Priolo earthquake fault zone	Any portion of facilities within zone	Earthquake fault zones are established under the Alquist-Priolo earthquake fault zone Act by the California Division of Mines and Geology (CDMG) to regulate development near active faults to mitigate the hazard of surface rupture. The Act applies only to structures for human occupancy but the zones accurately delineate areas at greatest risk for surface fault rupture.
3. Will Project facilities be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	CDMG rating of potential for liquefaction or more detailed mapping, where available	A rating of High for liquefaction for project facilities except irrigation pipes	Certain soil types, especially fine sandy soils, underlain by shallow groundwater, are prone to liquefaction. The Division of Mines and Geology has identified areas where soil properties are highly susceptible to liquefaction. Project facilities in these areas would be vulnerable to damage from liquefaction.
4. Will the Project induce seismicity?	Project induced ground shaking intensity	Ground shaking effects of Modified Mercalli[9] intensity V or greater (Table 4.3-1) decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	Earthquakes that produce ground shaking intensity of Modified Mercalli IV (generally corresponds to a magnitude 3 earthquake within an epicentral distance of several miles) are not generally associated with damage to people or property. CEQA defines damage to people or property as a significant effect.

[9] Modified Mercalli intensity scale is used because it describes the groundshaking affects of an earthquake at a given location. Scales, such as the Richter scale, based on Magnitude measures total energy released in an earthquake and does not account for distance from the epicenter or soil type.

Table 4.3-6

Evaluation Criteria with Point of Significance

Evaluation Criteria	As Measured by	Point of Significance	Justification
5. Will earthquake-induced strong ground shaking damage Project facilities?	Structural design and construction not in conformance with requirements of the Division of Safety of Dam or applicable building codes (refer to text).	Construction not in conformance with requirements of the Division of Safety of Dam or applicable building codes.	Division of Safety of Dam regulations and local building codes.
6. Will construction of the Project cause off-site water-related erosion?	Construction activities not in compliance with requirements of the project National Pollutant Discharge Elimination System Permit (NPDES), Division of Safety of Dams regulations, or building and grading codes.	Construction not in compliance with NPDES, Division of Safety of Dams, or building and grading codes.	Clean Water Act regulations, Division of Safety of Dam regulations, and local building or grading ordinances (refer to text).
7. Will Project facilities be exposed to damage due to expansive soils?	Shrink-swell potential as rated in Sonoma County Soil Survey (Soil Conservation Service 1972)	A rating of Moderate to High for shrink-swell potential for project facilities except irrigation pipes	The USDA Soil Conservation Service (SCS) indicates that: "If the shrink-swell potential is rated moderate to very high, shrinking and swelling can damage buildings, roads, and other structures."
8. Will Project facilities be exposed to damage due to construction on corrosive soils?	Corrosion potential as rated in Sonoma County Soil Survey (SCS 1972)	A rating of High for corrosion potential	The SCS indicates that soils with High corrosion can damage uncoated steel and concrete by chemical actions that dissolve and weaken the material.

Source: Parsons Engineering Science, Inc. 1996

Methodology

This impacts analysis is based on a review of relevant geologic literature and review and summary of technical reports prepared for evaluation of Project alternatives. The following technical reports were used:

- *Geotechnical Assessment of Alternative Reservoir Sites and Pipeline Routes* (Rust Environment and Infrastructure, Inc. 1996); and
- *Induced Seismicity Study Geysers Recharge Alternative* (Greensfelder and Parsons Engineering Science, Inc. 1996).

ENVIRONMENTAL CONSEQUENCES (IMPACTS) AND MITIGATION MEASURES

No Action (No Project) Alternative

Impact: **3.1.1-8. Will the No Action Alternative have geologic impacts based on evaluation criteria 1 through 8?**

Analysis: *No Impact, Alternative 1.*

There are no geologic hazards or impacts of the No Action Alternative because there will be no construction or new impacts from operation.

Mitigation: No mitigation is needed.

Headworks Expansion Component

Table 4.3-7

Geology Impacts by Component - Headworks Expansion

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.2.1. Will the headworks expansion component be located within an area of unstable slope conditions?	Overall rating of Moderate to High	None	P	==
3.2.2. Will the headworks expansion component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within an Alquist-Priolo earthquake fault zone	No	P	==
3.2.3. Will the headworks expansion component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction	Moderate to Low	P	❍

Table 4.3-7

Geology Impacts by Component - Headworks Expansion

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.2.4. Will the headworks expansion component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrence intervals of greater than one year	None	P	==
3.2.5. Will earthquake-induced strong ground shaking damage the pipeline component?	Construction not in conformance with requirements of the Division of Safety of Dams or applicable building codes	None	P	==
3.2.6. Will construction of the headworks expansion component cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project NPDES permit, Division of Safety of Dams regulations or building and grading codes	None	C	==
3.2.7. Will the headworks expansion component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential	None	P	==
3.2.8. Will the headworks expansion component be exposed to damage due to construction on corrosive soils?	A rating of High for corrosion potential	None	P	==

Source: Parsons Engineering Science, Inc. 1996

Notes:	1. Type of Impact		2. Level of Significance:
C	Construction	==	No impact
P	Permanent	❍	Less than significant impact; no mitigation proposed

Impact: **3.2.1, 2, 4-8. Will the headworks expansion component have geologic impacts based on criteria 1, 2, and 4-8?**

Analysis: *No Impact; All Alternatives.*

The new pumps will be installed in an existing building located on flat ground where there is no risk of slope instability.

The headworks location is not within an Alquist-Priolo earthquake fault zone.

The headworks expansion involves no injection of water into the earth or other process by which seismicity could be induced.

Construction of the new influent pumps at the headworks will conform with applicable building code; would not involve grading, and will not require new construction in soils.

Alternative 1 does not have a headworks component.

Mitigation: No mitigation is needed.

Impact: **3.2.3. Will the headworks expansion component be located in areas with soils and groundwater conditions that are susceptible to liquefaction?**

Analysis: *Less than Significant; Alternatives 2, 3, 4, and 5.*

The Laguna Plant is located in an area that is mapped as having a high potential for liquefaction (California Division of Mines and Geology, 1994). However, the pumps would be installed in a building with a deep foundation, about 45 to 50 feet below the ground surface, which is founded in clay material that is not susceptible to liquefaction (Harding-Lawson Associates, 1974).

No Impact, Alternative 1.

This alternative does not have a headworks component.

Mitigation: No mitigation is proposed.

Urban Irrigation Component

Impact: **3.3.1-8. Will the urban irrigation component have geologic impacts based on evaluation criteria 1 through 8?**

Analysis: *No Impact; All Alternatives.*

Because the urban irrigation component involves no construction, only replacement of the existing source of water with reclaimed water, there are no geologic hazards or impacts.

Mitigation: No mitigation is needed.

Pipeline Component

Table 4.3-8

Geology Impacts by Component - Pipelines

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.4.1. Will the pipeline component be located within an area of unstable slope conditions?	Overall rating of Moderate to High			
• Urban Irrigation (Bennett Valley only) Pipelines		High	P	⊙
• South County pipelines		Low	P	❍
• West County pipelines • (including Sebastopol)		Low	P	❍
• Geysers pipeline		High	P	●
• Discharge pipeline		Low	P	❍
3.4.2. Will the pipeline component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within an Alquist-Priolo earthquake fault zone			
• Urban irrigation pipelines		Yes	P	●
• South County pipelines		No	P	==
• West County pipelines • (including Sebastopol)		No	P	==
• Geysers pipeline		Yes	P	●
• Discharge pipeline		No	P	==
3.4.3. Will the pipeline component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction	High	P	⊙
3.4.4. Will the pipeline component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	None	P	==
3.4.5. Will earthquake-induced strong ground shaking damage project facilities?	Construction not in conformance with requirements of the Division of Safety of Dams or applicable building code.	None	P	==
3.4.6. Will construction of the Project cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project NPDES permit, Division of Safety of Dams regulations or	None	C	==

Table 4.3-8

Geology Impacts by Component - Pipelines

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
	building and grading codes			
3.4.7. Will the pipeline component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential			
• Discharge		Low	P	❍
• All alternatives except Discharge		Moderate to High	P	⊙
3.4.8. Will the pipeline component be exposed to damage due to construction on corrosive soils?	A rating of High for corrosion potential			
• Pipelines to bay flats and Lakeville agricultural irrigation areas		High	P	⊙
• All other pipelines		Moderate to Low	P	❍

Source: Parsons Engineering Science, Inc., 1996

Notes:

1. Type of Impact
   - C Construction
   - P Permanent

2. Level of Significance:
   - == No impact
   - ❍ Less than significant impact; no mitigation proposed
   - ⊙ Significant impact before mitigation; less than significant impact after mitigation
   - ● Significant impact before and after mitigation

Impact: **3.4.1. Will the pipeline component be located within an area of unstable slope conditions?**

Analysis: *Significant; Alternative 2,3 and 4.*

The segment of the geysers pipeline along Pine Flat Road will traverse areas of unstable slopes in steep terrain. Based on the occurrence of unstable bedrock and existing landslides along the northern geysers pipeline alignment, the area is considered to have a high potential for slope instability. Slope instability is a major geologic hazard along this portion of the alignment and could result in pipeline damage and/or rupture (Rust Environment and Infrastructure, Inc. 1995). Breakage of the pipe could result in release of reclaimed water and could cause substantial erosion and roadway damage at the discharge points.

The geysers pipeline is a large, 42-inch pressurized line (600 pounds per square inch). Because of its relatively remote location, prompt response to pipe failure will be difficult. Manual isolation valves are located at 10,000-foot intervals along the geysers pipeline. These valves will allow the isolation of 10,000-foot sections of the pipe to allow repairs to be made. However, in the event of a major break, it is unlikely that staff from the Utilities Department could travel to the pipeline and manually close the valve before all of the water had drained from the pipe. Intermediate pump stations along the alignment will prevent all of the water in the pipeline from being released if rupture were to occur. Placement of the geysers transmission pipeline along Pine Flat Road could result in significant damage to the pipeline because this portion of the alignment traverses areas that have a high potential for slope failure.

Bennett Valley Urban Irrigation Pipeline. The southeastern-most segment of the Bennett Valley urban irrigation pipeline is located in an area of unstable slope conditions (Rust 1995).

The transmission and distribution pipelines for both South County and West County alternatives are not located in areas of moderate to high risk of slope instability.

Less than Significant; Alternative 5A.

The discharge pipeline is in gently sloping terrain where slope stability would not be a concern.

No Impact; Alternative 1 and 5B.

These alternatives do not have a pipeline component.

Mitigation: *Alternatives 2, 3, and 4.*

2.3.4. Slope Stabilization Design.

2.3.7. Slope Monitoring and Response System.

2.3.8. Earthquake Preparedness and Emergency Response Plan.

Alternatives 1 and 5. No mitigation is proposed.

After Mitigation: *Less than Significant after Mitigation; Alternatives 2 and 3.*

Significant after Mitigation; Alternative 4.

Because of the extensive distribution of landsliding and potentially unstable rock units along Pine Flat Road it is unlikely that slope instability impacts can be completely mitigated. Engineering measures will be applicable only in localized areas where landslide deposits are shallow and of limited extent. Slope instability along the Pine Flat Road segment of the geysers pipeline alignment could not be feasibly mitigated and Project facilities will be at risk of damage or failure throughout the life of the Project.

Slope stability monitoring will not prevent impacts from occurring but will provide advanced warning so some slope stabilization measures could be implemented or repairs could be made to prevent larger-scale damage to the pipeline system.

Impact: 3.4.2. Will the pipeline component be subject to ground rupture due to location near a surface trace of an active fault?

Analysis: *Significant; Alternative 2, 3, and 4.*

The geysers transmission pipeline crosses both the Healdsburg-Rodgers Creek and Maacama Faults. Portions of the geysers 42-inch pipeline are located within Alquist-Priolo earthquake fault zones. The pipeline route crosses the Healdsburg Fault at Chalk Hill Road and the Maacama Fault at Pine Flat Road.

Surface fault rupture associated with seismic activity on the Healdsburg-Rodgers Creek and Maacama faults could result in pipeline damage and/or rupture. A large earthquake on the Rodgers Creek Fault will result in an estimated maximum surface displacement of six feet, although the estimated average surface displacement is approximately three feet (California Division of Mines and Geology 1994). Pipe rupture could result in release of reclaimed water and could cause substantial erosion at the discharge point. Pipe rupture and washout will probably damage Pine Flat Road at the rupture location because pipelines will be installed in roadways.

The geysers pipeline is a large, 42-inch pressurized line (600 pounds per square inch). Because of its relatively remote location prompt response to pipe failure would be difficult. Intermediate pump stations along the alignment will prevent all of the water in the pipeline from being released if rupture were to occur. The maximum volume of water that could be spilled from the geysers pipeline in the event of surface rupture on the Maacama Fault would be 1.7 million gallons.

Portions of the Fountaingrove and Bennett Valley 12-inch urban irrigation pipelines are within the Alquist-Priolo earthquake fault zone for the active Healdsburg-Rodgers Creek Fault. One fault crossing occurs at the Fountaingrove Parkway just west of the Fountaingrove Golf Course. Three sections of the Bennett Valley pipeline are within the Alquist-Priolo earthquake fault zone at a location about 1,000 feet east of the County Fairgrounds.

Urban irrigation pipelines have smaller diameters (12 to 18 inches) and lower pressure (about 100 pounds per square inch) than the geysers pipeline. The installation of isolation valves, the accessibility of pipelines, and anticipated rapid response to pipe rupture will limit spills to an estimated 100,000 gallons of water (approximately the amount contained in a standard 75-foot swimming pool) to be released in the event of surface fault rupture.

Damage to pipelines could occur throughout coastal California in the event of a large earthquake. The existing system, as well as components proposed by this Project, will be vulnerable to damage. Damage to pipelines is an unavoidable consequence of construction and operation of a wastewater system in a seismically active area. Though earthquake damage is a concern throughout California, significant impacts are identified for the following pipelines due to their proximity to faults:

- Urban irrigation pipeline to the Fountaingrove area crosses the Healdsburg-Rodgers Fault.
- Urban irrigation pipeline to the Bennett Valley area crosses the Healdsburg-Rodgers Creek Fault.
- Geysers transmission pipeline crosses the Maacama Fault and the Healdsburg Fault.

No Impact; Alternatives 1 and 5.

The Russian River discharge pipeline is not within an Alquist-Priolo earthquake fault zone. Alternatives 1 and 5B do not have a pipeline component.

Mitigation: *Alternatives 2, 3, and 4.*

2.3.8. Earthquake Preparedness and Emergency Response Plan.

Alternatives 1 and 5. No mitigation is proposed.

After Mitigation: *Significant after Mitigation; Alternatives 2, 3, and 4.*

After implementation of this mitigation measure potentially significant impacts could still result from surface fault rupture during a large earthquake such as the maximum credible earthquake on the Healdsburg-Rodgers Creek or Maacama Faults. Mitigation will reduce effects of a pipeline break but could not prevent pipe rupture.

Impact: **3.4.3. Will the pipeline component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?**

Analysis: *Significant; Alternatives 2, 3, 4 and 5A.*

Pipelines installed in areas underlain by alluvial soils where shallow groundwater is present will be vulnerable to damage caused by liquefaction. Liquefaction can cause pipes to crack and/or rupture and may disrupt the alignment of pipes. Pipelines throughout the Project area, particularly along the San Pablo Bay area, the Laguna de Santa Rosa, and the Russian River and Alexander valleys, could be damaged if liquefaction were to occur during a large earthquake.

The Earthquake Planning Scenario for a Major Earthquake on the Rodgers Creek Fault in the Northern San Francisco Bay Area (California Division of Mines and Geology 1994) was reviewed to determine potential impacts to Project pipelines. Effects on existing pipelines were evaluated as a method for projecting effects on proposed pipelines. The report indicates that existing main sewage lines of the Subregional System will be interrupted with breaks where they cross areas of potential liquefaction north of the Laguna Plant. Thus, proposed transmission pipelines that will be installed in the vicinity of the Laguna Plant to connect various project elements to the main plant will be vulnerable to damage from liquefaction. An estimated thirty days will be needed to restore service (California Division of Mines and Geology 1994).

No Impact; Alternatives 1 and 5B.

These alternatives do not have a pipeline component.

Mitigation: *Alternatives 2, 3, 4, and 5A.*

2.3.5. Liquefaction Stabilization Design.

Alternatives 1 and 5B. No mitigation is needed.

After Mitigation: *Less than Significant after Mitigation; Alternatives 2, 3, 4, and 5A.*

This measure avoids liquefaction hazards by removing liquefaction-prone soils, de-watering, or providing foundations at a depth where liquefaction is not expected to occur.

Impact: **3.4.4-6. Will the pipeline component have geologic impacts based on criteria 4, 5, and 6?**

Analysis: *No Impact; All Alternatives.*

Pipeline construction and operation will not involve direct injection of water, thus, would not induce seismicity.

Design and construction will be in conformance with applicable building codes, National Pollutant Discharge Elimination System Permit, and grading ordinances. These measures will insure that strong ground shaking during an earthquake and off-site erosion during construction would not be significant.

Alternatives 1 and 5B do not have a pipeline component.

Mitigation: No mitigation is needed.

Impact: 3.4.7. Will the pipeline component be exposed to damage due to expansive soils?

Analysis: *Significant; Alternatives 2, 3, and 4.*

The majority of soils within the study area contain clay and have moderate to high shrink-swell potential (Soil Conservation Service 1972). Highly expansive soils are particularly common in the South County. Soils that have a high clay content may expand when wet and contract when dry. These changes in soil moisture content may damage pipelines if not properly managed during construction.

Less than Significant; Alternative 5A.

Soils along the route of the discharge pipeline are rated as Low for shrink-swell potential, and damage due to expansive soils is therefore considered less than significant.

No Impact; Alternatives 1 and 5B.

These alternatives do not have a pipeline component.

Mitigation: *Alternatives 2, 3, and 4.*

2.4.3. Standard Engineering Methods for Expansive Soils.

Alternative 1 and 5. No mitigation is proposed.

After Mitigation: *Less than Significant after Mitigation; Alternatives 2, 3, and 4.*

This measure avoids impacts by removing the expansive soils, or remediates the situation by changing the composition of the soil, or avoids impacts by providing a deeper foundation or footing.

Impact: 3.4.8. Will the pipeline component be exposed to damage due to corrosive soils?

Analysis: *Significant; Alternative 2.*

Pipelines to the bay flats and Lakeville agricultural irrigation areas will be constructed in soils with a high rating for corrosivity. They could be exposed to potentially significant damage due to highly corrosive Reyes soils that could damage steel or concrete pipelines and other structures.

Less than Significant; Alternative 3, 4, and 5A.

These pipelines will be constructed in soils with a Low or Moderate rating for corrosivity and potential damage is considered less than significant.

No Impact; Alternatives 1 and 5B.

These alternatives do not have a pipeline component.

Mitigation: *Alternative 2.*

2.3.6. Standard Engineering Methods for Corrosive Soils.

Alternatives 1, 3, 4, and 5. No mitigation is proposed.

After Mitigation: *Less than Significant after Mitigation; Alternative 2.*

This measure avoids the corrosive soil problem by changing the type of pipe which will be used in the Project.

Storage Reservoir Component

Reservoirs will be exposed to geologic and other hazards. Many of these hazards would be mitigated by the California Division of Safety of Dams permitting procedure. Dam and reservoir design, plan review, and construction monitoring are regulated by the Division of Safety of Dams. Reservoirs will be designed and constructed in accordance with Division of Safety of Dams requirements and the Division will review all design and construction methods. State law requires that the Division of Safety of Dams issue a permit for a dam and reservoir of the type proposed by this project prior to construction. Additional reservoir mitigation measures are discussed in this section and Chapter 2.

Table 4.3-9

Geology Impacts by Component - Storage Reservoirs

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Signifi-cance[2]
3.5.1. Will the storage reservoir component be located within an area of unstable slope conditions?	Overall rating of Moderate to High			
• Tolay Extended, Tolay Confined, Sears Point		Moderate	P, O&M	●
• Adobe Road, Lakeville Hillside		High	P, O&M	●
• West County reservoirs		Low	P, O&M	❍
3.5.2. Will the storage reservoir component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within an Alquist-Priolo earthquake fault zone	None	P	==
3.5.3. Will the storage reservoir component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction	Moderate to Low	P	❍
3.5.4. Will the storage reservoir component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	None	P	==
3.5.5. Will earthquake-induced strong ground shaking damage storage reservoir component?	Construction not in conformance with requirements of the Division of Safety of Dams or applicable building codes.	None	P	==
3.5.6. Will construction of the storage reservoir component cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project NPDES permit, Division of Safety of Dams regulations or building and grading codes.	None	C	==

Table 4.3-9

Geology Impacts by Component - Storage Reservoirs

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Signifi-cance[2]
3.5.7. Will the storage reservoir component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential			
• South County reservoir sites		High	P	⊙
• West County reservoir sites		Low	P	❍
3.5.8. The storage reservoir component may be exposed to damage due to construction on corrosive soils.	A rating of High for corrosion potential	Moderate to Low	P	❍

Source: Parsons Engineering Science, Inc. 1996

Notes:	1. Type of Impact		2. Level of Significance:
C	Construction	==	No impact
O&M	Operation and Maintenance	❍	Less than significant impact; no mitigation proposed
P	Permanent	⊙	Significant impact before mitigation; less than significant impact after mitigation
		●	Significant impact before and after mitigation

Impact: **3.5.1. Will the storage reservoir component be located within an area of unstable slope conditions?**

Analysis: In addition to existing geologic conditions which may create instability for the dams, operation of the storage reservoir may create additional tendencies toward instability. The reservoir operation plan specifies that reservoirs will store water during the wet season. Water will be drained and pumped into the irrigation distribution system during the dry seasons. Seasonal reservoir management results in fluctuations in water levels. Alternating wetting and drying of reservoir slope material can reactivate existing landslides or create new landslides.

Significant; Alternative 2.

All South County reservoir sites are underlain by the Petaluma Formation, which is susceptible to slope failure. Slope failure at proposed South County reservoir sites with moderate to high slope instability hazards could result in damage to Project structures (such as diversion channels) or accelerated siltation. Slope instability at the Adobe Road and Lakeville Hillside reservoir sites will result in substantial accelerated siltation in the reservoir. Landsliding at the Adobe Road site could generate an estimated 100,000 to 200,000 cubic yards of silt that will enter the reservoir each year. Landsliding at the Lakeville Hillside site could generate an estimated 50,000 to 100,000 cubic yards of silt each year. Because there are fewer landslides and more gentle topography at Sears

Point and Tolay than at the Adobe Road and Lakeville Hillside sites, these sites have a slope stability rating of moderate instead of high. The geotechnical analysis has not quantified an annual siltation rate for these sites. The annual siltation rate at the Sears Point and Tolay reservoir sites will be less than those estimated for Adobe Road and Lakeville Hillside, but it would still be substantial. Slope instability at these sites would have a significant adverse impact on the project.

Siltation at Adobe Road and Lakeville Hillside sites will require dredging and removal of spoils. Section 4.11, Transportation, and Section 4.16, Public Services, Utilities, and Recreation, evaluate secondary impacts of removal and disposal of silt.

Less than Significant; Alternative 3.

Slope instability at all West County reservoir sites is rated as low and considered be a less than significant hazard.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have a storage reservoir component.

Mitigation: *Alternative 2.*

2.3.4. Develop slope stabilization measures.

2.4.2. Remove weak surficial deposits from reservoir footprint.

Alternatives 1, 4, and 5. No mitigation is proposed.

After Mitigation: *Significant after Mitigation; Alternative 2*

Removal of surficial deposits and implementation of slope stabilization measures will provide an adequate dam and reservoir foundation at all reservoir sites and substantially reduce the amount of land sliding at the reservoirs. However, some landsliding from the reservoir side slopes and associated siltation would continue throughout the life of the Project and will remain a significant impact of the Project. The amount of siltation resulting from landslides will decrease over the life of the Project.

Impact: 3.5.2. Will the storage reservoir component be subject to ground rupture due to location near a surface trace of an active fault?

Analysis: *No Impact; All Alternatives.*

None of the reservoir sites are located within an Alquist Priolo earthquake fault zone. The Tolay Creek dam site is located about one mile west of the Rodgers Creek Fault. Although the Tolay Creek Fault is not considered to be active, seismic activity on the Rodgers Creek Fault could be associated with sympathetic movement along the Tolay Fault. Therefore, the design of all embankments that are found across the Tolay Fault will consider the potential for some displacement (2 to 4 feet of displacement assumed). Design features will include the installation of a thick, plastic internal core to prevent rupture and resist cracking and a drainage zone downstream of the core zone designed to prevent piping of core material and yet accommodate large seepage flow rates (Rust Environment and Infrastructure, Inc. 1995).

Construction of all reservoirs will conform to requirements of the Division of Safety of Dams. With implementation of these design measures, reservoirs are expected to withstand strong ground shaking from earthquakes.

Alternatives 1, 4, and 5 do not have a storage reservoir component.

Mitigation: No mitigation is needed.

Impact: **3.5.3. Will the storage reservoir component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?**

Analysis: *Less than Significant; Alternatives 2 and 3.*

None of the reservoir sites are located in an area rated as High for liquefaction potential by the California Division of Mines and Geology. Ratings range from Low to Moderate, and therefore no significant hazard is expected due to liquefaction.

Reservoir emplacement may result in localized groundwater mounding in the vicinity of reservoir sites as discussed in Section 4.5, Groundwater. However, the extent of anticipated mounding is minimal and generally does not extend more than 500 feet downgradient of the dam. Surface soils in the vicinity of the reservoir sites are not granular and are not susceptible to liquefaction.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have storage reservoir component.

Mitigation: No mitigation is proposed.

Impact: **3.5.4. Will the storage reservoir component induce seismicity?**

Analysis: *No Impact; All Alternatives*

Research, including studies of thousands of case histories, indicates that a few, very large, reservoirs have induced large earthquakes (greater than magnitude 5) due to the weight of the stored water. However, a reservoir water depth of a minimum of 260 feet is required to induce seismicity. Induced earthquakes large enough to be damaging have never been documented to occur in reservoirs with lesser water depths. Even smaller seismic events have been convincingly documented in a total of only 16 cases out of some 11,000 worldwide "large" dams (Allen 1982). Storage reservoirs of the size proposed by this project will not induce seismicity because the weight of the water is insufficient. The maximum height of water proposed at a reservoir site is 200 feet at the Two Rock site.

Mitigation: No mitigation is needed.

Impact **3.5.5. Will earthquake-induced strong ground shaking damage the storage reservoir component?**

Analysis: *No Impact; All Alternatives*

Construction of all reservoirs will conform to requirements of the Division of Safety of Dams. With implementation of these design measures, reservoirs are expected to withstand strong ground shaking from earthquakes.

Mitigation: No mitigation is needed.

Impact: **3.5.6. Will storage reservoir construction cause off-site water-related soil erosion?**

Analysis: *No Impact; All Alternatives.*

Design and construction of dams, reservoirs, diversion structures, spillways and other facilities will be in conformance with National Pollutant Discharge Elimination System Permit and will be governed by a Stormwater Pollution Prevention Plan which will contain an erosion and sediment control plan. The Stormwater Pollution Prevention Plan is presented in Section 2.210.

Alternatives 1, 4, and 5 do not have a storage reservoir component

Mitigation: No additional mitigation isneeded.

Impact: 3.5.7. Will the storage reservoir component be exposed to damage due to expansive soils?

Analysis: *Significant; Alternative 2.*

South County reservoir sites are situated on soils with moderate to high shrink-swell potential.

Less than Significant; Alternative 3.

The West County reservoir sites are all situated on soils with low shrink-swell potential; expansive soils at these sites will be considered a less than significant hazard.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have a storage reservoir component.

Mitigation: *Alternative 2.*

2.4.2. Remove weak surficial deposits from reservoir footprint.

2.4. 3. Standard Engineering Methods for Expansive Soils.

Alternatives 1, 3, 4, and 5. No mitigation is proposed.

After Mitigation: *Less than Significant after Mitigation; Alternative 2.*

This measure avoids impacts by removing the expansion soils, or remediates the situation by changing the composition of the soil, or avoids impacts by providing a deeper foundation or footing.

Impact: 3.5.8. Will the storage reservoirs be exposed to damage due to corrosive soils?

Analysis: *Less than Significant; Alternatives 2 and 3.*

None of the reservoir sites are situated on soils with high corrosivity.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have a storage reservoir component.

Mitigation: No mitigation is proposed.

Pump Station Component

Table 4.3-10

Geology Impacts by Component - Pump Stations

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.6.1. Will the pump station component be located within an area of unstable slope conditions?	Overall rating of Moderate to High	Low	P	❍
3.6.2. Will the pump station component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within the Alquist-Priolo earthquake fault zones	No	P	==
3.6.3. Will the pump station component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction			
• S, BUS, FGS, SEB		High	P	⦿
• All other pump stations		Moderate to Low	P	❍
3.6.4. Will the pump station component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	None	P	==
3.6.5. Will earthquake-induced strong ground shaking damage pump station components?	Construction not in conformance with requirements of the Division of Safety of Dams or applicable building code.	None	P	==

Table 4.3-10

Geology Impacts by Component - Pump Stations

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.6.6. Will construction of the pump station component cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project NPDES permit, Division of Safety of Dams regulations or building and grading codes.	None	C	==
3.6.7. Will the pump station component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential			
• ASW; T; SBPS 2, 3, 7-12; FGB; ARSW; L; AR; TCSW; SP; WBPS3; G3		Moderate to High	P	⊙
• All other pump stations		Low	P	❍
3.6.8. Will the pump station component be exposed to damage due to construction on corrosive soils?	A rating of High for corrosion potential	Moderate to Low	P	❍

Source: Parsons Engineering Science, Inc. 1996

Notes:

1. Type of Impact
   - C Construction
   - P Permanent

2. Level of Significance:
   - == No impact
   - ❍ Less than significant impact; no mitigation proposed
   - ⊙ Significant impact before mitigation; less than significant impact after mitigation

Impact: 3.6.1. Will the pump station component be located within areas of unstable slope conditions?

Analysis: *Less than Significant; Alternatives 2, 3, and 4.*

Most primary pump stations and booster pump stations for irrigation pipelines are located on gently sloping terrain, typically on level areas along the side of roadways. Although some pump stations are close to hills and mountains, none of the locations are prone to instability.

Construction of large pump stations will be required under the Geysers Recharge Alternative; the two northernmost geysers pump stations are located on steep slopes adjacent to Pine Flat Road. Pump station PS-G3 is located on a relatively resistant ridge of Franciscan sandstone that is surrounded by landslide deposits. This mass of rock is apparently a coherent block within the melange. Pump Station PS-G4 is located on a broad ridge that is underlain by terrace deposits overlying Franciscan bedrock. The geologic material underlying these two pump stations should provide an adequate foundation for the proposed pump stations (Rust Environment and Infrastructure, Inc. 1995). Additional site specific geotechnical investigations should be conducted prior to final design and issuance of a building permit. Preliminary reconnaissance indicates that the geysers pump stations are relatively stable locations within an otherwise unstable terrain.

No Impact; Alternatives 1 and 5.

These alternatives do not have a pump station component.

Mitigation: No mitigation is proposed.

Impact: 3.6.2, 4-6. Will the pump station component have geologic impacts based on evaluation criteria 2, 4, 5, and 6?

Analysis: *No Impact; All Alternatives.*

No pump stations are located in an Alquist-Priolo earthquake fault zone.

Pump stations will not increase the elevation of groundwater or increase water pressure beneath them, so there will be no inducement of seismicity.

Design and construction of pump stations will be in conformance with applicable building codes, National Pollutant Discharge Elimination System Permit, and grading ordinances.

Mitigation: No mitigation is needed.

Impact: 3.6.3. Will the pump station component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?

Analysis: *Significant; Alternatives 2, 3, and 4.*

South County and West County (S, BVS, FGS, SEB) and geysers (G1) pump stations are located in areas that are mapped as having a high potential for liquefaction by California Division of Mines and Geology (1994) or were identified as having a high potential for liquefaction during geotechnical investigations for this project (Rust 1995). The remainder of the pump stations are located in areas rated Low to Moderate for liquefaction potential.

No Impact; Alternatives 1 and 5.

These alternatives do not have a pump station component.

Mitigation: *Alternatives 2, 3, and 4.*

2.3.5. Liquefaction Stabilization Design.

Alternatives 1 and 5. No mitigation is needed.

After Mitigation: *Less than Significant after Mitigation; Alternatives 2, 3, and 4.*

This measure avoids liquefaction hazards by removing liquefaction-prone soils, de-watering, or providing foundations at a depth where liquefaction is not expected to occur.

Impact: **3.6.7. Will the pump station component be exposed to damage due to expansive soils?**

Analysis: *Significant; Alternatives 2, 3, and 4.*

Tolay Extended (TASW; T; SBPSE, 8, 10; FGB), Adobe/Lakeville (ARSW; L; AR; SBPS 3, 8, 10, and 11; FGB), Tolay Confined (TCSW; T; SBPS 2, 3, 8, 10, 11; FGB), Lakeville/Sears Point (SP; L; SBPS 3, 7-12; FGB), West County (WBPS3, FGB), and geysers (G3) pump stations are located on soils with moderate to high potential for shrink-swell hazards. Pump stations underlain by highly expansive soils are located mainly in the South County area.

No Impact; Alternatives 1 and 5.

These alternatives do not have a pump station component.

Mitigation: *Alternatives 2, 3, and 4.*

2.4.3. Standard Engineering Methods for Expansive Soils.

Alternatives 1 and 5. No mitigation is needed.

After Mitigation: *Less than Significant after Mitigation; Alternatives 2, 3, and 4.*

This measure avoids impacts by removing the expansive soils, or remediates the situation be changing the composition of the soil, or avoids impacts by providing a deeper foundation or footing.

Impact: **3.6.8. Will the pump stationcomponentbe exposed to damage due to corrosive soils?**

Analysis: *Less than Significant; Alternatives 2, 3, and 4.*

No pump stations are located on soils with a high potential for corrosion.

No Impact; Alternatives 1 and 5.

These alternatives do not have a pump station component.

Mitigation: No mitigation is proposed.

Agricultural Irrigation Component

Table 4.3-11

Geology Impacts by Component - Agricultural Irrigation

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.7.1. Will the agricultural irrigation component be located within an area of unstable slope conditions?	Overall rating of Moderate to High	Low	P	❍
3.7.2. Will the agricultural irrigation component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within the Alquist-Priolo earthquake fault zones	None	P	==
3.7.3. Will the agricultural irrigation component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction for project facilities except irrigaton pipes		P	--
3.7.4. Will the agricultural irrigation component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	None	P	==
3.7.5. Will earthquake-induced strong ground shaking damage agricultural irrigation components?	Construction not in conformance with requirements of the Division of Safety of Dams or applicable building code.	None	P	==

Table 4.3-11

Geology Impacts by Component - Agricultural Irrigation

Evaluation Criteria	Point of Significance	Impact	Type of Impact[1]	Level of Significance[2]
3.7.6. Will construction of the agricultural irrigation component cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project NPDES permit, Division of Safety of Dams regulations or building and grading code.	None	C O&M O&M-CP	==
3.7.7. Will the agricultural irrigation component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential for project facilities except irrigation pipes	--	P	--
3.7.8. Will the agricultural irrigation component be exposed to damage due to construction on corrosive soils?	A rating of High for corrosion potential			
• Bay flats and Lakeville irrigation areas		High	P	⊙
• All other irrigation areas		Moderate to Low	P	❍

Source: Parsons Engineering Science, Inc.,1996

Notes:	1. Type of Impact		2. Level of Significance:
C	Construction	==	No impact
P	Permanent	❍	Less than significant impact; no mitigation proposed
O&M-CP	Contingency Plan	⊙	Significant impact before mitigation; less than significant impact after mitigation
		--	Not applicable

Impact: **3.7.1. Will the agricultural irrigation component be located in an area of unstable slope conditions?**

Analysis: *Less than Significant; Alternatives 2 and 3.*

Use of reclaimed water for agricultural irrigation could result in slope instability if unstable slopes were irrigated or if excessive amounts of water were applied to the land. Implementation of Project measures 2.2.3, Restrict Surface and Subsurface Irrigation Water Runoff, and 2.2.4, Restrict Soil Erosion and Sediment Movement (Irrigation Sites), will prevent over irrigating and will regulate soil saturation levels. In addition, development of new agricultural areas for irrigation in areas with slopes steeper than ten percent would be carefully reviewed under provisions of the Irrigation Management Guidelines for West County and South County Alternatives (Questa Engineering Coporation 1996). If soils and/or geologic conditions are determined to be unsuitable for irrigated cultivation, reclaimed water will not be provided.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have an agricultural irrigation component.

Mitigation: No additional mitigation is proposed.

Impact: **3.7.2. Will the agricultural irrigation component be subject to ground rupture due to location near a surface trace of an active fault?**

Analysis: *No Impact; All Alternatives.*

Fault rupture will not affect agricultural irrigation areas because no known active faults traverse these areas.

Alternatives 1, 4, and 5 do not have an agricultural irrigation component.

Mitigation: No mitigation is needed.

Impact: **3.7.3. Will the agricultural irrigation component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?**

Analysis: *Not Applicable; Alternatives 2 and 3.*

Irrigation pipelines and pumps in areas underlain by alluvial soils with shallow groundwater will be vulnerable to damage caused by liquefaction. Irrigation facilities in Sebastopol, the bay flats, and in the Americano Creek area would be at risk of liquefaction during a large earthquake. However, damage to pipelines and pump stations from liquefaction will be localized and reclaimed water released from the damaged pipelines will be confined to the immediate area of the damage, due to the fact that irrigation pipelines have shut-off valves. Thus these facilities are excluded from this criterion.

Winter irrigation under the Contingency Plan will only occur during dryer-than-normal winters, and impacts will not be different from standard agricultural irrigation.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have an agricultural irrigation component.

Mitigation: No mitigation is proposed.

Impact: **3.7.4. Will the agricultural irrigation component induce seismicity?**

Analysis: *No Impact; All Alternatives.*

Agricultural irrigation will not involve injection of reclaimed water into groundwater or build-up of pressure that could induce seismicity.

Alternatives 1,4,and 5 do not have an agricultural component.

Mitigation: No mitigation is needed.

Impact: 3.7.5 Will earthquake-induced strong ground shaking damage irrigation systems?

Analysis: *No Impact; All Alternatives*

Building codes are not applicable to design and construction of irrigation facilities, but would conform to standard engineering practices. It is possible that minor damage to irrigation equipment could occur during an earthquake. Repairs will be of the type associated with regular maintenance activities (e.g., replacement of broken couplings) and could be readily implemented. This impact is thus not assessed to be significant.

These alternatives do not have an agricultural irrigation component.

Mitigation: No mitigation is needed.

Impact: 3.7.6. Will the agriculturalirrigation component cause off-site water-related soil erosion?

Analysis: *No Impact; All Alternatives.*

Construction of irrigation facilities will conform with requirements of the National Pollutant Discharge Elimination System Permit, and will be governed by a Stormwater Pollution Prevention Plan, which will contain an erosion and sediment control plan. The requirement for a Stormwater Pollution Prevention Plan is outlined in Section 2.2.10.

Winter irrigation under the Contingency Plan will only occur during dryer-than-normal winters, and impacts will not be different from standard agricultural irrigation.

Alternatives 1,4 and 5 do not have an agricultural irrigation component

Mitigation: No mitigation is proposed.

Impact: 3.7.7. Will agricultural irrigation facilities be exposed to damage due to expansive soils?

Analysis: *Not Applicable; Alternatives 2 and 3.*

Lakeville/Bay Flats, North Petaluma, East of Rohnert Park agricultural irrigation are located on soils with moderate to high shrink-swell potential. Underground irrigation facilities (pipelines) could be damaged, however any release of reclaimed water from pipeline damage will be confined to the immediate area of the damage, due to the fact that irrigation pipelines have shut-off valves. Thus, these facilities are excluded from this criterion.

All West County agricultural irrigation areas are rated low for shrink-swell potential.

No Impact; Alternatives 1, 4, and 5.

These alternatives do not have an agricultural irrigation component.

Mitigation: No mitigation is proposed.

Impact: **3.7.8. The agricultural irrigation component may be exposed to damage due to corrosive soils.**

Analysis: *Significant; Alternative 2.*

The Bay Flats and Lakeville agricultural irrigation areas have a high corrosion potential and present a significant hazard to irrigation pipes. The East of Rohnert Park, Adobe Road and North of Petaluma agricultural areas have a low to moderate corrosion potential.

Less than Significant; Alternative 3.

Corrosion potential is low to moderate and the hazard to facilities is less than significant.

No Impact; Alternative 1, 4, and 5.

These alternatives do not have an agricultural irrigation component.

Mitigation: *Alternative 2.*

2.3.6. Standard engineering methods for corrosive soils.

Alternatives 1, 3, 4, and 5. No mitigation is proposed.

After Mitigation: *Less than Significant after Mitigation; Alternative 2*

This measure avoids the corrosive soil problem by changing the type of pipe which will be used in the Project or restricting the placement of the pipe to above ground.

Geysers Steamfield Component

Table 4.3-12

Geology Impacts by Component - Geysers Steamfield

Evaluation Criteria	As Measured by	Impact	Potential Type of Impact[1]	Level of Significance[2]
3.8.1. Will the geysers steamfield component be located within an area of unstable slope conditions?	Overall rating of Moderate to High	Moderate to Low	P	⊙
3.8.2. Will the geysers steamfield component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within the Alquist-Priolo earthquake fault zones	None	P	==
3.8.3. Will the geysers steamfield component be located in areas with soils and groundwater conditions that	Any facility within area rated High for liquefaction	None	P	==

Table 4.3-12

Geology Impacts by Component - Geysers Steamfield

Evaluation Criteria	As Measured by	Impact	Potential Type of Impact[1]	Level of Significance[2]
are susceptible to liquefaction during an earthquake?				
3.8.4. Will the geysers steamfield component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval (RI) by 50% or more for earthquakes with existing recurrences intervals of greater than one year	RI decrease of 38%	O&M	❍
3.8.5. Will earthquake-induced strong ground shaking damage geysers steamfield components?	Structural design and construction not in conformance with requirements of the Division of Safety of Dams or applicable building codes	None	P	==
3.8.6. Will construction of the geysers steamfield component cause off-site water-related soil erosion?	Construction activities not in compliance with requirements of the project National Pollutant Discharge Elimination System Permit (NPDES), Division of Safety of Dams regulations, or building and grading codes	None	C	==
3.8.7. Will the geysers steamfield component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential.	Low	P	❍
3.8.8. Will the geysers steamfield component be exposed to damage due to construction on corrosive soils?	A rating of High for corrosion potential	Moderate to Low	P	❍

Source: Harland Bartholomew & Associates, Inc. 1996

Notes: 1. Type of Impact 2. Level of Significance:

C	Construction	==	No impact
O&M	Operation and Maintenance	❍	Less than significant impact; no mitigation proposed
P	Permanent	⦿	Significant impact before mitigation; less than significant impact after mitigation

Impact: **3.8.1. Will the geysers steamfield component be located in an area of unstable slope conditions?**

Analysis: *Significant; Alternative 4.*

New pipelines within the geysers steamfield would traverse areas of steep terrain similar to the geysers pipeline alignment along Pine Flat Road. Slope instability could result in pipeline damage and/or rupture within the geysers steamfield area. Construction of new pipes within the geysers steamfield area will be subject to the existing use permit for the area, which specifies grading permits are required for new construction.

The distribution tanks at the end of the pipeline will be located on a ridge top. This area is underlain by Franciscan Complex melange and it is likely that the ridge is underlain by a resistant block of sandstone or greenstone within the melange (Rust Environment and Infrastructure, Inc. 1995). Landslides have been mapped on lower slopes northwest of the tank site. However, the ridge appears to be stable and should provide an adequate foundation for the proposed storage tank stations (Rust Environment and Infrastructure, Inc. 1995).

No Impact; Alternative 1, 2, 3, and 5.

These alternatives do not have a geysers steamfield component.

Mitigation: *Alternative 4.*

2.3.4 Slope Stabilization Design

Alternatives 1, 2, 3, and 5. No mitigation is needed.

After Mitigation: *Less than Significant after Mitigation; Alternative 4.*

This measure reduces impacts by implementing standard geotechnical recommendations.

Impact: **3.8.2, 3, 5, 6. Will the geysers steamfield component have geologic impacts based on evaluation criteria 2, 3, 5 and 6.**

Analysis: *No Impact; All Alternatives.*

Geothermal steamfield facilities will not be located within an Alquist-Priolo earthquake fault zone.

None of the geysers steamfield facilities are located in an area rated as High for liquefaction potential by the California Division of Mines and Geology. Therefore, no significant liquefaction hazard will result from this project component.

The construction of the geysers steamfield facilities will be in conformance with applicable building codes the National Pollutant Discharge Elimination System Permit and grading ordinances.

Alternatives 1, 2, 3, and 5 do not have a geysers steamfield component.

Mitigation: No mitigation is needed.

Impact: 3.8.4. Will the geysers steamfield component induce seismicity?

Analysis: Less than Significant; Alternative 4.

Injection of reclaimed water into deep geothermal wells and extraction of steam and hot water could result in increased seismic activity within a 10-kilometer (6.2-mile) radius of the geysers (Figure 4.3-15). Based on statistical analysis (Greensfelder and Associates and Parsons ES 1996) it is estimated that the Project will not affect the maximum magnitude of earthquakes that occur in the region. However, Project activities could increase the frequency of occurrence of earthquakes producing ground shaking intensity of Modified Mercalli V and VI (Table 4.3-1). Although ground shaking intensity less than Modified Mercalli VI does not produce structural damage, some non-structural damage could occur (Figure 4.3-15).

Analysis of induced seismicity indicates that the Project will result in approximately 14 microearthquakes per year per injection well. Up to 10 injection wells are proposed, therefore, the Project could result in up to 140 additional microearthquakes per year. Microearthquakes include magnitude 0.7 to 3.0. Many of these earthquakes will not be felt by people. A few microearthquakes could produce ground shaking intensity V on Modified Mercalli scale and can result in broken dishes, cracked windows, and cracked and fallen plaster in structures located in the vicinity of the geysers including Loch Lomond, Pine Grove, Hobergs, Cobb, Whispering Pines, and Anderson Springs.

The historical felt earthquake reports from Cobb indicate that during the period of 1980 to 1985, which was the peak geothermal energy production period, the recurrence interval[10] for earthquakes producing ground shaking intensity V was about two years. The statistical model indicates that the 1995 recurrence interval for intensity V earthquakes is 1.6 years and that the Project will decrease the recurrence interval to 1.0 year, an estimated 38 percent increase in frequency (Greensfelder and Parsons 1996). Therefore, the Project could cause the occurrence of earthquakes of Modified Mercalli intensity V, which may cause broken dishes and cracked plaster to increase from about sounds actual six events per decade to about ten events per decade.

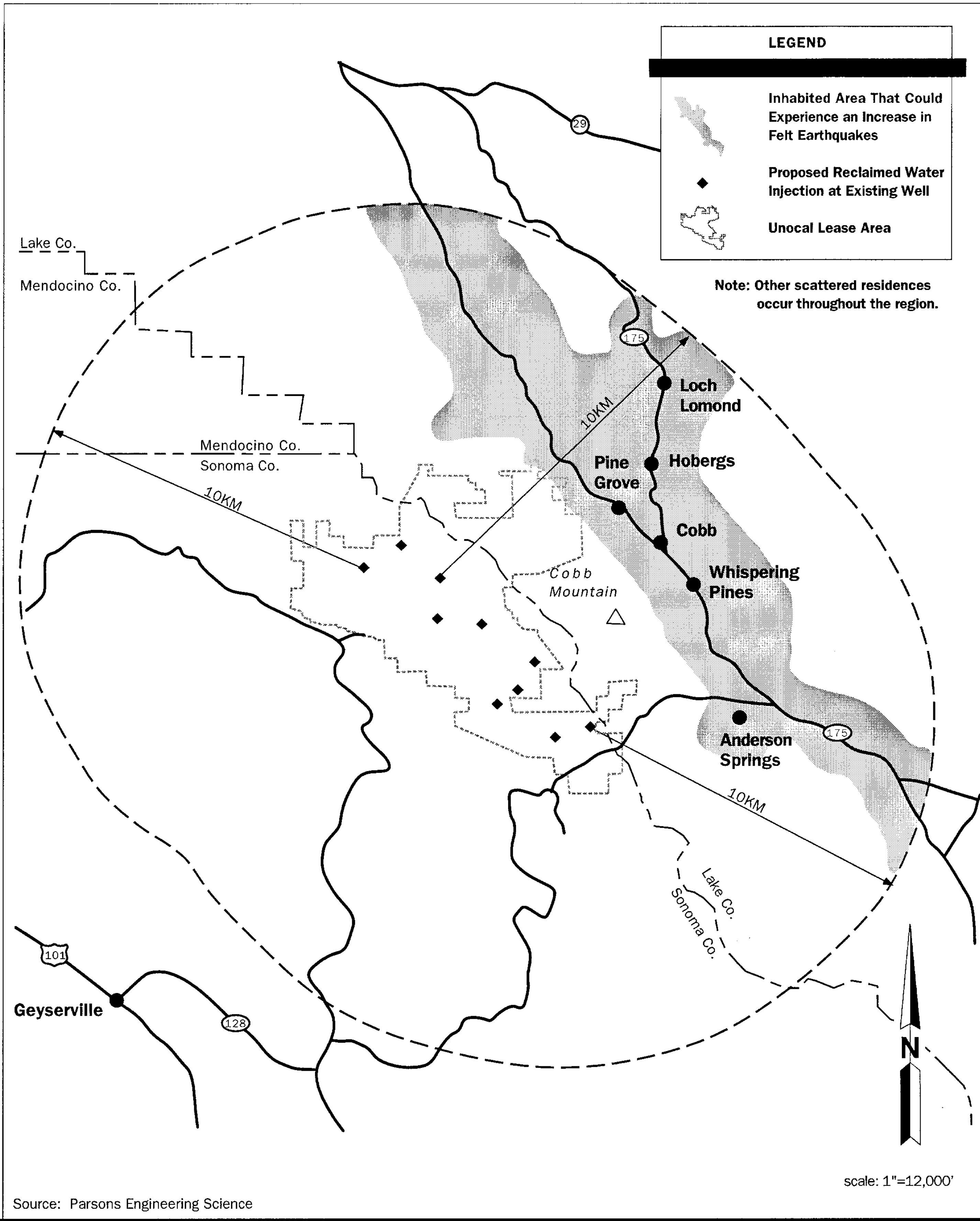
Effects of induced seismicity were modeled based on a peak injection rate of 19.5 mgd at the end of Project, when flows at the Laguna Plant have reached their capacity. Actual injection rates and resulting seismicity will start out considerably lower, and the average rate of injection at the end of the project would be 17.4 mgd. This analysis thus predicts the highest level of seismicity that might be expected. Based on the significance criteria, impacts from induced seismicity will be less than significant.

No Impact; Alternatives 1, 2, 3, and 5.

These alternatives do not have a geysers steamfield component.

Mitigation: *Alternative 4.*

[10] Recurrence interval is the average amount of time between events of equal intensity. A recurrence interval of ten years indicates that the event will occur, on average, once every ten years.



Source: Parsons Engineering Science

INHABITED AREAS POTENTIALLY AFFECTED by INCREASED FREQUENCY of FELT EARTHQUAKES

Figure 4.3-15

GEYSERS INDUCED SEISMICITY STUDY

2.3.8 Earthquake Preparedness and Emergency Response Plan.

2.5.8 Monitor seismic events and adjust injection rates.

Alternatives 1, 2, 3, and 5. No mitigation is needed.

Impact: 3.8.7. Will the geysers steamfield component be exposed to damage due to expansive soils?

Analysis: *Less than Significant; Alternative 4.*

The proposed tanks and pipelines within the geysers geothermal steamfield are underlain by gravelly loam soils that have a low shrink-swell potential.

No Impact; Alternatives 1, 2, 3, and 5.

These alternatives do not have a geysers steamfield component.

Mitigation: No mitigation is proposed.

Impact: 3.8.8. Will the geothermal steamfield component be exposed to damage due to corrosive soils?

Analysis: *Less than Significant; Alternative 4.*

Native soils within the geysers geothermal steamfield have low to moderate corrosivity ratings. However, industrial processes at the geysers may increase the risk of corrosion of steel pipes and other structures. This increased corrosion is typical of geothermal areas and is a result of chemical compounds in the recovered water and steam. Use of reclaimed water is expected to reduce the presence of deleterious compounds in the recovered steam and water and should, overall, reduce corrosion potential at geothermal facilities.

No Impact; Alternatives 1, 2, 3, and 5.

These alternatives do not have a geysers steamfield component.

Mitigation: No mitigation is proposed.

Table 4.3-13

Geology Impacts by Component - Discharge

Evaluation Criteria	As Measured by	Impact	Type of Impact[1]	Level of Significance[2]
3.9.1. Will the discharge component be located within an area of unstable slope conditions?	Overall rating of Moderate to High			
• Russian River		Low	P	❍
• Laguna		None	P	==
3.9.2. Will the discharge component be subject to ground rupture due to location near a surface trace of an active fault?	Any portion of facilities within the Alquist-Priolo earthquake fault zones	None	P	
3.9.3. Will the discharge component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?	A rating of High for liquefaction			
• Russian River		High	P	⊙
• Laguna		None	P	==
3.9.4. Will the discharge component induce seismicity?	Effects of Modified Mercalli V or greater decreasing in recurrence interval by 50% or more for earthquakes with existing recurrences intervals of greater than one year	None	O&M, O&M-CP	==
3.9.5. Will earthquake-induced strong ground shaking damage discharge components?	Structural design and construction not in conformance with requirements of the Division of Safety of Dam or applicable building codes	None	P	==
3.9.6. Will construction of the discharge components cause off-site water-related erosion?	Construction activities not in compliance with requirements of the project National Pollutant Discharge Elimination System	None	C	==

Table 4.3-13

Geology Impacts by Component - Discharge

Evaluation Criteria	As Measured by	Impact	Type of Impact[1]	Level of Significance[2]
	Permit (NPDES), Division of Safety of Dams regulations, or building and grading codes.			
3.9.7. Will the discharge component be exposed to damage due to expansive soils?	A rating of Moderate to High for shrink-swell potential.			
• Russian River		Low	P	❍
• Laguna		None	P	==
3.9.8. Will the discharge component be exposed to damage due to construction on corrosive soils?	A rating High for corrosion potential			
• Russian River		Moderate or Low	P	❍
• Laguna		None	P	==

Source: Harland Bartholomew & Associates, Inc. 1996

Notes:	1. Type of Impact		2. Level of Significance:
C	Construction	==	No impact
P	Permanent	❍	Less than significant impact; no mitigation proposed
O&M	Operations and Maintenance	⊙	Significant impact before mitigation; less than significant impact after mitigation
O&M-CP	Contingency Plan		

Impact: **3.9.1. Will the discharge component be located in an area of unstable slope conditions?**

Analysis: *Less than Significant; Alternative 5A*

The Russian River discharge outfall will be constructed in an area of gently sloping terrain. The river bank may have locally steep slopes but the area is not considered to be unstable.

No Impact; Alternatives 1, 2, 3, 4, and 5B.

These alternatives do not have a new discharge outfall.

Mitigation: No mitigation is proposed.

Impact: **3.9.2. Will the discharge component be subject to ground rupture due to location near a surface trace of an active fault?**

Analysis: *No Impact; All Alternatives.*

The discharge outfall for Alternative 5A is not located within an Alquist-Priolo earthquake fault zone

Alternatives 1, 2, 3, 4, and 5B do not have a new discharge outfall.

Mitigation: No mitigation is needed.

Impact: 3.9.3. Will the discharge component be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake?

Analysis: *Significant; Alternative 5A.*

The discharge facility along the Russian River will be located in an area with a high liquefaction potential. Liquefaction in this area could cause lateral spreading at the exposed river bank which could damage the outlet structure. The outfall structure will be exposed to significant impacts because the area has a high liquefaction potential.

No Impact; Alternative 1, 2, 3, 4, and 5B.

These alternatives do not have a new discharge outfall.

Mitigation: *Alternative 5A.*

2.3.5. Liquefaction Stabilization Design.

Alternatives 1, 2, 3, and 5B. No mitigation is needed.

After Mitigation: *Less than Significant after Mitigation; Alternative 5A.*

This measure avoids liquefaction hazards be removing liquefaction-prone soils, de-watering, or providing foundations at a depth where liquefaction is not expected to occur.

Impact: 3.9.4-6. Will the discharge component have geologic impacts based on evaluation criteria 4, 5, and 6?

Analysis: *No Impact; All Alternatives.*

The Russian River discharge outfall does not involve direct injection of water that could induce seismicity.

The construction of discharge facilities will be in conformance with applicable building codes.

Construction of a river outfall structure could result in streambank erosion during the construction period. However, construction will be in conformance with NPDES permit and grading ordinances, which will prevent significant impacts. In addition, the following measure, included as part of the Project, specifies that construction of a Russian River outfall would be restricted to the low flow period, when the water level is below the construction area: 2.2.5 Avoid Sensitive Biological Resources.

Combined with erosion control procedures specified in Chapter 2, this will avoid any significant impacts during construction of the outfall.

Potential erosion impacts related to increased river flows are discussed in Section 4.4, Surface Water Hydrology.

Mitigation: No additional mitigation is needed.

Impact: 3.9.7. Will the discharge component be exposed to damage due to expansive soils?

Analysis: *Less than Significant; Alternative 5A.*

Soils at the discharge outfall are composed of silt, sand, and gravel and have a low to moderate shrink-swell potential.

No Impact; Alternatives 1, 2, 3, 4, and 5B.

These alternatives do not have a new discharge outfall.

Mitigation: No mitigation is proposed.

Impact: 3.9.8. Will the discharge component be exposed to damage due to corrosive soils?

Analysis: *Less than Significant; Alternative 5A*

Soils at the discharge outfall have a low corrosivity rating.

No Impact; Alternatives 1, 2, 3, 4, and 5B

These alternatives do not have a new discharge outfall.

Mitigation: No mitigation is proposed.

CUMULATIVE IMPACTS

There are seven impacts – either less than significant or significant – identified in the Geology, Soils, and Seismicity section:

- Unstable slope conditions; potential for ground rupture, ground shaking, or liquefaction from an earthquake; damage from expansive or corrosive soils.

- The Project will construct additional facilities in a seismically active area, and thus contributes to the cumulative exposure of structures to seismic hazards in the region as a whole. However, this is the case for any project constructed in the state of California, and the actual level of risk is site specific and would not be cumulatively increased at any particular site.

- Induced seismicity. Geysers steamfield

Other sources of induced seismicity are the geysers geothermal resource activity and injection of water from Lake County Sanitary District. Cumulative impacts from these sources have been considered in the analysis presented in the Geology analysis section. The Lake County project has minor cumulative impacts on induced seismicity. The table below shows that there is virtually no difference between recurrence intervals with the Santa Rosa project (R+G+S) and predicted intervals with both the Santa Rosa and Lake County Projects (R+G+L+S).

Table 4.3-14

Recurrence Interval of Earthquake Effects at Cobb

Modified Mercalli Scale	Project	Project / Lake County Project
III	6.1 days	6.0 days
IV	33 days	33 days

V	.94 years	.93 years
VI	8.4 years	8.3 years
VII	80 years	80 years
VIII	900 years	900 years

Source: Taken from Table 7.3 in *Induced Seismicity Study Geysers Recharge Alternative*, Greensfelder 1996.

SUMMARY OF SIGNIFICANT IMPACTS AND MITIGATION MEASURES

Table 4.3-15

Summary of Significant Impacts and Mitigation Measures -- Geology, Soils, and Seismicity

	Level of Significance	Mitigation Measures
Pipeline Component		
3.4.1. The pipeline component may be located within an area of unstable slope conditions.	Alt 2 - ⦿ Alt 3 - ⦿ Alt 4 - ●	2.3.4. Slope Stabilization Design 2.3.7. Slope Monitoring and Response System 2.3.8. Earthquake Preparedness and emergency Response Plan
3.4.2. The pipeline component may be subject to ground rupture due to location near surface trace of an active fault.	Alt 2 - ● Alt 3 - ● Alt 4 - ●	2.3.8. Earthquake Preparedness and Emergency Response Plan
3.4.3. The pipeline component may be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake.	Alt 2 - ⦿ Alt 3 - ⦿ Alt 4 - ⦿ Alt 5A - ⦿	2.3.5. Liquefaction Stabilization Design
3.4.7. The pipeline component may be exposed to damage due to expansive soils.	Alt 2 - ⦿ Alt 3 - ⦿ Alt 4 - ⦿	2.4.8. Standard engineering methods for expansive soils
3.4.8. The pipeline component may be exposed to damage due to corrosive soils.	Alt 2 - ⦿	2.3.6. Standard engineering methods for corrosive soils.
Storage Reservoir Component		
3.5.1. The storage reservoirs component may be located within an area of unstable slope conditions.	Alt 2 - ●	2.3.4. Slope Stabilization Design 2.4.2. Remove weak surficial deposits from reservoir footprint.

Table 4.3-15

Summary of Significant Impacts and Mitigation Measures -- Geology, Soils, and Seismicity

	Level of Significance	Mitigation Measures
3.5.7. The reservoirs component may be exposed to damage due to expansive soils.	Alt 2 - ⊙	2.4.2. Remove weak surficial deposits from reservoir footprints 2.4.3. Standard engineering methods for expansive soils
Pump Station Component		
3.6.3. The pump station component may be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake.	Alt 2 - ⊙ Alt 3 - ⊙ Alt 4 - ⊙	2.3.5. Liquefaction Stabilization Design
3.6.7. The pump station component may be exposed to damage due to expansive soils.	Alt 2 - ⊙ Alt 3 - ⊙ Alt 4 - ⊙	2.4.3. Standard engineering methods for expansive soils
Agricultural Irrigation Component		
3.7.8. The agricultural irrigation component may be exposed to damage due to corrosive soils.	Alt 2 - ⊙	2.3.6. Use standard engineering methods for corrosive soils
Geysers Steamfield Component		
3.8.1 The geysers steamfield component may be located in an area of unstable slope conditions	Alt 4 - ⊙	2.3.4 Slope Stabilization Design
Discharge Component		
3.9.3. The discharge component may be located in areas with soils and groundwater conditions that are susceptible to liquefaction during an earthquake.	Alt 5A - ⊙	2.3.5. Liquefaction Stabilization Design

Source: Parsons Engineering Science, Inc., 1996

⊙ Significant impact before mitigation; less than significant impact after mitigation

● Significant impact before and after mitigation

SUMMARY OF IMPACTS BY ALTERNATIVE

Table 4.3-16

Summary of Impacts by Alternative - Geology, Soils, and Seismicity

Component	Alt 1	Alt 2A	Alt 2B	Alt 2C	Alt 2D	Alt 3A	Alt 3B	Alt 3C	Alt 3D	Alt 3E	Alt 4	Alt 5A	Alt 5B
No Action (No Project) Alternative	==	--	--	--	--	--	--	--	--	--	--	--	--
Headworks Expansion	--	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Urban Irrigation	--	==	==	==	==	==	==	==	==	==	--	--	--
Pipelines	--	●	●	●	●	●	●	●	●	●	●	●	--
Storage Reservoirs	--	●	●	●	●	❍	❍	❍	❍	❍	--	--	--
Pump Stations	--	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	--	--
Agricultural Irrigation	--	⊙	⊙	⊙	⊙	❍	❍	❍	❍	❍	--	--	--
Geysers Steamfield	--	--	--	--	--	--	--	--	--	--	⊙	--	--
Discharge	--	==	==	==	==	==	==	==	==	==	==	⊙	==

Source: Parsons Engineering Science, Inc., 1996

Notes: Level of Significance Codes

- -- Not applicable
- == No impact
- ❍ Less than significant impact; no mitigation proposed
- ⊙ Significant impact; less than significant after mitigation
- ● Significant impact before and after mitigation

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