HYDROGEOLOGY OF STORAGE/REUSE AREAS AND EVALUATION OF POTENTIAL IMPACTS TO GROUNDWATER

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa

and

U.S. Army Corps of Engineers

June 1996

Prepared by

PARSONS ENGINEERING SCIENCE, INC.
PLANNING · DESIGN · CONSTRUCTION MANAGEMENT
1301 MARINA VILLAGE PARKWAY, ALAMEDA, CA 94501 · 510/769-0100
OFFICES IN PRINCIPAL CITIES
723129/95-05

for

HARLAND BARTHOLOMEW AND ASSOCIATES, INC.

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1 INTRODUCTION

1.1 BACKGROUND

The City of Santa Rosa is developing a long-term wastewater project which may include an expansion of existing water reclamation and reuse activities. The project includes alternatives involving the storage of reclaimed water in reservoirs and its reuse in irrigation areas. The areas being considered for storage/reuse include South County areas in the Santa Rosa Plain, Petaluma Valley, and the Tolay Creek watershed and West County areas in the watersheds of Americano, Stemple, and Atascadero creeks (Figure 1.1).

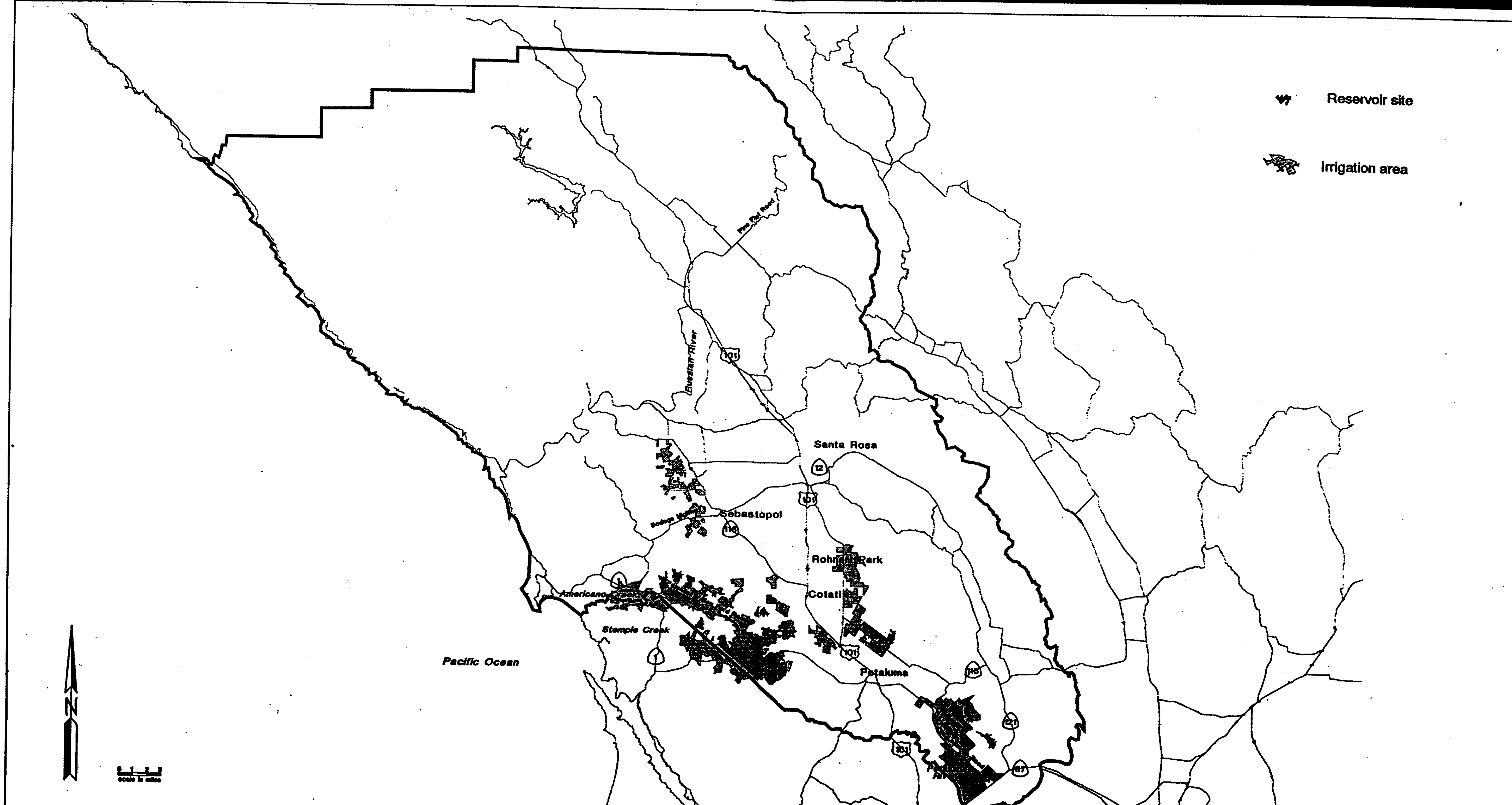
The purpose of this report is to characterize the hydrogeology and groundwater resources in these areas and to evaluate of potential impacts from the storage/reuse alternatives on groundwater resources. This study is one of a series of technical investigations performed to assist in the development of the Santa Rosa Subregional Long-Term Wastewater Project Environmental Impact Report/Environmental Impact Statement (EIR/EIS) which is being prepared for the City of Santa Rosa. The EIR/EIS utilizes the findings of the various technical studies to evaluate potential project impacts, assess the significance of impacts and discuss possible mitigation measures. The findings of this report are incorporated into the discussion of potential impacts in the EIR/EIS.

1.2 SUMMARY

The two potential impacts to groundwater from storage/reuse of reclaimed water in the project area are changes in groundwater quality and changes in groundwater levels. The first step in the evaluation of potential impacts was to review the regional hydrogeologic setting of the project area based on existing literature. The results of this review are included in sections 2 and 3 of this report. Section 4 consists of a summary of the hydrogeology of each storage/reuse area. The organization of this discussion is based on four geographic areas: the Santa Rosa Plain, Petaluma Valley, Tolay Creek watershed, and West County watersheds (i.e., Atascadero, Americano and Stemple creeks). This section is based on both existing documents and the results of studies performed in support of the EIR/EIS (Questa Engineering Corporation 1995a and 1995b, Rust Environment & Infrastructure 1995, Merritt Smith Consulting 1996, and Parsons Engineering Science, Inc. [Parsons ES] 1996).

Using the hydrogeologic conditions identified in Section 4 as a framework, Section 5 outlines the procedures and results of the evaluation of potential impacts of storage/reuse of reclaimed water on local groundwater conditions. Each storage area, i.e., reservoir site, was evaluated based on the quantity of reclaimed water that would infiltrate to groundwater and the percent of local groundwater this quantity would comprise downgradient of the reservoir. This evaluation also includes a comparison of local groundwater and reclaimed water quality and an estimate of groundwater level increases in the vicinity of the reservoir sites. The evaluation of irrigation areas consisted of estimates of groundwater level increases and potential groundwater quality impacts. The groundwater quality impact analysis includes a summary of groundwater monitoring at agricultural areas currently irrigated with reclaimed water.

All figures in this report are included in Appendix B. Tables are included in Appendix A.



Source: Parsons Engineering Science
USGS Quad Maps

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Santa Rosa Subregional Long-Term Wastewater Project

Figure 1-1

VICINITY MAP

2 SETTING

2.1 GEOGRAPHIC SETTING

For the purposes of this evaluation, the project areas are divided into South County and West County alternatives. This grouping is valid because the two areas are located in two distinctly different geographic and geologic settings. Because the geographic and geologic setting of the Sebastopol area is very similar to that of the West County areas, discussion of the Sebastopol area is included in the discussion of the West County.

The South County alternatives are primarily located in the northwest trending structural troughs which contains the Santa Rosa Plain, Petaluma Valley and the relatively small Tolay Creek watershed. The trough that contains both the Santa Rosa Plain and the Petaluma Valley is bounded on the west by the Mendocino Range and the Mayacamas and Sonoma ranges on the east. A low range of hills divides the trough into the topographically distinct northern and southern valleys: the Santa Rosa Plain and Petaluma Valley. In the Santa Rosa Plain most streams flow to the Laguna de Santa Rosa which discharges to the Russian River in the northwestern portion of the plain. The Petaluma Valley is drained by the Petaluma River which flows south to San Pablo Bay. Tolay Creek, in the small valley just east of the Petaluma Valley, also discharges to San Pablo Bay.

The West County storage/reuse areas are located in the Mendocino Plateau, a broad dissected upland area of the Mendocino Range. Streams have dissected this upland, dividing it into relatively small, isolated watersheds. The plateau contains the valleys of Americano, Stemple and Atascadero creeks. Americano Creek flows west and discharges to Estero Americano. Stemple Creek, just south of Americano Creek, flows west and discharges to Estero de San Antonio. Atascadero Creek flows north to the Russian River via Green Valley Creek.

South County components include storage/reuse areas in the Santa Rosa Plain (i.e., east Rohnert Park), Petaluma Valley and the Tolay Creek watershed (Figure 1-1). South County reuse components are located in all three of these geographic areas and include North Petaluma, Adobe Road, Lakeville, Baylands (Bayflats), East Rohnert Park, and urban irrigation areas in the vicinity of the city of Santa Rosa. Storage components are located in the eastern foothills of Petaluma Valley and in the Tolay Creek watershed and include Adobe Road, Lakeville-Hillside, Tolay and Sears Point reservoir sites.

West County components include storage/reuse areas in the watersheds of Americano, Stemple, and Atascadero creeks (Figure 1-1). Reuse components are located in all three watersheds and include Americano, Stemple and West Sebastopol irrigation areas. West County storage components are located in the watersheds of Americano and Stemple creeks and include Valley Ford East, Carroll Road North, Bloomfield, Huntley and Two Rock.

2.2 GEOLOGIC SETTING

South County project components are located in the Santa Rosa structural block of the Coast Ranges which contains major folds in association with some faulting. This structural block is composed of folded basement rocks of the Franciscan Complex and Tertiary sedimentary and volcanic rocks. These folded rocks are overlain by relatively undeformed younger sedimentary deposits. The Santa Rosa/Petaluma trough represents a major downfolded basin in this block. The Tolay Creek watershed represents a smaller downfolded area on the east side of the southern portion of the Petaluma Valley.

The West County project sites are located on the uplands of the Mendocino plateau west of the Santa Rosa/Petaluma trough. The plateau represents a regionally uplifted structural platform of Franciscan Complex basement rocks and overlying Merced Formation (also known as the Wilson Grove Formation [Fox 1983]). The Merced Formation has been uplifted without folding and bedding is nearly horizontal.

There are several faults in the vicinity of the project area. Faults in this portion of the Coast Ranges generally trend north-northwest and are steeply dipping. Faulting frequently causes different thicknesses of strata on the two sides of the fault (Cardwell 1958).

3 REGIONAL HYDROGEOLOGY

3.1 HYDROGEOLOGIC SETTING

The following discussion describes the groundwater resources in the vicinity of the proposed reservoir storage/reuse areas for reclaimed water in South County and West County.

Two of the major groundwater resources of Sonoma County are located in the relatively densely populated Santa Rosa Plain and Petaluma Valley. The Santa Rosa and Petaluma groundwater basins are contained in a structural trough that is subdivided into two separate groundwater basins by a hydrologic divide created by the low hills which separate the trough into the topographically distinct Santa Rosa Plain and Petaluma Valley.

Two South County reuse areas are located in the Santa Rosa Plain and several reuse and storage areas are located in the Petaluma Valley. The remaining storage/reuse areas located in South County are located in the relatively small, sparsely populated watershed of Tolay Creek which is located just east of Petaluma Valley. Section 2.1 of this report identifies the various storage/reuse areas and their locations.

The groundwater resources in West County consist of relatively small, detached groundwater basins whose limits are generally defined by the watersheds of the trunk streams. West County storage/reuse areas are located in the watersheds of the Americano, Stemple and Atascadero creeks. The groundwater basins associated with these watersheds provide water for domestic and irrigation purposes in this sparsely populated area.

The principal groundwater bodies in the project area are generally unconfined at shallow depths with varying levels of confinement at depth. The surface of the water table conforms approximately with the topography of the area. The groundwater surface is highest beneath uplands and is lowest beneath the adjacent valley areas. Groundwater is typically relatively shallow, generally less than 100 feet in subbasins in both South County and West County.

The principal groundwater recharge areas for the groundwater basins in South County and West County are located in upland areas surrounding the basins. The primary sources of recharge are precipitation and stream seepage. Infiltrating precipitation and stream seepage occur in significant quantities on slopes of relatively low gradient underlain by permeable materials.

Groundwater discharge occurs along the major trunk streams of the valleys and as deep subsurface flow which parallels the flow of the trunk streams. Groundwater discharge also occurs through evapotranspiration in low-lying marshy areas. Groundwater extraction through wells makes up a significant portion of groundwater discharge, particularly in the southern portion of the Santa Rosa Plain.

Although South County and West County are located in two generally different geologic settings, they share several of the same hydrogeologic units which are described in the following text.

3.2 HYDROGEOLOGIC UNITS

The groundwater occurrences in the project area are associated with several hydrogeologic units that range from high yield to very low yield and, locally, non-water yielding. The following discussion includes a geologic description of each unit, its general occurrence and its water yielding properties. The order in which the units are discussed is from oldest and generally stratigraphically lowest to youngest and stratigraphically highest.

Franciscan Complex (Jurassic to Cretaceous [Bailey 1966, Fox 1983]): The Franciscan Complex consists of well-lithofied rocks which include sandstone, shale, conglomerate, chert, greenstone (altered basalt), and metagraywacke. Clastic sedimentary rocks (i.e., sandstone, shale and conglomerate) are the predominant rock type in the project area. In Sonoma County these rock types occur both as continuous, coherent rock masses and as a melange. A melange is a chaotic mixture of isolated blocks of these lithologies contained in a sheared, fine-grained matrix.

The Franciscan Complex comprises the basement rock in both South County and West County. In most of West County, rocks of the Franciscan Complex are either exposed at the ground surface or occur beneath a thin veneer of younger sedimentary rock (Merced Formation) and/or alluvium. Locally, faulting can result in a thick wedge of younger sedimentary rocks covering the Franciscan Complex. In South County, the Franciscan Complex basement and Tertiary sedimentary rocks have been warped down to form the Santa Rosa/Petaluma trough and have been overlain by a thick accumulation of younger sedimentary deposits. In central and western Petaluma Valley, west of the Tolay fault, the Franciscan Complex basement occurs at a much shallower depth, and overlying water-bearing strata are much thinner. In the hills east of the trough the Franciscan Complex occurs as faulted blocks in contact with younger sedimentary and volcanic rocks (California Department of Water Resources [DWR] 1982a and 1982b).

The dense, well-lithofied nature of the Franciscan Complex greatly inhibits the movement of groundwater. The Franciscan Complex is generally not used as a groundwater resource in the Santa Rosa/Petaluma trough because of the availability of groundwater in shallower units that have much higher water-yielding capabilities. In the western uplands where the Franciscan Complex is exposed at or near the ground surface, small supplies of water are obtained from the upper weathered zone, poorly cemented sandstone or fractured zones (Cardwell 1958). Well yields are generally quite low. Preferential movement of groundwater in the Franciscan Complex is evidenced by the presence of springs that can be found in these rocks throughout the western uplands. The Franciscan Complex has a very low specific yield of less than 3 percent (DWR 1982a).

Petaluma Formation (late Miocene [Fox 1983]): The Petaluma Formation consists primarily of non-marine, massive claystone, siltstone, and mudstone with lenses of sandstone and conglomerate. The occurrence of the Petaluma Formation is confined to the Santa Rosa/Petaluma trough and the areas east of the Petaluma Valley. The formation does not occur in the western portion of the county. In the Santa Rosa/Petaluma trough, the Petaluma Formation overlies the Franciscan Complex and interfingers with and is overlain by the Merced Formation in the west and the Sonoma Volcanics in the east.

The maximum thickness of the Petaluma Formation, 4,000 feet, occurs on the eastern side of the Petaluma Valley (Cardwell 1958). The formation thins to 200 feet on the west side of the valley (Cardwell 1958). In the Santa Rosa basin the maximum thickness has not been determined.

The fine-grained units, which are the predominant lithology, produce relatively small quantities of water. Moderate water yield can be obtained when wells intersect significant thicknesses of the sandstone and conglomerate (Cardwell 1958). Specific yields for this unit are generally low, from 3 to 7 percent (DWR, 1982a; 1982b).

Merced Formation (late Miocene to Pliocene [Fox 1983], renamed Wilson Grove Formation by Fox [1983]): The marine Merced Formation typically consists of fine to very fine-grained sandstone with interbeds of siltstone, conglomerate and minor tuff beds. In most of West County including the uplands just east of the Santa Rosa Plain, the formation is exposed at the ground surface and directly overlies basement rocks of the Franciscan Complex. In the Santa Rosa/Petaluma trough the Merced Formation is overlain by alluvial deposits and overlies the Petaluma Formation. The Merced Formation thins toward the east and does not extend into the east margin of the trough. The maximum thickness of the Merced Formation beneath the western Santa Rosa Plain is up to 2,000 feet. In the Petaluma Valley the formation appears much thinner, approximately 200 feet (Cardwell 1958). In West County, the thickness typically ranges from 300 to 500 feet thick (Travis 1952).

Groundwater in the Merced Formation is unconfined at shallow depths, but semi-confined to confined conditions occur under laterally extensive fine-grained units. Because of its uniform high porosity and moderate permeability, this unit yields moderate to high quantities of water (Cardwell 1958). The Merced Formation has a high specific yield of 10 to 20 percent (DWR 1982a and 1982b).

Sonoma Volcanics (late Miocene to Pliocene [Fox 1983]): The Sonoma Volcanics consist of basalt, andesite and rhyolite flows, breccia, tuff and sedimentary deposits composed of volcanic detritus. The volcanics overlie and interfinger with the upper Petaluma Formation on the east side of the Santa Rosa/Petaluma trough where they are locally overlain by alluvial deposits. The volcanics form the bulk of Sonoma Mountain and portions of the hills to the east.

The production of water wells located in this unit is highly variable. Some volcanic flows are mostly impervious and restrict groundwater movement. Wells that encounter more permeable zones such as scoriaceous zones, weathered horizons, or air/water laid deposits may yield enough water for domestic purposes (Cardwell 1958). This unit has a highly variable specific yield, which ranges from 0 to 15 percent (DWR 1982a and 1982b).

Alluvial Fan Deposits (Pliocene to Recent): The alluvial fan deposits, which include the Glen Ellen Formation, are composed of a heterogeneous mixture of unconsolidated gravel, sand, silt and silty clay. The alluvial fan deposits extend from the base of the upland areas to the floor of the Santa Rosa/Petaluma trough becoming more fine-grained with distance from the uplands. These deposits occur over much of the surface of the trough where they overlie the Merced and Petaluma formations and locally the Sonoma Volcanics. The deposits range in thickness from about 50 to 400 feet (DWR 1982a, 1982b). Due to their overall coarse-grained nature, these deposits have a moderate to high specific yield of 8 to 17 percent (DWR 1982a and 1982b).

Alluvium (Pleistocene to Recent) These deposits consist of a variety of discontinuous beds of unconsolidated gravel, sand, silt and clay. In the Santa Rosa/Petaluma trough these undifferentiated alluvial deposits represent a mixture of coarse-grained stream channel and levee deposits, and fine-grained flood plain deposits. In West County, alluvium occurs as superficial stream channel deposits in narrow valleys cut into the Franciscan Complex or the Merced Formation. In South County, the alluvium deposits are generally thick, ranging up to 400 feet thick. In West County, the alluvium is relatively thin, usually several tens of feet.

The specific yield of the alluvium varies based on the clay content and the thickness of the deposits and ranges from 3 to 15 percent (DWR 1982a and 1982b).

Basin Deposits (Pleistocene to Recent). Basin deposits consist of organic-rich clay and silty clay that are the result of deposition in extensive freshwater marshes. These deposits occur in the project area only in low areas of the Santa Rosa Plain. They cover much of the central portion of the southern plain, the vicinity immediately adjacent to the Laguna de Santa Rosa and scattered low-lying areas. These thin deposits overlie and interfinger with coarser-grained alluvial fan deposits and alluvium. The basin deposits are typically thin, but in the southern portion of the plain they may reach thickness of more than 200 feet (DWR 1982a).

The fine-grained basin deposits have low permeabilities and do not yield significant quantities of groundwater. They restrict infiltration and downward percolation of water and form a confining layer to underlying water bearing deposits. These deposits have a low specific yield of 3 to 7 percent (DWR 1982a).

Bay Mud Deposits (Pleistocene to Recent). Bay mud deposits typically consist of organic-rich mud, silty mud, silt and some sand. These sediments cover much of the southern Petaluma Valley representing the present and former extension of San Pablo Bay estuarine environment. The deposits thicken to the south where they reach thicknesses of several 100 feet (DWR 1975).

Groundwater occurring in bay mud deposits is brackish to highly saline. Bay muds have a low permeability due to their overall fineness. The bay mud deposits are not considered a reliable source of potable water (DWR 1975). These deposits have a very low specific yield of less than 3 percent (DWR 1982b).

4 HYDROGEOLOGY OF STORAGE / REUSE AREAS

The following text describes the specific groundwater basins for the Santa Rosa Plain and Petaluma Valley and the watersheds of Tolay, Stemple, Americano and Atascadero creeks (Figure 4-1).

4.1 SANTA ROSA PLAIN

The groundwater basin of the Santa Rosa Plain occurs in the elongate trough bounded by hills on the east and west. The surface of the Plain is drained by the Laguna de Santa Rosa which flows north to the Russian River. The Santa Rosa groundwater basin extends to the Russian River on the north where it merges with the groundwater basin of the lower Russian River Valley. In the south, the Santa Rosa groundwater basin is separated from the Petaluma Valley by a groundwater divide that corresponds to the low hills separating the two valleys. The reuse areas in the Santa Rosa groundwater basin include the East Rohnert Park irrigation area in the southeastern portion of the basin and the urban irrigation areas (i.e., Bennett Valley and Fountaingrove) north and east of the City of Santa Rosa.

4.1.1 Groundwater Occurrence and Movement

The groundwater basin of the Santa Rosa Plain consists of a thick sequence of unconsolidated alluvial fan deposits and alluvium underlain by consolidated deposits of the Merced Formation in the west and Petaluma Formation in the east. The Franciscan Complex forms the relatively impermeable base of the groundwater basin. The alluvial fan deposits and the Merced Formation are considered the primary water-yielding units of the basin. Although the fine-grained Petaluma Formation in general yields relatively small quantities of water, significant quantities of water can be obtained from interbedded sandstone and conglomerate. The Sonoma Volcanics on the eastern edge of the basin can locally provide small quantities of water (DWR 1982a).

The alluvium and underlying sedimentary rock sequence generally comprise a single interconnected groundwater body. Groundwater occurs under unconfined conditions in the upper alluvial deposits. Confined to semiconfined conditions occur at depths. The degree of groundwater confinement is greatest in the Merced and Petaluma formations and increases with depth.

Two faults are located on the east side of the valley in the vicinity of the East Rohnert Park agricultural irrigation area. These faults are the Sonoma State and North College faults (DWR 1982a). The displacement on these faults has caused thinning of deposits on the eastern, uplifted side of the faults. Neither fault appears to be a barrier to groundwater movement (DWR 1982a).

Groundwater flow is generally from the highlands on the east and west toward the axis of the asymmetrical basin. The axis lies on the west side of the basin and is approximately delineated by the Laguna de Santa Rosa. The primary source of groundwater recharge on the west side of the basin is the broad uplands where rainfall and water from streams infiltrate the Merced Formation. On the east side of the basin, recharge is primarily from infiltration of rainfall and seepage from streams into the coarse-grained alluvial fan deposits that fringe the hills. The fine-grained basin deposits in the central and southern portions of the basin impede the infiltration of rain and surface waters to groundwater and tend to act as a confining layer to underlying units (DWR 1982a).

Groundwater discharges to the Laguna de Santa Rosa, which flows north and discharges to the Russian River. Deeper confined groundwater probably parallels this trend and eventually flows into the Russian

River Valley groundwater basin. A significant amount of discharge also occurs as evapotranspiration in the low-lying marshy areas that flank the Laguna de Santa Rosa. Well pumpage from the Rohnert Park municipal well field accounts for a large quantity of groundwater discharge in the southern portion of the plain. Groundwater is also removed by numerous domestic and irrigation wells throughout the rural portions of the valley and upland areas.

Groundwater levels in the Santa Rosa Plain are generally shallow. Adjacent to the Laguna de Santa Rosa groundwater may occur less than 10 feet below ground surface (bgs). In the alluvial fan deposits flanking the hills the depth to groundwater may be greater than 100 feet bgs (1982a).

4.1.2 Storage / Reuse Areas

The geology in the vicinity of the East Rohnert Park irrigation area is shown in Figure 4-2. The faults show in this figure are not considered active or potential active. Figure 4-3 is a geologic cross-section of the area. Most of the irrigation area is underlain by coarse-grained alluvial fan deposits with thicknesses of up to several hundred feet. These deposits are primarily underlain by the fine-grained deposits of the Petaluma Formation and locally the Sonoma Volcanics. The Merced Formation is absent in the eastern portion of the Santa Rosa Plain. Groundwater flow is generally to the west toward the cone of depression created by the City of Rohnert Park municipal wells.

The urban irrigation areas are located on the east side of the plain and in a similar geologic setting as the East Rohnert Park irrigation area. The urban irrigation areas are primarily underlain by coarse-grained alluvial fan deposits which are in turn underlain by the fine-grained Petaluma Formation. The alluvial fan deposits thin to the north and east locally exposing the Petaluma Formation. Groundwater flow is to the west toward the Laguna de Santa Rosa.

Two groundwater monitoring wells, MW-RPM and MW-RPS, were constructed in alluvial fan deposits in the East Rohnert Park irrigation area (Figure 4-2). MW-RPM was screened from 55 to 70 feet bgs and NW-RPS was screened from 45 to 60 feet bgs. Static water levels were measured at depths of 52 and 28 feet in MW-RPM and MW-RPS, respectively. There was no significant difference between the depth of static water levels and first encountered water, indicating groundwater is under unconfined conditions.

4.2 PETALUMA VALLEY

The groundwater basin of the Petaluma Valley occurs in the southern portion of the Santa Rosa/Petaluma trough. The two groundwater basins are separated by a groundwater divide that corresponds to the low hills that divide the trough into two valleys. The Petaluma Valley extends south to San Pablo Bay where it merges with the estuarine environment of the bay. The Petaluma Valley is drained by the Petaluma River which discharges to the bay.

4.2.1 Groundwater Occurrence and Movement

The groundwater basin is considered a single aquifer which ranges from unconfined near the ground surface to confined at depth. The geologic units that comprise the Petaluma Valley groundwater basin are the same units that occur in the Santa Rosa groundwater basin. The groundwater basin of the Petaluma Valley consists of a thick sequence of unconsolidated alluvial fan deposits and alluvium underlain by consolidated deposits of the Merced Formation in the west and Petaluma Formation in the east. The Franciscan Complex forms the relatively impermeable base of the groundwater basin. Similar to the Santa Rosa basin, the alluvial fan deposits and the Merced Formation comprise the principal water yielding units. However, the Merced Formation is thinner and its occurrence is less extensive in the Petaluma Valley than in the Santa Rosa groundwater basin. Although the fine-grained Petaluma Formation in general yields relatively small quantities of water, significant quantities of water can be obtained from interbedded sandstone/conglomerate zones. The Sonoma Volcanics on the eastern edge of the basin can locally provide small quantities of water (DWR 1982b).

The alluvium and underlying sedimentary rock sequence generally comprise a single interconnected groundwater body. Groundwater occurs under unconfined conditions in the upper alluvial deposits. Confined to semiconfined conditions occur at depths. The degree of groundwater confinement is greatest in the Merced and Petaluma formations and increases with depth.

The bay mud deposits blanket portions of the Petaluma Valley adjacent to the Petaluma River. The deposits extend from the City of Petaluma to San Pablo Bay. The width and thickness of the deposits increases toward the south. Near San Pablo Bay the bay mud deposits are up to 300 feet thick (DWR 1982b).

Groundwater flow is generally from the highlands on the east and west of the valley toward the axis of the basin which is delineated by the Petaluma River. The primary source of groundwater recharge on the west side of the basin is the broad uplands where rainfall and seepage from streams infiltrate the Merced Formation. On the east side of the basin recharge is from infiltration of rainfall and streams into the coarse-grained alluvial fan deposits that fringe the hills. The fine-grained bay mud deposits in the central and southern portions of the basin impede the infiltration of rain and surface waters to groundwater and tend to act as a confining layer to the underlying units.

Groundwater discharges to the Petaluma River, which flows south and discharges to San Pablo Bay. Deeper confined groundwater probably parallels this trend. A significant amount of groundwater discharge occurs as evapotranspiration in the marshy areas adjacent to the southern portion of the Petaluma River and the tidal flats adjacent to the San Pablo Bay. Groundwater is also removed by numerous domestic and irrigation wells throughout rural portions of the valley and upland areas.

Groundwater levels in the Petaluma Valley are generally shallow. Adjacent to the lower portion of the Petaluma River and the tidal areas, the depth to groundwater can be less than 10 feet bgs. In the hills flanking the valley the depth to groundwater can be greater than 100 feet bgs (1982b).

4.2.2 Storage / Reuse Areas

Both storage and reuse areas are located within the Petaluma Valley groundwater basin. Proposed irrigation areas are located in the northwest, northeast, and southeast portions of the basin. The Adobe Road and Lakeville Hillside reservoir sites are located in the hills on the east side of the valley.

The irrigation areas consist of the North Petaluma and the Adobe Road irrigation areas in the northern portion of the valley and the Lakeville irrigation area in the southern portion. The North Petaluma irrigation area is located in the narrow northwestern portion of the valley. The Adobe Road irrigation area is located in the narrow northeastern portion of the valley which is drained by Willow Brook. The Lakeville irrigation area is located in both the southern portion of the Petaluma Valley and in the northern portion of the Tolay Creek watershed. Only the portion of the Lakeville irrigation area located in the Petaluma Valley will be discussed here. The portion located in the Tolay Creek watershed will be included in the discussion of that watershed.

The geology in the vicinity of the North Petaluma and Adobe Road irrigation areas is shown in Figure 4-4. The only fault shown on this figure which is potential active is the Tolay fault. None of the faults are considered active. Figure 4-5 is a geologic cross-section through the North Petaluma irrigation area and Figure 4-6 is a geologic cross-section through the Adobe Road irrigation area. Both irrigation areas are primarily underlain by coarse-grained alluvial fan deposits. These deposits reach thicknesses of several hundred feet. The alluvial fan deposits are underlain by the Petaluma Formation except for a portion of the North Petaluma irrigation area where the Merced Formation underlies the alluvial fan deposits (Figure 4-5).

To evaluate groundwater quality in the vicinity of the storage/reuse areas, one well was constructed in the vicinity of the North Petaluma irrigation areas, MW-NP, and one well was located in the Adobe Road irrigation area, MW-AN (Parsons ES 1996). Alluvium was approximately 30 feet thick at MW-NP. The well was screened in the Merced Formation at a depth of 100 to 115 feet bgs. First water was encountered at 45 feet, but static water levels equilibrated at 5 feet bgs indicating confined conditions in the Merced Formation. At MW-AN the alluvium was approximately 20 feet thick. The well was screened in the Petaluma Formation at depths of 50 to 65 feet bgs. First water was encountered at 45 feet bgs. Static water levels rose to 20 feet bgs indicating confined conditions.

Adobe Road Reservoir Site

The Adobe Road reservoir site is located in an unnamed tributary stream valley on the east side of the Petaluma Valley. The geology in the vicinity of the reservoir subbasin is shown on Figure 4-7. None of the faults shown on this figure are considered active or potential active. Figure 4-8 is a geologic cross-section through the subbasin. The Adobe Road reservoir site is entirely underlain by the Petaluma Formation. Just east of Adobe Road the Petaluma Formation is buried by a basinward thickening wedge of alluvial deposits.

The groundwater subbasin containing the reservoir valley is delineated in Figure 4-9. The subbasin is defined by the ridgelines of the watershed. The boundaries of the subbasin in the main valley are defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines.

The groundwater contours of the Adobe Road subbasin indicate that topography strongly controls the direction of groundwater flow in the reservoir subbasin (Figure 4-10). Groundwater flows away from the ridges toward the tributary stream. The flow pattern causes the groundwater to be isolated in the reservoir subbasin until it reaches the valley floor where it mixes with the main body of groundwater and moves down gradient.

Based on DWR well logs, numerous domestic and/or agricultural wells were identified within the groundwater subbasin downgradient from the proposed Adobe reservoir site (Figure 4-9). Most of the wells on the east side of Adobe Road appear to be screened in the Petaluma Formation. West of Adobe Road most wells are screened in the alluvial deposits although several appear to be screened in both the alluvial deposits and the Petaluma Formation. The area west of Adobe Road is currently served by a municipal water purveyor. It is unknown how many of the documented wells, if any, are currently in use.

A groundwater monitoring well, MW-AS, was installed between the Adobe Road dam site and Adobe Road as part of this investigation (Parsons ES 1996). The well was constructed in the Petaluma Formation and screened at a depth of 60 to 75 feet bgs. First water was encountered at a depth of 50 feet and static water stabilized at 35 feet bgs indicating groundwater is under confined conditions at this location.

Lakeville-Hillside Rerservoir Site

The Lakeville-Hillside reservoir site is located in the stream valley of an unnamed tributary on the east side of lower Petaluma Valley. The geology in the vicinity of the reservoir subbasin is shown on Figure 4-11. The Tolay fault which is shown on this figure is considered potential active. Figure 4-12 is a geologic cross-section through the subbasin. The Lakeville-Hillside reservoir site is entirely underlain by the Petaluma Formation. Downgradient of the reservoir site the Petaluma Formation is capped by a basinward thickening wedge of alluvial deposits. At the valley floor the alluvial deposits are overlain by the extremely fine-grained bay mud deposits.

The groundwater subbasin containing the reservoir valley is delineated in Figure 4-13. The subbasin is defined by the ridgelines of the watershed. The boundaries of the subbasin in the main valley are defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines.

Based on the groundwater contours (Figures 4.14), topography strongly controls the direction of groundwater flow in this reservoir subbasin. Groundwater flows away from the ridges toward the tributary streams. The flow pattern causes the groundwater to be isolated in reservoir subbasins until it reaches the valley floor where it mixes with the main body of groundwater and moves downgradient parallel to the Petaluma River.

In the main valley floor, the groundwater in the bay mud and alluvial deposits in the lower Petaluma Valley tends to be brackish and of low quality (DWR 198b). Potable water is generally available at moderate depths in water bearing sands and gravels of the underlying Petaluma Formation.

Based on DWR well logs, three domestic and/or agricultural wells occur within the groundwater subbasin downgradient from the Lakeville-Hillside reservoir site (Figure 4-13). All three wells are screened in the Petaluma Formation at depths of over 100 feet bgs. A project-related groundwater monitoring well, MW-LM, was installed downgradient from the dam site (Parsons ES 1996). The Petaluma Formation was encountered under alluvial deposits at a depth of 25 feet bgs. The well was drilled to a total depth of 145 feet bgs. The entire thickness of Petaluma Formation was found to be claystone and non-water yielding. The well was screened from 20 to 30 feet bgs in fine-grained deposits just above the upper contact with the Petaluma Formation. Perched water was encountered at 20 feet and the static water level stabilized at 10 feet bgs indicating confined conditions.

4.3 TOLAY CREEK WATERSHED

Tolay Creek drains a separate structural basin formed by the downfolding and faulting of the Petaluma Formation in the hills east of the Petaluma Valley. Both the surface water and groundwater discharge to the San Pablo Bay.

Based on the occurrence of a bedrock narrows in the main stream valley, the watershed can be divided into an upper reach and a lower reach. A portion of the Lakeville irrigation area is located in the upper reach of the Tolay Creek watershed. Both configurations of the Tolay reservoir site (with and without backdam) are located in the upper reach of the watershed. The Sears Point reservoir site is located in the lower reach and is just upgradient from San Pablo Bay. Except for a small tributary valley near the San Pablo Bay, the reservoir groundwater subbasin corresponds to the entire watershed of Tolay Creek.

The geology in the vicinity of the Tolay Creek is shown in Figure 4-15. The Rodgers Creek fault is considered active and the Tolay fault is considered potential active. Figure 4-16 is a geologic cross-section which extends the length of the valley. Most of the watershed is underlain by the Petaluma Formation. Isolated blocks of the Franciscan Complex and the Sonoma Volcanics occur in the hills on the west side of the watershed. The Sonoma Volcanics comprise the upper portion of the eastern hills. A small wedge of alluvial deposits occurs in the downstream portion of the stream. These deposits interfinger with the bay mud deposits adjacent to the tidally influenced area. The Rodgers Creek fault slices through the area approximately at mid elevation of the eastern hills. The Tolay Fault is located on the west side of the Tolay Creek drainage basin.

The groundwater subbasin containing the reservoir sites is delineated in Figures 4.17 and 4.18. The subbasin is defined by the ridgelines of the watershed. The boundaries of the subbasin in the flat downgradient portion are defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines.

Based on the groundwater contours (Figure 4.19), topography strongly controls the direction of groundwater flow in this reservoir subbasin. Groundwater flows away from the ridges toward the trunk stream. The flow pattern causes the groundwater to be isolated in the watershed until it discharges to San Pablo Bay. The primary hydrogeologic unit of the Tolay/Sears Point groundwater subbasin is the Petaluma Formation.

Groundwater resources are generally not developed in the Tolay/Sears Point groundwater subbasin. Based on DWR well logs, seven wells are located in this groundwater basin. All of these wells are located in the southern reach of the watershed. Three are located near the western ridge line of the basin and are screened in the Franciscan Complex at depths as great as 600 feet. Three wells are located on the southeastern ridge line and are screened in Sonoma Volcanics at depths of several hundred feet. The seventh well is located near the mouth of Tolay Creek and appears to be screened in alluvial deposits.

A project-related well boring, Boring-SP, located downstream of the Sears Point reservoir dam site, was advanced through 120 feet of Petaluma Formation claystone without encountering any water-yielding units. Since none of the wells in the areas are screened in the Petaluma Formation and no water-yielding units were encountered in Boring-SP, the presence of any significant water yielding zones within the Petaluma Formation in the area of the Tolay Creek reservoir site is currently unknown.

4.4 WATERSHEDS OF STEMPLE, AMERICANO AND ATASCADERO CREEKS

The West County storage/reuse components and the Sebastopol reuse area are located on the Mendocino Plateau, a broad dissected upland area of the Mendocino Range. This plateau contains the valleys of Americano, Stemple and Atascadero creeks. The west flowing Stemple and Americano creeks drain two adjacent watersheds. Americano Creek discharges to Estero Americano and Stemple Creek, just south of Americano Creek, discharges to Estero de San Antonio. Atascadero Creek flows north to the Russian River via Green Valley Creek.

Proposed irrigation areas are located in all three watersheds. Reservoir sites are being evaluated for three tributary valleys in the Americano Creek watershed and two tributary valleys in the Stemple Creek watershed.

4.4.1 Groundwater Occurrence and Movement

The groundwater resources of West County occur as detached groundwater basins defined by the boundaries of the watersheds (DWR 1982b). The sandstones and conglomerates of the Merced Formation make up the principal water-yielding unit in West County. The formation forms a blanket of flat-lying sediments which range in thickness from 300 to 500 feet thick over most of the plateau. Locally, the Merced Formation has been offset along several nearly vertical faults. Where the Merced Formation has been downdropped relative to the adjacent fault block, a thick sequence of the formation is preserved. On fault blocks that have been uplifted relative to adjacent blocks the Merced Formation is thin to absent. Where the Merced Formation is thin or absent, the stream deposited alluvium and the more permeable zones in the Franciscan Complex are locally capable of producing small quantities of water (Travis 1952, Cardwell 1958).

The Franciscan Complex underlies the Merced Formation along a relatively flat regional erosion surface. Where the Merced Formation is missing, the higher water-yielding zones in the Franciscan Complex (i.e., upper weathered zone, poorly cemented sandstone or fractured zones) have locally been developed to provide relatively small quantities of water. Preferential movement of groundwater is evidenced by the presence of springs emanating from surface exposures of rocks of the Franciscan Complex that can be found throughout the western uplands. Groundwater seeps sometimes occur where the contact between the Merced Formation and Franciscan Complex is exposed (Travis 1952, Cardwell 1958).

Thin deposits of alluvium occur in the axes of the stream valleys. These coarse-grained stream deposits overly the Merced Formation or, if absent, the Franciscan Complex. Locally, these deposits provide small quantities of water for domestic purposes.

Only the shallowest zones of the West County groundwater basins appear to be under unconfined conditions. In the stream valleys semiconfined to confined conditions appear to occur at relatively shallow depths (less than 100 feet). The occurrence of confined conditions at relatively shallow depths is caused by the presence of overlying fine-grained deposits and the location of recharge zones in the steep hills surrounding the valleys. The depth to groundwater is generally at moderate depths (30 to 100 feet) in hills and is shallow (10 to 20 feet) adjacent to trunk streams.

In these relatively small, deeply incised stream valleys, groundwater movement is strongly controlled by topography. Groundwater flows from the upland areas approximately perpendicular to topography along a steep gradient to the valley floor. In the main valleys, shallow groundwater discharges to the trunk streams and deeper confined groundwater flows toward the esteros on the coast or to the Russian River in the case of Atascadero Creek.

4.4.2 Storage / Reuse Areas of Americano Creek Watershed

Both irrigation and reservoir sites are located in the watershed of Americano Creek. The irrigation area comprises most of the main valley floor and adjacent slopes. Figure 4-20 shows the geology in the vicinity of the irrigation area and Figure 4-21 is a geologic cross-section of the area. The Americano Creek and Bloomfield faults are consider potential active. The northern side of the watershed is primarily underlaid by a portion of a structural block which has been downdropped between the Bloomfield fault and the Americano Creek fault. This downdropped block contains a thick sequence (up to 500 feet thick) of rocks of the Merced Formation. The Merced Formation is the primary water-yielding unit in the vicinity of the irrigation areas. The Merced Formation thins in the vicinity of Valley Ford where Americano Creek fault either dies out or possibly cuts through the valley east of Valley Ford.

Three proposed reservoir sites are located within the watershed of Americano Creek. The Valley Ford East, Carroll Road North, and Bloomfield reservoir sites are located in adjacent tributary valleys on the north side of Americano Creek. Figure 4-20 shows the geology in the vicinity of the reservoir sites and Figure 4-21 is a geologic cross-section of the area. The portion of the watershed which contains the reservoirs is on the structural block which has been downdropped between the Bloomfield fault and Americano Creek fault. All three reservoir sites are underlain by the Merced Formation.

The groundwater subbasins containing the reservoir are delineated in Figure 4-22. The subbasins are defined by the ridgelines of the watershed. The boundaries of the subbasins in the main valley are defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines.

Based on the groundwater contours (Figure 4-23), topography strongly controls the direction of groundwater flow in the tributaries to Americano Creek. Groundwater flows away from the ridges toward the tributary streams. The flow pattern causes the groundwater to be isolated in groundwater subbasins until it reaches the valley floor where it mixes with the main body of groundwater and moves downgradient to the Estero Americano.

Valley Ford East Reservoir Site

The site of the proposed Valley Ford East Reservoir is the westernmost of the three reservoir sites and is approximately one mile east of Valley Ford (Figure 4-22). There are only a few known domestic/agricultural wells located in the groundwater subbasin containing the Valley Ford East reservoir site (Figure 4-22). The wells with known screened intervals are in the Merced Formation. As part of this project, a groundwater monitoring well, MW-AL, was installed just downgradient from the proposed dam site (Parsons ES 1996). This well was constructed in the Merced Formation and screened at a depth of 75 to 90 feet bgs. Perched water was encountered in the alluvium at 40 feet. In the Merced Formation first water and static water levels were both approximately 85 feet bgs indicating that groundwater exists under unconfined conditions at this location and depth.

Carroll Road North Reservoir Site

The Carroll Road North reservoir site is located in the tributary stream valley just east of the Valley Ford reservoir site (Figure 4-22). There are a number of domestic or agricultural wells located throughout this tributary valley. Most of these wells are screened in Merced Formation, but a few are screened in both the Merced Formation and the alluvial deposits. One well appears to be screened entirely in the alluvial deposits.

Bloomfield Reservoir Site

The Bloomfield reservoir site is located in the tributary valley just east of the Carroll Road North reservoir site. There are only a few agricultural/domestic wells located within the tributary valley. A monitoring well installed as part of this project, MW-AM, is located in the main valley across from the Bloomfield reservoir site (Parsons ES 1996). This well was screened in the Merced Formation at a depth of 35 to 50 feet bgs. First water was encountered at 30 feet bgs and the static water level stabilized at 10 feet bgs. Monitoring well MW-AU is located in the tributary valley just north of the Bloomfield reservoir site. The well was constructed in the Merced Formation and screened at a depth of 35 to 50 feet bgs. The first encountered water was at 25 feet bgs and static water stabilized at ten feet bgs indicating confined conditions.

4.4.3 Storage / Reuse Areas in Stemple Creek Watershed

The geology in the vicinity of the Stemple Creek watershed is shown in Figure 4-24. Figures 4-25 and 4-26 are geologic cross-sections of the valley. Several northwest trending faults transact the watershed. The Americano Creek and Bloomfield faults are considered potential active. The southwest portion of the watershed is on the uplifted side of the Americano Creek fault. The Merced Formation is relatively thin on this fault block and the contact between the Merced Formation and the Franciscan Complex occurs at a higher elevation than on the downdropped side of the fault. The Merced Formation forms the higher portions of the ridges and is preserved as locally downdropped remnants on the valley floor. Much of the main valley floor is underlain by the Franciscan Complex with a thin veneer of alluvial deposits. In the northeastern portion of the watershed a thick deposit of the Merced Formation is preserved on the downdropped block between the Americano Creek fault and the Bloomfield fault (Figures 4-24 and 4-26). Because of the isolated, relatively thin nature of the Merced Formation in the valley floor, it appears that the alluvial deposits and the upper weathered zone of the Franciscan Complex comprise the primary pathways for groundwater movement in this watershed.

The irrigation area comprises most of the main valley floor and adjacent slopes and is primarily located on the south side of the Americano Creek fault. This side of the fault has been uplifted relative to the north side causing the contact between the Merced Formation and the Franciscan Complex to occur at a higher elevation than the adjacent watershed of Americano Creek. The Merced Formation makes up many of the surrounding hills, but in the main valley and many tributary valleys, the Franciscan Complex is exposed at ground surface.

There are two reservoir sites in the Stemple Creek watershed. The Huntley reservoir site is located in a tributary valley on the north side of the middle reach of Stemple Creek (Figure 4-27). The Two Rock reservoir site is located in the large tributary valley on the north side of the upper reach of Stemple Creek (Figure 4-28).

The groundwater subbasins of the reservoir are delineated in Figures 4-27 and 4-28. The subbasins are defined by the ridgelines of the watershed. The boundaries of the subbasins in the main valley are defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines.

Topography strongly influences the direction of groundwater flow in the tributaries of Americano Creek, as indicated by the groundwater contours for the area (Figures 4-29 and 4-30). Groundwater flows away from the ridges toward the tributary streams. The flow pattern causes the groundwater to be isolated in groundwater subbasins until it reaches the main valley floor where it mixes with the main body of groundwater and moves downgradient to the Estero de San Antonio.

Huntley Resevoir Site

The geology in the vicinity of the Huntley reservoir site and associated geologic cross-section is shown in Figures 4-24 and 4-25. The Franciscan Complex underlies the reservoir site. The ridgelines above the reservoir site are composed of the Merced Formation. A short, unnamed fault segment crosses the tributary drainage downgradient from the reservoir site. The south side of the block has been faulted down relative to the north side, causing the contact of the Merced Formation and the Franciscan Complex to occur at a lower elevation. A relatively thin patch of the Merced Formation is preserved on this downdropped block. This patch of Merced Formation has been removed by stream erosion in the vicinity of Stemple Creek, exposing the Franciscan Complex at the ground surface.

There are few wells in the groundwater subbasin of the Huntley reservoir site and only two wells have known screened intervals (Figure 4-27). One of these wells appears to be screened in the alluvium of the tributary valley, the other is screened in the Merced Formation. Groundwater monitoring well, MW-SHL, is located between the proposed dam site and Stemple Creek (Parsons ES 1996). The well was constructed in the Merced Formation and screened at a depth of 30 to 45 feet bgs. The first occurrence of water was at a depth of 30 feet bgs, but the static water level rose to five feet bgs, indicating confined conditions.

Two Rock Reservoir Site

The proposed Two Rock reservoir site is located in the upper portion of a tributary which flows south to the upper reach of Stemple Creek. The geology and groundwater flow in this tributary valley are complicated by several faults which cut through it (Figures 4-24 and 4-26). The reservoir site is entirely underlain by the Franciscan Complex. The ridgelines above the reservoir site are composed of the Merced Formation. Both the Bloomfield and Americano Creek faults cut through the tributary valley downstream of the reservoir site. Between these two faults is a downdropped block where a thick sequence of the Merced Formation has been preserved (Figure 4-26). Downstream of the Americano Creek fault the Franciscan Complex occurs at the ground surface. A thin veneer of stream alluvium extends the entire length of the tributary. For the purposes of this discussion, the tributary will be divided into three areas: the area north of the Bloomfield fault, the area between the Bloomfield and Americano Creek faults, and the area south of the Americano Creek fault.

The reservoir site is located in the upper portion of the tributary, north of the Bloomfield fault. Based on a review of DWR well logs for the area, there are no known domestic or agricultural wells in this portion of the tributary valley. As part of this investigation a shallow monitoring well, MW-STRU, was installed in this portion of the valley. MW-STRU was screened in basal gravels in the alluvium just above the contact with the Franciscan Complex at a depth of 40 bgs. Groundwater was first encountered in the basal gravels at a depth of 30 feet bgs. Static water stabilized at 15 feet bgs, indicating confined conditions.

The middle section of the Two Rock reservoir subbasin is bounded by the Bloomfield and Americano Creek faults and is underlain by at least 200 feet of the Merced Formation. Based on available information, four domestic/irrigation wells are located in this portion of the tributary valley (Figure 4-28). One well is located in a side valley which joins the tributary valley downstream of the reservoir site. This well appears to be screened in the Merced Formation. The only other well in this portion of the valley with a known screened interval appears to be screened in the alluvial deposits and the Merced Formation.

A well boring, Boring-STRM, was completed in the middle portion of the valley (Parsons ES 1996). No groundwater was encountered in the boring, which reached a total depth of 122 feet in the Merced Formation. These findings indicate that except for possibly perched water in the overlying alluvial deposits, the depth to regional groundwater in this portion of the valley is greater than 122 feet. Several factors may contribute to the greater depth to groundwater in this portion of the tributary. It is possible that the Bloomfield Fault is acting as a barrier to groundwater movement. If this is the case, groundwater would be expected to be relatively high on the upgradient side of the fault. If a groundwater barrier is present, the downgradient portion of the groundwater basin would be relatively “starved” for water. Another factor that could be contributing to these relative groundwater levels is the greater porosity and permeability of the Merced Formation relative to the upgradient Franciscan Complex. The Franciscan Complex can only absorb and transmit relatively small quantities of water. Therefore, the groundwater basin upgradient can not transmit enough water to fill this block of more permeable Merced Formation.

The third segment of the Two Rock reservoir subbasin occurs downgradient of the Americano Creek fault. This portion of the subbasin is underlain by Franciscan Complex with a thin veneer of stream alluvium. Twenty-two wells have been tentatively documented in this portion of the subbasin. The wells appear to be primarily screened in alluvium and the Franciscan Complex although a few appear to intercept isolated sections of the Merced Formation.

As part of this project, MW-STRL was installed in the lower portion of the tributary. The well was completed in the alluvium immediately above the contact with the Franciscan Complex which was encountered at a depth of 12 feet bgs. Groundwater was first encountered in this boring in basal sands and gravels at a depth of about 10 feet. The static water stabilized at a depth of 6 feet bgs indicating confined conditions.

4.4.3 Reuse Areas in Atascadero Creek Watershed

The West Sebastopol irrigation areas consists of portions of the watersheds of Atascadero and Purrington creeks. The geology in the vicinity of the irrigation area is shown in Figure 4-31. Figure 4-32 is a geologic cross-section located along the axis of Atascadero Creek. As shown in the cross-section, the area is underlain by an extremely thick section of the Merced Formation. In the stream valleys alluvial deposits form a thin veneer on the Merced Formation.

As part of this investigation, two wells were installed in this area. MW-SBS, located in the narrow valley of Purrington Creek, was constructed in siltstone and fine-grained sandstones of the Merced Formation and screened from 45 to 60 feet bgs. First water was encountered at a depth of 18 feet. Static water stabilized as 9 feet bgs, indicating confined conditions. MW-SM, located in valley of Atascadero Creek, was constructed in Merced Formation and screened from 90 to 105 feet bgs. Saturated conditions were first encountered at a depth of approximately 34 feet bgs at MW-SM. Static water stabilized at 15 feet, indicating the groundwater was under confined conditions at both locations.

5 EVALUATION OF POTENTIAL IMPACTS OF STORAGE / REUSE COMPONENTS TO GROUNDWATER

The purpose of this section is to provide an evaluation of potential impacts to groundwater from the reclaimed water storage/reuse components of the project. The two potential impacts include changes in groundwater quality and changes in existing groundwater levels. These two impacts are evaluated for the both storage (i.e., reservoir sites) and reuse (i.e., irrigation areas). Potential impacts to groundwater at the reservoir sites will be evaluated first, followed by an evaluation of potential impacts from irrigation using reclaimed water.

Nine reservoir sites are currently under consideration for this project. They are located in four major watershed areas as listed:

1. Petaluma Valley Watershed
   - Adobe Road
   - Lakeview Hillside
2. Tolay Creek Watershed
   - Tolay with backdam
   - Tolay without backdam
   - Sears Point
3. Americano Creek Watershed
   - Valley Ford East
   - Carol Road North
   - Bloomfield
4. Stemple Creek Watershed
   - Huntley
   - Two Rock

An evaluation of the potential impacts was conducted for each of the nine reservoir sites. The procedures used for this evaluation are described in this section and include construction of groundwater contour maps, calculation of average groundwater gradients, estimation of flow parameters, and modeling of reservoir water contribution to groundwater discharge beneath each site.

The evaluation of potential impacts from reservoir sites is based on the conceptual design of the reservoir sites as described in the project geotechnical report (Rust 1995) and on available information on the subsurface geology and the hydrogeologic properties in the vicinity of the sites. A detailed site-specific hydrogeologic investigation should be conducted at any reservoir site that is selected for construction. This investigation should include aquifer testing and groundwater monitoring for the site. The reservoir configuration as designed for construction purposes should be used in the final evaluation of potential impacts. Additionally, a comprehensive well survey, which would include a field check of the location and use of all wells in the vicinity of the reservoir site, should be conducted prior to reservoir construction.

The reuse areas include the following:

1. Santa Rosa Plain
   - East of Rohnert Park Agricultural Irrigation Area
   - Bennett Valley Urban Irrigation Area
   - Fountaingrove Golf Course
2. Petaluma Valley
   - North Petaluma Valley Agricultural Irrigation Area
   - Adobe Road Agricultural Irrigation Area
   - Lakeville Agricultural Irrigation Area
   - Bayflats (Baylands) Agricultural Irrigation Area
3. Tolay Creek Watershed
   - Lakeville Agricultural Irrigation Area
4. Americano Creek Watershed
   - Americano Creek Agricultural Irrigation Area
5. Stemple Creek Watershed
   - Stemple Creek Agricultural Irrigation Area
6. Atascadero Watershed
   - Sebastopol Agricultural Irrigation Area

The discussion of potential irrigation impacts includes an evaluation of potential for increases in groundwater levels and groundwater quality impacts. This evaluation incorporates the results of Questa's (1995a) study of the response of stream flows to precipitation and basin water balance analysis. Results of the City of Santa Rosa's on-going groundwater monitoring program at agricultural areas, which are currently irrigated using reclaimed water, are summarized here.

5.1 RESERVOIR CONTRIBUTIONS TO GROUNDWATER

The evaluation of the potential impacts of the reservoir sites to groundwater required estimation of the percent contribution from each reservoir site to the groundwater subbasin in which the reservoir is located.

Estimates of the contribution to groundwater from the reservoir were used to evaluate groundwater quality impacts from the reservoir sites. The standards used to evaluate the potential impacts to groundwater are based on draft amendments to the regulations (Draft Regulations) contained in Title 22 California Code of Regulations. The Draft Regulations address potential groundwater impacts of the use of reclaimed water. Currently, Title 22 does not address potential impacts to groundwater from the surface uses of reclaimed water. The Draft Regulations do not specifically address the storage of reclaimed water in reservoirs. However, the Draft Regulations do specify various restrictions for the use of reclaimed water in “spreading basins,” i.e., surface impoundments that are designed to recharge groundwater. Although the intent of the reservoir design will be for storage of reclaimed water, not groundwater recharge, there is potential for leakage to occur through the footprints of the reservoirs. Since the intent of the Draft Regulations is to protect groundwater resources, they were used as guidelines for the purpose of this evaluation. The Draft Regulations specify that levels of reclaimed water at domestic wells cannot exceed 20 percent of the water obtained from that well and that the travel time from the impoundment to a domestic well must be greater than 6 months.

In order to estimate the percent contribution for the reservoir sites, the groundwater discharge for existing conditions was compared to the estimated groundwater discharge that would result after the emplacement of the reservoir. The following procedures were used to estimate the percent contribution from the reservoirs:

- Construction of groundwater contours for the reservoir groundwater subbasin under existing conditions based on available information;
- Calculation of groundwater gradient from the midpoint of the average reservoir footprint to the main valley floor under existing and reservoir conditions;
- Estimation of appropriate values of average hydraulic conductivity for reservoir groundwater subbasins;
- Using the estimates described above to calculate groundwater discharge under current and reservoir conditions using Darcy’s Law.

These steps are described in greater detail in the following text.

5.1.1 Construction of Groundwater Contour Maps In The Vicinity of Reservoir Sites

In order to establish baseline hydrologic conditions and calculate groundwater discharge for the reservoir subbasins under existing and reservoir conditions, groundwater contours were constructed for reservoir groundwater subbasins. For the purposes of this evaluation, each groundwater subbasin that would be under the influence of the reservoirs was defined by the topographic ridgelines of the tributary valley containing the reservoir site. The boundaries of the subbasins in the main valleys were defined based on the projection of flow lines (i.e., lines perpendicular to ground water contour lines) from the ridge lines. The groundwater contour maps for the subbasins were used to aid in the definition of the lateral extent of the reservoir groundwater subbasins and in calculating the groundwater gradient from the reservoir to the main valley floor.

Available sources of water level data included the following:

Cardwell 1958: groundwater contours for the Santa Rosa Plain and Petaluma Valley for the year 1951,
DWR 1982a: groundwater contours of the Santa Rosa Plain for fall of 1960, fall 1975 and spring 1980,
DWR 1982b: groundwater contours of the Petaluma Valley for fall 1980,
DWR well logs: well logs for the project area on file with DWR,
DWR data base of groundwater levels of Sonoma County for the years 1990 to 1995,
Rust 1995: geotechnical investigation of dam sites,
Parsons 1996: groundwater monitoring in the vicinity of the sites,
USGS topographic maps.

In general, groundwater level data from wells that were representative of the upper aquifer were used in the construction of groundwater contours. Another factor incorporated into the selection of water level data was the precision with which a well was located. Data from precisely located wells were used in the construction of groundwater contours in preference to data from wells that were only approximately located. The following text describes in more detail the methodology and sources of data used in the construction of groundwater contour maps for each subbasin.

Adobe Road Reservoir Site

The groundwater subbasin that contains the Adobe Road reservoir site is shown in Figure 4-9. The groundwater contour map for this subbasin is shown in Figure 4-10.

Sources of data used in the construction of groundwater levels in the vicinity of this subbasin included DWR 1982b, DWR well logs, DWR database on groundwater monitoring, and surface water bodies (i.e., springs, and intermittent and perennial streams) as shown on topographic maps of Glen Ellen, Petaluma and Petaluma River (USGS 1980a, 1980b and 1981). Water level data generated from geotechnical borings (Rust 1995) in the vicinity of the proposed dam site and a monitoring well installed just downgradient of the reservoir site (Parsons 1996) were also used in the construction of the groundwater levels.

Lakeville Hillside Reservoir Site

The groundwater subbasin that contains the reservoir subbasin for the Lakeville Hillside reservoir site is shown in Figure 4-13. The groundwater contour map for this subbasin is shown in Figure 4-14.

Sources of data used in the construction of groundwater levels in the vicinity of this subbasin included DWR 1982b, DWR well logs, DWR database on groundwater monitoring, and surface water bodies (i.e., springs, and intermittent and perennial streams as shown on topographic map of Petaluma River (USGS 1980b). Water level data generated from geotechnical borings (Rust 1995) in the vicinity of the proposed dam site and a monitoring well installed just downgradient of the reservoir site (Parsons 1996) were also used in the construction of the groundwater levels.

Tolay and Sears Point Reservoir Sites

The Tolay and Sears Point Reservoir sites are located in the same groundwater basin, which basically corresponds to the Tolay Creek watershed. The groundwater subbasin and the groundwater contours constructed for this basin are shown in Figures 4-17 and 4-18, respectively.

Very few wells are located within this basin and the DWR reports (1982a, 1982b, and 1987) did not include coverage of this area. The construction of groundwater contours was based on data from the DWR well logs, data from geotechnical borings in the vicinity of the several dams and backdams (Rust 1995) and surface water bodies (i.e., springs, and intermittent and perennial streams) as shown on topographic maps of Petaluma River and Sears Point (USGS 1968 and 1980b).

Americano Creek Reservoir Sites

The groundwater subbasins that contain the reservoir sites are shown in Figure 4-22. The groundwater contour maps for these subbasins are shown in Figure 4-23.

There was no coverage of groundwater contours of this area in any DWR reports. DWR well logs were the primary source of water level data. Most wells in the area are relatively deep, up to 300 feet bgs, and represent confined conditions. Therefore, the groundwater contour map constructed for this area may represent potentiometric head levels. The groundwater levels in the shallow zone may be slightly lower.

In addition to the DWR well logs, water level data were obtained from geotechnical investigations in the vicinity of the dam sites (Rust 1995), project related monitoring wells (Parsons 1996) and surface water bodies (i.e., springs, and intermittent and perennial streams) as shown on topographic maps of Valley Ford and Two Rock (USGS 1971 and 1974).

Stemple Creek Reservoir Sites

The groundwater subbasins that contain the Huntley and Two Rocks reservoir sites are shown in Figures 4-27 and 4-28, respectively. The groundwater contour maps for these subbasins are shown in Figures 4-29 and 4-30.

There was no coverage of groundwater contours of this area in any DWR reports. DWR well logs were the primary source of water level data. Most of the wells in the area are relatively shallow and are screened in the alluvial or upper weathered zone of the underlying Franciscan Complex.

In addition to the DWR well logs, other water level data were obtained from geotechnical investigations in the vicinity of the dam sites (Rust 1995), project related monitoring wells (Parsons 1996) and surface water bodies (i.e., springs, and intermittent and perennial streams) as shown on topographic maps of Valley Ford and Two Rock (USGS 1971 and 1974).

5.1.2 Estimates of The Average Hydraulic Conductivity Value for The Reservoir Subbasin

The values of hydraulic conductivity (K) for the various reservoir sites were estimated based on the results of geotechnical evaluations for the reservoir sites reported by Rust (1995) (Table 5-1). To evaluate the suitability of these values to the average hydraulic conductivity of a reservoir site, these values were entered into a three-dimensional finite difference groundwater flow model, Visual Modflow (Waterloo Hydrogeologic 1995). The groundwater contours developed for existing conditions were used to calibrate the model. Hydraulic conductivities were increased when necessary to obtain a closer fit between modeled and existing conditions. In most cases the hydraulic conductivity values were slightly higher than the values reported by Rust (1995). These calibrated values of hydraulic conductivity were used in the calculations of groundwater discharge from the reservoir subbasins (Table 5-1).

Another parameter that was entered in this model for each basin was the infiltration rate. Based on their mass balance evaluation, Questa concluded that most infiltration of precipitation moved laterally along horizontal permeability contrasts and discharged into ephemeral streams and only a relatively small portion of the infiltrating precipitation recharges the deeper, regional groundwater. The infiltration rates of the calibrated groundwater models for the subbasins were substantially less than the infiltration to the shallow zone estimated by Questa. Therefore, both surface water modeling and groundwater modeling indicate that infiltration of precipitation into the regional groundwater comprises a relatively small portion of the total water inflow in these basins.

5.1.3 Estimation of Reservoir Contributions To Groundwater Discharge And Potential Impacts To Wells

The procedures used to estimate the amount of reclaimed water that could infiltrate into groundwater at each reservoir site are described in the following text. The groundwater discharge for both existing conditions and reservoir conditions is estimated by applying Darcy's equation: Q = KiA, where K = hydraulic conductivity, i = hydraulic gradient and A = cross sectional area. The groundwater discharge for each subbasin was calculated across the line where the groundwater flows into the main valley floor of the watershed.

For existing conditions, the groundwater gradient (i) was estimated measuring the distance and change in the groundwater elevation from the midpoint of the average annual reservoir footprint to the point where the subbasin merges with the downstream main valley or surface water body. The change in groundwater levels was estimated using groundwater contours that were constructed for existing conditions at each reservoir subbasin. The cross-sectional area of each subbasin (A) was measured where the subbasin flows into the main valley or the trunk stream. The cross-section area was based on the width of the subbasin and the estimated thickness of the aquifer. The estimated thickness of the aquifer was based on either the known thickness of the hydrogeologic units or, in cases where the total thickness was unknown, on the deepest well in the vicinity of reservoir. The values of hydraulic conductivity (K) estimated previously were used in these calculations. The parameters used and the results of these calculations are shown in Table 5-1.

To calculate groundwater discharge after the construction of the reservoir, the same hydraulic conductivity and cross-sectional area were used as under existing conditions. The gradient was calculated using the same distance that was used for existing conditions (the midpoint of the average length of the reservoir footprint). The only variable that was changed was the height of the groundwater level at the reservoir site. For the purpose of this evaluation, the average height of the reservoir was used as the maximum groundwater level in the upgradient direction. The average height of the reservoir was used as the upgradient water level because it was assumed that saturated conditions under the reservoir would extend to the groundwater, allowing hydraulic connection between the reservoir and regional groundwater. This assumption appears reasonable since the groundwater levels are generally relatively shallow in the vicinity of the proposed reservoirs. The same downgradient water level estimated under existing conditions was used in the reservoir analysis. The parameters used and the results of these calculations are reported in Table 5-1.

The difference between the groundwater discharge from the subbasin for existing and reservoir conditions was assumed to be the average annual contribution to groundwater from the reservoir. Because the groundwater velocity is relatively low, it would take several years to reach these equilibrium conditions. Estimates of the average linear velocity indicate that the highest average rate of horizontal movement for any of the reservoir sites would be less than four feet per year. The vertical movement would be significantly slower since vertical hydraulic conductivity is commonly an order of magnitude smaller than horizontal hydraulic conductivity (Freeze and Cherry 1979).

Because most of the subbasins containing the proposed reservoirs are small relative to the size of the reservoir, the reservoir's contribution would make up a significant proportion of the groundwater flow in that subbasin. The annual average volume of water that would infiltrate to groundwater from each subbasin is reported in Table 5-2.

The calculated reservoir's percent contribution ranges from 9 to 44 percent for the various subbasins. The percentage was calculated at the point where the groundwater from reservoir subbasin flows into the main valley of the watershed. Some of the factors that affected the amount of the reservoir's contribution to groundwater discharge include the size of the reservoir relative to the size of the reservoir subbasin, the average height of the water level in the reservoir relative to existing water levels, the distance to the main stream valley, and the estimated value of hydraulic conductivity.

If the contribution from the reservoir was estimated to be greater than 20 percent across the area where groundwater from the subbasin flows into the main valley groundwater basin, then the dilution effects from groundwater upgradient of the reservoir subbasin were estimated. A contribution of more than 20 percent was used as the triggering point for further dilution modeling based on the Draft Regulations for spreading basins. As a conservative assumption, only the groundwater discharge from the subbasin adjacent to and directly upgradient of the reservoir was used in calculating dilution effects from upgradient flow. It is likely that the actual upgradient contribution would be proportional to the size of the entire upgradient watershed and the dilution would actually be larger than estimated here. If the contribution from the upgradient subbasin was found to dilute the contribution from the reservoir to 20 percent or less, then the boundary of the 20 percent contribution zone was shown to include that portion of the main valley adjacent to the reservoir subbasin and downgradient of the upstream basin. It is that portion of the main valley where the reservoir contribution would be diluted by the upstream basin to a level below 20 percent. Calculations of the percent contribution from the reservoirs and the dilution steps are shown in Table 5-2.

In cases where the reservoir's contribution after the inclusion of upgradient dilution effects was still greater than 20 percent, it was assumed that the groundwater discharge moving into the downgradient section of the main valley remained above the 20 percent contribution level. In these cases the groundwater discharge from the adjacent downgradient subbasin was included in the dilution calculations. In no case was the value of the reservoir contribution substantially greater than 20 percent after the inclusion of both upgradient and downgradient dilution effects. The boundary of the 20 percent contribution zone was shown to include that portion of the main stream valley directly downgradient of the reservoir subbasin. A discussion of the contribution and dilution for each reservoir subbasin is included in the following text.

Wells in the vicinity of the proposed reservoir sites were identified and located on the basis of three sources of information. The primary source of information was the California Department of Water Resources (DWR) file of well logs. Well drillers are required to submit well logs to DWR upon completion of any well in California. For the purposes of this project, DWR well logs in the vicinity of the proposed reservoir sites were obtained and compiled into a database. Although the DWR compilation of well logs is the most complete source of information on wells, some wells, especially relatively old wells, may not have associated logs on file with DWR. Another potential problem with the DWR compilation of well logs is that sometimes wells are poorly or inaccurately located. In cases where additional information such as street addresses or parcel numbers were available, the well locations were adjusted appropriately. In some areas where access was available, wells were located based on visual evidence (i.e., water tower) or anecdotal information from residents. Wells located based on visual evidence are designated on the relevant maps as “Site Reconnaissance” wells. A third source of well locations was the groundwater monitoring program conducted in 1989 and 1990 (CH2M Hill 1990). This source provided information only on wells in the Stemple Creek and Americano Creek watersheds. Some of these wells may represent duplicates of other wells since DWR well logs could not always be precisely located.

Petaluma Watershed

Evaluation of both the Adobe Road and Lakeville Hillside reservoir sites indicated that there could be reservoir contribution in excess of 20 percent as measured along the line where groundwater from the reservoir subbasin flows into the main valley floor, approximately at the break in slope (Table 5-2, Figures 5-1 and 5-2).

In the case of the Adobe Road reservoir site, the contribution along that line was estimated to be approximately 40 percent. Dilution effects from the subbasin immediately upgradient of the reservoir subbasin reduced that contribution to less than 30 percent. Inclusion of dilution effects from the subbasin immediately downgradient of the reservoir subbasin reduced the reservoir contribution to approximately 20 percent (21 percent).

Twenty wells have been documented in the Adobe Road subbasin. Four of these wells are located on the upgradient boundary of the reservoir and appear to be outside of the reservoir’s influence. Six wells are located just east of Adobe Road. Available information indicates that currently the area west of Adobe Road is served by municipal water from the City of Petaluma. It is unknown whether these wells are still in service.

Most of the wells east of Adobe Road are at least partially screened in the Petaluma Formation and could be impacted by the reservoir. The wells east of Adobe Road are screened in the alluvial deposits and would probably not be affected by the reservoir.

The contribution from the proposed reservoir site at Lakeville Hillside was estimated to be 30 percent at the main valley floor. Dilution from the subbasin immediately upgradient reduced the total contribution from the reservoir to less than 20 percent (Table 5-2).

Four wells have been located in the Lakeville Hillside subbasin. All of the wells appear to be located downgradient and within the greater than 20 percent contribution zone from the reservoir. At least three of these wells are screened in the Petaluma Formation and could be impacted by the reservoir sites. The screened interval of the fourth well is unknown.

Tolay Creek Watershed

Because of the large size of the groundwater basin relative to the sizes of the reservoir sites, the estimated percent contribution from each of the reservoir sites (the two configurations of Tolay Creek reservoir and the Sears Point reservoir) is significantly less than 20 percent where the basin discharges into the tidal flats (Table 5-2). The line along which the percent contribution was calculated is shown in Figures 5-3 and 5-4. The estimated percent contribution across this line is shown in Table 5-2.

All proposed reservoir configurations of the reservoirs for this watershed are primarily underlain by Petaluma Formation. It is unlikely that leakage from the reservoir would have significant impacts to wells located on the other geologic units in the watershed (i.e., Franciscan Complex, Sonoma Volcanics, and the alluvial deposits).

The only available source of information on wells in this watershed is the existing DWR well logs. Based on this source of information there are seven wells in the watershed. Six of these wells are located on steep slopes near the boundary of the watershed. At these locations the wells are upgradient of the reservoirs and appear to be outside the influence of the proposed reservoirs for this watershed. The wells on the west side of the watershed are screened in Franciscan Complex and are unlikely to be affected by the reservoir sites. The wells on the eastern side of the watershed appear to be screened in the Sonoma Volcanics and are also unlikely to be affected by the reservoir sites. Only one well is located downgradient of the reservoir sites. It was estimated that the well would receive significantly less than 20 percent contribution from any of the reservoirs proposed for this watershed. This well is screened in the alluvial deposits and would probably not receive input from the reservoir sites.

Americano Creek Watershed

The percent contribution and the dilution calculations for the reservoir sites in Americano Creek are shown in Table 5-2. The contribution from Valley Ford East is expected to be less than 20 percent by the time the groundwater reaches the edge of the main valley floor (Figure 5-5). The estimated contributions from proposed reservoirs at Carroll Road North and Bloomfield are approximately 30 and 45 percent, respectively, at the valley floor. The inclusion of dilution effects from the subbasin upgradient of Carroll Road North (i.e., Bloomfield subbasin) reduced the Carroll Road North reservoir's contribution to below 20 percent (Figure 5-6). In the case of the Bloomfield reservoir site, the inclusion of the upgradient subbasin dilution reduced the reservoir's contribution to slightly above 20 percent (23 percent). Therefore, the downgradient groundwater discharge (Carroll Road North) was included in the dilution which reduced the contribution to less than 20 percent (Figure 5-7).

Since all three of the reservoir sites are located on the Merced Formation, it is anticipated that groundwater contribution from the reservoir sites would be confined to that formation. Wells located in the reservoir subbasins in Americano Creek Watershed are shown on Figure 5-5. Available information (DWR well logs and CH2M Hill 1990) indicates that wells are primarily screened in the Merced Formation and occasionally partially screened in the Franciscan Complex. None of the wells in the subbasins appear to be screened in alluvial deposits. Since all of the proposed reservoirs would be located on the Merced Formation, all of the downgradient wells within the greater than 20 percent contribution zone could be affected by the reservoirs. The largest number of wells are located in the Carroll Road Reservoir subbasin.

Based on available information there are five wells located in the subbasin of the Valley Ford East reservoir site. One of these wells in located in the footprint of the proposed reservoir. The remaining wells are located at the downgradient reaches of the subbasin and are near the edge of the 20 percent contribution line (Figure 5-5).

Seventeen identified wells are located in the reservoir subbasin of Carroll Road North. Three of these wells are located in the footprint of the proposed reservoir and the remaining wells are located downgradient of the reservoir. All of the downgradient wells are within the estimated limits of greater than 20 percent contribution from the reservoir (Figure 5-6).

Three wells have been documented in the Bloomfield reservoir subbasin. All of these wells are located near the downstream extent of the subbasin and within the boundary of the greater than 20 percent contribution zone. The downgradient extent of the 20 percent contribution line from the Bloomfield reservoir site is estimated to be located at the downstream boundary of the Carroll Road North subbasin (Figure 5-7). There is also a cluster of domestic wells in the main valley located just upgradient from the Bloomfield reservoir subbasin. Since the groundwater levels in the main valley are not expected to be altered by the reservoir site, these wells would remain upgradient and outside of the influence of the reservoir.

Stemple Creek Watershed

Evaluation of both proposed reservoir sites in the Stemple Creek watershed indicated that contributions of more than 20 percent to groundwater could exist at the line where groundwater from the reservoir subbasin flows into the main valley floor (Table 5-2). At the Huntley reservoir site, inclusion of the groundwater discharge from the subbasin upgradient of the reservoir subbasin reduced the percent contribution from the reservoir to less than 20 percent (Figure 5-8). Since the Two Rock reservoir site is located near the upstream terminus of the watershed, all of the watershed upgradient of the Two Rock subbasin was used to estimate the amount of dilution in the main valley. Inclusion of this dilution reduced the contribution to nearly 20 percent (21 percent) downgradient of the subbasin (Figure 5-9).

Both Two Rock and Huntley reservoir sites are underlain by rocks of the Franciscan Complex. It is anticipated that the leakage from the reservoir would be confined to that unit and would have little or no impact to wells located in overlying units of Merced Formation and the alluvial deposits.

Seven wells have been documented in the Huntley reservoir subbasin (Figure 5-8). One of these wells is located in the footprint of the reservoir and appears to be screened in alluvium. Five of the wells are located downgradient and within the greater than 20 percent contribution zone from the reservoir. Information on the screened interval of the wells was not available. If these wells are screened in the Franciscan Complex. they could be impacted by the reservoir.

Twenty-six wells have been documented in the Two Rock reservoir subbasin (Figure 5-9). One of these wells is tentatively located in a tributary valley and appears to be outside the influence of the reservoir. The remaining wells are located in downgradient locations and are within the area of greater than 20 percent contribution from the reservoir.

Based on a review of the DWR well logs, some of the downgradient wells of the Two Rock reservoir site are screened exclusively in the alluvial deposits, but several appear to be screened in both alluvium and the Franciscan Complex. The reservoir could contribute to flow in the wells screened at least partially in the Franciscan Complex.

5.2 CALCULATION OF 6-MONTH TRAVEL TIME FROM RESERVOIR SITES

A second criterion selected for the evaluation of groundwater impacts was based on the Draft Title 22 regulations pertaining to spreading basins. The Draft Regulations specify a minimum travel time of 6 months before reclaimed water from a surface impoundment reaches a domestic well. The travel time was calculated using the equation for the average linear velocity (Table 5-3). As stated previously, the calculated average linear velocity was found to be relatively slow at all reservoir sites. The maximum average distance of flow over one year was less than 3 feet. The maximum average distance of flow over six months was approximately 1.5 feet. Therefore, the estimated groundwater flow rates at all of the proposed reservoir sites yield travel times much longer than specified by the Draft Regulation for this criterion.

5.3 CALCULATION OF DAM SEEPAGE

Questa (1995a) conducted an evaluation of the potential surface water impacts from irrigation using reclaimed water. The focus of the study was the watersheds of Americano, Stemple and Tolay creeks. Based on their evaluation of the response of those streams to precipitation and a water balance analysis, Questa concluded that most infiltration of precipitation moved laterally along horizontal permeability contrasts and discharged into ephemeral streams. The permeability contrast that inhibits deep infiltration occurs at a very shallow depth and is the result of a thin zone of relatively high permeability alluvium and/or surficial weathered zone in the rocks against the underlying unweathered rocks with significantly lower permeability with relatively minor infiltration to the regional or "deep" groundwater. This shallow, lateral flow is also referred to as interflow or throughflow and is not part of the regional groundwater (Shelby 1982 and Fetter 1994). The groundwater flow through this shallow zone discharges to surface water and represents a separate flow regime than the infiltration through the footprint of the dam that was used to calculate the reservoirs contribution to the regional groundwater.

Shallow lateral flow would be largely intercepted by the construction of a dam which would require the removal or sealing of the shallow zone. The only contribution to the streams through this zone would be through seepage through and around the dam itself.

In order to evaluate volume of seepage through this pathway after dam construction, a flow net analysis was performed for each of the nine dams. The flow nets were constructed according to the methodology contained in Cedergren (1989). The flow nets were based on the conceptual dam designs contained in Rust (1995). The values of hydraulic conductivity for the dam shell, foundation and core were the values reported by Rust (1995). Since these flow net analyses were based on preliminary, conceptual dam configurations, they are only estimates of seepage and should not be used for design purposes. The results of the analysis are shown in Table 5-5. These estimates of flow will be used in the evaluation of reservoir impacts on surface water bodies (Merritt Smith Consulting 1996).

5.4 POTENTIAL CHANGES IN GROUNDWATER LEVELS UNDER POST RESERVOIR CONDITIONS

A two-dimensional analytical model, WinFlow (Environmental Simulations, Inc. 1995), was used to determine the potential impact of the reservoirs on groundwater levels. The model was selected because reservoir leakage could be readily replicated through the use of the "pond" feature of this model. The groundwater gradient in the vicinity of the reservoir under existing conditions was used to establish baseline conditions. The same hydraulic parameters (i.e., hydraulic conductivity, storativity, porosity and aquifer thickness) that were used in the analysis of reservoir contribution were used in this modeling. The average size of the reservoir was used in constructing the "pond" for each reservoir.

Based on this evaluation it appears that there would be a moderate rise of groundwater within the vicinity of the reservoirs (Table 5-4). The maximum rise in potentiometric head was eighteen feet at the Adobe Road reservoir site and was located near the center of the reservoir footprint. At all of the reservoir sites the groundwater mound would decrease radially away from the center of the reservoir footprint.

The Project geotechnical report (Rust 1995) was used to determine the depth to groundwater at the dam site location under existing conditions (Table 5-4). This information was not available for the Two Rock dam site. A Project monitoring well, MW-STRU, is located near the dam site and water level data from that well was used to determine the depth to groundwater under existing conditions.

Assuming that the entire increase in the potentiometric head at each of the reservoir sites is translated into equivalent increase in the groundwater level, the depth to groundwater downgradient of the dam could rise to less than 6 feet below the ground surface at four of the reservoir sites. These four reservoir sites consist of Valley Ford East, Carroll Road North, and Bloomfield in the Americano Creek Watershed and the Huntley reservoir site in the Stemple Creek watershed. However, based on the results of the Project monitoring well installations (Parsons ES 1996), groundwater in the vicinity of these reservoir sites exists under confined conditions. Therefore, the increases in the potentiometric head would result in somewhat lower increases in the groundwater levels.

The other potential effect of the reservoirs on groundwater levels is a decrease in groundwater levels downgradient of the reservoir sites. The shallow lateral flow or "interflow" described in Section 5.3 would be cut off by the construction of the dam. The shallow flow occurs in the surfical alluvium or the upper weathered zone of the basement rocks (upper 12 feet). Shallow lateral flow is thought to occur at all of the reservoir sites, although it is not considered to be part of the regional groundwater flow regime. Since this shallow flow would be cut off by the dam construction, it would result in a substantial reduction of this kind of flow in the areas downgradient of the reservoirs. This reduction in lateral flow could affect the shallow or perched water immediately downgradient of the site. This reduction would not be expected to extend into the main stream valleys.

5.5 WATER QUALITY IMPACTS FROM RESERVOIR SITES

An evaluation of water quality in the vicinity of the reservoir sites is included in the *Well Installation and Groundwater Monitoring Results* (Parsons ES 1996). This evaluation is based on the results of the groundwater monitoring in the vicinity of the storage/reuse areas, which was conducted as part of this project. The report includes a comparison of groundwater quality to drinking water standards and to reclaimed water quality. Drinking water standards, known as primary and secondary maximum contaminant levels (MCLs), are the maximum permissible concentrations of contaminants in water delivered to a user of a public water supply system. Primary MCLs are enforceable standards that are set to protect human health and are feasible to obtain with current technology. Secondary MCLs are set to meet aesthetic considerations, such as appearance (color and clarity), odor and taste. Exceedance of secondary MCLs may be objectionable to a number of people, but is not generally hazardous to health.

Nitrate is the only constituent in reclaimed water from Laguna Waste Water Treatment Plant (Treatment Plant) with an average concentration that exceeds its MCL. The MCL for nitrate is 10 milligrams/liter (mg/L). The average detected level of nitrate in reclaimed water is 16.3 mg/L (Merritt Smith Consulting 1996). The average level expected after the completion of upgrades to the Treatment Plant is 14.6 mg/L or lower. The average concentrations of all other common anions are below their respective MCLs.

In general, concentrations of some common anions (i.e., nitrate, nitrite, fluoride, and phosphate) and total dissolved solids (TDS) were found to be higher in reclaimed water than in groundwater. Exceptions to this generalization occurred in the Stemple Creek watershed and in the vicinity of Lakeville Hillside where the concentration of TDS and nitrate in groundwater were found to exceed their respective MCLs. Exceedance of the MCL for TDS occurred in three of the four Stemple Creek monitoring wells. The MCL for TDS is 500 mg/L and the exceedances ranged from 930 to 3,530 mg/L. The average concentration of TDS in reclaimed water is 444 mg/L. The MCL for nitrate was exceeded in two of these wells with detected concentrations of 33 and 72 mg/L. At Lakeville Hillside two of the three wells exceeded the MCL for TDS with concentrations ranging from 830 to 980 mg/L. One of these wells also exceeded the MCL for nitrate with a detected concentration of 12 mg/L (Parsons ES 1996).

The average concentrations of metals detected in reclaimed water are below all the respective MCLs. Analysis of reclaimed water for iron and manganese has been conducted on one occasion. Neither iron or manganese were detected at or above their respective detection limit at that time. Based on the very limited data available, it appears that the levels of iron and manganese in reclaimed water are below their respective secondary MCLs. Several metals were detected in excess of the MCLs in monitoring wells in the storage/reuse areas (Parsons ES 1996). Aluminum exceeded a primary MCL in one of the three wells in Petaluma Valley and one of the two wells in the area east of Rohnert Park. Many of the wells in the storage/reuse areas exceeded the secondary MCLs for iron and manganese. Elevated levels of iron and manganese have been found in many wells throughout Sonoma County (DWR 1975, 1982a and 1982b). Exceedance of the MCL for both of these metals was detected in the monitoring wells installed in the area east of Rohnert Park, Petaluma Valley, Lakeville Hillside, and the watersheds of Americano and Stemple creeks. In the area west of Sebastopol, manganese was the only metal in excess of its MCL.

Fecal coliform is another constituent of concern in reclaimed water. Fecal coliform is commonly used as “an indicator organism,” i.e., an microorganism whose presence indicates fecal contamination from warm-blooded animals. Indicator organisms may be associated with pathogens, but do not necessarily cause disease themselves. In general, indicator organisms are present in greater numbers than pathogenic organisms, have greater survival time than pathogens, and their detection is more reliable and less time-consuming than for pathogens.

Although the average detected level of total coliform in reclaimed water has been below the detection limit of 2.2 most probable number (MPN)/100 milliliter (ml), the North Coast Region Water Quality Control Plan (Basin Plan) (California Regional Quality Control Board [RWQCB] 1994) contains a water quality objective of 1.1 MPN/100 ml for fecal coliform. The MCL for total coliform under the National Primary Drinking Water Regulations are based on the presence/absence of total coliforms in samples. Community water treatment systems are required to obtain routine total coliform samples at intervals during each month with the number of monthly samples based on the population served. When less than 40 samples per month are required, no more than one sample per month may be positive for total coliform. When 40 or more samples per month are required, no more than 5 percent of all monthly samples may be positive for total coliform (U.S. Environmental Protection Agency [USEPA] 1989). A positive sample for total coliform would be one or more MPL/100 ml. The determination of weather total coliform in reclaimed water is above drinking water standards cannot be made because the detection limit of the total coliform analysis performed on reclaimed water is greater than one (i.e., 2.2 MPL/100 ml).

All of the wells installed as part of this investigation were in exceedance of the MCL for total coliform (Parsons ES 1996). This may be the result of the shallow depth of most of the wells and the land use practices in the vicinity of the wells. Groundwater contamination by coliform is commonly considered to be the result of infiltration of surface water which has been contaminated from cattle, poultry or other animals. Bacteria, including coliform, are removed through filtration though the soil or formation material. There is generally greater filtration of bacteria over shorter distances in fine-grained material than in coarse-grained material (Ward, Giger and McCarty 1985). Studies of wastewater application reported by the USEPA (1981) indicated that fecal coliforms are normally removed after the wastewater has percolated five feet through the soil (USEPA 1981). Therefore, contamination is generally confined to shallow groundwater. Poorly constructed wells may allow contamination to reach deep zones.

Storage of the reclaimed water in reservoirs may cause some changes in the concentrations of the some constituents (Horne 1990). If thermal stratification takes place in the reservoirs, the water at the bottom of the reservoir will have a low dissolved oxygen content. Other problems could include elevated turbidity, hydrogen sulfide, pH and ammonia. While these conditions may have potential to adversely affect aquatic life in surface waters, their potential to affect groundwater is minimal because of their low mobility in groundwater and the filtering properties of the formation or, in the case of low dissolved oxygen, exposure to air.

Although there is a potential reduction in nitrate levels through thermal stratification, input from birds and animals could contribute to a slight increase. However, monitoring of water stored at the Laguna Treatment Plant ponds has not shown an increase in nitrate. Levels of nitrate in the pond water have either remained at the approximately 16.3 mg/L or have decreased slightly. Therefore, no overall increase in nitrate levels is expected from storage in reservoirs.

Based on the above analysis, it appears that nitrate is the only constituent in reclaimed water that has the potential to adversely affect groundwater at the reservoir sites. Nitrate is absorbed by plants and is readily immobilized in the unsaturated zone (USEPA 1981). However, once in the groundwater, nitrate is relatively stable and mobile. The primary mechanism for the reduction in nitrate levels in groundwater is through dilution by groundwater containing lower concentrations of nitrate. Therefore, if saturation is continuous from the bottom of the reservoir to the groundwater table, and future upgrades to the Treatment Plant do not lower the nitrate concentration in reclaimed water to below the MCL, there is potential for nitrate concentrations to increase in groundwater downgradient of the reservoir sites.

5.6 POTENTIAL IMPACTS OF IRRIGATION ON GROUNDWATER

The purpose of the following discussion is to evaluate the potential of reclaimed water used for irrigation purposes to infiltrate into groundwater. The potential impacts of infiltration of reclaimed water to groundwater are an increase in groundwater levels and/or degradation of groundwater quality. Potential infiltration to groundwater would be minimized by the implementation of the proposed Irrigation Management Plan (Peters et al. 1995).

5.6.1 West County, Tolay Creek Watershed and Lakeville Irrigation Area

Questa (1995a) conducted an evaluation of the potential surface water impacts from irrigation using reclaimed water. The focus of the study was the watersheds of Americano, Stemple and Tolay creeks. Based on their evaluation of the response of those streams to precipitation and water balance analyses, Questa concluded that most infiltration moves laterally along horizontal permeability contrasts and discharges into ephemeral streams. The permeability contrast that inhibits deep infiltration occurs at a very shallow depth and is the result of a thin zone of relatively high permeability alluvium and/or surficial weathered zone in the rocks against the underlying unweathered rocks with significantly lower permeability. Questa concluded that infiltration of reclaimed water would also follow this pathway to the streams as “shallow groundwater return flow” and little if any of the irrigated water would infiltrate to the regional or “deep” groundwater. This type of flow occurs above the regional groundwater and is also referred to as interflow or throughflow (Shelby 1982 and Fetter 1994).

Although Questa did not specifically address the West Sebastopol irrigation area, the subsurface conditions are similar to the Americano Creek watershed (i.e., horizontal beds of the Merced Formation overlain by thin deposits of alluvium along stream valleys). Because of these similar subsurface conditions, infiltrating waters would be expected to flow laterally as interflow above the regional groundwater. Irrigation in areas with this type of lateral flow regime would not be expected to contribute to an increase in regional groundwater levels. Because of the proposed irrigation management practices and the wide dispersal of the irrigation sites in the Sebastopol area, Questa concluded that surface water would not be affected by irrigation.

The Lakeville irrigation area consists of approximately 5,700 acres which are largely located on a portion of hillslopes on the southeast edge of the Petaluma Valley and the northern portion of the Tolay Creek watershed. Approximately two thirds of the 5,700 acres are located in the Petaluma Valley watershed and approximately one third in the Tolay Creek watershed. Both areas are primarily underlain by the Petaluma Formation. In the Petaluma Valley portion of the irrigation area, the depth to groundwater ranges from over 100 feet bgs near the ridge tops to ten feet bgs near the Petaluma River. In the Tolay Creek portion of the irrigation area, the depth to groundwater ranges from 100 feet bgs along the ridges to approximately 20 feet bgs in the valley of Tolay Creek.

Questa (1995a) concluded that irrigation in the Tolay Creek watershed would result in horizontal subsurface flow that would discharge to the streams with little or no infiltration to groundwater. Most of the proposed irrigation area located in Petaluma Valley is located on gentle to moderate slopes underlain by the Petaluma Formation. The Lakeville irrigation area is underlain by the same formation as the Tolay Creek watershed and infiltrating water will, therefore, tend to discharge to surface waters. However, irrigation is not expected to discharge to surface water because of the irrigation management practices that are specified in the project description (see Section 2.2 of the EIR/EIS) and because of the wide dispersal of the irrigation sites in the Lakeville irrigation area (Questa 1995a).

5.6.2 Santa Rosa Valley and Petaluma Valley

In their evaluation, Questa (1995a) found that subsurface conditions in the irrigation areas of East Rohnert Park, north Petaluma Valley and the Baylands were not equivalent to those of West County and the Tolay Creek watershed. In these South County project areas, there is the potential for irrigation water to infiltrate to regional groundwater. Infiltration was considered possible in the East Rohnert Park and North Petaluma Valley irrigation areas based on the high permeability of the underlying alluvial fan deposits and the lack of lateral extensive zones of low permeability that would promote the shallow lateral migration of infiltrated water to streams. In the case of the Baylands irrigation area, the potential to infiltrate to groundwater is the result of the extremely shallow depth to groundwater (approximately 5 feet).

The subsurface conditions and potential groundwater impacts for each of these irrigation areas are discussed in more detail in the following sections.

Santa Rosa Plain

Approximately 3,000 acres in an area east of Rohnert Park comprise a possible agricultural irrigation area. This area is primarily underlain by several hundred feet of alluvial fan deposits (Figures 4-2 and 4-3). The depth to groundwater ranges from 50 to 100 feet (DWR 1982a). Questa (1995a) stated that stream gauge records indicated that Copeland Creek, located in this irrigation area, was a "losing stream" implying that infiltration from surface water to groundwater was occurring and that irrigation waters could migrate into the regional groundwater. This potential infiltration is consistent with the relative coarse-grained nature of the alluvial fan deposits and lack of laterally extensive fine-grained units that would impede vertical movement of water.

The proposed urban irrigation component includes approximately 230 acres in the vicinity of Fountaingrove Golf Course just north of the City of Santa Rosa and 350 acres in the vicinity of Bennett Valley just east of the City of Santa Rosa. The geologic setting and groundwater conditions in these areas are similar to those east of Rohnert Park.

The potential to increase groundwater levels in the vicinity of the irrigation areas was evaluated using a two-dimensional analytical model, WinFlow (Environmental Simulations, Inc. 1995). The irrigation infiltration rate estimated by Questa (1995a) for another portion of South County, Tolay Creek watershed, was applied to the entire acreage proposed for irrigation. The number of acres that will actually be available for irrigation will probably be significantly less than this amount. Applying average annual infiltration under steady state conditions, the model predicted that regional groundwater levels would rise no more than 5 feet in the Santa Rosa Plain irrigation areas. Based on the conservative nature of the assumptions used (i.e., the total entire area would be irrigated), increases in groundwater levels in the vicinity of this irrigation area would probably be negligible.

North Petaluma Valley

Two areas in the North Petaluma Valley are being evaluated for the possible use of reclaimed water for irrigation. These areas are referred to as the Petaluma North and Adobe Road irrigation areas. Petaluma North irrigation area consists of approximately 900 acres located in the northwestern portion of the Petaluma Valley (Figures 4-4, 4-5 and 4-6). The area is primarily underlain by relatively thick deposits of coarse-grained alluvial fan deposits. Groundwater occurs at approximately 20 feet bgs.

The Adobe Road irrigation area consists of approximately 2,500 acres located in the northeastern portion of the Petaluma Valley (Figures 4-4 and 4-6). The irrigation area is underlain by several hundred feet of coarse-grained alluvial fan deposits. The groundwater occurs approximately 20 feet bgs.

The potential to increase groundwater levels in the vicinity of the irrigation areas was evaluated using a two-dimensional analytical model, WinFlow (Environmental Simulations, Inc. 1995). The irrigation infiltration rates estimated by Questa (1995a) for the Tolay Creek watershed, were applied to the entire acreage for both areas. The number of acres that will actually be available for irrigation will probably be significantly less than this amount. Applying average annual infiltration under steady state conditions, the model predicted that regional groundwater levels would rise less than 5 feet. Based on the conservative nature of the assumptions used (i.e., the total entire area would be irrigated), increases in groundwater levels in the vicinity of this irrigation area would probably be negligible.

5.6.3 Baylands Irrigation Area

The Baylands area is primarily underlain by the bay mud deposits, a very fine-grained unit which has very low permeability. Bay mud deposits are up to several hundred feet thick in this area (DWR 1982b). The regional groundwater occurring in bay mud deposits is brackish to highly saline and are not considered a source of potable water (DWR 1975). Shallow groundwater quality may vary from the regional quality.

Questa (1995a) found that the Bayland areas along the lower Petaluma River and adjacent to the San Pablo Bay do not drain or discharge naturally to local streams or the bay. These near-tidal areas require groundwater pumping to maintain the water table at a suitable depth for agriculture, approximately 5 feet bgs. Groundwater in the bay mud deposits is commonly brackish. The application of irrigation water could contribute to a rise in an already very shallow groundwater which would require increased pumping. Because of the very shallow depth of groundwater and its brackish nature, even a small increase in groundwater level could adversely affect agriculture. The application of irrigation water should be carefully managed and appropriate drainage practices applied to prevent increases in groundwater levels as specified in Section 2 of the EIR/EIS.

5.6.4 Water Quality Impacts

As discussed previously, nitrate is the only constituent in reclaimed water that exceeds an MCL. Therefore, nitrate is the primary constituent of concern that could impact groundwater quality. Currently, the mean concentration of nitrate in reclaimed water is 16.3 mg/L. The MCL for nitrate as nitrogen is 10 mg/L. In order to evaluate the potential impacts of current nitrate levels in reclaimed water, procedures in the EPA Process Design Manual for Land Treatment of Municipal Water (USEPA 1981) were applied (Questa 1995b). This analysis indicated that current nitrate concentrations are less than the nitrate requirements of crops. This estimate is based on the assumption that all available nitrogen is utilized efficiently by the crop, and none of the nitrogen migrates through the root zone to the underlying groundwater until the crop demand is satisfied. Since this assumption is not conservative in terms of potential impacts to groundwater, Questa (1995b) calculated the nitrogen input to groundwater based on the conservative assumption that 10 percent of the nitrogen in reclaimed water would migrate through the root zone and into groundwater. Based on this conservative assumption, Questa calculated that concentrations of nitrate in groundwater could increase by 2 mg/L in the case of West County irrigation areas and 3.5 mg/L in the case of South County irrigation areas. Therefore, there may be slight increases in nitrate levels in groundwater if the input of nitrate from irrigation using reclaimed water exceeded the nitrate input from current land use practices.

Metals would not adversely affect groundwater since all metals in reclaimed water are at levels below their respective MCLs. Additionally, metals are removed from water in soils through a complex process of adsorption, precipitation, ion exchange and complexation (USEPA 1981).

Removal of microorganisms, including bacteria and viruses, occurs in the soil through filtration, adsorption, desiccation, radiation, predation and exposure to other adverse conditions. Bacteria, including coliform, are removed by filtration through the soil or formation material. There is generally greater filtration of bacteria over shorter distances in fine-grained material than in coarse-grained material (Ward, Giger and McCarty 1985). Studies of wastewater application reported by the USEPA (1981) indicated that fecal coliforms are normally removed after the wastewater has percolated five feet through the soil (USEPA 1981).

These removal mechanisms may be less effective in the Baylands irrigation area because of the extremely shallow depth to groundwater. At that location, the unsaturated zone may be too thin to effectively remove nitrate or coliform and the acidic nature of the soils would increase the mobility of the metals. However, because of the salinity of the groundwater and the low yield of the formation, shallow groundwater at the Baylands is not considered a source of potable water (DWR 1982b).

5.6.5 Evaluation of Impacts of Existing Irrigation Areas on Groundwater

Several agricultural parcels of land in the vicinity of the Laguna Treatment Plant are currently being irrigated with reclaimed water under the Subregional Reclamation System. The number of acres irrigated with reclaimed water has increased from 2,814 in 1987 to 5,349 in 1994. The average amount of reclaimed water used to irrigate over this time period was 24 inches per acre (City of Santa Rosa 1994).

To evaluate potential groundwater impacts of irrigation using reclaimed water, groundwater monitoring wells were installed in the vicinity of the existing irrigation areas in 1991. Wells were located upgradient, midgradient (in the central portion of irrigated areas) and at the downgradient edge of irrigated areas. Groundwater from these wells was analyzed biannually (i.e., winter and spring) since installation. Analytical results for selected analytes are summarized in Table 5-6. The results of this monitoring data are presented here to gain a better understanding of the potential impacts in the proposed irrigation areas by evaluating this single existing study area.

The analyses indicate that there has been an overall decrease in nitrate levels in a downgradient direction. The average nitrate level in upgradient wells for the period of 1991 through 1995 was 24.4 mg/L. The average nitrate level in midgradient wells for the same period was 16.2 mg/L. The average nitrate level in downgradient wells for the same period was 7.4 mg/L. This trend of decreasing nitrate levels from upgradient to downgradient of the irrigated areas was noted based on the 1991 groundwater monitoring data (CH2M Hill 1991) and is apparent in all subsequent monitoring periods (Laguna Environmental Laboratory 1995). If irrigation using reclaimed water was a significant source of nitrate input to groundwater, the opposite trend would be expected, i.e., increased nitrate levels in the midgradient and downgradient wells. Explanations provided for the decrease in nitrate in the downgradient direction included denitrification and off-gassing of nitrogen gas (CH2M Hill 1991). Another possible explanation is that upgradient land-use practices provide a greater input of nitrate to groundwater than the land-use practices associated with irrigation using reclaimed water.

Another trend noted in the single sampling event conducted in 1991 is a higher concentration of TDS in the wells located downgradient relative to TDS levels in the mid and upgradient wells (CH2M Hill 1991). TDS levels exceeded secondary MCLs in upgradient, midgradient and downgradient wells. Secondary MCLs are based on the aesthetics of water (i.e., taste, odor, etc.) and are not generally considered detrimental to health.

The average level of TDS detected in upgradient wells for all sampling periods was 575 mg/L (Table 5-6). The average concentration of TDS detected in midgradient wells was slightly higher at 618 mg/L. There is a substantial increase in the levels of TDS detected in downgradient, wells which had an average value of 806 mg/L. The average concentration of TDS in reclaimed water is 444 mg/L which is below the secondary MCL of 500 mg/L and is lower than the average TDS concentrations in the upgradient, midgradient and downgradient wells. Since the reclaimed water have lower concentrations of TDS than the groundwater, .it is unlikely that infiltration of reclaimed water has caused the higher concentrations of TDS in downgradient wells. It is more likely that these TDS levels reflect a preexisting groundwater quality characteristic that is not related to the use of reclaimed water. The downgradient wells are very close to the Laguna de Santa Rosa and it is possible that wetland evapotranspiration has elevated TDS levels in the groundwater proximal to the Laguna de Santa Rosa.

Based on the results of ongoing monitoring of irrigated areas in the vicinity of the Laguna Treatment Plant it appears that the use of reclaimed water results in less nitrate input to groundwater than surrounding land use practices. TDS levels appear to be elevated in downgradient wells relative to mid- and upgradient wells. However, the average TDS concentrations in upgradient, midgradient and downgradient wells are all higher than the average TDS concentration detected in reclaimed water. Therefore, the elevated TDS levels in groundwater do not appear to be attributable to use of reclaimed water in this area.

6 SUMMARY OF RESULTS

The purpose of this report is to characterize the hydrogeology and groundwater resources in the project areas and to use these characterizations as a framework for the evaluation of potential impacts from the storage/reuse components of the Santa Rosa Subregional Long-Term Wastewater Project on groundwater resources.

Evaluation of the reservoir sites (storage areas) indicates that there would be groundwater level increases ranging from 5 to 18 feet above existing levels, but these increases would quickly dissipate downgradient of the reservoir. Based on estimates of groundwater discharge under existing and reservoir conditions, it was determined that the quantity of water that could infiltrate from the reservoirs to groundwater would in most cases make up at least 20 percent of the quantity of groundwater in the subbasins that contain the reservoir sites. The magnitude of the contribution from the reservoirs is primarily the result of the large size of the reservoirs relative to the groundwater subbasins containing the reservoirs and the relatively shallow depth to groundwater The contribution from the reservoirs would be largely diluted at the point where groundwater from the reservoir subbasins flows into the main stem valley and mixes with the larger body of groundwater in the main stream valley. Based on a review of existing data, domestic/irrigation wells are located in each of the groundwater subbasins of the reservoir sites. At least some of these wells in each reservoir subbasin, except for the Tolay and Sears Point reservoirs, appear to be located in areas that could potentially be affected by the reservoirs. Based on this evaluation, the few known wells located in the Tolay and Sears Point reservoir sites appear to be outside of the influence of the proposed reservoirs.

Based on analytical data on reclaimed water quality, nitrate is the only constituent in reclaimed water with an average value in exceedance of a MCL. Although nitrate is readily adsorbed and immobilized in the unsaturated zone, in groundwater it is considered stable and mobile. Assuming that saturated conditions under the reservoirs extend to the groundwater table, nitrate could infiltrate into the groundwater and contribute to degradation of existing groundwater quality in the groundwater subbasins of the reservoirs.

The evaluation of potential impacts from reservoir sites is based on the conceptual design of the reservoir sites as described in Rust (1995) and on available information on the subsurface geology and the hydrogeologic properties in the vicinity of the sites. A detailed site-specific hydrogeologic investigations should be conducted at any reservoir site that is selected for constructed. This investigation should include aquifer testing and groundwater monitoring for the site. The reservoir configuration as designed for construction purposes should be used in the final evaluation of potential impacts. Additionally, a comprehensive well survey which would include a field check of the location and use of all wells in the vicinity of the reservoir site should be conducted prior to well construction.

Evaluation of irrigation areas (reuse areas) indicates that irrigation using reclaimed water would not degrade groundwater quality. The nitrate levels in reclaimed water are currently below nitrate requirements of crops, therefore, only small, if any, increases in nitrate levels are anticipated. Since the average TDS concentration in reclaimed water is below the secondary MCL, this constituent of reclaimed water would not negatively impact groundwater. Since most of the reclaimed water will not migrate beyond the root zone, changes in groundwater levels would be negligible (less than 5 feet) at all irrigation areas.

7 REFERENCES

Bailey, E. H. 1966, Geology of Northern California, California Division of Mines and Geology Bulletin 190

California State Department of Water Resources in Cooperation with County of Sonoma 1975, Evaluation of Ground Water Resources: Sonoma County, Geologic and Hydrogeologic Data, Bulletin 118-4, Volume 1, p. 177. December

California State Department of Water Resources in cooperation with the Sonoma County 1982a, Evaluation of Ground Water Resources: Sonoma County, Volume 3: Petaluma Valley, Volume 2: p. 107. September

California State Department of Water Resources in cooperation with the Sonoma County 1982b, Evaluation of Ground Water Resources: Sonoma County, Volume 2: Santa Rosa Plain, p. 107. September

California State Department of Water Resources 1987, Santa Rosa Plain Ground Water Model, p. 281. September

California North Coast Regional Water Quality Control Board, 1994, Water Quality Control Plan for the North Coast Region

Cardwell, G.T. 1958, Geology and Ground Water in the Santa Rosa and Petaluma Valley Areas, Sonoma County, California, U.S. Geological Survey Water-Supply Paper 1427, p. 273

City of Santa Rosa 1994, Reclamation Annual Report

Cedergren, H.R. 1989, Seepage, Drainage and Flow Nets, Third Edition, Wiley-Interscience Publication

CH2M Hill, RDD 1990, Quality Results from Quarterly Groundwater Sampling 1988/1989 in the Stemple/Americano Creeks Area, technical report for Santa Rosa Subregional Water Reclamation System Long-Term Detailed Reclamation Studies, Technical Memorandum No. R10, Water February

CH2M Hill 1991, Santa Rosa Subregional Reclamation System Soils and Groundwater Monitoring Program Operations Manual, September

Environmental Simulations, Inc. 1995, WinFlow: Two-Dimensional Groundwater Flow Model

Fetter, C.W. 1994, Applied Hydrogeology, Third Edition, Macmillan College Publishing Company

Fox, K.F., Jr. 1983, Tectonic Setting of Late Miocene, Pliocene, and Pleistocene Rocks in Part of the Coast Ranges North of San Francisco, California, U.S. Geological Survey Professional Paper 1239, p. 33

Freeze, R.A. and Cherry, J.A. 1979, Groundwater, Prentice-Hall, Inc., p. 604

Horne, A.J. 1980, Draft Technical Report: Storage Reservoir Site Analysis: Limnology and Water Quality of T5 and B1A, Long-Term Detailed Wastewater reclamation Studies, Santa Rosa Subregional Water Reclamation System, January

Laguna Environmental Laboratory 1995 Groundwater Monitoring Data Sheets (Attached to unrevised but reissued: CH2M Hill 1991, Santa Rosa Subregional Reclamation System Soils and Groundwater Monitoring Program Operations Manual, September

Merritt Smith Consulting, 1996 Reclaimed Water Quality Technical Report, technical report for Santa Rosa Subregional Long-Term Wastewater Project. April

Parsons Engineering Science, Inc. 1996, Well Installation and Groundwater Monitoring Results, technical report for Santa Rosa Subregional Long-Term Wastewater Project, February

Peters, J.H., L. Brittan, and V. Marble 1995, Draft Irrigation Management Plan For The West County and South County Alternatives, technical report for Santa Rosa Subregional Water Reclamation System Long-Term Detailed Reclamation Studies. July

Questa Engineering Corporation 1995a, Draft Baseline Hydrology and Irrigation Drainage Evaluation for West and South County Reclamation Alternatives, technical report for Santa Rosa Subregional and Long-Term Wastewater Project, September

Questa Engineering Corporation 1995b, Memorandum: Irrigation Nitrogen Loading to Groundwater, West County and South County Reclamation Alternatives, technical report for Santa Rosa Subregional and Long-Term Wastewater Project, October

Rust Environmental and Infrastructure 1995, Geotechnical Evaluation of Alternative Reservoir Sites and Pipeline Routes, technical report for Santa Rosa Subregional and Long-Term Wastewater Project, December

Shelby, M.J. 1982, Hillslope Materials and Processes, Oxford University Press

Travis, R.B. 1952, Geology of the Sebastopol Quadrangle, California, California Division of Mines Bulletin 162

Ward, C.H., W. Giger and P.L. McCarty 1985, Ground Water Quality, Wiley-Interscience Publication

Waterloo Hydrogeologic 1995, Visual MODFLOW, Version 1.1

USEPA 1981, Process Design Manual for Land Treatment of Municipal Wastewater, October

USEPA 1989, National Primary Drinking Water Regulations: total coliforms (Including Fecal Coliforms and E. Coli); Final Rule. Federal Register 54:27544. 29 June

USGS 1968, Topographic quadrangle map of Sears Point, 7.5 Minute Series, photorevised 1968

USGS 1971, Topographic quadrangle map of Valley Ford, 7.5 Minute Series, photorevised 1971

USGS 1974, Topographic quadrangle map of Two Rock, 7.5 Minute Series, photorevised 1974

USGS 1980a, Topographic quadrangle map of Glen Ellen, 7.5 Minute Series, photorevised 1980

USGS 1980b, Topographic quadrangle map of Petaluma River, 7.5 Minute Series, photorevised 1980

USGS 1981, Topographic quadrangle map of Petaluma, 7.5 Minute Series, photorevised 1981

APPENDIX A - TABLES

TABLE 5-1: SUMMARY OF RESERVOIR SITES POTENTIAL CONTRIBUTION TO GROUNDWATER FLUX

WATERSHED Reservoir Site	GEOTECHNICAL EVALUATION [1]			CALCULATION OF RESERVOIR CONTRIBUTION TO GROUNDWATER FLUX [2]									
				Hydraulic Conductivity (K)		Gradient Calculations				Cross-sectional Area		Groundwater Flux	
	Geologic Unit	Depth Below Ground Surface (ft)	Hydraulic Conductivity (K) (cm/sec)	(cm/sec)	(ft/d)	Average Elevation of Reservoir (ft msl)	Current GW Elevation in at Reservoir Site	GW Elevation at Main Valley Floor (ft msl)	Distance From Midpoint of Avg. Res. To Main Valley Floor (ft)	Width of Subbasin at Main Valley Floor (ft)	Aquifer Thickness (ft)	With Reservoir (ft^3/d)	Without Reservoir (ft^3/d)
AMERICANO CREEK													
Valley Ford East	Merced F. sandy siltstone	20-44	7.50E-06	2.0E-05	5.6E-02	115	100	40	5,500	4,700	500	1,810	1,448
	Merced F. sandy siltstone	44-59	6.20E-06										
Carroll Road North	Merced F. siltstone	35-50	<9.0E-6	2.0E-05	5.6E-02	215	160	40	7,900	4,000	500	2,503	1,716
	Merced F. siltstone	35-50	<5.6E-6										
	Merced F. siltstone	35-50	6.10E-06										
Bloomfield	Merced F. Siltstone	ne	ne	2.0E-05	5.6E-02	220	140	40	6,600	4,000	500	3,082	1,712
STEMPLE CREEK													
Two Rock	Franciscan C. melange	ne	ne	1.0E-06	2.8E-03	315	220	60	17,400	5,000	300	62	39
Huntley	Franciscan C. melange	20-58	<4.5E-6	1.0E-06	2.8E-03	240	170	40	6,400	2,600	300	69	45
	Franciscan C. melange	20-58	<2.7E-6										
	Franciscan C. melange	20-58	<1.5E-6										
	Merced F. siltstone/ Franciscan C. Contact	35-76	5.30E-05										
PETALUMA CREEK													
Adobe Road	Petaluma F. claystone (40%)	49-72	3.70E-07	2.0E-06	5.6E-03	305	200	40	7,450	4,000	400	322	194
Lakeville Hillside	Petaluma F. sandstone (40%)	29-31	2.00E-04	2.0E-06	5.6E-03	175	140	60	8,000	3,000	400	97	68
	Petaluma F. sandstone (40%)	29-31	2.90E-05										
	Petaluma F. claystone (60%)	56-64	5.90E-06										
	Petaluma F. congl (40%)	35-45	1.80E-04										
TOLAY CREEK													
Sears Point	Petaluma F. claystone	50-70	<5.9E-6	3.0E-06	8.5E-03	115	100	5	8,875	3,000	400	126	109
	Petaluma F. claystone	50-70	1.90E-06										
	Petaluma F. claystone	50-70	2.30E-06										
	Petaluma F. claystone	38-70	<8.1E-6										
	Petaluma F. claystone	38-70	<4.0E-6										
	Petaluma F. claystone	38-70	2.00E-05										
Tolay (w/o backdam)	Petaluma F.	ne	ne	3.0E-06	8.5E-03	230	210	5	18,850	3,000	400	121	111
(w/ backdam)	Petaluma F.	ne	ne	3.0E-06	8.5E-03	248	220	5	18,100	3,000	400	137	121

Notes: E = exponent, ne = not evaluated, cm/sec = centimeters/second, ft = feet, ft/d = feet/day, msl = mean sea level

[1] Rust 1995 [2] Represents contribution to regional groundwater via the footprint of the reservoir. Estimates of seepage through dams (Table 5.4) represents shallow lateral flow separate from this flow regime.

TABLE 5.2: CALCULATION OF DILUTION EFFECTS OF RESERVOIR CONTRIBUTION TO GROUNDWATER

WATERSHED Reservoir Site	Groundwater Flux And Dilution In Reservoir Subbasin				Dilution Of Reservoir Contribution In Main Valley Floor			
					Up-gradient Subbasin[2]		Down-gradient Subbasin[3]	
	Existing Conditions (ft^3/d)	w/ Reservoir (ft^3/d)	Contribution from Reservoir (ft^3/d)	Percent Contribution from Reservoir[1]	Groundwater Flux (ft^3/d)	Percent Contribution	Groundwater Flux (ft^3/d)	Percent Contribution
AMERICANO CREEK								
Valley Ford East	1,448	1,810	362	20%	nc	nc	nc	nc
Carroll Road North	1,716	2,503	787	31%	1,712	19%	nc	nc
Bloomfield	1,712	3,082	1,370	44%	2,825	23%	1,716	18%
STEMPLE CREEK								
Two Rock	39	62	23	37%	48	21%	nc	nc
Huntley	45	69	24	35%	89	15%	nc	nc
PETALUMA CREEK								
Adobe Road	194	322	127	40%	170	26%	158	20%
Lakeville	68	97	30	30%	50	20%	nc	nc
TOLAY CREEK								
Sears Point	109	126	17	14%	nc	nc	nc	nc
Tolay w/o backdam	111	121	11	9%	nc	nc	nc	nc
Tolay w/ backdam	121	137	16	12%	nc	nc	nc	nc

Notes: nc =not calculated, ft^3/d = cubic feet/day

[1] Dilution calculated at break in slope where groundwater from reservoir subbasin enters main valley.

[2] Dilution in main valley from groundwater subbasin directly upgradient of reservoir subbasin

[3] Dilution in main valley from groundwater subbasin directly downgradient of reservoir subbasin

Table 5-3: AVERAGE LINEAR TRAVEL TIME OF RECLAIMED WATER FROM RESERVOIRS

WATERSHED Reservoir Site	Hydraulic Conductivity (ft/d)	Gradient (i)	Assumed Effective Porosity	Average Linear Velocity (ft/d)	Travel Distance After 365 days (ft)	Travel Distance After 6 mths (183 days) (ft)
AMERICANO CREEK						
Valley Ford East	5.65E-02	0.01	0.20	3.85E-03	1.4	0.7
Carroll Road North	5.65E-02	0.02	0.20	6.26E-03	2.3	1.1
Bloomfield	5.65E-02	0.03	0.20	7.70E-03	2.8	1.4
STEMPLE CREEK						
Two Rock	2.82E-03	0.01	0.10	4.14E-04	0.2	0.1
Huntley	2.82E-03	0.03	0.10	8.83E-04	0.3	0.2
PETALUMA CREEK						
Adobe Road	5.65E-03	0.04	0.10	2.01E-03	0.7	0.4
Lakeville	5.65E-03	0.01	0.10	8.12E-04	0.3	0.1
TOLAY CREEK						
Sears Point	8.47E-03	0.01	0.10	1.05E-03	0.4	0.2
Tolay w/o backdam	8.47E-03	0.01	0.10	1.01E-03	0.4	0.2
Tolay w/ backdam	8.47E-03	0.01	0.10	1.14E-03	0.4	0.2

Notes: ft = feet, ft/d = feet/day

TABLE 5.4 RESULTS OF FLOWNET ANALYSES OF POTENTIAL SEEPAGE BASED ON CONCEPTUAL DAM DESIGNS
(Preliminary: Not for Design Purposes[1])

Dam Site	Hydraulic Conductivity [2] (cm/sec)			Reservoir Water Height [3]	Equivalent Crestline Length	Estimated Seepage[4] (gpm)	
	Shell	Foundation	Core	(feet)	(feet)	w/o Core	w/ Core
Valley Ford East	1.0E-05	1.0E-05	5.0E-07	100	2,000	21	18
Carroll Road North	1.0E-05	1.0E-05	5.0E-07	165	1,650	30	25
Bloomfield Road	1.0E-05	1.0E-05	5.0E-07	165	2,500	46	38
Huntley	1.0E-05	1.0E-06	5.0E-07	160	2,000	11	9 [5]
Two Rock	1.0E-05	1.0E-06	5.0E-07	195	800	6	5 [5]
Adobe Road	5.0E-06	1.0E-06	1.0E-08	175	1,750	15	4
Lakeville Hillside	1.0E-05	5.0E-05	1.0E-08	125	600	25	20
Tolay Creek w/ Backdam	1.0E-05	5.0E-06	1.0E-08	108	600	nc	1.8
Tolay Creek w/o Backdam	1.0E-05	5.0E-06	1.0E-08	90	500	nc	1.2
Sears Point	5.0E-06	1.0E-06	1.0E-08	110	1,400	6	1.5

Notes: E = exponent, e.g., 1.0E-6 = $1x10^{-6}$

cm/sec = centimeters/ second, gpm = gallons per minute

nc = Not calculated; shell material not considered in calculations because core is very large and impermeable.

[1] Flownet analyses were based on conceptual dam designs contained in Rust (1995) and are only estimates of seepage and should not be used for da

[2] Estimated values based on field and laboratory testing reported in from Rust 1995

[3] Average operating pool hieght above excavated dam foundation.

[4] Estimates of seepage through dams represents shallow lateral flow separate from deeper regional groundwater flow regime evaluated in Table 5-1.

[5] Multiplier 0.83 used to estimate effect of core based on results of the calculations for Valley Ford East, Carroll Road North and Bloomfield.

TABLE 5-5: POTENTIAL GROUNDWATER RISE AT RESERVOIR SITES

	Existing Conditions	Post-Reservoir Conditions	
WATERSHED Reservoir Site	Depth to Groundwater at Dam Site Under Existing Conditions [1] (feet)	Maximum Groundwater Rise Under Reservoir (feet)	Minimum Depth to Groundwater Downgradient of Dam (feet)
AMERICANO WATERSHED			
Valley Ford East	10	7	~6
Carroll Rd	12	10	<6
Bloomfield	10	15	<6
STEMPLE WATERSHED			
Two Rock	30	7	>6
Huntley	10	8	<6
PETALUMA WATERSHED			
Adobe Road	22	18	>6
Lakeville - Hillside	30	7	>6
TOLAY WATERSHED			
Sears Pt.	20	5	>6
Tolay w/o backdam	11	5	>6
Tolay w/ backdam	11	5	>6

[1] All water level data was obtained from the Project geotechnical report (Rust 1995) with the exception of Two Rock reservoir site. Water level data at the Two Rock reservoir site was based on Project groundwater monitoring investigation (Parsons ES 1996).

TABLE 5-6: TOTAL DISSOLVED SOLIDS AND NITRATE CONCENTRATIONS FROM GROUNDWATER MONITORING AT EXISTING IRRIGATION AREAS USING RECLAIMED WATER

December 1991 through May 1995

Wells Sampled	Dec-91		May-92		Sep-92		May-93		Dec-93	
	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate
UP-GRADIENT WELLS										
104	850	18	618	30.2	721	24	788	30	799	22.7
105	460	23	408	31.7	412	33	524	122	391	23.8
109	320	9.1	405	13.7	469	17.1	510	21.7	446	21
111	490	15	545	11.75	649	15.5	626	13.6	578	15.3
Average	530	16.3	494	21.84	563	22.4	612	46.8	554	20.7
MID-GRADIENT WELLS										
102	690	3.2	587	2.86	587	7.9	420	12.8	413	4.2
103	530	0.54	618	0.723	600	1.9	510	1.1	595	1.84
106	690	13	1122	80.7	793	36	354	45.7	1081	33.2
Average	637	5.6	776	28.09	660	15.3	428	19.9	696	13.1
DOWN-GRADIENT WELLS										
101	740	0.34	652	2.44	667	2.6	826	3.18	652	10.9
107	950	0.065	1432	1.58	1603	3	786	2.2	1592	2.9
108	640	0.78	551	2	1422	2.3	830	1.56	1460	165
110	340	0.05	344	<0.5	341	1.06	632	0.5	334	0.86
112	800	0	495	24.7	743	0.8	678	0.67	753	0.73
Average	694	0.2	695	6.19	955	2.0	750	1.6	958	36.1

Notes:

All concentrations are presented in mg/L (milligrams per liter is equivalent to parts per million - ppm)

Maximum Contaminant Level (MCL) (primary) for nitrate = 10 mg/L

MCL (secondary) for TDS = 500 mg/L

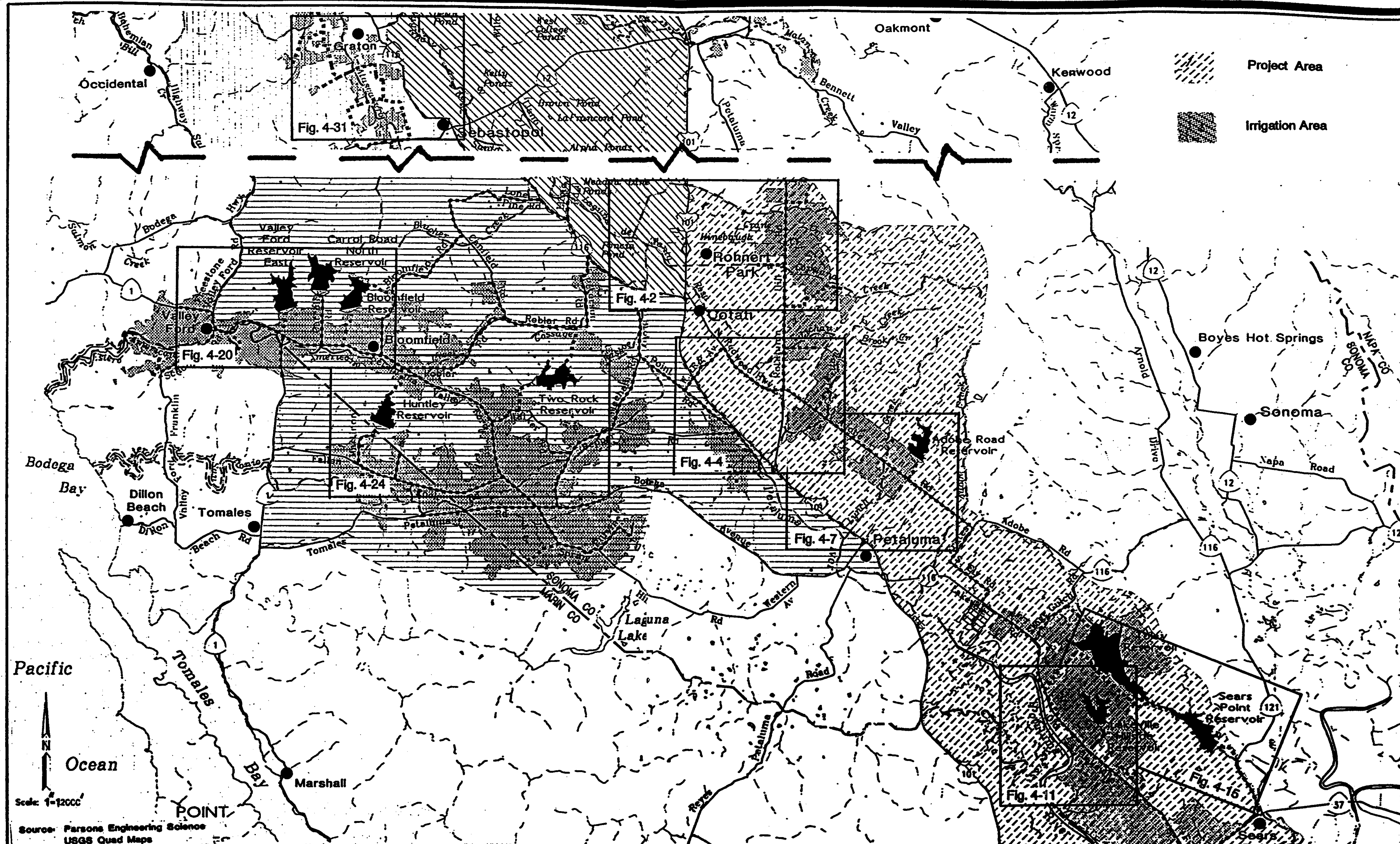
TABLE 5-6: TOTAL DISSOLVED SOLIDS AND NITRATE CONCENTRATIONS FROM GROUNDWATER MONITORING AT EXISTING IRRIGATION AREAS USING RECLAIMED WATER (Continued)

Wells Sampled	May-94		Nov-94		May-95		Average Value Over Sampled Period	
	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate	Total Dissolved Solids	Nitrate	TDS	Nitrate
UP-GRADIENT WELLS								
104	787	29	748	30	819	20.1		
105	550	31.8	414	24	793	24.3		
109	484	18	477	22.9	410	15.7		
111	502	10.9	581	21.7	504	11.4		
Average	581	22.4	555	24.7	632	17.9	575	24.4
MID-GRADIENT WELLS								
102	417	6.95	614	8.8	267	0.56		
103	596	1.37	598	1.4	587	0.36		
106	1066	61.4	740	32.6	840	27		
Average	693	23.2	651	14.3	565	9.3	618	16.2
DOWN-GRADIENT WELLS								
101	510	2.7	435	10.9	484	1.2		
107	1671	2.6	1710	6.1	1104	<0.01		
108	605	2.7	966	3.8	690	1.4		
110	340	0.5	504	1.9	324	<0.01		
112	705	1	720	2.7	650	1.13		
Average	766	1.9	867	5.1	650	0.7	806	7.4

Notes:

All concentrations are presented in mg/L (milligrams per liter is equivalent to parts per million - ppm)
Maximum Contaminant Level (MCL) (primary) for nitrate = 10 mg/L
MCL (secondary) for TDS = 500 mg/L

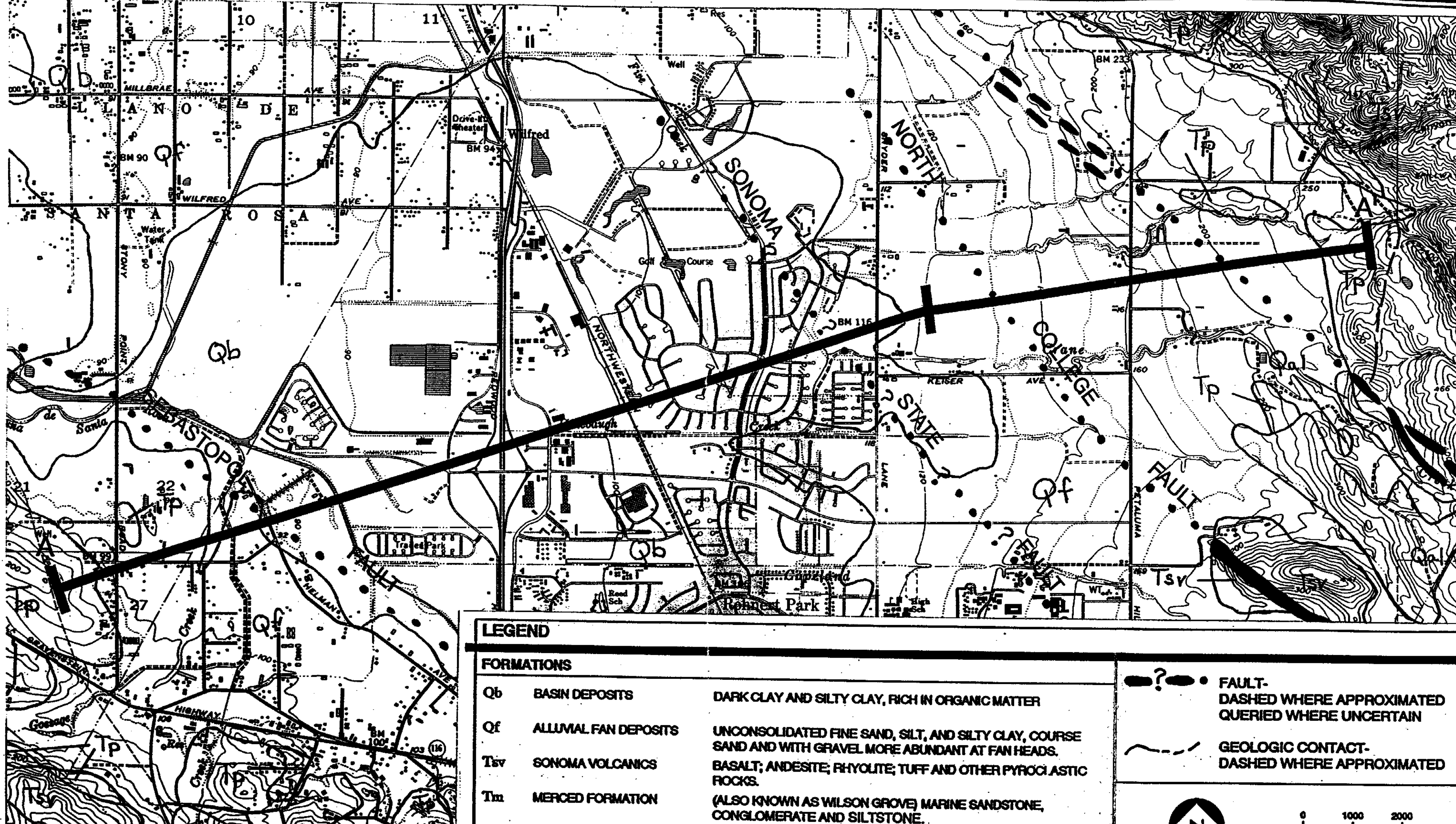
APPENDIX B -FIGURES



Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC CROSS-SECTION ALIGNMENT LOCATION MAP

FIGURE 4-1



LEGEND

FORMATIONS

Qb	BASIN DEPOSITS	DARK CLAY AND SILTY CLAY, RICH IN ORGANIC MATTER
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tsv	SONOMA VOLCANICS	BASALT; ANDESITE; RHYOLITE; TUFF AND OTHER PYROCLASTIC ROCKS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.

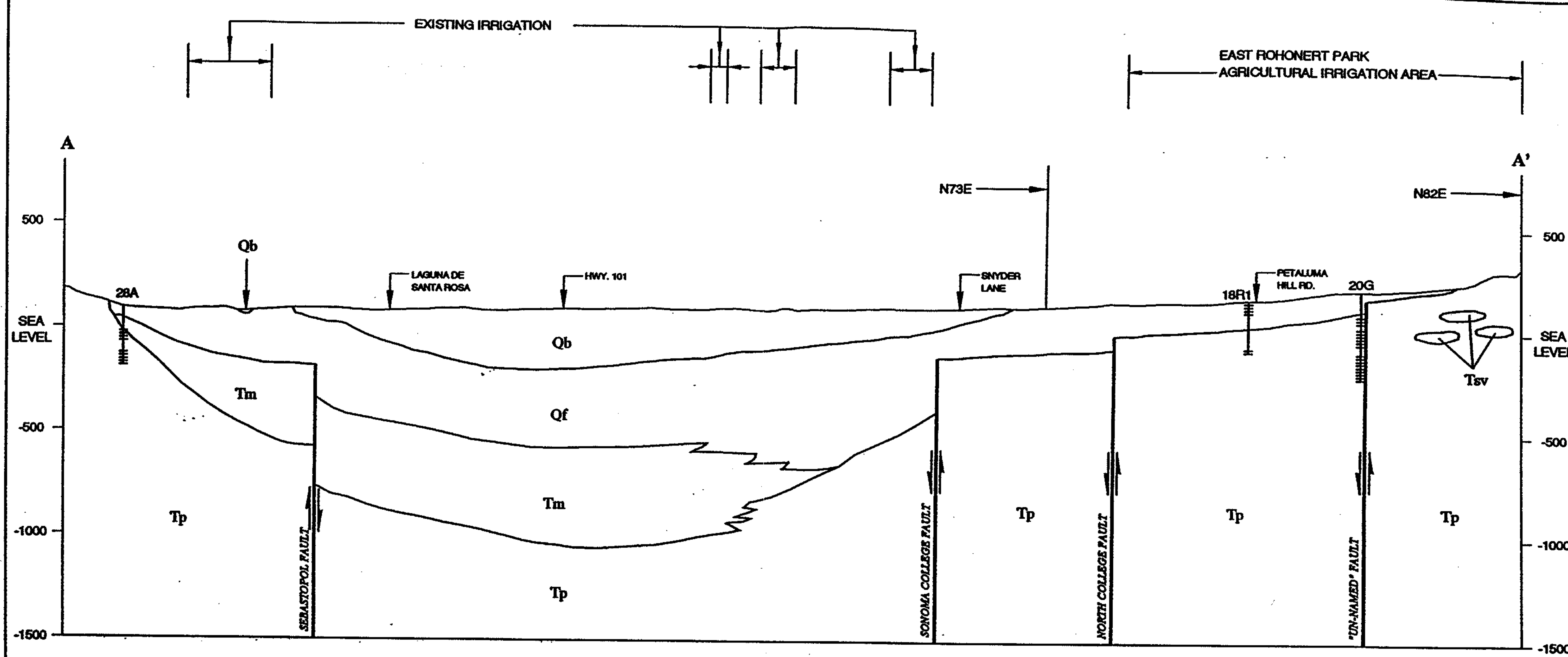
FAULT- DASHED WHERE APPROXIMATED QUERIED WHERE UNCERTAIN

GEOLOGIC CONTACT- DASHED WHERE APPROXIMATED

N

0 1000 2000
SCALE IN FEET

SOURCE: FROM DWR 1982a



LEGEND

FORMATIONS

Qb	BASIN DEPOSITS	DARK CLAY AND SILTY CLAY, RICH IN ORGANIC MATTER
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tsv	SONOMA VOLCANICS	BASALT; ANDESITE; RHYOLITE; TUFF AND OTHER PYROCLASTIC ROCKS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.

WELL LOGS

T6N/R8W 28A
T6N/R8W 18R1
T6N/R8W 20G

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

N73E → BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM DWR, 1982a.

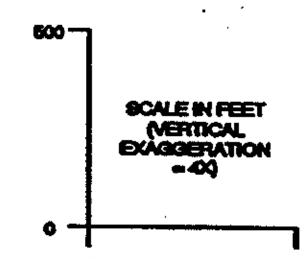


FIGURE 4-3

Santa Rosa
Subregional Long-Term Wastewater Project

REV. 3 SR904-04.DWG 02/28/96

GEOLOGIC CROSS-SECTION A-A'
SOUTH SANTA ROSA PLAIN

PARSONS ENGINEERING SCIENCE, INC.

LEGEND

FORMATIONS

Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT AND SILTY CLAY, COARSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILLSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

FAULT- DASHED WHERE APPROXIMATED QUERIED WHERE UNCERTAIN

GEOLOGIC CONTACT- DASHED WHERE APPROXIMATED

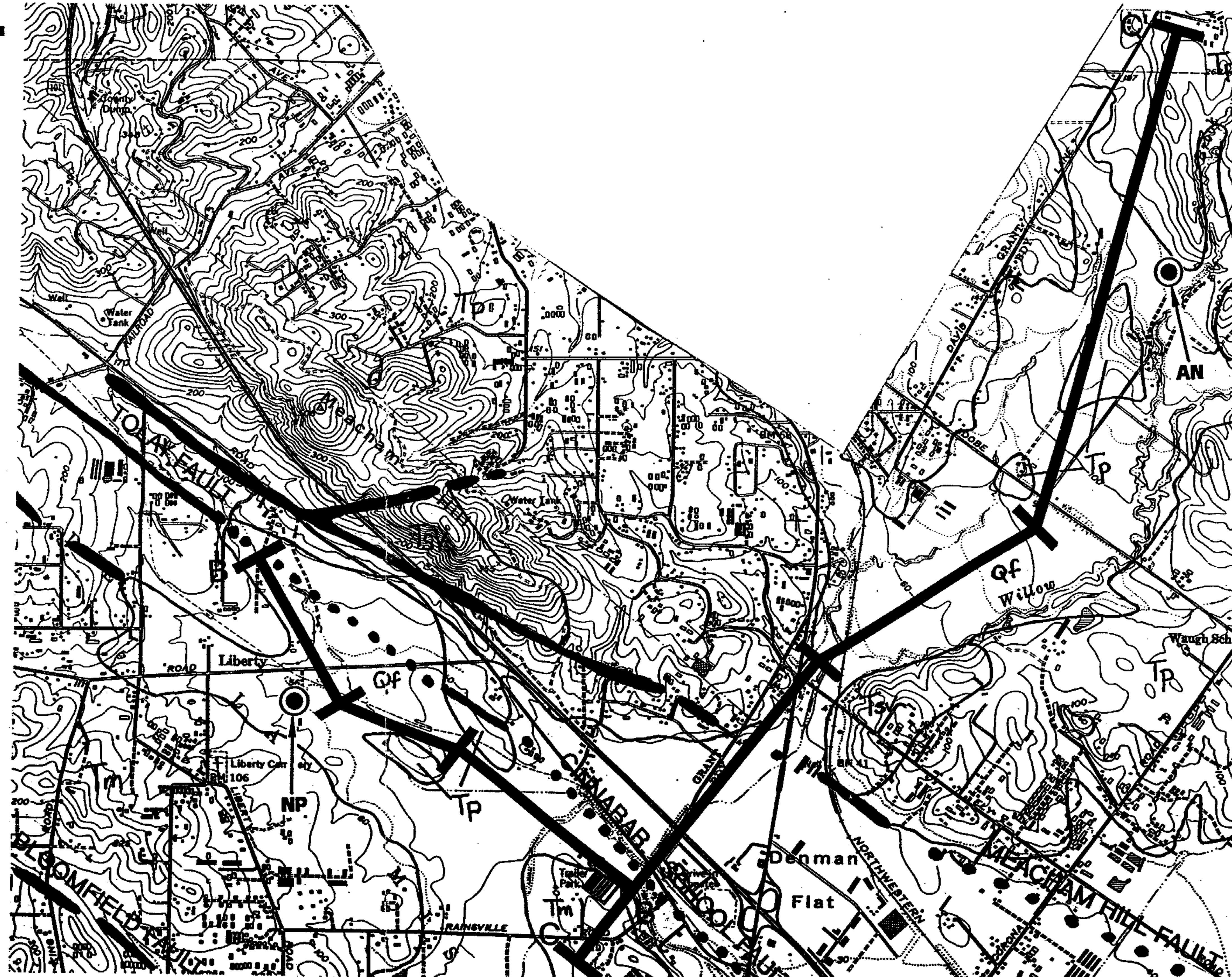
N

0 1000 2000
SCALE IN FEET

SOURCE: FROM DWR 1982b

WELL LOCATIONS

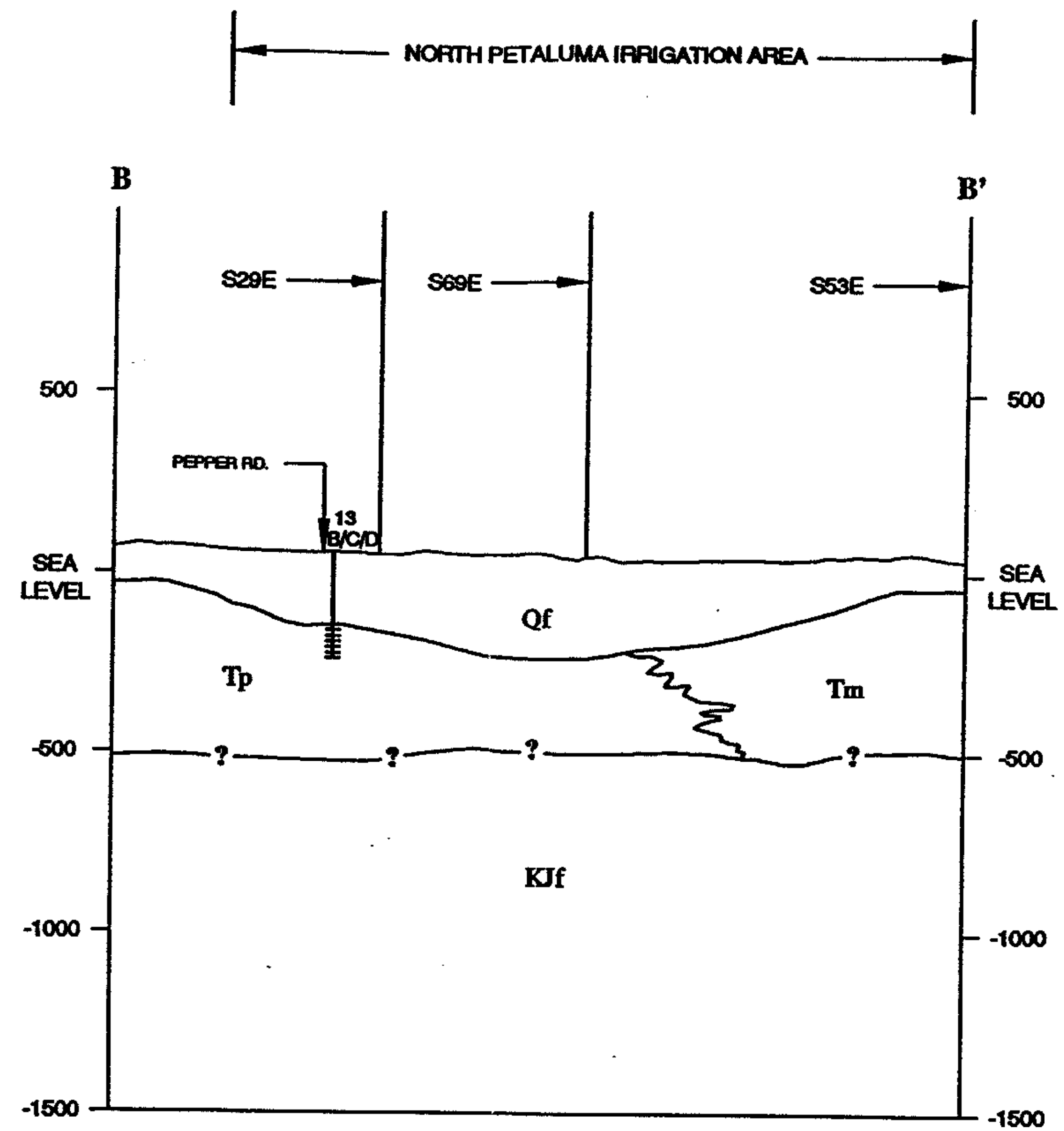
WELLS AND/OR BORINGS INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)



Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF NORTH PETALUMA VALLEY

FIGURE 4-4



LEGEND

FORMATIONS		
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS
T5N/R8W 13 B/C/D

Symbol	Meaning
	FAULT- DASHED WHERE APPROXIMATED
—?—	GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN
	WELL WITH SCREENED INTERVAL
S69E →	BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM DWR 1982, MODIFIED AFTER CARDWELL, 1958.

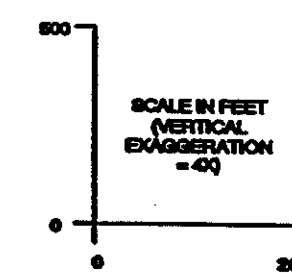


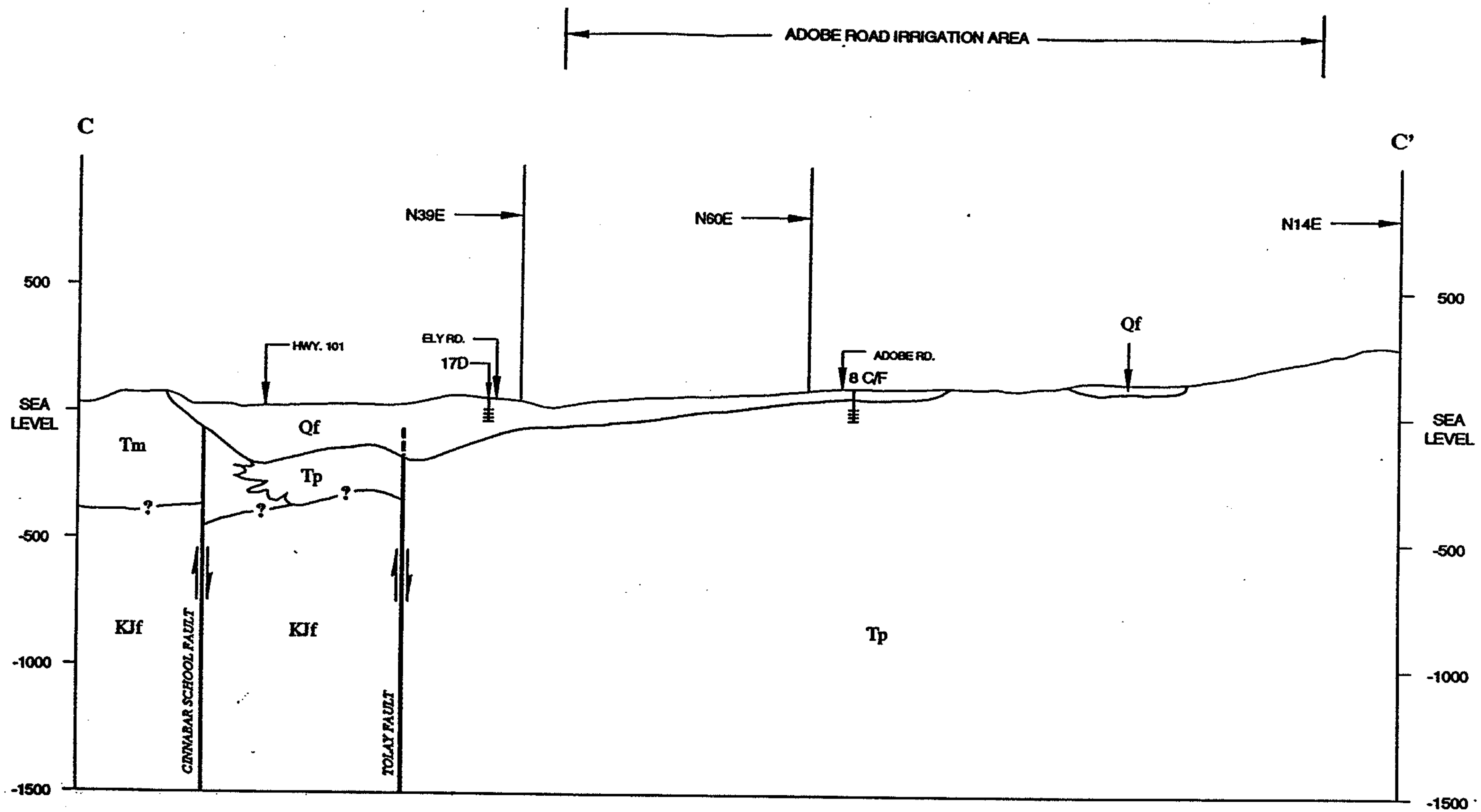
FIGURE 4-5

Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC CROSS-SECTION B-B'
NORTH/WEST PETALUMA VALLEY

REV. 3 SR904-01.DWG 02/28/06

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS		
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T5N/R7W 17D
T5N/R7W 8C/F

- FAULT- DASHED WHERE APPROXIMATED
- GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN
- WELL WITH SCREENED INTERVAL
- N60E → BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM DWR, 1982a, MODIFIED AFTER CARDWELL, 1958.

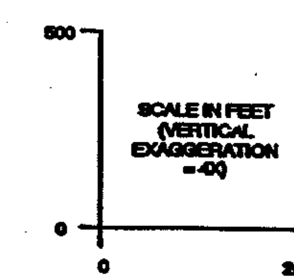


FIGURE 4-6

Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC CROSS-SECTION C-C'
NORTHEAST PETALUMA VALLEY

REV. 4 SR904-02.DWG 03/04/98

PARSONS ENGINEERING SCIENCE, INC.

LEGEND

FORMATIONS

Symbol	Formation	Description
Qbm	BAY MUD DEPOSITS	MUD, RICH IN ORGANIC MATTER, SILTY MUD, SILT, AND FINE SAND.
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT AND SILTY CLAY, COARSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILLSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.

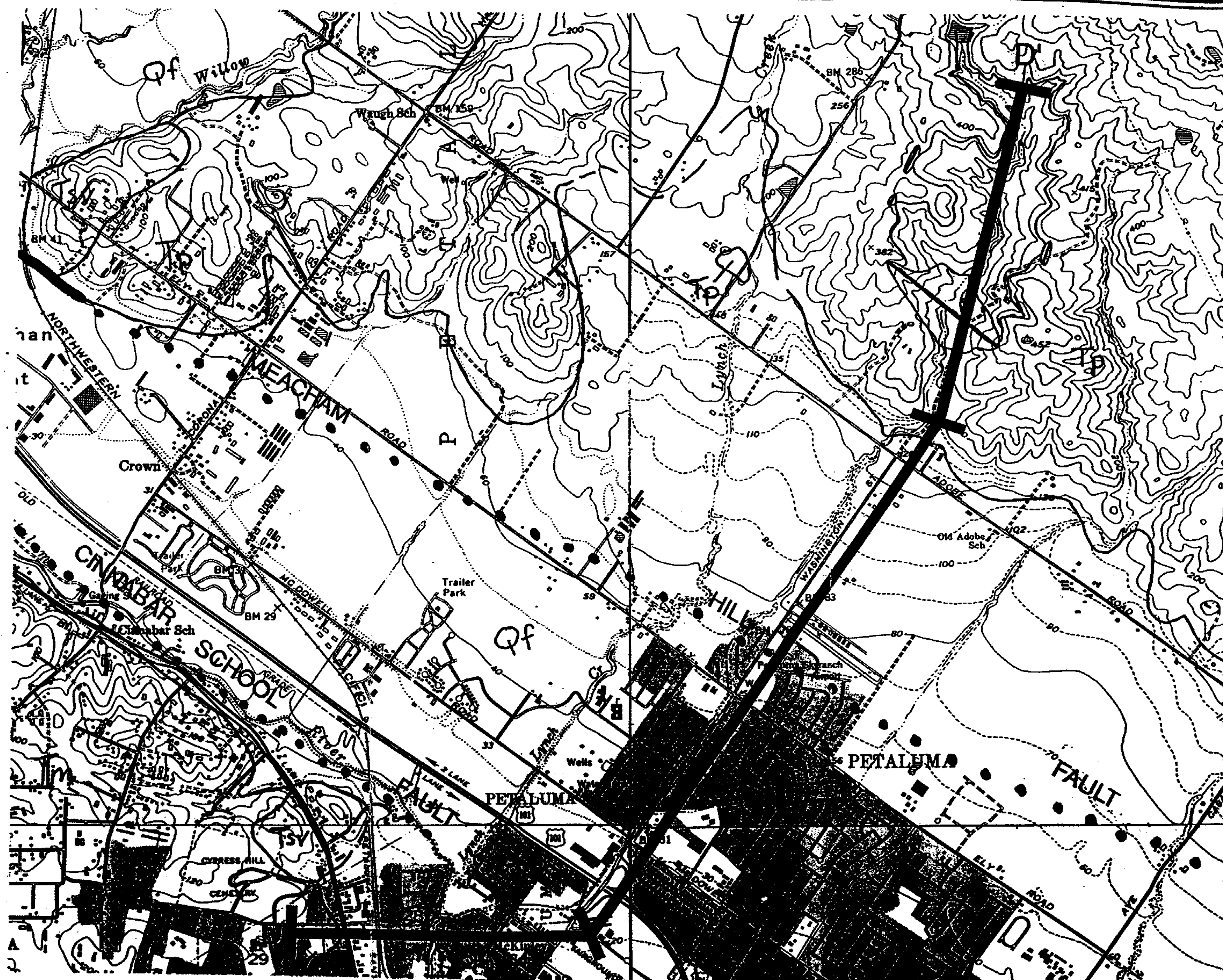
FAULT- DASHED WHERE APPROXIMATED QUERIED WHERE UNCERTAIN

GEOLOGIC CONTACT- DASHED WHERE APPROXIMATED

N

0 1000 2000
SCALE IN FEET

SOURCE: FROM DWR 1982b

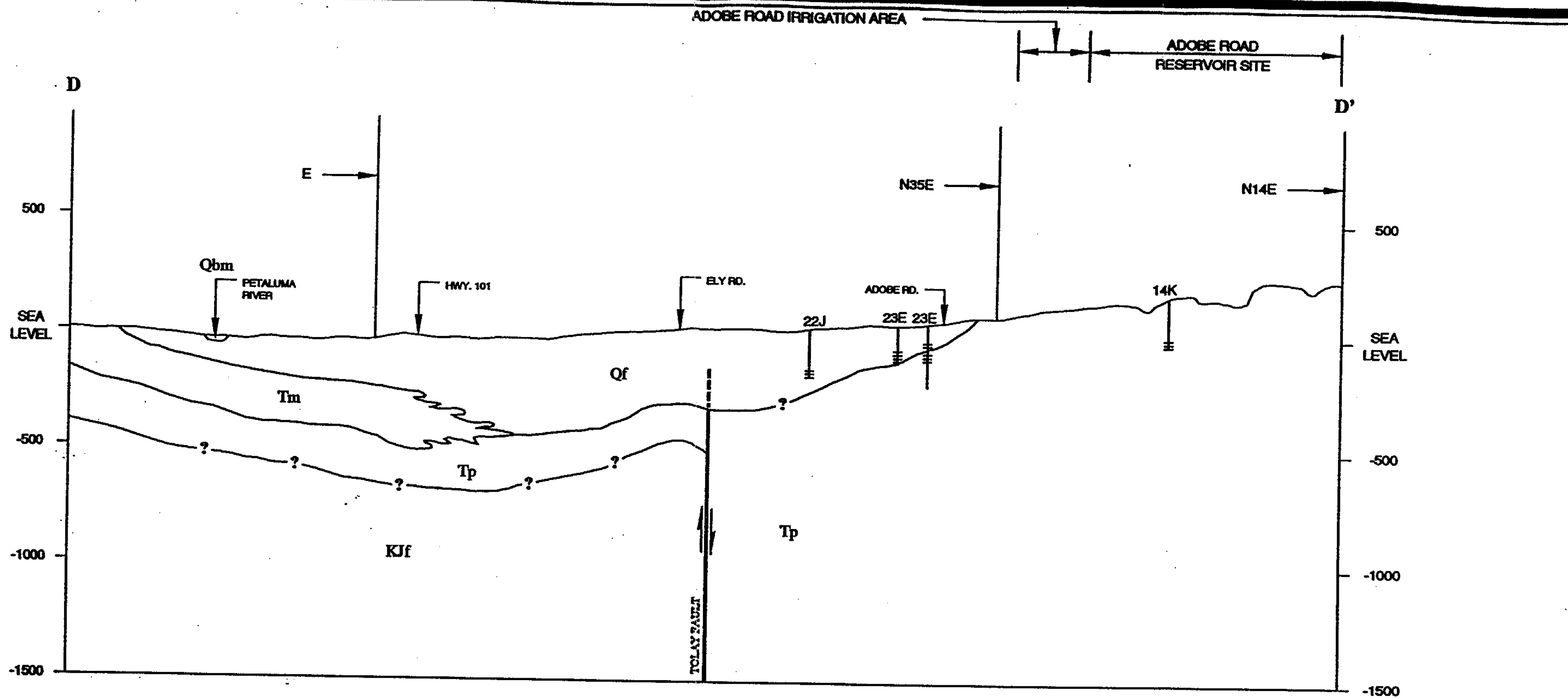


Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP IN VICINITY OF ADOBE ROAD RESERVOIR SITE

FIGURE 4-7

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS

Qbm	BAY MUD DEPOSITS	MUD, RICH IN ORGANIC MATTER, SILTY MUD, SILT, AND FINE SAND.
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T5N/R7W 22J
T5N/R7W 23E, 23E
T5N/R7W 14K

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

N35E — BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM DWR, 1982A, MODIFIED AFTER CARDWELL, 1958.

SCALE IN FEET (VERTICAL EXAGGERATION = 4X)

500
0
0
2000

FIGURE 4-8

Santa Rosa
Subregional Long-Term Wastewater Project

REV. 3 SR904-03.DWG 02/26/96

GEOLOGIC CROSS-SECTION D-D'
ADOBE ROAD RESERVOIR SITE

PARSONS ENGINEERING SCIENCE, INC.

Legend

RESERVOIR FOOTPRINT

DAM FOOTPRINT

BOUNDARY OF GROUNDWATER SUBBASIN

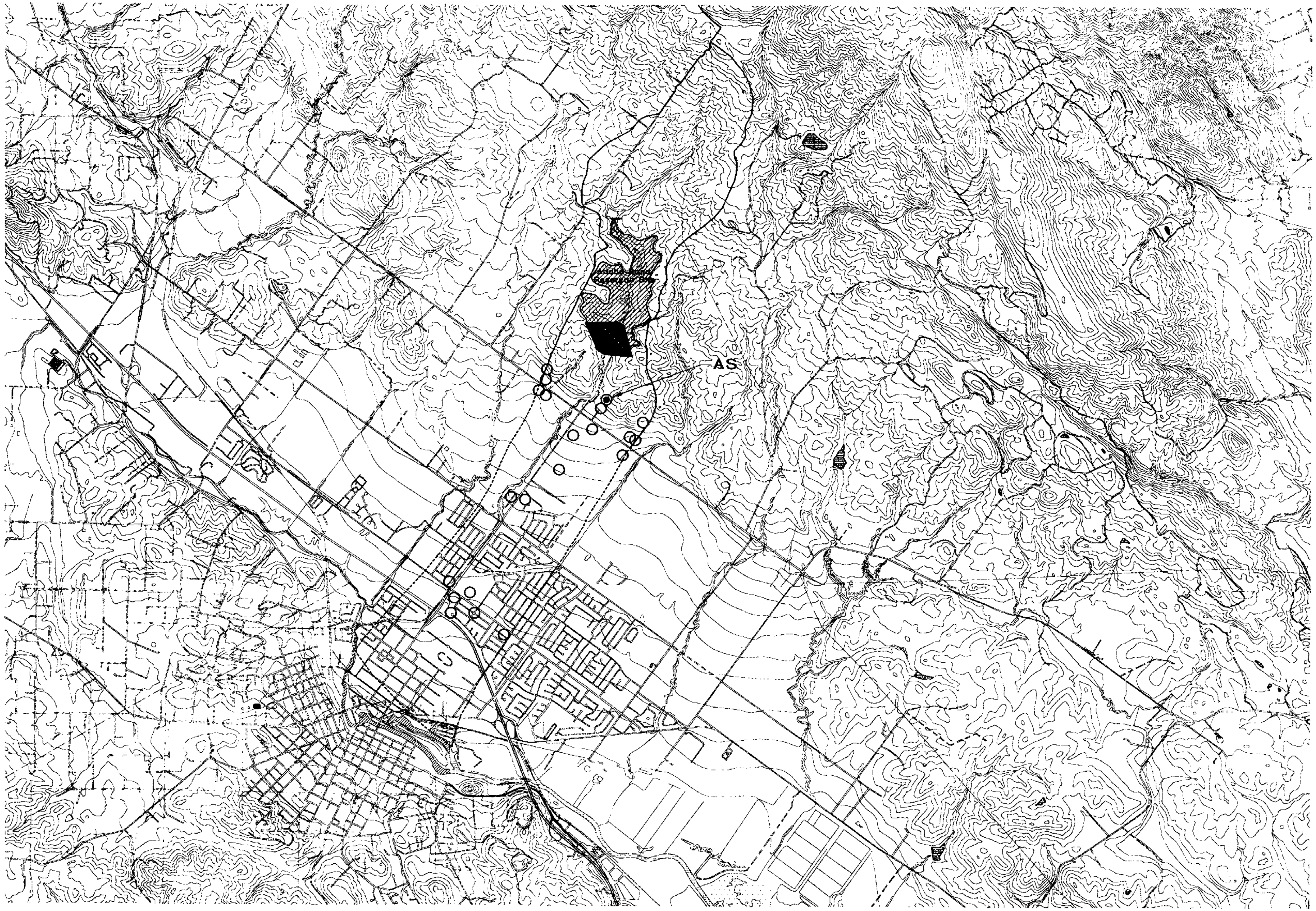
○ WELL LOCATION BASED ON DWR WELL LOGS

◉ WELL AND/OR BORING INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)

△ WELL LOCATION BASED ON SITE RECONNAISSANCE

□ LOCATION OF WELL SAMPLED 1989-1990 (CH2M HILL)

CONTOUR INTERVAL: 20 ft.



N

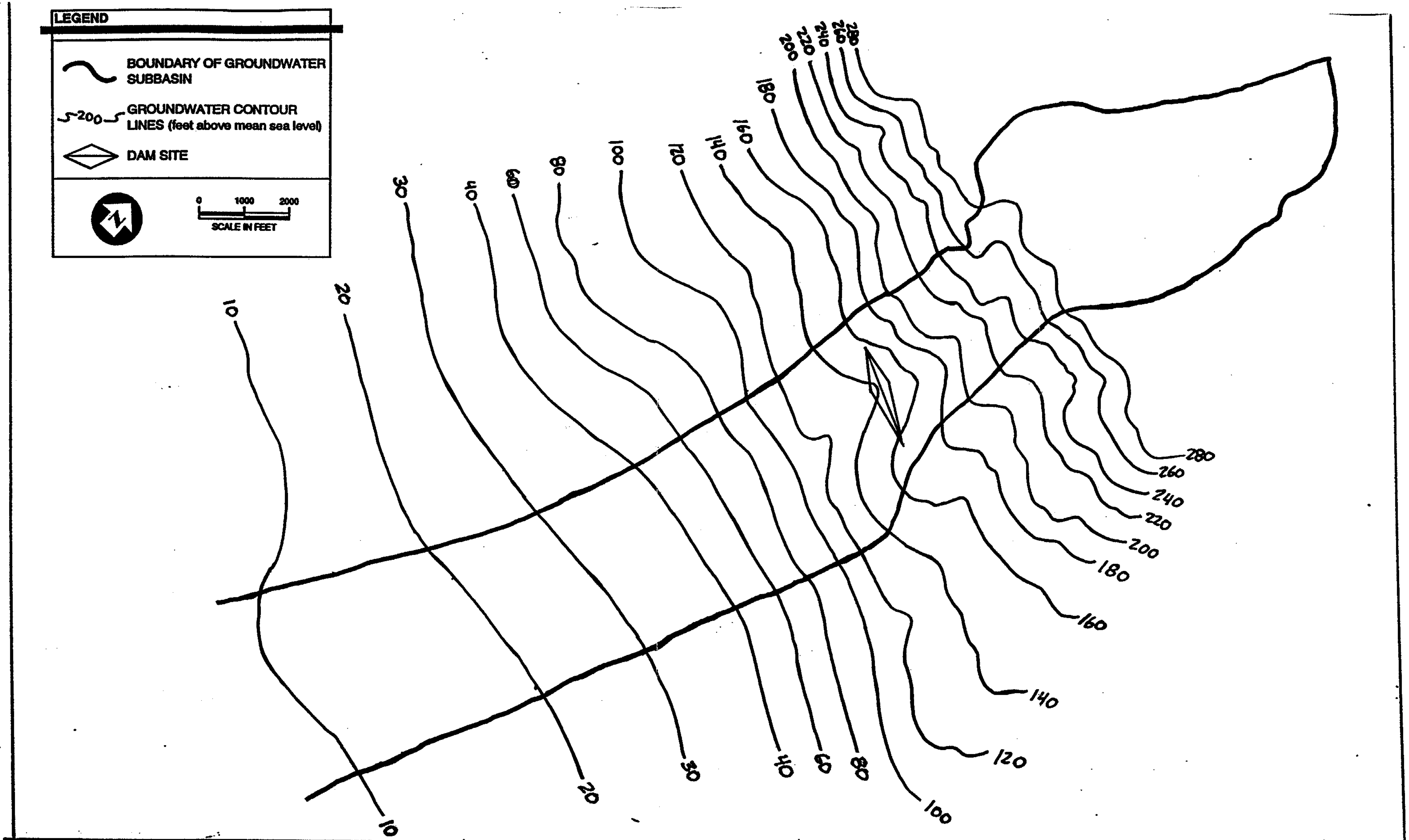
0 4000
Scale in feet

HARLAND BARTHOLOMEW and ASSOCIATES, INC.
PARSONS ENGINEERING SCIENCE, INC.
UNITS OF PARSONS INFRASTRUCTURE and TECHNOLOGY GROUP INC.
PARSONS

Santa Rosa Subregional Long-Term Wastewater Project

GROUNDWATER SUBBASIN FOR ADOBE ROAD RESERVOIR SITE

Figure 4-9



Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER CONTOURS FOR THE ADOBE ROAD RESERVOIR SITE SUBBASIN

FIGURE 4-10

PARSONS ENGINEERING SCIENCE, INC.

LEGEND

FORMATIONS

Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Qbm	BAY MUD DEPOSITS	MUD, RICH IN ORGANIC MATTER, SILTY MUD, SILT, AND FINE SAND.
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT AND SILTY CLAY, COARSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tsv	SONOMA VOLCANICS	BASALT; ANDESITE; RHYOLITE; TUFF; AND OTHER PYROCLASTIC ROCKS.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

FAULT- DASHED WHERE APPROXIMATED QUERIED WHERE UNCERTAIN

GEOLOGIC CONTACT- DASHED WHERE APPROXIMATED

N

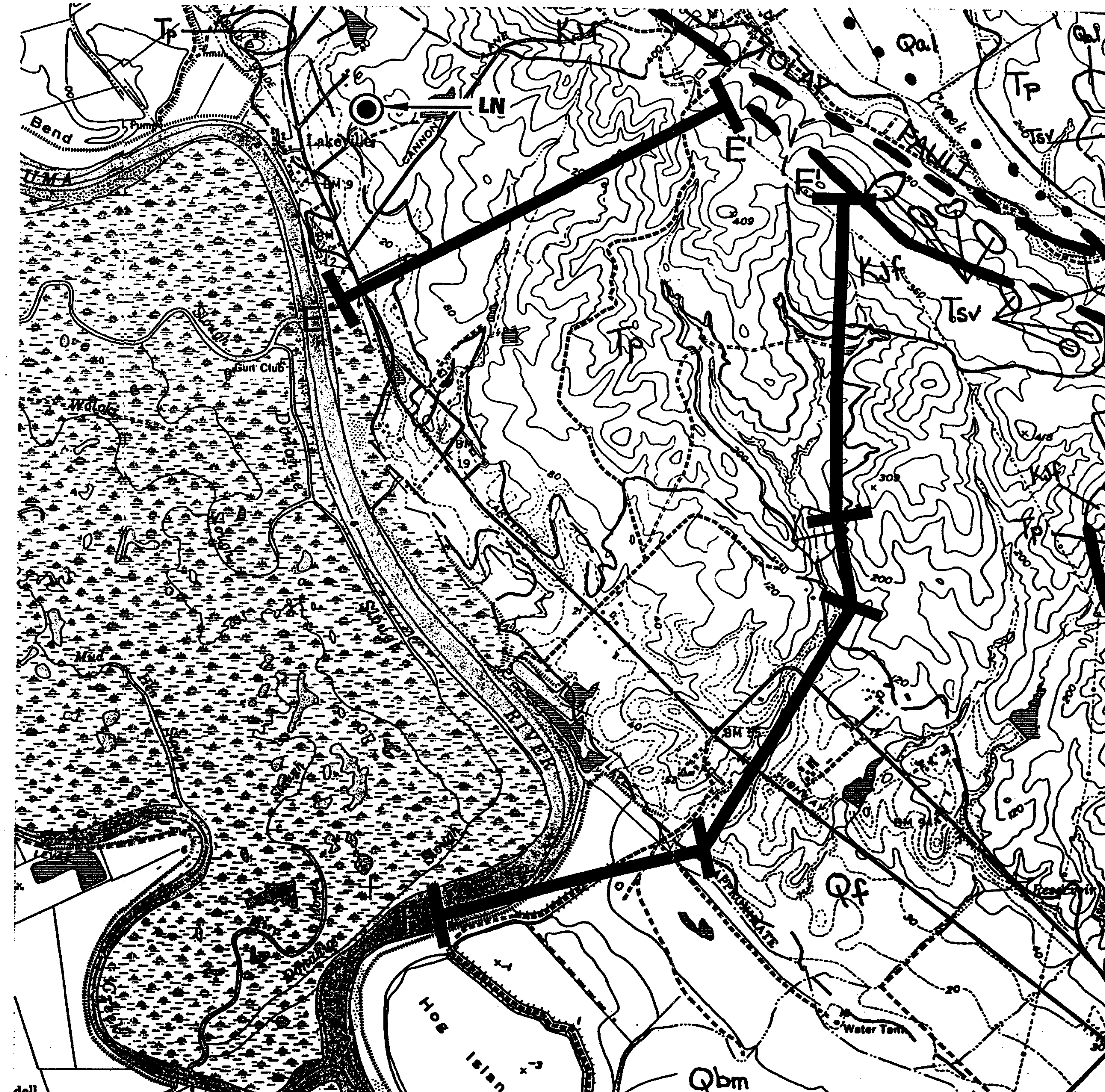
0 1000 2000

SCALE IN FEET

SOURCE: FROM DWR 1982b

WELL LOCATIONS

WELLS AND/OR BORINGS INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)

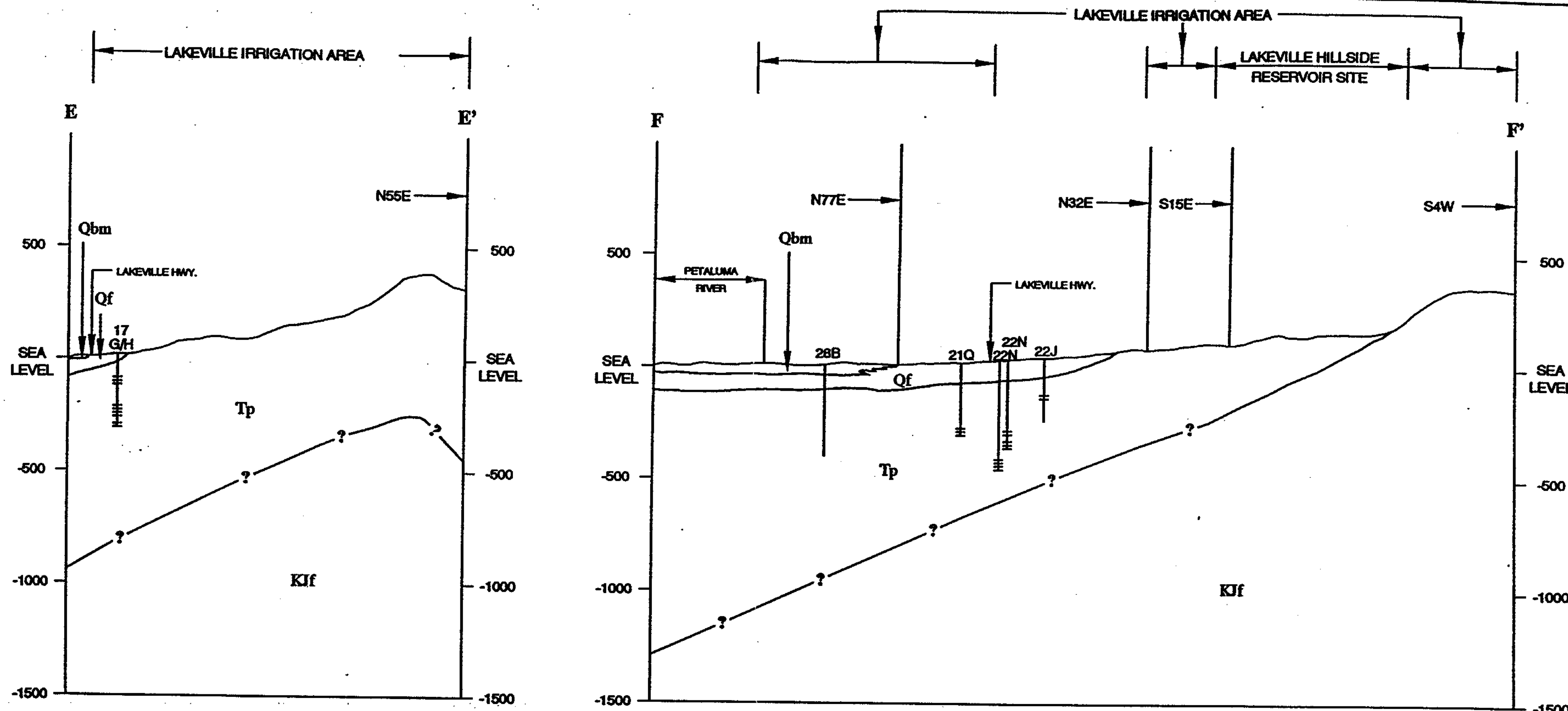


Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF SOUTH PETALUMA VALLEY

FIGURE 4-11

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS

Qbm	BAY MUD DEPOSITS	MUD, RICH IN ORGANIC MATTER, SILTY MUD, SILT, AND FINE SAND.
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T4N/R6W 28B
T4N/R6W 21Q
T4N/R6W 22N, 22N
T4N/R6W 21J
T4N/R6W 17G/H

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

N32E → BEND IN CROSS SECTION - DIRECTION INDICATED

SCALE IN FEET (VERTICAL EXAGGERATION =40)

SOURCE: FROM CARDWELL, 1958.

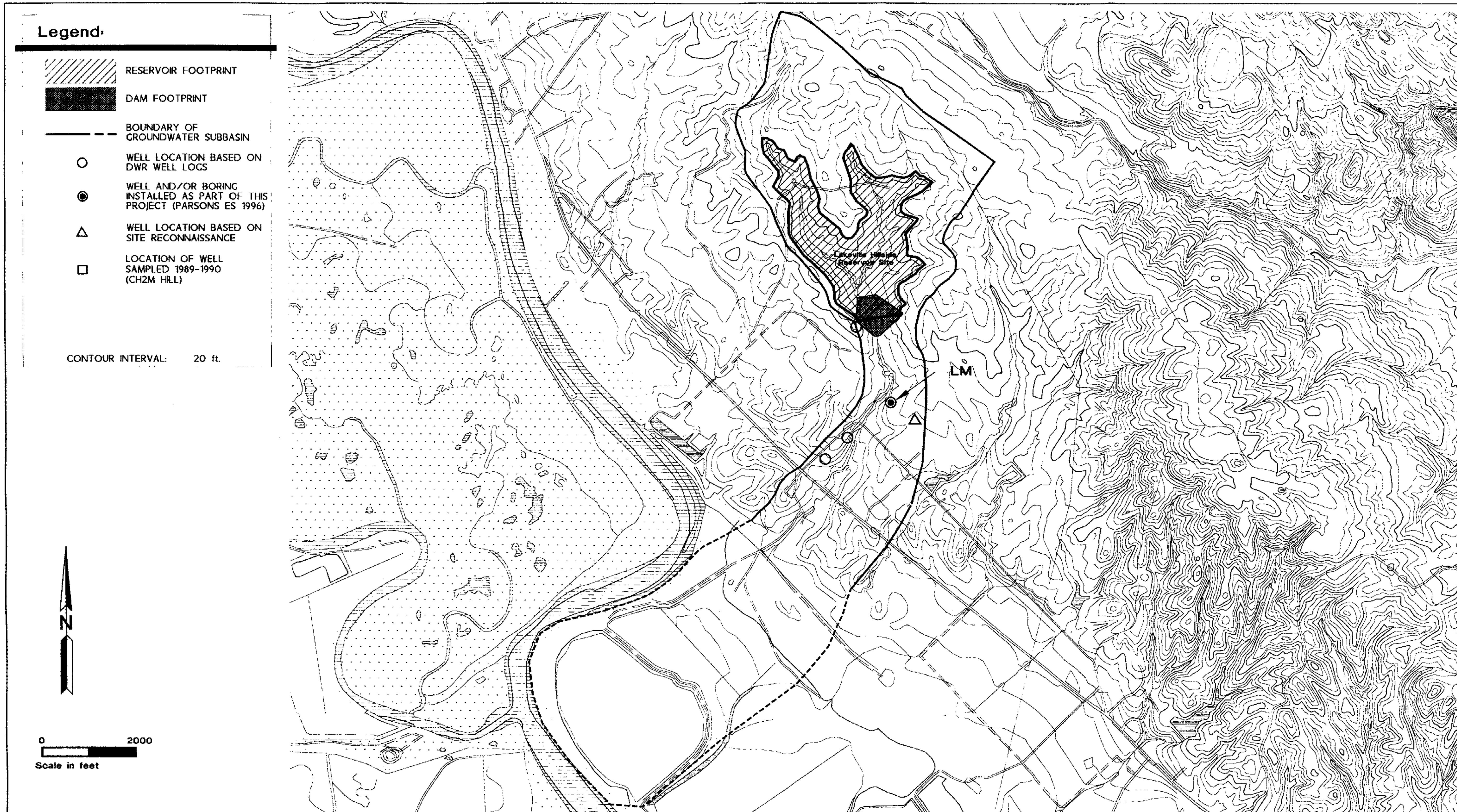
FIGURE 4-12

Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC CROSS-SECTION E-E' AND F-F'
SOUTH PETALUMA VALLEY

REV. 3 SR904-05.DWG 02/26/98

PARSONS ENGINEERING SCIENCE, INC.



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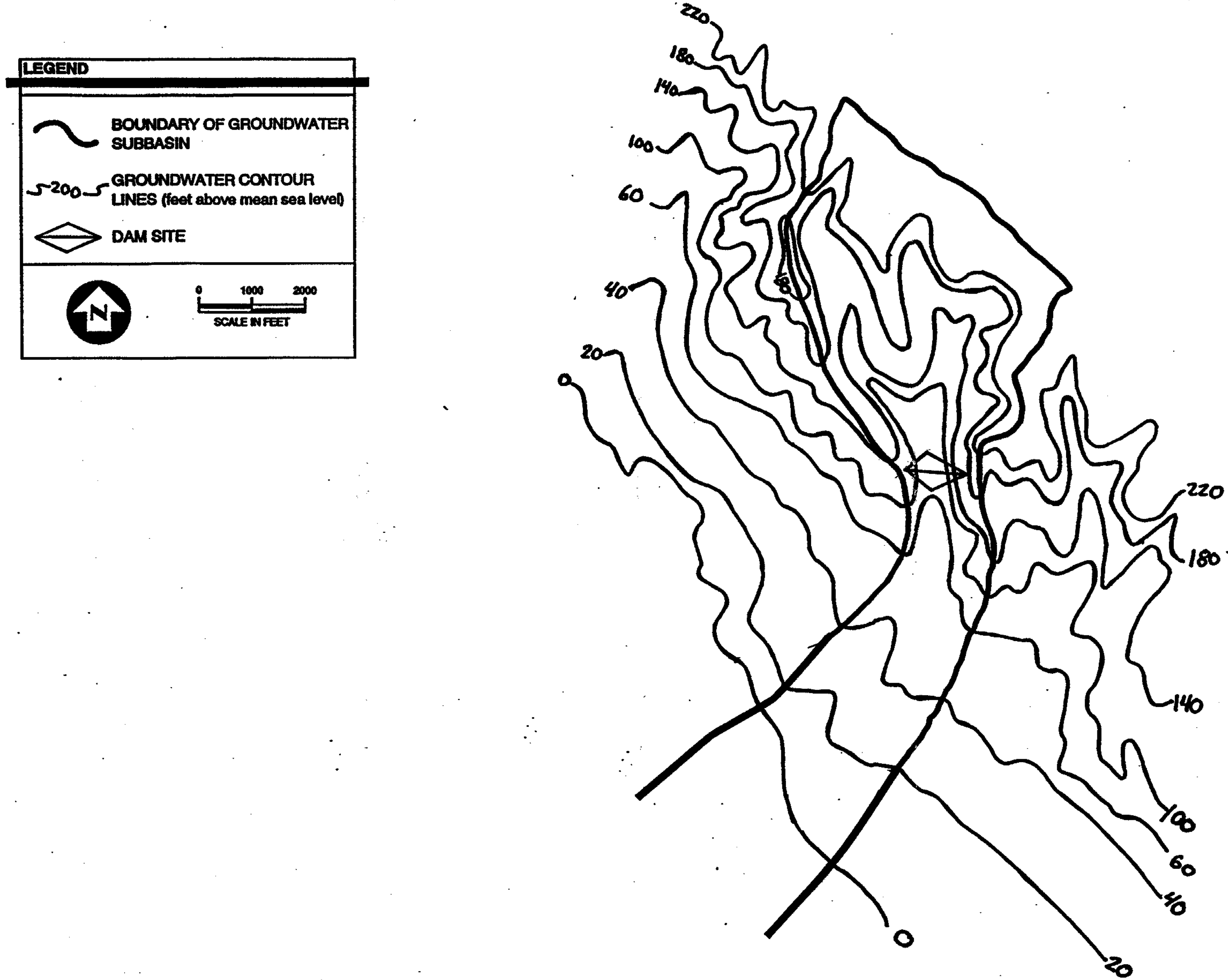
PARSONS ENGINEERING SCIENCE, INC.
UNITS OF PARSONS INFRASTRUCTURE and TECHNOLOGY GROUP INC.
PARSONS

Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER SUBBASIN FOR LAKEVILLE HILLSIDE RESERVOIR SITE

Figure 4-13

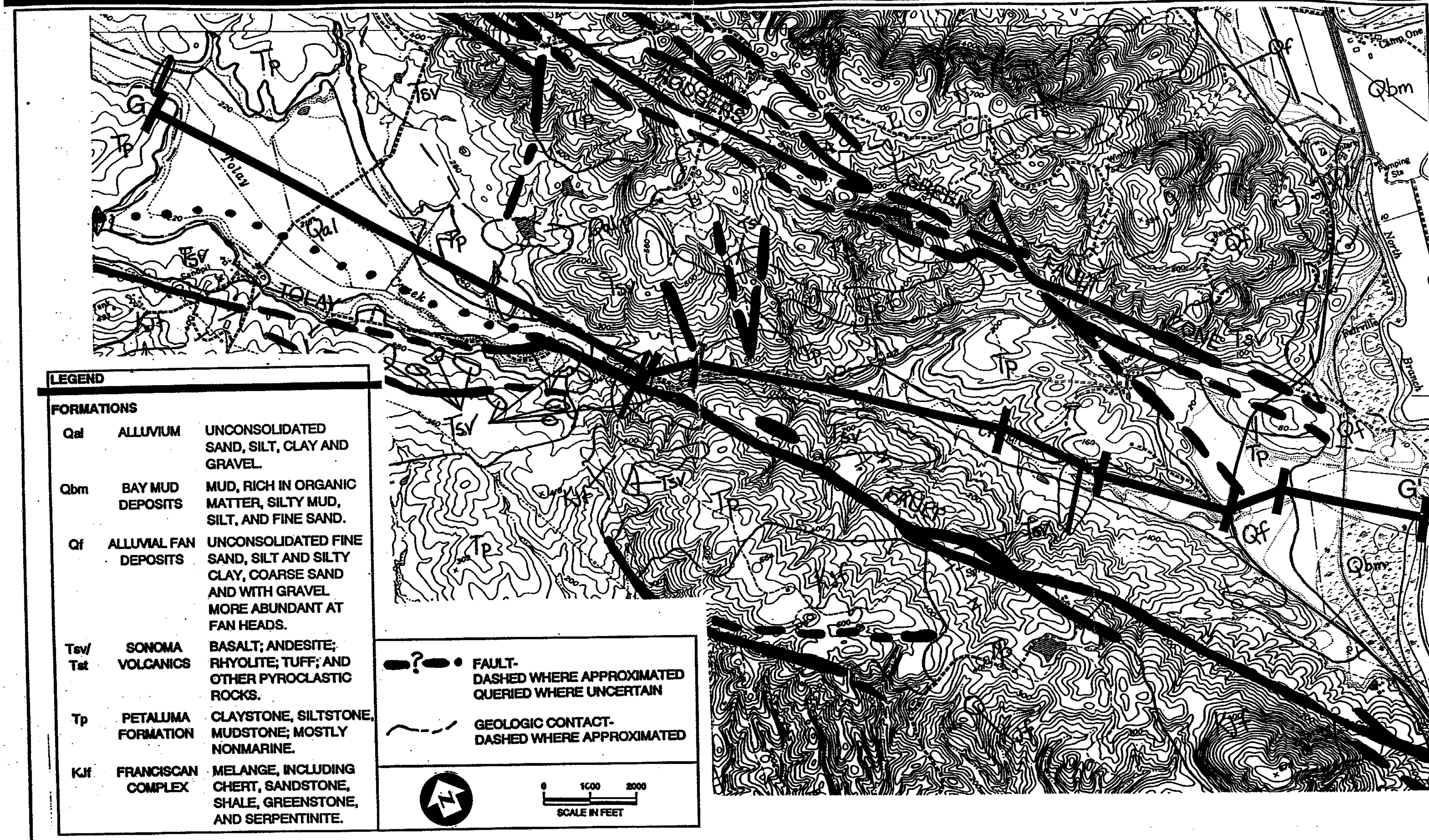


Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER CONTOURS FOR THE LAKEVILLE HILLSIDE RESERVOIR SITE SUBBASIN

FIGURE 4-14

PARSONS ENGINEERING SCIENCE, INC.



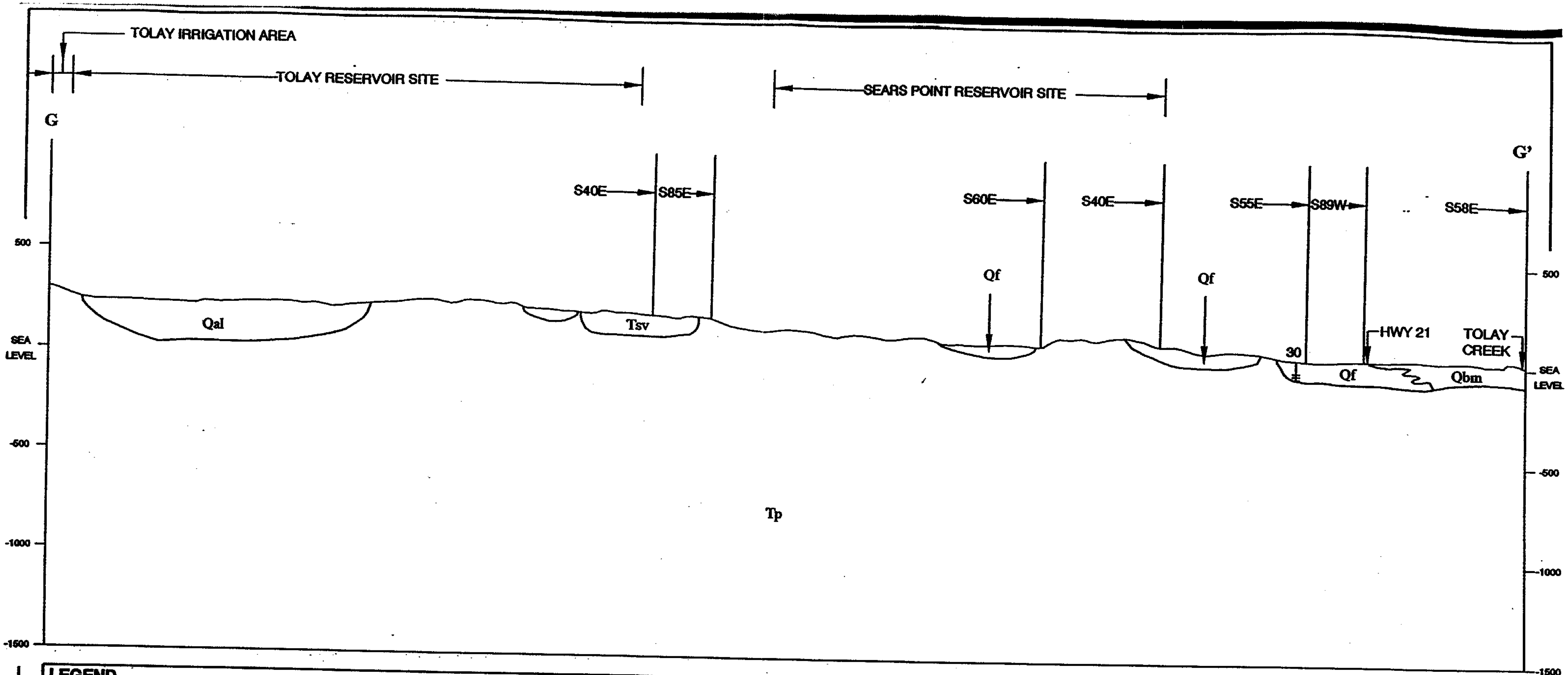
SOURCE: FROM DWR 1982b

Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF TOLAY CREEK

FIGURE 4-15

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS		
Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Qbm	BAY MUD DEPOSITS	MUD, RICH IN ORGANIC MATTER, SILTY MUD, SILT, AND FINE SAND.
Qf	ALLUVIAL FAN DEPOSITS	UNCONSOLIDATED FINE SAND, SILT, AND SILTY CLAY, COURSE SAND AND WITH GRAVEL MORE ABUNDANT AT FAN HEADS.
Tsv	SONOMA VOLCANICS	BALSALT; ANDESITE; RHYOLITE; TUFF AND OTHER PYROCLASTIC ROCKS.
Tp	PETALUMA FORMATION	CLAYSTONE, SILTSTONE, MUDSTONE; MOSTLY NONMARINE.

WELL LOGS

T4N/R5W 30

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

S40E → BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM DWR, 1982b, MODIFIED AFTER CARDWELL, 1958.

SCALE IN FEET (VERTICAL EXAGGERATION = 4X)

500 0 0 2000

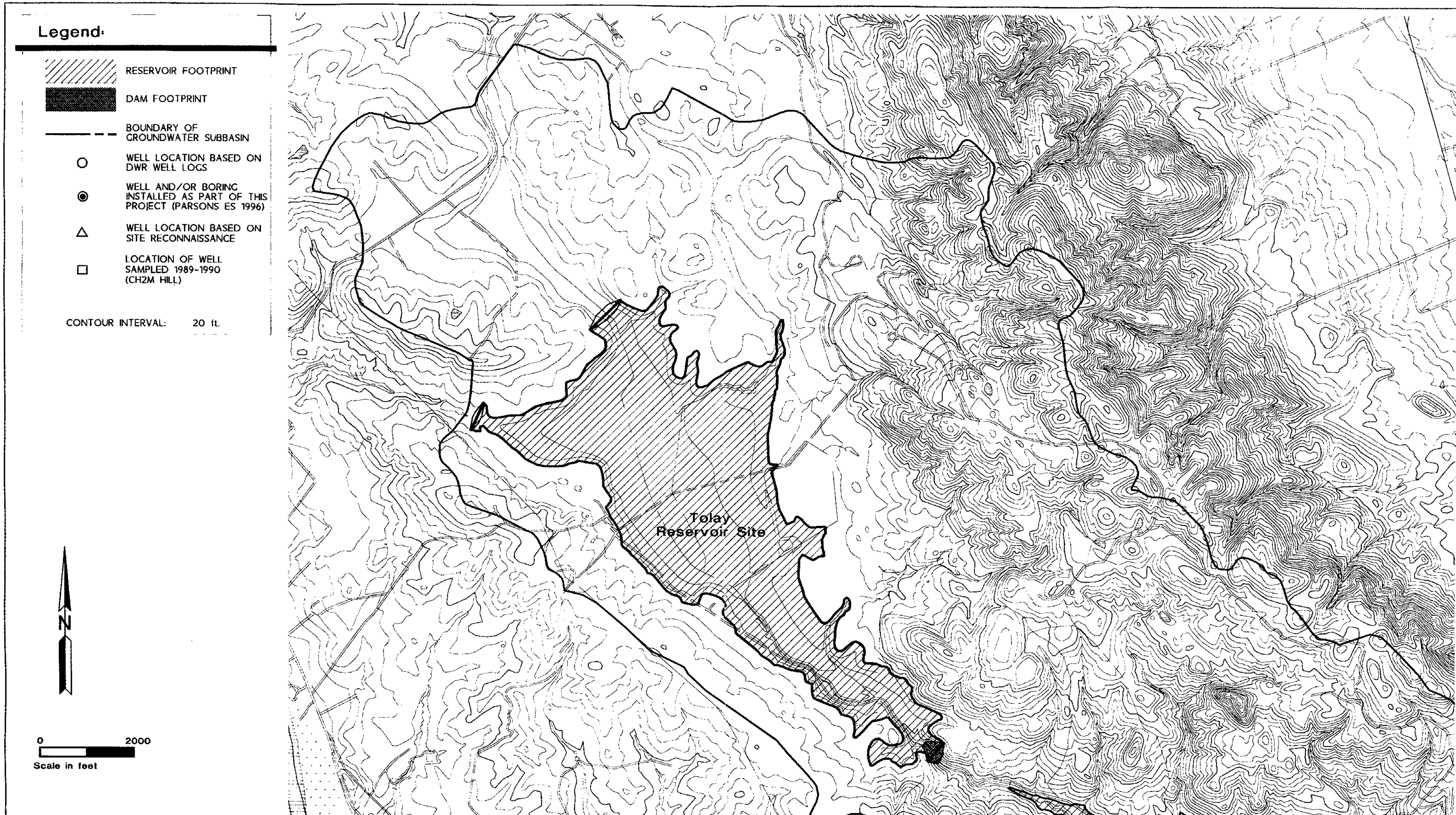
FIGURE 4-16

Santa Rosa Subregional Long-Term Wastewater Project

GEOLOGIC CROSS-SECTION G-G'
TOLAY CREEK

REV. 4 SR904-08.DWG 03/04/96

PARSONS ENGINEERING SCIENCE, INC.



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PARSONS ENGINEERING SCIENCE, INC.
UNITS OF PARSONS INFRASTRUCTURE and TECHNOLOGY GROUP INC.
PARSONS

Santa Rosa Subregional Long-Term Wastewater Project

NORTHERN PORTION OF GROUNDWATER SUBBASIN FOR TOLAY/SEARS POINT RESERVOIR SITES

Figure 4-17

Legend:

RESERVOIR FOOTPRINT

DAM FOOTPRINT

BOUNDARY OF GROUNDWATER SUBBASIN

WELL LOCATION BASED ON DWR WELL LOGS

WELL AND/OR BORING INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)

WELL LOCATION BASED ON SITE RECONNAISSANCE

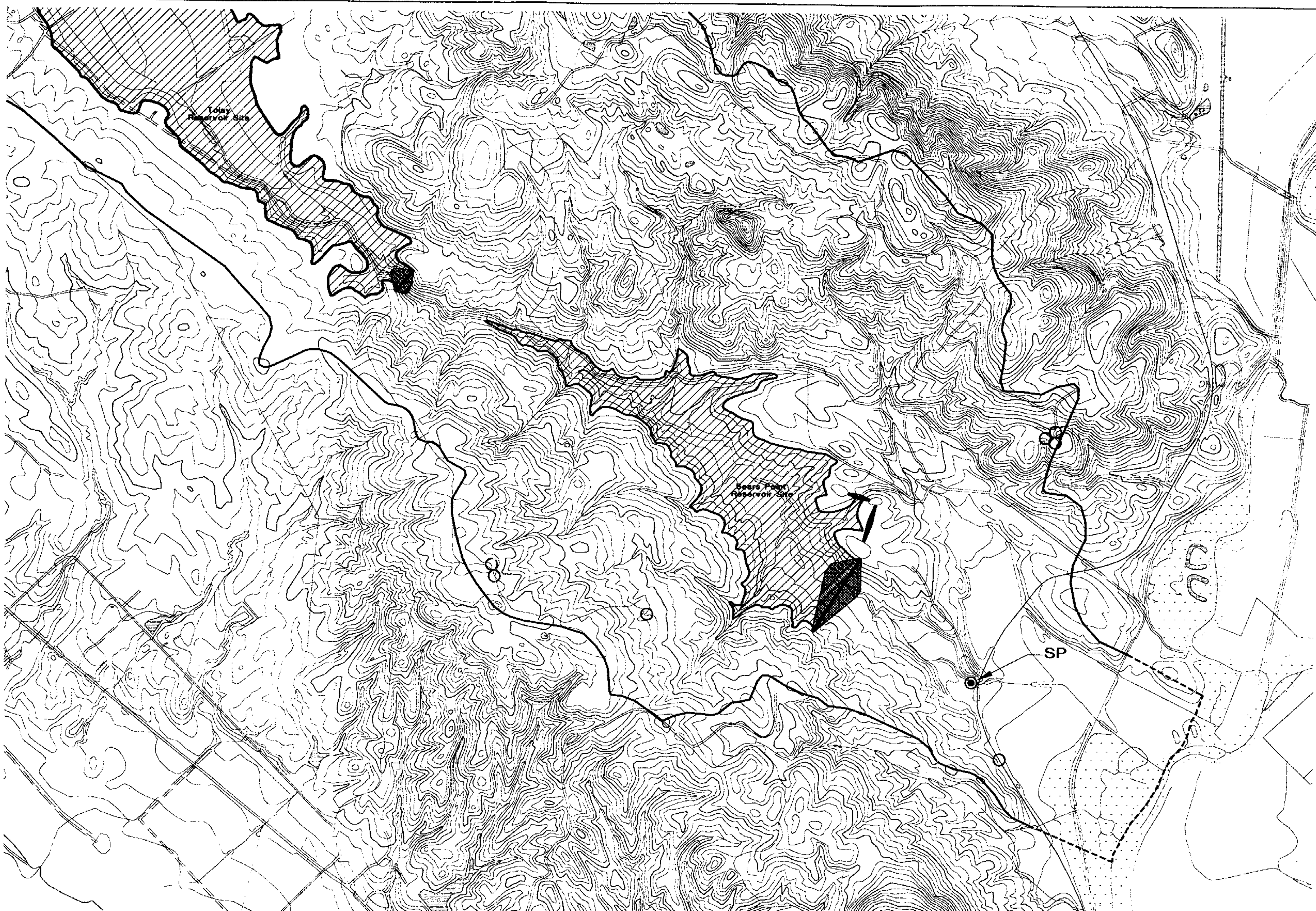
LOCATION OF WELL SAMPLED 1989-1990 (CH2M HILL)

CONTOUR INTERVAL: 20 ft.

N

0 2000

Scale in feet



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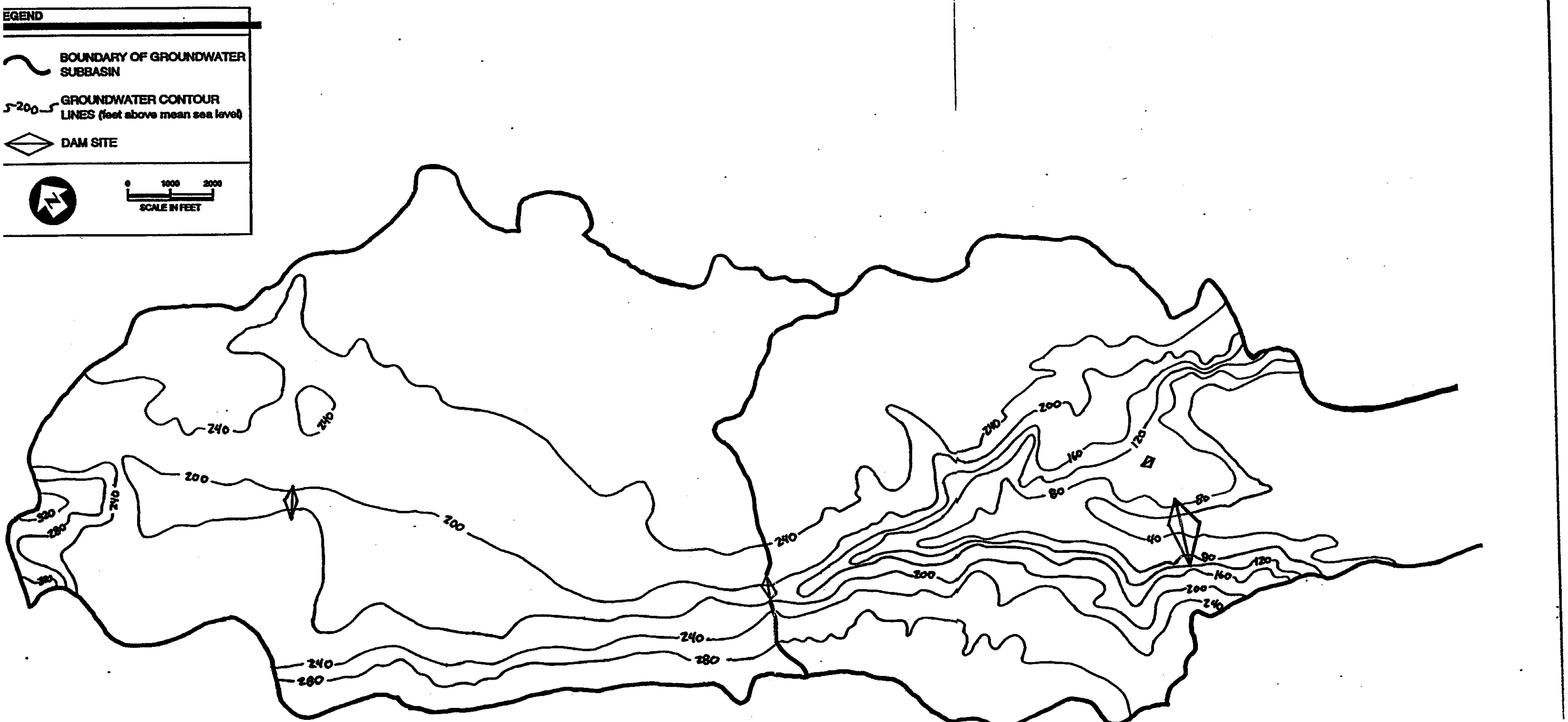
PARSONS

Santa Rosa Subregional Long-Term Wastewater Project

SOUTHERN PORTION OF GROUNDWATER SUBBASIN FOR TOLAY/SEARS POINT RESERVOIR SITES

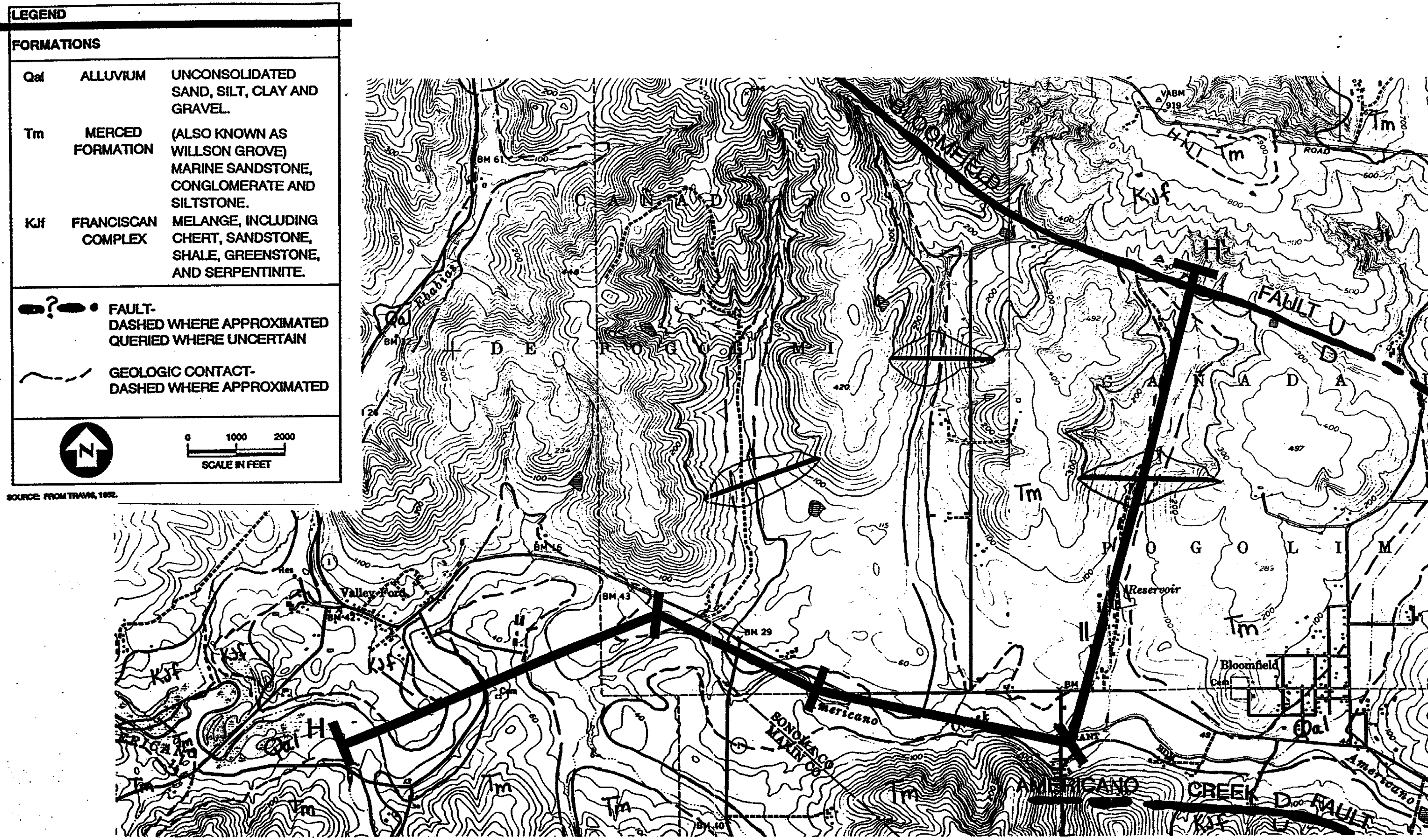
Figure 4-18



GROUNDWATER CONTOURS FOR THE TOLAY/SEARS POINT RESERVOIR SITE SUBBASINS

FIGURE 4-19

PARSONS ENGINEERING SCIENCE, INC.

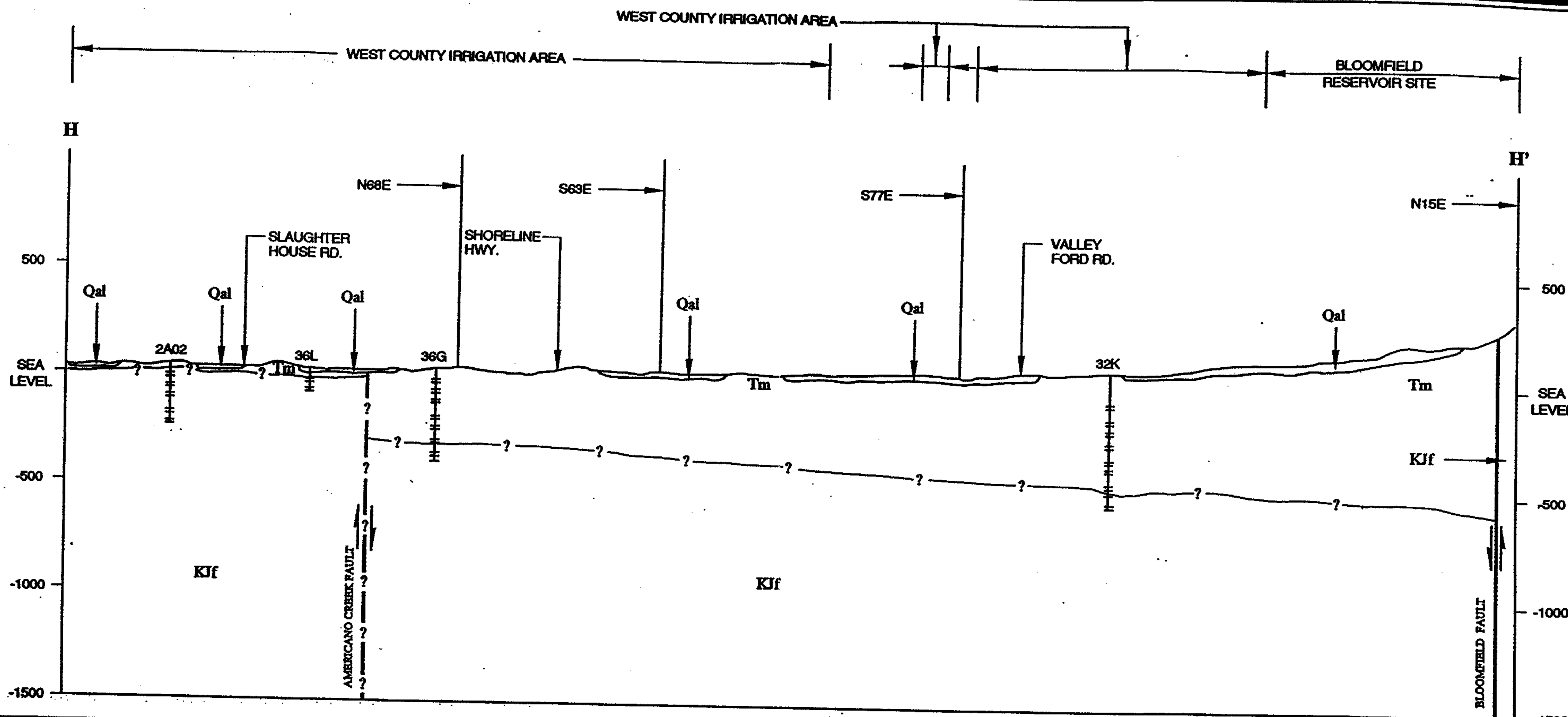


Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF A PORTION OF AMERICANO CREEK

FIGURE 4-20

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS

Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T5N/R10W 2A02

T6N/R9W 32K, 36G, 36L

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

S77E — BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM TRAVIS, 1952.

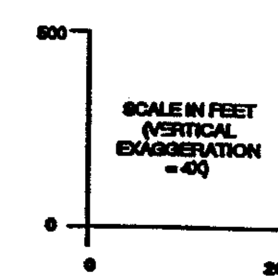


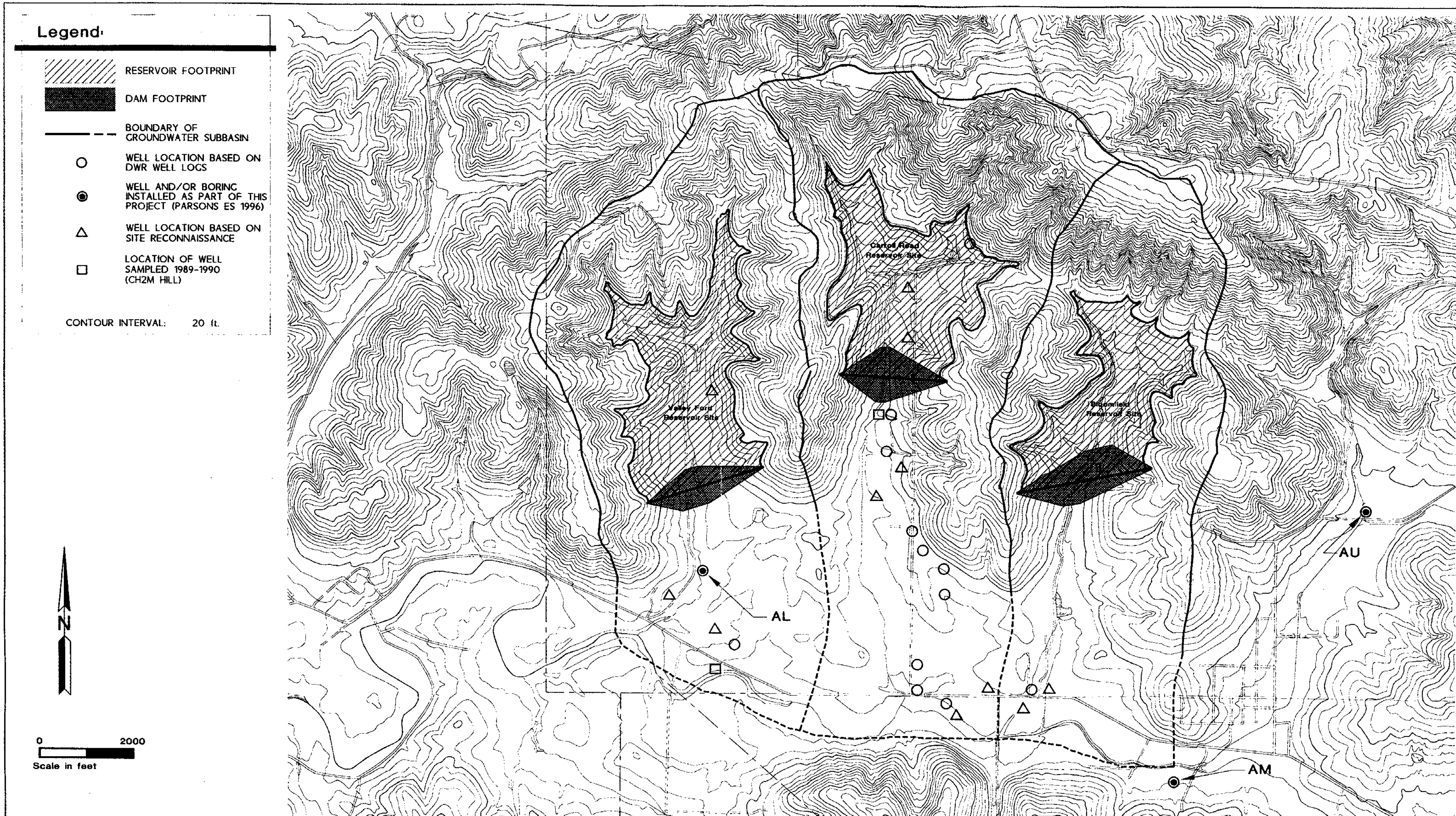
FIGURE 4-21

Santa Rosa Subregional Long-Term Wastewater Project

REV. 4 SR801-08.DWG 03/04/96

GEOLOGIC CROSS-SECTION H-H'
AMERICANO CREEK

PARSONS ENGINEERING SCIENCE, INC.



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UNITS OF PARSONS INFRASTRUCTURE and TECHNOLOGY GROUP INC.
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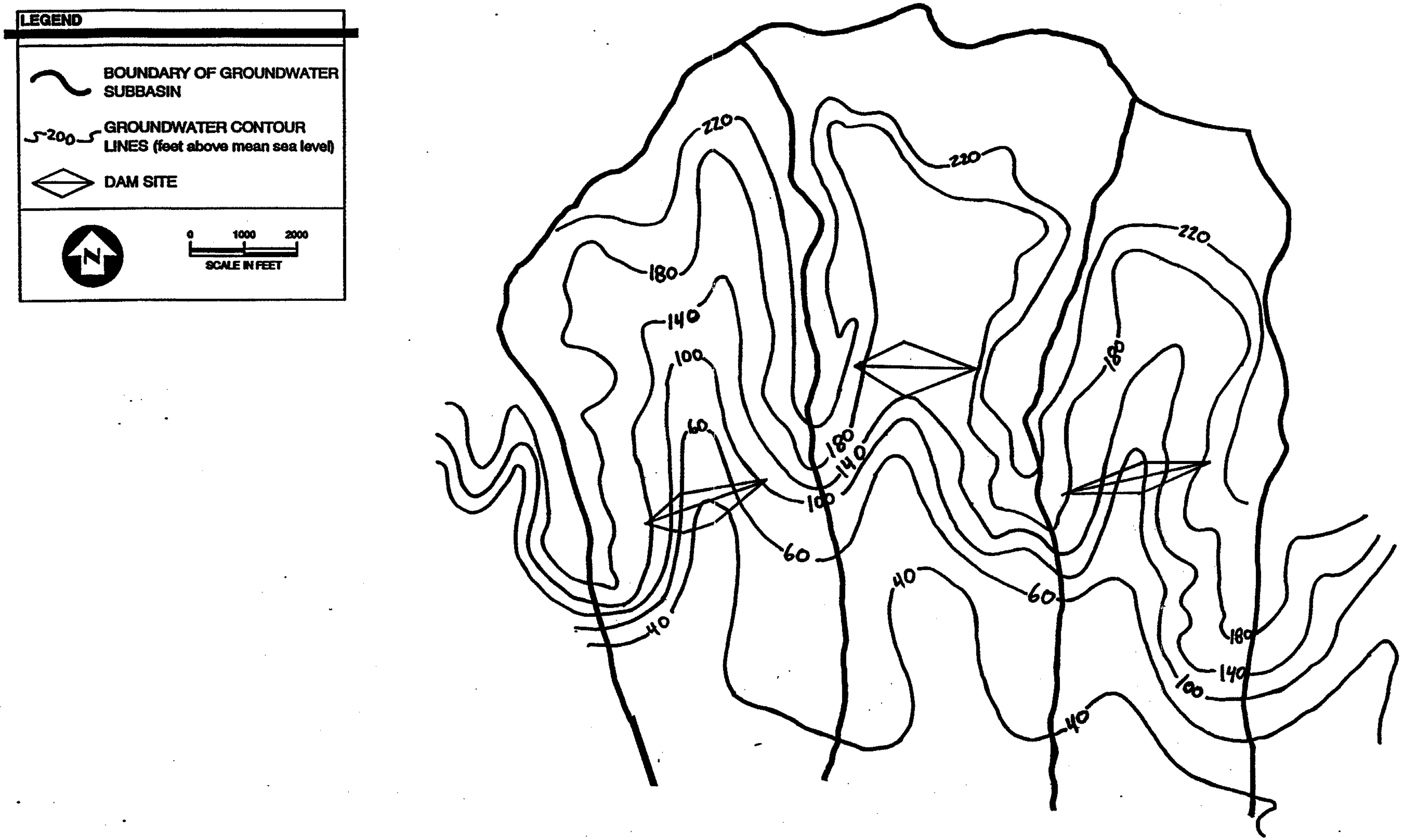
Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER SUBBASINS FOR VALLEY FORD, CARROLL RD. AND BLOOMFIELD RESERVOIR SITES

Figure 4-22

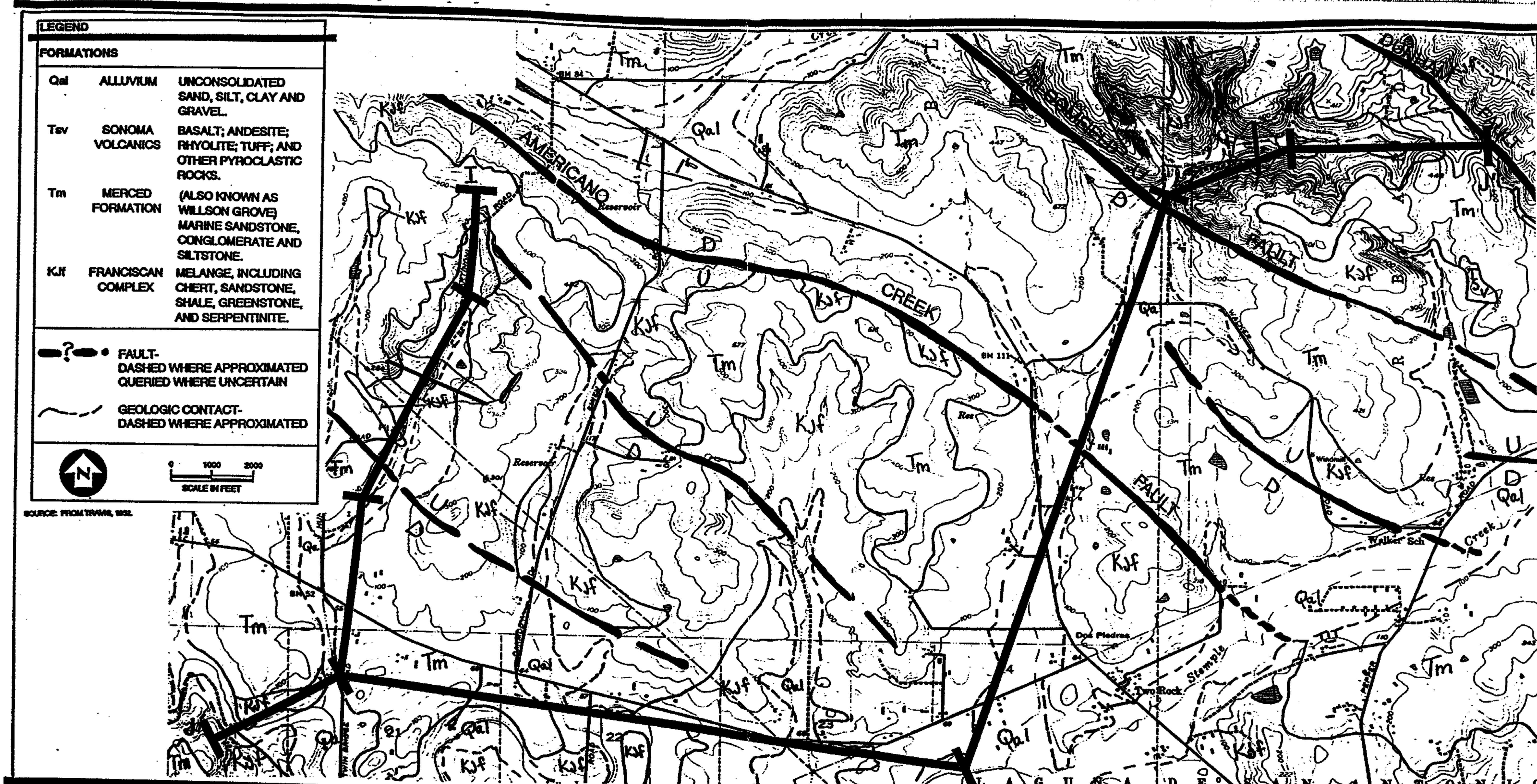


Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER CONTOURS FOR THE VALLEY FORD EAST, CARROLL ROAD NORTH, AND BLOOMFIELD RESERVOIR SITE SUBBASINS

FIGURE 4-23

PARSONS ENGINEERING SCIENCE, INC.

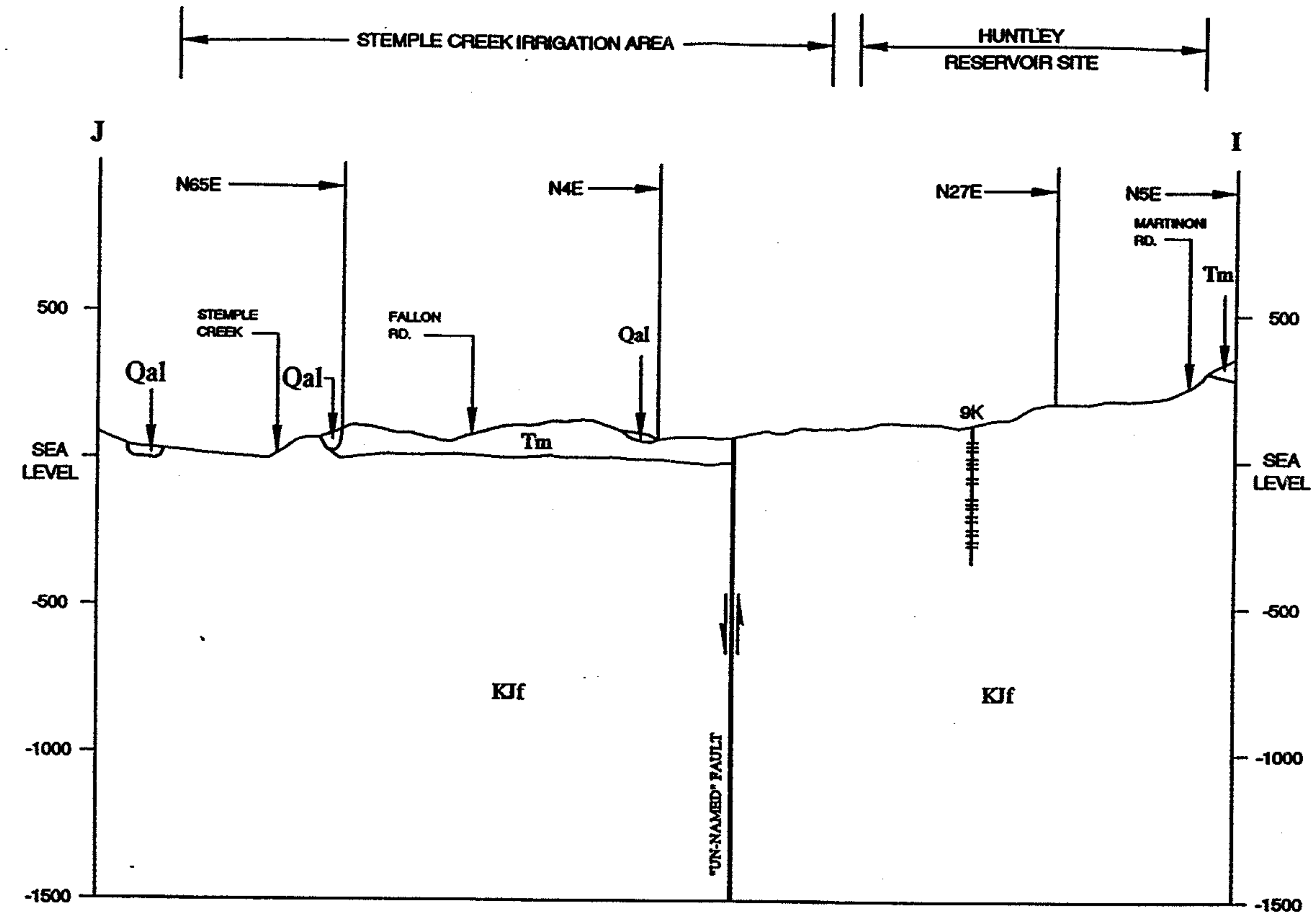


Santa Rosa Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF A PORTION OF STEMPLE CREEK

FIGURE 4-24

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS

Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T5N/R9W 9K

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

S60E — BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM TRAVIS, 1952.

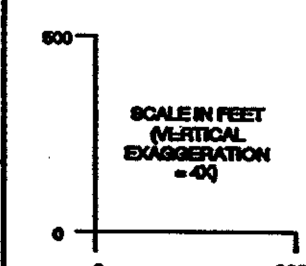


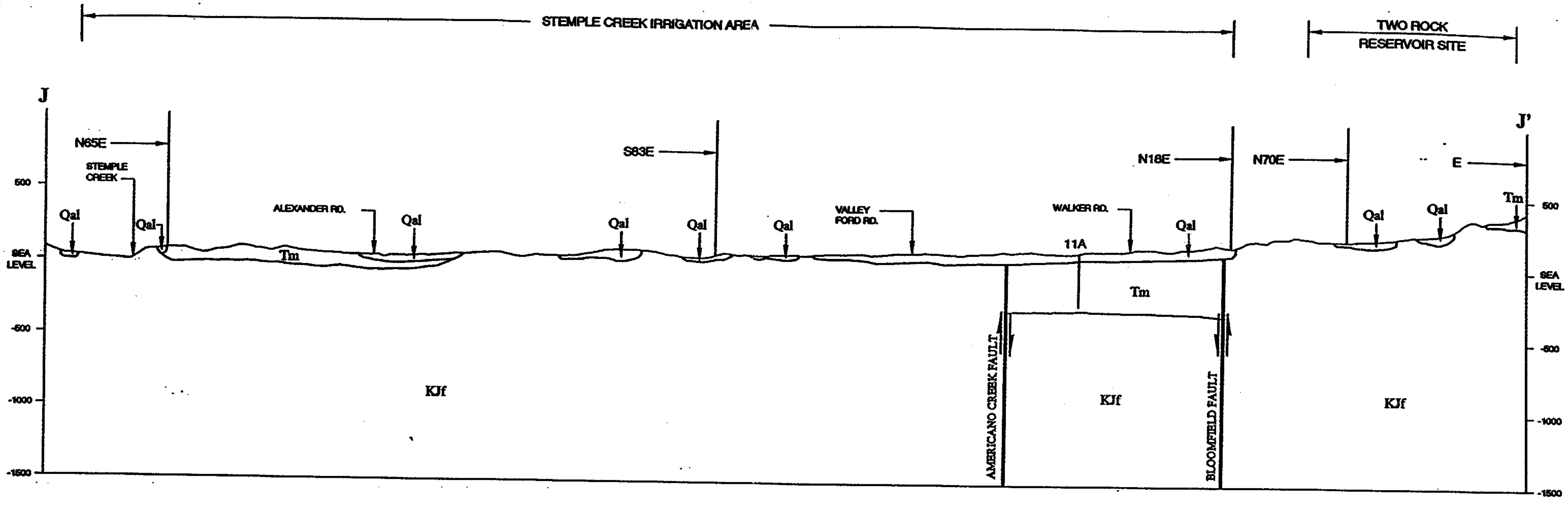
FIGURE 4-25

Santa Rosa
Subregional Long-Term Wastewater Project

REV. 4 SR904-09.DWG 03/04/96

GEOLOGIC CROSS-SECTION J-I
STEMPLE CREEK

PARSONS ENGINEERING SCIENCE, INC.



LEGEND

FORMATIONS

Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

T5N/R9W/ 11A

FAULT- DASHED WHERE APPROXIMATED

GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN

WELL WITH SCREENED INTERVAL

S83E → BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM TRAVIS, 1952.

SCALE IN FEET (VERTICAL EXAGGERATION = 4X)

500 0 0 2000

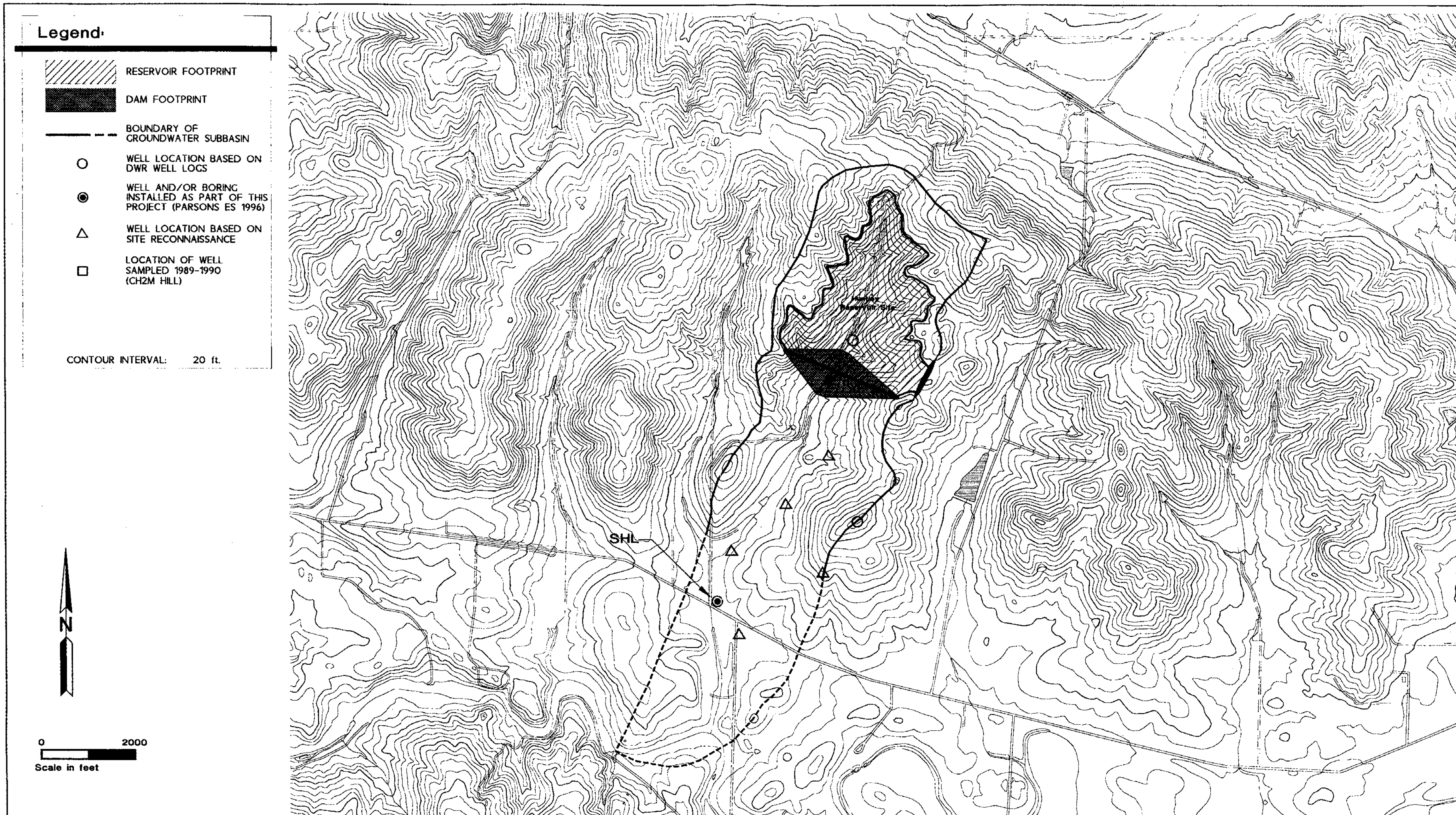
FIGURE 4-26

Santa Rosa
Subregional Long-Term Wastewater Project

REV. 3 SR904-10.DWG 02/27/96

GEOLOGIC CROSS-SECTION J-J'
STEMPLE CREEK

PARSONS ENGINEERING SCIENCE, INC.



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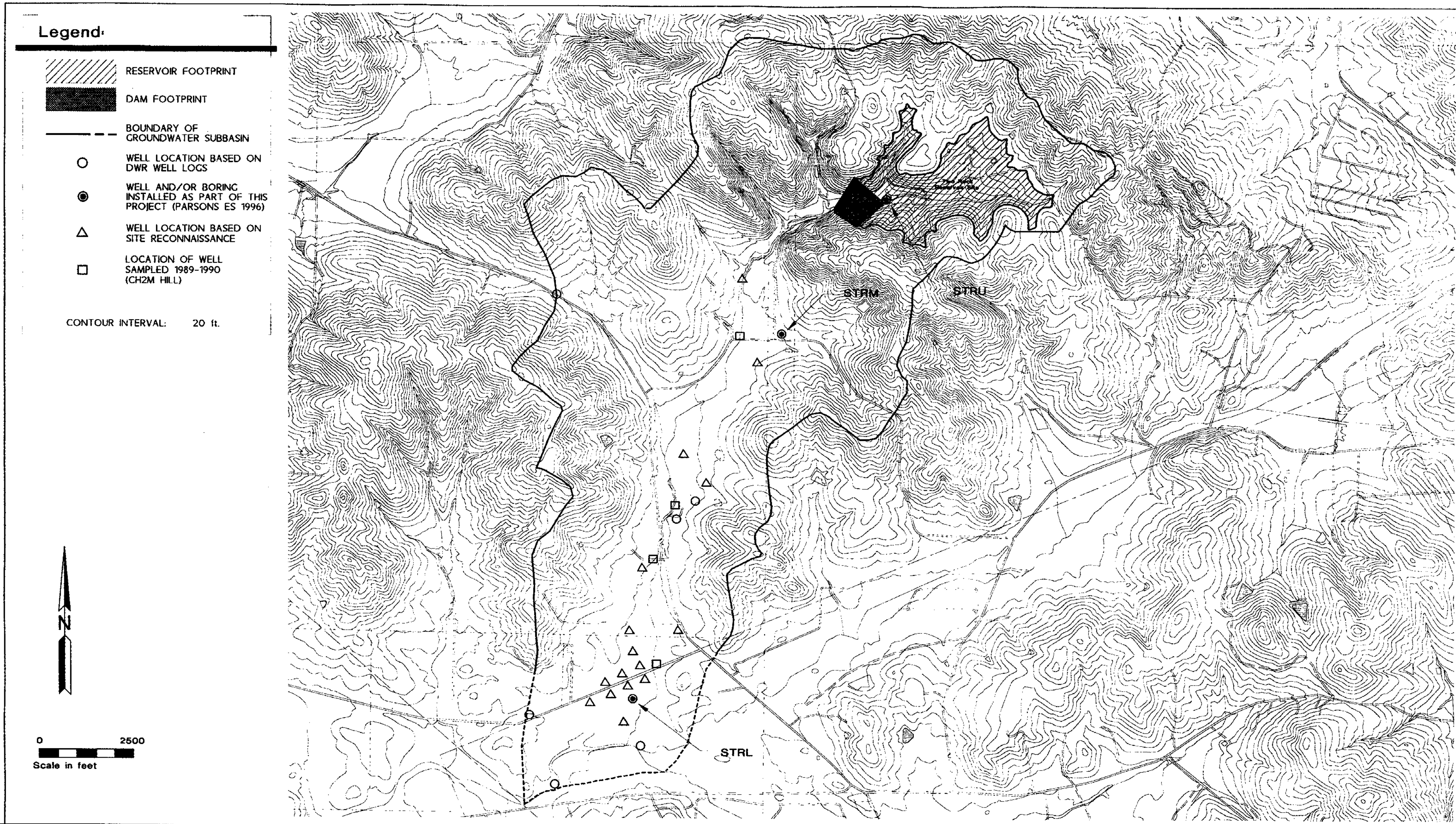
Subregional Long-Term Wastewater Project

GROUNDWATER SUBBASIN FOR HUNTLEY RESERVOIR SITE

Figure 4-27



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GROUNDWATER SUBBASIN FOR TWO ROCK RESERVOIR SITE

Figure 4-28

LEGEND

BOUNDARY OF GROUNDWATER SUBBASIN

GROUNDWATER CONTOUR LINES (feet above mean sea level)

DAM SITE

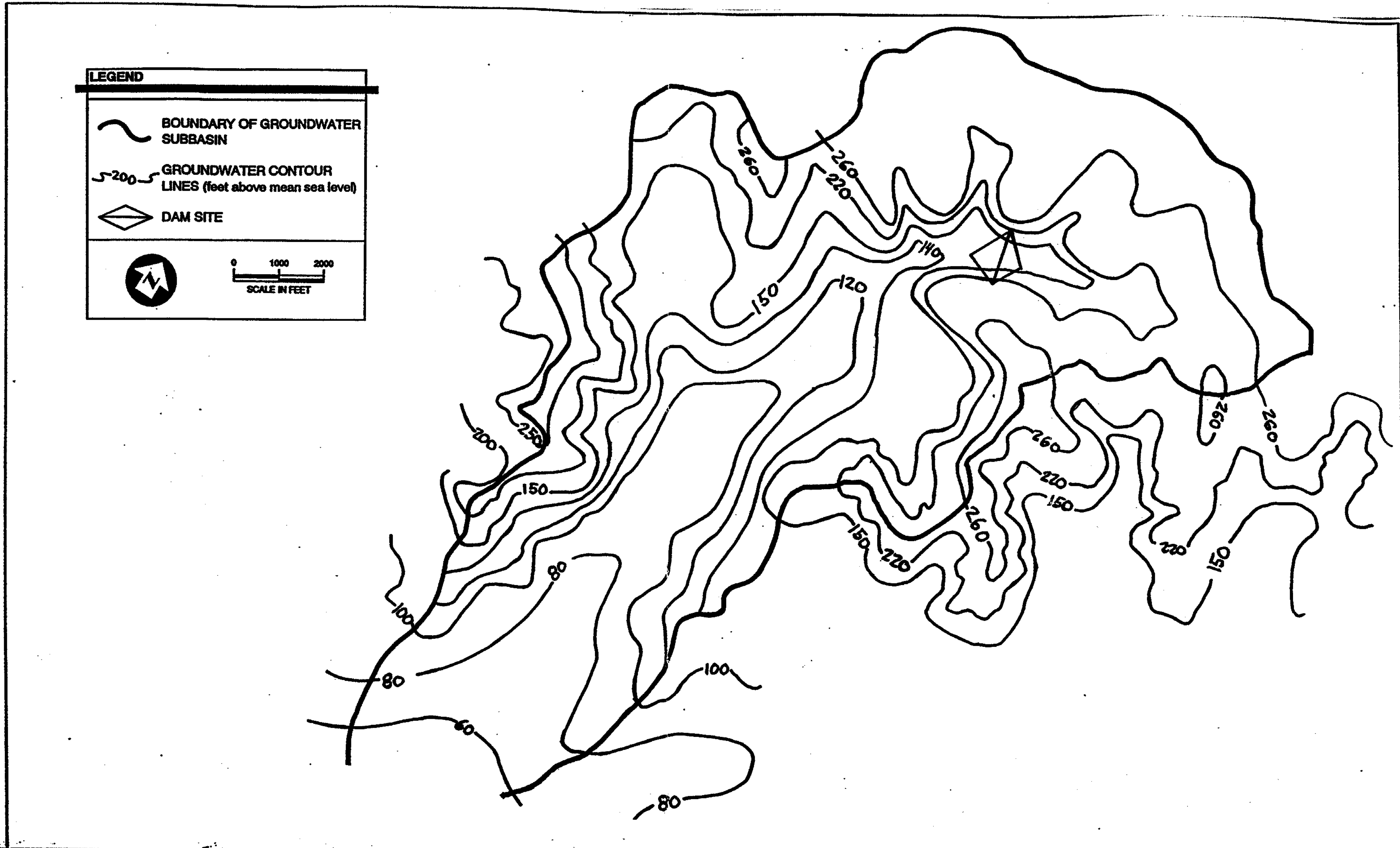
0 1000 2000
SCALE IN FEET

Santa Rosa
Subregional Long-Term Wastewater Project

GROUNDWATER CONTOURS FOR THE HUNTLEY RESERVOIR SITE SUBBASIN

FIGURE 4-29

PARSONS ENGINEERING SCIENCE, INC.



Santa Rosa
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GROUNDWATER CONTOURS FOR THE TWO ROCK RESERVOIR SITE SUBBASIN

FIGURE 4-30

PARSONS ENGINEERING SCIENCE, INC.

LEGEND

FORMATIONS

Qal	ALLUVIUM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILLSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

FAULT-
DASHED WHERE APPROXIMATED
QUERIED WHERE UNCERTAIN

GEOLOGIC CONTACT-
DASHED WHERE APPROXIMATED

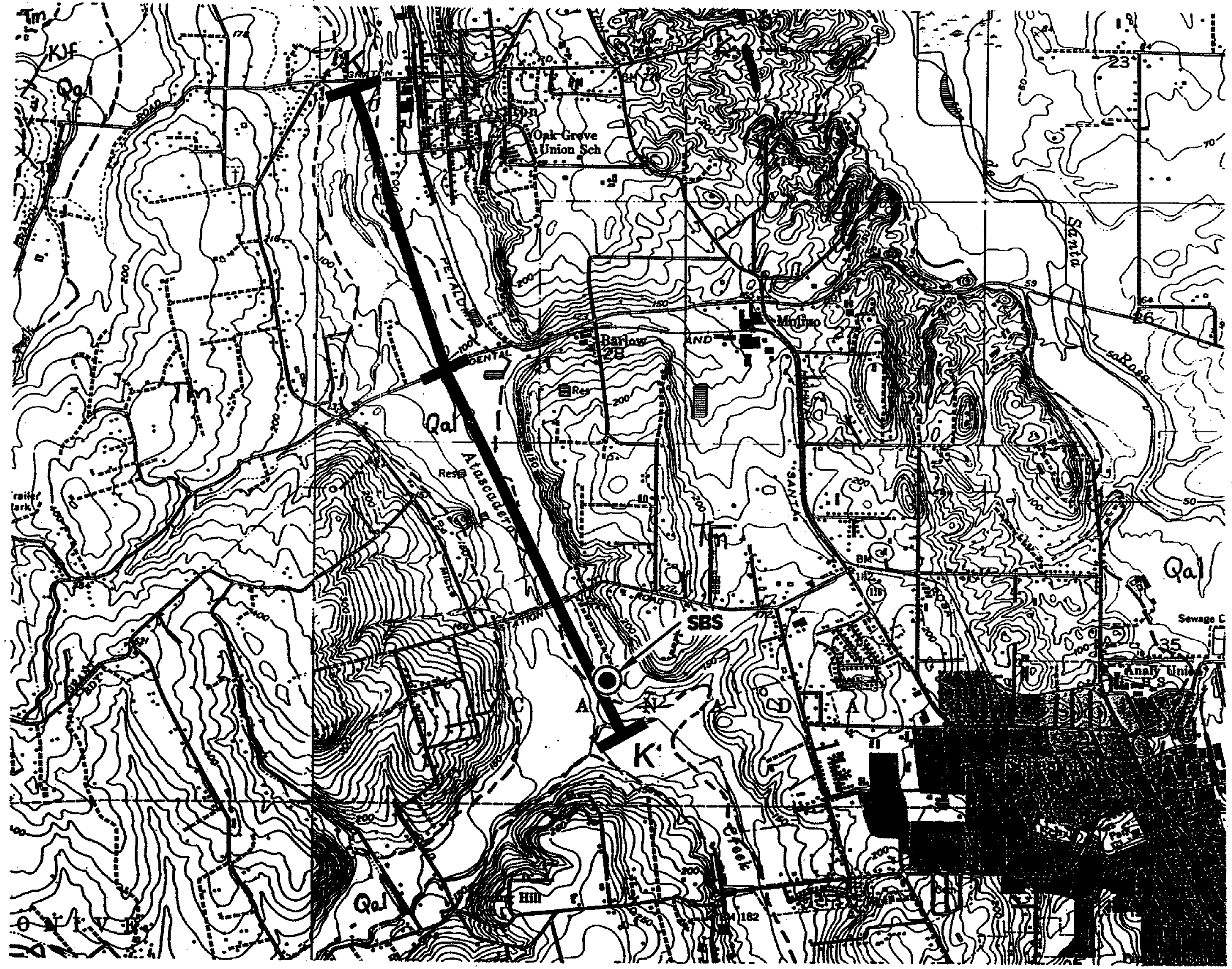
N

0 1000 2000
SCALE IN FEET

SOURCE: FROM TRAVIS, 1952 AND CARDWELL, 1958.

WELL LOCATIONS

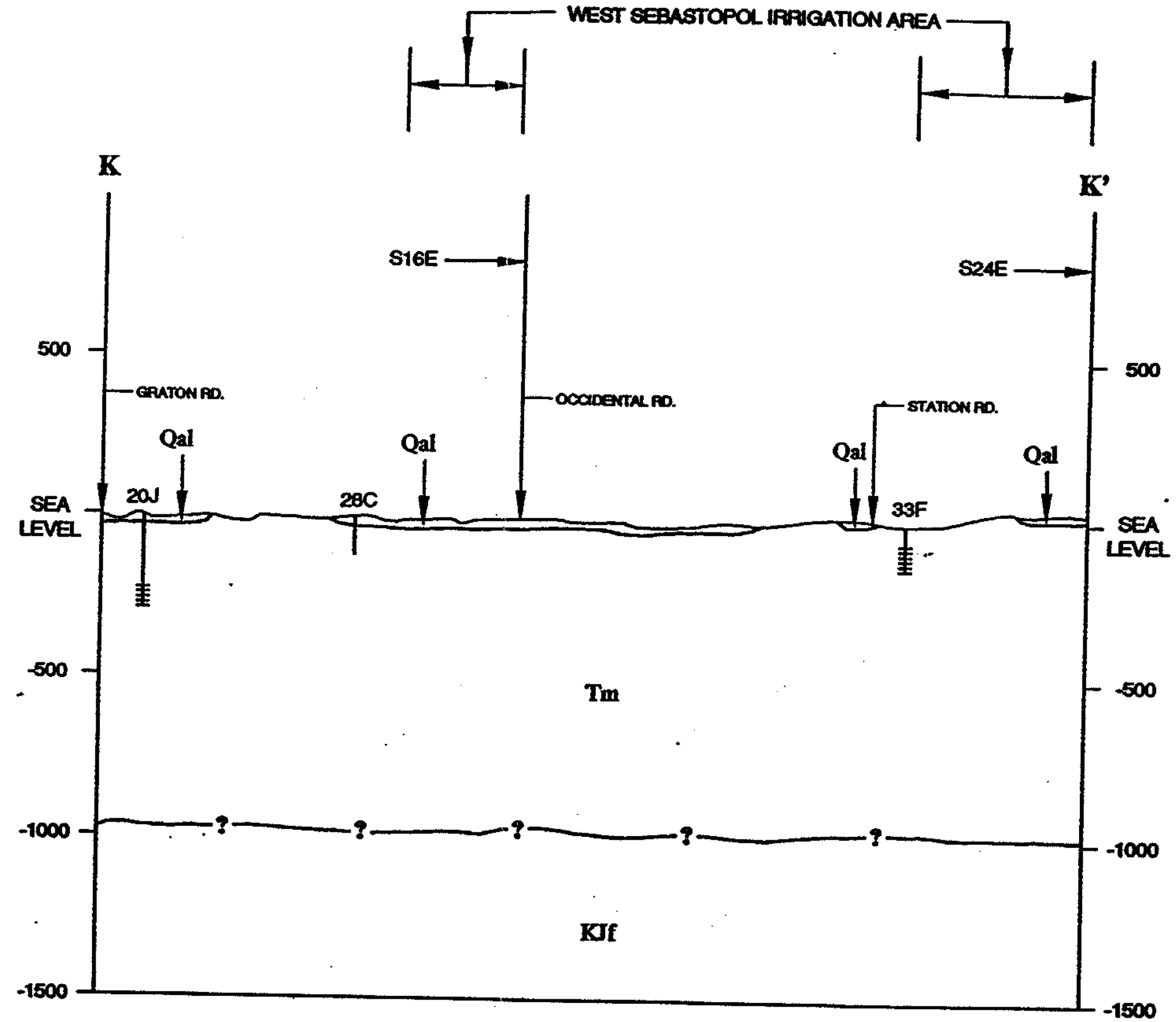
WELLS AND/OR BORINGS INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)



Santa Rosa
Subregional Long-Term Wastewater Project

GEOLOGIC MAP OF WEST SEBASTOPOL

FIGURE 4-31



LEGEND

FORMATIONS		
Qal	ALLUVIM	UNCONSOLIDATED SAND, SILT, CLAY AND GRAVEL.
Tm	MERCED FORMATION	(ALSO KNOWN AS WILSON GROVE) MARINE SANDSTONE, CONGLOMERATE AND SILTSTONE.
KJf	FRANCISCAN COMPLEX	MELANGE, INCLUDING CHERT, SANDSTONE, SHALE, GREENSTONE, AND SERPENTINITE.

WELL LOGS

- T7N/R9W 20J
- T7N/R9W 28C
- T7N/R9W 33F

Symbol	Meaning
(fault symbol)	FAULT- DASHED WHERE APPROXIMATED
—?—	GEOLOGIC CONTACT- QUERIED WHERE UNCERTAIN
(well symbol)	WELL WITH SCREENED INTERVAL
S16E —►	BEND IN CROSS SECTION - DIRECTION INDICATED

SOURCE: FROM TRAVIS, [illegible] AND CARDWELL, [illegible].

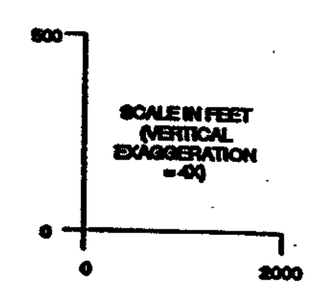


FIGURE 4-32

Santa Rosa
Subregional Long-Term Wastewater Project

REV. 3 SR004-07.DWG 02/27/96

GEOLOGIC CROSS-SECTION K-K'
WEST SEBASTOPOL

PARSONS ENGINEERING SCIENCE, INC.

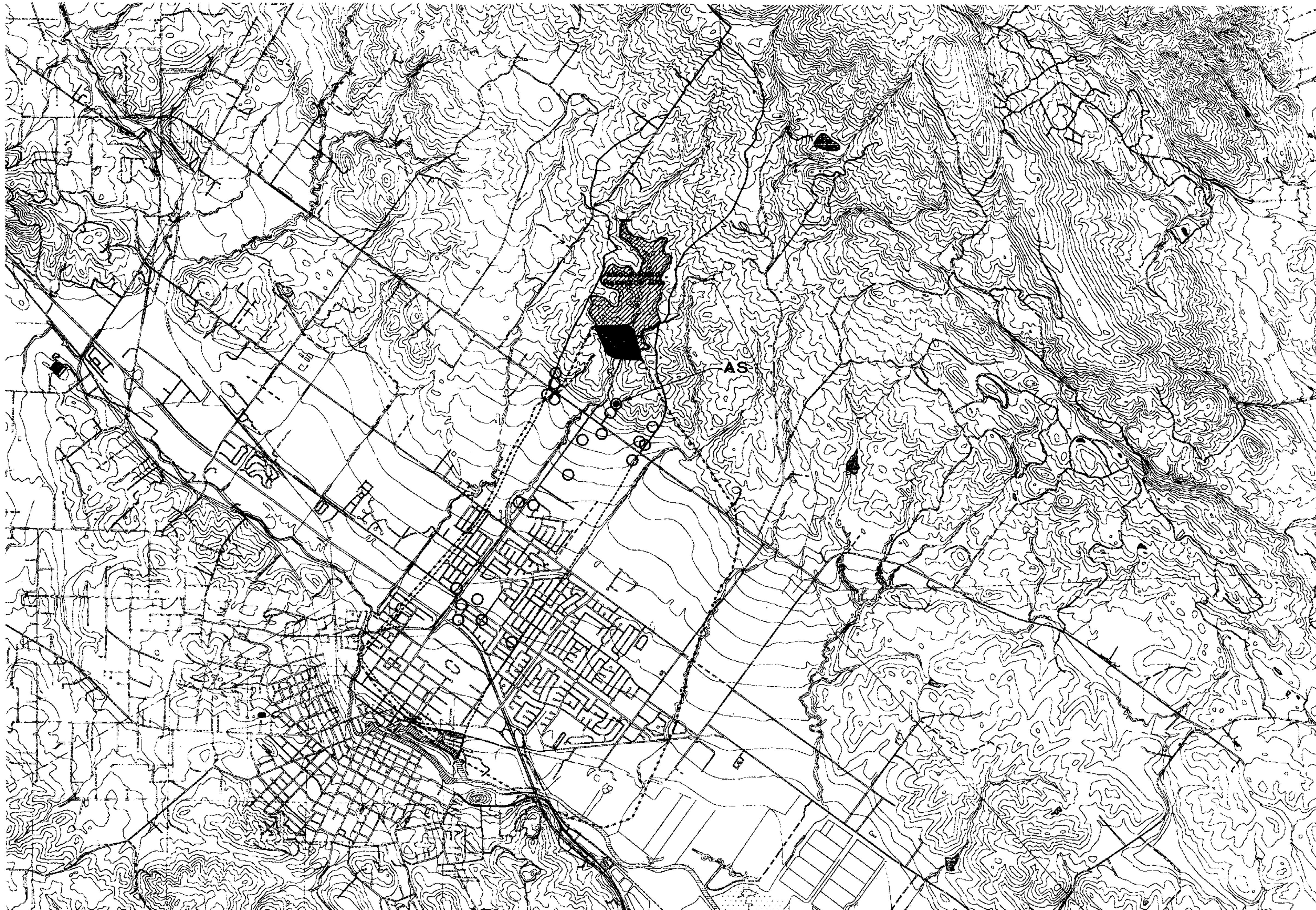
Legend

Symbol	Description
(hatched)	RESERVOIR FOOTPRINT
(solid dark)	DAM FOOTPRINT
——— - - -	BOUNDARY OF GROUNDWATER SUBBASIN
○	WELL LOCATION BASED ON DWR WELL LOGS
◉	WELL AND/OR BORING INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)
△	WELL LOCATION BASED ON SITE RECONNAISSANCE
□	LOCATION OF WELL SAMPLED 1989-1990 (CH2M HILL)
▬ ▬ ▬	20% CONTRIBUTION LINE

CONTOUR INTERVAL: 20 ft.

N

0 4000
Scale in feet



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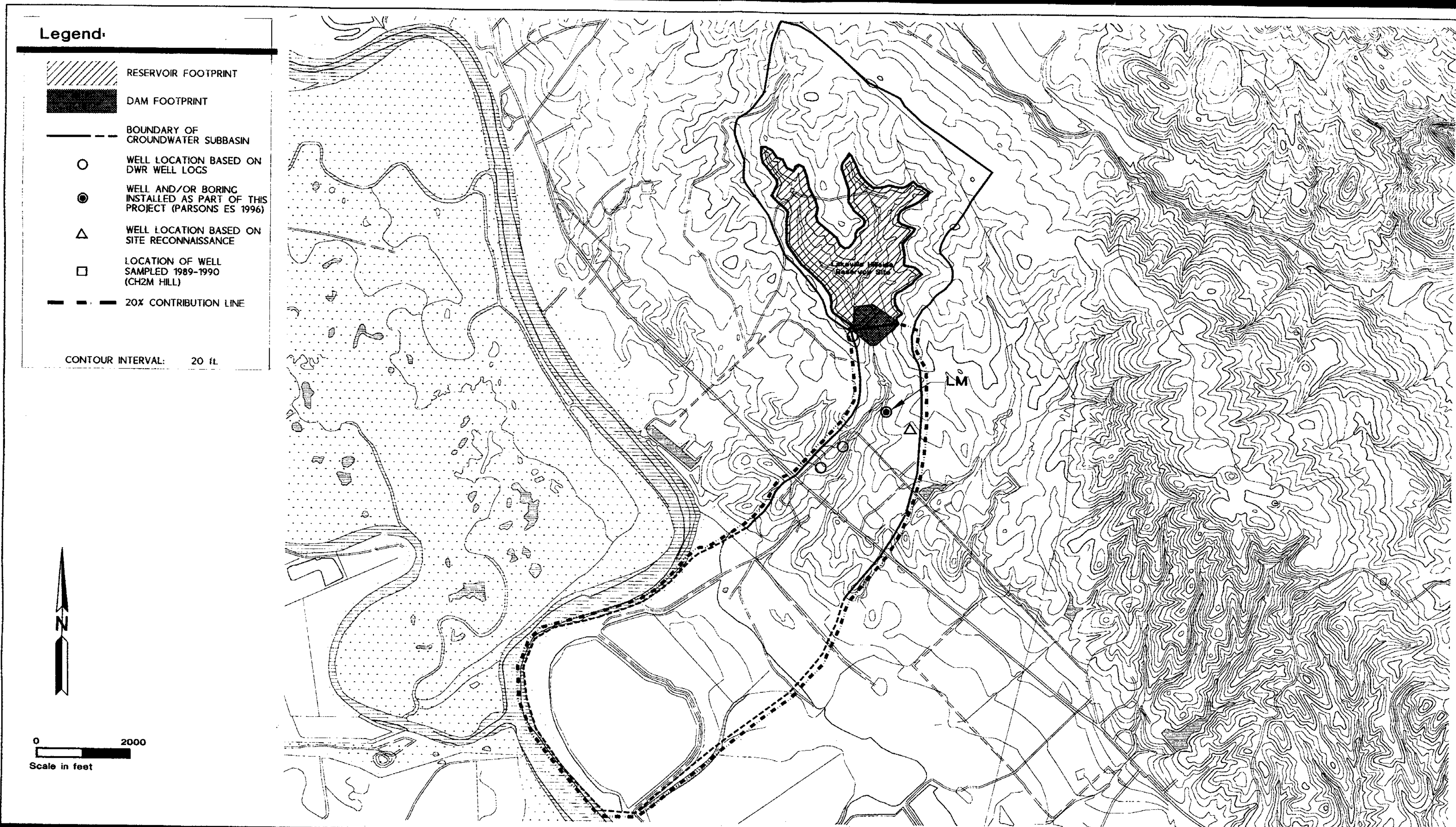
ADOBE ROAD RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-1



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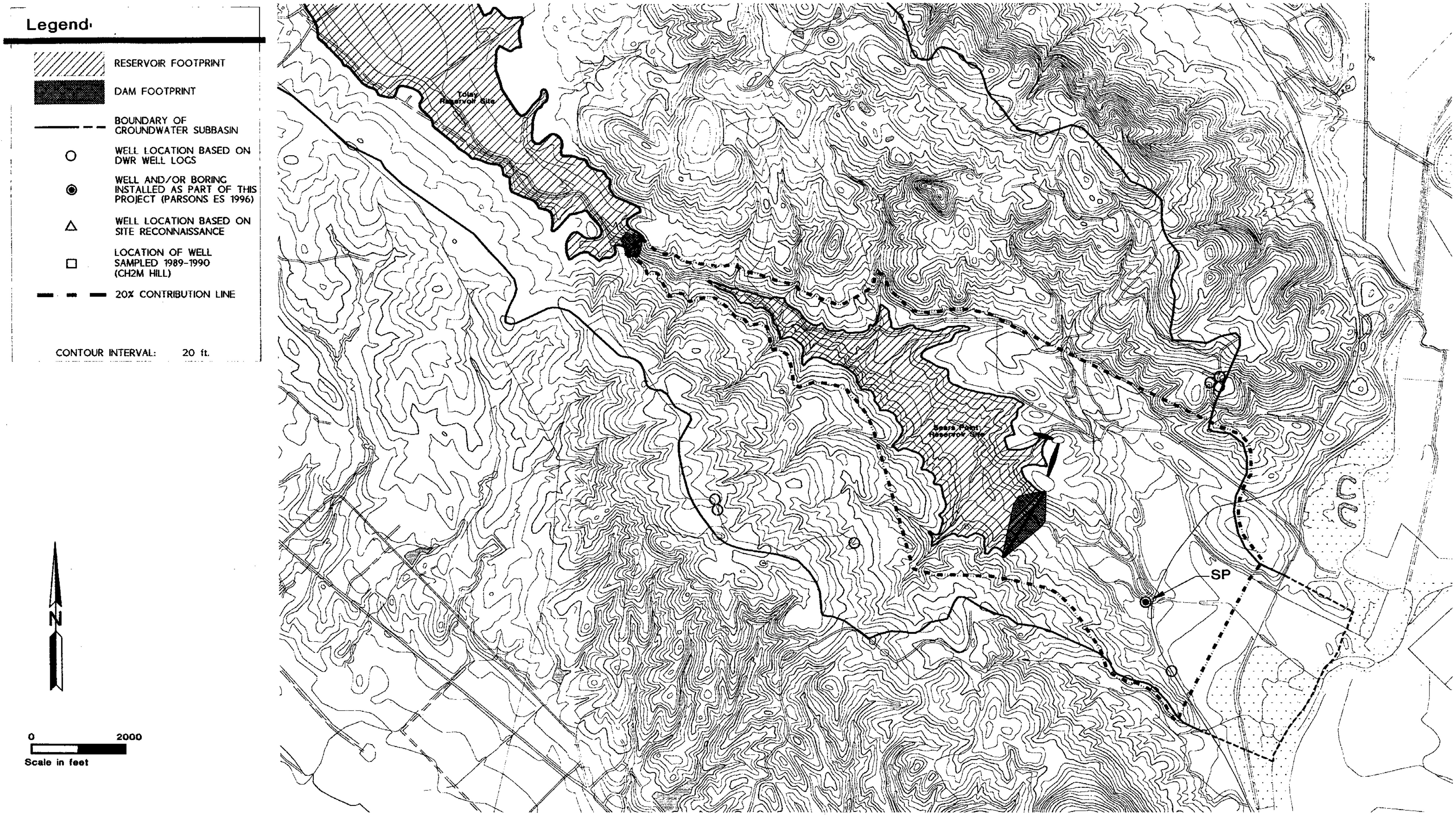
LAKEVILLE HILLSIDE RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-2



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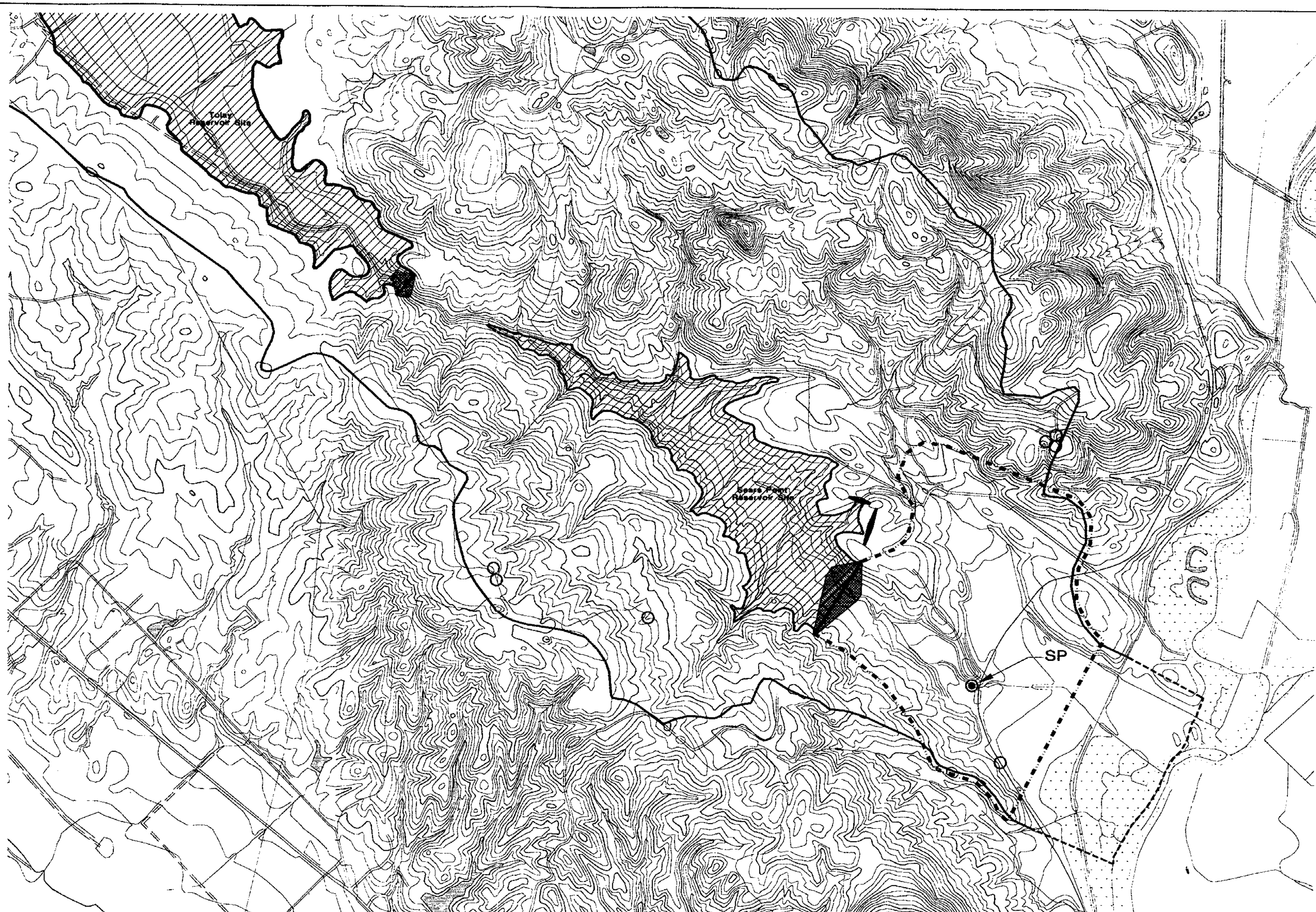
TOLAY RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-3

Legend

- RESERVOIR FOOTPRINT
- DAM FOOTPRINT
- BOUNDARY OF GROUNDWATER SUBBASIN
- ○ WELL LOCATION BASED ON DWR WELL LOGS
- ◉ WELL AND/OR BORING INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)
- △ WELL LOCATION BASED ON SITE RECONNAISSANCE
- □ LOCATION OF WELL SAMPLED 1989-1990 (CH2M HILL)
- 20% CONTRIBUTION LINE

CONTOUR INTERVAL: 20 ft.



N

0 2000
Scale in feet

HARLAND BARTHOLOMEW and ASSOCIATES, INC.
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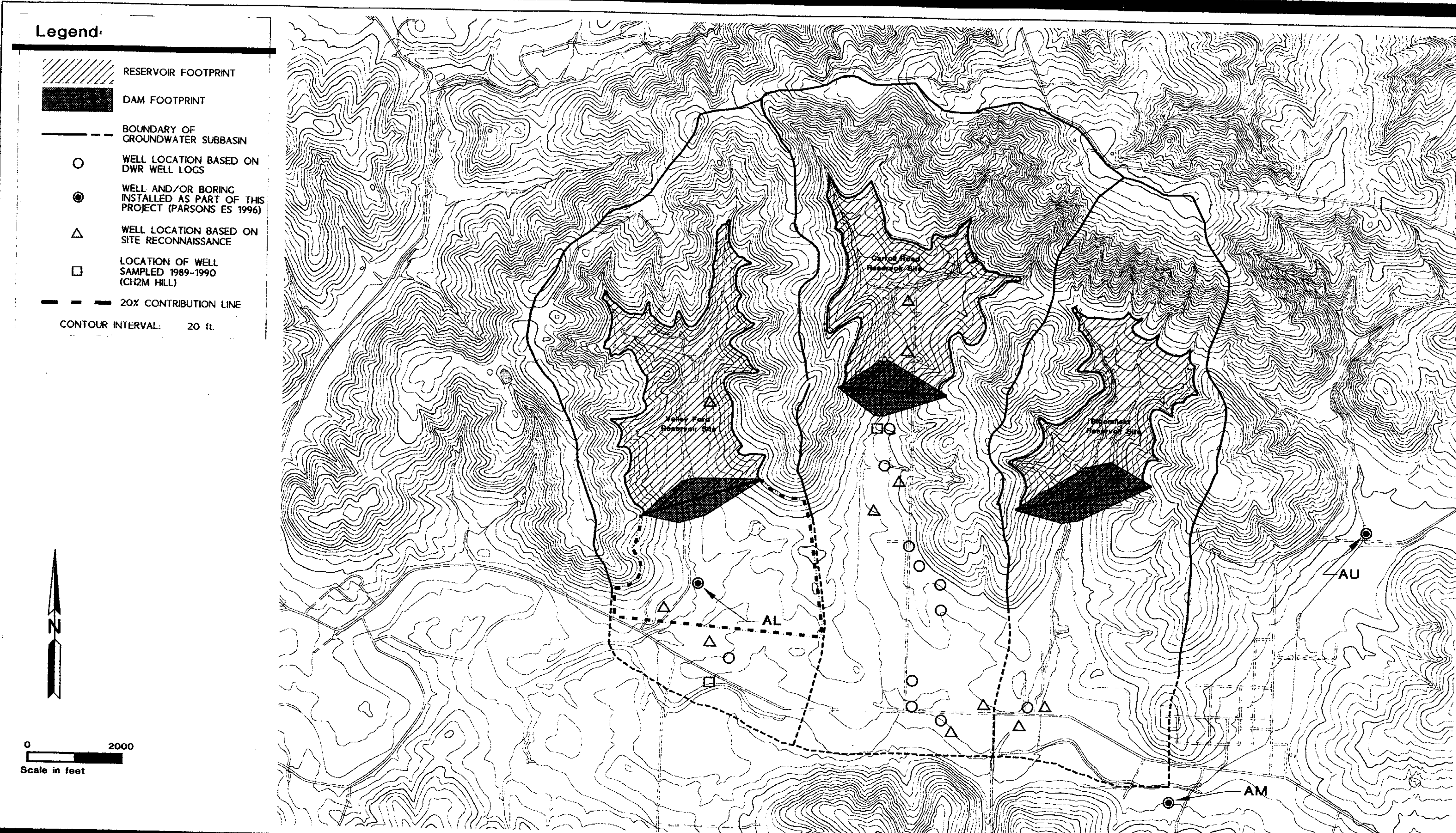
Santa Rosa Subregional Long-Term Wastewater Project

SEARS POINT RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-4



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Santa Rosa
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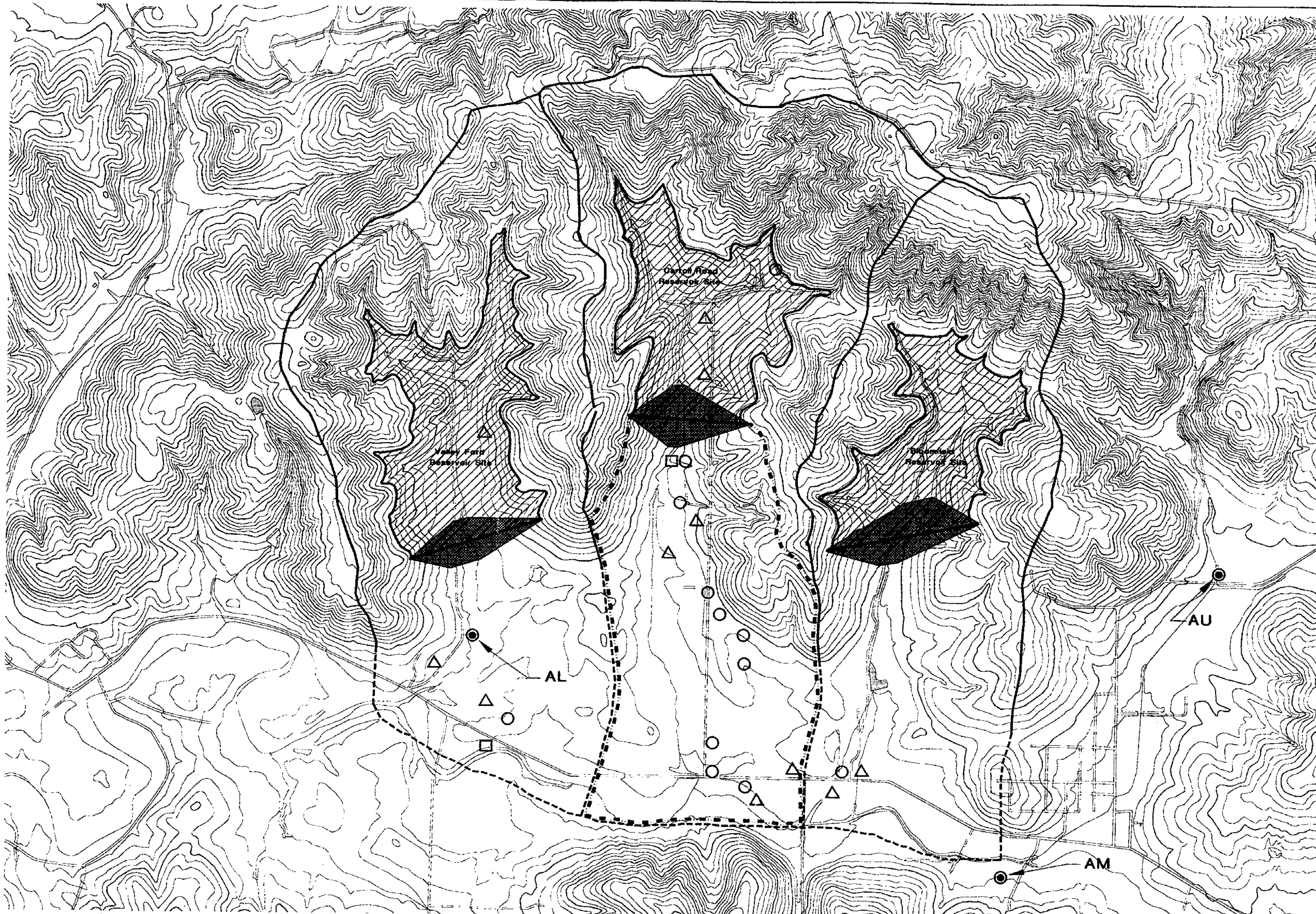
VALLEY FORD RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-5

nd:

- RESERVOIR FOOTPRINT
- DAM FOOTPRINT
- BOUNDARY OF GROUNDWATER SUBBASIN
- WELL LOCATION BASED ON DWR WELL LOGS
- WELL AND/OR BORING INSTALLED AS PART OF THIS PROJECT (PARSONS ES 1996)
- WELL LOCATION BASED ON SITE RECONNAISSANCE
- LOCATION OF WELL SAMPLED 1989-1990 (CH2M HILL)
- 20% CONTRIBUTION LINE

TOUR INTERVAL: 20 ft.



2000

t

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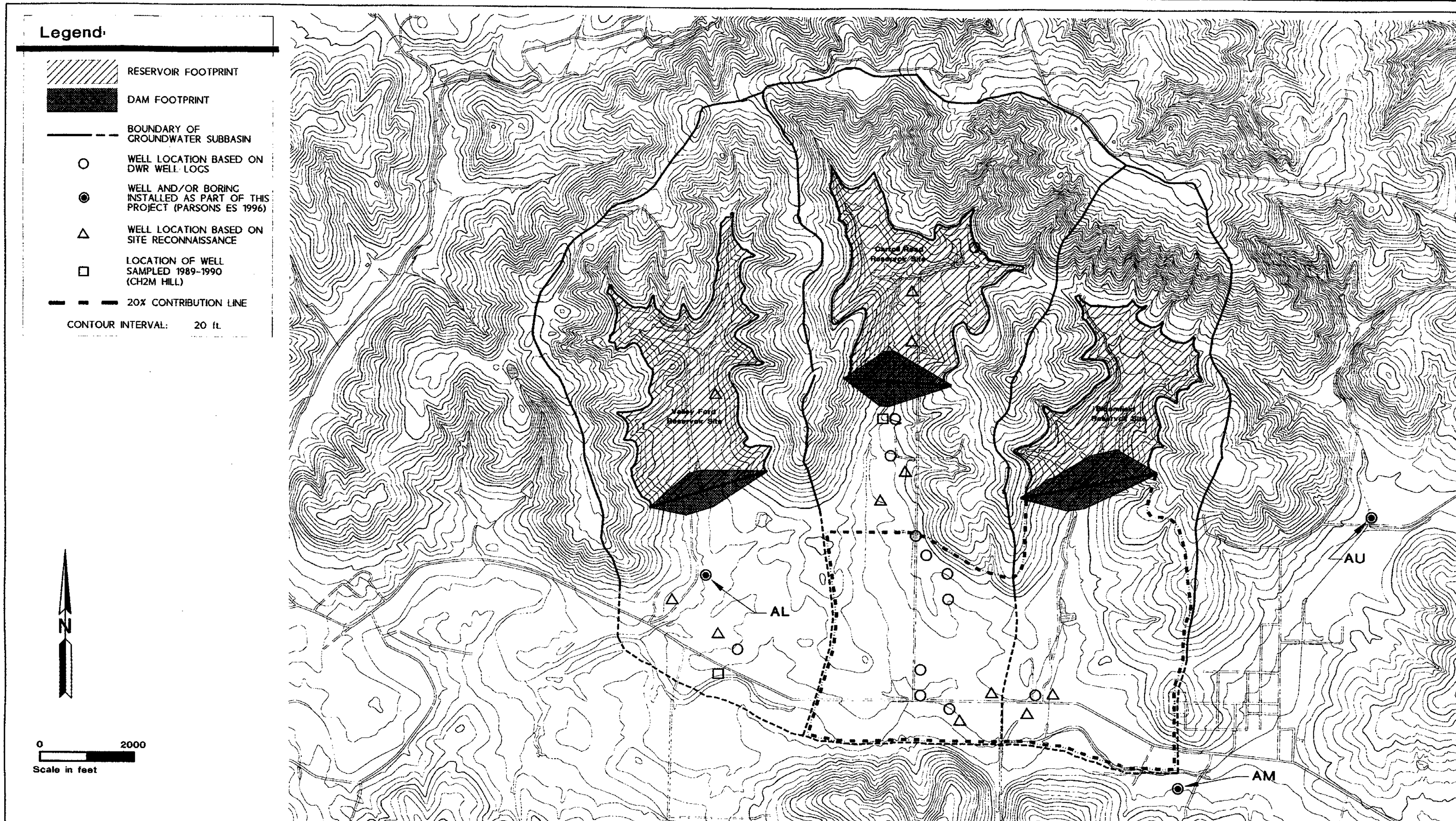
Santa Rosa Subregional Long-Term Wastewater Project

CARROLL ROAD RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-6



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PARSONS

Santa Rosa
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BLOOMFIELD RESERVOIR SITE POTENTIAL IMPACTED ZONE

Figure 5-7