3.3 GROUNDWATER RESOURCES

This section identifies the existing groundwater resources that could be affected by implementation of flow objectives of the San Joaquin River Agreement (Agreement). It presents general information on the regional groundwater resources within the San Joaquin Groundwater Basin. Area-specific information on the groundwater basins underlying the service areas of the willing sellers is described in Appendix B. Section 4.3, subsequently, describes the impacts to groundwater within the local groundwater basins.

3.3.1 Introduction

The discussion of groundwater conditions in this section is for the San Joaquin River Region. Included in the discussion are hydrogeology, groundwater storage and production, groundwater levels, land subsidence, groundwater quality, agricultural subsurface drainage, and seepage-induced waterlogging of farm lands. It covers the following basins and service areas:

- Turlock Groundwater Basin
- Modesto Basin
- Merced Groundwater Basin
- Eastern San Joaquin County Basin
- San Joaquin River Exchange Contractors Service Area

3.3.2 Historical Perspective and Recent Conditions

Groundwater resources of the San Joaquin Valley are described with regard to regional hydrogeology, groundwater storage and production, groundwater levels, and groundwater quality. The discussion of groundwater quality covers those constituents of concern that affect agricultural productivity and others that are noted to be in high concentrations and known to affect human health and wildlife, including: TDS, boron, nitrates, arsenic, selenium, and dibromochloropropane (DBCP).

In addition, three other issues are related to groundwater conditions: agricultural drainage associated with shallow groundwater, seepage-induced waterlogging of farm lands, and land subsidence caused by groundwater level declines. Agricultural subsurface drainage has historically been affected by the presence of perched shallow groundwater conditions in parts of the San Joaquin Valley. Seepage-induced waterlogging of farm land has historically occurred due to the movement of water from streams into adjacent shallow groundwater aquifers. Land subsidence may be caused by one or a combination of the following mechanisms: compaction of aquifer sediments, resulting from groundwater overdrafting and lowering of the hydraulic head in the aquifer system; compaction of sediments in petroleum reservoir rocks caused by oil and gas exploration and extraction; hydrocompaction (the compaction of moisture-deficient sediments following the first application of water); compaction of peat soils following land drainage; and tectonic subsidence (Bertoldi et al. 1991).

Historically, the greatest occurrence of land subsidence in the San Joaquin Valley has resulted from groundwater overdraft and lowering of the hydraulic head, and is the only type of land subsidence discussed in this section.

3.3.3 Overview of the Central Valley Regional Aquifer System

The Central Valley regional aquifer system of California is a 400-mile long, northwest-trending asymmetric trough averaging 50 miles in width. The location and geologic boundary of this aquifer system is shown in Figure 3.3-1.

The significant water-producing geologic units throughout the valley trough are the unconsolidated to semi-consolidated non-marine sediments that range from the Oligocene and Miocene ages (13 million to 25 million years old) to recent. The west side of the trough is bounded by pre-Tertiary and Tertiary semi-consolidated to consolidated marine sedimentary rocks of the Coast Ranges. These faulted and folded sediments extend eastward beneath most of the Central Valley; any water contained in the sediments is usually saline. The east side of the valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada. Only small quantities of water are extracted from the joints and cracks of these basement rocks.

3.3.4 Groundwater Resources of the San Joaquin River Region

The southern two-thirds of the Central Valley regional aquifer system extends from just south of the Delta to just south of Bakersfield, and is referred to as the San Joaquin Valley Basin (DWR 1975), covering over 13,500 square-miles. The Department of Water Resources (DWR) further divides this basin into subbasins. Subbasins in the northern half of the San Joaquin Valley basin, lying within the San Joaquin River Region, include the Tracy, Eastern San Joaquin County, Modesto, Turlock, Merced, Chowchilla, Madera, and Delta-Mendota subbasins (DWR 1994).

3.3.4.1 Hydrogeology of the San Joaquin River Region

The San Joaquin Valley Basin has accumulated up to 6 vertical miles of unconsolidated continental and marine sediment in the structural trough. The top 2,000 feet of these sediments consist of continental deposits that generally contain freshwater (Page 1986). As these sediments accumulated over the last 24 million years, large lakes periodically filled and drained, resulting in deposition of laterally extensive clay layers that formed significant barriers to the vertical movement of groundwater in the basin (USBR 1997d.). The most extensive of these is the Corcoran Clay (a member of the Tulare Formation which was deposited about 600,000 years ago), consisting of a clay layer zero to 160 feet thick, found at depths of 100 to 400 feet below the land surface in the San

Joaquin River Region. These hydrogeologic features are displayed in Figure 3.3-2, showing a generalized cross-sections for the San Joaquin River Region. Figure 3.3-2 shows the approximate distribution of the Corcoran Clay in the San Joaquin River Region and the location of the generalized cross section. Other clay layers are present above and below the Corcoran Clay and may have local impacts on groundwater conditions.

The Corcoran Clay divides the groundwater system into two major aquifers: a confined aquifer below the clay layer and a semi-confined aquifer above the layer (Williamson et al. 1989). Water recharge of the semi-confined upper aquifer generally occurs from stream seepage, deep percolation of rainfall, and subsurface inflow along basin boundaries. As agricultural practices expanded in the region, recharge was augmented with deep percolation of applied agricultural water and seepage from the distribution systems used to convey this water. Recharge of the lower confined aquifer consists of subsurface inflow from the valley floor and foothill areas to the east of the eastern boundary of the Corcoran Clay Member. Present information indicates that the clay layers, including the Corcoran Clay, are not continuous in some areas, and some seepage from the semi-confined aquifer above does occur through the confining layer.

Historically, the interaction of groundwater and surface water resulted in net gains to the streams. This condition existed on a regional basis through about the mid 1950s. Since that time groundwater level declines have resulted in some stream reaches losing flow through seepage to the groundwater systems below.

During pre-development conditions, groundwater in the San Joaquin River Region flowed from the valley flanks to the axis, then north toward the Delta. Large-scale groundwater development since the 1940s, combined with the introduction of imported surface water supplies, have modified the natural groundwater flow pattern. The groundwater pumping and recharge from imported irrigation water has resulted in a change in regional flow patterns. Flow largely occurs from areas of recharge towards areas of lower groundwater levels due to groundwater pumping (Bertoldi et at. 1991). The vertical movement of water in the aquifer has been altered in this region as a result of thousands of wells constructed with perforation above and below the confining unit (Corcoran Clay Member, where present), providing a direct hydraulic connection (Bertoldi et al. 1991). This may have been partially offset by a decrease in vertical flow resulting from the inelastic compaction of fine-grained materials within the aquifer system.

3.3.4.2 Groundwater Storage and Production

In DWR’s Bulletin 160-93, usable storage capacity for the San Joaquin River Region was estimated to be approximately 24 million acre-feet (DWR 1994). The change in groundwater storage from 1970 to 1992 for the San Joaquin River and Tulare Lake Regions combined is shown in Figure 3.3-3. Relative to 1970, groundwater storage in the San Joaquin Valley Basin during the 1970s reached a low point in 1978, a result of the 1976 to 1977 drought period. By the early 1980s, groundwater storage returned to pre-drought conditions. Groundwater storage declines returned during the 1987-1992 drought, reaching a low for the 1970 to 1992 period at the end of the drought in 1992.

Groundwater pumping ranged from 1.6 million acre-feet in 1922 to 4.7 million acre-feet in 1977. Groundwater pumping has increased through the 1970s, and has varied greatly from year to year depending on hydrologic conditions and water user needs. Immediately following the 1976-1977 drought, hydrologic conditions for the years 1978, 1979, and 1980, characterized as wet, above normal, and wet, respectively, were largely responsible for the reduced pumping following the drought period.

There have been numerous attempts to estimate the safe yield of the San Joaquin River Region. The most recent estimate, made by DWR, is approximately 3.3 million acre-feet of perennial yield (DWR 1994). DWR estimated recent groundwater pumping for 1990 conditions (normalized) in the San Joaquin River Region to be 3.5 million acre-feet. This exceeds the estimated perennial yield by approximately 200 thousand acre-feet. All of the subbasins within the San Joaquin River Region experienced some overdraft (DWR 1994).

3.3.4.3 Groundwater Levels in the San Joaquin River Region

Expansion of agricultural practices between 1920 and 1950 caused declines in groundwater levels in many areas of the San Joaquin River Region. Along the east side of the region, declines have ranged between 40 and 80 feet since redevelopment conditions (1860) (Williamson et al. 1989).

With the exception of perched water tables, declines began occurring in the 1940s along the west side of the San Joaquin River Region, dropping more than 30 feet by 1960. By spring 1970, groundwater levels (reported by DWR) in this same area were recorded as ranging from 200 feet to 100 feet below sea level, a drop of as much as 100 feet. Groundwater levels in central San Joaquin County reached 50 feet below sea level by spring 1970, causing saline groundwater intrusion problems for the city of Stockton. By spring 1980, confined aquifer groundwater levels (reported by DWR) along northwestern Fresno County and western Merced County increased up to 100 feet. Groundwater levels in the semi-confined aquifer between spring 1970 and spring 1980 declined in response to 1976-1977 drought conditions and recovered to near pre-drought levels by 1980. The 1987-1992 drought resulted in substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley (Westlands Water District 1995). Recent groundwater conditions, observed for spring 1993 following the drought, are shown in Figure 3.3-4.

Depression areas resulting from groundwater withdrawals are indicated along the east side of the San Joaquin River Region in Merced and Madera counties and are less than 50 feet above sea level. These groundwater levels are indicative of depleted conditions due to regional groundwater withdrawals resulting from the 1987-1992 drought period. This is consistent with observed storage recovery time which may span several years. For example, recovery to pre-drought storage conditions took more than five years following the 1976-1977 drought.

3.3.4.4 Groundwater Quality in the San Joaquin River Region

Groundwater quality conditions in the San Joaquin River Region vary throughout the area. Groundwater quality parameters are discussed below for the San Joaquin River Region, and sources and reasons for concerns associated with these parameters are listed. The discussion is limited to parameters that are associated with regional problems.

Total Dissolved Solids

TDS concentrations vary considerably in the San Joaquin River and Tulare Lake Regions, depending upon the groundwater zone. TDS concentrations in groundwater along the east side of the San Joaquin Valley are lower in comparison to concentrations in the west side of the San Joaquin River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates in the Sierra Nevada and the predominant regional groundwater flow pattern. In the center and on the east side, TDS concentrations generally do not exceed 500 mg/l. On the west side, TDS concentrations are generally greater than 500 mg/l, and are in excess of 2,000 mg/l along portions of the western margin of the valley (Bertoldi et al. 1991). The concentrations in excess of 2,000 mg/l commonly occur above the Corcoran Clay layer. Impaired municipal use of groundwater for drinking water supply due to elevated TDS concentrations occurs at several locations throughout the San Joaquin River Region (SWRCB 1991).

Boron

High boron concentrations occur in the groundwater in the northwestern part of the San Joaquin River Region from the northernmost edge of the region to the southernmost edge of the region (Bertoldi et al. 1991). Agricultural use of groundwater is impaired due to elevated boron concentrations in western Stanislaus and Merced counties (SWRCB 1991) due to boron's excessive phytotoxicity.

Nitrates

In the San Joaquin River Region, a large area within the northern San Joaquin County (between Lodi and Stockton) contains NO_3-N concentrations in groundwater exceeding 5 mg/l (Bertoldi et al. 1991). Municipal use of groundwater as a drinking water supply is also impaired due to elevated nitrate concentrations in the Tracy, Modesto-Turlock, Merced, and Madera areas (SWRCB 1991).

Arsenic

In the San Joaquin River Region, municipal use of groundwater as a drinking water supply is impaired due to elevated arsenic concentrations in Stanislaus and Merced counties and western San Joaquin County (SWRCB 1991).

Selenium

High selenium concentrations occur naturally in soils and groundwater on the west side of the San Joaquin River Region. These concentrations have raised considerable concern because of their potential to leach from the soil by subsurface irrigation return flow into the groundwater and into receiving surface waters. Selenium concentrations in shallow groundwater have been highest in the central and southern area south of Los Banos and Mendota (median concentrations of 10,000 to 11,000 µg/l) (Bertoldi et al. 1991). Although selenium is currently regulated by federal primary drinking water standards at an MCL of 50 µg/l, USEPA recently established chronic and acute toxicity criteria of 5 and 20 µg/l, respectively, for the protection of wildlife and aquatic organisms. The SWRCB, Central Valley Region, has established monthly mean and daily maximum selenium objectives of 5 and 12 µg/l, respectively, for the San Joaquin River from the mouth of the Merced River to Vernalis and 10 and 26 µg/l from Sack Dam to the mouth of the Merced River (SWRCB Central Valley Region 1992).

Dibromochloropropane

DBCP has been detected in many groundwater wells in the San Joaquin River Region. Municipal use of groundwater as drinking water supply is impaired due to elevated DBCP concentrations in groundwater near several cities within the San Joaquin River Region, including Chowchilla, Madera, Merced, and the Modesto-Turlock area (SWRCB 1991).

3.3.4.5 Land Subsidence in the San Joaquin River Region

Beginning in the 1920s, the use of San Joaquin Valley groundwater for crop irrigation began to increase rapidly until the mid-1960s. As a result of this heavy pumping, groundwater level declines have caused land subsidence on areas of the valley. Land subsidence is a significant problem in the San Joaquin River and Tulare Lake Regions. From 1920 to 1970, almost 5,200 square miles of irrigated land in the San Joaquin River and Tulare Lake regions registered at least 1 foot of land subsidence (Ireland 1986). By the mid 1970s, the use of imported surface water in the western and southern portions of San Joaquin Valley essentially eliminated new land subsidence. During the 1976 to 1977 drought, land subsidence was again observed in areas previously affected due to renewed high groundwater pumping rates. After nearly two decades of little or no land subsidence, significant land subsidence has been recently detected in the San Joaquin Valley due to increased groundwater pumping during the 1987-1992 drought. Land subsidence occurring between 1984 and

1996 was reported along the Delta-Mendota Canal. Two locations of note are: (1) near Mendota Pool where 1.3 feet of land subsidence was measured, and (2) approximately 25 miles northeast of Mendota Pool where 2.0 feet of land subsidence was measured (Central California Irrigation District 1996). Measured land subsidence by DWR between 1990 and 1995 of up to 2.0 feet was reported along the California Aqueduct in Westlands Water District (Dudley 1995).

Land subsidence in the San Joaquin Valley has occurred mostly in areas that are confined by the Corcoran Clay, where pressure changes caused by groundwater pumping promote greater compressive stress than in the unconfined zone (DWR 1977). The maximum land subsidence levels recorded in the Central Valley occurred in the 2,600 square-mile Los Banos-Kettleman City area. Because of the slow drainage of the fine-grained deposits, subsidence at a particular time is more closely related to past water-level change than to current change. For example, in the San Joaquin Valley, groundwater withdrawals increased greatly until large imports of surface water through various canals occurred; but even though water levels in the area started to rise, the rate of subsidence began to decrease three years later.

3.3.4.6 Agricultural Subsurface Drainage in the San Joaquin River Region

Inadequate drainage and accumulating salts have been persistent problems for irrigated agriculture along the west side and in parts of the east side of the San Joaquin River Region for more than a century. The most extensive drainage problems exist on the west side of the San Joaquin River and Tulare Lake Regions.

The soils on the west side of the region are derived from marine sediments and are naturally high in salts and trace elements. Irrigation of these soils has mobilized these compounds and facilitated their movement into the shallow groundwater. Since the early 1950s, much of this irrigation has been with imported water, resulting in rising groundwater and increasing soil salinity. Where agricultural drains have been installed to control rising water tables, drainage water frequently contains high concentrations of salts and trace elements (SJVDP 1990). The area of subsurface drainage problems extends along the western side of the San Joaquin River and Tulare Lake Regions from the Delta on the north to the Tehachapi Mountains south of Bakersfield. In some portions, groundwater levels often encroach on the root zone of agricultural crops, and natural subsurface drainage must be supplemented by constructed drainage facilities for irrigation agriculture to be sustained.

Toxic and potentially toxic trace elements in some soil and shallow groundwater on the western side of the San Joaquin River and Tulare Lake Regions are also of concern. These trace elements greatly complicate the disposal of subsurface drainage waters. Elements of primary concern are selenium, boron, molybdenum, and arsenic. Selenium is of greatest concern due to the wide distribution and known toxicity of selenium to aquatic animals and waterfowl.

3.3.4.7 Seepage and Waterlogging in the San Joaquin River Region

In the lower reaches of the San Joaquin River and in the vicinity of its confluence with major tributaries, high periodic streamflows and local flooding combined with high groundwater levels have resulted in seepage-induced waterlogging damage to low-lying farm land. In the western portion of the Stanislaus River watershed, groundwater pumping has historically been used for control of high groundwater levels and seepage-induced waterlogging conditions. Along the San Joaquin River from the confluence with the Tuolumne River through the South Delta, flood control operation requirements have recently contributed to some seepage-induced waterlogging damage to low-lying farm land, a result of streamflow seepage into adjacent shallow groundwater aquifers (USBR 1997f). The seepage-induced waterlogging places neighboring crops and farm land at risk and prevents cultivation of the land until the summer months, placing the annual crop production at risk. Concern has been raised that San Joaquin River flows in excess of 16,000 cfs at Vernalis can result in seepage-induced waterlogging damage of adjacent low-lying farm land in the south Sacramento-San Joaquin Delta area (Hildebrand 1996).

3.3.5 Summary of Groundwater Conditions

Each of the basins and service areas within the San Joaquin River Region are summarized in Table 3.3-1. The areas include:

- Turlock Groundwater Basin
- Modesto Basin
- Merced Groundwater Basin
- Eastern San Joaquin County Basin
- San Joaquin River Exchange Contractors Service Area

The Oakdale Irrigation District Service Area is contained in parts of both the Modesto Basin and the Eastern San Joaquin County Basin, and the groundwater conditions are not separated out for purposes of this summary. A detailed description of the groundwater resources in each of the districts is contained in Appendix B.

Table 3.3-1. SUMMARY OF GROUNDWATER CONDITIONS IN THE SAN JOAQUIN RIVER REGION

	GROUNDWATER BASIN OR SERVICE AREA				
Groundwater Conditions	**Turlock Groundwater Basin**	**Modesto Basin/Oakdale Irrigation District Service Area**	**Merced Groundwater Basin**	**Eastern San Joaquin County Basin**	**San Joaquin River Exchange Contractors Service Area**
Elevation/Levels	Depth to groundwater ranges from 6 to over 100 feet bgs.	Depth to groundwater ranges from less than 5 feet to over 100 feet bgs. Water table declined 15' for period 1970-90.	Depth to groundwater ranges from less than 1 foot to over 100 feet bgs. Water table declined up to 40' for period 1980-92.	Water table declined 20' to 30' since 1964.	No data available
Water Quality	Water table declined approximately 5 feet. Water hardness moderate to very hard	Generally acceptable	Numerous constituents detected	Increasing levels of contaminants	Localized poor groundwater quality
• **TDS**	High TDS in wells deeper than 350 feet	Relatively low	High TDS in wells deeper than 350 feet	No data available	No data available
• **Nitrates**	Localized and some levels above MCL	Localized and some levels above MCL	Below current MCL	Localized levels above MCL - wells closed or replaced	No data available
• **Arsenic**	Below current MCL	Below current MCL	Below current MCL	No data available	No data available
• **Iron and Manganese**	Elevated naturally occurring concentrations	Elevated naturally occurring concentrations	Elevated naturally occurring concentrations	No data available	Elevated concentrations

Table 3.3-1. SUMMARY OF GROUNDWATER CONDITIONS IN THE SAN JOAQUIN RIVER REGION (CONT.)

	GROUNDWATER BASIN OR SERVICE AREA				
Groundwater Conditions	**Turlock Groundwater Basin**	**Modesto Basin/Oakdale Irrigation District Service Area**	**Merced Groundwater Basin**	**Eastern San Joaquin County Basin**	**San Joaquin River Exchange Contractors Service Area**
• **Radionuclides**	High naturally occurring uranium	High naturally occurring uranium	No data available	No data available	No data available
• **Pesticides**	Localized and some levels above MCL.	Localized and some levels above MCL.	Levels detected at or below MCL.	Levels detected below MCL	No data available
• **Trace Organics/ Organics**	Isolated occurrences principally the result of leaking USTs - none in public water supply	Isolated occurrences principally the result of leaking USTs- some in public water supply	Localized and some levels above MCLs	No data available	No data available
Subsidence	Not a problem	Not a problem	Not a problem	Not a problem	Significant in western San Joaquin Valley
Agricultural Subsurface Drainage	Drainage pumping	Drainage pumping	Drainage pumping	Not a problem	Many subsurface drainage systems