The total outflow of water from the basin is on average 20,000 acre-feet per year (this is about 8% of the total groundwater storage: 240,000 acre-feet). Approximately 20,000 acre-feet per year recharges (i.e., inflow) the groundwater basin through percolation of irrigation and stream flow.

The ratio of inflow to outflow will vary depending on precipitation. During drought years outflow increases due to increased pumping. During wet years more imported water is available and used to artificially recharge the basin. Land use also plays an important role total inflow and outflow from the groundwater basin.

As evidenced by the increase in "gaining stream" reaches during seasonal highs, observed groundwater levels have appeared to rise in various parts of the basin. Primarily, these gaining reaches are in the northeastern and western portions of the groundwater basin (Figure 3.3). Reasons for these increases may in part be attributed to urban development, which uses more imported water than groundwater from localized wells. Urban development also increases applied water recharge due to landscape irrigation.

3.4 Occurrence and Movement of Groundwater

3.4.1 Definitions

For the purposes of this report, geologic formations will be grouped into one of three categories:

Water Bearing Formations - Water bearing strata represent geologic deposition of quaternary alluvium and portions of the Livermore Formation that are believed to extend beneath the alluvium.

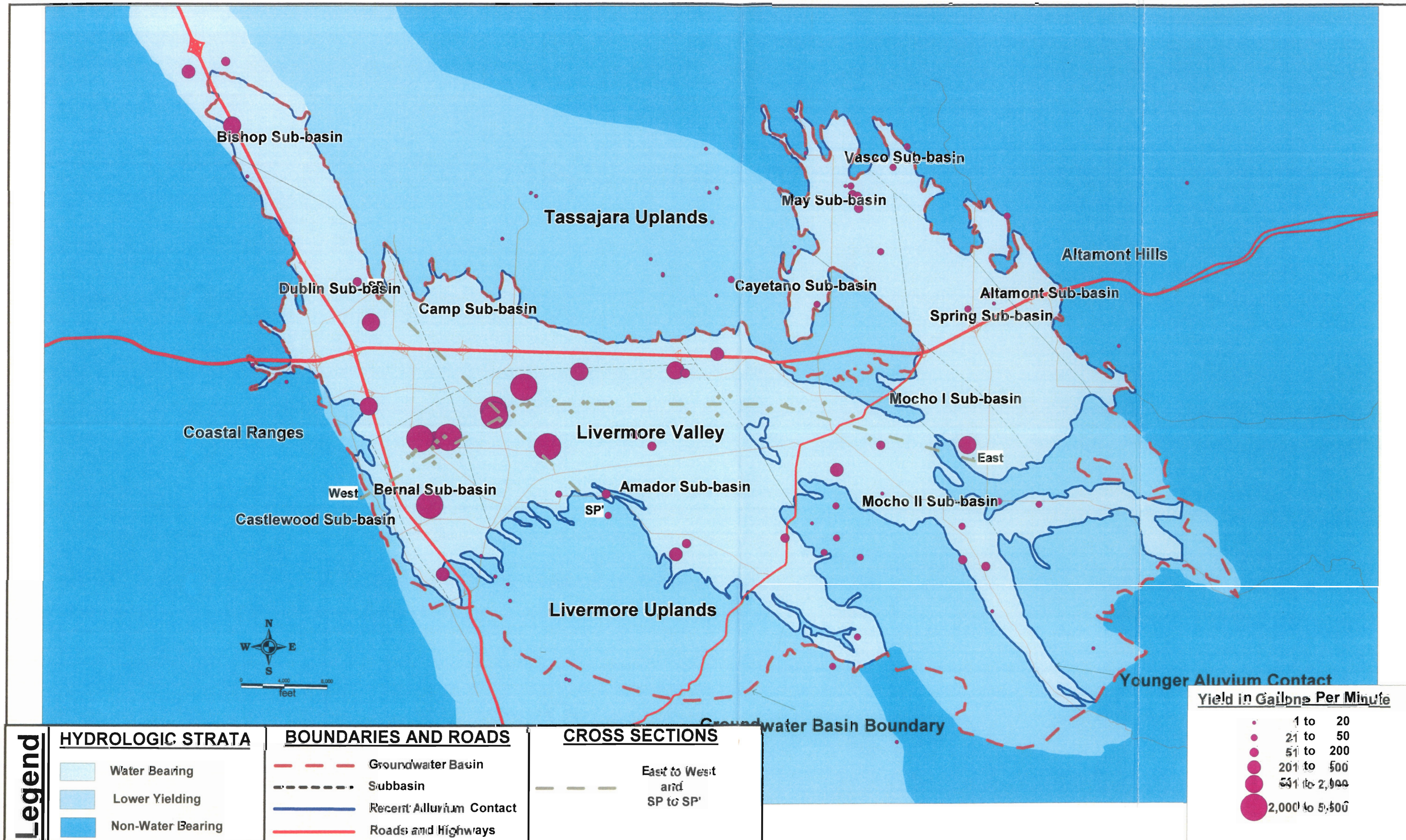
Low Yielding Formations - The Tassajara Formation, Green Valley Formation, and upland areas of the Livermore Formation display lower yields. Groundwater from these formations is sodium bicarbonate in nature and of moderately good quality.

Non-water Bearing Formations - Totally non-water bearing strata consist of Cretaceous to mid-Tertiary marine sediments that do not readily absorb, transmit, or yield water to wells in appreciable amounts. Often, the groundwater that is extracted is of a poor quality sodium bicarbonate-chloride or sodium chloride nature with dissolved solids ranging from 700 to 2150 parts per million (CDWR, 1964b).

Several types of groundwater boundaries are present either along the edges of the basin or within the basin. These boundaries can be categorized into four types:

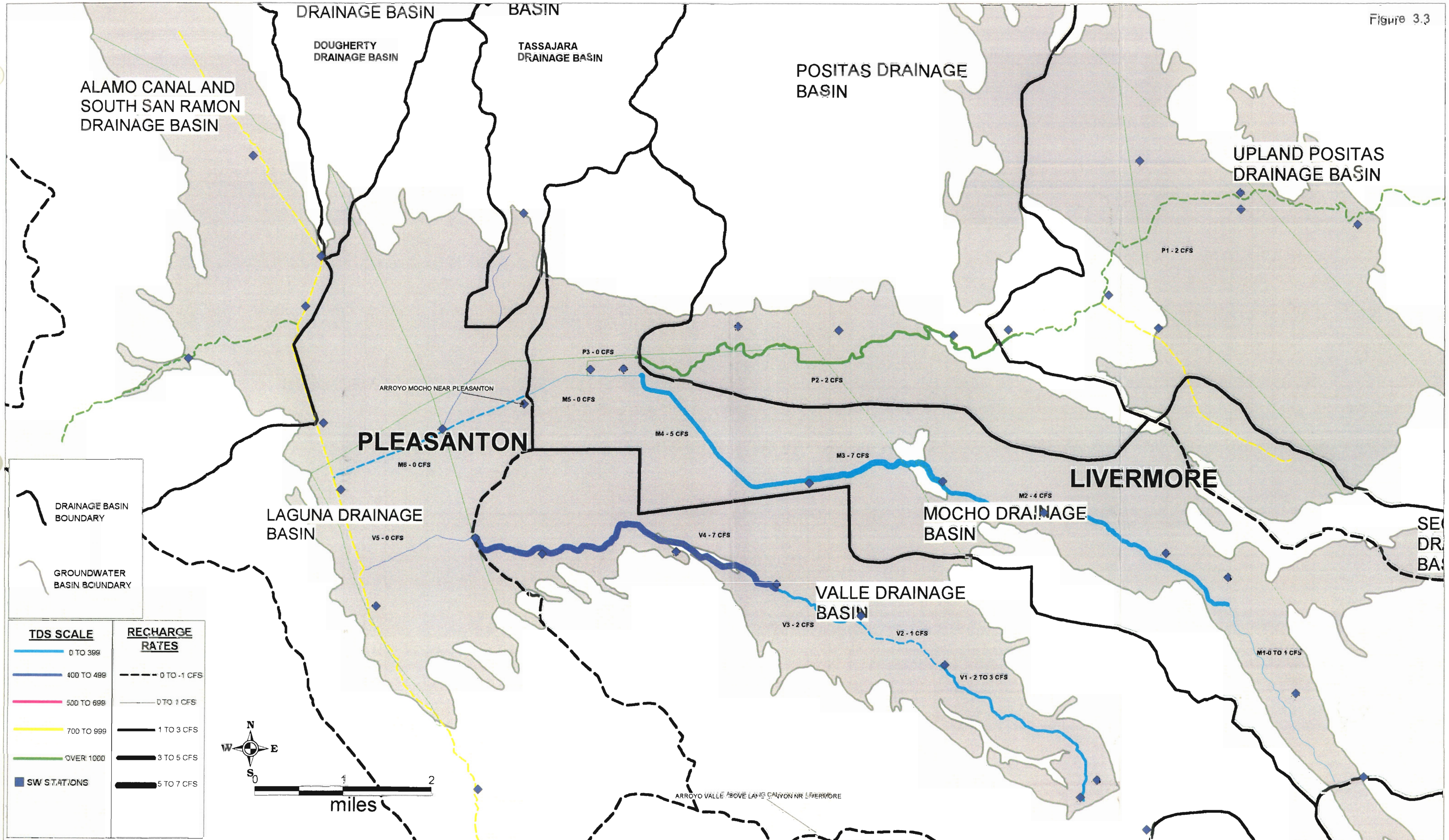
Barrier - A boundary where there is no hydraulic connectivity between the adjacent aquifer unit. Examples of this boundary may represent movement along a

	Zone 7 Water Agency 5997 Parkside Drive Pleasanton, CA. 94588	Water Resources Engineering Salt Management Plan **Figure 3.1: Vicinity Map**



ZONE 7 WATER AGENCY 5997 PARKSIDE DRIVE PLEASANTON, CA. 94588	DRAWN BY: C Mahoney	SCALE: 1" = 8,000'	WATER RESOURCES ENGINEERING SALT MANAGEMENT PLAN **FIGURE 3.2:** **BASIN OVERVIEW**
	DESIGNED BY: C MAHONEY	DATE: 3 JULY 2000	
	CHECKED BY: D LUNN	REVISED BY:	
	APPROVED:	FILE: \zone7-file\mapinfo\SMP\Fig3-2.WOR	

Figure 3.3



ZONE 7 WATER AGENCY 5997 PARKSIDE DRIVE PLEASANTON CA 94588	DRAWN BY: GERALD GATES DESIGNED BY: GERALD GATES CHECKED BY: DAVID LUNN APPROVED:	SCALE: 1" = 1 MILE DATE: 3 JULY 2000 REVISED BY: C MAHONEY FILE: h:\SMP\Fig3-3.WOR

WATER RESOURCES ENGINEERING
SALT MANAGEMENT PLAN

FIGURE 3.3:
STREAM RECHARGE RATES AND TDS

fault where a permeable unit has been displaced against a non-permeable unit or where the unit "pinches out" and abuts an impermeable unit.

Cascade - A boundary where movement along a fault has partially displaced an aquifer unit causing stepped flow across the boundary. This may exist along the upper aquifer of the Livermore fault boundary.

Leaky - A boundary where horizontal fault movement produces fault gouge that slows the movement of water across the boundary.

Unrestricted - A boundary where aquifer characteristics may change slightly, but do not impede the flow of water across the boundary. Examples of this can be observed by a slight change in head, but not in specific capacity between two wells on opposing sides of the boundary.

In a layered aquifer system, combinations of boundary types may exist along boundaries. The level of information varies as to which specific boundary conditions apply to many of the sub-basin boundaries. However, definite evidence for the existence of these boundaries is found in the differences in water level and/or water quality characteristics of the wells on either side of the given feature.

3.4.2 Basin Boundaries

The Livermore Valley Groundwater Basin is located in the heart of the Livermore Valley watershed and extends south into the hills south of Pleasanton and Livermore. It includes the areas occupied by both the flat portions of the Livermore Valley and the Livermore uplands (Figure 3.2). The basin is bounded on the:

- West by northwesterly trending ridges of the California Coast Ranges (including Pleasanton Ridge) and the Calaveras fault,
- North by the Tassajara Uplands and the steeply dipping east west trending Tassajara Formation.
- East by the Greenville fault and by the marine formations exposed in the Altamont Hills.
- South by the Verona faults and Livermore Uplands and the steeper Livermore Highlands.

While the Arroyo de la Laguna has little recharge, the other streams in the basin have "losing stream" stretches where at least a portion of their flow percolates through the stream bed and recharges the groundwater basin aquifers. In addition, three tributaries to the Arroyo Las Positas (i.e., Cayetano Creek, Altamont Creek, and Arroyo Seco) and one tributary to the Arroyo Mocho (i.e., Dry Creek) can also impact the basin. The stream locations and the known "losing stream" stretches are shown on Figure 3.3 along with their approximate recharge rates.

Several subsurface barriers form impediments to lateral movement of groundwater in the Livermore Valley basin (DWR, 1964b, 1974). Based on these apparent linear groundwater barriers, the basin has been divided into sub-basins. Some of these sub-basins have a much larger capacity to store and transmit groundwater and are very significant for the local groundwater supply. These had been called the central basin, but since 1985, they have been called the **Main Basin**. These consist of the following sub-basins (shown on Figure 3.2):

- Bernal (usually includes the smaller Castle Sub-Basin)
- Amador
- Mocho I

The other basins are called **Fringe Basins**. These consist of the following sub-basins:

- Altamont
- Bishop
- Camp
- Cayetano
- Dublin
- May
- Spring
- Vasco
- Mocho II

Vertically, the majority of the groundwater basin can be split into two hydraulic zones:

Upper Aquifer Zone - The upper aquifer zone consists of alluvial materials including primarily sandy gravel and sandy clayey gravels. These gravels are usually encountered underneath the surficial clays (typically 20 to 40 feet bgs) to about 80-150 feet bgs. This aquifer extends throughout the majority of the groundwater basin. Groundwater in this zone is unconfined. The 2004 Stratigraphic Evaluation called this zone the 'Clay Sequence'. In the Main Basin, the upper aquifer is underlain by a relatively-continuous, silty clay aquiclude up to 50 feet thick.

Lower Aquifer Zone – Due to a lack of accurate geologic information, the water bearing units below the upper aquifer zone have been collectively known as the Lower Aquifer Zone. The aquifer materials consist of semi-confined to confined, leaky, coarse-grained, water-bearing units interbedded with relatively impermeable, fine-grained units. As additional geologic information becomes available it is possible that this zone can be further subdivided into distinct aquifers. For example, Norfleet (2004) split the lower aquifer zone in the Amador Sub-basin into the "Gray," "Purple," and "Red" sequences. In future geologic and modeling studies, Zone 7 will likely extend the Norfleet sequence boundaries beyond the Norfleet study area.

In general, multiple aquifers are recognized in the alluvium of the Livermore Valley. As shown in Figure 3.4, a cross section of the basin from west to east, the water bearing alluvium increases in thickness from east to west across the basin and thins both north and south at its boundaries. Cross section SP to SP' (Figure 3.5) also shows a thickening of sediments from north to south to the central portion of the groundwater basin and then a thinning from the center towards the south. Although the upper aquifer zone appears to be very thick and continuous through the Central Amador Sub-basin, the water bearing units within the lower aquifer zone are often discontinuous and inter connected. The more recent geologic logging and monitoring of multilevel monitoring wells are allowing better understanding of the hydrostratigraphic units within the recent alluvium.

3.4.3 *Subsurface Inflow into the Main Basin*

The existence of groundwater barriers along the edges and within the basin continues to be confirmed by the groundwater level measurements, investigations by Zone 7, and other investigations. In 1974 these groundwater barriers were generally interpreted as fault related. However, some may be the result of hydrostratigraphic boundaries and not fault related.

South of the basin, groundwater from the Livermore Formation is believed to move along the strike of the beds to the northwest and enter the Main Basin at the southern portions of the Bernal and Amador sub-basins. North of the basin, the near-vertical structural dip of the Tassajara and Green Valley formations is believed to prevent the commingling of waters among these formations and the alluvium, essentially cutting this water off from the groundwater basin (DWR, 1966, 1974, Zone 7 files).

The outer boundaries of the Main Basin have been divided into 10 regions of interest with respect to groundwater connectivity (Figure 3.6). Region 1, followed by regions 2 and 7, contribute the greatest amounts of subsurface inflow to the Main Basin through the shallow aquifers (Upper Zone). Subsurface inflow from the deeper aquifers (Lower Zone) is considered negligible as shown in Table 3.1.

Estimates of future inflow are based on currently planned development and assume that the potentiometric surface of the Main Basin will be drawn down to accommodate the added demand. Future TDS was taken from the technical memorandum, *Phase 4 Groundwater Modeling: Salt Management Plan Simulations* (CH2MHill, 1999). Scenario 1A, which examined the base case