4 Stream Diversions

This section evaluates SLVWD's stream diversions with regard to watershed conditions, infrastructure, and recorded and potential water production. Figures 1-3 through 1-6 and Figure 4-1 show the location of SLVWD's five current diversion watersheds on Peavine, Silver, Foreman, Clear, and Sweetwater creeks. As summarized in Table 4-1, SLVWD has pre-1914 appropriative water rights for these streams as well as inactive diversions on Harmon, Earl, and Manson creeks. Table 4-2 provides watershed areas and elevations relevant to these diversions.

SLVWD's past and potential use of water from Loch Lomond Reservoir is addressed in Section 6. SLVWD's diversion rights to Fall Creek, which it obtained in its recent acquisition of the Felton system formerly operated by Cal-Am, are not within the scope of this report.

Since 1984, production from SLVWD stream diversions has ranged from about 500 to 1,200 AF/yr (160 to 400 MG/yr), averaging nearly 900 AF/yr (290 MG/yr or 0.8 mgd). These diversions satisfy more than half of SLVWD's Northern Service Area average annual water demand. Table 4-3 presents a summary of the annual diversion record. The monthly diversion record is included in appended Table A-1.

4.1 Diversion Watersheds

SLVWD currently diverts from a total of seven stream intakes with a combined contributing watershed area of approximately 1,400 acres, or 2.2 square miles (Figure 4-1, Table 4-2). This configuration of diversions allows gravity conveyance to centralized water treatment. Prior to 1995, the combined diversion watershed area was about 1,750 acres and included three additional intakes. Conveyance by gravity to the Lyon Water Treatment Plant (WTP; completed in 1994) required the upstream relocation of some points of diversion and the discontinuation of others.

4.1.1 Physiography

SLVWD's diversion watersheds are located west and northwest of the towns of Ben Lomond, Brookdale, and Boulder Creek along the steep northeast-facing slopes of Ben Lomond Mountain (Figure 4-1). Peavine, Silver, and Foreman creeks drain directly to Boulder Creek, which has a watershed area of nearly 12 square miles upstream of its confluence with the San Lorenzo River. Clear Creek and its tributary Sweetwater Creek drain directly to the San Lorenzo River. The river has a watershed area of about 55 square miles above and including Clear Creek, and 106 square miles upstream of the Big Trees USGS gage near Felton.

Elevations decline about 2,000 ft within a distance of only 1.5 miles from the crest of Ben Lomond Mountain to the river and Boulder Creek. The watershed divides of each diverted stream extend up to the crest of Ben Lomond Mountain, with the exception of Silver Creek and the formerly diverted Harmon, Earl, and Manson creeks. Areas of potential watershed recharge lie along the crest of Ben Lomond Mountain, as shown in Figure 4-1 and discussed in Section 4.1.3.

The diversion watersheds are underlain entirely by granitic rock except for a portion of the Sweetwater Creek watershed underlain by schist (Figure 1-5). Ridge-top areas of Ben Lomond Mountain are underlain by a thick mantle of weathered granitic rock. Figure 4-2 shows the distribution of landslides and debris flows in the watershed area following the January 1982 storm. Potential erosion hazards associated with watershed area soils are high to very high (Bowman and Estrada, 1980).

4.1.1.1 Active Diversion Watersheds

The watersheds upstream of SLVWD's seven current diversion intakes have areas ranging from 20 to 480 acres (Table 4-2). Due to the area's remote and heavily forested nature, the watershed topography and precise location, elevation, and drainage area of some intakes are approximate.[4] These watersheds are described briefly below, in order from north to south:

- ***Peavine Creek*** – diversion intake at elevation 1,264 ft msl, with a drainage area of approximately 230 acres, which is about 80 percent of the total 285-acre watershed area upstream of Peavine Creek's confluence with Boulder Creek. As shown on USGS 1:24,000-scale topographic maps, the mapped length of perennial stream above the intake is approximately 3,000 ft (Figure 4-1).
- ***Silver Creek*** – small watershed situated between Peavine and Foreman creeks with 100-acre area upstream of its confluence with Boulder Creek. SLVWD diverts from an intake at 1,250 ft msl that drains of the upper 30 acres of watershed. The mapped length of perennial stream upstream of the intake is approximately 500 ft.
- ***Foreman Creek*** – total watershed area of 580 acres upstream of its confluence with Boulder Creek. Intake at 927 ft msl has a drainage area of 480 acres (83 percent of the total watershed), the largest of SLVWD's diversion watersheds. The two main branches upstream of the intake have mapped lengths of 3,000 to 4,000 ft. The east branch is named Cool Creek. The maximum watershed elevations of both Foreman and Peavine creeks exceed 2,600 ft msl.

The combined watershed area of the above three diversions equals about 10 percent of the Boulder Creek watershed, about 2 percent of the San Lorenzo River watershed above Clear Creek, and 1 percent of the watershed above Big Trees (Table 4-2).

- ***Clear Creek*** – total watershed area of about 1,050 acres upstream of its confluence with San Lorenzo River. SLVWD currently diverts from four separate intakes, one on the main stem, two on small tributaries, and one on Sweetwater Creek. Excluding the latter (described separately below), these intakes range in elevation from 1,330 to 1,358 ft msl[5], have drainage areas ranging from 20 to 360 acres, and have a combined drainage area of 435 acres, which is about 40 percent of the Clear Creek watershed. The mapped length of perennial stream above the main-stem intake is approximately 3,800 ft.
- ***Sweetwater Creek*** – tributary to Clear Creek with a total watershed area of 335 acres. SLVWD currently diverts from an intake at 1,330 ft msl[4] with a drainage area of 225 acres (about 20 percent of the Clear Creek watershed). The mapped stream length above the intake is approximately 1,300 ft. The drainage divide is defined uncertainly in an area of anomalous topography underlain by schist (and marble?) near the southern corner of the watershed.

The maximum watershed elevations of both Clear and Sweetwater creeks exceeds 2,600 ft msl. The combined diversion-watershed area is about 60 percent of the Clear Creek watershed upstream of the river, about 2 percent of the river's watershed above Clear Creek, and 1 percent of the watershed above Big Trees. The total 1,400-acre area of SLVWD's current diversion watersheds is about 4 percent of the river watershed above Clear Creek and 2 percent of the watershed above Big Trees.

4.1.1.2 Inactive Diversion Watersheds

The configuration of SLVWD stream diversions differed prior to 1995, as described below:

- ***Harmon Creek*** – former diversion intake is at an approximate elevation of 1,100 ft msl, with a drainage area of approximately 100 acres, about 60 percent of the watershed upstream of the river. The upstream relocation of the diversion intake necessary for connection to the new raw-water

[4] Watershed areas may be revised when GPS coordinates of the diversion intakes are available.
[5] Some documentation provided by SLVWD gives intake elevations of 1,250 ft msl for all three Clear Creek diversions and 1,275 ft msl for the Sweetwater diversion.

pipeline was designed but never fully implemented given the small expected yield of the remaining 65-acre watershed.

- ***Malosky Creek*** – sometimes listed as one of SLVWD's surface water sources (e.g., CDM, 1996), although there are no water-right or diversion records. The watershed has an area of about 225 acres upstream of its confluence with the San Lorenzo River, of which only 25 acres are upstream of the raw-water pipeline. As a result of land purchases in 2006, SLVWD now owns a large portion of the Malosky Creek watershed.
- ***Clear Creek*** – former diversion intake was at 860 ft msl with a drainage area of 550 acres, about 20 percent larger than the watershed of the three current intakes combined.
- ***Sweetwater Creek*** – watershed area of former diversion intake was slightly larger than that of current intake.
- ***Earl Creek*** – approximate 200-acre tributary to the San Lorenzo River west of Ben Lomond. Former diversion intake was from a spring with an upstream watershed area of less than 100 acres.
- ***Manson Creek*** – approximate 300-acre tributary to San Lorenzo River west of Glen Arbor. Former intake was from a spring with an upstream watershed area of less than 50 acres.

Springflow diversions from Earl and Manson creeks (located in Figure 1-4) were deemed groundwater under the influence of surface water, and thus required treatment under the 1990 federal Surface-Water Treatment Rule. The relatively small yield of these two springs and their location roughly 2 miles south of SLVWD's other diversions justified neither conveyance to the Lyon WTP or a separate treatment facility.

This study does not address these inactive diversions any further because:

- SLVWD has no plans to resume diversions at any of these locations.
- There is no source of power to pump from the former intakes up to the raw-water pipeline.
- SLVWD's water rights for Harmon Creek and Earl and Manson springs may have been jeopardized (i.e., considered abandoned) by more than five years of no use.

4.1.2 Land Use

The distribution of land uses within SLVWD's diversion watersheds is mapped in Figure 4-3, inventoried in Table 4-4, and summarized as follows:

Diversion Watershed	SLVWD Land	State Park	Timber Production	Timber-Residential	Residential & Rural Residential
	Percent of Area				
Watershed Above Intake					
Peavine Ck	65	0	18	11	6
Silver Ck	100	0	0	0	0
Foreman Ck	58	0	3	19	20
Clear Ck	65	11	6	0	18
Sweetwater Ck	15	34	0	0	51
Combined Area	55	9	6	8	22
Potential Recharge Area West of Watershed					
Peavine Ck	0	0	91	5	4
Foreman Ck	0	0	94	6	0
Clear Ck	0	1	84	0	15
Sweetwater Ck	0	0	0	0	100
Combined Area	0	0	80	2	18

A contiguous block of SLVWD parcels occupies nearly 1,700 acres in the vicinity of the diversion watersheds (Figure 4-3). District lands comprise more than half (774 acres) of the total watershed area upstream of the diversion intakes. About one-fifth of the overall watershed consists of residential and rural-residential parcels. The remaining areas are split between State Park land and timber production parcels with and without residential use. Potential watershed recharge areas are mostly timber land, with the exception of the area west of Sweetwater Creek which is entirely residential.

The mapped perennial channels upstream of SLVWD's diversion intakes lie entirely within SLVWD properties, with the exception of the upper-most portion of Sweetwater Creek. Additionally, the raw-water pipelines that extend between the diversion intakes and the water treatment plant are almost entirely on District land (Figure 4-3).

No timber harvesting is conducted on SLVWD's watershed properties. SLVWD, State Park, and timber lands are mostly roadless wilderness. There are no mapped stream-road crossings within the diversion watersheds. Empire Grade, however, is a major road that follows the crest of Ben Lomond Mountain, down from which residential development extends into the upper portions of the diversion watersheds. This development is served by wells and individual wastewater disposal systems.

Approximately 140 wastewater disposal systems occur within SLVWD's diversion watersheds and potential watershed recharge areas (Johnson, June 2005). About half are within the contributing area for the Sweetwater Creek diversion, with the remaining half about equally split between the contributing areas for the Foreman and Clear creek diversions.

Alba Road comes within about 300 ft of the mapped portion of Sweetwater Creek upstream of the intake. A small portion of Camp Ben Lomond, operated by the California Youth Authority, lies within the northwest corner of the Peavine Creek watershed. The timber-residential land within the headwaters of Peavine and Foreman creeks includes a Christmas tree farm with developed inclusions.

The Sweetwater Creek diversion watershed has the lowest acreage of District-owned land; the greatest acreage of residential development; the greatest number and density of septic systems, the highest proximity of roadways to the intake; and the greatest exposure to recreational activities associated with State Park land.

4.1.3 Hydrology

As presented in Section 4.3.1, the available diversion record for SLVWD's surface-water sources dates back to January 1984. However, the amount of streamflow that bypasses the diversion intakes is not measured, and thus there is no record of total streamflow for these streams.

Using an approach similar to that of Geomatrix (1999), the following table provides water-budget estimates of average annual total streamflow for SLVWD's diversion watersheds:

Diversion Watershed	Water-shed Above Intake	Adjacent Recharge Area	Estimated Average Annual Water Budget					
			Rain-fall	Evapo-trans-pira-tion	Streamflow Derived from:			
					Watershed Rainfall		Recharge Area*	Total (rounded)
	(acres)		(in/yr)			(AF/yr)		
Peavine Ck	230	180	60	31	29	560	150	700
Silver Ck	30	0	58	30	28	70	20	100
Foreman Ck	480	115	60	31	29	1,160	220	1,400
Subtotal	740	295				1,790	390	2,200
Clear Ck	435	345	60	31	29	1,050	250	1,300
Sweetwater Ck	225	70	60	31	29	540	70	600
Subtotal	660	415				1,590	320	1,900
Total	1,400	710				3,380	710	4,100

*Roughly apportioned based on watershed and recharge areas, assuming 12 in/yr average recharge rate.

On average, rainfall of about 60 in/yr within SLVWD's diversion watersheds is estimated to split about equally between evapotranspiration (31 in/yr) and unit streamflow (29 in/yr). Consistent with Geomatrix (1999), unit streamflow derived from rain falling within the watershed is assumed to equal: (a) an amount predicted by extrapolation of the linear rainfall-streamflow relationship provided in Figure 3-12; plus (b) an additional 3 inches. Geomatrix justified the additional 3 inches as follows:

- Higher values of evapotranspiration would be excessive given:
  - The watersheds' shady northeast aspect
  - Published values of redwood-forest evapotranspiration (Section 3.2)
- Streamflow estimated by the linear relation is smaller than the recorded diversion in some instances.

The resulting estimate of unit streamflow is consistent with the estimated soil-water budget presented in Section 3.2 (Table 3-10, Figure 3-12).

Because of the steep eastern slopes of Ben Lomond Mountain, Geomatrix interpreted that the groundwater divide occurs west of the drainage divide along the mountain crest. As a result, it inferred that roughly 700 acres along the crest of Ben Lomond Mountain potentially provide additional groundwater recharge to SLVWD watersheds (Figure 4-1). Geomatrix assumed an average recharge rate of 12 in/yr for this area, which is consistent with an extrapolation of the average unit baseflows estimated for Boulder and San Vicente creeks (Figure 3-16). Effective recharge rates are also affected by residential groundwater use and wastewater return flows in contributing areas. Along with some expected decreases in evapotranspiration as a result of development, these influences are assumed to have a relatively minor effect on overall net recharge.

As a result of these assumptions, the above table estimates that the combined average streamflow of SLVWD's diversion watersheds is about 4,100 AF/yr. This is about 8 percent of the estimated average flow of the San Lorenzo River at Clear Creek, and about 4 percent of the river's average flow at Big Trees. The combined estimated average annual flow of the Peavine, Silver, and Foreman creek diversion watersheds comprises about 17 percent of Boulder Creek's estimated average flow. The estimated average annual flows of SLVWD's individual watersheds range from about 100 AF/yr for Silver Creek to 1,400 AF/yr for Foreman Creek.

Geomatrix was able to account for the SLVWD's diversion record by distributing these flows similar to the average monthly distribution of gaged flows for San Vicente, Laguna, and Majors creeks. These watersheds are also on Ben Lomond Mountain and share some characteristics with SLVWD's diversion watersheds (e.g., granitic bedrock, high baseflows, relatively small drainage area). Compared to the gaged records for the San Lorenzo River and several of its tributaries, a greater proportion of these streams' annual flow occurs as dry-season baseflow.

However, the gaging of streams relatively near and similar to SLVWD's watersheds ended 15 to 30 years ago with relatively short periods of record (Table 3-12). Thus, Geomatrix relied on the San Lorenzo River at Big Trees record to estimate monthly flow records for the SLVWD diversion watersheds. This study does not repeat that procedure as explained in Section 4.3.3.

The gaging record for Boulder Creek includes the January 4, 1982 storm when a peak discharge of 3,500 cubic feet per second (cfs) occurred. Based on watershed-area ratios, the corresponding peak flows of Foreman and Clear creeks at the diversion intakes were in excess of 200 cfs. These peak flow estimates are conservative given that (a) unit peak flow generally increases with decreasing watershed area and (b) the diversion watersheds tend to receive greater rainfall than most of the Boulder Creek watershed.

4.1.4 Water Quality

Analyses of SLVWD diverted water quality provide a reasonable indication of the watersheds' overall water quality. However, these records do not represent all locations, flow conditions, or times of year, and variations beyond the range of available data are likely. The presented tables include historical data for SLVWD's inactive diversions; however these streams are not addressed specifically in the following discussion. Diversions from Silver Creek are sampled only once mixed with Foreman Creek diversions. Treated water quality is discussed in Section 4.3.2.

4.1.4.1 Physical and Inorganic

Table 4-5 provides general mineral analyses of raw water samples collected annually since 1979 from SLVWD's stream diversions, usually between March and June. As indicated by the water quality summary provided in Table 4-6, the sampled water quality ranges between mixed- and calcium-bicarbonate types. Total dissolved mineral concentrations are low, usually less than 150 milligrams per liter (mg/L). This is consistent with Ben Lomond Mountain's high rainfall and well-flushed weathered granitic aquifer. These samples meet all drinking water standards except for infrequent exceedances of the secondary standards for iron and manganese.

Figure 4-4 provides time-series plots of annual electrical conductivity[6] and total dissolved mineral (or "solids," TDS) concentrations. Some of the data variability may be associated with the sample dates. Higher dissolved mineral concentrations are expected in baseflow toward the end of the dry season, and indeed some peak values are for the few samples collected from July through September. Considering this seasonality, the plots exhibit a similar pattern that appears to correspond to the climatic cycle. Following relatively wet 1978-83, TDS concentrations gradually increased in response to the 1987-94 drought. Total mineral concentrations gradually fell beginning in wet 1993 and continued to fall into the following wet period, reaching minimum values during and immediately following the 1998 El Niño year. As of 2006, mineral concentrations have remained low relative to the historical record, reflective of the sustained average to wet period during WYs 1995-2006.

Figure 4-5 provides time-series plots for annual measurements of pH and nitrate concentration. Samples from three of the streams exhibit a slight downward trend in pH, which may result from rainfall of increased acidity. Nitrate concentrations are discussed in Section 4.1.4.3.

Concentrations of metals and other inorganic chemicals are generally low relative to maximum allowable drinking water levels, and radioactivity levels are within standards.

4.1.4.2 Turbidity and Sedimentation

Turbidity correlates approximately with the concentration of total suspended solids and indicates the impact of sediment on water quality. This correlation varies among sources as well as with flow conditions. Turbidity itself is not a major health concern, but particulate matter associated with high turbidity may interfere with disinfection, provide a medium for microbial growth, and contribute to total organic carbon content.

Elevated turbidity occurs primarily in wet winter months as a result of sediment transport. The District stops diverting during periods of significantly elevated turbidity. As a result, the turbidity of its combined raw-water diversions exceeds 1 nephelometric turbidity units (NTU) only about 5 percent of the time.

---

[6] Electrical conductivity is an indirect indicator of TDS.

Potential causes of elevated turbidity include both natural and human-induced processes, including drainage along roads and recreation trails, timber harvesting, grading, feral pigs, slope failures (Figure 4-2), and wildfires. No timber harvesting occurs on District land.

A manmade pond covers approximately 2 acres on a large residential property near the headwaters of Clear Creek east of Empire Grade. Failure of the pond's dam could cause erosion and release sediment and turbid water into the watershed above the main-stem diversion.

4.1.4.3 Nitrate, Microorganisms, and Sanitary Conditions

Elevated concentrations of nitrate and coliform bacteria are indicative of contamination from human activities (e.g., wastewater disposal, fertilizers) and domestic and wild animals. The maximum allowable concentration of nitrate in drinking water is 45 mg/L[7] due to its potential toxicity to infants. Coliform bacteria, although not a health hazard, indicate the potential occurrence of harmful microorganisms.

Non-detected to very low concentrations of nitrate in samples from Peavine and Foreman creeks are indicative of naturally low background conditions in relatively undisturbed watersheds (Figure 4-5). Spikes in nitrate concentration up to 5 mg/L were measured in samples from Clear Creek during the 1980s. Samples from Sweetwater Creek have had intermittently elevated nitrate levels as high as 3 mg/L, with a possible upward trend. The occurrence of elevated nitrate in Clear and Sweetwater creeks is consistent with the distribution of wastewater disposal systems and potential fertilizer use in developed portions of SLVWD's diversion watersheds (Section 4.1.2).

As illustrated in Figure 4-6, coliform concentrations in SLVWD's combined stream diversions tend to spike moderately during the dry season (when dilution is least) and early during the wet season (as a result of the first "flushing" stormflows) (Figure 4-6). Detections of coliform bacteria in diverted streamflow indicate potential contamination from wastewater disposal and/or wild and domestic animals within the watershed.

4.1.4.4 Organic Chemicals and Other Potential Contaminant Sources

A search for parcels with hazardous-material permits within SLVWD's stream diversion source areas identified the following (Johnson, 2005):

- Camp Ben Lomond (California Youth Authority), mostly outside the Peavine Creek watershed (includes contaminated soil remediation).
- Christmas tree farm within the headwaters of Foreman and Peavine creeks.
- In potential recharge area of Clear Creek, parcel categorized as a utility station and/or maintenance area and zoned as a radio or television broadcast site and/or other facility.
- Parcels (a) zoned as government or institutional use and (b) associated with a cable television utility in the contributing area of Sweetwater Creek.

Empire Grade is a major County road that traverses the crest of the watershed. Additionally, Alba road traverses portions of the Clear and Sweetwater creek diversion watersheds (Figure 4-3). Traffic includes trucks carrying potential hazardous materials such as septage and supplies for the Lockheed test facility. Roadway accidents could result in spills of hazardous material into the diversion watersheds.

The diversion watersheds are not fenced although the access roads are gated. SLVWD-owned land provides a considerable buffer around the diversion intakes.

---

[7] When reported "as nitrogen," the standard is 10 mg/L.

4.2 Diversion Infrastructure

This section describes SLVWD's diversion intake, conveyance, and treatment infrastructure based on a site visit in February 2006 and information provided by District staff (system maps, design sheets, and personal and written communication).

4.2.1 Intakes

The direct-diversion intake structures on Peavine, Silver, and Foreman creeks were rebuilt in 1983 following damage from the January 1982 storm. The direct-diversion structures on Clear and Sweetwater creeks were reconstructed at upstream locations in 1995 to allow gravity drainage to the new Lyon WTP.

Figure 4-7 shows plan and section drawings of the direct-diversion intake structure on the main stem of Clear Creek. This design is typical of the other diversions and consists of the following:

- 3-ft high concrete and rock diversion dam about 12 to 20 ft long across the channel and anchored with a 2-ft deep concrete footing or rebar into bedrock.
- 4-ft wide and 3-ft tall rectangular notch in the dam face for the placement of redwood flashboards.
- Stilling basin formed by a wrap-around upstream extension of the dam structure on the non-flashboard side of the dam.
- 3-by-2-ft framed stainless steel screen with 40 percent open area mounted across the opening to the stilling basin.
- Fitting through the dam face for a 6- to 8-inch diameter intake pipe and valve.
- 4-inch by-pass pipe and valve through the dam face.
- Concrete splash apron on the downstream side of the dam.

The screen across the opening to the stilling basin clogs with leaves, especially during early wet-season storms when it requires cleaning up to several times a day.

The flashboards at each diversion must be manually removed and replaced before and after non-diversion periods. During stormy periods of intermittent peak flow, the flashboards might be removed and replaced several times a day. However, at the less accessible diversions (e.g., Clear Creek), the flashboards may be removed for long periods during the wet season given low seasonal demand and inconvenient site access.

The Foreman Creek intake is constructed across the low flow channel of a split channel, allowing high flows to bypass the diversion and lessen the potential for storm damage. Also, the Foreman Creek diversion has piping in place to divert selectively from Cool Creek, the east branch tributary, which typically has lower turbidity. A raw-water sample intake just upstream of the Foreman diversion is piped to a turbidity meter, allowing diversions to be automatically stopped when exceeding 15 NTU.

The diversion structures have been damaged in the past by streamflow and sediment transport during extreme events (e.g., January 1982). However, the repaired structures and those constructed in 1995 are believed to be less vulnerable to storm damage than previously. Large sediment deposits sometimes change a stream's course near the intake, requiring the placement of a temporary intake until the diversion structure can be modified.

The capacity of the diversion intakes has not been established but generally exceeds raw-water conveyance capacities, and thus is not a factor limiting diversions under most circumstances.

4.2.2 Raw-Water Conveyance and Mixing

SLVWD has more than 6 miles of high-density polyethylene (HDPE) pipeline that convey raw water from the diversion intakes to the WTP (Figure 4-8). A northern branch nearly 1 mile long, the Foreman/Peavine Supply Line, conveys diversions from Peavine and Silver creeks to the mixing vault adjacent to the Foreman Creek diversion. A southern branch conveys diversions from the Clear and Sweetwater creek intakes about 5 miles to the mixing vault. Referred to as the Five-Mile Pipeline, it passes near the WTP before reaching the Foreman mixing vault. The vault helps dissipate excess hydraulic energy at the terminus of the Five-Mile Pipeline and reduce aeration below levels that impede treatment. The combined diversions are conveyed from the mixing vault approximately 2,400 ft to the WTP.

Hydraulic testing in February-March 2006 determined that the Five-Mile Pipeline has a flow capacity of approximately 400 gallons per minute (gpm; 54 AF/month). This is less than the design rate (550 gpm or 74 AF/month), possibly because of entrained air and energy losses associated with construction limitations in the rugged and remote terrain. According to the monthly record, however, the Five-Mile Pipeline conveyed an average of 515 gpm (71 AF) in May 2000, 457 gpm in June 2000, 447 gpm in July 2006, and 416 gpm in June 1999 (Table 4-7, column B). These rates exceed the capacity determined during the winter 2006 testing because (a) the effective capacity of the Five-Mile Pipeline may be lower during winter months due to backpressure from the Foreman and Peavine creek diversions and/or (b) the monthly record is incorrect. A travel time of several hours through the Five-Mile Pipeline is suggested by the outflow's delayed turbidity response to storms.

The hydraulic capacities of the mixing vault and other pipelines are uncertain, other than indicated by recorded maximum monthly diversions. The pipeline from the Peavine and Silver creek intakes conveyed an average of 270 gpm in April 1997, 249 gpm in May 1997, 214 gpm in June 1997, and 197 gpm in June 1999, the four highest months of record (Table 4-7, col. D).

The maximum monthly diversion processed by the WTP in July 1998 averaged 1,010 gpm, followed by about 980 gpm in both August 1998 and May 2006 (Table 4-7, col. I). Conversely, the sum of each intake's maximum monthly rate of diversion is nearly 1,700 gpm (Table 4-7, col. H). The difference between actual peak production and apparent total supply reflects (a) limited demand coinciding with periods of greatest supply, (b) uncertain hydraulic constraints in the raw-water conveyance system, and (c) uncertain hydraulic and operational constraints of the WTP.

Air entrainment, especially at high flow rates, is another constraint on conveyance. High aeration interferes with treatment by affecting the buoyancy of floating filter media in the first stage of each filter unit. The degree to which this limits rates of diversion is uncertain.

The Foreman Creek facility uses 48-volt monitoring and operating equipment powered by batteries charged by a small hydroelectric generator on a separate, small pipeline from the Peavine and Silver creek diversions. A siltation pit near the Foreman Creek diversion is used for diversion overflows and periodic backflush from the WTP.

The current raw-water pipeline system is considerably more durable than the former system, although still vulnerable to damage from slope failure. Repairs could be performed relatively quickly (e.g., 3-7 days), but may require assistance by helicopter.

4.2.3 Treatment Plant

SLVWD operates a centralized water treatment facility for its stream diversions in compliance with the U.S. Environmental Protection Agency's (USEPA) 1989 Surface Water Treatment Rule (SWTR) and subsequent SWTR enhancements. This set of regulations seeks to limit the occurrence of water-borne pathogenic microorganisms, including *Giardia lambia*, viruses, *Legionella*, and

Cryptosporidium, through the required use of disinfection and filtration, and strict limits on finished-water turbidity. The WTP was sized based on past and expected water demand, not hydrologic estimates of available flows.

Completed in 1994, the Lyon WTP is located on a ridge southeast of the Foreman Creek intake. Figure 4-9 shows the general layout of the WTP facility. The filter plant consists of three Neptune Trident Microfloc package units that perform adsorption, clarification, and two stages of filtration: (1) floating media to remove floc particles followed by (2) granular media filtration. Each unit has a 350-gpm design capacity and a 420-gpm maximum-rated capacity. Tests conducted by SLVWD in early 2006 demonstrated that the plant's effective, sustainable maximum capacity is approximately 1,200 gpm. To date, the maximum monthly rate of WTP production was at an average rate of 1,010 gpm in July 1998 (Table 4-7).

Within the first-stage chamber of each filter unit, water is pushed up through a layer of floating plastic beads, trapping micro-flocculated sediment. Backflushing is achieved by reversing current and aerating the flow, causing the beads to lose buoyancy. Limiting aeration of the plant inflow is important for this reason.

In the second-stage chamber, water percolates downward through several feet of layered charcoal, sand, iron sand, and gravel. Some charcoal is lost as a result of backflushing and must be replaced. The remainder of the filter pack lasts approximately 20 years, at about which time the denser packing of rounded sand grains results in a significant reduction in filter permeability.

These units use automated pre- and post-filter chlorinators and an automated floc delivery system. The turbidity of the plant influent and filter-unit outflow is also monitored automatically. Inflow to the plant shuts off when its turbidity exceeds 10 NTU.

Chlorinated outflow from the filter units collects in the WTP sump and is piped to tanks to achieve required disinfection times. The hydraulic capacity of the WTP sump may be one factor that limits plant throughflow.

The water used to backwash the filter units is discharged to two concrete clarifier basins near the plant building (Figure 4-9). This water is then fed back into the WTP at rates no greater than 10 percent of total inflow, per DHS regulations. The clarifier basins are dried out in summer and the silt is cleaned out and landfilled as an approved solid waste.

The WTP's filters must be regularly flushed and backwashed. Times required for each flushing and backwashing are typically about 20 and 32 minutes, respectively. The interval between these procedures varies by season, ranging from 10 to 12 hours for flushing and 48 to 72 hours for backwashing. Recycling the flush and backwash water through the WTP recovers about 50 to 67 percent of the production lost during these procedures, depending on whether 2 or all 3 of the filter units are operating.

Diversions are discontinued during high turbidity stormflows for a total of roughly 40 hours during an average winter, 24 hours during a dry year, and 60 hours during a particularly wet year. Additionally, diversion rates may be reduced for periods of time before and after storm-related downtimes.

Table 4-8 presents estimates of the WTP's potential yield based on these typical rates of flushing, backwashing, and bypassing turbid stormflows. Based on these assumptions, the WTP is capable of the following:

- Operating at a maximum monthly rate of about 155 AF/month (51 MG/month or 1,100 gpm) during periods of peak production, given potential diversion losses of no more than 3 percent due to downtime.
- Production capacity of approximately:
  - 930 to 1,220 AF/yr (300 to 400 MG/yr) during average years
  - 700 to 1,020 AF/yr (230 to 330 MG/yr) during dry years
  - 990 to 1,350 AF/yr (320 to 440 MG/yr) during wet years

Compared to the stream-diversion production record for WYs 1985-2006 (Table 4-9), these capacity estimates are higher than actual with regard to average and drought years, and overlap with the range of actual wet years.

The system for storing and distributing finished water from the WTP is addressed in Section 7.1.

4.3 Surface-Water Production

This section presents and analyzes the diversion record; evaluates various operational constraints and procedures; describes the quality of water produced post-treatment; and estimates potential monthly and annual rates of diversion under various climatic and demand conditions. SLVWD's potential to divert streamflows is carefully considered given its inverse relation to the need and timing for groundwater production, and its potential to provide some additional supply to the Southern Service Area.

In this section, "water demand" refers to the demand for produced water, including the water losses that occur in distribution, which equals the total amount of water produced each month in SLVWD's Northern and Southern Service Areas.

4.3.1 Diversion Record

SLVWD's record of stream diversions is summarized and assessed by the following tables and figures:

- Monthly diversions, 1976-77 (partial) and 1984-2006 (Table A-1)
- Annual diversions, 1977 and 1984-2006 (Table 4-3 & Figure 4-10)
- Annual diversions vs. rainfall, river flow, and total production, 1977, 1984-2006 (Table 4-10)
- Monthly diversions versus rainfall and total production, 1984-2006 (Figure 4-11)
- Average, minimum, and maximum monthly diversions, 1984-2006 (Table 4-11 & Figure 4-12)
- Rankings of monthly and annual diversions (Tables 4-7 and 4-9)

4.3.1.1 Caveats

Monthly total diversions for February 1976 through June 1977 were digitized from a bar chart found in SLVWD files.

From 1984 through 1995, the metered monthly record was for (a) the combined, undifferentiated diversions of Peavine, Silver, and Foreman creeks, (b) individually metered diversions for Harmon, Clear, and Sweetwater creeks, and (c) the combined diversions for Earl and Manson springs.

Since 1997, the diversion record is based on three separately metered raw-water flows: (1) outflow from the Peavine and Silver creek diversion pipeline into the Foreman mixing vault, (2) outflow from the Five-Mile Pipeline into the Foreman mixing vault, and (3) total inflow to the WTP. Based on these values, the Foreman Creek diversion is estimated by subtracting the Peavine, Silver, and Five-Mile Pipeline diversions from the total diversion. Typically, diversions from Clear and Sweetwater creeks are estimated as 60 and 40 percent, respectively, of the outflow from the Five-Mile Pipeline. However, the record indicates that the ratio used to attribute diversions to Clear and Sweetwater creeks has varied widely among some months since 1997. Before construction of the Five-Mile Pipeline, average rates of diversion from Clear and Sweetwater creeks were roughly equal, although varying widely in relation to each other from month to month.

The diversion record has been influenced by several factors since 1984, including:

- The climatic cycle – a major drought occurred during the first half of the diversion record, WYs 1987-94, whereas the latter half of the record has been relatively wet.
- Diversion interruptions due to storm damage (e.g., 1986), construction (e.g., 1994-97), and maintenance (e.g., 2002).
- The upstream relocation of Clear and Sweetwater creek intakes in 1995, resulting in reduced contributing drainage area and possibly diversion potential.
- The shared conveyance of Clear and Sweetwater creek diversions in the Five-Mile Pipeline since 1996, which may constrain diversion potential.
- The discontinuation of diversions from Harmon Creek and Earl and Manson springs.
- Advanced filtration at the Lyon WTP since 1994, which may have increased the potential to divert flows of poorer quality (e.g., in terms of turbidity).
- Changes in the way the diversion record is estimated from a few metered flows.
- Uncertain flow meter accuracy as a result of infrequent calibration (current plan is to begin testing and calibrating the flow meters every 3 years).
- Increasing water demand, which increases the potential for diverting excess winter and spring flows.
- Decreased water demand during and following droughts as well as during very wet years.
- SLVWD's impetus to always maximize diversions and reserve groundwater use for the dry season and droughts.

There is no record of total streamflow or the amount of flow that bypasses the diversion intakes. SLVWD has found site conditions difficult for establishing permanent gages on these streams.

4.3.1.2 Observations

Excluding diversions from Harmon Creek and Earl and Manson springs, total annual diversions since WY 1985 have ranged from 470 to 1,200 AF/yr (150 to 390 MG/yr) and averaged about 880 AF/yr (290 MG/yr) (Table 4-9). Diversions were only about 400 AF/yr in WY 1977. Total monthly diversions have ranged up to nearly 140 AF/month (45 MG/month) (Table 4-7, col. I), and thus have yet to be limited by an estimated WTP capacity of 155 AF/month (51 MG/month).

Since the 1997 reconfiguration of the diversion intakes and raw-water conveyance, the average contribution of each source to total diversions is as follows:

Peavine and Silver Creeks	13%
Foreman Creek	60%
Clear and Sweetwater Creeks (Five-Mile Pipeline)	27%

The 1984-2006 diversion record mimics the climatic cycle, as demonstrated in Table 4-10 and Figure 4-10. During the 1987-94 drought, total water-year diversions were 73 percent of average overall and as low as 56 percent of average. During the 1995-2000 wet period, annual diversions were 125 percent of average overall and as high as 135 percent. The climatic variability of the annual diversion record is similar to the variability of the Ben Lomond rainfall record, and less variable than the San Lorenzo River at Big Trees record (Table 4-10). The variability of annual diversions is only weakly correlated to annual water demand.

Regression analysis indicates that water-year diversions correlate significantly with the current year and two previous years' rainfall. The level of correlation (r^2) increases about 25 percent by including the prior two years' rainfall as independent variables. Individual year examples include: a relatively large diversion in WY 1999, despite moderate rainfall, because of residual high baseflows following the 1998 El Nino year; a relatively small diversion in WY 1993, despite that year's high rainfall, due to the lingering effects of drought during 1987-92 (Table 4-10 inset plot).

Figure 4-11 is a plot of SLVWD 1984-2006 monthly stream diversions in relation to monthly and water-year rainfall and monthly total water production. Diversions supply nearly all of the Northern Service Area's water demand during typical, non-drought winter and early spring months. However, given the lack of significant surface-water storage capacity,[8] a large dry-season gap occurs between surface-water supplies and peak demand that must be supplied by groundwater pumping. Monthly diversions from Foreman Creek tend to correlate with the hydrologic cycle whereas diversions from Peavine, Silver, Clear, and Sweetwater creeks tend to peak during late spring and summer, and may be entirely bypassed in winter. Monthly diversions often dip sharply in February as a result of low water demand and the shortness of the month. A daily or hourly record would be needed to evaluate the diversion record in relation to stormflow events.

Table 4-11 and Figure 4-12 provide a summary of SLVWD average, minimum, and maximum monthly stream diversions for 1984-2006. On average, Foreman Creek diversions peak in March in response to peak-seasonal rainfall; diversions from the other streams peak in June as seasonal water demand surpasses the Foreman Creek diversion; and total diversions peak in May. Near-zero minimum winter diversions for Peavine, Silver, Clear, and Sweetwater creeks reflect months when flows are allowed to bypass the intakes. Conversely, minimum Foreman Creek diversions reflect reduced flows during drought conditions.

The diversion record for the 1987-94 drought remains fairly representative given that subsequent changes in infrastructure would have improved those conditions relatively little. Also, increased diversion efficiency and treatment capability may partially offset the effect of relocating the Clear and Sweetwater creek intakes upstream.

SLVWD's ten highest total monthly diversions range between approximately 120 and 140 AF/month (40 to 45 MG/month; Table 4-7). These generally occurred during spring and summer. The WTP has not produced at its estimated monthly capacity (~155 AF/month or 51 MG/month) because of (a) the need to bypass turbid stormflow; (b) lower water demand during winter when flows are available; and (c) hydraulic, aeration, and operational constraints that limit the simultaneous conveyance of high flows from each stream intake to the WTP. Since 1984, monthly diversions have been 30 percent or more below the WTP's estimated capacity about 85 percent of all months.

Tables 4-7 and 4-9 include sums of the highest ranked individual diversions (columns C and H) which exceed the highest total diversions. These sums reflect the approximate potential supply of water available for diversion. Actual diversions are less because of limited demand and/or limited conveyance and treatment capacity.

The following table compares estimates of total average annual streamflow above the diversion intakes (from Section 4.1.3) to average annual diversions since completion of the current raw-water intake, conveyance, and treatment system. On average, diversions from Peavine, Silver, Clear, and Sweetwater creeks are less than 20 percent of total flow, and diversions from Foreman Creek are

[8] Approximately 25 AF in the northern service area (see Table 7-1).

slightly more than 40 percent of total flow. These percentages are elevated somewhat by above average rainfall since the current infrastructure was completed (see Table 4-10).

	Average Annual		
	Total Stream-flow above Intake[a]	SLVWD Diversions[b] (since WY 1998)[c]	SLVWD Diversions as Percent of Total Streamflow
Diversion Watershed	(AF/yr)		
Peavine & Silver Cks	800	140	18%
Foreman Ck	1,400	620	44%
Clear & Sweetwater Cks	1,900	280	15%
Total	4,100	1,040	25%

[a]See Section 4.1.3. [b]Tables 4-3 & 4-11.
[c]Wet period, higher than long-term average.

4.3.2 Operational Procedures and Constraints

The diversion system is affected by seasonal and other operational constraints and procedures, as described below.

4.3.2.1 Water Rights

SLVWD's water rights do not specify required bypass flows except to provide for a downstream water right of 30 gpm on Clear Creek (Table 4-1). If challenged, attempts could be made to set SLVWD water rights at estimated pre-1914 diversion rates. Although poorly documented, pre-1914 water uses included powering mills and hydroelectric generators, requiring fairly high diversion rates. When SLVWD relocated the intakes on Clear and Sweetwater creeks, the California Department of Fish and Game (CDFG) stipulated that the diversions should not capture the entire flow. During dry periods when the diversion of available flows is maximized, the channels downstream of the intakes are fed by (a) seepage through the diversion structures, (b) other channel underflow, and (c) groundwater discharge. Underflow can be significant due to the aggradation of sediment and storm debris in the channel upstream of the diversion structure.

4.3.2.2 Seasonal

Raw-water production is closely correlated to short-term water demand, given that the operable storage capacity of the northern distribution system is only 25 AF (about a 3- to 8-day supply, depending on season; see Table 7-1). Low seasonal demand is typically the limiting factor for diversions during periods of high flow. The Five-Mile Pipeline and its contributing diversions typically are shut down during mid-winter when seasonal high flows available from Peavine and Foreman creeks exceed low seasonal water demand. Thus, SLVWD has little experience operating its diversions and WTP at near capacity.

During major storms, diversion flashboards are removed to prevent siltation of the intake pool, effectively limiting the opportunity to divert during high-flow periods. Additionally, the manual effort required to remove and replace flashboards and clean intake screens may limit diversions during storm periods.

Since 1984, diversions have fulfilled the entire monthly water demand of the Northern Service Area about 3 percent of the time (about one month every three years). Although total diversions tend to parallel demand during winter and spring, they typically run about 10 AF/month (3.3 MG/month) below demand (Figure 4-11). This suggests that a combination of factors – including storm timing, turbid-stormflow bypass, conveyance limitations, and WTP operations – result in an average need for about 10 AF/month of groundwater production, even when streamflows are plentiful. The WTP's estimated effective capacity (~155 AF/month or 51 MG/month) may be assumed to account for these factors at times when available flows reach that level.

The WTP's clarifier basins may become full with backwash at about the same time that diversion rates begin to decline toward the end of a wet period. This makes it difficult to recycle backwash at rates high enough to prevent basin overflow, yet below the 10 percent limit on the contribution of backwash to WTP inflow. Also, high rates of backwash recycling are responsible for water color problems unaddressed by the WTP. Alternative means for emptying the clarifier basins are needed at such times.

To date, diversions have not been shut down due to lack of flow. However, SLVWD has no drought experience with the Clear and Sweetwater creek intakes since they were relocated in 1995.

4.3.2.3 Turbidity

High turbidity streamflow events in SLVWD's diversion watersheds last from hours to days, which is relatively short compared to the duration of elevated turbidity in larger, main-stem streams. SLVWD typically avoids needing to divert during high turbidity flows by relying on treated water stored in the distribution system (up to 25 AF in the northern distribution system; see Section 7).

SLVWD's diversion operating plan includes monitoring turbidity at the intakes and shutting them off once a specified level of turbidity is reached, e.g., 5 NTU. Although the WTP can handle higher turbidity, it is usually unnecessary in terms of water demand, and is undesirable in terms of WTP operations.

In practice, remote monitoring and control of the diversion intakes has been problematic. In these cases, monitoring the turbidity influent to the WTP determines when to halt diversions, e.g., at about 2 NTU. Operating by this procedure is undesirable because the raw-water pipelines often contain high turbidity water by the time 2 NTU is observed at the WTP. Processing these turbid diversions requires sustained use of the clarifier basins. If the clarifier basins fill, the turbid pipeline water can be cycled back to the Foreman intake and discharged.

4.3.3 Production Potential

Quantifying SLVWD's potential to divert streamflow is a function of several key but weakly defined constraints. Given a monthly WTP capacity of about 155 AF (51 MG), estimates of available streamflow in excess of this are not critical to estimating potential diversions. Water rights have not been a critically limiting factor. Diversion bypasses due to elevated turbidity and WTP flush and backwash cycles should reduce potential diversions by only about 3 percent, although in practice better management of turbid flows appears needed. The hydraulic constraints that limit raw-water conveyance to the WTP appear significant but difficult to interpret except in aggregate from an empirical review of the diversion record. Diversion potential is affected most by the climatic cycle and changes in demand at times when flows are available.

This study characterizes SLVWD's surface-water supply by constructing a 1984-2006 hydrograph of total streamflow available for diversion based on extrapolation of the monthly diversion record. The diversion record reflects total, practically available diversions adjusted for the effect of operational constraints, with the exception of times when available flows exceed demand. This is because stream diversions are preferred over groundwater pumping. Stream diversions cannot be stored, whereas groundwater is essentially stored until pumped.

Hydrographs of available streamflow are constructed by extrapolating the monthly diversion record above levels imposed by low winter demand. Extrapolating flows above the maximum expected capacity of the conveyance and treatment system is unnecessary. Monthly rainfall and water-demand records help guide the extrapolation.

To estimate monthly diversions, these hydrographs are evaluated against (a) the estimated capacity of the diversion system and (b) assumed monthly water demand.

A previous study estimated monthly total streamflows for each SLVWD diversion watershed from assumed percentages of selected gaged flows (Geomatrix, 1999). However, only a portion of total monthly streamflow is effectively available due to the timing and magnitude of stormflow events within each month, as well as various hydraulic, turbidity, and treatment constraints. Quantifying these constraints would require an analysis of detailed stormflow and diversion records, which are unavailable. Although such a procedure could be calibrated to known diversions, a more direct approach is to evaluate the monthly diversion record as a partial representation of practically available flows.

The analysis presented here assumes that the effective capacity of the combined diversion conveyance and treatment system is 155 AF/month (51 MG/month) (i.e., the WTP capacity estimated in Section 4.2.3). This exceeds the highest monthly rates of recorded total diversion by nearly 20 AF/month (7 MG/month) (Table 4-7). Additionally, it assumes that the hydraulic capacity of the conveyance system is no less than that of the WTP. The actual system capacity may remain poorly defined until tested by higher rates of demand at times when such flows are available. In this analysis, past diversions from Harmon, Earle, and Manson creeks are included in the water demand record, but omitted from the water-supply record given that those intakes are no longer active.

4.3.3.1 Estimation Procedure

The rate of monthly diversion tends to increase quickly during late autumn and early winter as streamflows increase with the onset of the wet season. Then, during spring and summer, diversion rates decline as a function of the dry-season baseflow recession (see Section 3.3.4). This analysis uses straight-line extensions of the rising and falling limbs of the total diversion hydrograph to estimate potential diversions in excess of historical water demand. The hydrograph extensions are performed at both arithmetic and semi-logarithmic scales. Hydrograph extensions on arithmetic plots provide relatively low, conservative estimates of potential diversions. Estimates from extrapolating semi-logarithmic plots are larger and appear more representative of the actual streamflow hydrograph. Maximum diversion estimates are made by either (a) extrapolating a plot of maximum monthly diversions or (b) extending the diversion hydrograph up to the capacity of the WTP throughout the stormflow season. The generally unreasonable estimates provided by these last two approaches establish an upper bound to the estimated range of potential diversions.

Extrapolations of the rising and falling limbs of the diversion hydrograph rely on early and late season data relatively unaffected by stormflow conditions. As noted previously (Section 4.3.2.2), stormflow conditions appear to result in diversions about 10 AF/month (3.3 MG/month) lower than needed to satisfy demand. The assumed system capacity (~155 AF/month or 51 MG/month) may be assumed to account for this once available flows reach that level.

Estimation of potential monthly diversions under the various conditions considered involves the following steps:

1. Extrapolation of the total diversion hydrograph using the methods described above.
2. Limiting potential diversions to no more than the assumed system capacity.
3. Estimating actual diversions by limiting potential diversions to assumed monthly rates of water demand.

4. Adjusting the estimated diversions downward by 10 AF/month (3.3 MG/month) during stormflow periods.

The following section presents the results of the first two steps and Section 4.3.3.3 provides the results of the third and fourth steps.

4.3.3.2 Extrapolation of Total Diversion Hydrographs

The procedure for estimating potential diversions is applied to two sets of hydrographs: (1) generic representations of average, drought, and wet-period years and (2) the 1984-2006 historical record.

Representative Average, Drought, and Wet-Period Years

Figure 4-13 shows arithmetic and semi-logarithmic extensions of SLVWD monthly diversion hydrographs averaged for (a) 1984-2006, (b) drought WYs 1987-92 and 1994, and (c) wet-period WYs 1986, 1995-2000, and 2005-06; and (d) constructed from 1984-2006 maximum monthly diversions. Average rainfall during the selected drought and wet-period years was 65 and 120 percent of average, respectively. Diversions exceeded 1,000 AF/yr (325 MG/yr) during each of the wet-period years.

Table 4-12 documents the process of generating these representative hydrographs and Figure 4-14 illustrates the results. Limited by an assumed system capacity of 155 AF/month (51 MG/month), potential annual diversions are estimated as follows:

Year Type	Arithmetic Extrapolation				Semi-Logarithmic Extrapolation				Source:
	Peak Month		Annual		Peak Month		Annual		
	(AF/mth)	(MG/mth)	(AF/yr)	(MG/yr)	(AF/mth)	(MG/mth)	(AF/yr)	(MG/yr)	
Average	140	46	1,005	330	155	50	1,110	360	Tables 4-12a,b,c, cols. F & M
Drought	95	30	635	205	120	40	680	220	
Wet Period	155	50	1,255	410	155	50	1,310	425	
Max. Months	-	-	-	-	155	50	1,580	515	Table 4-12d, col. E

1984-2006 Hydrograph

Table 4-13 documents the process and Figure 4-15 presents the results of estimating the monthly potential diversion hydrograph for 1984-2006. These estimates correct for periods when diversions from Clear and Sweetwater creeks were interrupted by construction and maintenance of the Five-Mile Pipeline (i.e., 1995-97 and 2002). The following table summarizes the average and range of estimated potential annual diversions limited by an assumed system capacity of 155 AF/month (51 MG/month):

Water Year	Arithmetic Extrapolation		Semi-Log Extrapolation		Maximum Extrapolation		Source:
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	
Average	1,090	350	1,130	370	1,300	425	Tables 4-13c,d cols. G, N, & T
Minimum	524	171	537	175	750	245	
Maximum	1,620	530	1,620	530	1,670	545	

These results are consistent with the representative hydrographs estimated above. However, as expected, the estimates for individual years have a greater range of variability.

4.3.3.3 Estimated Diversions

Plausible diversions are estimated by (a) limiting potential diversions to assumed rates of monthly water demand and (b) assuming diversions average about 10 AF/month (3.3 MG/month) less than water demand during stormflow months. As stated above, "water demand" here refers to the demand for produced water, including distribution losses, which equals the total amount of water produced each month in SLVWD's Northern and Southern Service Areas. Potential diversions are evaluated relative to (a) demand in the Northern Service Area and (b) District-wide demand. The difference between these represents diversions potentially available for use in the Southern Service Area (e.g., through a proposed intertie between service areas), assuming that the Northern Service Area has priority of use.[9]

Potential diversions are evaluated against the following demand scenarios:

- 2001-2006 average monthly demand (i.e., current)
- 2001-2006 average monthly demand adjusted to projected 2030 demand
- 1984-2006 historical record of monthly demand
- 1984-2006 historical record adjusted to projected 2030 demand

The past, current, and projected annual demand for produced water (i.e., stream diversions and pumped groundwater) is as follows:

Annual Water Production	Avg 1984-2006		Avg 2001-2006		Projected 2030	
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)
N. Service Area	1,550	505	1,730	560	1,800	585
S. Service Area	340	110	410	140	500	165
Total	1,890	615	2,140	700	2,300	750

The District's annexation of Mañana Woods had little effect on 2001-2006 average production but is fully reflected in the projected demand (Table 2-4). As discussed in Section 2.3, SLVWD projects a fairly modest increase in water demand through 2030.

Representative Average, Drought, and Wet-Period Years

Table 4-12 and Figure 4-16 present monthly diversion estimates for average, drought, and wet-period years relative to 2001-06 average water demand. This analysis assumes that the Northern Service Area has first priority to available diversions. These results are summarized as follows:

Year Type	Arithmetic Extrapolation				Semi-Log Extrapolation						Source:
	N. Service Area		S. Service Area		N. Serv. Area		S. Serv. Area		Total > NSA		
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	
Average	910	295	30	10	940	305	75	25	170	56	Tables 4-12a,b,c, cols. I,K,P,R
Drought	615	2001	0	0	650	210	7	2	25	9	
Wet Period	1,085	355	75	25	1,105	360	90	30	195	64	
Max. Months	2001-06 average demand				1,380	450	90	30	200	65	Table 4-12d, cols. H,J,P,R
	2001-06 max. monthly demand				1,450	475	70	25	130	43	

The estimated average and range of diverted-water use in the Northern Service Area are reasonably consistent with the diversion record (Tables 4-3, -9, & -11). In the case of each semi-logarithmic extrapolation, estimated diversions in response to Northern Service Area demand are about 60 AF/yr (20 MG/yr) greater than actual diversions averaged for similar years. Based on these results, diversions available for use in the Southern Service Area under 2001-06 demand levels average about 75 AF/yr (25 MG/yr) and range from 0 to 100 AF/yr (33 MG/yr). Total potential diversions in excess of North Service Area demand are estimated to average about 170 AF/yr (56 MG/yr) and range up to 200 AF/yr (65 MG/yr).

---

[9] Additional diverted water could be used in the southern service area if offset by groundwater pumping and/or conservation in the northern service area.

As expected, maximum-month diversion estimates exceed annual maximums for the period of record. These estimates illustrate that above-average diversions could supply a larger share of Northern Service Area demand without providing much additional water to the Southern Service Area. Alternatively, additional diverted water used in the Southern Service Area could be offset by groundwater pumping and/or conservation in the Northern Service Area.

On an annual basis, diversions estimated for representative average, dry, and wet years constitute 91 to 97 of estimated potential diversions within the system's assumed capacity range (i.e., ≤155 AF/month or 51 MG/month) (Tables 4-12a,b,c).

As discussed in Section 2.3, SLVWD projects a fairly modest increase in water demand by 2030. Assuming required water production of 1,800 and 500 AF/yr (586 and 163 MG/yr) by 2030 in the Northern and Southern Service Areas (Table 2-4), respectively, estimated diversions would increase modestly as follows:

	Arithmetic Extrapolation				Semi-Log Extrapolation					
	N. Service Area		S. Service Area		N. Serv. Area		S. Serv. Area		Total > NSA	
Year Type	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)
Average	920	300	30	10	955	310	75	25	155	50
Drought	615	200	0	0	655	215	2	0.7	20	7
Wet Period	1,100	360	80	25	1,125	365	100	30	185	60

Increased demand by 2030 results in using about 2 percent more estimated potential diversions within the system's capacity.

1984-2006, Historical Demand

Table 4-13 and Figure 4-17 present the results of monthly diversion estimates for 1984-2006 based on actual demand during those years. These results are summarized on a water-year basis as follows:

Year Type	Arithmetic Extrapolation				Semi-Log Extrapolation				Max. Extrapolation				Source:
	N. Serv. Area		S. Serv. Area		N. Serv. Area		S. Serv. Area		N. Serv. Area		S. Serv. Area		
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	
Average	9108	295	60	20	935	305	60	20	1,020	330	105	35	Tables 4-13c,d cols. J,L,Q,S, U,W
Minimum	480	155	5	2	480	155	5	2	580	190	45	15	
Maximum	1,270	415	140	45	1,325	430	135	45	1,385	4520	185	60	

The average and minimum arithmetic and semi-logarithmic diversion estimates are consistent with the historical record average and minimum, respectively, whereas the maximum estimated diversions are slightly (up to 10 percent) higher than historical maximums.

The estimated contribution of streamflow diversions to the water supplies of the Northern and Southern Service Areas is limited by their respective monthly water demand. The total amount of available divertible streamflow (i.e., as limited by WTP capacity, etc.) in excess of Northern Service Area demand is estimated as follows:

	Semi-Log Extrapolation: Total in Excess of Northern Service Area Demand	
Year Type	(AF/yr)	(MG/yr)
Average	195	65
Minimum	55	18
Maximum	350	115

If an intertie between service areas existed, an average of approximately 60 AF/yr (20 MG/yr) and range of 5 to 135 AF/yr (2 to 44 MG/yr) are estimated to have been available for use in the Southern Service Area after serving the production needs of the Northern Service Area.

Estimated annual diversions for the period of record constitute 80 to 94 percent of estimated potential annual diversions within the system capacity (Tables 4-13).

1984-2006, Adjusted to Projected 2030 Demand

Figures 4-18 and 4-19 document adjustments to the historical production record in order to represent 2030 demand levels of 1,800 and 500 AF/yr (586 and 163 MG/yr) in the Northern and Southern Service Areas, respectively (Table 2-4). These adjustments accomplish the following: (a) remove an upward trend in production since 1986, (b) mimic current degrees of seasonal fluctuation, (c) maintain the effects of the climatic cycle (e.g., lower demand during drought years due to conservation), and (d) achieve average demand consistent with that projected for 2030.

Table 4-14 and Figure 4-20 present the results of monthly diversions estimated from (a) the semi-logarithmic extrapolation of the 1984-2006 diversion record (Figure 4-15) and (b) the historical demand cycle adjusted to 2030 (Figures 4-18 and 4-19). These results are summarized on a water-year basis as follows:

Year Type	Semi-Log Extrapolation								Source:
	N. Serv. Area		S. Serv. Area		N. & S. Serv. Areas		Total Excess		
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	
Average	988	322	78	25	1,065	347	144	47	Tables 4-14b cols. N,O,P
Minimum	507	165	0	0	507	165	30	10	
Maximum	1,433	467	156	51	1,549	505	250	81	

Based on 2030-projected demand and semi-logarithmic extrapolation of the 1984-2006 diversion record, the average rate of diversion for use in the Northern Service Area is about 975 AF/yr (317 MG/yr). An average of about 75 AF/yr (25 MG/yr) and range of 0 to 155 AF/yr (0 to 51 MG/yr) would be available for use in the Southern Service Area after serving the production needs of the Northern Service Area. Diversions would supply a total of about 1,050 AF/yr (342 MG/yr) to both service areas, on average.

Under 2030 demand, the average rate of diversion estimated for the Northern Service Area is nearly 100 AF/yr (33 MG/yr) greater than average actual diversions during 1984-2006. This represents about a 6 percent increase in the use of estimated potential diversions as limited by system capacity. However, these estimates rely on a significantly greater rate of maximum diversion (>1,500 AF/yr or >500 MG/yr) than has occurred historically (i.e., <1,200 AF/yr or <390 MG/yr). If annual diversions are limited to 1,200 AF/yr, estimated average 2030 diversions are lower by 24 AF/yr for the Northern Service Area and 35 AF/yr for the Southern Service Area.

4.3.3.4 Summary and Conclusion

Average monthly diversions estimated for the various climatic and demand conditions discussed above are summarized in Table 4-15 by month and service area, and in Table 4-16 by year and service area. Given the range of conditions and assumptions considered, SLVWD's expected supply of stream diversions is estimated as follows (assuming the Northern Service Area has priority of use):

Year Type	Service Area						Total in Excess of NSA Demand	
	North		South		North & South			
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)
Average	950	310	50+	16+	1,000	330	150	50
Drought	650	200	<10	<3	650+	200+	25	8
Wet-period	1,200	400	<100	<33	1,200+	400+	200	65

Differences between diversion estimates reflecting current versus 2030 demand are relatively minor and within the range of overall uncertainty, given other variables and assumptions.

On average, diversions are estimated to supply slightly more than 50 percent of demand in the Northern Service Area (Table 4-15a). Potential diversions in excess of this amount could provide an average of about 15 percent of demand in the Southern Service Area (Table 4-15b). In this case, diversions would supply slightly less than 50 percent of SLVWD's District-wide demand, on average (Table 4-15c).

The drought- and wet-period values in the above table represent expected averages for such periods. Individual years with diversions as low as 400 AF/yr (130 MG/yr) should be expected (e.g., 1977), especially given the upstream relocation of some intakes and discontinuation of others since 1996. Maximum annual diversions of as much as 1,500 AF/yr (490 MG/yr) are expected if the diversion system can sustain operation at capacities approaching 155 AF/month (51 MG/month) for periods of several months during the wettest years.

Potential diversions estimated to be available for use in the Southern Service Area are small relative to total estimated diversions, and thus have a relatively high degree of uncertainty. On average, about 90 percent of estimated diversions available to the Southern Service Area occur from December through April (Table 4-15b). Maximum monthly rates of diversion would be about 30 AF/month (10 MG/month), requiring a service-area intertie capacity of 250 gpm or more. Diversions available to the Southern Service Area would supply less than 10 percent of annual demand during about 35 percent of all years, and up to 30 percent of annual demand during other years (Table 4-16). The diversion estimates for the Southern Service Area are highly dependent on the system operating at near capacity during the wettest months and periods.

The diversion estimates are sensitive to the system's assumed capacity and efficiency as follows:

- Assuming an effective system capacity of only 140 AF/month (46 MG/month) reduces the estimated average annual total diversion by about 10 to 20 AF/yr (3 to 7 MG/yr) and reduces estimated maximum-year total diversions by about 100 AF/yr (33 MG/yr).
- Assuming a 20 rather than 10 AF/month reduction in divertible flows during stormflow periods (3 to 7 MG/month) reduces estimated annual total diversions by 50 AF/yr (16 MG/yr).
- Potential improvements in WTP and conveyance efficiency could render all of the presented diversion estimates as conservatively low.

As stated in the report introduction, this water-supply assessment does not address potential environmental constraints on raw water production. And, as discussed further in the report summary and conclusion (Section 8), this assessment does not project changes in water supply as a result of climate change given considerable uncertainty about such trends.