Part B—Freshwater flow and seasonal variation

This Technical Support Document (TSD) provides additional analysis of freshwater flows in San Diego Creek and other tributaries that flow into Newport Bay. This TSD examines rainfall records, daily stream flow rates, flow-based tiers and associated flow volumes, and how hardness is associated with flow rates.

Overview

In the semi-arid climate of Southern California there are two seasons—dry weather occurs during most of the year and intermittent wet weather events occur typically between November and March. This two-season climate creates significant differences in freshwater flow through the creeks and streams. In general, storm events yield both high flow rates and high flow volumes; the vast majority of flow volume occurs during the months of December, January and February. Nonetheless, some storms occur in other months of the year.

EPA Region 9 has evaluated the merits of developing TMDLs for each pollutant (or group of pollutants) by using the seasonal variation approach (i.e., loading determined for wet versus dry weather seasons) or by using a flow-based approach. In the flow-based approach, the continuous range of stream flow that occurs at each target site is broken down into ranges or tiers. This incorporates high flows that may occur outside of the wet season as well as low flows that happen in between rain events. Thus the applicable loading capacity and total allocation for a given pollutant does not depend on the time of year, but on the actual stream flow at the time of discharge. A flow-based approach is used in the TMDLs.

The following discussion concentrates on establishing flow tiers for San Diego Creek, since it is the most significant source of freshwater (and associated pollutants) to Newport Bay. The flow-based approach is applied to Se and metals TMDLs where four flow tiers have been identified: base flows, small flows, medium flows and large flows. This interpretation of four tiers comes from analysis of nearly twenty years daily flow rate records for San Diego Creek at Campus Drive (USGS and OCPFRD data). For metals, flow rate is indirectly related to measurements of in-stream hardness. The flow-based approach is also applied to the organochlorine, chromium and mercury TMDLs, whereby two tiers were applied: mean flow and high flow. Further details are provided below.

Annual precipitation

Precipitation during a water year (defined from July 1 to June 30) will influence the total flow volume within each freshwater system. Average annual rainfall is 13 inches based on the Tustin/Irvine Ranch rain gage station; a site often used for precipitation analysis within the Newport Bay watershed. During water year 1998, 34.7 inches of rain fell (El Nino conditions), whereas in 1999, 8.6 inches of rain fell. Table B-1 summarizes rainfall records at Tustin/Irvine Ranch from 1958/59 to 2000/01.

Table B-1. Annual Precipitation Records at Tustin-Irvine Ranch Station

Water Year *	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)
1958-59	5.03	1971-72	5.02	1983-84	10.47	1995-96	11.17
1959-60	9.6	1972-73	14.9	1984-85	10.25	1996-97	16.19
1960-61	4.13	1973-74	9.81	1985-86	14.42	1997-98	34.72
1961-62	13.07	1974-75	12.36	1986-87	8.79	1998-99	8.6
1962-63	5.76	1975-76	5.11	1987-88	11.14	1999-00	8.8
1963-64	9.38	1976-77	10.2	1988-89	8.17	2000-01	14.6
1964-65	10.28	1977-78	27.96	1989-90	5.93	Summary	
1965-66	12.68	1978-79	18.59	1990-91	11.23	Min:	4.13
1966-67	14.22	1979-80	20.75	1991-92	17.18	Max:	34.7
1967-68	8.58	1980-81	8.47	1992-93	27.09	Mean:	13.03
1968-69	19.91	1981-82	13.22	1993-94	10.23	Median:	10.8
1969-70	8.48	1982-83	25.92	1994-95	24.65	Count:	42

*Source: OCPFRD; *Water years run from July 1 to June 30 of the following year.*
Rainfall data for water year 1970-71 not available

Annual flow volumes

Orange County Public Facilities and Resources Department (OCPFRD) have established stream gages at several locations in the Newport Bay watershed. Based on annual flow data from different sites, San Diego Creek is by far the largest freshwater contributor (95%) to Upper Newport Bay and it drains over three-quarters of the entire Newport Bay watershed. The remaining freshwater contributions are from Santa Ana / Delhi Channel (<5%), Costa Mesa Channel (<1%), and Big Canyon Creek (undetermined) and other minor storm drains.

As can be expected, total flow volumes for each stream or tributary are directly related to annual precipitation. For example, the total flow volumes recorded for San Diego Creek at Campus were 90,267 acre-ft. in water year 1997 / 98 (due to El Nino conditions) and 17,330 acre-ft in water year 1998 / 99 (due to slightly below normal annual rainfall). Within San Diego Creek, nearly equal flows have been recorded for Peters Canyon Wash (BARSED station) in comparison to San Diego Creek at Culver (WYLSED station), 38% and 35% respectively. Other channels (Lane Channel, Big Canyon, Sand Canyon, etc.) have very limited data and have not been adequately quantified.

Daily Flow Records

Daily flow records for San Diego Creek at Campus (OCPFRD data) reveal a wide range of flow rates. In dry weather base flows range typically range from 8 to 15 cfs; whereas, in wet weather, daily storm flows can fluctuate between 800 and 9,000 cfs (cubic feet per second). During the El Nino year, San Diego Creek registered the highest momentary peak flow (43,500 cfs on Dec. 6, 1997) in recent history. Records for Santa Ana-Delhi show average dry weather flows between 1 and 2 cfs and daily storm flows ranging from 100 to 1,370 cfs. The momentary peak discharge at Santa-Ana Delhi station for the El Nino season was 6,450 cfs.

EPA and Regional Board staff reviewed San Diego Creek at Campus daily flow records from two sources: USGS, who installed the gaging station in fall 1977 and OCPFRD who took over in fall 1985. We selected daily flow records corresponding to water year records. For example, July 1, 1978 to June 30, 1979 is water year 1979. This approach yielded 19 water year records for San Diego Creek at Campus Dr: three water years by USGS (78 / 79, 83 / 84, 84 / 85) and 16 water years by OCPFRD (1985 to 2001). Incomplete

USGS data for the period 1979/80 to 1982/83 were not used because only partial records were available for each year.

OCPFRD provided comments and alternate analysis of flow tiers based on recent daily flow records and precipitation records (1996 to 2001) for four nearby rainfall stations in the watershed. This analysis was based on four flow tiers as originally proposed in the draft Toxics TMDLs. The maximum base flow was determined to be approximately 20 cfs, based on comparison of rainfall and daily flow data. OCPFRD comments along with their analysis of records for 1996 to 2001 are highlighted here:

- Six years of flow and rainfall records were used (WY 1995/96 – 2000/01) and chosen due to reliability and representative nature of both rainfall and daily flow records over this period. Prior to the mid-1990s, base flows recorded at San Diego Creek at Campus Dr. were generally greater than current conditions. This is likely attributable to greater discharges stemming from nursery and agricultural operations and authorized discharges by Irvine Ranch Water District.
- Flow records were from the San Diego Creek at Campus Drive station. Daily rainfall records were derived from four Automated Local Evaluation in Real Time (ALERT) rainfall stations in the watershed (El-Modena-Irvine at Michelle, Sand Canyon at I-5 freeway, Peters Canyon Wash at Barranca Pkwy., and SDCreek at Culver). ALERT data were preferred over rainfall data from Tustin-Irvine precipitation records since rainfall amounts from ALERT stations more closely corresponded with daily mean flow determinations (12 midnight to 12 midnight).
- These six years of data provide a reliable picture of rainfall and daily flows in that it includes on very wet year (WY 1997/98) and two drier than average years (WY 98/99 and 99/00).
- Four flow tiers were partitioned from daily flow records based on corresponding rainfall data. Small storms correspond to >0” to 0.24”, medium storms correspond to 0.25 to 0.74”, large storms correspond to >0.75”.
- Rainfall-runoff relationships by their nature are not precise, yet this basic analysis is more robust than methods provided in draft Toxics TMDLs. It is very rare to have daily mean flow above 20 cfs when no precipitation has occurred.

Flow Tiers for Se and Metals TMDLs

EPA and Regional Board staff evaluated daily flow records for 19 water years at San Diego Creek at Campus to determine the flow tiers used in developing Se and metals TMDLs. We utilized the rainfall-runoff information outlined by OCPFRD above and extended the analysis to include all available complete water year records; i.e., water years 1978/79, 1983/1984, 1984/85 and so on up to 2000/01. The rainfall-runoff breakpoints for each flow tier, and the associated percentiles are: base flows (0-20 cfs) correspond to 0” rainfall (90th%), small flows (21-181 cfs) correspond to <0.25” rainfall (96th%), medium flows (182-814 cfs) correspond to rainfall between 0.25” and 0.75” (99th%), and large storms (>814 cfs) correspond to >0.75” rainfall.

Flow volumes associated with each tier were calculated by summation of daily flow rates within each tier for all 19 water years. Table B-2 provides summary statistics for each of the flow tiers. Table B-3 provides a synopsis of the mean annual flow volume for each tier and the corresponding hardness values in San Diego Creek.

Table B-2. Flow rate summary statistics for flow tiers
San Diego Creek at Campus Station (1978/79 and 1983/84 to 2000/01 water years)

Flow Tier	Flow Rates (cfs)	Number of Days Total (days)	Number of Days Annual Avg (days/year)	Measured Flow Rate Statistics (cfs) Min	Max	Mean	Std	Median
Base Flows	≤ 20	4,557	240	2	20	13.3	3.42	13
Small Flows	> 20 to ≤ 181	2,129	112	20	181	35.9	24.8	28
Medium Flows	> 181 to ≤ 814	198	10.4	182	808	397	170	365
Large Flows	>814	56	2.95	835	9,220	1,841	1,284	1,595
Non-Large Flows	≤814	6,884	362.32	2	808	31.3	71.4	16

Table B-3. Flow based tiers and corresponding hardness values in San Diego Creek.

Flow tier	Corresponding flow rate (cfs)	Mean annual flow volume associated with tier # (million cubic ft.)	Flow rate used to determine hardness	Corresponding Hardness (mg/L)
Base flows	≤ 20	275.4	N/a	400
Small flows	> 20 to ≤ 181	347.5	181	322
Medium flows	> 181 to ≤ 814	357.6	814	236
Large flows	>814	468.8	1595	197

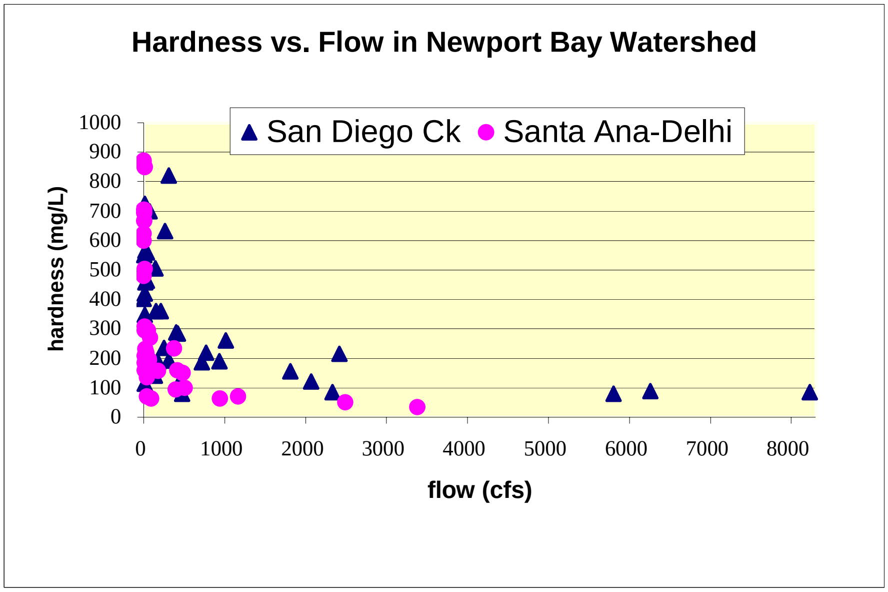
Mean annual volume for each tier based on daily flow records for 19 water years: 1977/78, 83/84 to 00/01 (combination of USGS and OCPFRD data).

Flow rate and Hardness values

To develop metal (Cd, Cu, Pb and Zn) TMDLs, EPA examined monitoring data (OCPFRD 1997 to 2000) collected during high and low flow sampling events to evaluate in-stream hardness values relative to flow rates. The paired data consist of composite samples of hardness results along with the corresponding composite flow rates. An indirect relationship exists between flow rate and hardness such that higher flow rates correspond with lower hardness values, and lower flow rates often have higher hardness values (Figure B-1). Of foremost concern, lower hardness values are associated with lower dissolved metals water criteria. Thus when storm events occur, flow rates are high, hardness is low and the correspondingly low dissolved metals criteria are most likely to be exceeded in freshwater systems.

The paired data show relatively high hardness values are observed during lower flows; in fact these values are often above 400 mg/L. However, for base flows, EPA used the maximum hardness value (400 mg/L) as allowed in CTR (USEPA 2000). To determine the hardness value associated with small, medium and large flow tiers, EPA used a linearization technique to transpose observed flow rates to the corresponding hardness values. (Hardness vs. natural log (flow rate) yields a linear relationship.) For the small and medium flows EPA selected the highest flow value within this tier to determine the corresponding hardness value. For large flows, EPA reviewed daily flow rates for 4-consecutive days and used the highest (4 day) mean flow rate to determine the corresponding hardness value. (See example for copper below.)

Figure B-1. Hardness vs. flow rate for two freshwater streams. (OCPFRD data)



Note: Linear equation for hardness and flow at San Diego Creek: y = -57.742 (ln[x]) + 622.5
(Linear equation for Santa Ana Delhi Channel: y = -102.43 (ln[x]) + 713.41)

Here is an explanation of the sequence of steps to determine metals criteria associated with each flow tier. We use small flow tier and dissolved copper criteria as an example.

1. Range of flow is 21 to 181 cfs. Choose highest flow rate within the tier = 181 cfs.
2. Use linear equation to find corresponding hardness value….start with natural log (flow rate)
3. For SDCreek, hardness = -57.742 (ln [flow])+ 622.5
4. Use this hardness value (322 mg/L as $CaCO_3$) in CTR equations to determine acute and chronic criteria for each metal.
5. Dissolved chronic Copper criteria = e(0.8545[ln(hardness)]-1.702)*0.96 =24.3 ug/L

Determination of dissolved metal numeric targets based on hardness

Once, the hardness value for each flow tier was determined, the dissolved metal numeric targets were based on (water quality criteria) equations presented in CTR (USEPA 2000). The hardness value for each flow tier yielded two possible dissolved numeric targets—the acute value and the chronic value. The acute value applies to one-day exposures, whereas the chronic value applies to exposures lasting 4-consecutive days. EPA reviewed daily flow records during the same 19 water years described above and observed that elevated flows (>181cfs) occur for 4-consecutive days or longer. This happens repeatedly within a water year (e.g., four times in WY 1997/98) as well as over the 19 years of daily flow records. Therefore, EPA selected both acute and chronic water quality criteria within base, small and medium flow tiers to serve as numeric targets for dissolved metals in San Diego Creek.

Similar methods of flow analysis were applied to daily flow records for Santa Ana Delhi Channel, however the time span covered only six water years: 1995/96 to 2000/01. Breakpoints in flow rates for Santa Ana Delhi were determined via similar percentages as those used for San Diego Creek: 90%, 96% and 99%. Table B-4 show corresponding flow rates, associated flow volumes, and hardness values for each flow tier.

Table B-4. Flow based tiers and corresponding hardness values in Santa Ana Delhi Channel.

Flow tier	Corresponding flow rate (cfs)	Flow volume associated with tier # (million cubic ft.)	Flow rate used to determine hardness	Corresponding Hardness (mg/L)
Base flows	0 – 3.5	49.3	N/a	400
Small flows	3.6 – 39	47.1	39	338
Medium flows	39.1 - 165	22.3	165	190
Large flows	>165	118.7	329	120

mean volume for each tier based on daily flow records for 6 water years: 1995/96 to 00/01 (OCPFRD data); chronic conditions for base, small, and medium flows, and acute for large flows

Flow Tiers for Organochlorine TMDLs

For the organochlorine TMDLs, we evaluated daily flow records for San Diego Creek at Campus Dr. We utilized the same 19 water year records as described above (USGS and OCPFRD database). Three flow tiers were defined to accommodate the range of flows: low flow (base and small flows), medium flow and high flow. The low flow rate (15 cfs) was determined from median value of all flow records < 181 cfs. The medium flow rate (365 cfs)was determined from the median value of flows between 181 and 814 cfs. The high flow rate was the median value (1595 cfs) within the large flows >814 cfs. For calculations of total annual flow and consequently the annual loads, the low flow rate was applied for 352 days, the medium flow rate for 10 days and the high flow rate for 3 days. Direct application of these three flow tiers was used to estimate loading capacity and existing loads of organochlorines within San Diego Creek only. More information can be found in Technical Support Document – Part F.