Memo: Estimates of hydrology in small (<80 km^2) urbanized watersheds under dry weather and high flow conditions

Alicia Gilbreath and Lester McKee
San Francisco Estuary Institute

March 2010

This memo can be cited as:
Gilbreath, A.N, and McKee, L.J, 2010. Memo: Estimates of hydrology in small (<80 km^2) urbanized watersheds under dry weather and high flow conditions. San Francisco Estuary Institute, Oakland, CA.

INTRODUCTION

It has been estimated that about 20 kg of polychlorinated biphenyls (PCBs) and 160 kg of mercury (Hg) enter San Francisco Bay from via urban runoff annually (Looker and Johnson, 2004; Hetzel, 2007). The Bay Area Storm Water Management Agencies (BASMAA) that hold National Pollutant Discharge Elimination System (NPDES) permits have been asked to increase effort and implement best management practices (BMPs) to achieve load reduction and demonstrate at the end of 20 years (2025) that annual loads entering the Bay are no greater than 2 kg PCB and 82 kg Hg. If we accept the current estimates of loads, these represent a load reduction of 90% for PCBs and 50 % for Hg. There are a variety of BMPs that BASMAA could potentially apply to meet these reduction objectives including source, maintenance and treatment controls. Provision C.11.f for the Stormwater Municipal Regional Permit (MRP; CRWQCB San Francisco Bay Region, October 2009) calls for Permittees to implement pilot projects to divert dry weather and first flush flows from pump station facilities to publicly owned treatment works (POTWs) to address these flows as a source of PCBs and mercury to receiving waters. In order to achieve this, Permittees must make preliminary decisions about which stations to test. Questions include which stations receive the greatest mercury and PCBs loads, what volumes are associated with station specific climatic conditions, and how do these compare to nearby wastewater treatment capacity? The objective of this small project was to make first order estimates of flow volume associated with a variety of climatically reasonable conditions for individual watersheds.

The information generated can be used to answer these basic questions and to help BASMAA with a preliminary ranking of pump station watersheds to focus on in response to provision C.11.f of the municipal regional permit. This information could also form the basis of unit cost estimates (i.e. cost (k$) per kg Hg or PCBs removed). It should be noted that while BASMAA is being asked to test the feasibility of wastewater treatment options, there are a number of other stormwater reuse/treatment options that would benefit from similar types of information including:

- Construction of seasonal freshwater wetlands and freshwater slope wetlands for habitat, sea level rise protection, and treatment of stormwater before discharge to the Bay
- Creek flow augmentation for enhancing freshwater beneficial uses such as coldwater fish rearing and habitat for other native or endangered species
- Landscape irrigation (reducing the demand on potable water and increasing drought security)
- Duel reticulation for toilet flushing in near-Bay industrial redevelopments
- Industrial reuse for cooling water (this might require pretreatment to ensure a supply of water of a reliable quality)
- Drinking water (reverse osmosis)

The first objective of this project was achieved by completing the following first order flow analyses for watersheds in the counties of Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco, which drain to the San Francisco Bay, and that have primarily urban sediment sources and little or no sediment supplied from fluvial channel or hillslope processes:

A. Total annual <u>average wet season</u> runoff volume

B. Total annual <u>wet season</u> runoff volume for the last 10 years

C. First flood runoff volume each year for the last 10 years

D. Largest flood runoff volume each year for the last 10 years

E. Total annual average dry season runoff volume

F. Total annual dry season runoff volume for the last 10 years

METHODS AND RESULTS

Precipitation is the driving factor in the equations used in the first four tasks of this report, and is the one dataset that varies across the tasks. Otherwise, the tasks include three common datasets including a watershed boundary layer, land use data from the Association of Bay Area Governments (2000), and land use specific runoff coefficients. The watershed boundary layer was compiled digitally by SFEI from the storm drain map series of Oakland Museum of California and William Lettis and Associates (Givler et al., 2005; 2007; Ramirez-Herrera et al., 2007; Sowers, 1993; 1997; 1999; 2004; 2006; Sowers and Givler, 2006; Sowers and Henkle, 2008; Sowers and Richard, 2003; Sowers and Thompson, 2005; Thompson and Sowers, 2005; Tillery et al., 2007). The resulting watershed boundary map was then distributed to local government representatives for verification of the watershed names. Not all of the watersheds mapped were analyzed in this report. Watersheds in this analysis all meet the following criteria:

a) Are greater than 0.5 sq. km and smaller than 100 sq km (minimum watershed size is 0.5 sq km and maximum watershed size is 75.9 sq km),
b) Are named watersheds,
c) Do not have a large reservoir, and
d) Are not a salt pond, marsh or slough.

The final watershed boundary layer includes 96 watersheds in the counties of Contra Costa, Alameda, Santa Clara, and San Mateo (Figure 1).

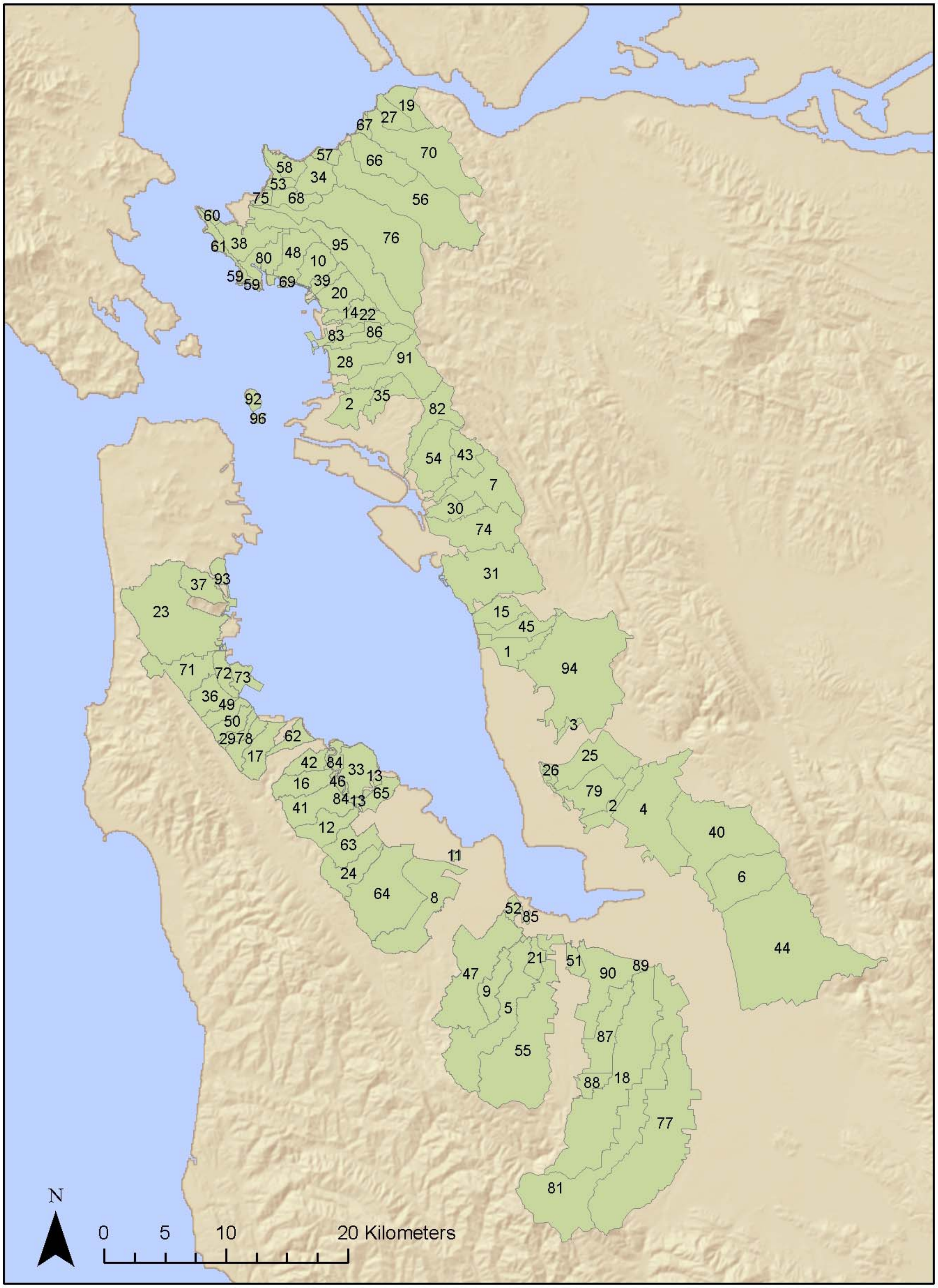

Figure 1: Watersheds in which first order flow estimates were calculated for this report.

Land use data was available for most of the Bay Area from the Association of Bay Area Governments (ABAG). The dataset was developed based on existing land use in 2000 and is at 100 square meter resolution, or better[1]. The 2000 dataset was determined sufficient for this study because major development in the Bay Area since 2000 has primarily occurred in non-urban watersheds away from the Bay margin and the estimated land use change in Bay margin urban watersheds is small. There were approximately 160 detailed classifications, which were generalized into six categories in a previous study (Davis et al, 2000): agricultural, commercial, industrial, open, residential, and water[2]. Table 1 in the appendix lists all 160 ABAG categories and the corresponding generalized categories used in this report (table extracted from Davis et al., 2000). Using the generalized land use layer and the watershed boundary layer, the area of each land use within in each watershed was determined in ArcGIS.

The land use categories were each assigned a land use specific runoff coefficient. Runoff coefficients describe the estimated percentage of rainfall onto a surface that becomes runoff, and vary between land use types based on a number of surface properties including soil characteristics, slope, vegetation, soil saturation, temperature, and the presence of impervious or fractured layers. Although these characteristics may be quite variable on temporal and spatial bases within a land use category, in this study we use the simplest approach of assigning a single coefficient for each land use category. We use the same coefficients Davis et al. (2000) selected as the “best estimates” for their modeling of contaminant loads from stormwater in the San Francisco Bay Region (Table 1). The coefficients from other reports Davis et al. considered are shown in Table 2 of the Appendix.

Table 1. Runoff coefficients for each land use category.

Land Use	Runoff Coefficient
Residential	0.35
Commercial	0.9
Industrial	0.9
Agriculture	0.1
Open Space	0.25

Adapted from Davis et al. 2000

[1] County assessor’s data was incorporated where available (not in Alameda County, Santa Clara County, or the incorporated portions of Solano and Sonoma Counties *except in the City of Sonoma*).

[2] Davis et al. categorized the 1995 ABAG land use dataset classifications, most of which were the same in the 2000 land use dataset used in this analysis (differences are noted in the Appendix Table 1 under the Comment field). The protocols Davis et al. used for generalizing these detailed land uses were developed from the San Francisco Estuary Project land use study (Perkins et al. 1991) and in collaboration with the Southern California Coastal Watershed Research Project (SCCWRP) and Moss Landing Marine Laboratories (MLML).

A. Total annual average wet season runoff volume

Objective

The objective of this task is to calculate a total annual average wet season volume for each urban watershed.

Methods

The simple equation used to estimate total annual average wet season volumes for each watershed assumes a linear correlation between runoff and annual precipitation and land uses within each watershed. In this task, the total annual average wet season volume for each urban watershed is calculated using the following equation:

$$V = P * 95\% * \sum_{j=1}^{n} (C_j * A_j) \qquad \text{Equation (1)}$$

V	=	Total annual average wet season volume
P	=	Average annual rainfall for the watershed
C	=	Runoff coefficient for land use *j*
A	=	Area of land use *j* in the watershed

Rainfall (P) in each watershed was estimated using a GIS digitization of the isohyets of Rantz (1971) developed for the San Francisco Bay Area. This isohyetal map represents mean annual precipitation for the years 1907-56 (Figure 2). At the time of creation (1971), longer-term examination of precipitation records indicated that this 1907-56 time period was representative of the longer-term mean annual precipitation. The isohyets were digitized in GIS and interpolated using the inverse distance weighted method to create a continuous surface model, from which the area-weighted average rainfall of each watershed was calculated. The power in the inverse distance weighted calculation was taken to the power of 2 for this dataset, but left as a parameter that could easily be altered in the model.

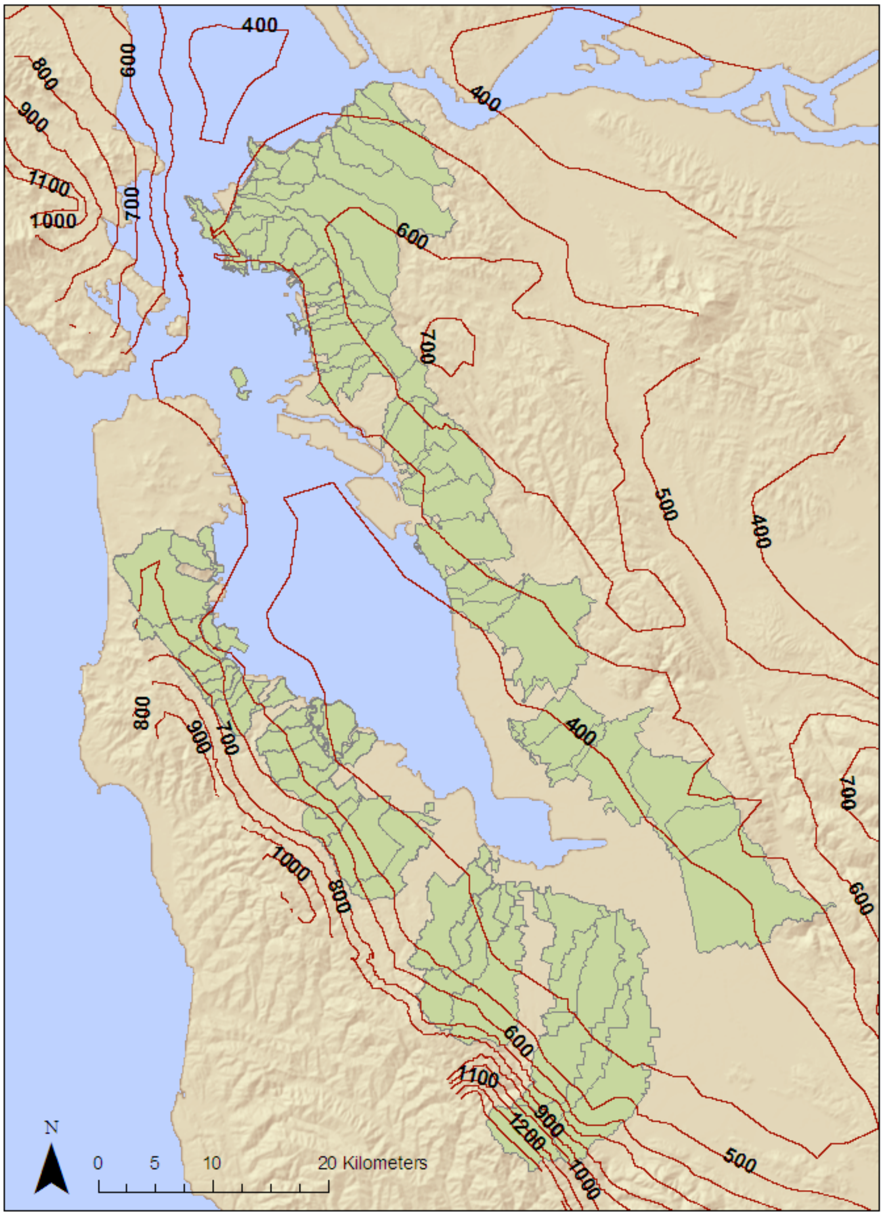

Figure 2: Rantz isohyets (interpolated to mm) overlayed on watersheds used in this analysis.

The area-weighted average annual rainfall for each watershed was multiplied by 95% based on the results from McKee et al. (2003), who found that the average amount of Bay Area annual rainfall during October-April in the watersheds evaluated ranged from 94-96% of the total annual rainfall. This provides a wet-season-only total average runoff volume.

<u>Results</u>

Appendix A Table 3: Results of Analysis A

Methods for improving the accuracy of these results are listed below, and it is noted that the values presented in Appendix A Table 3 are more reliable as relative predictions between watersheds than absolute values. While total runoff volume in each watershed is affected by rainfall, land use, and watershed size, the single most significant factor affecting runoff volume is watershed size. As shown in Figure 3, 50% of the total accumulated runoff volume for all of the watersheds combined, flows out of the 16 largest watersheds (27.1 – 75.9 km^2) in the analysis.

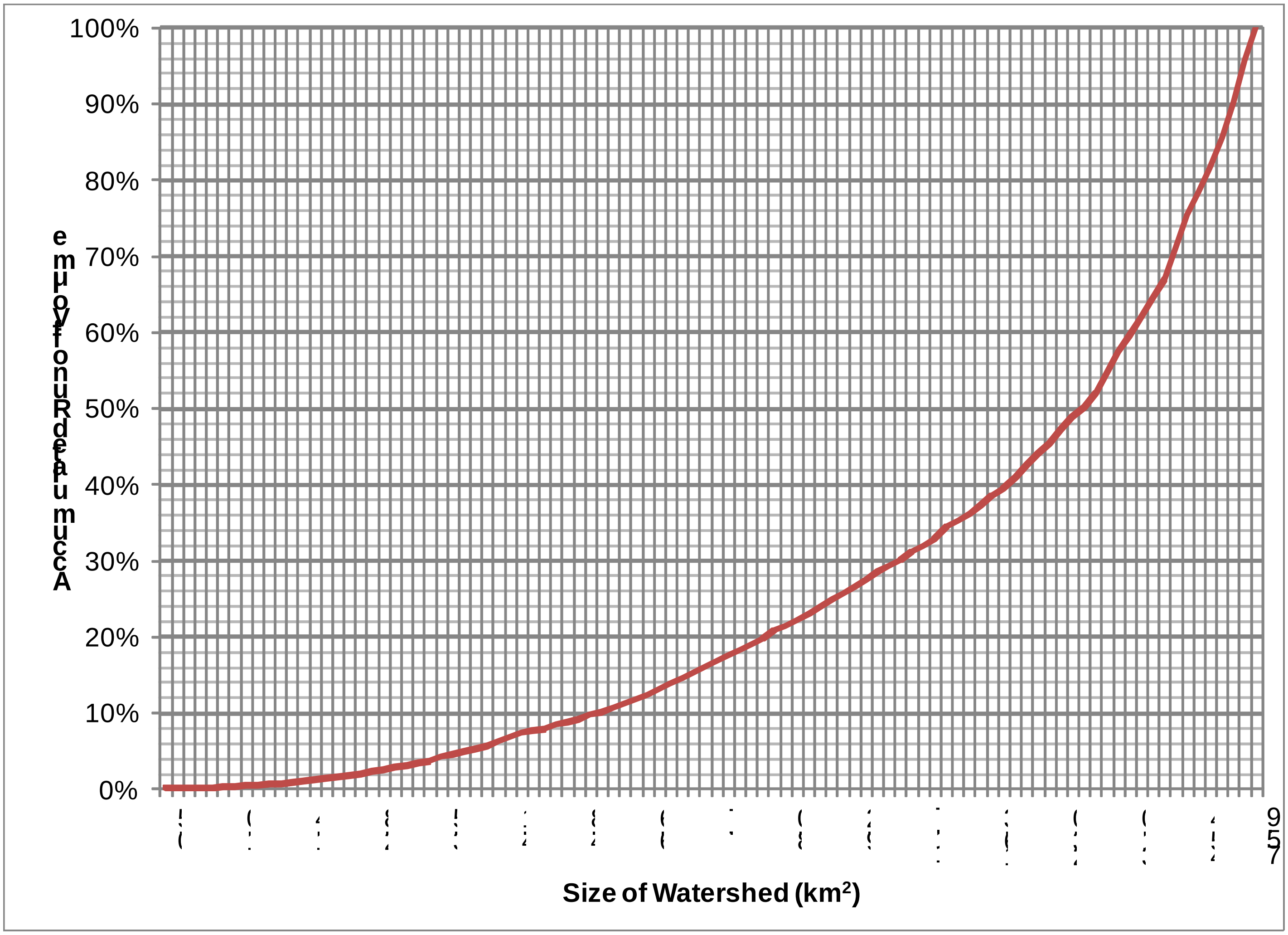

Figure 3. Total accumulated annual runoff volume for all of the watersheds in the analysis by watershed area.

<u>Methods for Improving Accuracy</u>

To improve the certainty and accuracy of the results of this dataset, one could:

a) Use updated land use data
b) Use more land use categories; requires defining accurate runoff coefficients for a wider variety of land use categories
c) Use an updated isohyet map. Rantz's 1971 isohyets may be outdated due to climate changes.
d) Use a more sophisticated method to estimate flow such as a flow simulation model such as HSPF or SWMM.

B. Total annual wet season runoff volume for the Water Years 1998 - 2007

Objective

The objective of this task is to calculate total annual wet season volumes for each of the last 10 years (Water years 1998-2007) for each urban watershed to provide a more realistic understanding of typical inter-annual variation in flow associated with reasonable climatic variation.

Methods

The methods of this analysis are similar to those in Task A, except that the annual rainfall depths are based on real data from the past ten years at precipitation gauging stations around the Bay Area. Rainfall has varied from 58% to 164% of the mean annual precipitation (MAP) (16.1 inches) in the last 10 years in San Jose, CA, from 57% to 182% of MAP (23.9 inches) in the last 10 years in Oakland, CA, and from 55% to 176% of MAP (21.1 inches) in the last 10 years at the San Francisco International Airport. This time period for analysis was chosen because in provided a balance between data availability, climatic variability and computational effort. Total annual wet season runoff volume for each urban watershed over the past ten years was calculated using the following equation:

$$V_i = P_i * \sum_{j=1}^{n} (C_j * A_j) \qquad \text{Equation (2)}$$

$\mathbf{V}_i$	=	Total annual wet season volume in year i
$\mathbf{P}_i$	=	Annual rainfall for the watershed in year i
C	=	Runoff coefficient for land use *j*
A	=	Area of land use *j* in the watershed

The total wet season rainfall depth used in the calculation for each watershed is based on real rainfall data from precipitation gauging stations throughout the Bay Area (Table 2, Figure 4).

Table 2: Precipitation Stations used in analysis.

MapID	County	Station Name	Reference/Website	Station ID
PS1	San Francisco	San Francisco Mission Dolore/Downtown	www.wrcc.dri.edu	47772
PS2	San Francisco	San Francisco Richmond/Oceanside	www.wrcc.dri.edu	47767
PS3	San Mateo	San Francisco WSO AP	www.wrcc.dri.edu	47769
PS4	San Mateo	Pacifica 4 SSE	www.wrcc.dri.edu	46599
PS5	San Mateo	Redwood City	www.wrcc.dri.edu	47339
PS6	San Mateo	Woodside Fire Stn 1	www.wrcc.dri.edu	49792
PS7	Santa Clara	Palo Alto	www.wrcc.dri.edu	46646
PS8	Santa Clara	Los Altos California	www.raws.dri.edu	43912
PS9	Santa Clara	Mountain View RF	SCVWD	121/1515
PS10	Santa Clara	San Jose	www.wrcc.dri.edu	47821
PS11	Santa Clara	Guadalupe Slough RF	SCVWD	16/2053
PS12	Santa Clara	Curtner Ranch RF	SCVWD	23/1514
PS13	Alameda	Newark	www.wrcc.dri.edu	46144
PS14	Alameda	Fremont50	ACPW	50dly

MapID	County	Station Name	Reference/Website	Station ID
PS15	Alameda	Lebanon St., Hayward	ACPW	541a-LB
PS16	Alameda	Mardie St., Hayward	ACPW	544G
PS17	Alameda	Upper San Leandro Fltr	www.wrcc.dri.edu	49185
PS18	Alameda	Oakland Museum	www.wrcc.dri.edu	46336
PS19	Alameda	Berkeley	www.wrcc.dri.edu	40693
PS20	Contra Costa	Richmond	www.wrcc.dri.edu	47414
PS21	Contra Costa	Martinez Water Plant	www.wrcc.dri.edu	45378

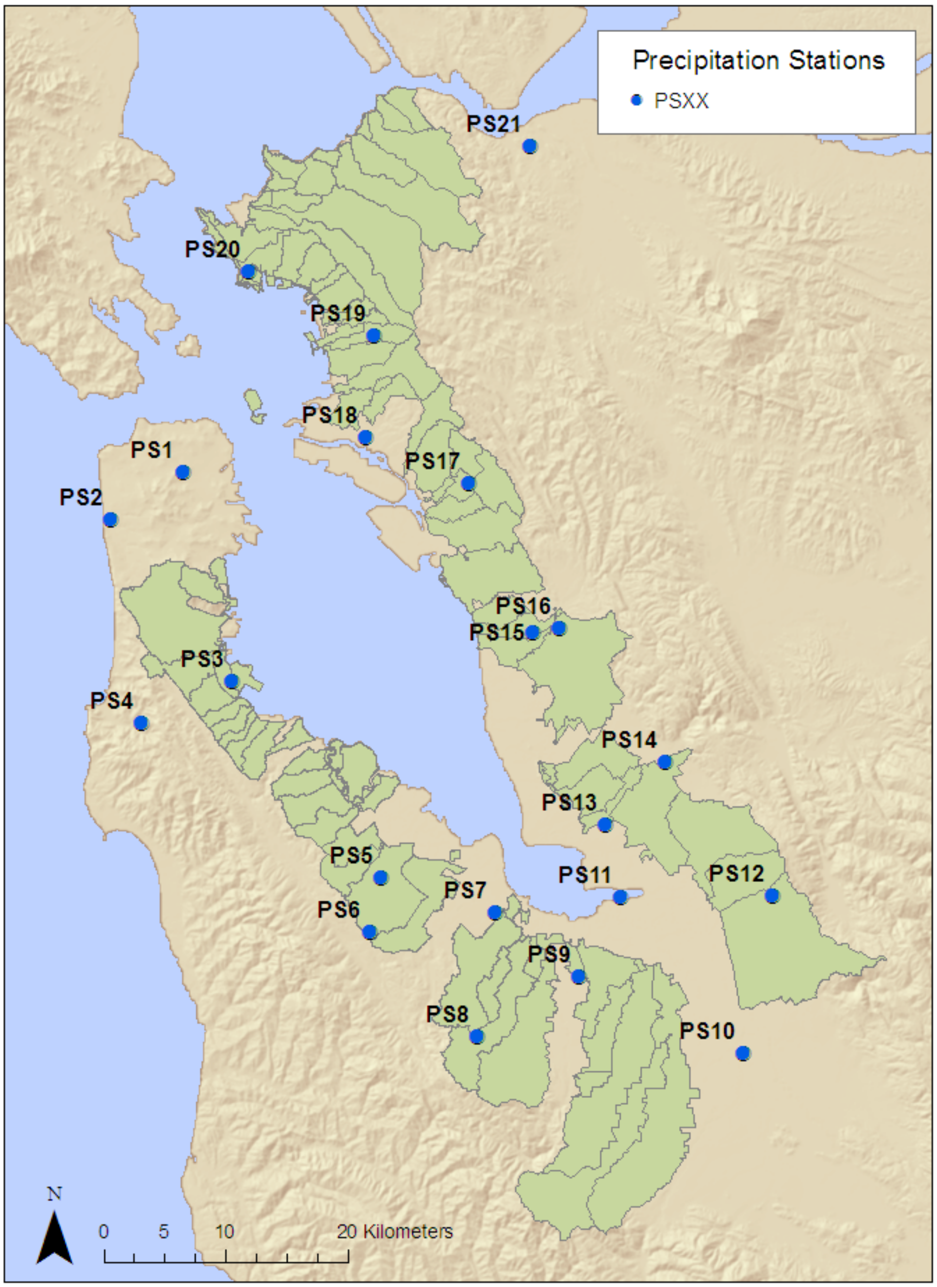

Figure 4: Map of precipitation stations used in analysis.

"Wet-season rainfall" for a given year is defined as rain falling between the dates of October 1 – April 30 (inclusive), where the given wet season year refers to the same calendar year as the January-April rainfall. Monthly totals were compiled for each of the gauging stations used to sum the wet-season total. Where records included flags for missing days, the record was corrected using the following equation from Dunne and Leopold (1978):

$$P_A = (1/X)\ [(N_A/N_B)*P_B + (N_A/N_C)*P_C + \ldots.] \qquad \text{Equation (3)}$$

$\mathbf{P_i}$	=	Precipitation for a given station
X	=	Number of stations
$\mathbf{N_i}$	=	Long-term normal precipitation for a given station
A,B,C..	=	Stations

If this equation yielded precipitation depths smaller than the original depth in the record, the original record was retained.[3]

The wet season precipitation depths for each watershed were calculated using data from the 2-3 closest precipitation stations[4] and weighting each station based on an inverse distance to the centroid of each watershed. The purpose and effect of using the inverse distance equation is to ensure precipitation data recorded from the closest observing station are weighted most strongly in the interpolation. The equation used in this analysis to derive the annual rainfall for each watershed is:

$$P_i = \sum_{g=1}^{n} r_{ig} w_g \qquad \text{Equation (4)}$$

$\mathbf{P_i}$	=	Annual rainfall for the watershed in year i
n	=	2-3 closest rain gauges to the centroid of each watershed
$\mathbf{r_{ig}}$	=	Annual rainfall depth at each of the 2-3 closest rain gauges
$\mathbf{w_g}$	=	Weight function assigned to each rain gauge

The classical form of the weight function is:

$$w_g = \frac{D_g^{-p}}{\sum_{g=1}^{n} D_g^{-p}} \qquad \text{Equation (5)}$$

$\mathbf{w_g}$	=	Weight function assigned to each rain gauge
$\mathbf{D_g}$	=	Distance from rain gauge to watershed centroid
p	=	Power parameter

[3] Take for example a case in which a monthly record indicated 1.7 inches of rainfall for a given station and flagged the month for having 3 days of missing information. Should Equation (3) yield a result of 1.65 inches, which is less than the original 1.7 inches despite 3 days of missing data, we recorded the monthly total as 1.7 inches.

[4] The 2 closest stations were used in all cases, and in instances where the third closest station was located within 15 km of the watershed's centroid, that third station was also considered in the inverse-distance weighted calculation for the watershed.

The power parameter, p, is an arbitrary positive real number. How strongly the closest station is weighted over the further stations can be manipulated depending on the power parameter used. The optimal power parameter may vary for each watershed, depending on rainfall characteristics and the distances of each of the precipitation stations from the watershed (Chang et al.). It was not feasible to determine the optimal value for each individual watershed, and therefore the inverse-distance weighted (IDW) interpolation in this analysis is calculated using the power parameter p=2 for all watersheds.

Results

Appendix A Table 4: Results of Analysis B

Results comparison to real data in monitored watershed:

SFEI has been monitoring rain and runoff at the Zone 4 Line A (Z4LA) watershed in Hayward; which is a 4.7 square kilometer subwatershed of the Zone 4 watershed analyzed in this memo. The WY 2007 rainfall for the Zone 4 watershed estimated in this analysis (331 mm) nearly matched with the Alameda County gage located in the slightly upper watershed of Zone 4 Line A (Alameda County 541A gage returned 330 mm for the wet weather season; the correlation was so strong because the Alameda County 541A gage was part of this analysis and was so heavily weighted due to its proximity to the watershed centroid). The real total runoff volume in the Zone 4 Line A watershed monitored by SFEI in WY 2007 was 527,000 cubic meters, about 51% of the volume estimated using our simple equation 1,028,380 cubic meters for the larger Zone 4 watershed. This result is a supportive quality assurance check on the method as the drainage area of Z4LA is approximately 54% of the larger Zone 4 watershed.

Methods for Improving Accuracy

To improve the certainty and accuracy of the results of this dataset, one could:

a) Use updated land use data.
b) Use less simplified land use categories; requires defining accurate runoff coefficients for a wider variety of land use categories
c) Use local flow data (where available) to improve land use coefficients in individual watersheds.
d) Increase the density of precipitation gauges used in the interpolation.
e) Alter runoff coefficients interannually based on deviation from an average wet season. This should be an improvement over fixed runoff coefficients not accounting for soil saturation.

C. First flood runoff volume each year for the Water Years 1998 – 2007

<u>Objective</u>
The objective of this task is to calculate the first flood runoff volume for each urban watershed for the Water Years 1998 - 2007. Real rainfall data is used in this analysis.

<u>Methods</u>
The methods of this analysis are similar to those in Task B except that rainfall depths are used for only the first flood of each wet season. The total first flood runoff volume for each urban watershed is calculated using the following equation:

$$V_{fi} = P_{fi} * \sum_{j=1}^{n} (C_j * A_j) \qquad \text{Equation (6)}$$

$\mathbf{V}_{fi}$	=	First flood runoff volume in year i
$\mathbf{P}_{fi}$	=	First flood rainfall for the watershed in year i
C	=	Runoff coefficient for land use *j*
A	=	Area of land use *j* in the watershed

The first flood precipitation depth used in the calculation for each watershed is based on real daily rainfall data from precipitation gauging stations throughout the Bay Area. It would have been ideal to use 5-minute or 15-minute data but that resolution was only available for a few gauges. Such data would allow identification of individual rain bands since a single storm can consist of multiple rain bands passing over the region within a single 24 hour period or if a storm system is slow moving rain can occur over multiple days, As a result, rainfall depths derived from this data are coarse but suitable for making first order estimates for the purpose of comparing total storm volume among watersheds or to wastewater treatment capacity. The precipitation gauging stations and reference information for each station for this analysis are the same as used in Task B (Table 2). The "first flood" of each season is defined as the first storm in which the large majority (> 75%) of gauges in the sample hit greater than or equal to 0.2 inches/day. In cases where the storm spanned more than one day, the first daily precipitation depth greater than or equal to 0.2 inches was used, or the largest rainfall depth in the storm sequence was used if no rainfall depths were greater than or equal to 0.2 inches. In some cases, this method overlooks the first storms of the season localized in smaller areas that may have exceeded 0.2 inches/day at some gauges. We accept these inaccuracies because the overall objective is to calculate first-order estimates of runoff associated with first floods, and because we have 10 years of data to draw on, thus some inaccuracy in individual years is acceptable.

The first flood precipitation depths for each watershed were calculated using data from the 2-3 closest precipitation stations and weighting each precipitation guage depth based on an inverse distance to the centroid of each watershed[5]. As stated in Task B, the purpose and effect of using the inverse distance equation is so that depths from the closest precipitation station are weighted most strongly in the interpolation. The equation used in this analysis to derive the first flood rainfall is:

[5] As in Task B, the 2 closest stations were used in all cases, and in instances where the third closest station was located within 15 km of the watershed's centroid, that third station was also considered in the inverse-distance weighted calculation for the watershed.

$$P_{fi} = \sum_{g=1}^{n} r_{fig} w_g \qquad \text{Equation (7)}$$

$\mathbf{P}_{fi}$	=	First flood rainfall for the watershed in year i
n	=	2-3 closest rain gauges to the centroid of each watershed
$\mathbf{r}_{fig}$	=	First flood rainfall depth at each of the 2-3 closest rain gauges
$\mathbf{w}_g$	=	Weight function assigned to each rain gauge

The classical form of the weight function is used and is the same as in Task B (see Equation 5, pg 13). For ease of calculation, as in Task B, the IDW interpolation in this analysis is calculated using the power parameter p=2 for all watersheds.

Results

Appendix A Table 5: Results of Analysis C

Methods for Improving Accuracy

To improve the certainty and accuracy of the results of this dataset, one could:

a) Use updated land use data.
b) Use less simplified land use categories; requires defining accurate runoff coefficients for a wider variety of land use categories
c) Use local flow data (where available) to improve land use coefficients in individual watersheds.
d) Increase the density of precipitation gauges used in the interpolation.
e) Use 15-minute time-step precipitation data, if it can be located for enough rain gauges.
f) Perform the same inverse-distance weighted calculations for more first flood precipitation events each year and then use the earliest dated interpolated depth for each watershed that is greater than 0.25 inches of rain. This would better capture the localized first flood events.

D. Largest flood runoff volume each year for the last 10 years

Objective

The objective of this task is to calculate the largest flood runoff volume for each urban watershed for each of the last ten years. Real rainfall data is used in this analysis.

Methods

The methods of this analysis are virtually identical to Task C except that the rainfall data used is for the largest one-day Bay Area-wide precipitation event of each year for the last ten years. The total largest flood runoff volume for each urban watershed is calculated using the following equation:

$$V_{li} = P_{li} * \sum_{j=1}^{n} (C_j * A_j) \qquad \text{Equation (8)}$$

$\mathbf{V}_{li}$	=	Largest one-day flood runoff volume in year i
$\mathbf{P}_{li}$	=	Largest flood rainfall for the watershed in year i
C	=	Runoff coefficient for land use *j*
A	=	Area of land use *j* in the watershed

The largest flood precipitation depth used in the calculation for each watershed is based on real daily rainfall data from precipitation gauging stations throughout the Bay Area. Only total daily precipitation depths were available regionally, so total daily depths are used; depths of storms that span multiple days are not represented in this analysis. Table 2 presented earlier lists the precipitation gauging stations and reference information for each station. The "largest flood" precipitation event of each season was determined by identifying the largest annual event to occur at all of the following stations: Richmond, Hayward 544, San Jose, and San Francisco Mission Dolore/Downtown. When it was unclear which storm represented the largest Bay-Area wide event by looking at only those four gage stations, precipitation depths from other stations were also considered to determine the largest event. In cases where the storm spanned more than one day, the larger daily precipitation depth was used. In some cases, this method overlooks larger storms localized in smaller areas.

The largest flood precipitation depths for each watershed were calculated using data from the 2-3 closest precipitation stations and weighting each precipitation guage depth based on an inverse distance to the centroid of each watershed[6]. The equation used in this analysis to derive the first flood rainfall is:

[6] As in Tasks B and C, the 2 closest stations were used in all cases, and in instances where the third closest station was located within 15 km of the watershed's centroid, that third station was also considered in the inverse-distance weighted calculation for the watershed.

$$P_{li} = \sum_{g=1}^{n} r_{lig} w_g \qquad \text{Equation (9)}$$

$\mathbf{P}_{li}$	=	Largest flood rainfall for the watershed in year i
n	=	2-3 closest rain gauges to the centroid of each watershed
$\mathbf{r}_{lig}$	=	Largest flood rainfall depth at each of the 2-3 closest rain gauges
$\mathbf{w}_g$	=	Weight function assigned to each rain gauge

The classical form of the weight function is used and is the same as in Task B (see Equation 5, pg 13). As in previous tasks, the IDW interpolation in this analysis is calculated using the power parameter p=2 for all watersheds.

Results

Appendix A Table 6: Results of Analysis D

Methods for Improving Accuracy

To improve the certainty and accuracy of the results of this dataset, one could:

a) Use updated land use data.
b) Use less simplified land use categories; requires defining accurate runoff coefficients for a wider variety of land use categories
c) Use local flow data (where available) to improve land use coefficients in individual watersheds.
d) Increase the density of precipitation gauges used in the interpolation.
e) Use 15-minute time-step precipitation data, if it can be located for enough rain gauges.
f) Perform the same inverse-distance weighted calculations for more large precipitation events each year and then use the largest interpolated depth for each watershed. This would better capture the large, but localized, events.

E. Total annual average dry season runoff volume

Objective

The objective of this task is to calculate a total annual average dry season volume for each urban watershed using available dry-flow data from local pump stations in comparison to information from literature.

Methods

Data pertaining to dry flow discharge rates was requested from pump station operators around the Bay Area. Some pump stations maintain records of their pumping via an hour-meter log, which records the amount of time each pump meter is running, or a more advanced Supervisory and Control Data Acquisition (SCADA) system. As a result, some pump stations could provide information about dry flow discharges, although the quality of this data is uncertain because we received only information about the discharge rate during the dry period[7], rather than the actual raw data. Discharge rates were generally reported as monthly averages, or estimated monthly averages. Using the records from the pump stations that could supply this data (n=44; see Table 3 and Figure 5), we calculated total dry season volumes (multiplying the monthly average provided by the pump station operator by five to represent the five months defined as the dry season, May 1 – September 30) for the pump station watersheds and normalized the volumes based on drainage area[8]. We also divided the total dry flow by 153 (153 days between May 1 – September 30) to find an average daily flow for each pump station. The Ettie Street Pump Station in Oakland supplied the complete flow record from May 5, 2005 through September 30, 2008. Dry flow data reported in literature from two Los Angeles County watersheds is also presented for comparison.

Results

Operators of 44 pump stations around the Bay Area reported monthly average dry-weather pumping totals (Table 3). Total dry weather flow volume estimates ranged extensively from 0.1 to 1042.5 million liters per square kilometer. The most extensive dataset that informs these results are for the Ettie St. Pump Station, which averaged 86.7 10^6L/km^2. Estimates from two urban Los Angeles County watersheds were calculated at 12 and 13 x 10^6L/km^2 based on empirical flow data collected in storm drains, while the authors of that paper also use a scaling factor of 27.5 10^6L/km^2 (180 m^3/km^{2}day) to estimate dry-flow runoff in the Ballona Creek watershed.

Table 3. Dry weather flow for selected pump stations in the Bay Area.

Map ID	Pump Station/Watershed	Location	Method of Flow Calculation	Drainage Area (km^2)	Dominant Land Use	Avg. Total Pumped (10^6gallons/ day)	Normalized Avg. Total Pumped/May -Sept (10^6L/km^2) (equivalent to mm of runoff)
1	42nd Ave Storm	San Mateo	?	0.6880	Res/Comm	0.0001	0.1
2	South Airport Blvd.	South San Francisco	Hour Meter/Logs	0.0235	Commercial	0.00001	0.2
3	JPS	Fairfield	Estimate from SCADA	0.1578	Residential	0.0001	0.3

[7] We requested the discharge rate in gallons per month (see Appendix B for pump station metadata).
[8] The drainage area for each pump station was that reported by the pump station operator. Data quality unknown.

Map ID	Pump Station/Watershed	Location	Method of Flow Calculation	Drainage Area (km^2)	Dominant Land Use	Avg. Total Pumped (10^6gallons/ day)	Normalized Avg. Total Pumped/May -Sept ($10^6L/km^2$) (equivalent to mm of runoff)
4	SSPS	Fairfield	Estimate from SCADA	0.0243	Commercial	0.0001	1.2
5	Linda Mar	City of Pacifica	Estimated by pump station operator	0.6479	Residential	0.0014	1.3
6	Shaw Road	South San Francisco	Hour Meter/Logs	0.0336	Commercial	0.0001	1.8
7	Anza	City of Pacifica	Estimated by pump station operator.	0.6497	Res/Open	0.0020	1.8
8	Hillsdale	San Mateo	?	0.2954	Commercial	0.0011	2.2
9	Casanova	San Mateo	?	0.6880	Residential	0.0033	2.8
10	San Mateo Ave.	South San Francisco	Hour Meter/Logs	0.0911	Commercial	0.0006	3.9
11	South Maple	South San Francisco	Hour Meter/Logs	0.0223	Commercial	0.0002	4.0
12	South Canal	South San Francisco	Hour Meter/Logs	0.0413	Commercial	0.0004	5.6
13	New Poplar	San Mateo	?	3.3994	Res/Comm	0.0363	6.2
14	Coyote Point	San Mateo	?	0.7082	Res/Comm	0.0098	8.0
15	AM	Hayward	Hour Meter/Logs	3.1282	Industrial	0.0463	8.6
16	ABPS	Fairfield	Estimate from SCADA	0.0283	Underpass	0.0005	10.0
17	3rd/Detroit	San Mateo	?	0.9712	Res/Comm	0.0196	11.7
18	MPS	Suisun City	Estimate from SCADA	0.7932	Residential	0.0176	12.9
19	KPS	Suisun City	Estimate from SCADA	0.3602	Res/Comm	0.0084	13.5
20	Pulgas	City of San Carlos	?	0.0822	Commercial	0.0029	20.7
21	Marina Lagoon	San Mateo	?	23.3099	Mixed	0.8824	21.9
22	Granite Rock	South San Francisco	Hour Meter/Logs	0.0599	Commercial	0.0035	34.3
23	CHPS	Suisun City	Estimate from SCADA	0.3845	Residential	0.0261	39.4
24	RU	Hayward	Hour Meter/Logs	0.3116	Residential	0.0226	42.1
25	Airport Blvd. South/Bound	South San Francisco	Hour Meter/Logs	0.0010	Commercial	0.0001	43.4
26	BS	Hayward	Hour Meter/Logs	1.3031	Industrial	0.1112	49.4
27	South Linden	South San Francisco	Hour Meter/Logs	0.0053	Commercial	0.0005	59.7
28	H	San Leandro	Hour Meter/Logs	0.3683	Residential	0.0412	64.8
29	Richmond Pkwy @ Gertrude Ave.	Contra Costa County	Based on 8 minute pump time average per day.	2.6952	Residential	1.0663	77.7
30	BV	San Leandro	Hour Meter/Logs	0.8863	Residential	0.3615	78.0
31	ET	Oakland	Hour Meter/Logs	8.0937	Res/Indust	0.1194	76.3

Map ID	Pump Station/Watershed	Location	Method of Flow Calculation	Drainage Area (km^2)	Dominant Land Use	Avg. Total Pumped (10^6gallons/ day)	Normalized Avg. Total Pumped/May -Sept (10^6L/km^2) (equivalent to mm of runoff)
32	Airport Blvd. North/Bound	South San Francisco	Hour Meter/Logs	0.0010	Commercial	0.0002	93.1
33	MC	Oakland	Hour Meter/Logs	0.0162	Residential	0.0027	98.2
34	D-1	San Leandro	Hour Meter/Logs	0.6920	Industrial	0.1194	99.9
35	AL	Union City	Hour Meter/Logs	2.9340	Residential	0.5456	107.7
36	F	San Leandro	Hour Meter/Logs	0.9672	Residential	0.1863	111.5
37	MSPS	Suisun City	Estimate from SCADA	0.1416	Res/Comm	0.0333	136.3
38	J-3	Union City	Hour Meter/Logs	1.3881	Residential	0.3833	159.9
39	EL	Hayward	Hour Meter/Logs	1.2383	Industrial	0.5400	252.6
40	J-2	Union City	Hour Meter/Logs	1.4973	Residential	0.8471	327.6
41	Foster City Lagoon	Foster City	?	0.8579	Res/Comm	0.4902	330.9
42	ID	Hayward	Hour Meter/Logs	3.4277	Industrial	2.6098	441.0
43	WV	Union City	Hour Meter/Logs	0.3399	Residential	0.3235	551.2
44	SD4	Livermore	?	0.0364	Underpass	0.0656	1042.5
*	Ballona	Los Angeles County	24 drains sampled in 2002-03 (Stein and Ackerman, 2007)	338.00	Residential	6.8473	11.7
*	Walnut	Los Angeles County	83 drains sampled in 2003 (Stein and Ackerman, 2007)	205.00	Res/Open	4.5649	12.9

* Watersheds in Southern California. Data reported in: Stein, Eric D., and Drew Ackerman, 2007. Dry Weather Water Quality Loadings in Arid, Urban Watersheds of the Los Angeles Basin, California, USA. Journal of the American Water Resources Association (JAWRA) 43(2): 398-413. DOI: 10.1111/j.1752-1688.2007.00

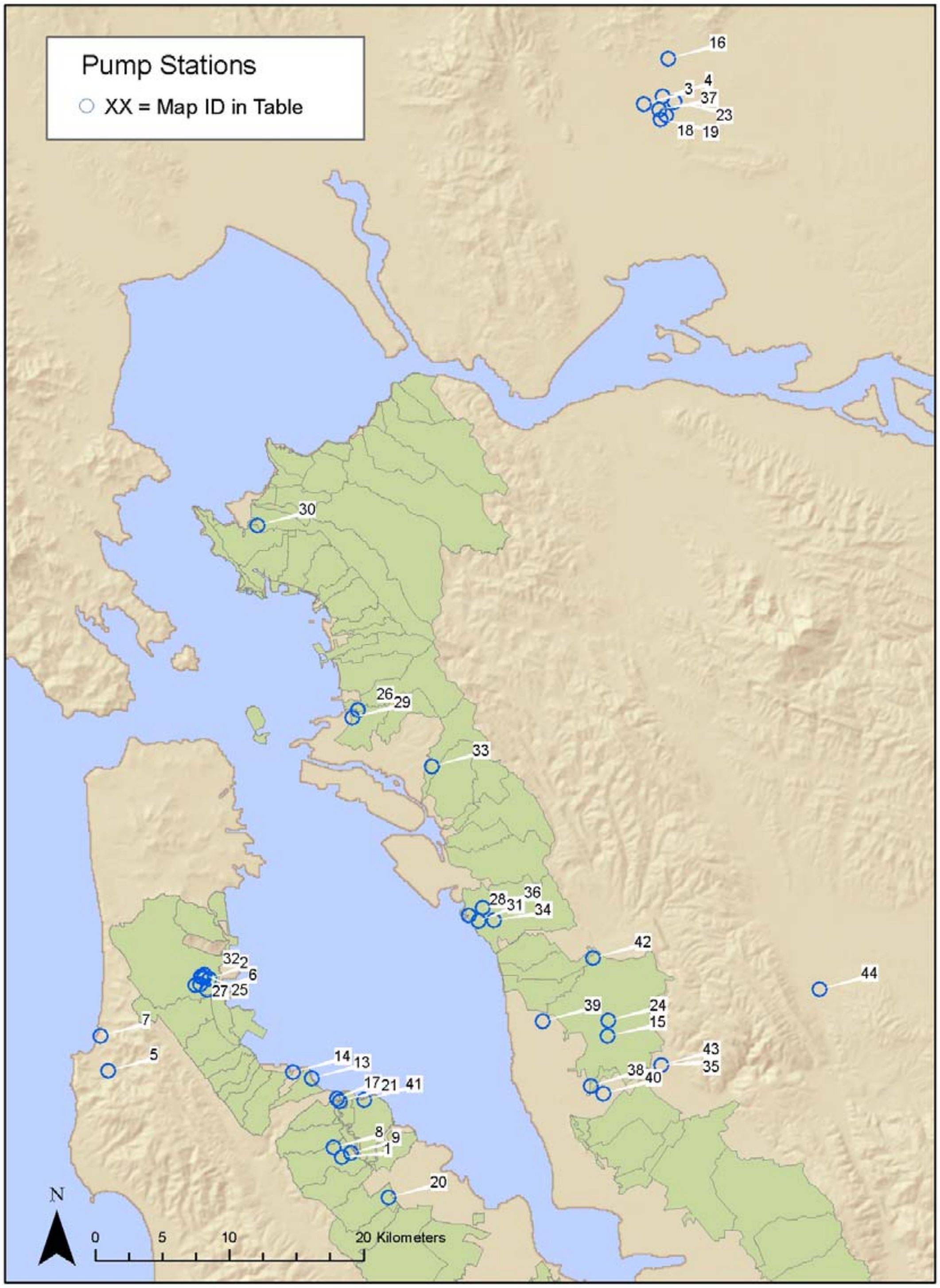

Figure 5: Pump stations with dry flow information; number in map refers to Map ID number in Table 4.

F. Total annual dry season runoff volume for the last ten years

Objective

The objective of this task is to calculate the total annual dry season volumes for each urban watershed using available dry-flow data from local pump stations.

Methods

Data pertaining to dry flow discharge rates was requested from pump station operators around the Bay Area. Discharge rates were generally reported as averages, or estimated averages, and not suitable for calculating dry season volumes for individual years. The Ettie Street Pump Station in Oakland supplied the complete flow record from May 5, 2005 through September 30, 2008. Using this data, we calculated the total dry season runoff (May 1 - September 30) volume for the Ettie Street Pump Station watershed for four dry seasons (the beginning of May 2005 was estimated based on the record from May 11-31 of the same year) and three wet seasons (October 1 - April 30). We also calculated the wet- and dry-weather runoff volumes for the same years, defining "wet-weather flow" as flow during and within 14 days after any rain event greater than or equal to 0.1 inches at the Oakland Museum rain gauge and "dry-weather flow" as flow not within 14 days after any rain event greater than or equal to 0.1 inches at the Oakland Museum rain gauge.

Results

The total volume pumped at the Ettie Street Pump Station during the dry seasons with available flow data ranged from 96 million gallons to 225 million gallons, varying by up to 129 million gallons in this short time series. These volumes equate to an average of 0.6 – 1.5 million gallons per day. The 2006, 2007, and 2008 dry seasons from May 1st to September 30th accounted for 7-14% of the total annual flow through the station.

Table 4. Wet and Dry Season Flows

Ettie St. Pump Station	Total Gallons Pumped Oct. 1 - April 30th	Total Gallons Pumped May 1 - Sept. 30th	Wet Season Flow/Total Flow (%)	Dry Season Flow/Total Flow (%)
2005		225,011,400		
2005-06	2,047,597,200	186,986,400	92%	8%
2006-07	875,001,600	144,178,800	86%	14%
2007-08	1,190,716,800	96,212,400	93%	7%

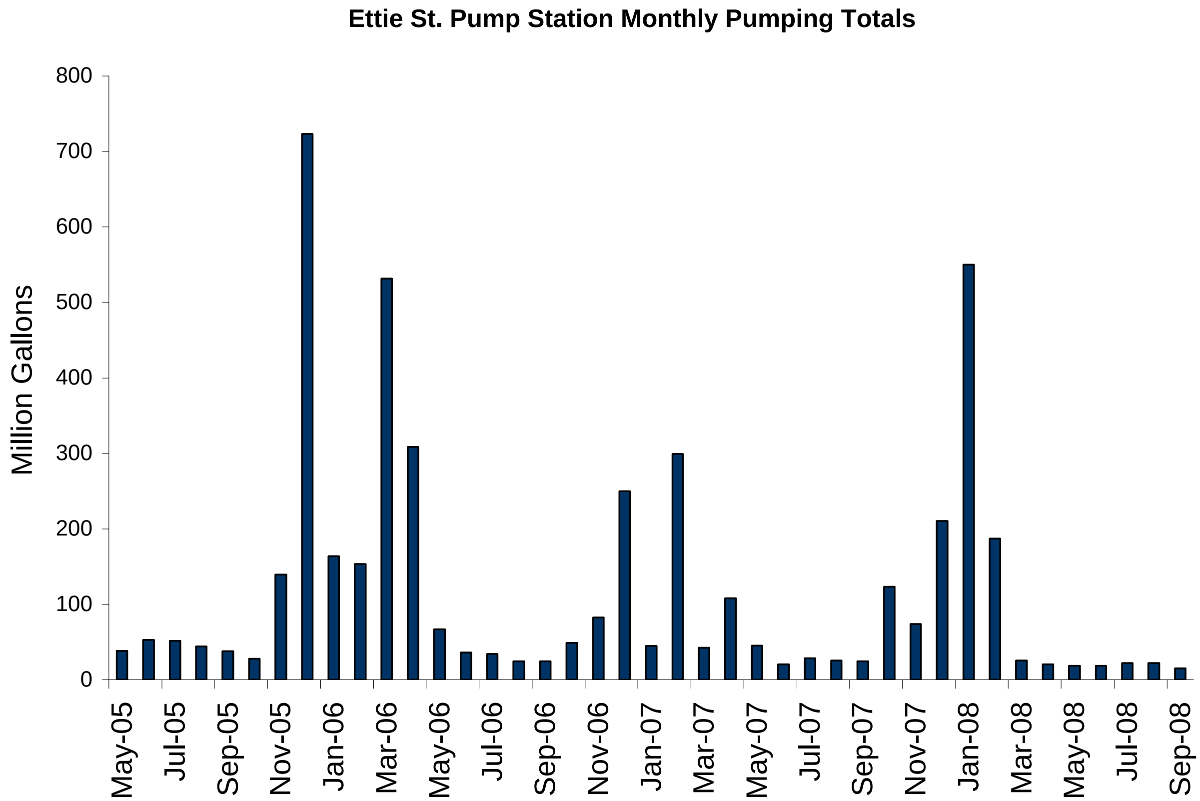

Figure 6. Monthly pumping totals at the Ettie Street Pump Station, May 2005-September 2008.

<u>Methods for Improving Accuracy</u>

This analysis would be greatly improved with a longer flow record, and it would be helpful to compare the Ettie St. results to other pump stations around the Bay Area. Such a comparison would improve our understanding of dry-flow volumes in the Bay Area, particularly in urban watersheds where relatively little information currently exists.

REFERENCES

Association of Bay Area Governments, 2002. Existing Land Use in 2000: Data for Bay Area Counties. GIS file and report.

BASMAA, 1996. San Francisco Bay Area Stormwater Runoff Monitoring Data Analysis 1988 - 1995. Bay Area Stormwater Management Agencies Association; prepared by URS Greiner Woodward-Clyde.

BCDC. 1991. The effects of land use change and intensification on the San Francisco Estuary. Prepared for the San Francisco Estuary Project, EPA Region IX. 186 pp.

California Regional Water Quality Control Board (CRWQCB) San Francisco Bay Region, October 2009. Municipal Regional Stormwater NPDES Permit. Order R2-2009-0074. NPDES Permit No. CAS612008. Available on the web at:
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/mrp.shtml

Chang, C.-L., Lo, S.-L., and Yu, S.-L. 2006. The Parameter Optimization in the Inverse Distance Method by Genetic Algorithm for Estimating Precipitation. Environmental Monitoring and Assessment. Vol. 117, pp 145-155.

Davis, J.A., Leatherbarrow, J.E., and Daum, T.H. 2000. Contaminant Loads from Stormwater to Coastal Waters in the San Francisco Bay Region: Comparison to other Pathways and Recommended Approach for Future Evaluation. San Francisco Estuary Institute, September 2000.

Givler, R. W., Sowers, J.M., and Vorster, P. 2005, Creek & Watershed Map of Western Santa Clara Valley: Oakland Museum of California, 1:25,800 scale. (Map #8)

Givler, R. W., Sowers, J.M., and Vorster, P. 2007, Creek & Watershed Map of Daly City & Vicinity: Oakland Museum of California, 1:25,800 scale. (Map #11)

Hetzel, 2007

Looker and Johnson, 2004

NOAA. 1987. National coastal pollutant discharge inventory: urban runoff methods document with west coast addendum. Strategic Assessments Branch, Ocean Assessments Division, National Oceanic and Atmospheric Administration, Rockville, MD. 20852.

Ramirez-Herrera, M.T., Sowers, J. M., Richard, C. M., and Grossinger, R.M., 2007, Creek & Watershed Map of San Francisco: Oakland Museum of California, 1:25,800 scale. (Map #12)

Rantz, S.E., 1971, Mean annual precipitation and depth-duration frequency data for the San Francisco Bay region, California: U.S. Geological Survey Open-File Report, 23 p.

Sowers, J. M., 1993, revised 1995 and 2000, Creek and watershed map of Oakland & Berkeley: Oakland Museum of California, Oakland, CA, scale = 1:26,000. (Map #1)

Sowers, J. M., 1997, Creek and watershed map of Hayward and San Leandro: Oakland Museum of California, Oakland, CA, scale = 1:26,000. (Map #2)

Sowers, J. M., 1999, Creek and watershed map of Fremont & Vicinity: Oakland Museum of California, Oakland, CA, scale = 1:26,000. (Map #3)

Sowers, J. M., 2004, Creek & Watershed Map of Palo Alto & Vicinity: Oakland Museum of California, 1:25,800 scale. (Map # 9)

Sowers, J. M., 2006, Creek & Watershed Map of Richmond & Vicinity: Oakland Museum of California, 1:25,800 scale. (Map #14)

Sowers, J. M., and Givler, R. W., 2006, Creek & Watershed Map of South San Jose: Oakland Museum of California, 1:25,800 scale. (Map #15)

Sowers, J. M., and Henkle, J., 2008 (expected), Creek & Watershed Map of Morgan Hill & Gilroy: Oakland Museum of California, 1:25,800 scale. (Map #16)

Sowers, J. M., and Richard, C.R.., 2003, Creek & Watershed Map of the Pleasanton & Dublin Area: Oakland Museum of California, 1:25,800 scale. (Map #4)

Sowers, J. M., and Thompson, S. C., 2005, Creek & Watershed Map of Northern San Jose & Milpitas: Oakland Museum of California, 1:25,800 scale. (Map #6)

Thompson, S. C., and Sowers, J. M., 2005, Creek & Watershed Map of Central San Jose: Oakland Museum of California, 1:25,800 scale. (Map #7)

Tillery, A., Sowers, J. M., and Pearce, S., 2007, Creek & Watershed Map of San Mateo & Vicinity: Oakland Museum of California, 1:25,800 scale. (Map #10)

Wong, K, E. Strecker and M. Stenstrom. 1997. GIS to estimate storm-water pollutant mass loadings. Journal of Environmental Engineering. August, 1997.

APPENDIX A

TABLE 1. Land use classifications used by ABAG (2002) and their assigned categories for this report (categorization scheme generally follows from Davis et al., 2000; deviations from Davis et al. are noted by an asterisk and comment).

General Land Use	Land Use Identification Code Number	Land Use Description	Comment
Agricultural	21	Cropland and Pasture	
Agricultural	211	Cropland	
Agricultural	2111	Row Crops	
Agricultural	2112	Small Grains	
Agricultural	212	Pasture	
Agricultural	22	Orchards, Groves, Vineyards, Nurseries and Ornamental Horticulture Areas	
Agricultural	221	Orchards or Groves	
Agricultural	222	Vineyards and Kiwi Fruit	
Agricultural	223	Greenhouses and Floriculture	
Agricultural	23	Confined Feeding	
Agricultural	24	Farmsteads and Agricultural Buildings	
Commercial	12	Commercial and Services	
Commercial	121	Retail and Wholesale	
Commercial	1221	RV Parks (currently not used)	*new subcategory, not in Davis et al. 2000
Commercial	122	Commercial Outdoor Recreation	
Commercial	123	Education	
Commercial	1231	Elementary and Secondary Schools	
Commercial	1232	Colleges and Universities	
Commercial	1233	Stadiums	
Commercial	1234	University Housing	
Commercial	124	Hospitals, Rehabilitation Health and State Prison Facilities	
Commercial	1241	Hospital Trauma Centers	
Commercial	1242	Community Hospitals	
Commercial	1243	Medical Long-Term Care Facilities	
Commercial	1244	Medical Clinics	
Commercial	1246	Out-Patient Surgery Centers	
Commercial	1247	State Prisons	
Commercial	1248	State Mental Health and Developmentally Disabled Facilities	
Commercial	1249	State Psychiatric Facilities	
Commercial	125	Military Installations	
Commercial	1252	Military Commercial/Services	
Commercial	1253	General Military Use	
Commercial	1254	Military Hospital	
Commercial	1256	Military Airport	
Commercial	1258	Military Port	
Commercial	1259	Closed Military Facilities	*new subcategory, not in Davis et al. 2000
Commercial	126	Local Government and Other Public Facilities	

TABLE 1 (cont.). Land use classifications used by ABAG (2002) and their assigned categories for this report.

General Land Use	Land Use Identification Code Number	Land Use Description	Comment
Commercial	1261	Stadium (when not associated with a college or university)	
Commercial	1262	Churches, Synagogues and Mosques	
Commercial	1263	Fire Station	
Commercial	1264	Police Station	
Commercial	1265	City Halls, and County, State or Federal Government Centers	
Commercial	1266	Government Emergency Operations Center (EOC)	
Commercial	1267	Local Jails or Rehabilitation Centers	
Commercial	1268	Convention Centers	
Commercial	1269	Museums and Libraries	
Commercial	127	Research Centers	
Commercial	128	Offices	
Commercial	129	Hotels and Motels	
Commercial	146	Municipal Wastewater Facilities	
Commercial	1461	Wastewater Treatment Plant	
Commercial	1462	Wastewater Pumping Station	
Commercial	1463	Wastewater Storage	
Commercial	147	Municipal Water Supply Facilities	
Commercial	1471	Water Treatment (Filtration) Plant	
Commercial	1472	Water Pumping Station	
Commercial	1473	Water Storage (covered)	
Commercial	1474	Water Storage (open)	
Commercial	148	Communication Facilities	
Commercial	1481	Communications, Network Tower	
Commercial	1482	Communications, Tower	
Commercial	1483	Media Broadcast Tower and Communications Facilities	
Commercial	16	Mixed Residential and Commercial Use	
Commercial	161	Transitional (mixed use of land areas)	
Commercial	162	Mixed Use In Buildings	
Industrial	13	Industrial	
Industrial	131	Heavy Industry	
Industrial	132	Light Industry	
Industrial	133	Metal Salvage or Recycling	
Industrial	134	Food Processing	*new subcategory, not in Davis et al. 2000
Industrial	135	Warehousing	*new subcategory, not in Davis et al. 2000
Industrial	14	Transportation, Communication and Utilities	
Industrial	141	Road Transportation Facilities	
Industrial	1411	Highways and Interchanges	
Industrial	1412	Bus Transit Centers	
Industrial	1413	Park and Ride Lots	
Industrial	1414	Truck or Bus Maintenance Yard	

TABLE 1 (cont.). Land use classifications used by ABAG (2002) and their assigned categories for this report.

General Land Use	Land Use Identification Code Number	Land Use Description	Comment
Industrial	1415	City, County or Utilities Corporation Yard	
Industrial	1416	Parking Garages	*new subcategory, not in Davis et al. 2000
Industrial	1417	Inspection and Weighing Stations	*new subcategory, not in Davis et al. 2000
Industrial	1418	Local Streets and Roads	*new subcategory, not in Davis et al. 2000
Industrial	142	Rail Transportation Facilities	
Industrial	1421	Rail Passenger Stations	
Industrial	1422	Rail Yards	
Industrial	143	Airports	
Industrial	1431	Commercial Airport Passenger Terminal	
Industrial	1432	Commercial Airport Air Cargo Facility	
Industrial	1433	Commercial Airport Airline Maintenance	
Industrial	1434	Commercial Airport Runway	
Industrial	1435	Commercial Airport Utilities	
Industrial	1436	Commercial Airport - Other	
Industrial	1437	General Aviation (Public) Airfield	
Industrial	1438	Private Airfield	
Industrial	144	Marine Transportation Facilities	
Industrial	1441	Commercial Port Passenger Terminal	
Industrial	1442	Commercial Port Container Terminal	
Industrial	1443	Commercial Port Oil and Liquid Bulk Terminal	
Industrial	1444	Commercial Port - Other Terminal and Ship Repair	
Industrial	1445	Commercial Port Storage Facility or Warehouse	
Industrial	1446	Tow Boat Facility	
Industrial	1447	Ferry Terminal	
Industrial	1448	Marina	
Industrial	145	Power Facilities	
Industrial	1451	Electricity, Power Plant	
Industrial	1452	Electricity, Substation	
Industrial	1453	Electricity, Other	
Industrial	15	Mixed Commercial and Industrial Complexes	
Industrial	75	Strip Mines, Quarries and Gravel Pits	
Industrial	751	Strip Mines or Quarries are the Principal Uses	*new subcategory, not in Davis et al. 2000
Industrial	752	Earth Works Not Associated with a Commercial Operation	*new subcategory, not in Davis et al. 2000
Industrial	761	Sanitary Land Fills	
Open	1255	Military Communications	*from Commercial based on footnote suggestion on pg. 9, ABAG 2002

TABLE 1 (cont.). Land use classifications used by ABAG (2002) and their assigned categories for this report.

General Land Use	Land Use Identification Code Number	Land Use Description	Comment
Open	1257	Military Open Areas	*from Commercial based on footnote suggestion on pg. 9, ABAG 2002
Open	17	Other Urban and Built-Up Land	*from Residential - moved because this broader category was represented in "Open" classification for all of it's subcategories
Open	171	Extensive Recreation	
Open	1711	Golf Courses	
Open	1712	Racetracks	
Open	1713	Camps and Campgrounds	
Open	172	Cemeteries	
Open	173	Urban Parks	
Open	174	Open Space--Urban	
Open	175	Urban Vacant Undeveloped Land	*from Residential - moved because land is currently undeveloped
Open	1751	Vacant Residential	*new subcategory, not in Davis et al. 2000
Open	1752	Vacant Commerical or services	*new subcategory, not in Davis et al. 2000
Open	1753	Vacant Industrial	*new subcategory, not in Davis et al. 2000
Open	1754	Vacant Infrastructure	*new subcategory, not in Davis et al. 2000
Open	31	Herbaceous Rangeland	
Open	311	Herbaceous Rangeland - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	32	Shrub and Brush Rangeland	
Open	321	Shrub and Brush Rangeland - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	33	Mixed Rangeland	
Open	331	Mixed Rangeland - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	41	Deciduous Forest	
Open	411	Deciduous Forest - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	42	Evergreen Forest	
Open	421	Evergreen Forest - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	43	Mixed Forest	
Open	431	Mixed Forest - Protected as Parkland	*new subcategory, not in Davis et al. 2000
Open	61	Forested Wetlands	

TABLE 1 (cont.). Land use classifications used by ABAG (2002) and their assigned categories for this report.

General Land Use	Land Use Identification Code Number	Land Use Description	Comment
Open	62	Nonforested Wetlands	
Open	63	Salt Evaporation Ponds	
Open	64	Land on USGS Base Maps but Water on USGS Land Use Maps	*from water - moved to fit rationale for keeping category 56 in the Water general category
Open	72	Beaches	
Open	73	Sand Other than Beaches	
Open	74	Bare Exposed Rock	
Open	76	Transitional Areas	
Open	762	Other Transitional	
Open	764	Right-of-Way	
Open	77	Mixed Sparsely Vegetated Land	
Residential	11	Residential	
Residential	111	Approx. One Dwelling Unit per Hectare	
Residential	112	Approx.Two to Eight Dwelling Units per Hectare	
Residential	113	Nine to Nineteen Dwelling Units per Hectare	
Residential	114	Mobile Home Parks	
Residential	115	Twenty or More Dwelling Units per Hectare	*new subcategory, not in Davis et al. 2000
Residential	119	Recreation and Common Facilities Associated with Multifamily Residential	*new subcategory, not in Davis et al. 2000
Residential	1251	Military Residential	*from Commercial based on footnote suggestion on pg. 9, ABAG 2002
Water	5	Water	
Water	51	Streams and Canals	
Water	52	Lakes	
Water	53	Reservoirs	
Water	54	Bays and Estuaries	
Water	56	Water on USGS Base Maps but Land on USGS or Assessors' Land Use Maps	

TABLE 2. Average annual runoff coefficients from selected studies (from Davis et al. 2000)
The highlighted coefficients in boxes were selected as the "best estimate" input data for the model.

		BASMAA (1996)	BCDC (1991)	NOAA (1987)	Wong et al. (1997)	SCCWRP (2000)
	single family			0.2	0.39	
Residential	multi-family				0.58	
	undiff	0.35	0.38			0.23
Commercial		0.9	0.85	0.65	0.74	0.57
	light	0.7			0.74	
Industrial	heavy	0.9				
	transportation	0.95				
	undiff		0.72	0.3		0.58
Agricultural						0.1
Open		0.25	0.12	0.06	0.1	0.08
Other	mixed			0.23	0.66	0.38

BASMAA (1996) Monitoring Data analysis 1988 - 1995
BCDC (1991) Land use Change report
NOAA (1987) National Coastal Pollutant Discharge Inventory
Wong et. al. (1997) GIS to estimate storm-water pollutant mass loadings
SCCWRP (2000) Pollutant Mass Emissions to the Coastal Ocean of California

Table 3: Results of Analysis A, the total annual average wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using interpolated rainfall isohyets.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Avg Annual Rainfall (mm)	Total Annual Avg Wet Season Volume (1000 m^3)
1	ACFC_Zone 4	8.7	0.74	422	2,586
2	ACFC_Zone 5 Line F-1	6.5	0.63	400	1,566
3	ACFC_Zone 5 Line J-3 Pump Station	1.4	0.45	400	237
4	ACFC_Zone 5 Line P and Zone 6 Line N	33.8	0.51	406	6,627
5	Adobe Creek	29.0	0.38	517	5,373
6	Agua Fria and Torogas Creek and Scott Creek	20.4	0.41	451	3,597
7	Arroyo Viejo	16.3	0.40	579	3,588
8	Atherton Creek	23.0	0.53	460	5,311
9	Barron Creek	8.0	0.44	424	1,409
10	Baxter Creek	7.5	0.56	534	2,137
11	Bayfront Park	0.6	0.90	400	209
12	Belmont Creek	8.4	0.57	510	2,333
13	Belmont Slough	1.2	0.51	400	234
14	Blackberry and Marin Creeks_A	4.3	0.43	567	989
15	Bockman Canal	7.6	0.47	486	1,637
16	Borel Creek	8.0	0.57	508	2,194
17	Burlingame Creek	7.9	0.48	553	2,019
18	Calabazas Creek	52.9	0.48	482	11,658
19	Canada del Cierbo	6.4	0.46	500	1,410
20	Cerrito Creek	7.8	0.51	554	2,092
21	Coast Casey Forebay	3.6	0.63	400	869
22	Codornices Creek	3.1	0.42	587	735
23	Colma Creek	40.7	0.55	586	12,475
24	Cordilleras Creek	9.4	0.50	599	2,666
25	Crandall Creek and ACFC_Zone 5 Line P	16.9	0.37	400	2,364
26	Crandall Creek and ACFC_Zone 5 Line P	1.4	0.24	400	124
27	Davis Point	4.9	0.54	500	1,265
28	Derby and Potter Creeks_A	10.9	0.53	554	3,031
29	Easton Creek	2.8	0.54	607	851
30	Elmhurst Creek_A	6.6	0.59	501	1,868
31	Estudillo Canal	29.5	0.56	499	7,761
32	Ettie Street Pump Station_A	8.3	0.60	516	2,443
33	Foster City Lagoon Water	9.9	0.49	400	1,848
34	Garrity Creek	7.7	0.57	511	2,137
35	Glen Echo Creek	6.6	0.42	569	1,509
36	Green Hills Creek	7.3	0.58	631	2,536
37	Guadalupe Valley Creek	6.9	0.48	568	1,783
38	Herman Slough and Castro Creek	9.6	0.68	500	3,133
39	Hoffman Channel	3.0	0.56	539	864
40	Laguna Creek	36.9	0.50	458	7,959
41	Laurel Creek	11.7	0.52	505	2,920

Table 3 (cont.): Results of Analysis A, the total annual average wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using interpolated rainfall isohyets.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Avg Annual Rainfall (mm)	Total Annual Avg Wet Season Volume (1000 m^3)
42	Leslie Creek	4.8	0.61	484	1,339
43	Lion Creek	9.1	0.51	581	2,541
44	Lower Penitencia Creek	75.9	0.41	427	12,727
45	Lower Sulphur Creek	8.0	0.62	474	2,241
46	Marina Lagoon	1.0	0.49	400	182
47	Matadero Creek	31.0	0.45	450	6,011
48	Meeker Slough	8.6	0.64	516	2,691
49	Millbrae Creek	4.0	0.65	634	1,566
50	Mills Creek	4.1	0.59	626	1,457
51	Moffett West	2.8	0.73	400	767
52	Palo Alto Golf Course	1.8	0.55	400	371
53	Parchester	2.7	0.43	500	557
54	Peralta and Courtland and Seminary Creeks	14.7	0.47	550	3,601
55	Permanente Creek	45.4	0.40	523	8,931
56	Pinole Creek	38.1	0.30	580	6,315
57	Pinole Shores	2.2	0.49	500	525
58	Point Pinole	4.7	0.47	500	1,044
59	Point Richmond	0.7	0.48	500	165
60	Point San Pablo Peninsula North	0.8	0.74	500	270
61	Point San Pablo Peninsula West	3.7	0.71	500	1,259
62	Poplar Creek	3.9	0.52	491	932
63	Pulgas Creek	9.2	0.56	506	2,457
64	Redwood Ck and Arroyo Ojo de Agua Ck	29.8	0.53	531	7,890
65	Redwood Shores Lagoon Water	4.5	0.47	400	804
66	Refugio Creek	11.7	0.39	510	2,227
67	Refugio North	1.4	0.48	500	313
68	Rheem Creek	5.3	0.56	511	1,436
69	Richmond Inner Harbor	1.4	0.58	500	383
70	Rodeo Creek	27.1	0.30	500	3,829
71	San Bruno Creek	11.8	0.65	594	4,340
72	San Francisco International Airport A	4.1	0.90	505	1,777
73	San Francisco International Airport B	3.5	0.90	500	1,511
74	San Leandro Creek Below Lake Chabot	19.1	0.46	525	4,355
75	San Pablo	1.4	0.73	500	489
76	San Pablo Creek	47.6	0.33	595	8,835
77	San Tomas	69.7	0.47	503	15,692
78	Sanchez Creek	4.7	0.54	593	1,421
79	Sanjon de los Alisos A	12.4	0.45	400	2,120
80	Santa Fe Channel	7.6	0.68	500	2,460
81	Saratoga Creek	44.3	0.34	825	11,888
82	Sausal Creek	10.9	0.37	606	2,339
83	Schoolhouse Creek	3.5	0.46	533	806
84	Seal Slough	3.0	0.54	400	622

Table 3 (cont.): Results of Analysis A, the total annual average wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using interpolated rainfall isohyets.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Avg Annual Rainfall (mm)	Total Annual Avg Wet Season Volume (1000 m^3)
85	Sewage Treatment Plant	0.6	0.28	400	67
86	Strawberry Creek	8.0	0.69	581	3,062
87	Sunnyvale East Channel	14.1	0.51	400	2,721
88	Sunnyvale East Channel	3.9	0.61	431	973
89	Sunnyvale West	0.6	0.28	400	60
90	Sunnyvale West Channel	18.6	0.68	400	4,785
91	Temescal Creek	17.5	0.42	596	4,177
92	Treasure Island	1.5	0.90	500	649
93	Visitacion Point	3.0	0.63	500	904
94	Ward and Zeile Creeks	55.3	0.53	479	13,267
95	Wildcat Creek	25.6	0.35	579	4,959
96	Yerba Buena Island	0.5	0.90	500	227

Table 4: Results of Analysis B, a summary of the annual wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Wet Season Vol 1998-2007 (1000 m^3)	Max Wet Season Vol 1998-2007 (1000 m^3)	Avg Wet Season Vol 1998-2007 (1000 m^3)
1	ACFC_Zone 4	8.7	0.74	2,129	6,135	3,108
2	ACFC_Zone 5 Line F-1	6.5	0.63	922	3,031	1,589
3	ACFC_Zone 5 Line J-3 Pump Station	1.4	0.45	209	555	311
4	ACFC_Zone 5 Line P and Zone 6 Line N	33.8	0.51	4,469	12,952	7,147
5	Adobe Creek	29.0	0.38	2,212	6,847	5,784
6	Agua Fria and Torogas Creek and Scott Creek	20.4	0.41	2,253	6,013	3,336
7	Arroyo Viejo	16.3	0.40	2,764	7,518	4,430
8	Atherton Creek	23.0	0.53	3,300	12,128	6,897
9	Barron Creek	8.0	0.44	728	2,299	1,584
10	Baxter Creek	7.5	0.56	1,625	4,693	2,884
11	Bayfront Park	0.6	0.90	135	495	278
12	Belmont Creek	8.4	0.57	1,273	4,852	2,768
13	Belmont Slough	1.2	0.51	161	614	350
14	Blackberry and Marin Creeks_A	4.3	0.43	741	2,003	1,263
15	Bockman Canal	7.6	0.47	1,187	3,452	1,755
16	Borel Creek	8.0	0.57	1,284	4,563	2,605
17	Burlingame Creek	7.9	0.48	1,264	3,895	2,333
18	Calabazas Creek	52.9	0.48	5,188	14,713	10,196
19	Canada del Cierbo	6.4	0.46	824	2,660	1,600
20	Cerrito Creek	7.8	0.51	1,575	4,361	2,715
21	Coast Casey Forebay	3.6	0.63	454	1,391	853
22	Codornices Creek	3.1	0.42	539	1,435	913
23	Colma Creek	40.7	0.55	8,327	23,052	13,992
24	Cordilleras Creek	9.4	0.50	1,117	4,551	2,585
25	Crandall Creek and ACFC_Zone 5 Line P	16.9	0.37	1,734	4,966	2,751
26	Crandall Creek and ACFC_Zone 5 Line P	1.4	0.24	87	250	138
27	Davis Point	4.9	0.54	761	2,440	1,468
28	Derby and Potter Creeks_A	10.9	0.53	2,322	6,273	3,947
29	Easton Creek	2.8	0.54	496	1,493	890
30	Elmhurst Creek_A	6.6	0.59	1,641	4,515	2,633
31	Estudillo Canal	29.5	0.56	5,814	16,991	8,868
32	Ettie Street Pump Station_A	8.3	0.60	1,806	5,503	3,124
33	Foster City Lagoon Water	9.9	0.49	1,322	4,869	2,778
34	Garrity Creek	7.7	0.57	1,695	4,915	3,015
35	Glen Echo Creek	6.6	0.42	1,048	3,079	1,795
36	Green Hills Creek	7.3	0.58	1,347	4,158	2,434
37	Guadalupe Valley Creek	6.9	0.48	1,179	3,233	1,897
38	Herman Slough and Castro Creek	9.6	0.68	2,470	7,445	4,491
39	Hoffman Channel	3.0	0.56	656	1,866	1,147
40	Laguna Creek	36.9	0.50	4,847	14,082	7,909
41	Laurel Creek	11.7	0.52	1,671	6,156	3,515
42	Leslie Creek	4.8	0.61	875	2,885	1,712
43	Lion Creek	9.1	0.51	1,938	5,289	3,124
44	Lower Penitencia Creek	75.9	0.41	8,101	21,990	12,330
45	Lower Sulphur Creek	8.0	0.62	1,639	4,723	2,366

Table 4 (cont): Results of Analysis B, a summary of the annual wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Wet Season Vol 1998-2007 (1000 m^3)	Max Wet Season Vol 1998-2007 (1000 m^3)	Avg Wet Season Vol 1998-2007 (1000 m^3)
46	Marina Lagoon	1.0	0.49	131	480	274
47	Matadero Creek	31.0	0.45	3,016	9,705	6,320
48	Meeker Slough	8.6	0.64	2,081	6,174	3,750
49	Millbrae Creek	4.0	0.65	831	2,560	1,501
50	Mills Creek	4.1	0.59	806	2,448	1,449
51	Moffett West	2.8	0.73	366	1,060	626
52	Palo Alto Golf Course	1.8	0.55	218	724	395
53	Parchester	2.7	0.43	447	1,315	802
54	Peralta and Courtland and Seminary Creeks	14.7	0.47	2,782	7,832	4,574
55	Permanente Creek	45.4	0.40	3,506	10,577	8,703
56	Pinole Creek	38.1	0.30	3,864	11,358	7,011
57	Pinole Shores	2.2	0.49	427	1,232	758
58	Point Pinole	4.7	0.47	840	2,459	1,502
59	Point Richmond	0.7	0.48	130	1,624	237
60	Point San Pablo Peninsula North	0.8	0.74	214	639	387
61	Point San Pablo Peninsula West	3.7	0.71	993	2,992	1,805
62	Poplar Creek	3.9	0.52	628	1,991	1,180
63	Pulgas Creek	9.2	0.56	1,204	4,919	2,791
64	Redwood Ck and Arroyo Ojo de Agua Ck	29.8	0.53	3,423	14,748	8,351
65	Redwood Shores Lagoon Water	4.5	0.47	526	2,041	1,157
66	Refugio Creek	11.7	0.39	1,537	4,571	2,807
67	Refugio North	1.4	0.48	200	633	381
68	Rheem Creek	5.3	0.56	1,128	3,317	2,023
69	Richmond Inner Harbor	1.4	0.58	303	906	547
70	Rodeo Creek	27.1	0.30	2,312	7,138	4,375
71	San Bruno Creek	11.8	0.65	2,811	8,075	4,941
72	San Francisco International Airport A	4.1	0.90	1,097	3,509	2,003
73	San Francisco International Airport B	3.5	0.90	938	3,007	1,714
74	San Leandro Creek Below Lake Chabot	19.1	0.46	3,532	9,850	5,591
75	San Pablo	1.4	0.73	390	1,157	702
76	San Pablo Creek	47.6	0.33	6,207	17,221	10,774
77	San Tomas	69.7	0.47	7,196	20,351	12,334
78	Sanchez Creek	4.7	0.54	871	2,588	1,557
79	Sanjon de los Alisos A	12.4	0.45	1,276	4,103	2,170
80	Santa Fe Channel	7.6	0.68	1,935	5,848	3,524
81	Saratoga Creek	44.3	0.34	3,174	7,975	6,608
82	Sausal Creek	10.9	0.37	1,579	4,548	2,651
83	Schoolhouse Creek	3.5	0.46	638	1,741	1,090
84	Seal Slough	3.0	0.54	393	1,503	850
85	Sewage Treatment Plant	0.6	0.28	38	125	69
86	Strawberry Creek	8.0	0.69	2,279	6,023	3,853
87	Sunnyvale East Channel	14.1	0.51	1,260	3,736	2,438
88	Sunnyvale East Channel	3.9	0.61	473	1,342	971
89	Sunnyvale West	0.6	0.28	28	86	49
90	Sunnyvale West Channel	18.6	0.68	2,275	6,605	3,895

Table 4 (cont): Results of Analysis B, a summary of the annual wet season volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Wet Season Vol 1998-2007 (1000 m^3)	Max Wet Season Vol 1998-2007 (1000 m^3)	Avg Wet Season Vol 1998-2007 (1000 m^3)
91	Temescal Creek	17.5	0.42	2,929	8,079	4,967
92	Treasure Island	1.5	0.90	525	1,502	879
93	Visitacion Point	3.0	0.63	678	1,870	1,097
94	Ward and Zeile Creeks	55.3	0.53	9,689	26,931	14,737
95	Wildcat Creek	25.6	0.35	3,555	9,967	6,206
96	Yerba Buena Island	0.5	0.90	188	519	307

Table 5: Results of Analysis C, a summary of the first flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min First Flood Vol 1998-2007 (1000 m^3)	Max First Flood Vol 1998-2007 (1000 m^3)	Avg First Flood Vol 1998-2007 (1000 m^3)
1	ACFC_Zone 4	8.7	0.74	73	238	118
2	ACFC_Zone 5 Line F-1	6.5	0.63	22	114	41
3	ACFC_Zone 5 Line J-3 Pump Station	1.4	0.45	5	19	9
4	ACFC_Zone 5 Line P and Zone 6 Line N	33.8	0.51	84	382	172
5	Adobe Creek	29.0	0.38	49	300	148
6	Agua Fria and Torogas Creek and Scott Creek	20.4	0.41	19	252	113
7	Arroyo Viejo	16.3	0.40	42	369	143
8	Atherton Creek	23.0	0.53	120	366	221
9	Barron Creek	8.0	0.44	14	84	44
10	Baxter Creek	7.5	0.56	31	148	81
11	Bayfront Park	0.6	0.90	4	14	8
12	Belmont Creek	8.4	0.57	51	186	99
13	Belmont Slough	1.2	0.51	6	24	12
14	Blackberry and Marin Creeks_A	4.3	0.43	22	63	36
15	Bockman Canal	7.6	0.47	39	128	65
16	Borel Creek	8.0	0.57	45	174	90
17	Burlingame Creek	7.9	0.48	32	142	76
18	Calabazas Creek	52.9	0.48	46	659	307
19	Canada del Cierbo	6.4	0.46	11	54	31
20	Cerrito Creek	7.8	0.51	44	137	78
21	Coast Casey Forebay	3.6	0.63	4	64	28
22	Codornices Creek	3.1	0.42	16	45	27
23	Colma Creek	40.7	0.55	206	703	419
24	Cordilleras Creek	9.4	0.50	47	192	99
25	Crandall Creek and ACFC_Zone 5 Line P	16.9	0.37	35	150	68
26	Crandall Creek and ACFC_Zone 5 Line P	1.4	0.24	2	8	4
27	Davis Point	4.9	0.54	10	48	28
28	Derby and Potter Creeks_A	10.9	0.53	68	195	114
29	Easton Creek	2.8	0.54	11	54	29
30	Elmhurst Creek_A	6.6	0.59	25	211	85
31	Estudillo Canal	29.5	0.56	157	495	318
32	Ettie Street Pump Station_A	8.3	0.60	35	188	88
33	Foster City Lagoon Water	9.9	0.49	50	189	96
34	Garrity Creek	7.7	0.57	30	149	85
35	Glen Echo Creek	6.6	0.42	23	99	51
36	Green Hills Creek	7.3	0.58	29	164	81
37	Guadalupe Valley Creek	6.9	0.48	23	105	57
38	Herman Slough and Castro Creek	9.6	0.68	26	223	124
39	Hoffman Channel	3.0	0.56	15	59	33
40	Laguna Creek	36.9	0.50	65	502	214
41	Laurel Creek	11.7	0.52	64	232	121
42	Leslie Creek	4.8	0.61	29	116	59
43	Lion Creek	9.1	0.51	30	252	99

Table 5 (cont): Results of Analysis C, a summary of the first flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min First Flood Vol 1998-2007 (1000 m^3)	Max First Flood Vol 1998-2007 (1000 m^3)	Avg First Flood Vol 1998-2007 (1000 m^3)
44	Lower Penitencia Creek	75.9	0.41	89	830	412
45	Lower Sulphur Creek	8.0	0.62	58	184	90
46	Marina Lagoon	1.0	0.49	5	19	9
47	Matadero Creek	31.0	0.45	67	354	183
48	Meeker Slough	8.6	0.64	28	186	104
49	Millbrae Creek	4.0	0.65	18	100	50
50	Mills Creek	4.1	0.59	18	92	47
51	Moffett West	2.8	0.73	2	64	26
52	Palo Alto Golf Course	1.8	0.55	2	22	11
53	Parchester	2.7	0.43	7	40	22
54	Peralta and Courtland and Seminary Creeks	14.7	0.47	46	306	140
55	Permanente Creek	45.4	0.40	33	487	220
56	Pinole Creek	38.1	0.30	104	273	180
57	Pinole Shores	2.2	0.49	8	37	21
58	Point Pinole	4.7	0.47	13	74	42
59	Point Richmond	0.7	0.48	1	12	7
60	Point San Pablo Peninsula North	0.8	0.74	2	19	11
61	Point San Pablo Peninsula West	3.7	0.71	10	90	50
62	Poplar Creek	3.9	0.52	16	77	39
63	Pulgas Creek	9.2	0.56	50	208	106
64	Redwood Ck and Arroyo Ojo de Agua Ck	29.8	0.53	151	707	342
65	Redwood Shores Lagoon Water	4.5	0.47	20	75	40
66	Refugio Creek	11.7	0.39	41	112	71
67	Refugio North	1.4	0.48	5	16	9
68	Rheem Creek	5.3	0.56	17	100	56
69	Richmond Inner Harbor	1.4	0.58	4	29	15
70	Rodeo Creek	27.1	0.30	53	160	104
71	San Bruno Creek	11.8	0.65	69	259	151
72	San Francisco International Airport A	4.1	0.90	22	154	70
73	San Francisco International Airport B	3.5	0.90	19	133	60
74	San Leandro Creek Below Lake Chabot	19.1	0.46	64	414	186
75	San Pablo	1.4	0.73	5	35	20
76	San Pablo Creek	47.6	0.33	154	474	299
77	San Tomas	69.7	0.47	78	940	377
78	Sanchez Creek	4.7	0.54	21	89	50
79	Sanjon de los Alisos A	12.4	0.45	30	147	55
80	Santa Fe Channel	7.6	0.68	19	175	97
81	Saratoga Creek	44.3	0.34	31	407	181
82	Sausal Creek	10.9	0.37	30	140	78
83	Schoolhouse Creek	3.5	0.46	18	55	31
84	Seal Slough	3.0	0.54	16	63	32
85	Sewage Treatment Plant	0.6	0.28	0	4	2
86	Strawberry Creek	8.0	0.69	68	192	112

Table 5 (cont): Results of Analysis C, a summary of the first flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min First Flood Vol 1998-2007 (1000 m^3)	Max First Flood Vol 1998-2007 (1000 m^3)	Avg First Flood Vol 1998-2007 (1000 m^3)
87	Sunnyvale East Channel	14.1	0.51	12	180	88
88	Sunnyvale East Channel	3.9	0.61	4	59	29
89	Sunnyvale West	0.6	0.28	0	4	2
90	Sunnyvale West Channel	18.6	0.68	15	394	162
91	Temescal Creek	17.5	0.42	81	247	144
92	Treasure Island	1.5	0.90	10	45	24
93	Visitacion Point	3.0	0.63	13	62	33
94	Ward and Zeile Creeks	55.3	0.53	282	1,101	512
95	Wildcat Creek	25.6	0.35	84	315	174
96	Yerba Buena Island	0.5	0.90	3	16	9

Table 6: Results of Analysis D, a summary of the maximum flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Largest Flood Vol 1998-2007 (1000 m^3)	Max Largest Flood Vol 1998-2007 (1000 m^3)	Avg Largest Flood Vol 1998-2007 (1000 m^3)
1	ACFC_Zone 4	8.7	0.74	134	575	277
2	ACFC_Zone 5 Line F-1	6.5	0.63	65	369	130
3	ACFC_Zone 5 Line J-3 Pump Station	1.4	0.45	15	52	26
4	ACFC_Zone 5 Line P and Zone 6 Line N	33.8	0.51	296	1,437	549
5	Adobe Creek	29.0	0.38	205	840	408
6	Agua Fria and Torogas Creek and Scott Creek	20.4	0.41	82	409	224
7	Arroyo Viejo	16.3	0.40	180	708	388
8	Atherton Creek	23.0	0.53	276	914	598
9	Barron Creek	8.0	0.44	65	282	127
10	Baxter Creek	7.5	0.56	113	340	223
11	Bayfront Park	0.6	0.90	11	44	24
12	Belmont Creek	8.4	0.57	110	374	248
13	Belmont Slough	1.2	0.51	14	43	30
14	Blackberry and Marin Creeks_A	4.3	0.43	58	207	114
15	Bockman Canal	7.6	0.47	78	334	158
16	Borel Creek	8.0	0.57	96	326	231
17	Burlingame Creek	7.9	0.48	77	285	198
18	Calabazas Creek	52.9	0.48	297	1,476	744
19	Canada del Cierbo	6.4	0.46	41	243	132
20	Cerrito Creek	7.8	0.51	121	408	236
21	Coast Casey Forebay	3.6	0.63	32	163	68
22	Codornices Creek	3.1	0.42	43	156	84
23	Colma Creek	40.7	0.55	483	1,841	1,201
24	Cordilleras Creek	9.4	0.50	106	394	241
25	Crandall Creek and ACFC_Zone 5 Line P	16.9	0.37	127	528	214
26	Crandall Creek and ACFC_Zone 5 Line P	1.4	0.24	6	27	11
27	Davis Point	4.9	0.54	37	218	118
28	Derby and Potter Creeks_A	10.9	0.53	186	667	362
29	Easton Creek	2.8	0.54	28	111	76
30	Elmhurst Creek_A	6.6	0.59	109	415	232
31	Estudillo Canal	29.5	0.56	390	1,484	785
32	Ettie Street Pump Station_A	8.3	0.60	155	510	290
33	Foster City Lagoon Water	9.9	0.49	106	344	242
34	Garrity Creek	7.7	0.57	113	359	229
35	Glen Echo Creek	6.6	0.42	88	288	166
36	Green Hills Creek	7.3	0.58	75	316	209
37	Guadalupe Valley Creek	6.9	0.48	76	271	168
38	Herman Slough and Castro Creek	9.6	0.68	96	561	310
39	Hoffman Channel	3.0	0.56	48	150	94
40	Laguna Creek	36.9	0.50	297	1,292	562
41	Laurel Creek	11.7	0.52	136	431	308
42	Leslie Creek	4.8	0.61	59	209	151

Table 6 (cont): Results of Analysis D, a summary of the maximum flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Largest Flood Vol 1998-2007 (1000 m^3)	Max Largest Flood Vol 1998-2007 (1000 m^3)	Avg Largest Flood Vol 1998-2007 (1000 m^3)
43	Lion Creek	9.1	0.51	145	491	276
44	Lower Penitencia Creek	75.9	0.41	315	1,520	858
45	Lower Sulphur Creek	8.0	0.62	98	469	213
46	Marina Lagoon	1.0	0.49	10	34	24
47	Matadero Creek	31.0	0.45	261	1,191	556
48	Meeker Slough	8.6	0.64	109	460	270
49	Millbrae Creek	4.0	0.65	46	194	129
50	Mills Creek	4.1	0.59	45	184	124
51	Moffett West	2.8	0.73	18	121	54
52	Palo Alto Golf Course	1.8	0.55	13	91	36
53	Parchester	2.7	0.43	27	97	59
54	Peralta and Courtland and Seminary Creeks	14.7	0.47	216	666	410
55	Permanente Creek	45.4	0.40	226	1,220	520
56	Pinole Creek	38.1	0.30	276	910	599
57	Pinole Shores	2.2	0.49	29	90	58
58	Point Pinole	4.7	0.47	54	181	112
59	Point Richmond	0.7	0.48	5	30	16
60	Point San Pablo Peninsula North	0.8	0.74	7	49	26
61	Point San Pablo Peninsula West	3.7	0.71	39	226	125
62	Poplar Creek	3.9	0.52	39	147	100
63	Pulgas Creek	9.2	0.56	114	408	258
64	Redwood Ck and Arroyo Ojo de Agua Ck	29.8	0.53	342	1,345	799
65	Redwood Shores Lagoon Water	4.5	0.47	46	154	103
66	Refugio Creek	11.7	0.39	105	369	234
67	Refugio North	1.4	0.48	11	55	30
68	Rheem Creek	5.3	0.56	68	245	149
69	Richmond Inner Harbor	1.4	0.58	15	68	39
70	Rodeo Creek	27.1	0.30	158	642	397
71	San Bruno Creek	11.8	0.65	163	635	419
72	San Francisco International Airport A	4.1	0.90	59	275	173
73	San Francisco International Airport B	3.5	0.90	51	236	148
74	San Leandro Creek Below Lake Chabot	19.1	0.46	230	907	490
75	San Pablo	1.4	0.73	20	86	50
76	San Pablo Creek	47.6	0.33	457	1,486	902
77	San Tomas	69.7	0.47	462	1,883	1,017
78	Sanchez Creek	4.7	0.54	50	191	132
79	Sanjon de los Alisos A	12.4	0.45	88	491	175
80	Santa Fe Channel	7.6	0.68	71	442	242
81	Saratoga Creek	44.3	0.34	190	876	453
82	Sausal Creek	10.9	0.37	128	357	242
83	Schoolhouse Creek	3.5	0.46	50	177	98
84	Seal Slough	3.0	0.54	34	117	80
85	Sewage Treatment Plant	0.6	0.28	3	16	6

Table 6 (cont): Results of Analysis D, a summary of the maximum flood runoff volume (in 1000 m3) for each watershed based on the SIMPLE method and using real rainfall data from nearby precipitation stations for the years 1998-2007.

Watershed ID	Watershed Name	Drainage Area (km^2)	Runoff Coefficient	Min Largest Flood Vol 1998-2007 (1000 m^3)	Max Largest Flood Vol 1998-2007 (1000 m^3)	Avg Largest Flood Vol 1998-2007 (1000 m^3)
86	Strawberry Creek	8.0	0.69	182	666	356
87	Sunnyvale East Channel	14.1	0.51	67	417	194
88	Sunnyvale East Channel	3.9	0.61	26	138	68
89	Sunnyvale West	0.6	0.28	1	9	4
90	Sunnyvale West Channel	18.6	0.68	108	752	337
91	Temescal Creek	17.5	0.42	236	819	458
92	Treasure Island	1.5	0.90	41	107	72
93	Visitacion Point	3.0	0.63	44	154	97
94	Ward and Zeile Creeks	55.3	0.53	759	2,578	1,292
95	Wildcat Creek	25.6	0.35	260	820	508
96	Yerba Buena Island	0.5	0.90	16	44	27

APPENDIX B

Metadata for: **San Francisco Bay Pump Stations, Geographic WGS84, SFEI (2010) [SFBayPumpStations]**

Identification_Information:
Citation:
Citation_Information:
Originator: San Francisco Estuary Institute
Publication_Date: March 2010
Title:
San Francisco Bay Pump Stations, Geographic WGS84, SFEI (2010) [SFBayPumpStations]
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage: <http://www.sfei.org/stormwaterbmps/>
Larger_Work_Citation:
Citation_Information:
Originator: San Francisco Estuary Institute
Publication_Date: March 2010
Title:
Regional Stormwater Monitoring and Urban BMP Evaluation: A Stakeholder Driven Partnership to Reduce Contaminant Loadings
Online_Linkage: <http://www.sfei.org/stormwaterbmps/>
Description:
Abstract:
This dataset was created through the collaborative efforts of the San Francisco Estuary Institute (SFEI) and the Regional Water Quality Control Board (RWQCB) San Francisco Bay Region in the effort to identify the location and specific attributes of stormwater pump stations surrounding the San Francisco Bay under the jurisdiction of Phase 1 permittees and the California Department of Transportation. The RWQCB requested information from Phase 1 permittees during the fall of 2007 and SFEI organized the information into a database and this GIS shapefile. Attempts were made to standardize the data presented in this GIS into standard language and units for each attribute, however, no information offered by the permittees was deleted and differences are either noted within the dataset or the information was moved to the notes section. The RWQCB later requested similar information from Caltrans. Caltrans responded with information about 62 of their pump stations in the counties of Alameda, Contra Costa, Napa, San Mateo, and Santa Clara. This data was incorporated into the shapefile in March 2009. As of March 2010, the RWQCB plans to request the Phase 1 permittees to review the dataset to verify, update, and add additional information for each pump station as appropriate.
Purpose:
This dataset was prepared as part of the San Francisco Estuary Institute's "Regional Stormwater Monitoring and Urban BMP Evaluation".
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2010
Currentness_Reference: publication date
Status:
Progress: Complete

Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.495560
East_Bounding_Coordinate: 0.000000
North_Bounding_Coordinate: 38.321300
South_Bounding_Coordinate: 0.000000
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: pump station
Theme:
Theme_Keyword_Thesaurus: ArcIMS Metadata Service Themes
Theme_Keyword: structure
Theme_Keyword: inlandWaters
Place:
Place_Keyword: San Francisco Bay
Access_Constraints: None
Use_Constraints: None
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Alicia Gilbreath
Contact_Organization: San Francisco Estuary Institute
Contact_Position: Environmental Analyst
Contact_Address:
Address_Type: mailing and physical address
Address: 7770 Pardee Lane, 2nd Floor
City: Oakland
State_or_Province: CA
Postal_Code: 94610
Country: us
Contact_Voice_Telephone: 510-746-7334
Contact_Electronic_Mail_Address: alicia@sfei.org
Data_Set_Credit:
Data request to Phase 1 Permitees and Caltrans by the San Francisco Bay Regional Water Quality Control Board. Data collation and organization by the San Francisco Estuary Institute.
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.3.1.3000

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
The information in this GIS dataset was the information provided by the Phase 1 permittees and Caltrans. The accuracy has not be QA/QC'd. In some cases, where permittees presented data in alternative units, SFEI converted that data into the standard units for this dataset.

Completeness_Report:
Data is only included for the RWQCB Phase 1 Permittees plus 62 Caltrans Stations. Non-Phase 1 Permittees were not queried for this information.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Some permittees provided coordinate information for the pumpo stations and some did not. The accuracy of those coordinates provided by the permittees has not been QA/QC'd. In those cases that the permittees did not provide coordinates, the coordinates were obtained by geocoding (using the geocoder at the following web url: <http://www.batchgeocode.com/>) the locations based on the descriptions provided in the "Location" column. The accuracy of these geocoded stations is variable depending on the specificity of the location description. One Caltrans station location description did not return any coordinates based on the location description. This station has all other attribute data in the attribute table, but the coordinates are listed as 0.0, 0.0.
Lineage:
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
S:\Lester\Prop 13 Stormwater BMPs\3.5-1 Orange Zones mapping\1e Map of pump station locations\gis\SFBayPumpStations
Process_Date: 20100402
Process_Time: 11280800

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 279

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution: 0.000000
Longitude_Resolution: 0.000000
Geographic_Coordinate_Units: Decimal degrees
Geodetic_Model:
Horizontal_Datum_Name: D_WGS_1984
Ellipsoid_Name: WGS_1984
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257224

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: SFBayPumpStations
Attribute:
Attribute_Label: FID

Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: ID
Attribute_Definition: SFEI assigned ID number.
Attribute:
Attribute_Label: Name
Attribute_Definition:
Name of pump station according to dataset submitted by Phase 1 permittee.
Attribute:
Attribute_Label: Agency
Attribute_Definition: Agency which maintains and operates the pump station.
Attribute:
Attribute_Label: Location
Attribute_Definition: Street address or location description of pump station.
Attribute:
Attribute_Label: City
Attribute:
Attribute_Label: Lat
Attribute_Definition: Latitude coordinate in WGS 1984.
Attribute_Value_Accuracy_Information:
Attribute_Value_Accuracy: Variable.
Attribute_Value_Accuracy_Explanation:
In cases where the coordinates were provided by the permittee, the accuracy has not been QA/QC'd. In cases where the coordinates were obtained via geocoding the location description, the accuracy is variable depending on the specificity of the location description.
Attribute:
Attribute_Label: Long
Attribute_Definition: Longitude coordinate in WGS 1984.
Attribute_Value_Accuracy_Information:
Attribute_Value_Accuracy: Variable
Attribute_Value_Accuracy_Explanation:
In cases where the coordinates were provided by the permittee, the accuracy has not been QA/QC'd. In cases where the coordinates were obtained via geocoding the location description, the accuracy is variable depending on the specificity of the location description.
Attribute:
Attribute_Label: Crd_note
Attribute_Definition:

SFEI added this column to indicate where coordinates were provided by permitttees versus obtained using the geocoded location descriptions.
Attribute:
Attribute_Label: Num_Pump
Attribute_Definition:
Number of pumps at station. The number of pumps at each station ranges from 1 to 6.
Attribute:
Attribute_Label: DA_acres
Attribute_Definition:
Drainage area, in acres, of the land/watershed that drains into the pump station. Drainage areas range from <1 to 5,760 acres.
Attribute:
Attribute_Label: Dom_LUse
Attribute_Definition:
Dominant land use in the pump station's watershed. In many cases, the permittee offered the two most dominant land uses, or even got more specific about the relative percentages of each land use.
Attribute:
Attribute_Label: Rcvng_WB
Attribute_Definition: The first receiving water body for water pumped out of station.
Attribute:
Attribute_Label: MxPC__gpm
Attribute_Definition:
Maximum total pumping capacity at station, in gallons per minute. Total capacities ranged from 7 to 468000 gallons per minute. If capacity per pump was given, it is in the notes section. In cases where capacity was given in horse-power, we made no conversion to gpm.
Attribute:
Attribute_Label: QMsrble_
Attribute_Definition:
Does the pump station have the capability to measure flow? (yes or no)
Attribute:
Attribute_Label: Method
Attribute_Definition: If flow is measurable, what is the method used to measure it?
Attribute:
Attribute_Label: WetQ_gpm
Attribute_Definition:
Average discharge rate during wet weather, measured in gallons per minute. Average discharge rates ranged from <1 to 300,000 gallons per minute.
Attribute:
Attribute_Label: DryQ_
Attribute_Definition: Does the station pump during dry weather? (yes or no)
Attribute:
Attribute_Label: DryQ_g_mo
Attribute_Definition:
If the station makes dry weather discharges, the amount discharged in gallons per month. Average dry weather discharge rates ranged from 0 to 79,860,000 gallons per month.
Attribute:
Attribute_Label: Cap_gals
Attribute_Definition:

Storage capacity of wet well/catchment basin, in gallons. Storage capacities ranged from 230 to 424,000,000 gallons.
Attribute:
Attribute_Label: Tr_Ctrl_
Attribute_Definition: Are there any trash control measures? (yes or no)
Attribute:
Attribute_Label: Type_TrC
Attribute_Definition: Type of trash control mechanisms used.
Attribute:
Attribute_Label: Date_Blt
Attribute_Definition: Date the pump station was originally built.
Attribute:
Attribute_Label: PS_Lupdt
Attribute_Definition: Date the pump station was last updated.
Attribute:
Attribute_Label: Notes_1
Attribute_Definition:
Any other comments on pump station or pump station management. If information for other attributes was presented but not in the appropriate format, that text has been transferred into these notes columns. Notes columns are all equivalent; there are multiple Notes columns because the amount of text for some stations exceeds the column character limit.
Attribute:
Attribute_Label: Notes_2
Attribute_Definition: Same as Notes_1 attribute definition.
Attribute:
Attribute_Label: Notes_3
Attribute_Definition: Same as Notes_1 attribute definition.
Attribute:
Attribute_Label: Notes_4
Attribute_Definition: Same as Notes_1 attribute definition.
Attribute:
Attribute_Label: Cnt_Name
Attribute_Definition:
Contact name of person submitting information on the pump stations to the RWQCB.
Attribute:
Attribute_Label: Cnt_emal
Attribute_Definition: Contact email.
Attribute:
Attribute_Label: LU_by
Attribute_Definition:
Name of person who last updated the information for each station.
Attribute:
Attribute_Label: LU_Date
Attribute_Definition:
Date that the information for each station was updated in this GIS.
Overview_Description:
Entity_and_Attribute_Overview:

No information provided by the Phase 1 permittees was deleted. In cases where the information did not fit a specific column, the information was appended in the Notes section. In some cases, data was provided without unit information; those cases are noted. In some cases, the permittees used different language than others for the attributes; language was not changed in these instances.

Distribution_Information:

Resource_Description: Downloadable Data

Distribution_Liability:

SFEI GIS Data Liability Disclaimer

In no event shall the creators, custodians, or distributors of this information be liable for any damages arising out of its use (or the inability to use it). These data are not legal documents or of survey quality and are not intended to be used as such.

Although extensive effort has been made to produce error-free and complete data, all geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. Users should consult available data documentation (metadata) for these particular data to determine limitations and the precision to which the data depict distance, direction, location or other geographic characteristics. Data may be subject to change without prior notification.

If this data is modified, changes should be documented in a metadata record that should accompany all redistributed data. If data is transmitted or provided in any form to another user, the data must be accompanied by a copy of this disclaimer and all documentation provided with the original data set, including the full metadata record.

SFEI requests that the use of these data in any map, publication, or report should cite the data source(s) used and give proper attribution and credit to the originators of the data.

Standard_Order_Process:

Digital_Form:

Digital_Transfer_Information:

Transfer_Size: 0.008

Metadata_Reference_Information:

Metadata_Date: 20100402

Metadata_Contact:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: San Francisco Estuary Institute

Contact_Person: Alicia Gilbreath

Contact_Position: Environmental Analyst

Contact_Address:

Address_Type: mailing and physical address

Address: 7770 Pardee Lane, 2nd Floor

City: Oakland

State_or_Province: CA

Postal_Code: 94621

Contact_Voice_Telephone: 510-746-7334

Contact_Electronic_Mail_Address: alicia@sfei.org

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998

Metadata_Time_Convention: local time

Metadata_Extensions:

Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile