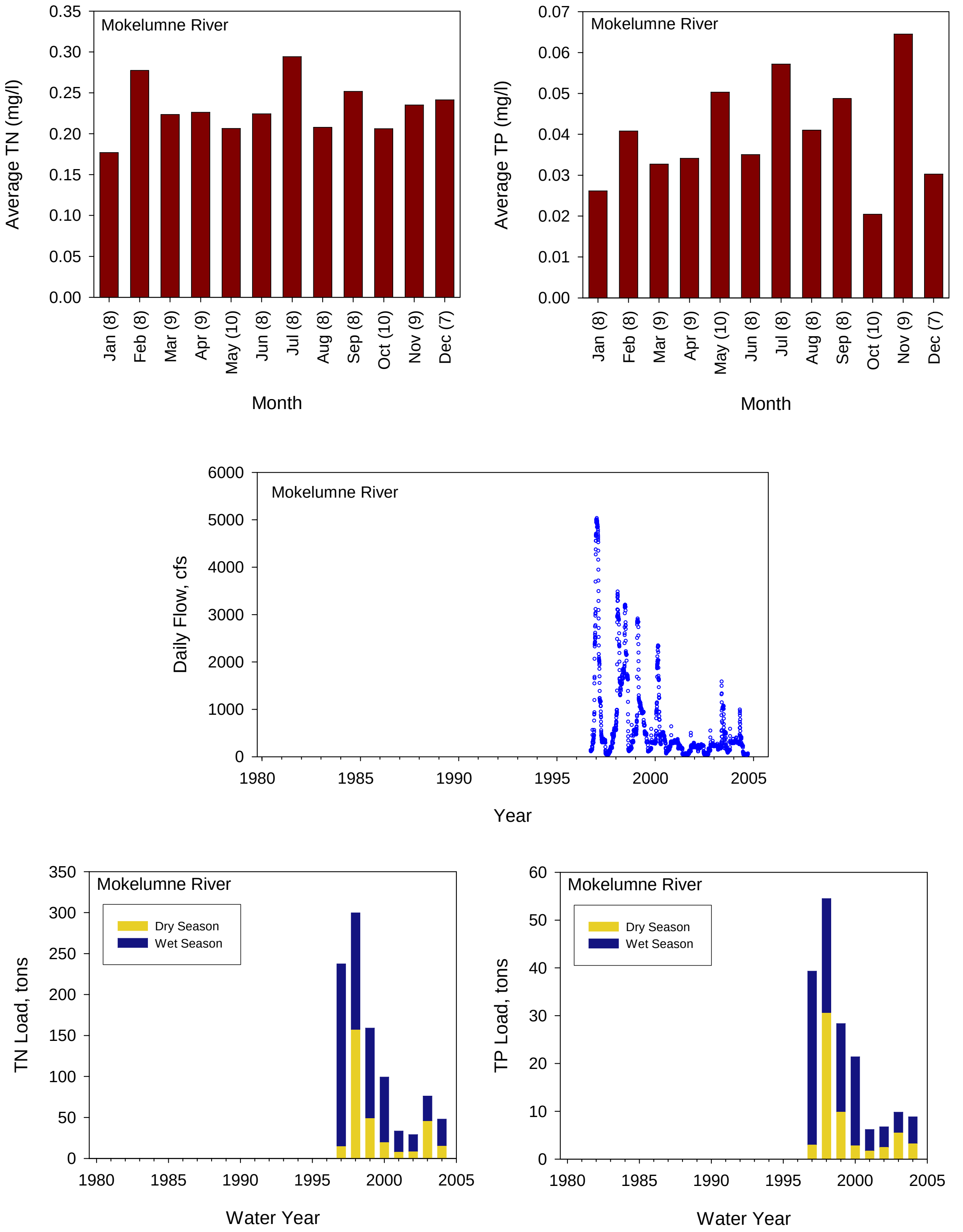

Figure 4-21. **Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for the Mokelumne River.**

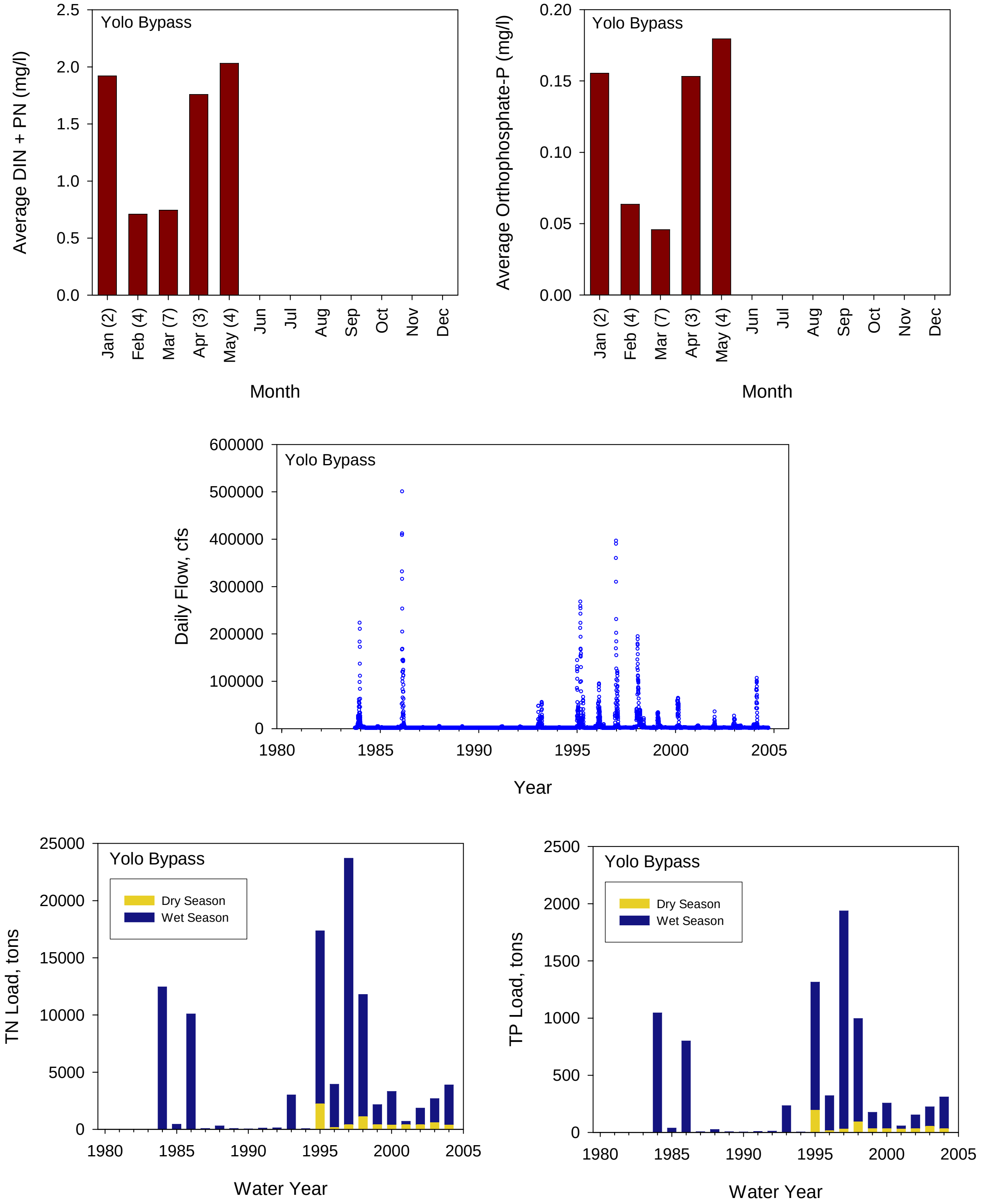

Figure 4-22. Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for the Yolo Bypass.

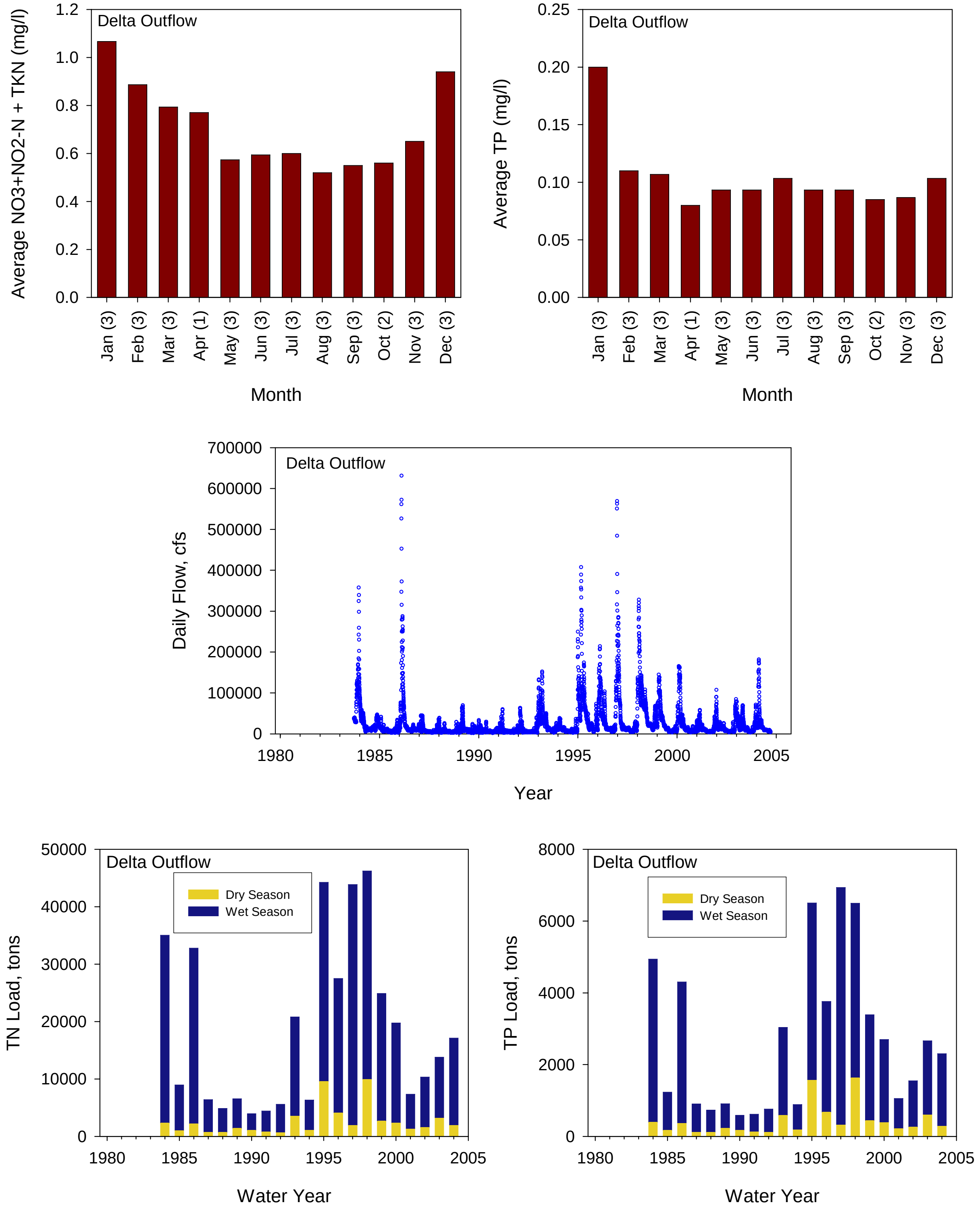

Figure 4-23. Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for Delta outflows. MWQI concentration data for Mallard Island were used and downloaded from the internet at http://wdl.water.ca.gov/wq-gst/.

The loads calculated for the key subwatersheds are summarized in Table 4-3 and Table 4-4 for the dry and wet season of wet and dry years for TN and TP, respectively. Loads of TN and TP during wet years are shown graphically in Figures 4-24 and 4-25, respectively. The graphical representation uses arrow thicknesses to scale loads, and can be used to compare across locations. The loads closely follow the pattern for flows shown in Figure 4-5, with the Sacramento River being the dominant source. This is true even though concentrations in the San Joaquin River are generally much higher than in the Sacramento River (Chapter 3). Wet season tributary loads and Delta exports can be several times higher than the dry season loads. Similarly, wet year tributary loads and Delta exports can be several times higher than the dry year loads.

Estimated loads from this study compare favorably with loads estimated in previous studies, as shown in Table 4-5 and 4-6 for TN and TP, respectively, with the exception of TN agreement in the Sacramento River with Saleh et al. (2003). At the Sacramento River (either Freeport or Greene's Landing), loads from Woodard (2000) for wet and dry years are within 25% of the estimates from this study for both TN and TP. Loads from Saleh et al. (2003) are within 20% of the estimates from this study for TP. At the San Joaquin River at Vernalis, loads from Woodard (2000) and from Saleh et al. (2003) for wet and dry years are within 20% of the estimates from this study for both TN and TP. Loads from Kratzer et al. (2004) for the San Joaquin River at Vernalis (all years) are between wet and dry year estimates from this study for both TN and TP.

Table 4-3.
Total nitrogen loads transported at locations corresponding to the outflow points of the subwatersheds in Table 4-1.

			Dry Years (tons)			Wet Years (tons)			Export Rates (tons/km^2)	
ID	**Watershed Name**	**Upstream Area (km^2)**	Dry Season	Wet Season	Total	Dry Season	Wet Season	Total	Dry year	Wet Year
1	Sacramento River above Bend Bridge	23,144	360	580	940	456	1,457	1,913	0.041	0.083
2	Butte Creek	2,402	-	-	-	-	-	-	-	-
3	Sacramento River at Colusa	36,807	709	2,615	3,323	1,018	5,429	6,447	0.090	0.18
4	Yuba River	3,502	37	129	166	149	538	687	0.047	0.20
5	Feather River	9,994	-	-	-	953	2,424	3,378	-	0.34
6	Cache Creek	3,112	8.7	234	243	144	2,271	2,414	0.078	0.78
7	American River	5,528	181	262	442	346	1,054	1,400	0.080	0.25
8	Sacramento River at Hood/Greene's	61,316	3,442	7,750	11,193	4,241	13,342	17,583	0.18	0.29
9	Cosumnes River	2,390	4.7	52	57	28	322	350	0.024	0.15
10	San Joaquin River at Newman	19,085	446	965	1,411	2,776	6,475	9,251	0.074	0.48
11	Stanislaus River	3,478	114	236	350	245	732	976	0.10	0.28
12	Tuolumne River	4,586	165	594	759	1,241	2,660	3,901	0.17	0.85
13	Merced River	3,289	177	351	528	-	-	-	0.16	-
14	Bear Cr/Owens Cr/Mariposa Cr/ Deadmans Cr	2,397	-	-	-	-	-	-	-	-
15	Chowchilla River	850	-	-	-	-	-	-	-	-
16	San Joaquin River at Sack Dam	11,667	-	-	-	-	-	-	-	-
17	Mokelumne River	3,022	19	27	47	60	138	199	0.015	0.066
18	Bear River	1,229	2.7	42	45	16	268	284	0.037	0.23
19	Putah Creek	1,795	-	-	-	-	-	-	-	-
20	Delta North	2,148	-	-	-	-	-	-	-	-
21	Delta South	5,730	-	-	-	-	-	-	-	-
22	San Joaquin River at Vernalis	32,782	1,555	3,343	4,898	3,748	7,702	11,450	0.15	0.35
-	Yolo Bypass	-	132	565	697	561	8,490	9,051	-	-
-	**Delta Outflow Loads**	**-**	**1,171**	**6,264**	**7,435**	**4,243**	**26,642**	**30,885**	-	-

Note: Loads for watersheds without data in this table are presented in Table 4-10 and 4-11 for dry and wet years, respectively, as estimated using export rates.

Table 4-4.
Total phosphorus loads transported at locations corresponding to the outflow points of the subwatersheds in Table 4-1.

			Dry Years (tons)			**Wet Years (tons)**			**Export Rates (tons/km^2)**	
ID	**Watershed Name**	**Upstream Area (km^2)**	Dry Season	Wet Season	Total	Dry Season	Wet Season	Total	Dry year	Wet Year
1	Sacramento River above Bend Bridge	23,144	163	177	341	196	550	746	0.015	0.032
2	Butte Creek	2,402	-	-	-	-	-	-	-	-
3	Sacramento River at Colusa	36,807	249	796	1,045	276	1,494	1,770	0.028	0.048
4	Yuba River	3,502	4.6	14	18	17	56	73	0.0052	0.021
5	Feather River	9,994	-	-	-	56	357	413	-	0.041
6	Cache Creek	3,112	0.15	10	10	2.3	69	72	0.0033	0.023
7	American River	5,528	22	26	48	41	99	141	0.0087	0.025
8	Sacramento River at Hood/Greene's	61,316	602	1,284	1,886	766	2,316	3,082	0.031	0.050
9	Cosumnes River	2,390	1.0	8.3	9.3	5.2	50	55	0.0039	0.023
10	San Joaquin River at Newman	19,085	41	87	128	272	576	848	0.0067	0.044
11	Stanislaus River	3,478	17	28	45	36	86	122	0.013	0.035
12	Tuolumne River	4,586	15	27	42	109	126	235	0.0092	0.051
13	Merced River	3,289	7.7	12	20	-	-	-	0.0061	-
14	Bear Cr/Owens Cr/Mariposa Cr/ Deadmans Cr	2,397	-	-	-	-	-	-	-	-
15	Chowchilla River	850	-	-	-	-	-	-	-	-
16	San Joaquin River at Sack Dam	11,667	-	-	-	-	-	-	-	-
17	Mokelumne River	3,022	3.3	4.6	7.9	12	24	36	0.0026	0.012
18	Bear River	1,229	0.20	2.9	3.1	1.1	18	19	0.0025	0.016
19	Putah Creek	1,795	-	-	-	-	-	-	-	-
20	Delta North	2,148	-	-	-	-	-	-	-	-
21	Delta South	5,730	-	-	-	-	-	-	-	-
22	San Joaquin River at Vernalis	32,782	148	305	454	425	1,077	1,502	0.014	0.046
-	Yolo Bypass	-	11	45	57	49	681	730	-	-
-	**Delta Outflow Loads**	**-**	**192**	**857**	**1,049**	**708**	**3,765**	**4,473**	-	-

Note: Loads for watersheds without data in this table are presented in Table 4-12 and 4-13 for dry and wet years, respectively, as estimated using export rates.

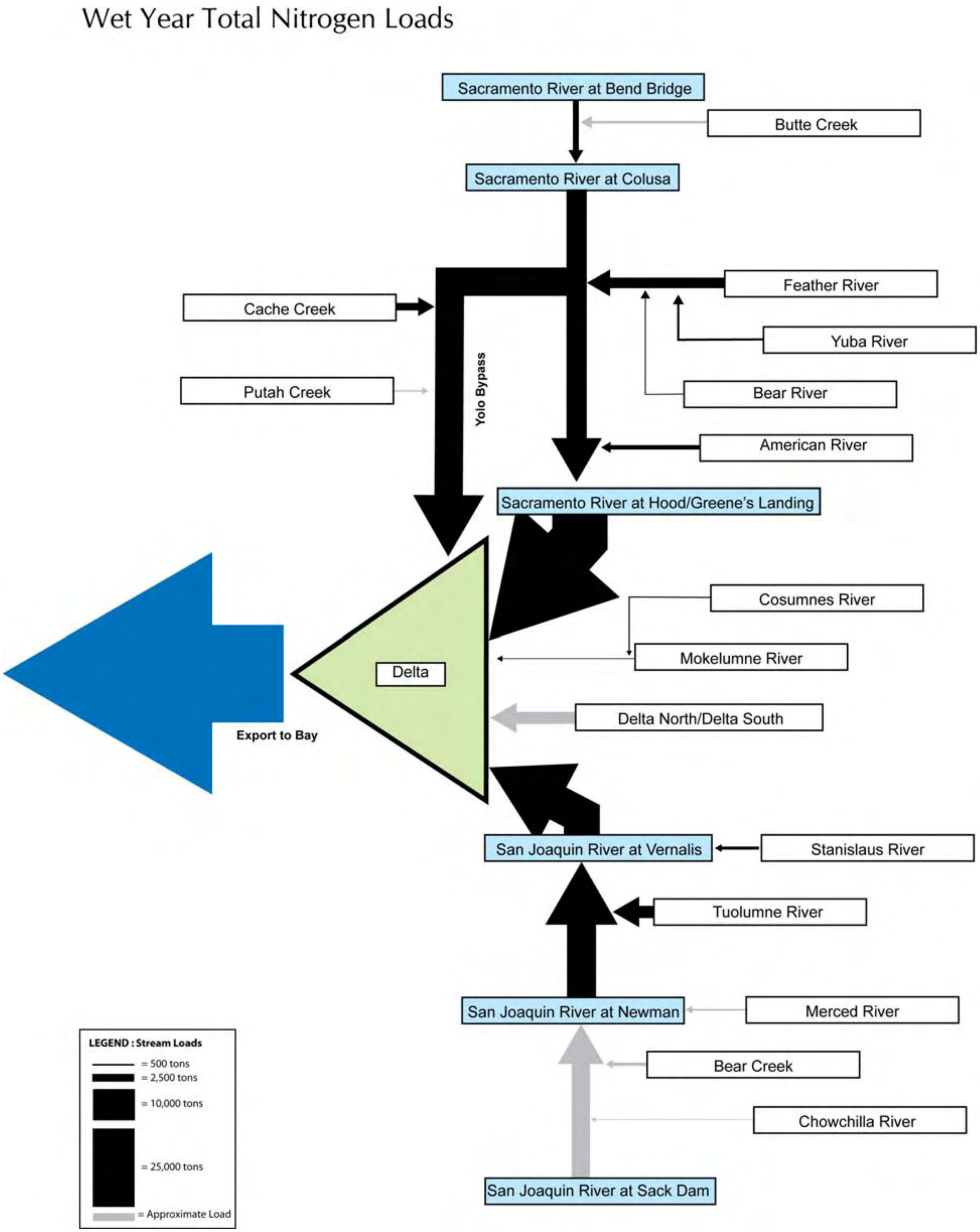

Figure 4-24. TN loads for an average wet year on a schematic representation of the San Joaquin-Sacramento River systems. In-Delta nutrient sources and sinks are presented in Chapter 5.

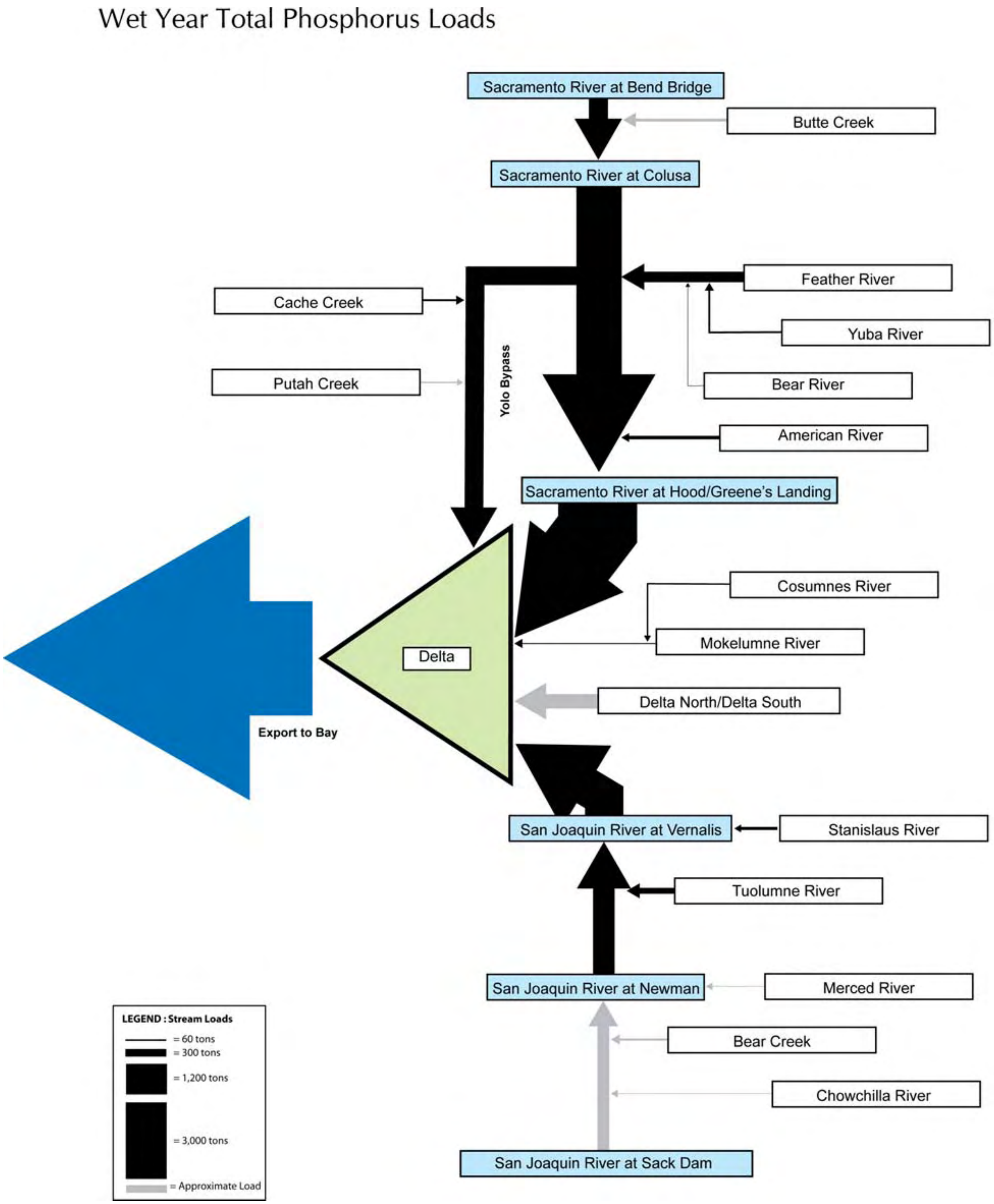

Figure 4-25. TP loads for an average wet year on a schematic representation of the San Joaquin-Sacramento River systems. In-Delta nutrient sources and sinks are presented in Chapter 5.

Table 4-5.
Estimated TN loads from this study compared with other published studies (Saleh et al., 2003; Woodard, 2000, Kratzer et al., 2004).

	This Study (tons)		Saleh et al., 2003; Data from 1980-2000 (tons)		Woodard, 2000; Data from 1980-1999 (tons)		Kratzer et al., 2004; Data from 1972-1999 (tons)
Watershed Name	**Dry Years**	**Wet Years**	**Dry Years**	**Wet Years**	**Dry Years**	**Wet Years**	**All Years[2]**
Sacramento River at Hood/Greene's Landing	11,193	17,583	4,116[1]	8,848[1]	13,516[1]	21,917[1]	-
San Joaquin River at Vernalis	4,898	11,450	3,843	9,017	4,391	10,923	7,000

[1] Data from Sacramento River at Freeport.

[2] Breakdown between wet and dry years not available.

Table 4-6.
Estimated TP loads from this study compared with other published studies (Saleh et al., 2003; Woodard, 2000, Kratzer et al., 2004).

	This Study (tons)		Saleh et al., 2003; Data from 1980-2000 (tons)		Woodard, 2000; Data from 1980-1999 (tons)		Kratzer et al., 2004; Data from 1972-1999 (tons)
Watershed Name	**Dry Years**	**Wet Years**	**Dry Years**	**Wet Years**	**Dry Years**	**Wet Years**	**All Years[2]**
Sacramento River at Hood/Greene's Landing	1,886	3,082	1,483[1]	3,358[1]	1,409[1]	3,070[1]	-
San Joaquin River at Vernalis	454	1,502	517	1,536	453	1,213	944

[1] Data from Sacramento River at Freeport.

[2] Breakdown between wet and dry years not available.

4.4 ESTIMATION OF WATERSHED LOADS

Stream loads calculated above can be compared with loads originating in the watershed that include non-point sources (principally different land uses, such as agriculture, urban land, wetlands, and other natural lands), and point sources (principally wastewater treatment, although other sources may be contributors). The sections below discuss the approach used to estimate these contributions. These are preliminary estimates due to the limited data that were available to calculate export rates from individual land uses.

4.4.1 ESTIMATION OF NUTRIENT EXPORT RATES FROM NON-POINT SOURCES

Non-point source contributions of nutrient loads to streams are expressed as mass delivered to the stream per unit area per unit time. The stream outflow represents the load contributions in surface runoff as well as baseflow (i.e., through groundwater). The export rate calculations are similar to the load estimates from streams except that for the rates to be applicable to one type of land use, the watershed in consideration must contain only that land use. Thus, an urban land nitrogen or phosphorus export rate is obtained from a watershed that is entirely urban land, and a background export rate is obtained from a watershed with minimal development. In practice, finding watersheds with only one type of land use is very difficult, although in some instances small indicator watersheds may be found that fit this criterion. Export rates from specific land uses, weighted by the area of that land use in a watershed, can be used to compute the non-point source contribution, as shown schematically in Figure 4-26.

Nitrogen and phosphorus export rates were estimated for urban land and agricultural land, background loads from a mix of forest, shrubland, or rangeland, and from wetlands. Further stratification of land use-based export rates (e.g., by crop type for agricultural land) was not possible given the existing data. This is an area that will benefit greatly through collection of additional data in small indicator watersheds as described in Chapter 6.

The following locations were used to develop preliminary export rates:

- The Colusa Basin Drain was used for estimating agricultural loads in the Sacramento River Basin as shown in Figure 4-27. Although the Colusa Basin Drain watershed includes non-agricultural land, it was the best station based on the existing data.

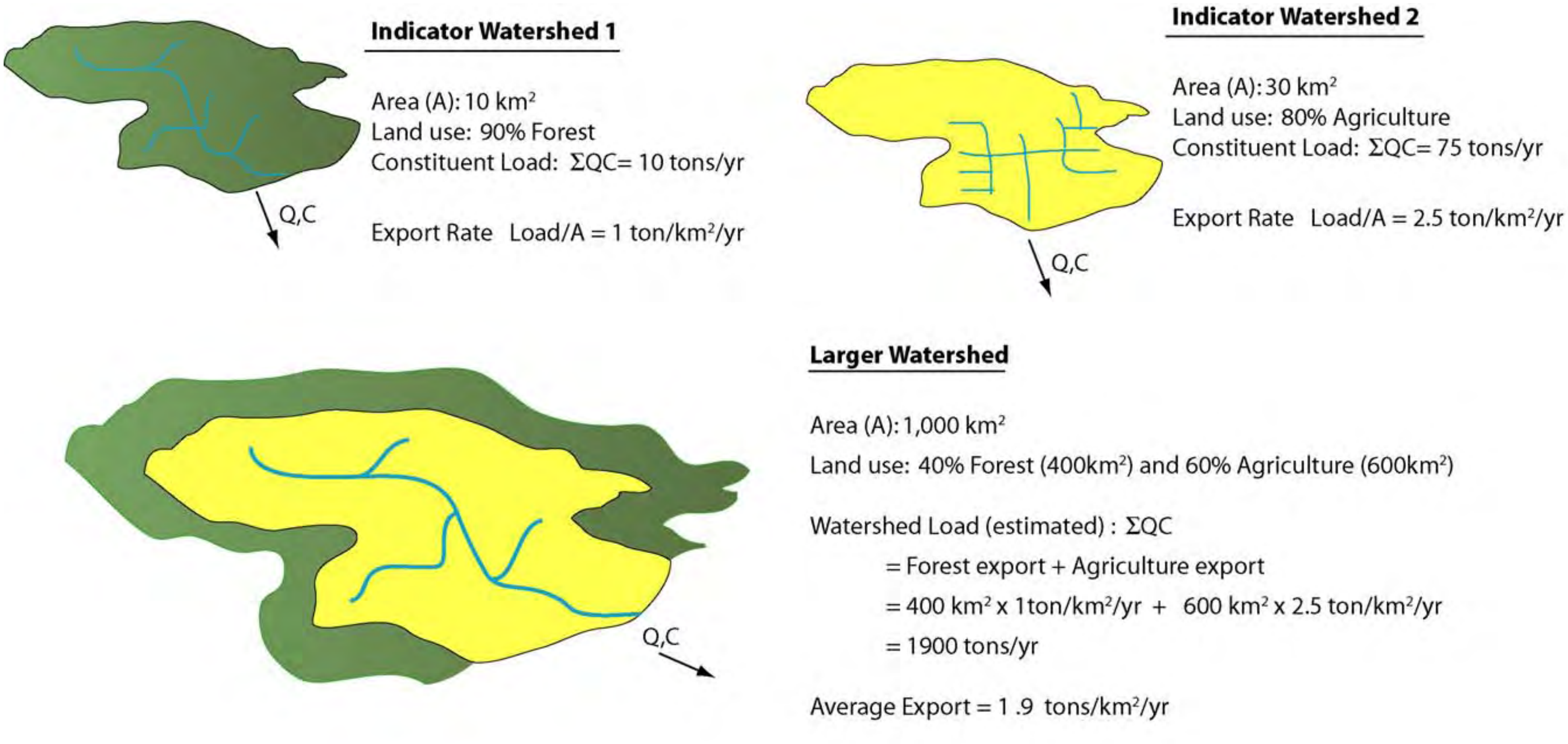

Figure 4-26. Export rates from specific land uses, weighted by the area of that land use in a watershed, can be used to compute the non-point source contribution for a mixed land use watershed.

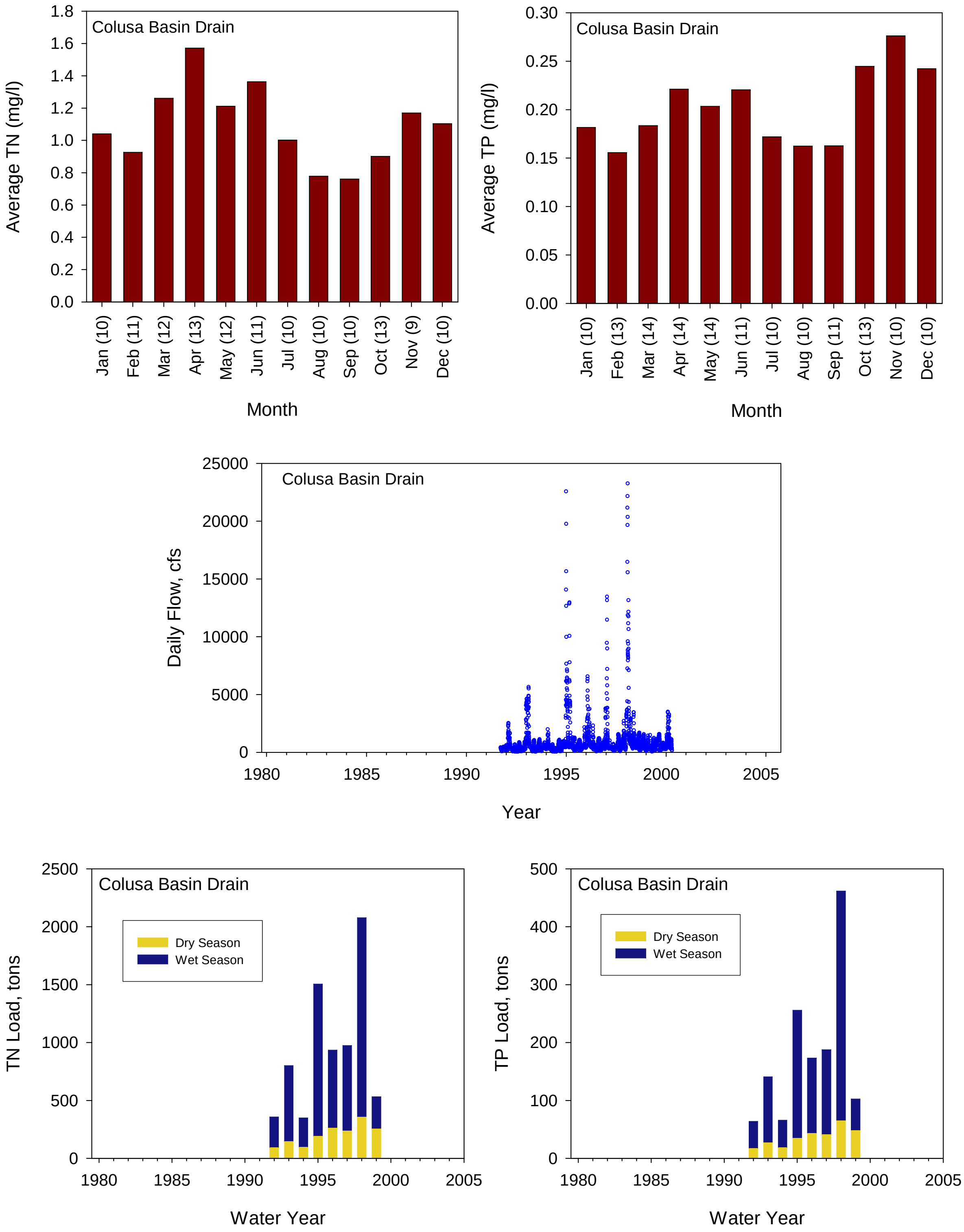

Figure 4-27. Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for the Colusa Basin Drain. These data were used to estimate the nutrient export rate from agriculture in the Sacramento River basin.

- Mud Slough was used for estimating agricultural loads in the San Joaquin River Basin as shown in Figure 4-28. For the Organic Carbon Conceptual Model Report (Tetra Tech, 2006), Harding Drain was used for agricultural loads in the San Joaquin Basin. Nutrient concentrations in the Harding Drain are impacted by effluent received from the City of Turlock wastewater treatment plant, however, and calculated monthly average concentrations were as high as 30 mg/l for TN and 10 mg/l for TP. Mud Slough also has some drawbacks associated with its use as representative of San Joaquin Valley agricultural loads. It contains an atypical mix of tile drainage transported via the San Luis drain and also receives overflow from private duck clubs. Thus, Mud Slough provides only a preliminary estimate of the export rate from agriculture in the San Joaquin Basin.

- Salt Slough was used for estimating wetland loads in the San Joaquin Basin as shown in Figures 4-29.

- The urban runoff export rate for nutrients was estimated using USGS NWIS data collected at Arcade Creek, which is a small, entirely urban, watershed (Figure 4-30). Data collected at the Natomas East Main Drainage Canal (NEMDC) may also be used for estimating urban runoff loads. Although this watershed is rapidly urbanizing, it still contains some agricultural land. The Arcade Creek watershed was considered the best choice for this analysis since it is an entirely urbanized watershed. Other urban runoff data in the Drinking Water Policy Database, from the cities of Sacramento and Stockton, could not be used for load calculations because these data were not accompanied by flow measurements. Figure 4-31 presents NO3-N, TKN, and TP data for the NEMDC and for dry weather and stormwater flows at Sacramento and Stockton. NEMDC data were obtained from the MWQI website for the period 2001 to 2004. The urban runoff data from Sacramento, Stockton, and from the NEMDC were compared to the data collected on Arcade Creek. Note that there is a degree of overlap among these data sources. Arcade Creek is a subwatershed of the NEMDC and both overlap with the Sacramento Stormwater program area. This fact should be taken into consideration when comparing the data. The monthly average concentrations for Arcade Creek ranged from 1 to 2.5 mg/L for TN and 0.2 to 0.5 mg/L for TP. The Sacramento, Stockton, and NEMDC nitrogen data showed some degree of variability with median concentrations of both NO3-N and TKN ranging from approximately 1 mg/l to 2 mg/l, which are comparable to Arcade Creek data. The Sacramento, Stockton, and NEMDC phosphorus data show median values from 0.3 to 0.8 mg/l, slightly higher than the Arcade Creek data.

- For the Sacramento Basin, no station could be clearly identified as a background station with insignificant anthropogenic activity. As a first approximation, the Yuba River watershed was used to estimate background

> loads (representing forest/rangeland) for the Sacramento River Basin. Of the major tributaries, the Yuba River watershed has the least amount of urban and agricultural land. For background loads representing forest/rangeland in the San Joaquin Basin, Merced River at Happy Isles Bridge near Yosemite was identified as a possible station. This station is part of the Hydrologic Benchmark Network, which is a USGS program that provides long-term measurements of streamflow and water quality in areas that are minimally impacted by human activities (http://ny.cf.er.usgs.gov/hbn/). Flows for this station are higher in the dry season, however, due to snowmelt in late spring. Because this behavior is not reflective of the majority of the basin, this station was not used to calculate an export rate for background loads.

The summary of export rates for various land uses in the Central Valley is presented in Table 4-7. Although it would be preferable to obtain separate export rates for the Sacramento and San Joaquin Basins because of the distinct differences in rainfall, this was not possible with existing data. Rainfall during water years 2002 and 2003 measure at three stations in the Sacramento Valley averaged 23.7 inches and measured at three stations in the San Joaquin Valley averaged 11.7 inches (MWQI, 2005), which is a factor of two difference. Therefore, when a rate from the Sacramento Basin was applied to the San Joaquin Basin (for urban runoff and forest/rangeland), the export rate was divided by two to account for the lower rainfall in the San Joaquin Basin. When a rate from the San Joaquin Basin was applied to the Sacramento Basin (for wetlands), the rate was multiplied by two to account for the higher rainfall in the Sacramento Basin. For agricultural land, separate values were used for the Sacramento and San Joaquin Basins.

In summary, it was not possible to calculate export rates for each type of land use present in the Central Valley and Delta. A limited amount of nutrient data was available from watersheds with one particular type of land use. Significant inherent uncertainty exists in the calculated export rates due to sparse or inadequate data, and in the application of export rates from one basin to another. Export rates, as currently approximated, could be improved through focused flow and concentration data collection in small, relatively homogenous watersheds.