S A N D I E G O R I V E R P A R K F O U N D A T I O N

LOWER SAN DIEGO RIVER WATER QUALITY CHARACTERISTICS

Cyclic Patterns, Averages, Variances and Trends in Water Quality Data

RiverWatch Water Quality Monitoring Results (October 2004 - December 2010)

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Lower San Diego River Water Quality Characteristics

Section 1 - SDRiverWatch Monitoring and Water Quality Data Summary

Introduction: This report provides a synopsis of the past 6+ years of water quality monitoring (WQM) data collected by the San Diego River Park Foundation's (SDRPF) RiverWatch Team. The information allows interested readers an understanding of the cyclic patterns, variances and trends in water quality characteristics evident within the lower San Diego River (SDR) watershed.

Monitoring Period & Coverage: Monthly monitoring over past 6 years (Oct. 2004 – Dec. 2010) covering Lower San Diego River extending downstream from Lakeside (river mile 19.8 elev. 340 ft amsl) to the Estuary (river mile 2.96, elev. 4.8 ft amsl) at I-5/Pacific Hwy. overpasses. The lower watershed and monitoring sites are shown on **Figure 1.1.**

Monitoring Sites: 15 total - 12 on main course (Mission Valley Section - sites 1-7, Mission Gorge Section - sites 8-10, Santee Basin Section - sites 11-15T) plus 3 tributary ('T') stream sites are listed in **Table 1.1.** Site locations, river milage, bed elevations and coordinates are provided in **Table 1.2.**

Table 1.1 SDR Sections, Reaches and Monitoring Sites

Section/Reach/Tributary	Site #	Comments
Estuary Entrance	1E/1W	Tidal Influence at transition to SDR Estuary
Lower Mission Valley (LMV)	2E/W, 3 & 4	4 miles of lower river extending to I-805
Upper Mission Valley (UMV)	5,6 & 7L/Z	4 mile stretch from I-805 to Princes View Dr
Mission Valley (West Sites)	1-7	Western 8 mile portion through Mission Valley
Mission Gorge (MG)	8 & 10	5 mile mid-section, Princess View Dr to Kumeyaay Lk
Mission Gorge (MG)	8-10	5 mile mid-section, Princes View Dr to Kumeyaay Lk
Lower Santee Basin (LSB)	11-12T	2 mile stretch from Kumeyaay Lk to Carlton Hills Blvd
Upper Santee Basin (USB)	13-15T	3 mile stretch from Carlton Hills Blvd to Riverford Rd
Santee Basin (SB)	11-15	5 mile eastern section from Kumeyaay Lk to Lakeside
Eastern Portions (East Sites)	8 -15T	10- mile eastern/upper 3 reaches (2 sections)
Tributaries:		
Murphy Canyon Creek [a]	5T	Enters SDR southwest of Qualcomm Stadium
Birchcreek Outfall [b]	9T	Enters SDR at Sycott Wash (d/s of Site 8)
Santee Lakes/Sycamore Creek	12T	Enters SDR d/s of Carlton Oaks GC (u/s of Site 11)
Forester Creek [c]	15T	Enters SDR just u/s of Carlton Oaks Golfcourse
Lower SDR Watershed (Mid-SDR)	1-15T	Weighted average of all 5 reaches or all 3 sections

(a) Monthly monitoring discontinued in WY07; site also termed Qualcomm Stadium.
(b) Monthly monitoring initiated in WY08; site also termed Jackson Drive Outfall at Mission Trails Park.
(c) Monthly monitoring initiated in 2007.

Color Codes:
Reaches (5) - averaged values for combination of adjacent sites excluding tributaries within identified portions of river (LMV, UMV, MG, LSB, USB) .
Sections (3) - averaged values for adjacent reaches (MV = LMV+UMV, MG=MG, SB = LSB+USB
Tributaries (3) – sites located on small creeks/drainages tributary to main watercourse.
Mid-SDR – computed values for entire lower watershed (distance-weighted average of all 5 reaches or all 3 sections); average (LMV+UMV+MG+SB) or average (MV2+MG+SB).

Table 1.2 - SDR WQM Site Information

Site #	Site Name	u/s mi.	Elev. ft	Location	GIS Coordinates	
					Latitude	Longitude
LMV - Lower Reach W. Mission Valley: I-5 Bridge to I-805 Bridge (Sites 1-4 below)						
1	Estuary W/E	2.96	6	Between PC Hwy & I-5 on encased sewer main	32.76131	-117.2037
2	River Gardens E/W	3.50	11	W of YMCA past Trolly overpass at riffle	32.76230	-117.1944
3	Fashion Valley Mall W	5.08	22	Behind Parking Structure at T&C Ped. Bridge	32.76517	-117.1687
4	FSDRIP	5.98	36	N. of Mimi's Cafe on Mission Center Rd Bridge	32.76986	-117.1548
UMV - Upper Reach E. Mission Valley: I-805 Bridge to North end of Admiral Baker Field (Sites 5-7 below)						
5	Ward Rd Bridge	8.89	50	S of Trolly at Del Rio S intersection	32.78024	-117.1103
6	Kaiser Ponds	9.46	56	Mission SD de Acala at SD Mission Rd	32.78406	-117.1042
7	Admiral Baker Field	9.98	58	L. Lower (below Friars Rd bridge)	32.79038	-117.1031
	Z. ABF - Zion	10.2	62	Z. Terminus of Zion Ave at Riverdale St	32.79304	-117.0998
MV - Mission Valley Section: Estuary to Admiral Baker Field (Sites 1-7 above) [LMV+UMV]						
MG - Mission Gorge Reach: Quarry Area to Old Mission Dam (Sites 8-10 below)						
8	Mission Trails at Jackson Dr	13.8	159	At SDCWA/Scycott Crossing	32.82124	-117.0621
9T	Birchcreek OF	13.9	198	San Marcos Tributary along Jackson Dr. trail	32.82268	-117.0622
10	Old Mission Dam W/E	15.7	265	Downstream side of OMD	32.83977	-117.0433
MG - Mission Gorge Section: Quarry Area to Old Mission Dam (Sites 8-10 above) [MG]						
LSB - Lower Reach Santee Basin: W. Hills Pkwy to Carlton Hills Blvd Bridge (Sites 11-12T below)						
11	West Hills Pkwy	17	300	at/below West Hills Pkwy Bridge	32.83936	-117.0244
12T	Carlton Oaks Dr/Santee	18.2	320	Sycamore Ck (Santee Lakes) at Carlton Oaks Dr.	32.84431	-117.0064
USB - Upper Reach Santee Basin: Carlton Hills Blvd Bridge to Riverford Rd (Sites 14-15T below)						
13	Mast Park	18.5	330	Pedestrian Bridge behind (N of) Walmart	32.84696	-116.9734
14	Cottonwood Ave/RCP	19.8	340	W of RCP plant at Chubb Ln/Cottonwood Ave	32.84434	-116.9895
15T	Forester Creek	18.9	336	Forester Ck (tributary) at Prospect Ave.	32.83221	-116.9866
SB - Santee Basin Section: West Hills Parkway to Lakeside (Sites 11-15T above) [LSB+USB]						
Mid-SDR - Lower San Diego River Watershed: Estuary to Lakeside (Sites 1-15T above) [MV2+MG+SB]						

WQ Parameters: Seven measured and recorded parameters (Temp, pH, SpC, DO, DO%Sat, NO_3 & PO_4) plus subjective field observations re: environs and characteristics are listed in **Table 1.3.** As nutrient testing for NO_3 and PO_4 is carried out at five selected sites; two in West (2&6) and three in East (11,14&15T), respectively, results are not used in performing statistical analyses regarding reaches/sections of the river. Number of datum for each of the five physical-chemical parameters monitored monthly at each site over the 6-yr period (Oct. 04 - Dec. 10) is in the range of 60 to 75.

Protocol: *East Side* – (Santee Basin & Mission Gorge Sections). The eight sites within upper three reaches (MG, LSB & USB) typically monitored 3rd Fri./Sat. of month. *West Side* - (Mission Valley Section). Seven sites within lower two reaches (LMV & UMV) monitored monthly, typically 3rd Sun. morning of month.

Table 1.3 - Lower SDR Water Quality Monitoring Parameters

WQ Parameter	unit	Comments
Measured Monthly at All Sites:		
1. Temperature (Temp)	oC	Basic characteristic and WQ driver
2. pH	-	Degree of Acidity or Alkalinity (7.0 pH neutral)
3. Specific Conductivity (SpC)	mS/cm	Measure of ionic content or dissolved solids
4. Dissolved Oxygen (DO)	mg/L	Good indicator of relative/overall water quality
5. Percent of DO Saturation (DO%Sat)	%	Same as DO, good indicator of general water quality
Sampled/Tested Monthly at Selected Sites: (typically 4 - 2 East & 2 West)		
6. Nitrate (NO_3-N)	mg/L	Important nutrient for biological activity
7. Phosphate (PO_4-P)	mg/L	Key nutrient for biological activity
Discontinued on regular basis in 2006:		
8. Turbidity	NTU	Discontinued due to inaccurate/invalid readings
9. Barometric Pressure	mBars	Suspended readings as data available externally
Environmental Observations Recorded at All Sites:		
Abnormal conditions (scum, discoloration, odors, etc.), trash/debris, homeless encampments, biological activity (aquatic, avian, terrestrial), expansion of invasive species, erosion, scouring, other noteworthy comments re: water-course, shoreline and adjacent environs.		
General WQ Conditions Observed at All Sites: (numerical coding added in 2010)		
Weather Conditions, Presence of Algae, Clarity, Color, Odor, Flow, Foam, Litter, Odor, Oil & Grease		

A Team Leader and Volunteers (typically 3-8 persons) meet at an appointed site, organize field equipment/transportation, drive to sites, measure physical-chemical water quality using Sonde instrument, note special conditions/observations, collect samples for subsequent testing, return to office, perform nutrient (NO_3 & PO_4) tests, store samples for subsequent laboratory (e.g., sediment toxicity) analyses and clean/check in equipment.

Data Management: Water quality data are managed in a three-step process.
1. *Raw* (source) data - each site, several of which have two monitoring locations (e.g. upstream/ downstream of dam, riffle or crossing), date/time, measured WQ parameters, and non-quantifiable supporting observations and comments.
2. *Compiled* (vetted/proofed) data - provided on Ecolayers w/date, site location, parameter value and additional observations of interest.
3. *Processed* (formatted/aggregated) data - with statistical computations associated with SDR sites, reaches, sections and tributaries for each WQ parameter of interest.

Statistical Computations: Various basic statistical values have been calculated from the data.

Mean – average of a series (sum of values/number of values)
Median – middle value of an ordered series (50% larger/50% smaller)
Minimum – lowest/smallest value measured
Maximum – highest/greatest value measured
Range – Difference between Maximum and Minimum

Statistical Computations (cont.):

1st Quartile (Q1) – 25% of values smaller (75% larger)
2nd Quartile (Q2) – 50% of values larger/smaller (same as median)
3rd Quartile (Q3) – 75% of values smaller (25% larger)
Variance – sum of the squares of deviation from the Mean or Average
Standard Deviation (SD) – square root of Variance
Skew – third moment about the Mean divided by the Standard Deviation (SD)
Coefficient of Variance – Variance divided by the Mean
Trendline - Moving Average taken over 12 month period

WQM Data Summary:
A *temporal* (WY05 through WY10) summary of SDRPF RiverWatch water quality monitoring data for overall Mid-SDR (Lower SDR Watershed) annual, summer and winter values is provided in **Table 1.4.** The percent change in most recent (WY10) values from the previous year (WY09), from the initial year (WY05) and from the 6-year Average is also presented for each parameter. Overall annual average physical-chemical water quality within the lower watershed, as expressed by the WQI, has declined by approximately 15 percent over the past 6 years. Winter season values (Dec-March) are down approximately 8 percent, while summer values (June-Sept) are down 21 percent over the 6-yr period. The average annual WQI for WY10 is down 10 percent from the previous (WY09) year.

A *spatial* (by distance and reach) summary of SDRPF RiverWatch water quality monitoring data for average annual, summer and winter values for each parameter is provided in **Table 1.5.** The Mission Gorge reach/section consistently presents the best water quality within the lower SDR watershed, whereas the Upper Mission Valley reach (just downstream) presents the lowest. The lower/west section of the river (Mission Valley) consistently presents poorer water quality both on an average-annual and summer-season basis than evident in either upstream section. Overall (Mid-SDR) 6-yr average water quality within the lower watershed ranges from low 'Marginal' (D-) in summer to 'Good' (B) in winter, or 'Fair' (C) expressed on a average annual basis.

Winter and average annual SDR water quality is anticipated to generally improve should WY11 continue to be an above average rainfall and runoff -river discharge year. Summer water quality results could, however, continue to remain poor, should dry-weather flows next summer be significantly below season norms.

Questions regarding this WQM database or interpretation of results can be directed to the attention of the report's author, John C. Kennedy, through contacting SDPRPF at info@SanDiegoRiver.org, or calling the WaterWatch Coordinator at 619-297-7380.

Figure 1.1 - Lower SDR Watershed and WQM Sites

(Google Earth) - *see next full page*

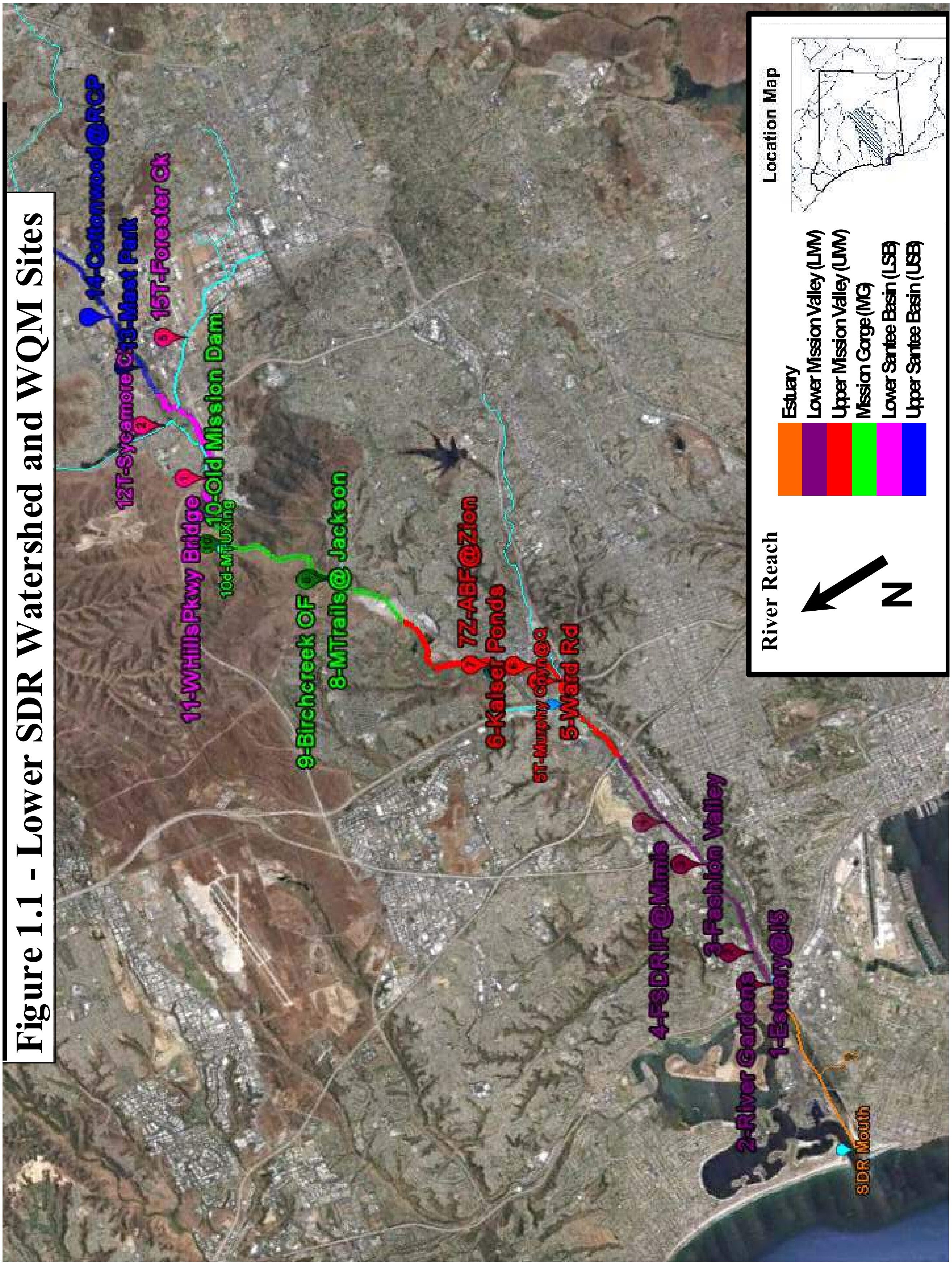


Figure 1.1 - Lower SDR Watershed and WQM Sites

Table 1.4 WQM Data Summary (Mid-SDR Temporal Averages)

	WY05	WY06	WY07	WY08	WY09	WY10	6-Yr Avg.	Percent Change		
								1 Yr [a]	6 Yr [b]	Avg. [c]
Annual (Oct-Sept):										
ADF, cfs	76	14	10	19	21	36	**29**	72%	-52%	13%
Temp, ºC	18.0	18.4	17.7	17.6	17.6	18.1	**17.9**	2.4%	0.3%	1.0%
SpC, uS/cm	2.08	2.15	2.37	2.28	2.45	2.32	**2.28**	-5%	12% [d]	2.1%
DO, mg/L	6.91	5.80	5.60	6.11	5.93	5.17	**5.92**	-13%	-25%	-13%
DO%Sat, %	73	61	58	64	62	54	**62**	-12%	-25%	-12%
pH	7.6	7.3	7.4	7.5	7.5	7.5	**7.45**	0.2%	-1.4%	0.2%
WQ Index	48	43	40	41	40	36	**41**	-10%	-15%	-12%
Grade	C+	C	C	C	C	C-	**C**	down	down	down
Rating	FAIR	FAIR	FAIR	FAIR	FAIR	FAIR	**FAIR**			
Summer (June-Sept):										
ADF, cfs	3.6	2.5	1.5	1.6	1.2	1.7	**2.0**	44%	-52%	-14%
Temp, ºC	21.1	23.6	21.7	22.9	22.7	22.0	**22.5**	-3.2%	-0.5%	-2.2%
SpC, uS/cm	2.40	2.17	2.59	2.73	2.89	2.61	**2.57**	-10%	9%	1.8%
DO, mg/L	5.17	4.83	4.48	5.24	4.47	4.28	**4.74**	-4%	-17%	-10%
DO%Sat, %	60	56	50	60	51	48	**54**	-5%	-19%	-11%
pH	7.5	7.4	7.4	7.5	7.5	7.5	**7.47**	1.2%	0.2%	0.9%
WQ Index	34	30	25	28	24	23	**28**	-3%	-21%	-15%
Grade	D+	D	D-	D	E+	E+	**D**	unchg	down	down
Rating	MAR	MAR	MAR	MAR	POOR	POOR	**MAR**			
Winter (Dec-March):										
ADF, cfs	175	23	22	51	54	91	**67**	69%	-48%	36%
Temp, ºC	13.9	13.0	13.8	12.3	13.1	14.2	**13.4**	8.1%	2.4%	5.9%
SpC, uS/cm	1.76	2.13	2.16	1.82	2.01	2.04	**1.99**	1.1%	16%	2.4%
DO, mg/L	8.65	6.77	6.73	6.98	7.40	6.05	**7.10**	-18%	-30%	-15%
DO%Sat	86	66	67	68	73	61	**70**	-17%	-30%	-13%
pH	7.5	7.3	7.4	7.7	7.5	7.3	**7.47**	-1.4%	-2.6%	-1.7%
WQ Index	61	56	54	54	56	51	**56**	-9%	-8%	-7%
Grade	B	B	B	B-	B	B-	**B**	down	down	down
Rating	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	**GOOD**			

(a) Percent change in this year's value (WY10) from last year (WY09).
(b) Percent change in this year's value (WY10) from first year (WY05).
(c) Percent change in this year's value (WY10) above (+) or below (-) 6-yr Average.
(d) Changes in red represent periods of declining quality.

Table 1.5 WQM Data Summary (SDR 6-Yr Spatial Averages)

Section	Mission Valley		Mission Gorge	Santee Basin		**Watershed**
Sites	1-4	5-7	8-10	11,12T &15T	13&14	all (1-15T)
Reach	LMV	UMV	MG	LSB	USB	**Mid-SDR [a]**
Annual (Oct-Sept):						
ADF, cfs	37	32	23 [b]	23	17	**29**
Temp, °C	19.1	17.9	17.3	17.6	18.1	**17.8**
SpC, mS/cm	2.58	2.57	2.17	2.00	1.95	**2.29**
DO, mg/L	5.75	4.88	7.83	6.49	5.82	**5.92**
DOSat, %	62	51	82	67	62	**62**
pH	7.4	7.4	7.4	7.5	7.7	**7.45**
WQ Index	39	33	54	48	33	**41**
Grade	C	D+	B-	C	D+	**C**
Rating	FAIR	MARG	GOOD	FAIR	MARG	**FAIR**
Summer (June-Sept):						
ADF, cfs	2.3	2.0	1.7 [c]	1.6	1.2	**2.0**
Temp, °C	24.5	20.9	21.8	21.2	23.0	**22.3**
SpC, mS/cm	3.27	3.20	2.73	2.48	2.17	**2.83**
DO, mg/L	3.83	2.97	6.95	5.46	4.86	**4.74**
DOSat, %	47	34	79	60	57	**54**
WQ Index	20	15	43	39	24	**28**
Grade	E	E	C	C	E+	**D**
Rating	POOR	POOR	FAIR	FAIR	POOR	**MARG**
Winter (Dec-March):						
ADF, cfs	87	73	55	47	35	**67**
Temp, °C	19.3	17.3	17.1	17.0	18.0	**17.8**
SpC, mS/cm	1.82	1.77	1.49	1.47	1.62	**1.61**
DO, mg/L	7.06	6.57	8.72	7.53	6.78	**7.64**
DOSat, %	71	63	85	73	66	**75**
WQ Index	58	53	62	55	42	**56**
Grade	B	B-	B	B-	C	**B-**
Rating	GOOD	GOOD	GOOD	GOOD	FAIR	**GOOD**

(a) Distance-weighted average of all reaches within the Lower SDR watershed.
(b) Estimated flow based on averaged river gains and losses between Santee Basin and Mission Valley.
(c) Intermittent - there have been a number of summer months when river flow in the Mission Gorge reach has been non-detectable (below ground); 1.3 cfs represents an average daily value determined during portions of the summer season (J,J,A,S) when flows were detectable.

Section 2 - SDR Hydrology and Water Quality

Stream flow or discharge, the volume of water that moves past a designated location over a fixed period of time, is a primary driver of changes in water quality. Flow, often expressed as cubic feet per second (cfs) or million gallons per day (mgd), is the amount of water moving off a watershed into a channel, as affected by weather (increasing during rainstorms and decreasing during dry spells) and changing during different seasons. It decreases during summer months when rainfall is minimal, evaporation rates high and actively growing riparian vegetation is extracting water from the ground. August and September are typically our months of lowest flow. A function of both volume and velocity, flow has a major impact on living organisms, watercourse habitats and on overall stream water quality. Velocity, typically increasing as volume increases, determines the kinds of organisms that live in the system and also affects the amount of silt and sediment that is transported. Fast moving watercourses usually have higher levels of DO than slow streams as they are better aerated.

SDR average daily flow (ADF) values as recorded at the two USGS gauging stations located in the lower watershed are expressed in **Table 2.1** for both the monitoring period (Oct 2004 - Sept 2010) and the past 45 years (1965-2010) of official records**.** The six- and 45-year average annual values are in close accord.

Table 2.1 - Lower SDR Average Daily Flows (WY05-WY10)

Season	Fashion Valley		Santee Basin		Mid-SDR [a]	
Units [b]	cfs	mgd	cfs	mgd	cfs	mgd
Fall (Oct/Nov)	21	13.5	14	9.1	18	11.3
Winter (Dec-Mar)	83	53.4	41	26.8	62	40.1
Spring (April/May)	17	11.1	10	6.5	14	8.8
Summer (June-Sept)	2.4	1.5	1.7	1.1	2.1	1.3
6-Yr Annual Avg. (Oct-Sept)	37.1	24.0	21.0	13.6	29	18.8
Recent 45-Yr Avg. (1965-2010)	36.3	23.5	21.7	14.0	29	18.7
Annual Discharge, AF [c]	26,320		15,680		20,940	

(a) Lower SDR watershed average daily flow represents a theoretical mean hydrologic condition based on averaging the two USGS stream gauging station values.
(b) ADF values are expressed in both cubic feet per second (cfs) and million gallons per day (mgd); 1 mgd = 1.7 cfs.
(c) Average annual total discharge expressed in acre-feet (1 AF = 325,900 gallons) between 1965 and 2010.

Correlations between total annual rainfall and ADF considered over the past 97 years of hydrologic record and during the period of SDRPF RiverWatch monitoring for the two lower SDR gauging stations are presented in **Tables 2.2 and 2.3**, respectively. WY05 was a "Very Wet" hydrologic year, whereas WY07 was "Very Dry". WY06 & 08 were "Dry" years while the past two years (WY09 & 10) were considered "Normal" in terms of both total annual rainfall and average daily flow. The 6-yr ADF in the East and West is 21 and 37 cfs, respectively; both values are approximately the same as the past 45- and 97-yr SDR average daily discharges. Based on December rainfall, WY11 shows indications of being an "Above Normal" or "Wet" in terms of total annual rainfall, watershed runoff and river discharge.

Monthly discharge data (min, max and average daily flow) at the two gauging stations extending from Oct 2004 through Sept 2010 are presented in **Chart 2.1.** Average daily flow (ADF) for the SDR system varies from less than 1 cfs during the summer (dry) months to nearly 200 cfs during some winter (wet) seasons in the East (Santee Basin) and up to 380 cfs in the West (Mission Valley) section. ADF values have been trending upward since WY07 as shown by the 12-month moving average.

Table 2.2 - Rainfall and Long-Term ADF (1914-2010)

Type	# of Years	Percent of Total Years		Total Annual Rainfall [a]			Average Daily Flow, cfs		
				inches	mm	Avg., mm	East (b)	West (c)	Mid-SDR
Very Wet	3	3%	30%	>20	>500	580	105	175	142
Wet	10	10%		15-20	380-499	430	75	125	102
Above Norm [d]	16	17%		12-15	300-379	340	40	68	54
Normal	38	39%	39%	8-12	200-299	245	14	24	18
Dry	25	26%	31%	5-8	125-199	160	7	11	9
Very Dry	5	5%		<5	<125	100	5	8	6.5
Long-Term Avg.	97	100%		10.2		260	26	43	35

a) Total Annual Rainfall (October 1 through September 31).
b) Santee Basin USGS Stream Gauge Station # 11022480 at Mast Rd.
c) Mission Valley USGS Stream Gauge Station # 11023000 at Fashion Valley Mall; incomplete data prior to 1968.
d) Slightly Above Normal annual rainfall (12-15 in/yr) and SDR Average Daily Flows (40-100 cfs).

Table 2.3 - Annual Rainfall and Average Daily Flow (WY05-WY10)

(Type of Year)	Total Annual Rain-fall		Variance [a]	ADF, cfs			Variance [d]
	mm	inches		East [b]	West [c]	Mid-SDR	
WY05 (Very Wet)	576	22.7	122%	51	100	76	118%
WY06 (Dry)	153	6.02	-41%	11	18	14	-59%
WY07 (Very Dry)	98	3.86	-62%	7	13	10	-71%
WY08 (Dry)	185	7.28	-29%	13	25	19	-45%
WY09 (Normal)	232	9.13	-11%	15	27	21	-39%
WY10 (Normal)	269	10.60	4%	30	42	36	4%
6-Yr Average (2005-10)	254	10.0	-2%	21	37	29	-17%
27-Yr Avg. (1983-2010)	261	10.3	1%	25	39	32	-9%
97-yr Long-Term Avg.	260	10.2	0%	26	43	35	0%

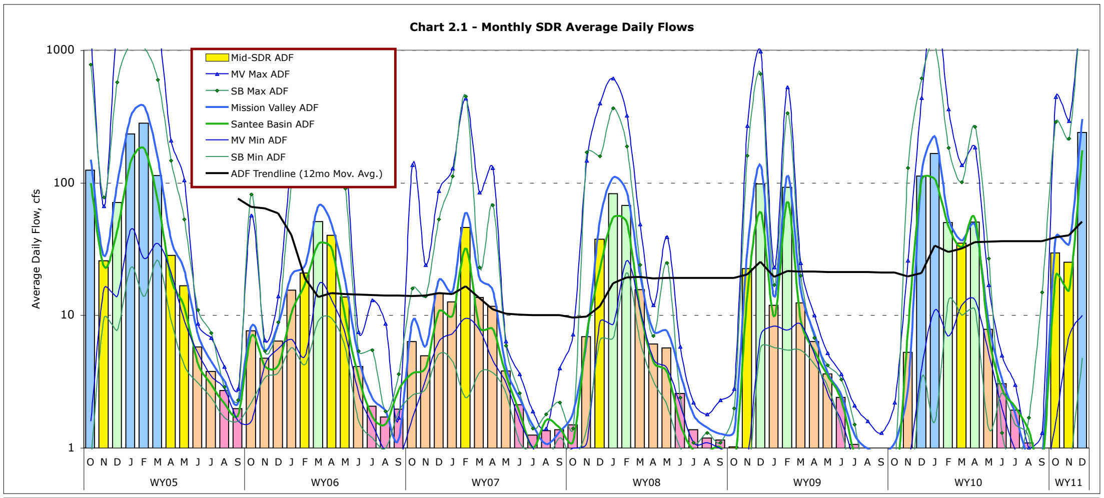
(a) Percent difference from long term average annual rainfall (260 mm/yr or 10.2 in/yr); black-above, red-below.
(b) Santee Basin USGS Stream Gauge Station at Mast Rd.
(c) Mission Valley USGS Stream Gauge Station at Fashion Valley Mall; incomplete data prior to 1965.
(d) Percent difference from long-term average annual daily flow (i.e., 26 cfs at Santee and 43 cfs in Mission Valley).

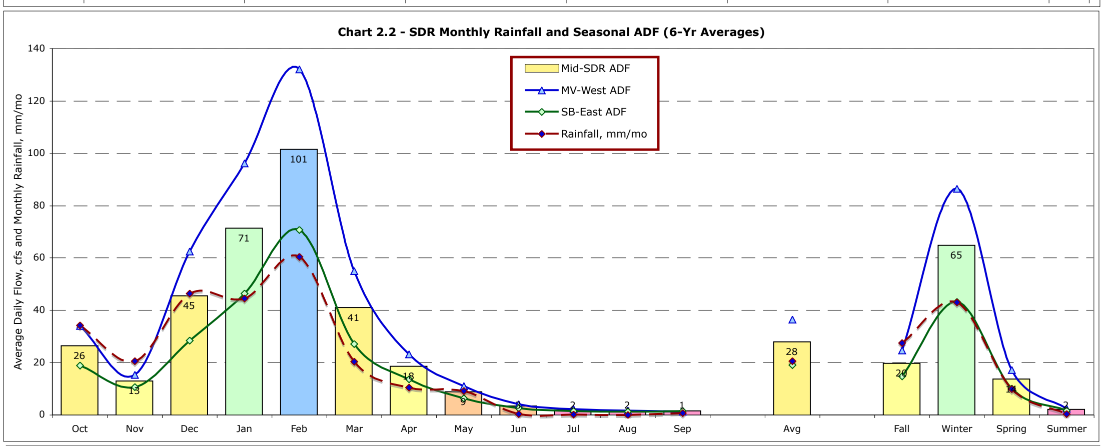
Monthly and seasonal average annual flows and rainfall over the 6-yr monitoring period for both stations are shown in **Chart 2.2.** The seasonal flow patterns describe the range, variance and correlation in monthly ADF and rainfall over the past 6 years. Winter wet season SDR flows within the lower watershed are 100 to 250 times greater on average than the summer, dry season flows.

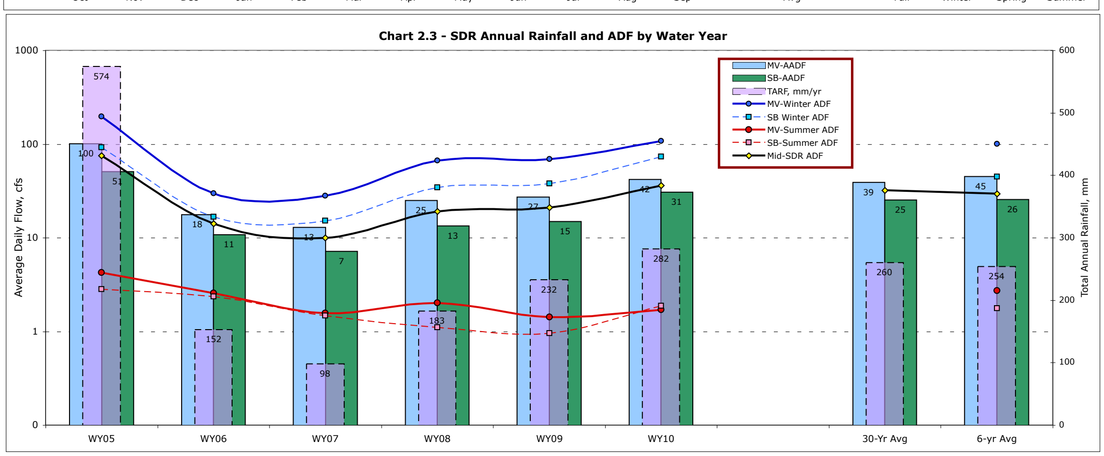
Average annual, winter and summer flows and rainfall for each of the last 6 water years are presented in **Chart 2.3.** Highest flows during the monitoring period at both gauging stations were recorded in WY05 (very wet year); the lowest in WY07 (very dry year). Water years (WY06-08) each witnessed below normal rainfall and runoff/flow. The past two years presented normal rainfall/runoff and flow conditions. The relationship between rainfall, discharge and general physical-chemical water quality within the lower SDR watershed is further explored in subsequent sections of this report.

Monthly SDR Average Daily Flow (Oct. 2004 - Dec. 2010)
Charts 2.1, 2.2 & 2.3
MV (blue lines) USGS 11023000 SDR @ Fashion Valley
SB (green line: USGS 11022480 SDR @ Mast Rd Nr Santee

Flow, cfs	
> 100	Well Above Normal (Wet Winter Month)
50--99.9	Above Normal (Typical of Winter period)
10--49.9	Normal (Typical of Spring & Fall periods)
3--9.9	Below Normal (Typical of Summer period)
0.1--2.9	Well Below Normal (Dry Summer Month)







Section 3 - SDR Water Quality Index

Interpretation and Communication of WQM Data Using an Index

Background: SDRPF's RiverWatch monitoring team's water quality index (WQI) is an attempt at an imperfect answer to non-technical questions regarding Lower San Diego River water quality. The index constitutes a single unit-less number ranging from 1 to 100; a higher number indicative of better water quality. In general, sites scoring 75 or above exceed expectations for water quality and are of "least concern," scores of 25 to 75 indicate "intermediate concern," while quality at sites or sections with scores below 25 do not meet expectations and are of "greatest concern." For temperature, pH, specific conductivity and dissolved oxygen, the index expresses results relative to generally acceptable concentration levels required to maintain beneficial uses based on State of California Water Quality Standards. For flows, where standards are non-specific, results are expressed relative to general conditions in coastal southern California's non-estuarine watercourses. The multiple physical-chemical parameters are combined and results aggregated to produce a score for each site, river reach and section over time and distance.

Political decision-makers, non-technical water managers, vested watershed stakeholders and the general public usually have neither time nor training to study and understand a traditional, detailed technical review of water quality data. Over the past several decades numerous indexes have been developed to summarize water quality data in an easily expressed and readily understood format. Water quality professionals are frequently resistant to the automated, uncritical summarization represented by such indexes and there are sound reasons to use results with caution. Professionals often prefer to give no answer rather than an imperfect answer that can lead to misunderstanding. Layman, however, prefer an imperfect answer to no answer at all. While the use of an index may not be the best way to understand large-scale water quality conditions, it is for many the only way. Professionals must understand the need for imperfect answers, while others need to recognize and accept any answer's limitations.

Water quality indexing was first proposed and demonstrated back in the 1970s, however, prior to the personal computer era, calculations were somewhat labor intensive and it was not widely used or accepted by many monitoring agencies. As use and limitations were commonly misunderstood, the potential of using an index in communicating status and trends was often overlooked. Evaluation of water quality only in terms of raw data can be very misleading and confusing not only for the general public but also to multiple stakeholders with diverse and sometimes conflicting perspectives. As a result, it is typically difficult for individuals interested in water quality to interpret reams of raw data in order to gain an understanding of water quality conditions. This quest often results in faulty conclusions regarding water quality status and watershed management practices. An index is an attempt to integrate complex analytical data and generate a single number expressing the relative degree of impairment of a given water body at a given point in time or given locale. The underlying objective of the exercise is to enhance communications with the general public, interested stakeholders, public agencies and increase citizen awareness of water quality conditions.

Limitations. By design indexes contain less information than the raw data they summarize; many uses of water quality data cannot be met with an index. An index is generally most useful for comparative purposes (e.g., what river sites or reaches have particularly poor water quality?) and for temporal questions (e.g., how is the water quality at present relative to what is has been in the past?). Indexes are less suited to specific questions. Site specific decisions need to be based on analysis of original water quality data. Basically, an index is a useful tool for "communicating water quality information to the lay public and to legislative decision makers," it is not, however "a complex predictive model for technical and scientific application". This index was developed as a mechanism to summarize and report routine SDRPF monitoring data to interested parties. SDRPF's RiverWatch team does not monitor biological constituents or toxic substances thus issues related to public health, body contact recreation and aquatic life are not effectively addressed by the index.

Besides being general in nature (i.e., imprecise), there are several reasons that an index may fail to accurately communicate water quality information. First, most indexes are based on pre-identified sets of water quality constituents. For example, a specific site may show a good WQI score, and yet have water quality impaired by other constituents not included in the index. Another reason, data aggregation can mask, normalize or over-emphasize short-term water quality issues. A satisfactory WQI at a particular site or reach does not necessarily mean that water quality is or always was satisfactory. A good score, however, does at least indicate that inferior water quality for those constituents evaluated is not chronic during the period included for the index.

SDR Index. The San Diego River Water Quality Index (SDR WQI) is a number that expresses basic physical-chemical river quality by integrating aggregate data of four key water quality parameters (Temp, pH, SpC and DO) combined with stream discharge (ADF) through determination of "Q-values" (numerical ratings) for each. The resulting normalized values have then been combined, without weighting, to arrive at an overall index ranging in value from 0 to 100. The SDR WQI values, grade, color coding, range and general conventions employed are presented in **Table 3.1.**

Table 3.1 SDR Water Quality Index

SDR WQI (0-100)	GRADE	COLOR CODE	RANGE	PHYSICAL-CHEMICAL WATER QUALITY STANDARDS	GENERAL
75 or Greater	A - Very Good	Dark Blue	25%	Well Above Acceptable WQ Criteria	Least Concern
50 - 74	B - Good	Light Blue	25%	Exceeds Minimum Acceptable Criteria	Intermediate (25-74)
35 - 49	C - Fair	Green	15%	Meets Most Criteria	
25 - 34	D - Marginal	Yellow	10%	Meets Some Minimum Criteria	
10 - 24	E - Poor	Brown	15%	Meets Few Minimum Acceptable Criteria	Greatest Concern
0 - 9	F - Very Poor	Red	10%	Well Below Minimum Acceptable Criteria	

In summary *the index has been developed for the purpose of providing a simple and concise expression of regularly monitored physical-chemical water quality data compiled by the SDRPF RiverWatch Team as well as several other monitoring agencies; it is intended to aid in assessment of the Lower San Diego River watershed primarily for non-body contact recreational uses and environmental enhancement. It constitutes a mechanism to compare averages, variances and trends in normalized values over time (temporally) and by relative location (spatially) within the watershed. The index allows anyone to easily interpret large amounts of aggregated data and relate overall water quality variation to changes, be they from natural causes or man-made impairments. The WQI is used to identify general water quality trends over the past 6 years of monitoring and potential problem areas within the SDR watershed. Such patterns and locations can then be screened and evaluated in greater detail through direct observation of pertinent site-specific data by public agencies and water quality professionals entrusted with protection and enhancement. Used in this manner, the index provides a supplemental metric for evaluating effectiveness of San Diego River water quality improvement programs and also assist responsible agencies and organizations in establishing priorities for watershed management purposes.*

Annual, monthly and seasonally averaged SDR WQI values are presented on subsequent pages in **Table 3.2** by river reach, section, overall (Mid-SDR) average and in **Table 3.3** for each water year over the past 6 years (WY05-WY10) of monitoring. The tabulated results are presented temporally in **Charts 3.1** (monthly values over past 6 years for each reach plus trend-lines - 12-mo moving average) and **3.2** (6-yr averaged monthly, seasonal and annual values) and spatially in **Chart 3.3** by site number in chronological order ascending upstream. The average river distance between individual sites is approximately 1 mile although there is a considerable range (from <0.1 to >1.8 miles) from one locale to another.

Comments/Observations/Findings: The recurrent cyclic pattern of water quality data expressed on a monthly and averaged basis within the lower SDR watershed is evidenced in both **Charts 3.1 and 3.2**, respectively. Index values at all river monitoring sites, reaches and sections are highest in the winter (wettest period) and lowest in the summer (driest) months. Regardless of time of year or season, WQI values are highest in the Mission Gorge reach/section (Sites 8-11), and lowest in the UMV (Sites 5-7) reach. Eastern upstream sites (8-15T) typically present slightly higher values throughout the year than the downstream western sites (1-7) as evidenced in **Chart 3.3.**

WQI trend-lines for the SDR reaches, sections and an aggregated average value (Mid-SDR) are shown on **Chart 3.1.** Values have declined by approximately 10 points over the 6-yr monitoring period in each of the river's sections and for the entire lower watershed as a whole. Mid-SDR annual average values (35-50) for lower watershed remain in the C (Fair) water quality range. This past water year (WY10) presented the lowest overall Mid-SDR WQI for all river sections as shown in **Chart 3.3**; with summer values running 40% below the 6-yr seasonal average and the annual value 20% below the 6-yr annual average.

As presented in the three charts, the SDR WQI, extending from Oct 2004 through Dec 2010, typically fluctuates between the low 20's (E Poor) during the dry season and the high 50's (B Good) during the winter (wet) season. Greater river discharges (flow) results in improved water quality (higher DO levels and lower specific conductivity and temperature). Water quality values decline significantly as river temperatures and conductivity increase while flow and dissolved oxygen levels decrease during the summer. With lowered temperatures, increased discharges and elevated DO levels, river water quality noticeably improves in the fall and early winter months.

Should WY11 be a year of above average rainfall and runoff, an increase in index value would be anticipated. Continued decline in the WQI can be expected should the watershed experience another below normal wet season. Local climate, river hydrology and water quality, irrespective of specific monitoring site, reach or section of the watercourse, are closely inter-tied. The individual patterns, variances and trends in specific water quality parameters that have been monitored over the past 6 years are presented in Section 4.

Table 3.2 - 6-Yr Average WQI Values by SDR Reach and Section

	LMV Reach	UMV Reach	MV Section	MG Section	LSB Reach	USB Reach	SB Section	Overall Watershed Mid-SDR	
6-Yr Average	39	33	36	54	48	33	40	41	C - Fair
Maximum	81	75	74	87	78	78	79	68	B - Good
Minimum	12	8	11	26	18	7	20	18	E - Poor
Monthly Avg:	LMV	UMV	MV	MG	LSB	USB	SB	Mid-SDR	
Oct	26	24	25	44	39	28	33	32	D - Marginal
Nov	42	31	37	59	52	30	41	43	C - Fair
Dec	53	46	50	60	53	34	43	51	B - Good
Jan	58	54	56	57	53	41	47	54	B - Good
Feb	60	58	59	61	52	45	49	57	B - Good
March	61	54	58	70	63	50	57	61	B - Good
April	51	41	47	65	55	40	48	51	B - Good
May	34	23	29	58	51	34	43	39	C - Fair
June	24	18	21	52	42	28	35	32	D - Marginal
July	20	15	18	38	36	20	28	25	D - Marginal
Aug	18	13	16	37	38	19	28	24	E - Poor
Sept	18	14	16	47	41	27	34	28	D - Marginal
Seasonal Avg:	LMV	UMV	MV	MG	LSB	USB	SB	Mid-SDR	
Fall (O-N)	34	27	31	51	41	25	33	37	C - Fair
Winter (D-M)	58	53	56	62	55	42	46	56	B - Good
Spring (A-M)	42	32	38	62	53	37	45	45	C - Fair
Summer (J-S)	20	15	18	43	39	24	31	28	D - Marginal

WQI Color Code:

Dk Blue - (A) Very Good, Lt Blue - (B) Good, Green - (C) Fair, Yellow -(D) Marginal, Brown - (E) Poor, Red -(F) Very Poor

Lower SDR Water Quality Index (Oct. 2004 - Dec. 2010)

Charts 3.1, 3.2 & 3.3

Grade	Descrip	Value	Range	
A	Very Good	>75	25	Well Above Stream Standards
B	Good	50-75	25	Above Minimum Acceotable Standards
C	Fair	35-50	15	Meets Acceptable criteria
D	Marginal	25--35	10	Slightly Below Acceptable criteria
E	Poor	10-25	15	Below Minimum Acceptable criteria
F	Very Poor	<10	10	Well Below Minimum Standards

Least Concern

Intermediate

Greatest Concern

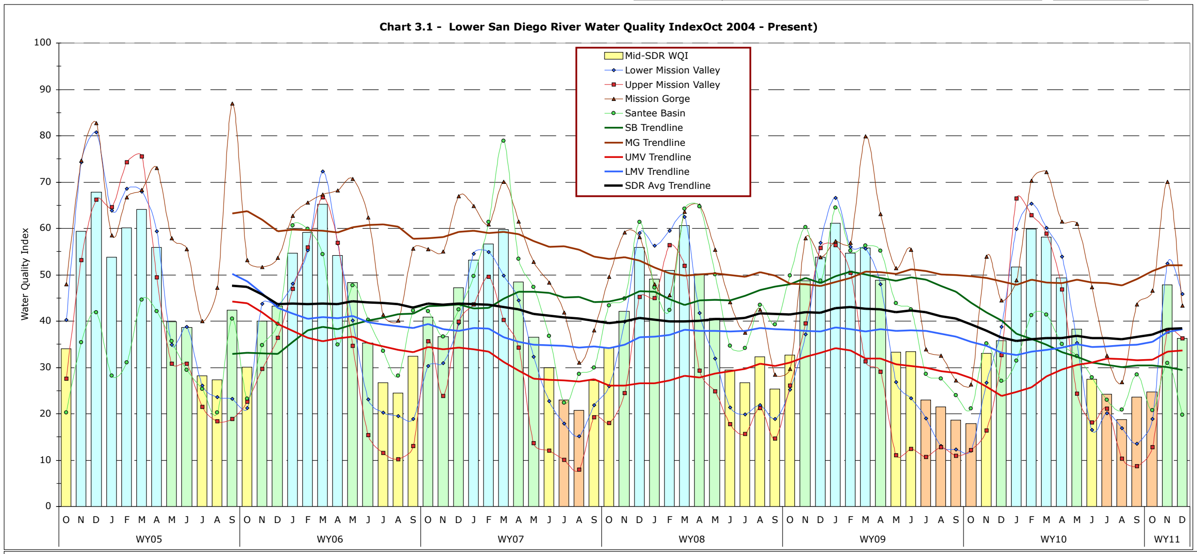


Chart 3.1 - Lower San Diego River Water Quality IndexOct 2004 - Present)

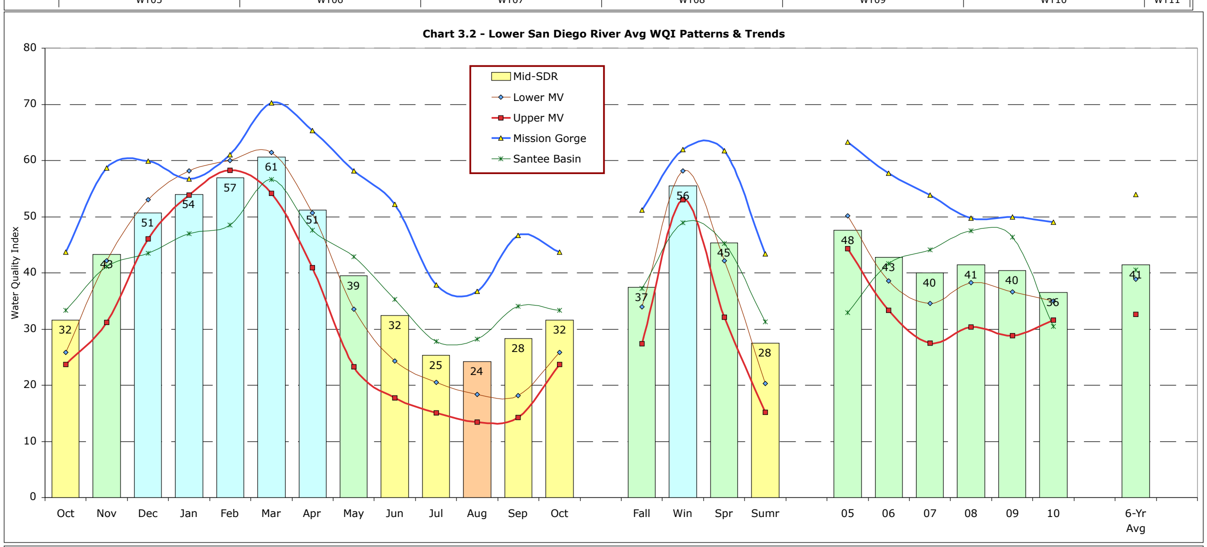


Chart 3.2 - Lower San Diego River Avg WQI Patterns & Trends

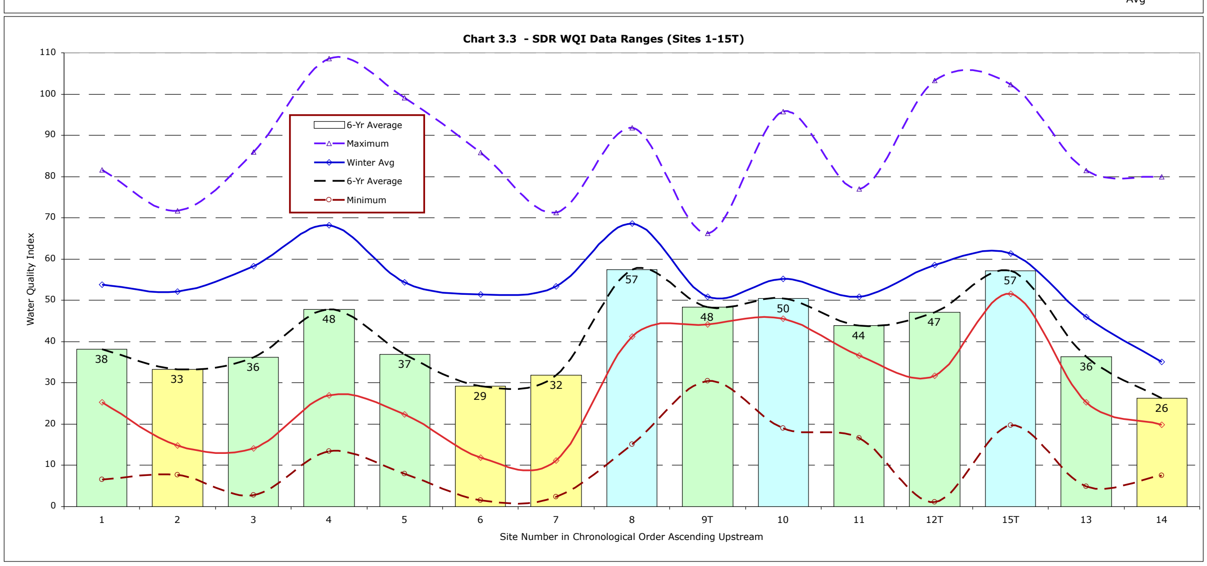


Chart 3.3 - SDR WQI Data Ranges (Sites 1-15T)

Table 3.3 - Average Annual and Seasonal WQI Values by SDR Reach and Section

Annual Avg.	LMV Reach	UMV Reach	MV Section	MG Section	LSB Reach	USB Reach	SB Section	Overall Watershed Mid-SDR	
WY05	50	44	48	63	41	25	33	48	C - Fair
WY06	39	33	36	58	51	32	42	43	C - Fair
WY07	35	27	32	54	54	34	44	40	C - Fair
WY08	38	30	35	50	50	45	47	41	C - Fair
WY09	37	29	33	50	51	42	46	40	C - Fair
WY10	35	32	33	49	41	19	30	36	C - Fair
6-Yr Avg	39	33	36	54	48	33	40	41	C - Fair
Winter	LMV	UMV	MV	MG	LSB	USB	SB	Mid-SDR	
WY05	70	70	70	69	42	30	36	61	B - Good
WY06	55	51	53	62	62	46	54	56	B - Good
WY07	50	43	47	66	67	49	58	54	B - Good
WY08	59	50	55	54	55	53	54	54	B - Good
WY09	59	48	54	62	60	52	56	56	B - Good
WY10	56	55	56	59	47	24	35	51	B - Good
6-Yr Avg	58	53	56	62	55	42	49	56	B - Good
Summer	LMV	UMV	MV	MG	LSB	USB	SB	Mid-SDR	
WY05	28	22	26	57	38	20	29	34	D - Marginal
WY06	20	13	17	50	46	26	39	30	D - Marginal
WY07	19	12	16	40	39	19	29	25	D - Marginal
WY08	20	17	19	38	40	36	38	28	D - Marginal
WY09	17	12	15	37	36	26	31	24	E - Poor
WY10	17	15	16	38	36	14	25	23	E - Poor
6-Yr Avg	20	15	18	43	39	24	31	28	D - Marginal

WQI Color Code:

Dk Blue - (A) Very Good, Lt Blue - (B) Good, Green - (C) Fair, Yellow -(D) Marginal, Brown - (E) Poor, Red -(F) Very Poor

Section 4 - WQM Data Patterns, Variances and Trends

A. *Temperature (Temp)* - *Chemical and biological processes and their rates depend upon temperature. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for optimal health. In addition to its own toxic effect, temperature also affects the solubility and, in turn, toxicity of many other chemical constituents. Generally, the solubility of solids increases with increasing temperature, while gases such as oxygen tend to be more soluble in cold water. Simply put, "the warmer the water, the less the DO and lower the general WQ, and vice versa."*

Monthly water temp patterns at all reaches and sections of the river are cyclic being highest in summer months (June-Sept) and lowest in the winter (Dec-March) as evidenced in **Chart A4.1.** The typical seasonal patterns in temperature variation within the lower watershed are summarized in **Chart A4.2.** As shown in **Chart A4.3**, during any time of the year, water temps are slightly lower upstream, in eastern reaches, than to the west (downstream), due to warming/cooling by the landmass as well as ambient air temps. A minor exception in this pattern is at Site 5 (Ward Rd) where recorded temps are slightly lower during extended dry-weather portions of the year and slightly higher during cooler periods than measured upstream at sites 6 (Kaiser Ponds) and 7 (ABF). This anomaly is likely due to groundwater replenishment/return flows along the river channel in the reach where Alvarado Creek joins the main course between Kaiser Ponds and Ward Rd.

Average summer period river water temps range between 21 and 24^{o}C (70-75 ^{o}F), while average winter season temps range between 12 and 14^{o}C (54-57 ^{o}F) depending on the specific site. The 6-yr average annual temperature of the river is 17.65^{o}C (63.7 ^{o}F); with West (Mission Valley) and East (Mission Gorge/Santee Basin) site temps running approximately 1^{o}C above and below the SDR Avg., respectively. There is little evidence of a statistically significant variance in average annual, winter and summer period temps at any river sites, reaches or sections over the 6-yr period. The highest and lowest recorded river temps during the entire monitoring period were 29.2^{o}C (84.5^{o}F) in July 2006 (Site 4 – FSDRIP) and 7.6^{o}C (45.7^{o}F) in Jan 2006 (Site 8 - Mission Trails@Jackson), respectively.

Although temperature itself is not a direct indicator of water quality, as mentioned above, it affects the amount of DO that can be carried by the river and available for utilization by most aquatic life forms. Cooler water temps allow a greater amount of DO to be entrained, whereas the maximum amount of DO absorbed in water is reduced as water temperatures increase. For example, the saturation level of DO declines from 12.8 mg/L at 5^{o}C (41^{o}F) to less than 7.6 mg/L at 30^{o}C (86^{o}F). Monthly water temps over the entire monitoring period for both reaches and sections as well as an overall SDR average are presented temporally and spatially in the three charts **(A4.1, A4.2 & A4.3)** on the following page.

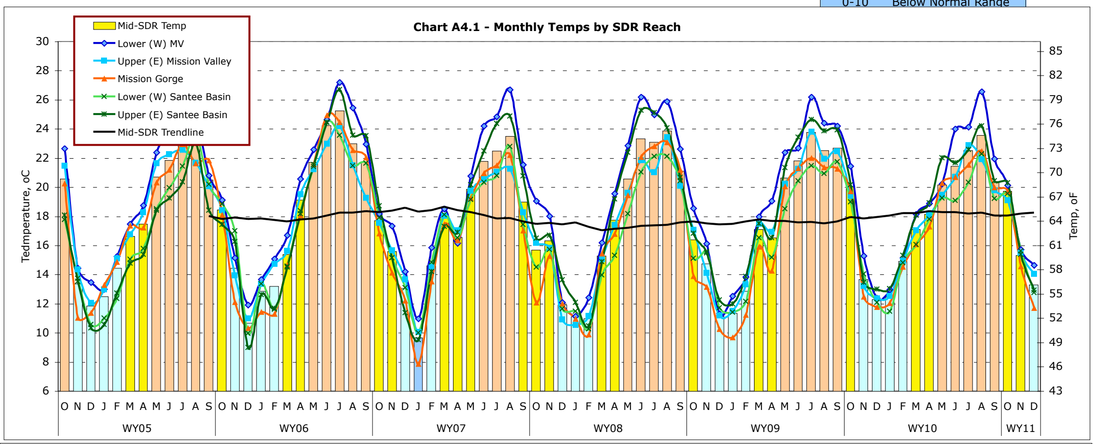
B. ***pH*** **–** *pH is a term used to indicate the alkalinity (- ions) or acidity (+ ions) of water as ranked on a log scale from 1.0 to 14.0, where the value 7.0 is neutral. Acidity increases as the pH gets lower. Although pH affects many chemical and biological processes in water, a large variety of aquatic animals prefer a range of 6.5 to 8.4. Outside this range, pH commonly reduces biological diversity and reproduction rates. Low pH (more acidic) can also allow toxic elements and compounds to become mobile or 'available' for uptake by aquatic plants and animals.*

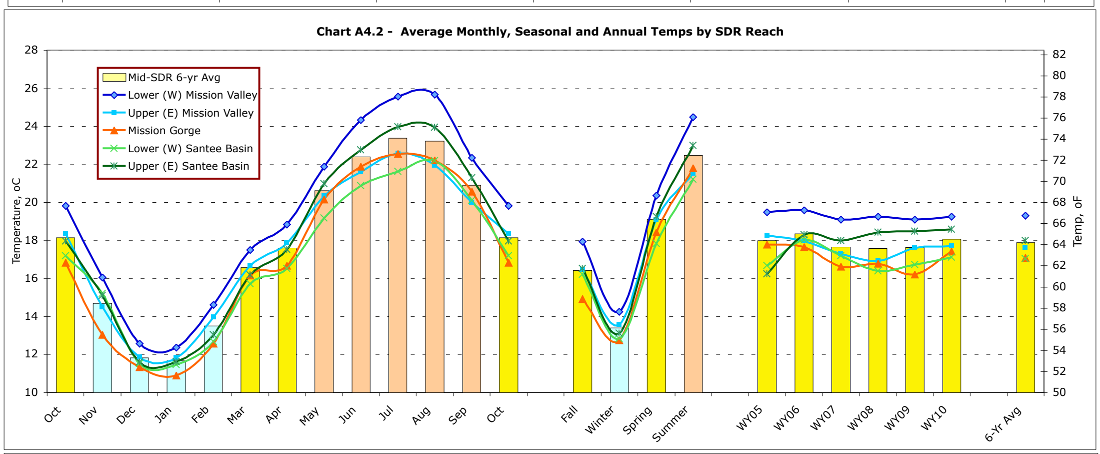
Monthly pH values and variations by river reach, section and water year are presented in **Charts B4.1, B4.2 & B4.3.** As shown in **B4.1**, the range in average pH values throughout the year, as well as from reach-to reach, is fairly narrow (7.3 to 7.9). There is an insignificant variance in annual average and seasonal values from month, season or water year to the next as shown in **B4.2.**

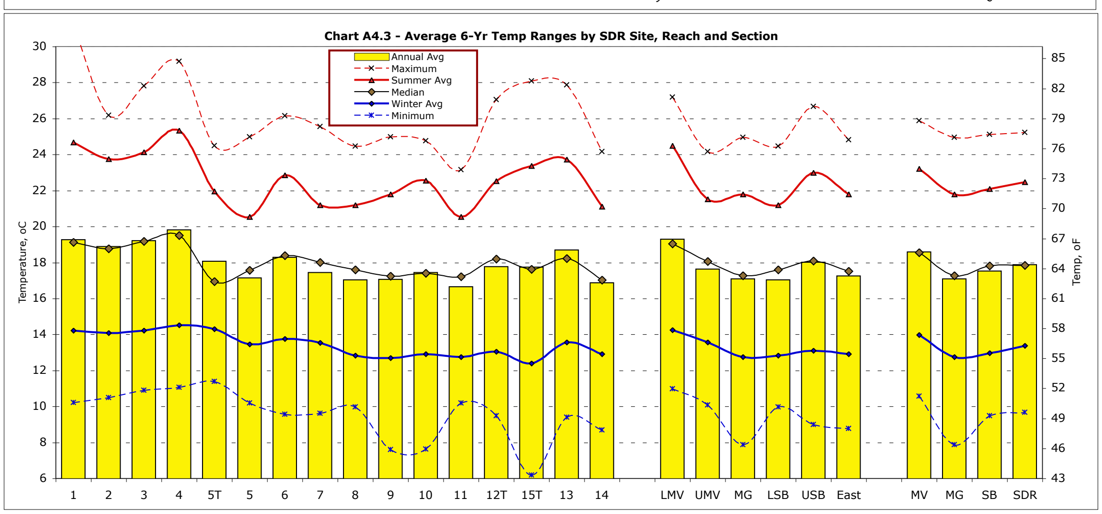
A - Lower SDR Temperature Data (Oct. 2004 - Dec. 2010)

Charts A4.1, A4.2 & A4.3

Temp, oC	
>25	Above Normal Range
20--25	Summer Norms
15--20	Spring & Fall Norms
10--15	Winter Norms
0-10	Below Normal Range



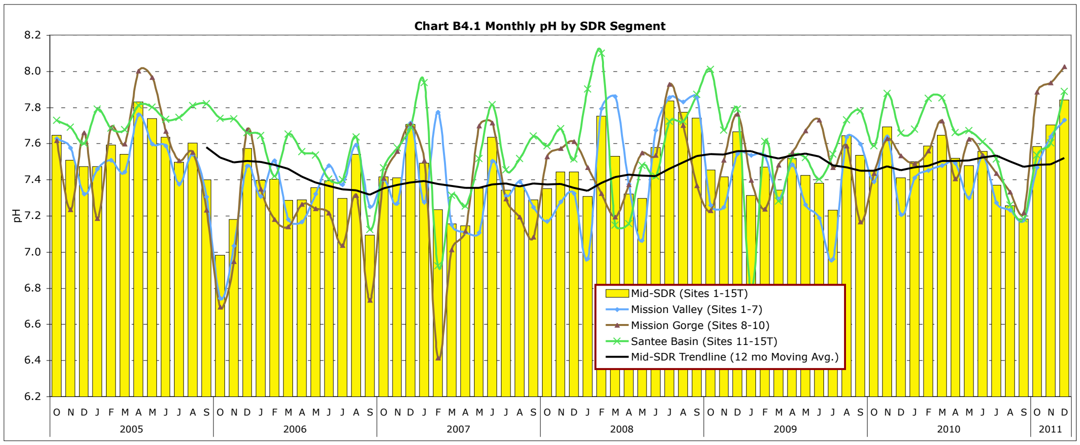


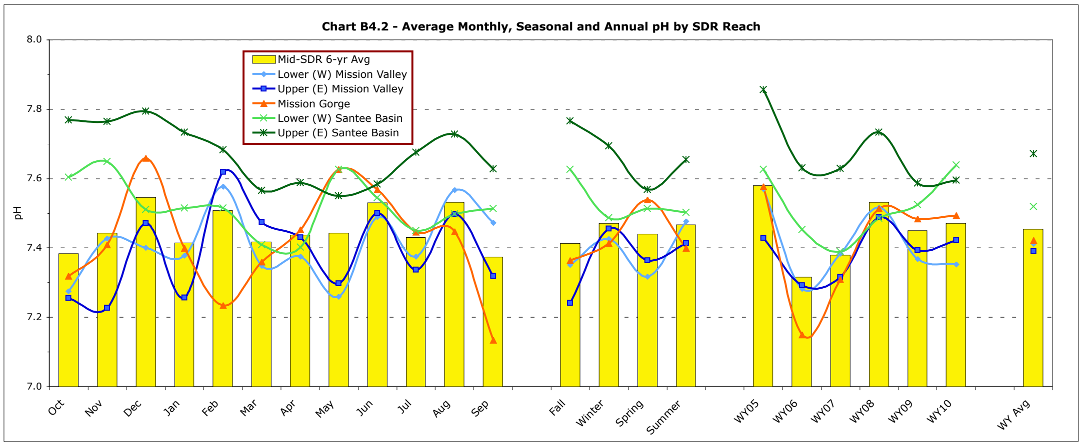


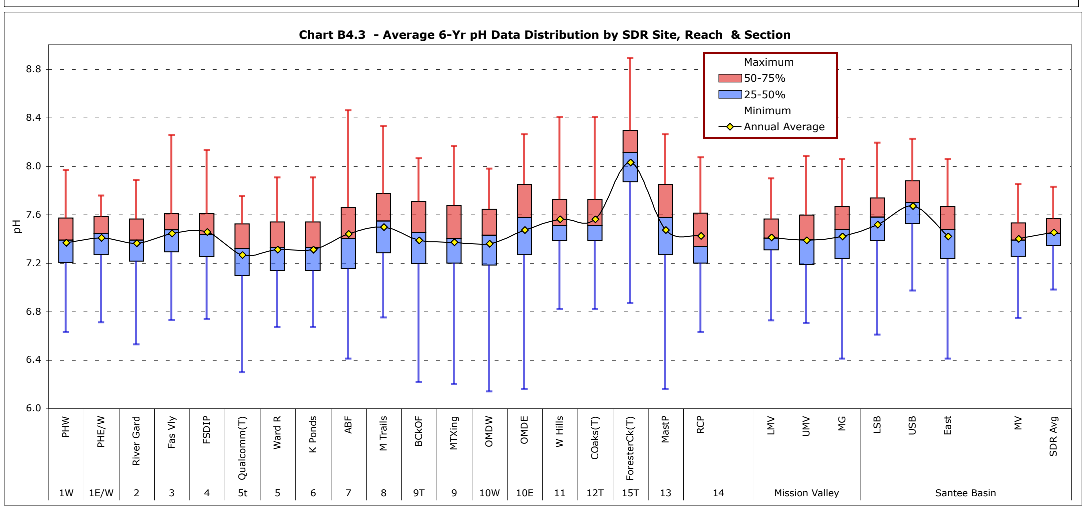
B - Lower SDR pH Data (Coc. 2004 - Dec. 2010)

Charts B4.1, B4.2 & B4.3

pH	
>8.5	Above Normal
6.5--8.4	Normal Range
<6.5	Below Normal







Individual sites as shown in **B4.3,** present a reasonably wide range in min-to-max values (6.2 to 8.8), however, seasonal (winter-to-summer) values as well as annual averages do not vary significantly from site to site.

Average pH of the river within the lower watershed is 7.44, indicating a slightly alkaline (7.0 being neutral) water. Winter (higher flow) pH averages are slightly lower (less alkaline) than evident during extended low flow (summer) periods. Downstream sites (Mission Valley) are also just slightly higher (less acidic or more alkaline) in pH than the upstream sections (Mission Gorge and Santee Basin sites). Seawater typically ranges in pH between 8.5 and 10, whereas freshwater streams in Southern California commonly range in pH between 6.5 and 8.5. All pH measurements taken at SDR monitoring sites were found well within the acceptable range. Highest pH values within the lower watershed were measured in Forester Creek (Site 15T).

C. Specific Conductivity (SpC) *– Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids (+ and - ions). SpC is also affected by temperature: the warmer the water - the higher the conductivity.*

Monthly SpC values also describe recurrent cyclic patterns at all sites/sections, being highest in summer months during lowest flow and lowest during the winter period when flows are greatest. In any given month SpC values are lowest upstream and steadily increasing as moving downstream. Highest SpC values are measured at Site 1 where estuarine waters mix with the upstream freshwater river discharge. Site 1W values are often greater than measured at Site 1E (u/s side of the encased sewer line) dependent on the tidal condition. The repetitive seasonal patterns in SpC values are shown in **Charts C4.1 and C4.2** for each reach and river section.

Conductivity is also a reasonably accurate indication of the amount of total dissolved solids (TDS) or salts carried in water. The relationship between SpC and TDS for SDR waters is as follows: TDS (in mg/L) = 670 (a constant) x SpC (in uS/cm) or TDS (in ppm) = 0.67 SpC (in mS/cm). Measuring SpC allows computation of TDS and thus a reasonable estimate (based on flow) of the total salt load carried by the river. SpC, when factored with Temp and DO values, also provides a basis for calculating the water quality index (WQI) for sites, reaches and sections within the system as previously presented in Section 3. Typical conductivity and TDS ranges for various water classifications/types in California are listed in **Table C4.1.**

Table C4.1 Typical Specific Conductivity and Salinity Ranges

Type	SpC, mS/cm	TDS, mg/L (or ppm)
Distilled water	0	0
Rainwater	0.05 - 0.20	35 - 135
Freshwater streams (upper San Diego Co watersheds)	0.20 – 0.75	135 - 500
Freshwater streams (below impoundments)	0.75 - 2.2	500 – 1,500
Coastal streams of So. California	2.2 – 7.5	1,500 – 5,000
Estuaries and brackish groundwater	10.0 – 45.0	7,000 - 30,000
Seawater	>45.0	>30,000

C. Lower SDR - Specific Conductivity Data (Oct. 2004 - Dec. 2010)

Charts C4.1, C4.2 & C4.3

Color Code & Range

SpCond, mS/cm		TDS, mg/L	
> 5.0	Very Poor	> 3200	Well Above Normal
3.0 - 4.9	Poor	1900 - 3200	Above Normal
2.0 - 2.9	Fair	1280 -1900	Normal
1.0 - 1.9	Good	650 - 1280	Below Normal
< 1.0	Excellent	< 650	Well Below Normal

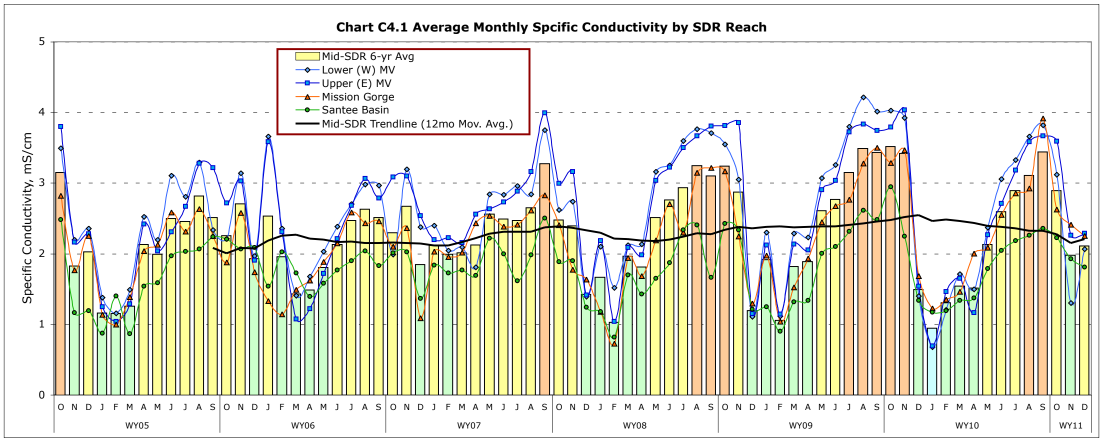


Chart C4.1 Average Monthly Spcific Conductivity by SDR Reach

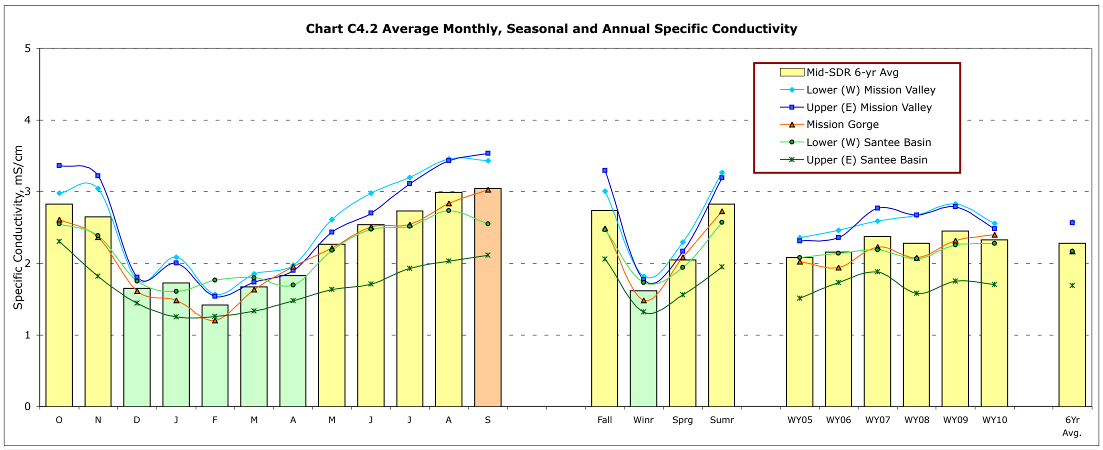


Chart C4.2 Average Monthly, Seasonal and Annual Specific Conductivity

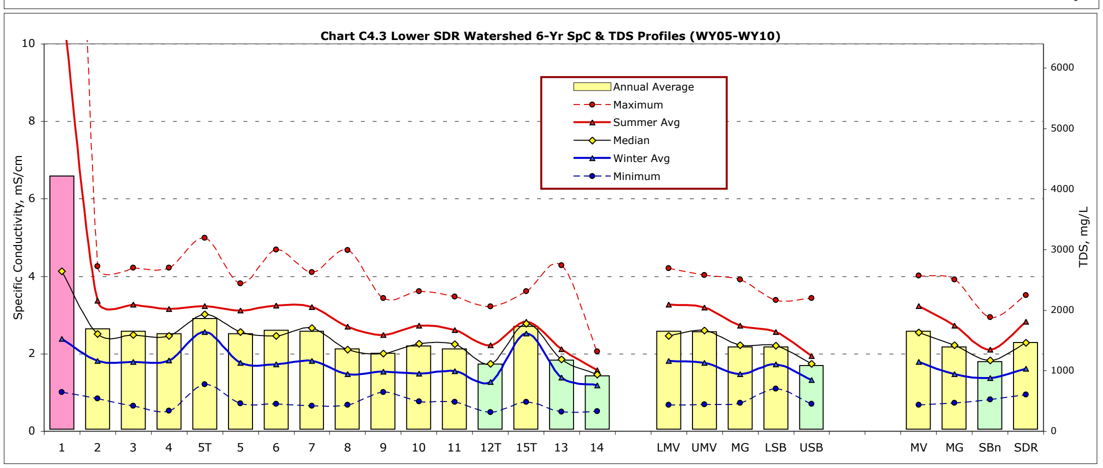


Chart C4.3 Lower SDR Watershed 6-Yr SpC & TDS Profiles (WY05-WY10)

A summary of monthly SpC and TDS over the 6-yr monitoring period for the main river sections and an overall SDR average is provided in **Chart C4.1**. Salinity levels for all three sections slowly increased between 2005 and 2009, most noticeably in Mission Valley. Overall average annual TDS increased by about 400 mg/L from 1,500 mg/L (2.2 mS/cm SpC) in WY05 to 1,900 mg/L (2.8 mS/cm) in WY09.

River salinities began decreasing this past year (2010) as the watershed experienced slightly above normal rainfall and extended runoff. The overall 6-yr average salinity of the SDR is 1,560 mg/L (2.33mS/cm SpC). Mean summer and winter salinities in Mission Valley range from 2,700 mg/L down to 1,300 mg/L over the 6 years. Santee Basin summer salinity levels are approximately 60 percent of those for Mission Valley whereas winter levels are approximately 70 percent of downstream values.

Average winter-to-summer period SpC values range from slightly above 3.0 mS/cm to a low of approximately 1.0 mS/cm. The annual average SpC value lies in the 2.0-2.2 mS/cm range. September presents the highest value month over the 6-yr period while February the lowest. There is a slight trend toward greater average annual values over the years driven by higher summer period values. The lowest SDR annual average of 2.2 mS/cm (10 % below average) occurred in WY06, the highest 2.5 mS/cm (10% above average) in WY09 as shown in **Chart C4.3.**

D. *Dissolved Oxygen (DO) and Percent of Saturated DO (DO%Sat)* *– DO, the amount of gaseous oxygen (O2) dissolved in solution, is one of the most important parameters in aquatic systems. O2 is an absolute requirement for the metabolism of aerobic organisms and also influences inorganic chemical reactions. River systems both produce and consume oxygen. Water gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning action (aeration), rapidly dissolves more oxygen than still water. Respiration by aquatic animals, decomposition and various chemical reactions all consume oxygen. Aquatic animals are most vulnerable to lowered DO levels in early morning on hot summer days when flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset. DO can be expressed as an absolute concentration (in mg/L, ppm, etc) or as a percent of the total amount that is soluble at its saturation point that is dependent on temperature, atmospheric pressure, pH and conductivity. Both DO values are measured and recorded in the field.*

Monitored monthly and seasonal dissolved oxygen (DO) and Percentage of DO Saturation (DO%Sat) patterns together with annual trends over the past 6 years are presented in **Charts D4.1, D4.2 & D4.3.** DO values vary considerably over time as well as from one site to another. The DO values provide the best overall single indication of general health of the river in terms of oxygen available for aquatic life (respiration). Highest DO values over the past 6 years have been consistently measured in the Mission Gorge section with winter highs averaging above 10 mg/L (>95%Sat); the lowest at Kaiser Ponds (Site 6) and River Gardens (Site 4) where summer values often decline to below 3 mg/L (<35%Sat). The 6-yr average (mean) DO value for the entire river is 6.56 mg/L (68%Sat), however, as stated, the variances over time- and distance along the watercourse are notable.

Summer period DO values measured at most river sites lie in the 3.0 to 6.0 mg/L range (35 to 70%Sat), whereas winter season values are typically between 7.0 and 10 mg/L (70 to 95%Sat). Minimum DO levels of less than 1.0 mg/L (<10%Sat) have been measured at sites 3 (Fashion Valley), 5 (Kaiser Ponds) & 6 (Admiral Baker Field) in August and September. Maximum levels, in the 13 to 14 mg/L (>150%Sat) range, have been measured during winter periods (Dec-March) at sites 8 (Mission Trails), 10 (OMD) and 4 (FSDRIP). DO values are consistently higher where the river is moving swiftly and can re-aerate with higher gradients. DO levels drop significantly once waters reach the Upper Mission Valley reach at Admiral Baker Field where stream velocities decline. River DO levels recover somewhat past Qualcomm

Stadium and into the mid-valley (FSDRIP) portion, however, as velocity/current diminishes through the lower reach, DO levels again decline.

Chart D4.1 presents monthly DO and %DO Sat levels for the main river reaches and segments as well as showing an overall SDR average and trends in each. Average annual SDR DO levels declined from nearly 7 mg/L (73% Sat) in WY06 to a low of 5 mg/L (55% Sat) in WY10. DO levels have begun to improve within all reaches and sections over the past several months as flows have increased.

The present SDR average DO value for the Lower watershed of 6 mg/L (70%Sat) is nearly the same as the 6-yr annual average . Oxygen levels can be expected to further improve with above normal river flows. However, another year of protracted dry weather would likely result in further declines..

As shown in **Chart D4.2,** SDR average and wintertime DO levels were highest in WY05 (nearly 40% above the annual norm) and lowest in WY10. This past year also presented the lowest summer period average DO levels of nearly 25% below the annual norm. DO levels indicate that overall river water quality is greatly dependent on flushing and regenerative actions during wet-weather season as well as maintenance of minimum base flows throughout the summer period. **Chart D4.3** presents a profile of average DO and %DOSat values for each site, reach and section extending over the 6-yr monitoring period.

E. WQM Data Summary:

A *temporal* (WY05 through WY10) summary of SDRPF RiverWatch water quality monitoring data for overall Mid-SDR (Lower SDR Watershed) annual, summer and winter values is provided in **Table 1.4.** The percent change in most recent (WY10) values from the previous year (WY09), from the initial year (WY05) and from the 6-year average is presented for each WQ parameter. Overall annual average physical-chemical water quality within the lower watershed, as expressed by the WQI, has declined by approximately 15 percent over the past 6 years. Winter season values (Dec-March) are down approximately 8 percent, while summer values (June-Sept) are down 21 percent over the 6-yr period. The annual index for WY10 is down 10 percent from the previous (WY09) year's average.

A *spatial* (by distance and reach) summary of SDRPF RiverWatch water quality monitoring data for average annual, summer and winter values for each parameter is provided in **Table 1.5.** The Mission Gorge reach/section consistently presents the best water quality within the lower watershed, whereas the Upper Mission Valley reach (just downstream) presents the lowest. The lower/west section of the river (Mission Valley) consistently presents poorer water quality both on an average-annual and summer-season basis than evidenced in either upstream section. Overall (Mid-SDR) 6-yr average water quality within the lower SDR watershed ranges from low 'Marginal' (D-) in summer to 'Good' (B) in winter, or 'Fair' (C) expressed on a average annual basis.

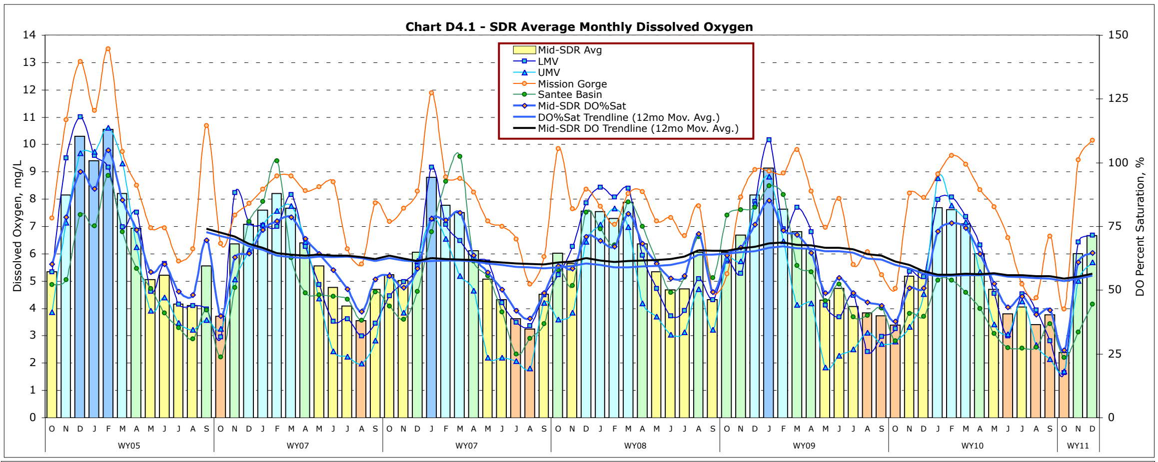
Winter and average annual SDR water quality in WY11 is anticipated to generally improve should this year continue to be an above average rainfall, runoff, river discharge year. Summer water quality results could, however, continue to remain poor, should next summer's dry-weather flows be significantly below seasonal norms. It is intended that dry weather flows and summer-time water quality relationships will be further explored and assessed by the RiverWatch Team in 2011.

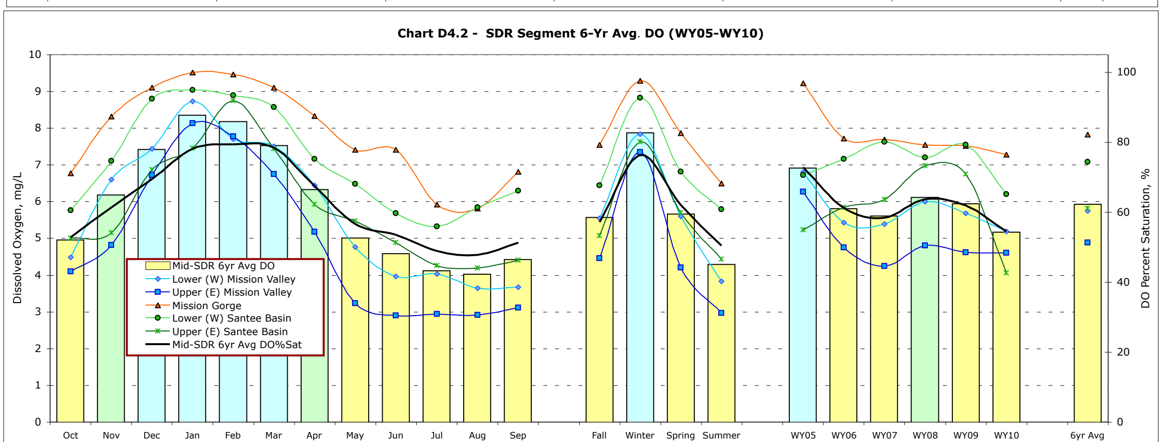
Questions regarding this WQM database or interpretation of results can be directed to the attention of the report's author, John C. Kennedy, through contacting SDPRPF at info@SanDiegoRiver.org, or calling the WaterWatch Coordinator at 619-297-7380.

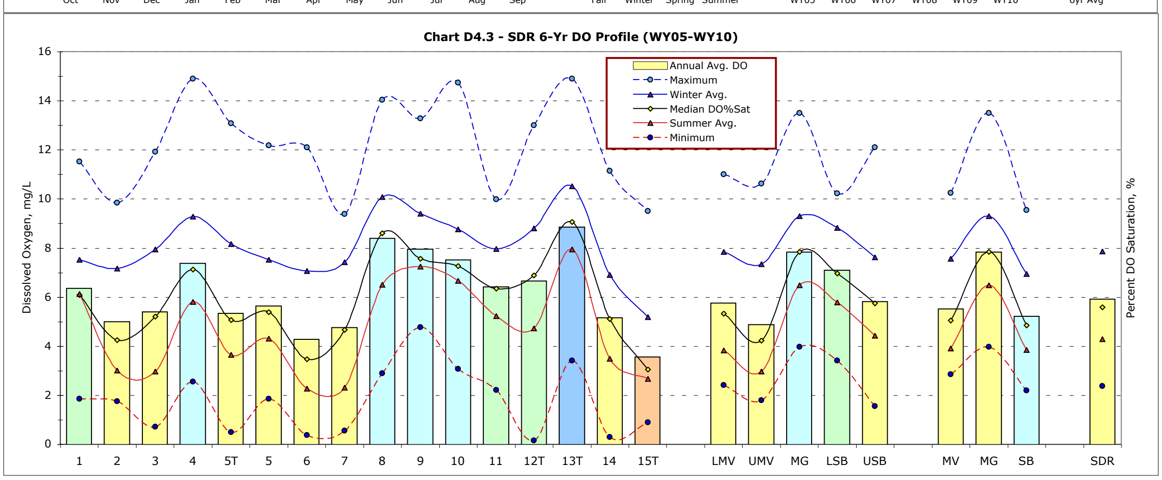
D - Lower SDR Dissolved Oxygen Data (Oct. 2004 - Dec. 2010)

Charts D4.1, D4.2 & D4.3

DO mg/L	DO%Sat %	
>8.5	>90%	A - Very Good
7 -8.4	75 - 89	B - Good
6--6.9	55 -- 74	C - Fair
4--5.9	35--54	D - Marginal
2 ---3.9	15--34	E - Poor
< 2	< 15%	F - Very Poor







Glossary

Abbreviations:

AADF - Average Annual Daily Flow
ADF – Average Daily Flow
AF – acre-foot (1 AF = 43,560 cf = 325,900 gal)
amsl – above mean sea level (elevation)
Avg.– Average
cfs - cubic feet per second (flow/discharge)
Ck – Creek
CY - Calendar Year (Jan 1 - Dec 31)
DO – Dissolved Oxygen
DO%Sat – DO expressed as percentage of DO level at saturation point
d/s – downstream, u/s – upstream
E – East; W –West
SpC – Specific Conductivity (also Conductivity or Conductance)
Elev. - Elevation
FSDRIP – First San Diego River Improvement Project
ft. – feet; mi. - mile
gal – gallon; gpm – gallons per minute; mgd – million gallons per day
L/U – lower/upper (as in river reaches)
lbs - pounds
max/min – maximum/minimum
mg/L – milligrams per liter
mS/cm –milli-Semiens per centimeter (1 mS/cm = 1000 *u*S/cm)
MV – Mission Valley; MG – Mission Gorge; SB – Santee Basin (river sections)
NO_3 - Nitrate (a nutrient)
*u*S/cm –micro-Semiens per centimeter (1 *u*S/cm = 0.001 mS/cm)
PDMWD – Padre Dam Municipal Water District
$P0_4$ - Phosphate (another key nutrient)
pH – measure of acidity or basicity (decimal logarithm of hydrogen ion activity)
ppb – parts per billion
ppm – parts per million
SB – Santee Basin
SD – Standard Deviation (also San Diego)
SDR – San Diego River
SDRPF – San Diego River Park Foundation
SpC - Specific Conductivity
sqft –square feet
TDS – Total Dissolved Solids
Temp – Temperature
TN/TP – Total Nitrogen/ Total Phosphorus (nutrients)
tppd – thousand pounds per day
USGS – U.S. Geological Survey
WQI – Water Quality Index
WY – Water Year (Oct 1 – Sept 31)
% - percent
^oC – degrees Celsius,
^oF – degrees Fahrenheit

Formulas:

$^oC = (^oF-32)x5/9$
$^oF = (^oC*9/5)+32$
Flow (cfs) = Velocity (ft/sec)*Cross-sectional area (sq ft)

Constituent Load (lbs/day) = Flow (mgd)*Constituent Concentration (mg/L)*8.34; or = Flow (cfs)*Concentration (mg/L)*5.39

Total Dissolved Solids (TDS in mg/L) = 670*Specific Conductivity, (where SpC is in mS/cm). An approximate relationship for Lower SDR watershed; other variables (e.g., temperature, pressure, specific ions) are considered negligible.

For the lower SDR watershed - the DO//DO%Sat relationship is defined by the following polynomial equation: $DO(mg/L)=DO\%Sat(\%)*[0.0041*T^2-0.0127*T+14.157]/100$; or $DO\%Sat (\%) = DO(mg/L)*100/[0.0041*T^2-0.0127T+14.157]$, (where T-temperature is in ^oC). Other variables, incl. barometric pressure, elevation and conductivity, have negligible impact on the DO/DO%Sat relationship within the Lower SDR watershed.

SDR Water Quality Index (WQI) is computed through the following formulas:
WQI = DO%Sat/log(SpC)*2.5*Tfactor*Qfactor; where SpC is expressed in *u*S/cm; the T factor = $.002T^3-.0756T^2+.7264T-1.0687$ and the Q-factor = $0.5537+0.1728LnQ-0.0015LnQ^2-0.0033LnQ^3$ (Mission Valley);
$= 0.7074+0.1516LnQ-0.0041LnQ^2-0.0045LnQ^3$ (Mission Gorge);
$= 0.7687+0.1467LnQ-0.0069LnQ^2-0.0051LnQ^3$ (Santee Basin);

$=0.7777+0.222Ln0.7687+0.1467LnQ-0.0069LnQ^2-0.0051LnQ^3$ (Tributaries)

Water Equivalents:

1 cf = 7.48 gal = 62.4 lbs of water
1 AF = 43,560 cf = 325,900 gal
1 psi = 2.31 ft of water
1 mg/L = 1 ppm (in water)
1 cfs = 450 gpm = 0.64632 mgd =1.98 AF/day = 724 AFY
1 mgd = 694 gpm =1.547 cfs = 3.06 AF/day = 1,120 AFY
1000 gpm = 1.436 mgd = 2.23 cfs = 4.42 AF/day = 1,614 AFY
1 mS/cm = 1000 *u*S/cm
1 inch = 25.4 mm

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