LOWER SAN DIEGO RIVER WATER QUALITY

WY20 Water Quality Monitoring Report (Appendices A through H)

Early Spring flood flow immediately downstream of Admiral Baker Filed (Monitoring Site 7).

Supporting Water Quality Monitoring Data for the Lower San Diego River

John C. Kennedy, PE

November 2020

LOWER SAN DIEGO RIVER
WY20 WATER QUALITY REPORT
(APPENDICES A-H)

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Appendix A - SDRPF RiverWatch WQM Team

Supervision/Coordination: Rob Hutsel (2004-2005), Kym Hunter (2006-2007), Shannon Quigley-Raymond (2008-2019), Lisa Schiavinato, Natasha Rodriguez, Aixa Willoughby (2020)

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Calvin Vine **
Cameron Bradley
Carl Abulencia
Celena Cui
Chandler Hood
Chris Peter
Chris (Soltan)
Christine Lavoine
Clint Williams
Cody Gallagher
Conrad Brennen **
Craig McCartney
Dani Tran
Danielle Marshall
David Lapota
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Appendix A - Team Volunteers (continued)

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*** Team Leaders*

Appendix B - Glossary

Abbreviations:

AADF - Average Annual Daily Flow
ACC - Average Coliform Count (arithmetic mean of fecal coliform, e-Coli & total coliform in MPN/100mL)
ADWF – Average Daily (stream) Dry-Weather Flow
AFY - acre-feet per year
Avg– Average
cfs - cubic feet per second (flow/discharge)
Ck – Creek
CY - Calendar Year (Jan 1 - Dec 31)
DO – Dissolved Oxygen
DOD- Dissolved Oxygen Depletion (level below minimum required
DO%Sat – Dissolved Oxygen expressed as percentage of DO level at saturation point
d/s – downstream // {u/s – upstream}
E – East // {W –West}
FSDRIP – First San Diego River Improvement Project
ft. – feet // {mi. - mile}
gal – gallon
Ln(x) - natural logarithm of (x) to base-e (2.718)
log(x) - common logarithm of (x) to base-10
L//U – lower//upper (as in river reaches)
LSDR – Lower San Diego River
max//min – maximum//minimum
MCC - Mean Coliform Count (geometric mean of fecal coliform, e-Coli & total coliform in MPN/100mL)
mg/L – milligrams per litre
mi. - mile
mS/cm – milliSeimens per centimetre (1 mS/cm = 1,000 *u*S/cm)
MG – Mission Gorge (mid-section of LSDR)
MV – Mission Valley (West section of LSDR)
MPN - Most Probable Number (of coliform organisms)
SB – Santee Basin (East section of LSDR)
PDMWD – Padre Dam Municipal Water District
pH – measure of acidity or basicity (decimal logarithm of hydrogen ion activity)
ppm – parts per million
Q - stream flow or discharge
SB – Santee Basin
SpC – Specific Conductivity (also Conductivity or Conductance; sometimes abbreviated SC)
SDRPF – San Diego River Park Foundation
TDS – Total Dissolved Solids
Temp. – Temperature
TN/TP – Total Nitrogen/ Total Phosphorus (nutrients)
USGS – U.S. Geological Survey
*u*S/cm –microSeimens per centimetre (1 *u*S/cm = 0.001 mS/cm)
u/s - upstream // {d/s - downstream}
W - West // {E - East}
WQI – Water Quality Index (WQI_a)
$WQI_{(4)}$ - WQI using 4 parameters
$WQI_{(6)}$ - WQI using 6 parameters
WY – Water Year (Oct 1 – Sept 31)
% - percent
%Sat - percent of DO saturation value
C – degrees Celsius $^oC = (^oF-32)*5/9$
^{o}F – degrees Fahrenheit $^oF = (^oC*9/5) + 32$

Formulas:

Flow (cfs) = Velocity (ft/sec)*Cross-sectional area (sq ft)

Constituent Load (lbs/day) = Q (mgd)*Concentration (ppm)*8.34; or Q (cfs)*Concentration (mg/L)*5.39 where Q is streamflow/river discharge.

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

DO - DO%Sat relationship is defined by the following polynomial equation:
$DO(mg/L)=DO\%Sat*[0.004*T^2-0.343*T+14.2]/100$; $DO\%Sat = DO(mg/L)*100/[0.004*T^2-0.343T+14.2]$,
where T = temperature is in ^{o}C.
Other variables, incl. barometric pressure, elevation and conductivity (SpC), have negligible impact on the DO-DO%Sat relationship within the LSDR watershed.

SDR Water Quality Index (WQI) is calculated using the following set of equations:

WQI_4 = DO%Sat*2.5*T factor*Q factor/log(SpC); where SpC is expressed in *u*S/cm;
the T factor = $0.0055T^3-0.163T^2+1.37T-2.5$, and the Q factor =
$0.56+0.173LnQ-0.002LnQ^2-0.0033LnQ^3$ (M Valley);
$0.72+0.15LnQ-0.0051LnQ^2-0.004LnQ^3$ (M Gorge);
$0.87+0.107LnQ-0.018LnQ^2-0.003LnQ^3$ (Santee);
$0.1+0.05LnQ-0.042LnQ^2-0.0011LnQ^3$ (Tributaries)

WQI_6 = Avg.[$DO\%f*wt_{(DO)}$, $SpCf*wt_{(SC)}$, $pHf*wt_{(pH)}$, $MCCf*wt_{(MCC)}$, $Qf*wt_{(Q)}$, $Tempf*wt_{(T)}$]^1.75
where $wt_{(DO)} = 3$, $wt_{(SC)} = 2$, $wt_{(pH)} = 1$, $wt_{(MCC)} = 1$, $wt_{(Q)} = 2$ and $wt_{(T)} = 1$

The SDR WQI is developed specifically for the SDRPF RiverWatch Monitoring Program, however, the equations could also be applied to water quality and hydrologic data for other coastal watercourses where comparable metrics are available.

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 (head)
1 mg/L = 1 ppm (in water)
1 cfs = 450 gpm = 0.646 mgd =1.98 AF/day = 724 AFY
1 mgd = 694 gpm =1.547 cfs = 3.06 AF/day = 1,120 AFY
1,000 gpm = 1.436 mgd = 2.23 cfs = 4.42 AF/day = 1,614 AFY
1 inch (rainfall) = 25.4 mm

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Appendix D - LSDR Water Quality Monitoring Metrics 16-yr Summary

Table D.1 WQM Metrics 16-yr Summary (Annual & Seasonal Averages)

WY	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	**20**	*16-yr Norms*
Annual (October-September):																	
ADF, cfs	57	12	9	17	19	32	24	13	8	5	9	14	42	6	**23**	**30.1**	*(20.1)*
Temp, °C	17.7	18.3	17.8	17.8	17.9	18.1	17.9	18.0	17.4	17.9	18.6	18.2	18.6	18.3	17.9	**18.4**	*(18.0)*
SpC, uS/cm	2.05	2.14	2.37	2.22	2.40	2.26	2.15	2.30	2.42	2.53	2.16	2.23	2.15	2.78	2.16	**2.15**	*(2.28)*
DO, mg/L	6.32	5.66	5.52	5.99	5.92	4.85	5.10	4.73	4.90	3.52	3.93	4.10	4.70	3.98	4.63	**5.01**	*(4.98)*
DO%Sat,	60	56	56	61	61	50	53	49	50	37	42	43	50	42	48	**53**	*(51.3)*
pH	7.57	7.34	7.47	7.88	7.61	7.83	7.86	7.68	7.75	7.64	7.76	7.73	7.78	7.95	7.75	**7.81**	*(7.71)*
WQI	40	35	34	36	35	32	36	31	30	20	25	25	31	22	30	**32**	*(31.3)*
Grade	C	D+	D	D+	D+	D	D+	D	D	E	D-	D-	D	E	D	**D**	*(D Marg)*
Summer (June-September) Period:																	
ADF, cfs	3.3	3.8	1.4	1.9	1.2	1.9	3.1	1.6	1.2	0.8	5.2	0.7	1.8	0.5	2.4	**2.7**	*(2.1)*
Temp, °C	21.7	23.6	21.8	23.0	23.0	22.0	21.8	23.0	21.7	22.8	22.9	21.9	23.3	23.0	22.1	**23.5**	*(22.6)*
SpC, uS/cm	2.52	2.37	2.69	2.93	3.10	2.88	2.75	2.96	2.95	2.94	2.16	3.05	2.73	3.16	2.74	**2.61**	*(2.78)*
DO, mg/L	4.02	4.20	3.81	4.56	4.20	3.45	3.28	3.20	2.91	2.26	3.06	2.60	3.13	2.59	2.75	**3.95**	*(3.42)*
DO%Sat, %	42	49	43	51	49	39	38	38	34	27	35	30	37	30	32	**47**	*(39.5)*
pH	7.51	7.47	7.41	7.91	7.50	7.84	7.92	7.94	7.71	7.94	7.81	7.80	7.74	8.00	7.72	**7.92**	*(7.70)*
WQIa	24	23	20	22	20	19	20	17	14	11	17	11	17	9	15	**21**	*(18.0)*
Grade	E+	E+	E	E	E	E	E	E	E	F	E	F	E	F	E	**E**	*(E Poor)*
Winter (December-March) Period:																	
ADF, cfs	147	19	18	44	53	83	49	20	20	10	18	33	116	15	63	**17.7**	*(45.3)*
Temp, °C	13.7	12.9	13.9	12.5	13.4	14.2	13.8	12.4	12.4	13.4	15.3	14.1	14.4	13.8	14.2	**13.6**	*(13.6)*
SpC, uS/cm	1.38	2.00	2.02	1.53	1.49	1.32	1.32	1.65	1.99	2.22	1.86	1.69	1.22	2.16	1.28	**1.63**	*(1.67)*
DO, mg/L	9.16	6.40	6.59	6.96	7.31	5.76	7.01	6.30	7.26	4.68	4.56	5.56	7.24	5.44	7.18	**6.79**	*(6.56)*
DO%Sat	83	58	64	66	71	57	68	59	68	45	46	54	72	53	71	**66**	*(62.9)*
pH	7.57	7.33	7.69	8.06	7.72	7.68	7.84	7.41	7.76	7.53	7.79	7.57	7.77	7.89	7.75	**7.81**	*(7.71)*
WQIa	58	46	47	52	53	49	50	41	48	29	32	37	53	36	52	**47**	*45.8*
Grade	B	C	C	B-	B-	C+	B-	C	C+	D	D	D+	B-	D+	B-	**C**	*(C Fair)*

(a) Values in red text are below 16-yr norms (expressed in parenthese); values above norms are in blue.

Table D.2 WQM Metrics Summary by River Section and Reach (WY20 & 16-yr Norms)

Section	Mission Valley		Mission Gorge	Santee Basin		**Watershed**
Sites	1-4	5-7	8-10	11,12,15	13,14	**all (1-15)**
Reach	LMV	UMV	MG	LSB	USB	**LSDR** [a]
Annual (October 2019 - September 2020):						
ADF, cfs	49 *(29.6)*	46 (27.5)	26 (18.7) [b]	21 *(16.3)*	9.3 *(5.0)*	**30** *(20.0)*
Temp, °C	19.9 *(19.4)*	18.5 *(17.9)*	17.3 *(17.1)*	17.5 (17.4)	18.2 *(18.1)*	**18.4** *(18.0)*
SpC, mS/cm	2.63 (2.58)	2.46 (2.55)	2.09 *(2.28)*	2.07 (2.25)	1.52 *(1.78)*	**2.15** *(2.28)*
DO, mg/L	5.52 (5.06)	3.73 *(4.44)*	7.50 *(7.49)*	6.50 *(6.54)*	2.33 *(2.99)*	**5.01** *(4.98)*
DO %of Sat.	60 *(54)*	38 *(46)*	77 *(77)*	67 *(64)*	25 *(31)*	**53** *(51)*
WQIa	37 *(34.8)*	34 *(30.0)*	45 *(45.6)*	41 *(36.5)*	15 *(17.1)*	**32** *(31)*
WY20 Grade	D+ Marginal	D Marginal	C Fair	C Fair	E Poor	**D Marginal**
16-yr Norm	*(D Marginal)*	*(DMarginal)*	*(C Fair)*	*D+ Marginal)*	*(E Poor)*	*(D Marginal)*
Summer (June 2020 - September 2020) Period:						
ADF, cfs	3.4 *(3.2)*	3.2 (2.9)	2.9 (1.9) [c]	2.8 (1.8)	1.1 (0.4)	**2.7** *(2.1)*
Temp, °C	25.5 (24.3)	23.6 (21.9)	22.2 (21.8)	21.6 (21.5)	23.7 (22.9)	**23.5** *(22.6)*
SpC, mS/cm	3.32 (3.25)	3.09 (3.17)	2.39 (2.86)	2.07 (2.25)	1.52 (1.78)	**2.61** *(2.78)*
DO, mg/L	4.24 (3.22)	2.88 (2.51)	3.90 (5.58)	6.66 (5.62)	2.13 (2.13)	**3.95** *(3.42)*
DO % of Sat.	52 (39)	34 (29)	42 (61)	76/(64)	26 (25)	**47** *(39)*
WQI	25 (20.5)	17 (14.5)	30 (27.5)	29 (24.4)	10 (9.2)	**21** *(18.0)*
WY20 Grade	D- Marginal	E Poor	D Marginal	D Marginal	F Very Poor	**E Poor**
16-yr Norm	*(E Poor)*	*(E Poor)*	*(D Marginal)*	*(E+ Poor)*	*(F VeryPoor)*	*(E Poor)*
Winter (December 2019- March 2020) Period:						
ADF, cfs	27 *(67.8)*	25 (61.9)	16.3 (42.6)	13.7 (36.4)	5.8 (11.4)	**17.7** *(45.3)*
Temp, °C	14.6 (14.5)	14.1 (13.7)	12.7 (12.7)	13.3 (13.4)	13.2 (13.6)	**13.8** *(13.6)*
SpC, mS/cm	1.86 (1.84)	1.75 (1.76)	1.76 (1.63)	1.75 (1.81)	1.24 (1.44)	**1.64** *(1.67)*
DO, mg/L	7.59 (6.91)	7.84 (6.57)	9.64 (9.16)	8.24 (7.92)	2.75 (3.94)	**5.46** *(6.46)*
DO % of Sat.	74 (68)	76 (64)	92 (87)	79 (73)	27 (37)	**53** *(62)*
WQI	54 (50.1)	57 (47.7)	63 (62.7)	54 (50.1)	19 (27.1)	**47** *(45.8)*
WY20 Grade	B Good	B Good	B Good	B Good	E Poor	**C Fair**
16-yr Norm	*(B- Good)*	*(C+ Fair)*	*(B Good)*	*(B- Good)*	*(DMarginal)*	*(C Fair)*

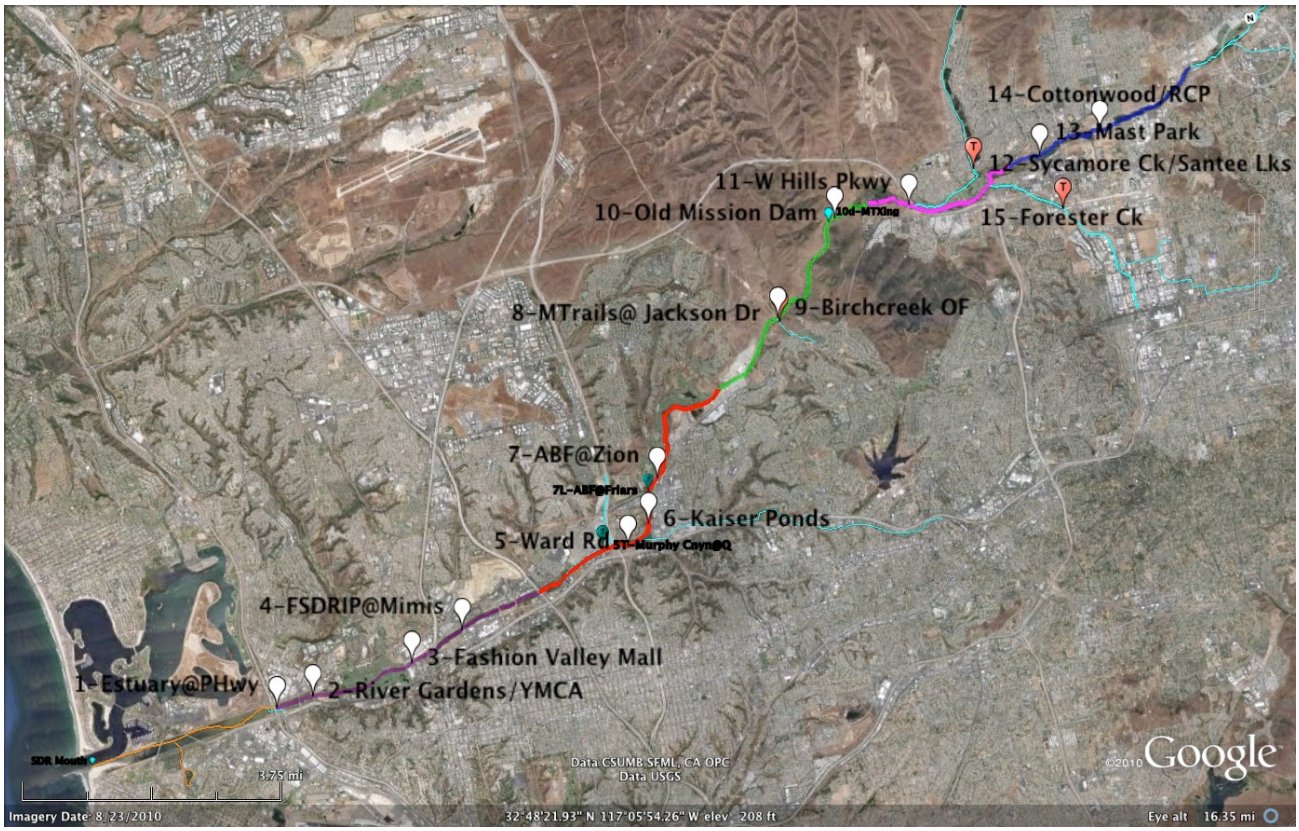
WY20 WQ metrics below (less than) 16-yr norms (expressed in parenthese) are in red text; values above norms are in blue.
(a) Weighted average of all five reaches within the Lower River watershed.
(b) Streamflow based on seasonal river channel gains/losses between Santee Basin and Mission Valley.

Appendix E - San Diego RiverWatch WQ Monitoring Program

Appendix E provides an overview of SDRPF's RiverWatch water quality monitoring (WQM) program that, over the last 14 years, has been engaged in collecting and assessing data pertaining to the Lower San Diego River (LSDR) watershed on a continuous monthly basis.

Monitoring Period & Coverage: Monthly monitoring over past 14 years (Oct. 2004 – Sept. 2018) covering the Lower San Diego River and its tributaries extending downstream from Lakeside (river mile 19.8 elev. 340 ft amsl) to the Estuary (river mile 2.96, elev. 5.8 ft amsl) under the I-5/ Pacific Hwy. overpasses. The LSDR watershed and monitoring sites are shown on **Figure E.1.**

Figure E.1 - Lower San Diego River Catchment and WQM Sites



Color Code for LSDR reaches on figure above: Estuary (orange), LMV (purple), UMV (red), MG (dark green), LSB (violet), USB (dark blue), Lakeside (light green), tributaries (light blue). Figure details can be downloaded through Google Earth from SDRPF website/River Monitoring page: file <Fig1.1WQMR.kmz>

Monitoring Sites: 15 total - 12 on main course (Mission Valley Section - sites 1-7, Mission Gorge Section - sites 8-10, Santee Basin Section - sites 11-15) plus three tributary stream sites are listed in **Table E.1.**

Table E.1 LSDR Sections, Reaches and Monitoring Sites

Section/Reach/Tributary	Site #s	Comments
Estuary Entrance	1E/1W	Tidal influence at transition from river to estuary
Lower Mission Valley (LMV)	2E/W, 3 & 4	4 miles of lower river extending to I-805
Upper Mission Valley (UMV)	5,6 & 7	4-mile stretch from I-805 to Princes View Dr
Mission Valley (West Sites)	1-7	8-mile western portion through Mission Valley
Mid-Section : Mission Gorge (MG)	8,9T & 10	5-mile mid-section, Princess View Dr to Kumeyaay Lk
Lower Santee Basin (LSB)	11,12T&15T	2-mile stretch from Kumeyaay Lk to Carlton Hills Blvd (Mast Park West)
Upper Santee Basin (USB)	13 & 14	3-mile stretch from Carlton Hills Blvd (Mast Park West) to Riverford Rd
Santee Basin (SB)	11-15T	5-mile eastern section from Kumeyaay Lk to Lakeside
Eastern Sections (East Sites)	8 -15T	10-mile eastern/upper 3 reaches (2 sections)
Tributaries:		
Murphy Canyon/Qualcom [a)]	5a	Enters LSDR southwest of SDSU Stadium
Jackson Dr/Birchcreek Wash [b)]	9T	Enters LSDR at Sycott Wash (just d/s of Site 8)
Santee Lakes/E. Sycamore Cnyn Ck	12T	Enters LSDR at Carlton Oaks GC (u/s of Site 11)
Forester Creek [c)]	15T	Enters LSDR d/s of Carlton Oaks GC at Site 11
Lower SDR Watershed (LSDR)	1-15T	Weighted average of all 5 reaches or all 3 sections

(a) Monthly monitoring discontinued in WY07; nearby Ward Rd Bridge site renumbered as 5.
(b) Monthly monitoring initiated in 2008; site also termed Jackson Dr. Outfall (OF).
(c) Monthly monitoring initiated in 2007 with adjusted site location in 2009 and again in 2017 back to original location in vicinity of SR 52.

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 E.2.** 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 13-yr period (Oct. 04 - Sept. 17) are in the range of 100 to 120. Two other water quality parameters monitored by others at several sites, streamflow from USGS (Poway Office) and coliform counts from SDCoastKeeper, are also recorded for purposes of computing the water quality index.

Protocol: *East Side* – (Santee Basin & Mission Gorge Sections). The 8 sites within upper three reaches (MG, LSB & USB) typically monitored 3rd Fri. or Sat. of month. *West Side* - (Mission Valley Section). Seven sites within the lower two reaches (LMV & UMV) monitored monthly, typically 3rd Sun. of month.

Table E.2 - LSDR Water Quality Monitoring Parameters

WQ Parameter	unit	Comments
Measured monthly at all sites:		
1. Temperature (Water Temp)	°C	Basic characteristic and WQ driver (see Table G.1)
2. pH	-	Degree of acidity (<7.0) or alkalinity (>7.0) (see Table G.3)
3. Specific Conductivity (SpC)	mS/cm	Measure of ionic content or dissolved solids (see Table G.2)
4. Dissolved Oxygen (DO)	mg/L	Good indicator of relative water quality (see Table G.4)
5. Percent of DO Saturation (DO%Sat)	%	Good indicator of general water quality (see Table G.5)
Sampled/tested monthly at selected sites: (typically 5 - 3 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
8. Turbidity	NTU	General indicator of amount of suspended and settleble solids
9. Barometric Pressure	mBars	Atomosphiric (air) pressure that along with water temperature affects dissolved oxygen levels.
Environmental Observations recorded at all sites:		
Atypical or notable conditions (scum, discoloration, odors, etc.), trash/debris, homeless encampments, biological activity (aquatic, avian, terrestrial), expansion of invasive species, erosion, scouring, other noteworthy comments re: watercourse, shoreline and adjacent environs. Special note as to invasive aquatic plant growth on water surface.		
General WQ Conditions observed at all sites: (numerical coding added in 2010)		
Weather Condition, Presence of Algae, Clarity, Color, Odor, Flow, Foam, Litter, Odor, Oil and Grease (O&G), e		
Parameters measured by others at selected sites		
10. Streamflow	cfs	USGS gauging stations at Fashion Valley and Mast Rd. near Santee (see Table H.1)
11. Coliform counts: (Escheria-coli, Enterococcus, Total Coliform bacteria)	MPN/ 100mL	SD CoastKeeper data taken at Fashion Valley Rd and Old Mission Historic Dam monitoring sites (see Table H.2)

Team Leaders (1-2) and citizen volunteers (3-8) meet at an appointed location, organize field equipment/transportation, drive to sites, measure physical-chemical water quality using the YSI Sonde meter, note special conditions/observations, collect samples for subsequent testing, then return to office, perform nutrient (NO_3 & PO_4) tests, store samples for subsequent laboratory analyses and clean/check-in/store field equipment.

Data Management: Water quality data are typically 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.

Table E-3 - WQM Site Locations

Site #	Site Name	u/s mi.	Elev. ft.	Location	GIS Coordinates Lat.	Long.
LMV - Lower Reach W Mission Valley: I-5 Bridge to I-805 Bridge (Sites 1-4)						
1	Estuary W/E	2.96	6	between PCH & I-5 on encased sewer main	32.76131	-117.20373
2	River Gardens E/W	3.50	11	W of YMCA, d/s of trolly at sewer X-ing	32.7623	-117.1944
3	Fashion Valley Mall W	5.08	22	T&C pedestrian bridge, Fashion Valley Rd (temp)	32.76517	-117.16869
4	FSDRIP	5.98	36	N of Mimi's on Mission Center Rd. Bridge	32.76986	-117.15482
UMV - Upper Reach E Mission Valley: I-805 Bridge to N end of Admiral Baker Field (Sites 5-7)						
5	Ward Rd Bridge	8.89	50	S. of Trolly overpass at Del Rio S intersection	32.78024	-117.11029
6	Kaiser Ponds	9.46	56	E. of Mission SD de Acala at SD Mission Rd.	32.78406	-117.10419
7	Admiral Baker Field	9.98	58	L - Lower (below Friars Rd bridge)	32.79038	-117.10314
	ABF - Zion Rd	10.2	62	Z - Terminus of Zion Ave at Riverdale St.	32.79304	-117.09984
West (MV) - Mission Valley Section: Estuary to Admiral Baker Field (Sites 1-7) [LMV+UMV]						
MG - Mission Gorge Reach: Quarry Area to Old Mission Dam (Sites 8-10)						
8	Mission Trails @ Jackson Dr	13.82	159	SDCWA downstream of Scycott Crossing	32.82124	-117.06205
9T	Jackson/Birchcreek Wash	13.86	198	San Marcos area drainage by Jackson Dr. Trail	32.82268	-117.06224
10	Old Mission Dam W/E	15.65	265	Downstream side of Old Mission Dam	32.83977	-117.04332
Mid-Section (MG) -Mission Gorge Section: Quarry Area to Old Mission Dam (Sites 8-10)						
LSB - Lower Reach Santee Basin: W Hills Pkwy to Carlton Hills Bridge (Sites 11,12 &15)						
11	West Hills Pkwy	17.03	300	at/below West Hills Pkwy overpass at USGS sta.	32.83936	-117.02436
12T	Carlton Oaks Dr/Santee	18.23	320	W Sycamore Ck/Santee Lakes @ Carlton Oaks Dr.	32.84431	-117.00635
15T	Forester Creek at Mission Gorge Rd (Rt 52/Prospect)	18.86	334	Primary tributary entering SDR just u/s of Site 11 past W.Hills Pky & Rt 52) at west end of COGC.	32.83221	-116.98658
USB - Upper Reach Santee Basin: Carlton Hills Bridge to Riverford Rd (Sites 13W, 13E & 14)						
!3W	Mast Park West	18.35	328	below Carlton Hills Blvd, overpass		
13E	Mast Park East	18.50	330	Pedestrian bridge behind (N of) Walmart, end of River Rock Ct.	32.84696	-116.97335
14	Cottonwood Ave/RCP	19.84	340	N. of Chubb Ln. at N. Magnolia Ave.	32.84434	-116.98947
14	Magnolia Ave	19.9	342	Under Magnolia Bridge/West end of culvert	32.84424	-116.98950
East (SB) - Santee Basin Section: West Hills Parkway to Lakeside (Sites 11-15 above) [LSB+USB]						
LSDR - Lower San Diego River Watershed: SD Estuary to Lakeside (Sites 1-15 above) [LMV+UMV+MG+LSB+USB]						

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 LSDR sites, reaches, sections and tributaries for each WQ parameter of interest including those monitored by others.

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

Mean – average of a series (sum of values divided by number of values)
Median – middle value of an ordered series (50% larger - 50% smaller)
Minimum – lowest or smallest value measured
Maximum – highest or greatest value measured
Range – Difference between maximum and minimum values
1st Quartile (Q1) – 25% of values smaller - 75% larger
2nd Quartile (Q2) – 50% of values larger - 50% smaller (same as median value)
3rd Quartile (Q3) – 75% of values smaller - 25% larger
Variance – sum of the squares of deviation from the mean or average value
Standard Deviation (SD) – square root of the variance
Skew – third moment about the mean divided by the standard deviation (SD)
Coefficient of Variance (CoV)– Variance divided by the mean
Trendline - Moving/running average values taken over 12-month period.

Appendix F - LSDR Hydrology and Water Quality

Streamflow or river discharge, is the volume of water moving past a designated location over a fixed period of time. It constitutes one of the primary drivers of changes in water quality. Often expressed as cubic feet per second (cfs) or million gallons per day (mgd), flow is the amount of water moving off a watershed into the watercourse, as affected by weather (increasing during rainstorms and decreasing during dry spells) and continually changing during each season. River flow rapidly decreases during summer months when rainfall is minimal, evaporation rates high and riparian vegetation extracts water from the ground. August and September, the last two months of summer (and a water year), are typically, but not always, months of lowest flow. A function of both volume and velocity, streamflow has a major impact on living organisms, riparian habitat, benthic conditions and overall water quality. Velocity of flow, typically increasing as volume increases, determines the kinds of organisms that live in an aquatic system and also affects the amount of silt and sediment transported. Fast moving water typically contains much higher DO concentration levels than sluggish flow, as its better aerated.

LSDR average daily flow (ADF) values as recorded at the two USGS gauging stations in the lower watershed are expressed in **Table F.1** for both the 16-yr monitoring period (Oct 2004 - Sept 2020) and over the past 55 years (1965-2020) of record**.** The ADF values are in close accord for both stations. River discharge over the last 16 years is roughly 20% below the 55-year norm in Mission Valley and 25% below the Santee norm. WY20 discharges are 47% greater than than the 55-yr norm at the Fashion Valley Site and 21.5% above the norm at Santee. The average annual LSDR streamflow for WY20 of 33.1 cfs is 16.5% more than the long-range (55-yr) norm and 42% above the current 16-year norm.

Correlations between total annual rainfall and ADF over the past 56 years of hydrologic record and during the 16-year period of RiverWatch monitoring for the two lower SDR gauging stations are presented in **Tables F.2 and F.3**, respectively. In terms of total annual rainfall (TARF), WY05 was a "Very Wet" (TARF > 20") hydrologic year, whereas WY07 and WY18 were "Very Dry" years (TARF <5"). WY11, WY15, WY17, WY19 and WY20 were all "Above Normal" rainfall years (12-15") while WY09 and WY10 (8-12") were considered "Normal". The 16-yr ADF in the East and West sections are 18 and 32 cfs, respectively; values that are 15-20 percent below long-range ADFs at the two stations. WY20 total rainfall of 13.60 inches (345 mm) is 37% above the long-range average while average daily flow for this year was 17% above the long-range (55-yr) norm of 28.4 cfs (18 mgd).

Monthly discharge data (min, max and average daily flow) for the two USGS gauging stations extending from Oct. 2004 through Oct. 2020 are plotted in **Chart F.1.** Average daily flow (ADF) for the Lower San Diego River varies from less than 0.2 cfs (0.1 mgd) during the summer (dry) months to nearly 220 cfs (142 mgd) during several winter (wet) periods in the East (Santee Basin) and up to 390 cfs (252 mgd) in the West (Mission Valley) section. Running average ADF values, trending downward in WY12-WY14 increased in WY15, fell in WY16 and WY18, then increased in WY17, WY19 and WY20 as expressed on **Charts F.1** and **F.3**.

Table F.1 - Lower SDR Average Daily Flow (WY20 and 16-yr Norms)

Season	West - Mission Valley		East - Santee Basin		LSDR [a]	
	WY20	16-yr	WY20	16-yr	WY20	16-yr
Fall (Oct-Nov)	6.5	*(7.7)*	3.6	*(3.9)*	4.5	*(5.0)*
Winter (Dec-Mar)	66.1	*(70.2)*	24.0	*(37.0)*	39.1	*(46.7)*
Spring (April-May)	145.3	*(25.9)*	67.3	*(14.8)*	92.5	*(17.7)*
Summer (June-Sept)	3.5	*(3.2)*	2.8	*(1.8)*	2.7	*(2.1)*
Annual ADF [b], cfs	48,5	*(29.6)*	20.8	*(16.3)*	30.1	*(20.0)*
Wet Season (Nov-April)	90.0	*(55.0)*	37.1	*(29.1)*	55.2	*(36.6)*
Dry Season (May-Oct)	7.0	*(5.1)*	4.5	*(3.0)*	5.0	*(3.5)*
Annual Discharge, AFY [c]	35,114	*(21,430)*	15,059	*(11,800)*	21,792	*(14,480)*

(a) Lower San Diego River average daily flow represents a mean hydrologic condition based on averaging the two USGS gauging station flow values.
(b) ADF values are expressed in cubic feet per second (cfs) and million gallons per day (mgd); 1 cfs = 0.646 mgd.
(c) Total annual discharge volume expressed in thousand acre-feet (1 AF = 325,900 gallons); WY20 and 16-Yr averages.

Table F.2 - Rainfall and Long-Term Average Daily Flow (1914-2020)

Type	# of Years	Percent of Total Years		Total Annual Rainfall [a]			Average Daily Streamflow, cfs		
				inches	mm	Avg., mm	East [b]	West [c]	LSDR
Very Wet	3	3%	31%	>20	>500	580	68	113	92
Wet	10	10%		15-20	380-499	430	48	81	66
Above Norm [d]	19	18%		12-15	300-379	340	26	44	35
Normal	40	38%	38%	8-12	200-299	250	10	18	15
Dry	26	25%	31%	5-8	125-199	160	7	12	10
Very Dry	7	7%		<5	<125	100	5	9	7
Sum/An. Avg	105	100%		9.94		250	14.2	23.3	17.4

a) Total annual rainfall from 1 October through September 31.
b) Santee Basin USGS Stream Gauge Station #11022480 at/below Mast bridge near Santee.
c) Mission Valley USGS Stream Gauge Station #11023000 at Fashion Valley Mall; incomplete data prior to 1968.
d) Above normal annual rainfall (12-15 in/yr) resulting in LSDR average daily flows in the 25-50 mgd range.

Table F.3 - Annual Rainfall and Average Daily Flow (WY05-WY20)

(Type of Year)	Annual Rainfall		Variance [a]	ADF, cfs (mgd)			Variance [d]
	mm	inches		East [b]	West [c]	LSDR	
WY05 (Very Wet)	574	22.60	127%	50.9 (33)	100 (65)	71.5 (46)	152%
WY06 (Dry)	152	6.00	-40%	10.7 (7)	17.5 (11)	13.6 (9)	-52%
WY07 (Very Dry)	98	3.85	-61%	7.2 (5)	12.8 (8)	9.5 (6)	-67%
WY08 (Dry)	183	7.20	-28%	13.3 (9)	25.0 (16)	18.2 (12)	-36%
WY09 (below normal)	232	9.15	-8%	15.0 (10)	27.2 (18)	20.1 (13)	-29%
WY10 (above normal)	282	11.10	12%	25.1 (16)	42.5 (27)	32.4 (21)	14%
WY11 (above normal)	323	12.70	28%	43.3 (28)	61.9 (40)	46.9 (30)	65%
WY12 (Dry)	201	7.91	-20%	10.1 (8)	19.0 (12)	14.9 (10)	-48%
WY13 (Very Dry)	166	6.56	-34%	8.2 (5)	10.9 (7)	9.1 (6)	-68%
WY14 (Very Dry)	129	5.06	-49%	4.3 (3)	6.1 (4)	5.1 (3)	-82%
WY15 (above normal)	302	11.91	20%	7.1 (5)	15.2 (10)	10.5 (7)	-63%
WY16 (Dry)	208	8.20	-18%	12.2 (8)	24.4 (16)	15.6 (10)	-45%
WY17 (above normal)	323	12.73	28%	27.7 (18)	57.3 (37)	40.0 (26)	41%
WY18 (Very Dry)	83	3.34	-67%	5.0 (4)	7.2 (5)	5.9 (4)	-79%
WY19 (above normal)	324	12.83	29%	20.0 (13)	36.9 (24)	27.0 (17)	-4%
WY20 (above normal)	**345**	**13.60**	**37%**	**22.5 (14)**	**48 (31)**	**33.1 (21)**	**17%**
16-yr Norm (05-20)	232	9.41	-8%	17.7 (6)	31.8 (20)	23.3 (14)	-20%
55-yr AADF	252	9.92	0%	21.8/(14)	36.7 (24)	28.4 (18)	0%

a) Percent difference from 55-yr average annual rainfall (252 mm/yr or 9.92 in/yr); black-above, red-below average.
b) Santee Basin USGS Stream Gauge Station 00067556 at Mast Rd., Santee.
c) USGS Stream Gauge Station 00459999 at Fashion Valley Mall; incomplete data prior to 1965.
d) Percent difference from average annual daily flow (AADF).

Monthly and seasonal average annual flow (lines) and rainfall (bars/columns) over the monitoring period for both stations are shown in **Chart F.2.** The seasonal flow patterns express range, variance and positive correlation in monthly ADF and rainfall over the past 16 years. Winter season flows within the lower watershed are several hundred times greater than summer, dry-season flow.

Average annual, winter and summer flows and rainfall are expressed graphically in **Chart F.3.** Highest flows during the 16-yr monitoring period at both gauging stations were recorded in WY05 (very wet year); the lowest in WY14 (very dry year). Water years '06, '07, '08, '12, '13, and '14 were all below normal, witnessing both below average rainfall and stream discharge. Water years '10, '11, '15, and '17 were slightly above normal in terms of total annual rainfall (verticle bars) and average daily streamflow (lines). WY19 witnessed above normal rainfall but below normal streamflow whereas WY20 flows and rainfall were both above.

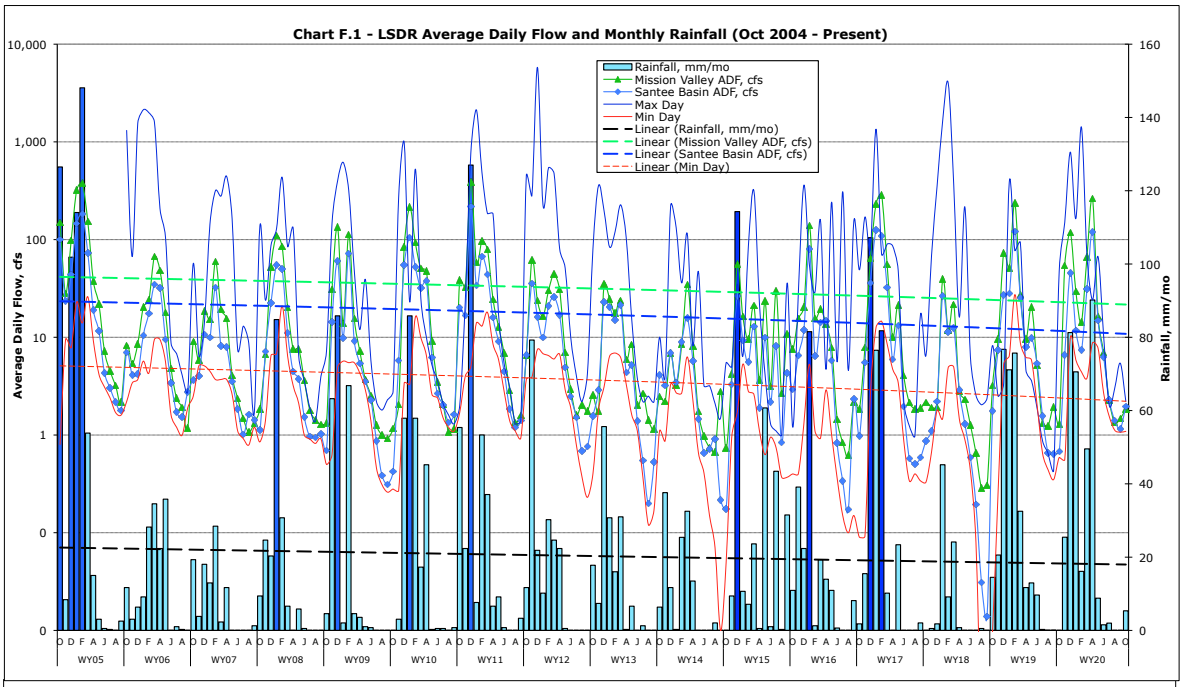


Chart F.1 - LSDR Average Daily Flow and Monthly Rainfall (Oct 2004 - Present)
Rainfall, mm/mo
Mission Valley ADF, cfs
Santee Basin ADF, cfs
Max Day
Min Day
Linear (Rainfall, mm/mo)
Linear (Mission Valley ADF, cfs)
Linear (Santee Basin ADF, cfs)
Linear (Min Day)
Average Daily Flow, cfs
Rainfall, mm/mo
WY05
WY06
WY07
WY08
WY09
WY10
WY11
WY12
WY13
WY14
WY15
WY16
WY17
WY18
WY19
WY20

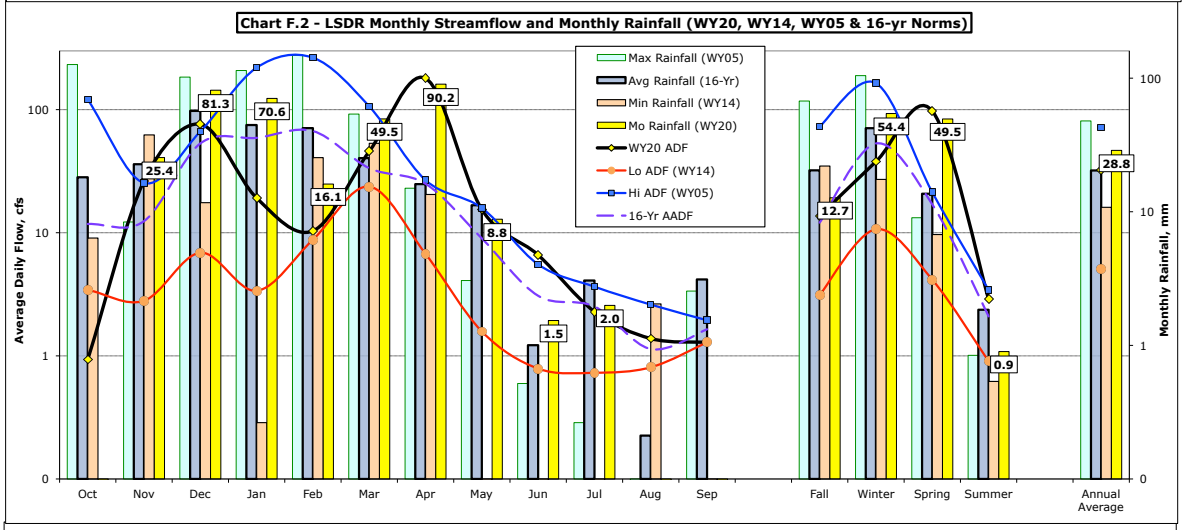


Chart F.2 - LSDR Monthly Streamflow and Monthly Rainfall (WY20, WY14, WY05 & 16-yr Norms)
Max Rainfall (WY05)
Avg Rainfall (16-Yr)
Min Rainfall (WY14)
Mo Rainfall (WY20)
WY20 ADF
Lo ADF (WY14)
Hi ADF (WY05)
16-Yr AADF
Average Daily Flow, cfs
Monthly Rainfall, mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Fall
Winter
Spring
Summer
Annual Average

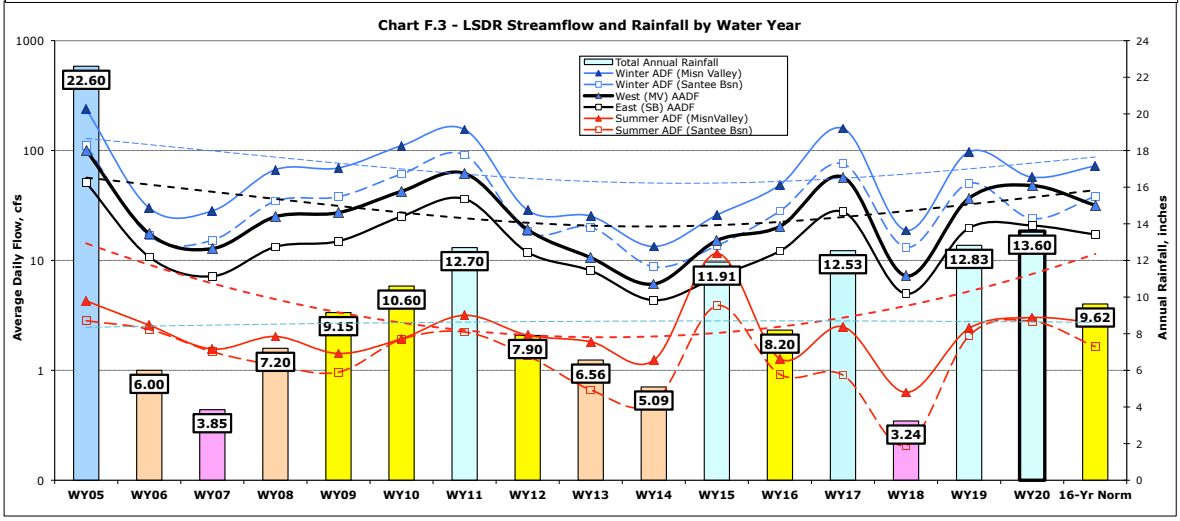


Chart F.3 - LSDR Streamflow and Rainfall by Water Year
Total Annual Rainfall
Winter ADF (Misn Valley)
Winter ADF (Santee Bsn)
West (MV) AADF
East (SB) AADF
Summer ADF (MisnValley)
Summer ADF (Santee Bsn)
Average Daily Flow, cfs
Annual Rainfall, inches
WY05
WY06
WY07
WY08
WY09
WY10
WY11
WY12
WY13
WY14
WY15
WY16
WY17
WY18
WY19
WY20
16-Yr Norm

Appendix G - WY20 LSDR Monthly WQM Site Data

Appendix G consists of six tables listing WY20 RiverWatch water quality monitoring data by month and site. Tables G.1(W) and G.1(E) present water temperature recordings. Tables G.2 (W&E) -Specific Conductance, Tables G.3 - pH, G.4 - Dissolved Oxygen Concentration , G.5- DO as Percent of Saturation and G6 Nutrients (NO3 & PO4) at selected sites.

Table G.1(W) West Section Water Temperature (WY20 Readings)

Site #	1	2	3	4	5	6	7
Reach	Lower Mission Valley				Upper Mission Valley		
Oct	24.4	19.8	20.7	20.5	16.0	18.3	18.8
Nov	18.4	17.5	17.8	18.0	14.4	16.0	16.5
Dec	13.2	12.1	12.1	11.8	11.6	11.8	11.4
Jan	12.8	12.6	12.5	12.4	11.7	12.0	11.6
Feb	16.6	16.5	16.5	15.7	15.2	15.7	15.5
Mar	18.3	16.7	17.2	16.6	18.3	16.9	17.5
Apr	17.5	17.2	17.6	17.7	16.9	17.2	17.6
May	21.5	21.2	21.5	21.5	20.8	21.0	20.9
Jun	23.1	*23.0*	23.0	23.2	22.3	23.1	23.2
Jul	28.9	27.3	26.6	27.1	23.2	26.2	24.4
Aug	29.2	27.5	26.6	28.1	23.4	25.9	25.9
Sept	24.0	23.0	23.9	23.5	20.7	21.2	23.2
WY20	**20.7**	**19.53**	**19.66**	**19.67**	**17.87**	**18.78**	**18.87**
Norn	*19.7*	*19.0*	*19.2*	*19.7*	*17.2*	*18.3*	*18.1*

a) All values expressed in °C; WY20 averages greater than 16-yr norms (in parenthese) are shown in red; below in blue.
b) Water year results are based on unweighted averaging of monthly data (Oct-Sept); water temps >22oC are in tan cells; values <15oC within blue.

Table G.1(E) Mid and East Section Water Temperature (WY20 Readings)

Site	8	9T	10	11	12T	13	14	15T
Reach	Mission Gorge			Lower Santee Basin		Upper Santee Basin		LSB [c]
Oct	16.3	15.3	17.6	17.5	21.4	18.6	20.5	17.7
Nov	16.6	13.8	14.5	16.0	18.6	14.3	17.3	15.1
Dec	9.2	8.2	8.8	9.9	12.8	10.9	12.3	9.6
Jan	11.3	13.7	11.1	12.0	12.4	11.1	12.0	11.6
Feb	13.9	12.7	13.7	13.3	16.8	12.8	15.1	15.2
Mar	16.9	16.4	16.6	16.4	17.0	16.3	16.6	14.2
Apr	19.2	19.1	16.0	16.3	18.7	17.3	16.8	16.7
May	19.5	17.5	18.0	17.3	19.9	18.9	20.2	18.7
Jun	21.1	17.4	21.2	20.0	21.6	21.1	23.1	21.5
Jul	23.3	18.9	24.3	21.4	-	23.5	26.6	23.1
Aug	23.4	21.4	25.1	22.7	-	25.1	28.7	24.1
Sep	23.3	19.8	21.8	20.3	=	21.3	23.9	20.5
WY20[b]	**17.83**	**16.18**	**17.39**	**16.93**	**17.68**	**17.59**	**19.42**	**17.33**
Norm	*17.16*	*15.78*	*17.66*	*16.70*	*17.74*	*18.37*	*17.58*	*18.01*

a) All values expressed in oC; WY20 values greater than 16-yr norms are shown in red; below in blue.
b) Water year WY20 and 16-yr values are based on unweighted averaging monthly data (Oct-Sept); water temps >22oC in tan cells, <15oC blue cells.
c) Forester Creek discharges within the Lower Santee Basin reach at the west end of Carlton Hills Golfcourse just upstream of Site 11.

Table G.2(W) West Section Specific Conductance (WY20 Readings)

Site #	1	2	3	4	5	6	7
Reach	Lower Mission Valley				Upper Mission Valley		
Oct	10.75	3.88	3.54	3.18	3.69	3.78	3.03
Nov	22.77	4.00	3.75	3.26	3.93	4.03	2.99
Dec	22.62	1.96	1.86	1.91	1.91	1.71	1.92
Jan	2.12	2.02	2.01	2.04	1.88	1.86	1.96
Feb	2.74	2.47	2.36	2.19	1.96	2.15	2.05
Mar	3.97	1.12	1.05	1.03	1.16	1.16	1.24
Apr	1.23	0.93	0.92	0.93	0.86	0.87	0.92
May	2.71	2.42	2.32	2.32	2.25	2.10	2.12
Jun	4.68	2.88	2.80	2.70	2.83	2.52	2.46
Jul	6.45	3.23	3.14	3.15	3.28	2.92	2.90
Aug	26.56	3.64	3.48	3.32	3.47	3.40	3.44
Sep	44.35	4.16	3.37	2.95	3.37	3.40	3.05
Avg [b]	**12.579**	**2.547**	**2.550**	**2.415**	**2.549**	**2.492**	**2.340**
Norm	*8.682*	*2.641*	*2.541*	*2.453*	*2.590*	*2.586*	*2.461*

a) All values expressed in milli-Siemens/cm; SpC values >4.0 are in tan cells, values < 2.0 mS/cm are in blue cells.
b) WY20 annual average values greater than 16-yr norms are in red; blue values below.

Table G.2(E) Mid and East Section Specific Conductance (WY20 Readings)

Site	8	9T	10	11	12T	13	14	15T
Reach	Mission Gorge			Lower Santee Basin		Upper Santee Basin		LSB [c]
Oct	3.13	5.37	3.00	2.91	2.06	2.50	1.81	2.76
Nov	2.05	4.63	2.08	2.10	1.89	1.38	1.12	2.88
Dec	1.82	3.32	1.85	1.84	0.92	1.40	0.86	2.31
Jan	1.97	4.29	2.00	2.12	0.97	1.55	1.16	2.66
Feb	1.11	3.02	1.19	1.26	0.69	1.07	0.88	0.99
Mar	0.89	2.21	1.01	1.08	0.50	0.63	0.62	2.63
Apr	1.24	2.93	1.28	1.39	0.57	1.11	1.01	2.55
May	1.87	4.16	1.88	2.00	0.71	1.67	1.44	2.63
Jun	2.38	4.85	2.44	2.59	-	1.91	1.59	2.89
Jul	2.66	4.88	2.65	2.72	=	2.09	1.66	2.84
Aug	2.66	4.62	2.58	2.54	-	1.99	1.55	2.68
Sep	3.13	5.37	3.00	2.91	2.06	2.50	1.81	2.76
WY20 [b]	**2.110**	**4.130**	**2.078**	**2.114**	**1.132**	**1.640**	**1.286**	**2.539**
Norm	*2.308*	*4.811*	*2.245*	*2.233*	*1.615*	*1.904*	*1.488*	*2.687*

a) All values expressed in milli-Siemens/cm; WY20 values greater than 16-yr norms are in red, below in blue. Cells in blue <2.0: cells in tan >4.0 mS/cm

b) WY20 annual averages and 16-yr norms are based on averaging of monthly data (Oct-Sept);

c) Forester Creek discharges within the Lower Santee Basin enter SDR beyond the west end of Carlton Hills Golf Course.

Table G.3(W) West Section pH (WY20 Readings)

Site #	1	2	3	4	5	6	7
Reach	Lower Mission Valley				Upper Mission Valley		
Oct	7.82	7.65	7.84	7.79	7.48	7.47	7.30
Nov	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Dec	7.70	7.75	7.94	7.78	7.71	7.73	7.67
Jan	7.89	7.75	7.83	7.77	7.73	7.63	7.60
Feb	7.80	7.78	-	-	7.77	7.64	-
Mar	7.75	7.70	7.79	7.85	7.84	7.92	7.60
Apr	7.75	7.77	7.73	7.74	7.74	7.58	7.69
May	8.03	7.83	8.03	7.95	7.84	7.28	7.81
Jun	7.58	7.81	7.87	7.86	7.71	7.64	7.68
Jul	7.98	8.01	7.99	8.02	7.71	7.80	7.85
Aug	7.99	7.93	7.92	8.15	7.36	7.58	7.81
Sep	8.14	8.10	8.14	8.25	7.94	7.89	8.05
WY20 [b]	**7.83**	**7.80**	**7.87**	**7.88**	**7.69**	**7.64**	**7.69**
Norm	*7.76*	*7.69*	*7.77*	*7.79*	*7.63*	*7.62*	*7.56*

a) All values are unit-less; monthly values above 8.0 are in tan cells, and those beloe 7.5 in pink.
b) WY20 and 16-yr annual average values based on averaging monthly results (Oct-Sept); annual averages >16-yr norms are shown in blue; below norms in red.

Table G.3(E) Mid and East Section pH (WY20 Readings)

Site	8	9T	10	11	12T	13	14	15T
Reach	Mission Gorge			Lower Santee Basin		Upper Santee Basin		LSB [c]
Oct	7.57	8.24	7.45	7.28	7.60	7.42	7.86	7.85
Nov	7.53	8.13	7.63	7.27	7.89	7.18	7.63	7.82
Dec	8.11	8.38	7.57	7.36	7.94	7.46	7.77	8.34
Jan	8.14	8.31	7.70	7.51	7.90	7.50	8.02	8.11
Feb	8.13	8.42	7.70	7.29	8.07	7.35	8.08	8.17
Mar	8.14	8.49	8.05	7.85	8.06	7.55	7.96	8.05
Apr	8.20	8.50	7.95	8.02	7.90	7.64	7.88	8.29
May	8.13	8.44	7.78	7.85	7.97	7.81	8.02	8.19
Jun	8.07	8.29	7.79	7.71	7.92	7.48	8.04	8.05
Jul	8.08	8.27	7.97	8.02	-	7.80	8.26	8.18
Aug	7.60	8.29	7.92	7.67	-	7.65	8.23	8.05
Sep	8.13	8.44	8.13	8.06	-	8.14	8.23	8.24
WY20 [b]	**7.99**	**8.35**	**7.80**	**7.66**	**7.92**	**7.58**	**8.00**	**8.11**
Norm	*7.68*	*7.87*	*7.81*	*7.55*	*7.93*	*7.65*	*7.83*	*8.05*

a) All pH values are unit-less; monthly values above 8.0 are in tan cells, and below 7.5 in pink.
b) WY20 annual average and 16-yr norms are based on averaging of monthly data (Oct-Sept); averages > 16-yr norms are shown in blue; belwo norms in red.
c) Forester Creek discharges within the Lower Santee Basin section of the river downstream of Carlton Oaks Golf course; just upstream of Site 11.

Table G.4(W) West Section Dissolved Oxygen Concentration (WY20 Readings)

Site #	1	2	3	4	5	6	7
Reach	Lower Mission Valley				Upper Mission Valley		
Oct	5.38	2.60	3.09	4.92	2.32	**0.07**	4.15
Nov	4.63	3.60	3.42	6.03	3.24	**0.80**	4.27
Dec	8.12	9.03	10.80	10.55	8.02	8.45	9.66
Jan	10.23	8.10	9.01	7.93	8.55	8.42	9.94
Feb	5.53	6.15	6.72	5.20	6.17	5.00	7.75
Mar	6.22	5.54	6.04	5.99	7.55	6.04	8.52
Apr	6.59	5.82	6.39	5.82	6.41	6.44	7.57
May	6.49	4.74	3.36	7.04	3.90	2.53	5.29
Jun	4.72	4.14	2.90	4.18	3.18	1.78	4.18
Jul	5.27	3.49	3.30	3.50	2.48	1.67	3.50
Aug	8.33	3.35	5.32	7.79	2.90	**0.43**	5.06
Sep	6.32	3.71	3.38	5.88	3.10	1.20	5.11
WY20	**6.49**	**5.02**	**5.31**	**6.24**	**4.82**	**3.57**	**6.25**
Norm	*6.15*	*4.42*	*4.64*	*6.11*	*4.77*	*3.56*	*5.08*

a) All values expressed in milligrams/liter and (Percent of Saturation); WY20 and 16-yr averages less than 5 mg/L (DO depletion threshold) shown in red, less than 2.5 mg/L (hypoxic level) cells highlighted in light yellow and <1.0 mg/L (exaerobic zone) in dark yellow. DO levels of 7.0 mg/L or greater are shown in blue cells.

Table G.4(E) Mid and East Section Dissolved Oxygen Concentration (WY20 Readings)

Site	8	9T	10	11	12T	13	14	15T
Reach	Mission Gorge			Lower Santee Basin		Upper Santee Basin		LSB [c]
Oct	2.94	8.40	4.81	4.22	5.47	2.67	2.03	4.80
Nov	6.86	7.30	6.79	4.95	5.66	**0.09**	2.55	6.17
Dec	12.12	12.47	9.34	9.21	7.27	1.79	2.89	9.55
Jan	11.53	10.52	9.33	7.92	8.18	**0.45**	5.93	9.51
Feb	10.20	11.30	8.71	7.85	8.78	**0.11**	7.66	8.51
Mar	8.60	10.30	6.01	7.27	7.31	**0.92**	9.94	8.18
Apr	8.57	9.49	5.77	6.90	8.41	2.00	4.07	9.80
May	7.65	9.65	3.75	5.71	7.78	1.55	4.10	6.80
Jun	6.73	9.04	2.27	4.76	6.32	1.42	2.99	4.30
Jul	4.44	8.18	5.80	4.82	-	1.24	3.64	6.05
Aug	3.51	10.26	5.76	5.32	-	**0.89**	5.16	4.76
Sep	7.00	9.70	5.58	4.66	-	1.57	3.51	5.86
WY20 [b]	**7.51**	**9.72**	**6.16**	**6.07**	**7.24**	**1.23**	**4.54**	**7.03**
Norm	*7.29*	*9.21*	*6.99*	*5.89*	*7.09*	*2.84*	*3.39*	*7.41*

a) All values expressed in milligrams/liter; WY20 values less than 5 mg/L (DO depletion threshold) are expressed in red ,< 2.5 mg/L (hypoxic level) cells highlighted in light yellow and <1 mg/L (exaerobic zone) dark yellow. DO levels of 7.0 mg/L or greater are shown in blue cells,

b) WY20 annual averagea and 16-yr normss are based on averaging of monthly data (Oct-Sept).

c) Tributary discharges within the Lower Santee Basin reach enter below the west end of Carlton Oaks Golf Course.

Table G.5(W) West Section DO Percent of Saturation (WY20 Readings)

Site #	1	2	3	4	5	6	7
Reach	Lower Mission Valley				Upper Mission Valley		
Oct	65	29	35	55	24	1	45
Nov	49	38	37	64	32	8	44
Dec	77	80	101	99	74	78	89
Jan	97	77	85	75	79	78	92
Feb	58	65	69	54	62	50	79
Mar	67	57	64	62	80	63	84
Apr	70	61	67	62	67	67	80
May	74	55	39	83	45	29	61
Jun	56	50	35	50	37	21	50
Jul	68	45	42	44	27	20	42
Aug	107	43	66	100	35	5	63
Sep	70	44	41	70	34	14	59
WY20	**71.5**	**53.7**	**56.7**	**68.2**	**49.8**	**36.3**	**65.6**
Norm	*67.3*	*46.3*	*48.9*	*65.8*	*48.8*	*36.4*	*52.4*

a) All values expressed as percent of saturation; WY20 values < 55% (DO depletion threshold) are expressed in red ,< 25% (hypoxic level) cells highlighted in light yellow and <10% (exaerobic zone) dark yellow. DO% Sat vlues of 70 or greater are shown in blue cells.

Table G.5(E) Mid and East Section DO Percent of Saturation (WY20 Readings)

Site	8	9T	10	11	12T	13	14	15T
Reach	Mission Gorge			Lower Santee Basin		Upper Santee Basin		LSB [c]
Oct	31	85	49	45	62	29	23	51
Nov	87	56	68	51	61	**1**	27	61
Dec	106	107	81	78	69	17	27	85
Jan	107	103	86	74	78	**4**	55	88
Feb	100	108	85	76	90	**1**	77	86
Mar	84	106	61	75	76	**9**	103	81
Apr	95	103	58	71	92	21	42	102
May	85	102	39	60	86	18	46	73
Jun	75	91	26	52	71	17	35	48
Jul	53	89	70	55	-	17	46	71
Aug	40	117	69	62	-	**11**	67	58
Sep	83	108	64	52	-	17	42	66
WY20 [b]	**78.7**	**97.9**	**63.1**	**62.6**	**79.8**	**13.6**	**49.2**	**72.5**
Norm	*74.3*	*93.5*	*72.7*	*59.5*	*71.6*	*29.3*	*34.0*	*71.0*

a) All values expressed as percent of saturation; WY20 values < 55% (DO depletion threshold) are expressed in red ,< 25% (hypoxic level) cells highlighted in light yellow and <10% (exaerobic zone) dark yellow.. DO% Sat values of &) or greater are shown in blue cells.

b) WY20 annual average and 16-yr norms are based on averaging of monthly data (Oct-Sept).

Table G.6 WY20 Nutrient (NO3/PO4) Readings at Selected Sites

Site #	2-YMCA	7-ABF	11-WHPE	14E-MPE	14W-MPW	15-FCK
Section	Mission Valley		Santee Basin			
Oct	0.0/0.4	0.0.0.1	0.2/**0.6**	0.1/0.2	-	**1.0**/0.3
Nov	-	-	0.3/0.4	0.0/0.4	-	**1.3**/0.1
Dec	0.0/0.3	0.0/0.1	0.6/0.2	0.3/**0.6**	-	**3.4**/0.1
Jan	0.0.0.1	0.0/0.0	0.3/0.2	0.1/0.2	-	0.13/0.3
Feb	-	-	0.2/0.1	0.0/0.1	-	0.0/0.1
Mar	0.0/0.25	0.2/0.4	0.3/0.25	0.0/0.1	-	**0.7**/0.15
Apr	-	-	-	-	-	-
May	0.0/**0.65**	0.0/0.9	-	-	-	-
Jun	-	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	0.05/**0.8**	0.08/0.1	0.2/**0,8**	0.1/**0.8**	0.1/**0.6**	**0.8/0.6**
Sep	0.1/0.4	0.1/0.3	0.1/0.4	0.01/0.1	0.1/0.1	**0.9**/0.4

a) *All nutrient values (Nitrogen as N03/Phosphate as PO4) expressed in mg/L. Nutrient concentrations >0.5 mg/L, indicating a cause for concern, are shown in red.*

Appendix H - Water Quality Indexing

The Lower San Diego River (LSDR) Water Quality Index (WQI) has been developed for the purpose of providing a simple and concise expression of regularly monitored physical-chemical and bacteriological water quality data compiled by the SDRPF RiverWatch Team and others. The index is intended to aid in assessment of the LSDR watershed, primarily for non-body contact recreational uses and environmental enhancement. As designed, the metric constitutes a means to compare averages, variances and trends in normalized values over time (temporally) and by relative location (spatially) within the watershed. The index allows one to interpret large amounts of aggregated data and relate overall water quality variations to changes, be they from natural causes or anthropogenic impairments. The WQI has been used to identify general water quality trends over the past 16 years of monitoring and potential problem areas within the LSDR watershed. Such patterns and locations are then 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 of the environment. Used in this manner, the index provides an additional metric for evaluating effectiveness of some of the San Diego River water quality improvement programs and may also assist responsible agencies and organizations in reformulating priorities or updating specific policies.

Running average WQI values from WY05 through WY20 are expressed by river section and reach on charts H.1 and H.2, respectively. The overall temporal varience in WQI values and streamflow are expressed in Chart H.3. The spacial variance in index values for the lower river monitoring sites is shown on Chart H.4.

Chart H.1 provides the range (max.=green - min.= red) in monthly values, the running averages by river section as well as monthly streamflow (blue bars) over the 16-yr period (WY05-WY20_ of RiverWatch monitoring. The positive correlations in seasonal fluctuation between streamflow and water quality values are shown. General trends of lower water quality at all sites in years of below average stream discharge are evident. The overall (heavy black line) general decline in the index over 16 years is shown as a dashed line. Although the average annual rate of decline in the index is on the order of one percent; WYs 19 & 20 have witnessed a measurable recovery from WY18 near-minimum values. The current running average index of 32.4 is three percent above the 16-year norm of 31.3. The WY18 index of 22.4 was 28% below the current 16-yr norm. The lowest running average index value of 19 was reached in October of 2014; 39 percent below the 16-yr norm

Chart H.2 presents overall (LSDR) monthly running avearge WQI values (heavy black lines) over the 16-year period. Seasonal patterns expressed in monthly results and trends described by running averages in values are apparent for each reach of the river. The water quality fluctuations over time in individual reaches, sections and the overall LSDR flow-weaighted values expressed on both a running average and seasonal cycle basis can be observed. The Upper Santee Basin (USB) reach (red line sites 13&14) have presented the lowest index values since March of 2010, whereas Mission Gorge (blue line=mid-section of the lower river watershed) consistently presents highest values. It can also be noted (in both charts H1 & H2) that the greatest rate of decline in lower river water quality occured over a three year period (WY12 through WY 14) during a period of well-below normal streamflow.

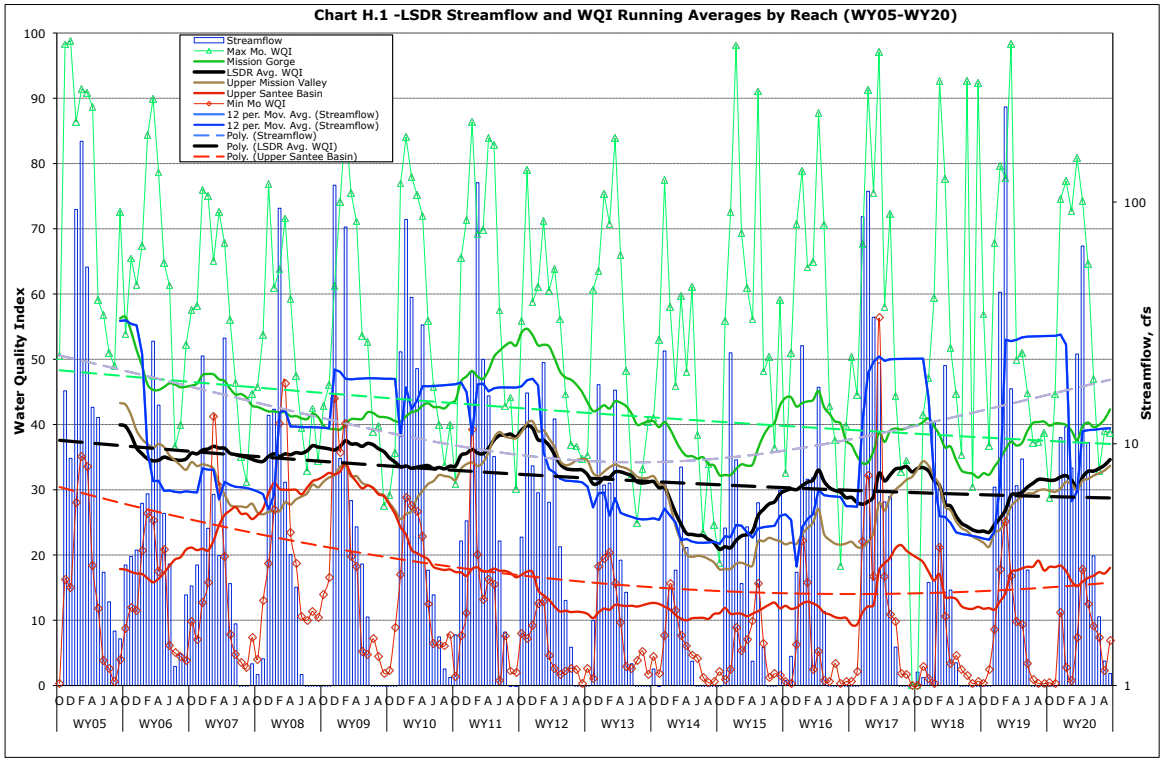


Chart H.1 -LSDR Streamflow and WQI Running Averages by Reach (WY05-WY20)
Streamflow
Max Mo. WQI
Mission Gorge
LSDR Avg. WQI
Upper Mission Valley
Upper Santee Basin
Min Mo WQI
12 per. Mov. Avg. (Streamflow)
12 per. Mov. Avg. (Streamflow)
Poly. (Streamflow)
Poly. (LSDR Avg. WQI)
Poly. (Upper Santee Basin)
Water Quality Index
Streamflow, cfs
WY05
WY06
WY07
WY08
WY09
WY10
WY11
WY12
WY13
WY14
WY15
WY16
WY17
WY18
WY19
WY20

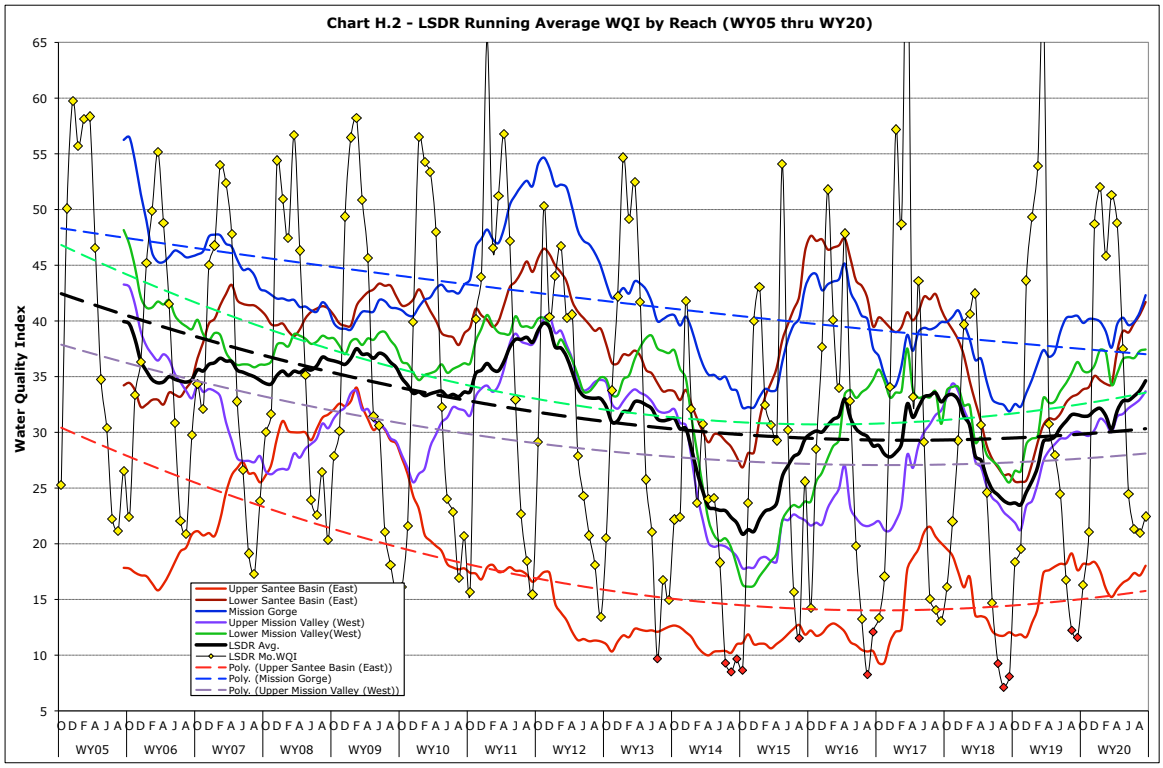


Chart H.2 - LSDR Running Average WQI by Reach (WY05 thru WY20)
Upper Santee Basin (East)
Lower Santee Basin (East)
Mission Gorge
Upper Mission Valley (West)
Lower Mission Valley(West)
LSDR Avg.
LSDR Mo.WQI
Poly. (Upper Santee Basin (East))
Poly. (Mission Gorge)
Poly. (Upper Mission Valley (West))
Water Quality Index
WY05
WY06
WY07
WY08
WY09
WY10
WY11
WY12
WY13
WY14
WY15
WY16
WY17
WY18
WY19
WY20

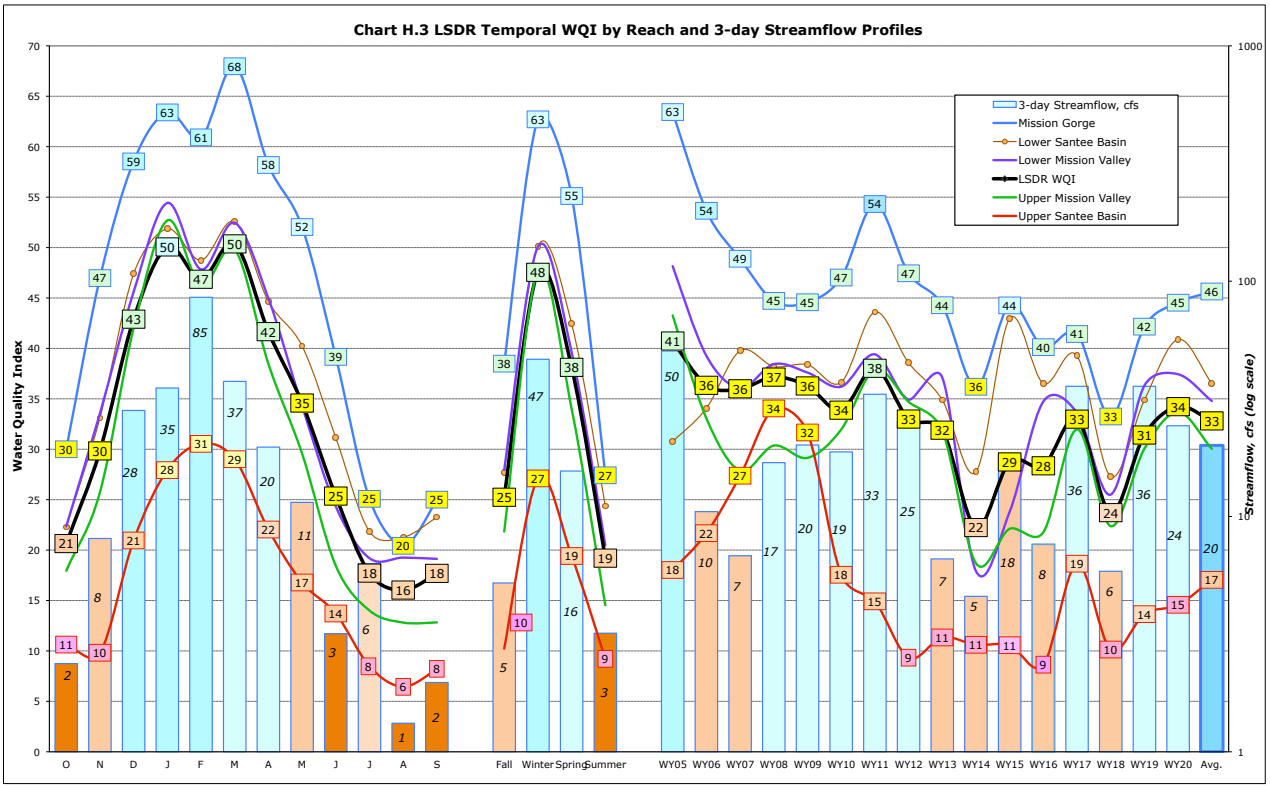


Chart H.3 LSDR Temporal WQI by Reach and 3-day Streamflow Profiles
Water Quality Index
Streamflow, cfs (log scale)
3-day Streamflow, cfs
Mission Gorge
Lower Santee Basin
Lower Mission Valley
LSDR WQI
Upper Mission Valley
Upper Santee Basin
O N D J F M A M J J A S
Fall Winter Spring Summer
WY05 WY06 WY07 WY08 WY09 WY10 WY11 WY12 WY13 WY14 WY15 WY16 WY17 WY18 WY19 WY20 Avg.

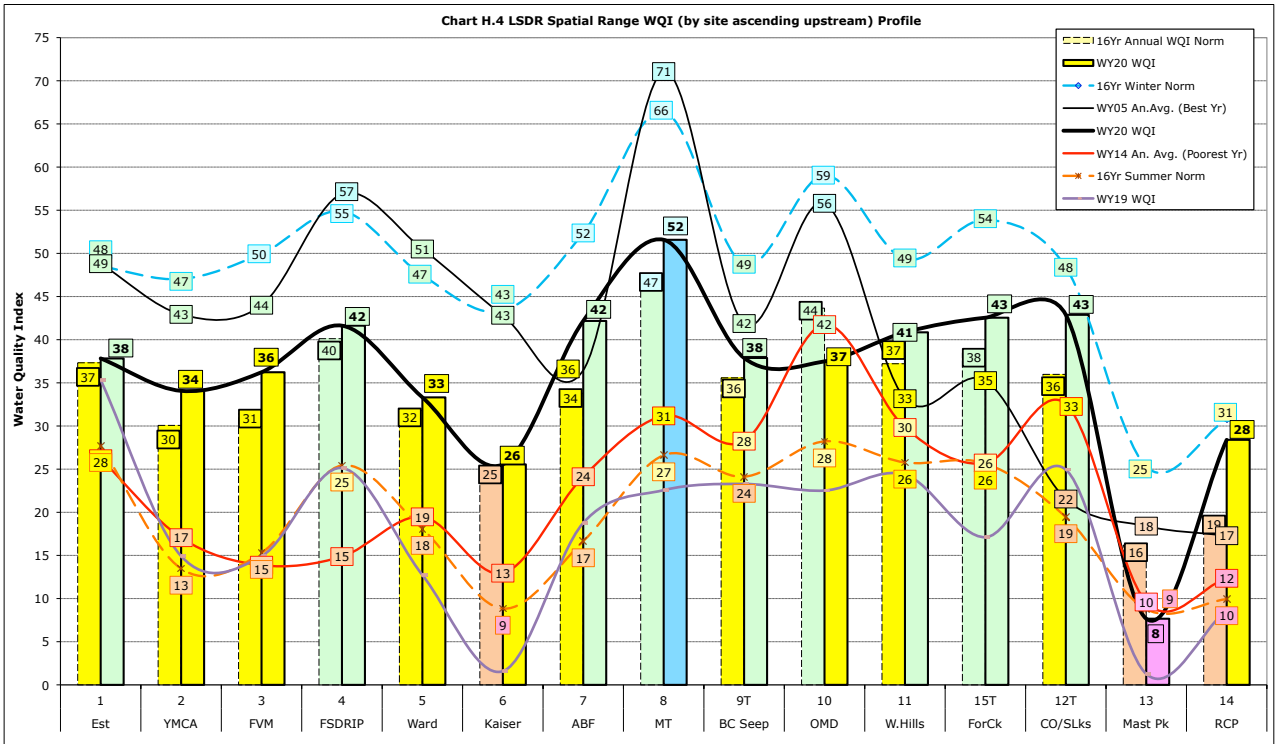


Chart H.4 LSDR Spatial Range WQI (by site ascending upstream) Profile
Water Quality Index
16Yr Annual WQI Norm
WY20 WQI
16Yr Winter Norm
WY05 An.Avg. (Best Yr)
WY20 WQI
WY14 An. Avg. (Poorest Yr)
16Yr Summer Norm
WY19 WQI
1 Est
2 YMCA
3 FVM
4 FSDRIP
5 Ward
6 Kaiser
7 ABF
8 MT
9T BC Seep
10 OMD
11 W.Hills
15T ForCk
12T CO/SLks
13 Mast Pk
14 RCP

Chart H.3 presents a temporal summary of variances in the water quality index values profiled on a monthly, seasonal and average annual water year basis for the five river reaches and the overall weighted LSDR averages. The variances in WQI can be visually compared to changes in 3-day streamflow (blue bars) on the same basis. Positive correlations are evident, i.e., increased average daily flow results in improved water quality metrics. Low flow throughout the summer months results in considerably poorer water quality. The past two year's of above average dry-weather (base) flows, extending from early April through the end of September, resulted in significant improvements in index values for each of the five reaches and overall (heavy black line) of the lower river system from WY18 and WY14 results. Irrespective of the water year the Mission Gorge reach (blue curve) has presented the highest WQI values while the Upper Santee Basin reach (red curve) has (with exception of WY's 07 & 08) has shown the lowest values. The next to poorest quality reach is the Upper Mission Valley reach (green curve). The next to best water quality reach is the Lower Santee Basin reach (brown curve). On a seasonal basis Autumn and Summer results are consistantly lower than Winter (hihest) and Spring (next highest) values in all reaches and overall. August is the month of lowest water quality and lowest flow. January and March are commonly the moths of best water quality in all reaches as greater flood flows commonly occuring in February often lower WQI values by several points.

Chart H.4 provides a spatial profile of average annual WQI by river monitoring site, reach and section for this year (WY20), compared to last year (WY19), the best (WY05), the worst (WY14) and 16-yr winter (Dec-Jan), summer (Jun-Sept) and annual (Oct-Sept) norms. The sites are in the order they occur ascending upstream. The current (WY20) average annual WQI values for each site, shown as both a heavy black line and as colored bars, are above annual norms (also dashed color bars) at all but two sites (#10-OMD and #13-Mast Pk E). Sites with lowest water quality in WY20, as well as over the past decade, are #13-Mast Pk E, #14-Magnolia Ave. within the Upper Santee Basin (red curve) and #6-Kaiser Pnds in Upper Mission Valley (green curve). The Mission Gorge portion (blue curve) of the watershed (site#'s 8-10) continues to demonstrate best overall water quality. The 16-yr winter and summer WQI norms (dashed blue and red curves, respectively) are also shown in profile to provide a basic appreciation of the range in index values occuring throughout the lower river system extending some 23 miles from Lakeside to the estuary in lower Mission Valley between I-5 and Pacific Highway.

Monthly and running average WQI values for each reach of the lower river and overall are presented in Section 5 of the WY20 Annual WQM Report (see Charts 5.1-5.6) together with discussion of the individual treands associated with each. It is becomming apparent that a number some reaches of the river experience water quality changes more rapidly than others and that several sites represent "hotspots" of poorer water quality, less susettable to change in ambient conditions.

(JCK 11/08/2020)