Technical Memorandum

2019 Wet-Weather Monitoring, South Platte River at Burlington Ditch

On behalf of the Barr Milton Watershed Association (BMW), GEI Consultants, Inc. (GEI) performed wet weather monitoring on the South Platte River, approximately 400 m upstream of the Burlington Ditch headgate. BMW implemented a monitoring program to characterize base and storm flow water quality conditions on the South Platte River which influences water quality in the Burlington Ditch, and eventually Barr Lake and Milton Reservoir. GEI collected stormwater samples and compiled hydrological data while the Metro Wastewater Reclamation District (MWRD) collected baseflow samples and provided the daily precipitation record. The Colorado Division of Water Resources (DWR) stream flow gage (PLADENCO) at 19th Street, Denver is the nearest upstream monitoring station (~2.8 river miles) on the South Platte River. Between the DWR gage and SPRBD, the river is primarily bordered by industrial/commercial landscape with four permitted municipal separate storm sewer system (MS4) outfalls that can influence the discharge downstream of the gage.

Stormwater Sample Collection

GEI sampled seven storm events at the SPRBD station between March 12 and September 9, 2019 (Table 1). The March 12-14, 2019 event was characteristic of an early snow/rain storm event that provided a "first flush" of the Denver metropolitan area while the other storms were characteristic of rainfall driven events.

GEI accessed the Mile High Flood District (MHFD) Automated Local Evaluation in Real Time (ALERT) system, regional radar, and gaged surface water levels to assess storm event conditions at the monitoring site and determined appropriate times to activate the automated storm sampler via phone telemetry. The goal was to activate each sampler at the beginning of the stormwater runoff. GEI personnel continued to monitor the storm event and flow condition once the automated sampler was activated and collected the samples near the end of the sampling interval or storm event depending upon timing.

The SPRBD monitoring station includes a Tracom enclosure, a refrigerated 6712 series ISCO water sampler, and a Sierra wireless RV50 modem. The ISCO is configured with eight 2-liter (L) containers and programed to collect approximately 600 milliliter (mL) of stormwater every hour for a 24-hour period. Each container should receive a composite water sample comprised of three individual hourly samples (i.e., totaling approximately 1,800 mL). At the end of the 24-hour period the ISCO is programed to stop collecting samples, unless manually

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terminated for sample collection. A typical sampling event will collect 8 3-hour composite samples.

Following a successfully sampled storm event, each 2-L container was thoroughly mixed, and water decanted to ensure the same volume of water from each time-weighted sub-sample was combined into the churn splitter prior to dispensing into the sample aliquot container. A churn-splitter ensured that the composited time-weighted sub-samples were adequately mixed prior to dispensing the sample aliquot. Samples were stored in a cooler on ice during transportation to the MWRD Laboratory. Due to the close proximity of the laboratory, GEI submitted the raw water samples and did not field filter or preserve the samples. The analyte list was the same as the Colorado Department of Public Health and Environment (CDPHE) approved Phase I MS4 monitoring program for the metropolitan area, and included total suspended solids, dissolved major ions (calcium and magnesium), dissolved organic carbon, hardness, several different nutrients (ammonia plus organic nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, total phosphorous, dissolved orthophosphate), and selected dissolved and total-recoverable trace elements (copper, lead, manganese, and zinc). Conductivity and pH were also measured during lab analysis. Notably, Storm 1 samples were only analyzed for a suite of nutrients.

Quality Assurance and Quality Control

To reduce sample contamination, all sampling bottles and the automated sampler were cleaned prior to use. Multiple bottle sets are maintained for the ISCO which allows for easy replacement of sample containers following a storm event. All sample bottles were cleaned with Alconox detergent, followed by a 10 percent hydrochloric acid rinse and a final deionized water rinse. The churn splitter was also cleaned using the same method for the sample bottles between storm events. The automated sampler was maintained throughout the sampling season and repairs conducted as necessary to ensure the proper operation of the sampling device.

Daily Mean Streamflow

A total of seven storm events were sampled from March 12th, 2019 to September 9th, 2019 with a total of 23 water quality samples analyzed in 2019. Annual precipitation data and the annual hydrograph with the daily mean stream flow and stormwater sample dates were compiled for the wet weather sampling site (Figure 1).

Storm 1 – March 12 -14, 2019

Storm 1 was a heavy snow and rain mixed precipitation event that occurred on March 12 - 14, 2019. Composite samples for Storm 1 consisted of 15 3-hour composite samples and one 2.5-hour composite sample collected over a 47.5-hr period, for a total of 16 separate samples. Precipitation over the storm period measured at the MWRD indicated a total of 0.16 inches (in) of accumulation (Figure 2).

Storm 2 – April 11 -12, 2019

Storm 2 occurred on April 11 - 12, 2019. The sample for Storm 2 consisted of a seven-sample composite over a 23-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.00 in of accumulation (Figure 3).

Storm 3 – May 8 -10, 2019

Storm 3 occurred on May 8 - 10, 2019. Two samples were collected for Storm 3 and each consisted of an eight-sample composite over a 23-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.11 in of accumulation (Figure 4).

Storm 4 – May 28 - 29, 2019

Storm 4 occurred on May 28 - 29, 2019. One sample was collected for Storm 4 and consisted of an eight-sample composite over a 22-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.44 in of accumulation (Figure 5).

Storm 5 – June 17 -18, 2019

Storm 5 occurred on June 17 - 18, 2019. The sample for Storm 5 consisted of a seven-sample composite over a 19-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.04 in of accumulation (Figure 6).

Storm 6 – July 20 - 21, 2019

Storm 6 occurred on July 20 - 21, 2019. The sample for Storm 6 consisted of an eight-sample composite over a 21-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.19 in of accumulation (Figure 7).

Storm 7 – September 8 - 9, 2019

Storm 7 occurred on September 8 - 9, 2019. The sample for Storm 7 consisted of a seven-sample composite over an 18-hr period. Precipitation over the storm period measured at MWRD indicated a total of 0.15 in of accumulation (Figure 8).

Data Summary

The water quality data are summarized slightly different between Storm 1 and the remaining storm. Storm 1 presented the opportunity to collect a first flush event at SPRBD. The ISCO was initiated prior to the peak flow event and allowed to sample through the falling limb of the hydrograph. In total, 16 3-hour composite samples were collected over a 48-hour period with each composite sample being individually analyzed. The individual composite samples have been summarized into three components of the storm hydrograph: baseflow, rising limb-peak flow, and falling limb. Samples 1-6 were averaged to create a baseflow condition; 7-10 were averaged for a rising limb-peak flow condition; and 11-16 were averaged were averaged for a falling limb condition. For the remaining six storm samples the ISCO generally collected a full suite of 8 3-hour composite samples with each sample being field

processed as discussed above and analyzed to provide an average concentration for the storm event. The duration of Storm 3 occurred over a two-day period; thus, two stormwater samples were submitted (e.g. Storm 3a, Storm 3b).

We've selected Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP) to display for the individual concentrations observed during Storm 1 (Figure 9) as well as provided a snapshot for these two analytes over time (Figure 10). The time-weighted mean concentrations for the three flow conditions in Storm 1 are summarized in Table 3, and the time-weighted mean storm concentrations for the remaining storms are summarized in Table 4. The time-weighted mean storm concentrations were also calculated for Storm 1 using only the rising limb-peak flow and falling limb samples for comparative purposes with the other storms presented in Figure 10.

Briefly, the concentrations for the inorganic/dissolved nutrient fractions were generally the greatest during the baseflow condition and as the storm progressed the concentrations decreased due the increased discharge (Table 3). The noted exception is ammonium ion (Total Ammonia as N) which responded similarly to the organic and particulate fractions. The organic/particulate nutrient fractions showed that the rising limb – peak flow component contained the highest concentration of the three hydrograph components (Table 3) and as the stormwater receded towards baseflow conditions the concentrations became more similar to baseflow conditions. The TKN concentrations appear to return to baseflow concentrations at a slower rate than TP (Figure 9). Over the course of the monitoring season, the time-weighted storm concentrations for TKN and TP remained relatively consistent over the seasonal hydrograph conditions, while the characteristic first flush strongly influenced the TKN and TP concentrations relative to other storm events. The seasonal 7median TKN and TP concentrations for Storms 2 – 7 were 1.6 and 0.39 mg/L, respectively, while the first flush concentrations were 4.0 and 0.89 mg/L, respectively.

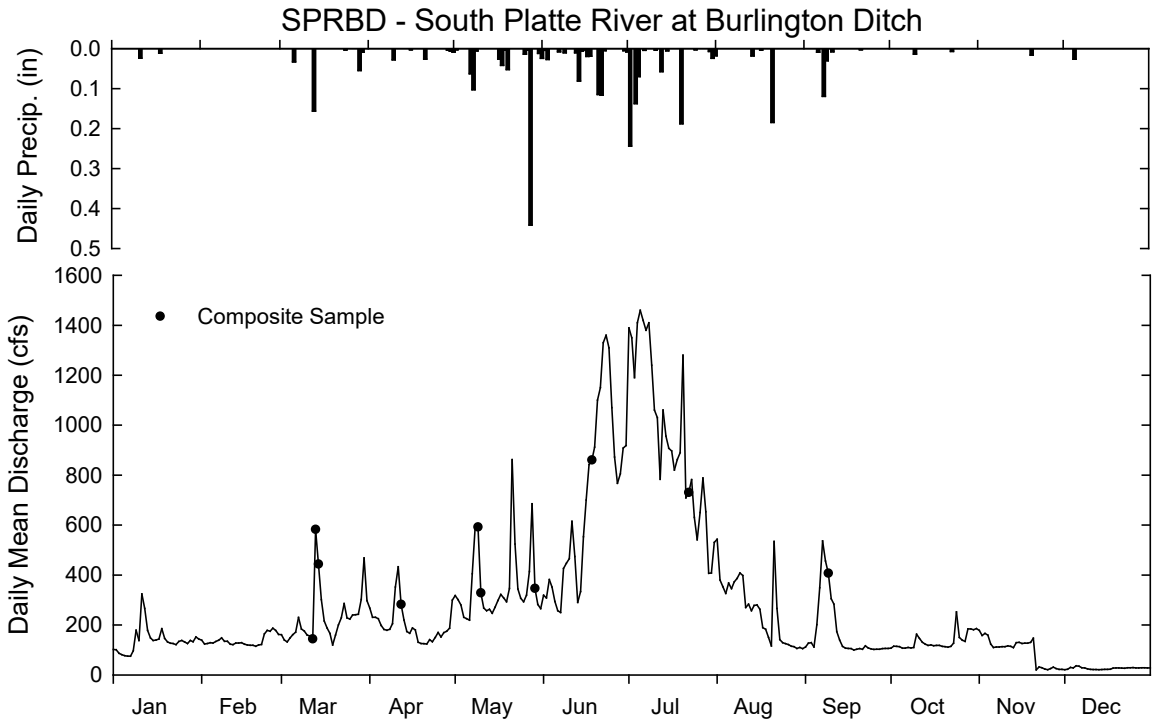

Figure 1: Daily mean streamflow on the South Platte River and accumulative daily precipitation in 2019 (Data source: DWR PLADENCO, MWRD).

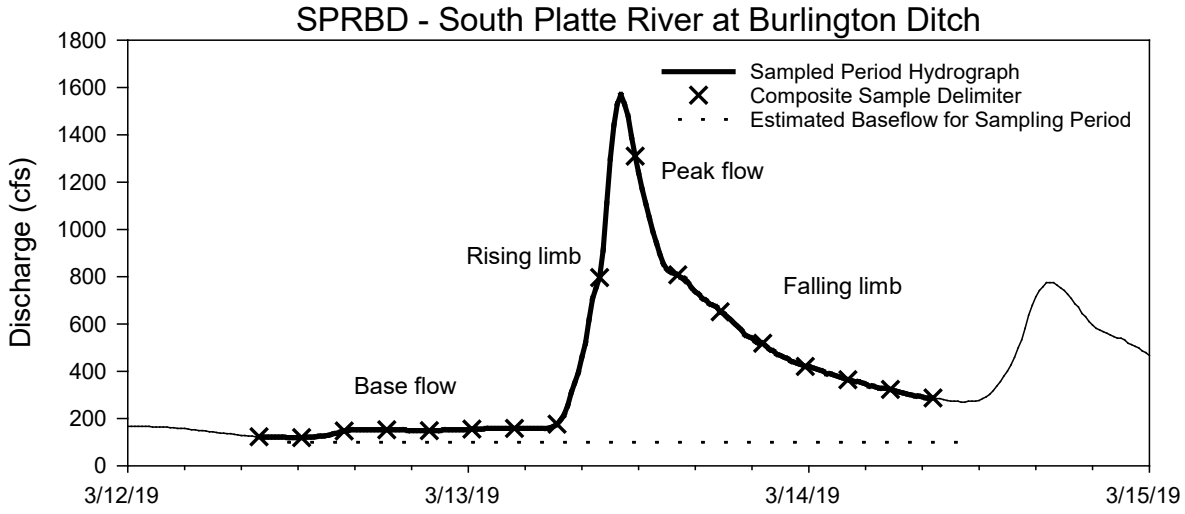

Figure 2: Hydrograph for Storm 1 at South Platte River at Burlington Ditch, CO (SPRBD).

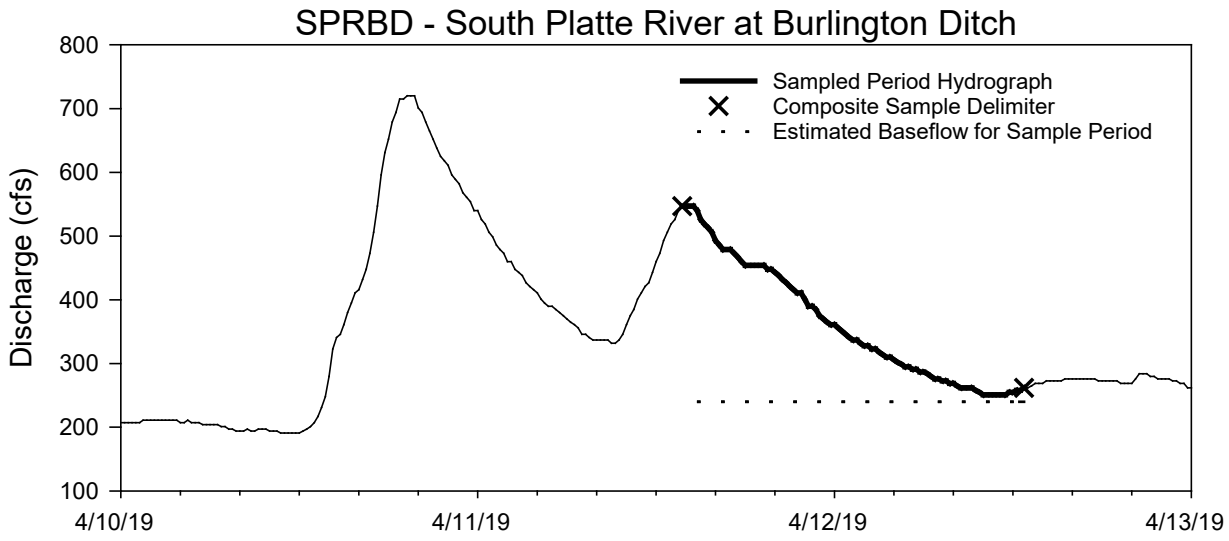

Figure 3: Hydrograph for Storm 2 at South Platte River at Burlington Ditch, CO (SPRBD).

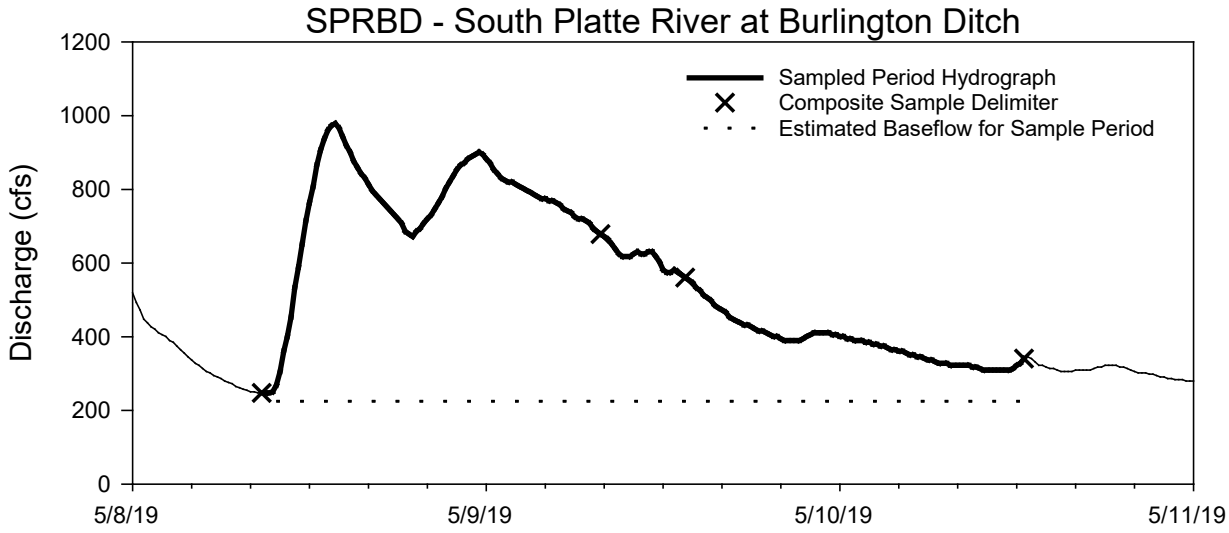

Figure 4: Hydrograph for Storm 3 at South Platte River at Burlington Ditch, CO (SPRBD).

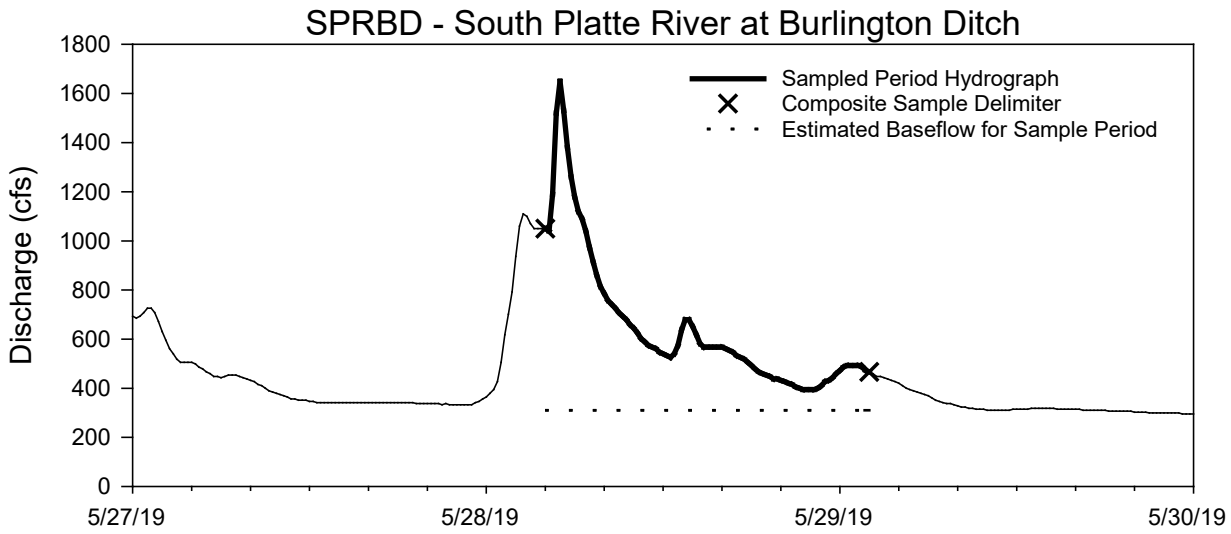

Figure 5: Hydrograph for Storm 4 at South Platte River at Burlington Ditch, CO (SPRBD).

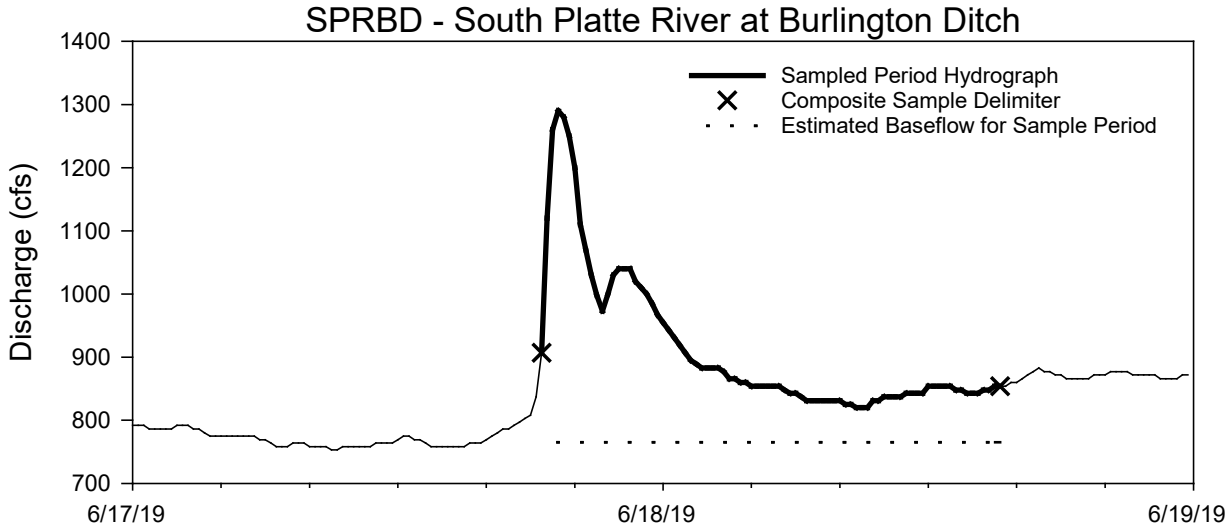

Figure 6: Hydrograph for Storm 5 at South Platte River at Burlington Ditch, CO (SPRBD).

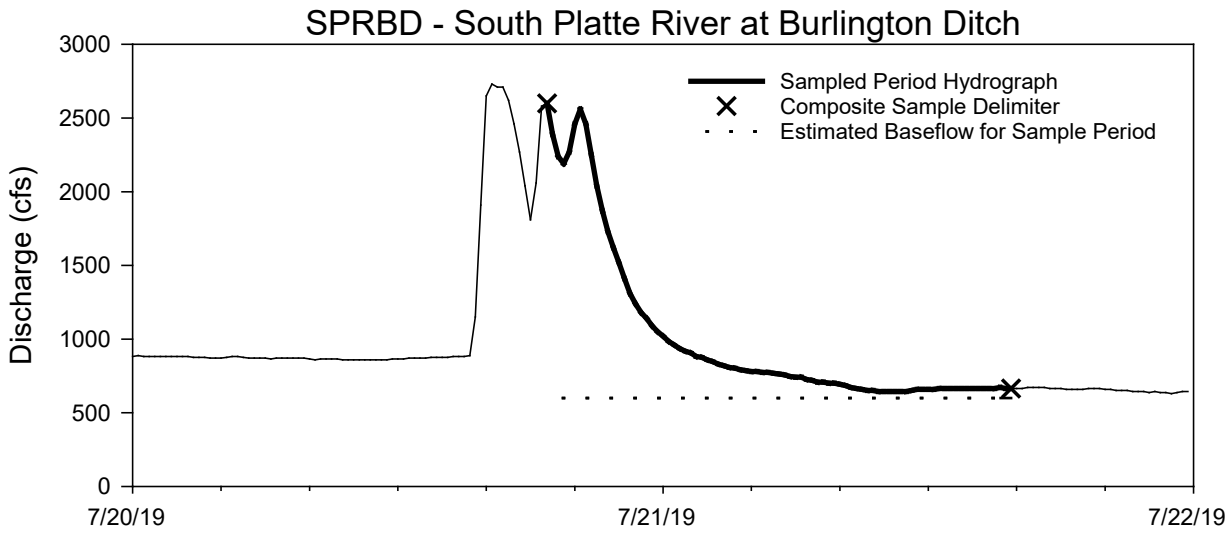

Figure 7: Hydrograph for Storm 6 at South Platte River at Burlington Ditch, CO (SPRBD).

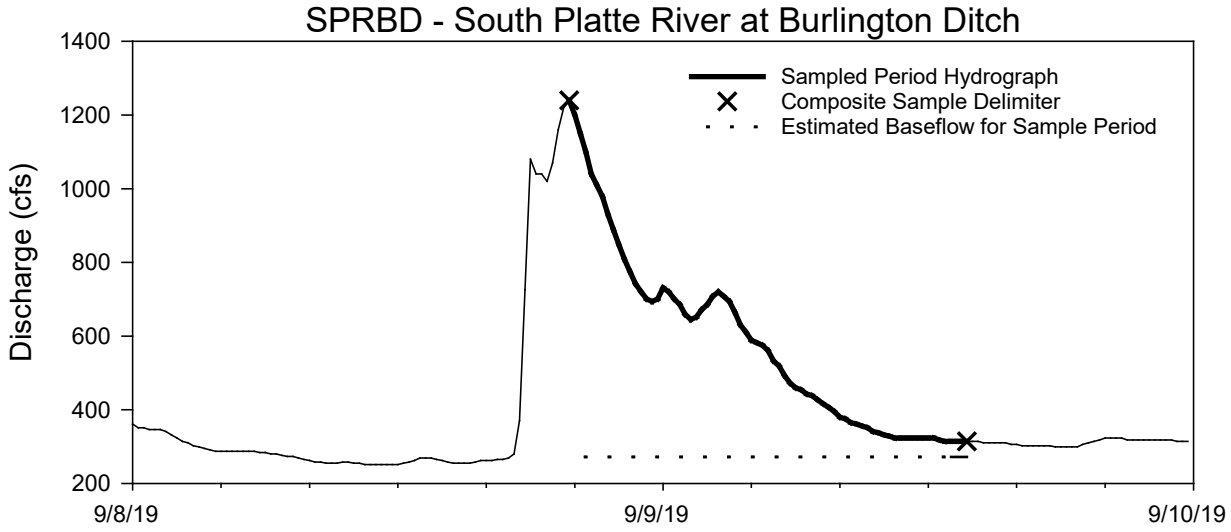

Figure 8: Hydrograph for Storm 7 at South Platte River at Burlington Ditch, CO (SPRBD).

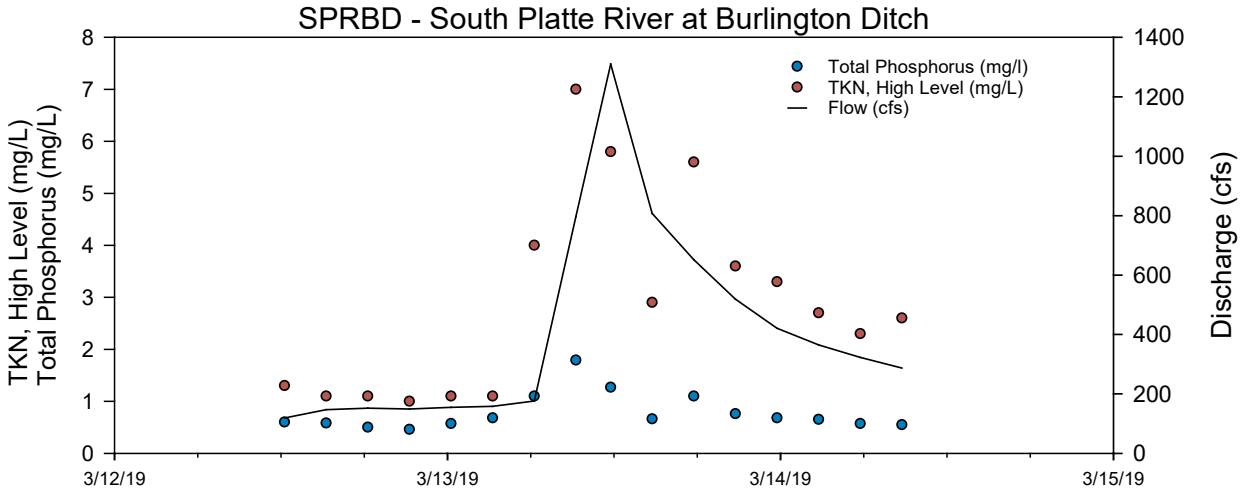

Figure 9: Storm 1 TKN and Total Phosphorus data at South Platte River at Burlington Ditch, CO (SPRBD) for each of the 16 samples.

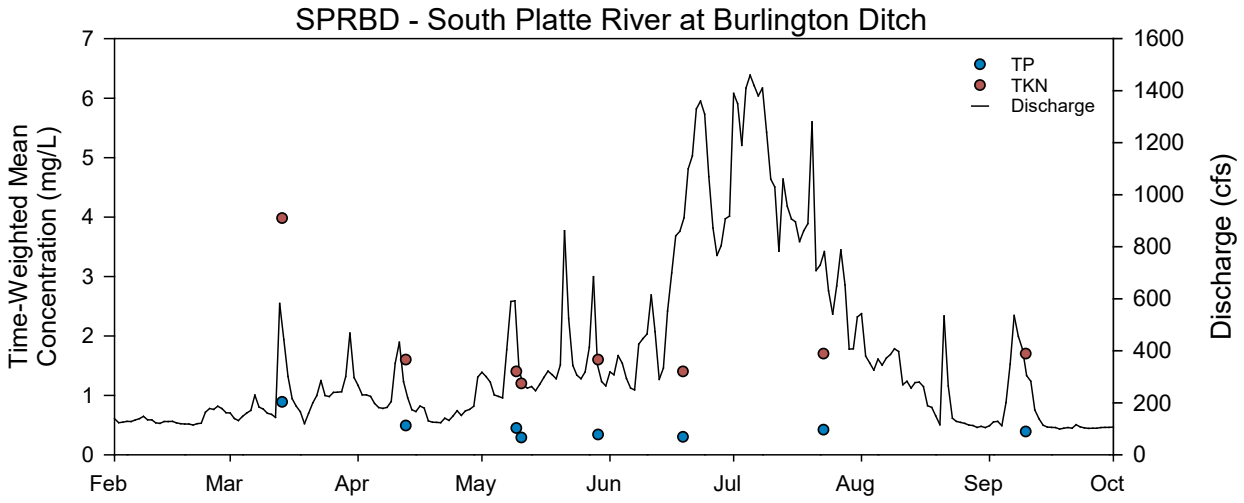

Figure 10: Time-weighted mean TKN and Total Phosphorus for each storm sampled at South Platte River at Burlington Ditch, CO (SPRBD).

Table 1: Storm samples collected during storm events in 2019.

	Storm Events						
	Storm 1	**Storm 2**	**Storm 3**	**Storm 4**	**Storm 5**	**Storm 6**	**Storm 7**
Number of Samples	16	1	2	1	1	1	1
Sample Dates	3/12/2019	4/12/2019	5/9/2019	5/29/2019	6/18/2019	7/22/2019	9/9/2019
	3/13/2019	--	5/29/2019	--	--	--	--
	3/14/2019	--	--	--	--	--	--

Table 2: Daily mean streamflow (in cubic feet per second) on the South Platte River in 2019 (Data source: DWR PLADENCO).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	102	139	161	267	318	319	1,390	543	112	107	178	102
2	101	124	140	231	301	308	1,350	380	127	115	158	122
3	86.6	126	132	231	280	382	1,190	353	129	114	166	175
4	80.8	129	148	225	231	352	1,410	326	112	113	159	153
5	77.2	128	161	198	225	294	1,460	368	201	107	123	196
6	75.5	134	171	182	219	257	1,420	345	349	107	110	165
7	75.2	139	230	179	405	250	1,380	372	536	110	112	115
8	96.3	148	184	183	590	426	1,410	386	456	108	112	107
9	179	135	176	205	592	447	1,240	408	407	110	113	96.6
10	138	135	160	352	328	465	1,060	398	305	163	113	100
11	324	123	156	433	268	615	1,030	270	283	146	116	97.7
12	266	121	144	282	257	474	783	283	173	131	114	97.3
13	178	128	582	220	263	290	1,060	257	139	123	109	95.2
14	148	128	443	174	247	334	956	278	114	118	129	95.7
15	138	129	302	167	271	553	907	280	107	120	130	94.4
16	140	123	216	188	298	700	896	263	106	117	126	95.9
17	144	120	188	180	322	842	820	189	105	118	127	93.1
18	185	119	166	131	308	860	862	183	99.5	118	127	98.9
19	146	119	120	126	293	912	889	150	103	114	130	93.8
20	132	115	160	125	346	1,100	1,280	116	105	113	147	90.8
21	127	120	200	124	862	1,150	709	534	103	111	115	93.8
22	126	122	228	141	524	1,330	730	266	116	114	151	93.2
23	121	164	286	133	344	1,360	782	141	108	127	133	99.4
24	134	178	228	150	307	1,310	631	129	104	252	105	112
25	138	175	224	170	293	1,070	541	125	102	150	97	110
26	132	187	240	152	319	872	650	121	103	139	112	110
27	126	178	241	169	414	767	788	115	103	134	116	112
28	138	162	243	175	685	804	653	113	105	184	116	114
29	133	--	302	187	346	908	407	106	106	184	107	115
30	152	--	468	299	282	918	408	110	106	181	104	113
31	144	--	297	--	265	--	530	105	--	185	--	114

Table 3: Time-weighted mean concentrations for Storm 1 flow conditions – baseflow, rising limb – peak flow, and the falling limb flow from March 12, 2019 to March 14, 2019.

Station	Storm 1 Base	Storm 1 Rising-Peak	Storm 1 Falling	Storm 1
Beginning Date	**3122019**	**3132019**	**3132019**	**Weighted**
Beginning Time	**0915**	**0630**	**1500**	**Average**
Ending Date	**3132019**	**3132019**	**3142019**	**Rising-Peak+**
Ending Time	**0615**	**1445**	**0845**	**Falling**
Total Alkalinity, mg/L	163	93	111	105
Total Ammonia as N, mg/L	0.06	0.43	0.29	0.34
Nitrite Nitrogen, mg/L	0.07	0.08	0.06	0.07
NO3+NO2 as N, mg/L	3.04	1.1	2.17	1.81
Orthophosphate as P, mg/L	0.49	0.18	0.22	0.21
Total Dissolved Phosphorus, mg/L	0.49	0.19	0.23	0.22
Total Phosphorous, mg/L	0.64	1.24	0.72	0.89
TKN, mg/L	1.53	5.23	3.35	3.98
Total Inorganic Nitrogen, mg/L	3.1	1.53	2.44	2.14
Total Nitrogen, mg/L	4.56	6.33	5.66	5.88

Table 4: Time-weighted mean concentrations for storms 2 through 7, and seasonal median concentrations from April 11, 2019 to September 9, 2019.

Station	Storm 2	Storm 3a	Storm 3b	Storm 4	Storm 5	Storm 6	Storm 7	Seasonal Median
Beginning Date	**4112019**	**5082019**	**5092019**	**5282019**	**6172019**	**7202019**	**9082019**	
Beginning Time	**1340**	**842**	**1333**	**400**	**1830**	**1848**	**1945**	
Ending Date	**4122019**	**5092019**	**5102019**	**5292019**	**6182019**	**7212019**	**9092019**	
Ending Time	**1240**	**742**	**1233**	**200**	**1330**	**1548**	**1345**	
pH, std	--	7.6	--	6.9	7.5	--	7.3	7.4
Conductivity, µS/cm	--	627	--	606	592	--	506	599
Hardness (as CaCO3), mg/L	--	162	--	173	170	--	146	166
Total Dissolved Calcium, mg/L	68.2	39	60.5	45	43	32.1	37.6	43.0
Total Dissolved Magnesium, mg/L	18.1	9.24	15.1	10.9	10.8	7.9	8.8	10.8
Total Suspended Solids, mg/L	102	182	42	131	99	255	144	131
TKN, mg/L	1.6	1.4	1.2	1.6	1.4	1.7	1.7	1.6
Total Ammonia as N, mg/L	0.20	0.27	0.12	0.05	0.05	0.10	0.00	0.10
NO3+NO2 as N, mg/L	2.42	1.56	2.29	1.05	0.61	0.67	1.08	1.08
Orthophosphate as P, mg/L	0.25[a]	0.17	0.21	0.13	0.12[a]	0.10	0.14[a]	0.15
Total Phosphorous, mg/L	0.49	0.45	0.29	0.34	0.30	0.42	0.39	0.39
Dissolved Organic Carbon, mg/L	--	8	--	12	14	--	14	13
Total Dissolved Copper, µg/L	2.8	2.6	2.3	4.6	2	2.6	2.9	2.6
Total Copper, µg/L	7.0	19.0	7.0	18.0	15.0	40.0	42.0	18.0
Total Dissolved Lead, µg/L	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0
Total Lead, µg/L	2.7	11.6	2.5	13.1	4.6	18.8	8.0	8
Total Dissolved Manganese, µg/L	86.1	16.2	27.8	36.5	16.1	22.2	17.8	22.2
Total Manganese, µg/L	120.0	274.0	122.0	187.0	243.0	295.0	238.0	238
Total Dissolved Zinc, µg/L	16.2	13.1	11.6	15.2	15.1	13.7	16.7	15.1
Total Zinc, µg/L	30.2	87.6	26.4	88	49.8	106	71.7	71.7

[a] Hold time exceeded