Supplemental Cape's Dam and Mill Race Assessment

Prepared for:

City of San Marcos

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Purpose of assessment

The purpose of this assessment was to evaluate aquatic habitat upstream of Cape's Dam and within the Mill Race, provide information on the fish community within the Mill Race, and document recreational use in the vicinity of the Cape's Dam and Mill Race entrance. This also included information requests by the U.S. Fish and Wildlife Service. The supplemental assessment included: (1) re-survey of the longitudinal surface water profile upstream of Cape's Dam and identify Texas wild-rice stands within and upstream of the backwater effect of Cape's Dam, (2) survey bathymetry, surface water, discharge, and water quality along the longitudinal profile of the Mill Race, (3) document the seepage extent and direct points of seepage located in the Mill Race, (4) measure the mixing of water between the San Marcos River proper, mill race outfall, and TPWD A. E. Woods hatchery outflow, (5) map aquatic vegetation in the Mill Race, (6) assess the fish community in the Mill Race and estimate fountain darter number and densities in the Mill Race, and (7) quantify recreational use of Cape's Dam and Mill Race and compare to recreational use in other portions of the San Marcos River.

Methods

Surveying habitat and water quality parameters

Standard survey equipment was used to collect bathymetry and surface water measurements along the longitudinal profile of the Mill Race. Additional bathymetry measurements were collected after the large rain event on September 26, 2016, which altered the channel topography at the mill race opening (Figure 1). The weir at the end of the mill race was also surveyed to determine the basic shape and dimensions of the structure. Standard survey

equipment was used to measure the longitudinal surface water profile upstream of Cape's Dam to re-assess the upstream extent of the backwater effect of Cape's Dam. Texas wild-rice (TWR) stands in the backwater extent were mapped with a GPS point or polygon to identify position and water depth under existing higher than median flow rates in the San Marcos River.These measurements were measured in the middle of the stand.

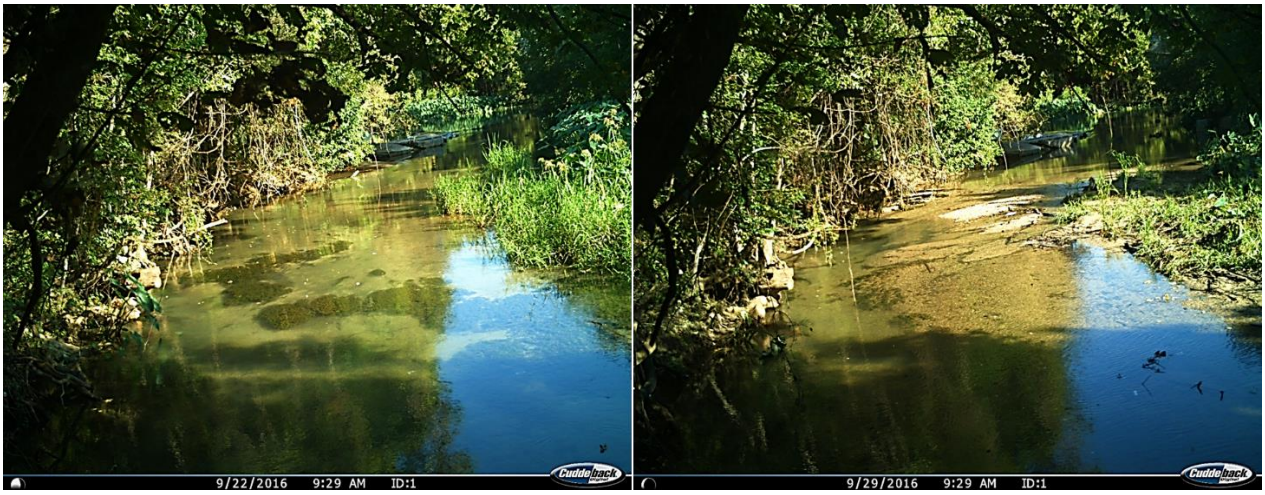

Figure 1. Channel topography at the opening of the Mill Race prior to (left) and after (right) the large rain event on September 26, 2016.

Water quality parameters

Water quality parameters were measured in the morning and then again in the afternoon at 5 sites (Figure 2) at Sites 2-6 longitudinally within the Mill Race and two sites within the San Marcos River: upstream of Cape's dam (Site 1) and downstream of Cape's Dam (Site 7). Dissolved oxygen (mg/l), water temperature, conductivity, and pH were measured using a Manta +30. Turbidity was measured using a HI93703 Portable Logging Turbidity Meter. Water quality measurements were taken at the top and bottom of the water column twice per day (i.e., morning and afternoon) at each site. Water quality measurements were averaged to create a single measurement per sampling time, site, and day. Water quality parameters were recorded on three dates: 8/29/2016, 10/05/2016, and 10/07/2016.

Photosynthetic active radiation (PAR) and canopy closure were measured along the longitudinal profile of the Mill Race at Sites 2-6 on 8/15/2016 using a LI 1400 Datalogger and a Forestry Suppliers Spherical Densiometer: Convex Model A, respectively. PAR measurements were taken in the air above the water, at the air/water interchange, and at depth intervals of 1ft.

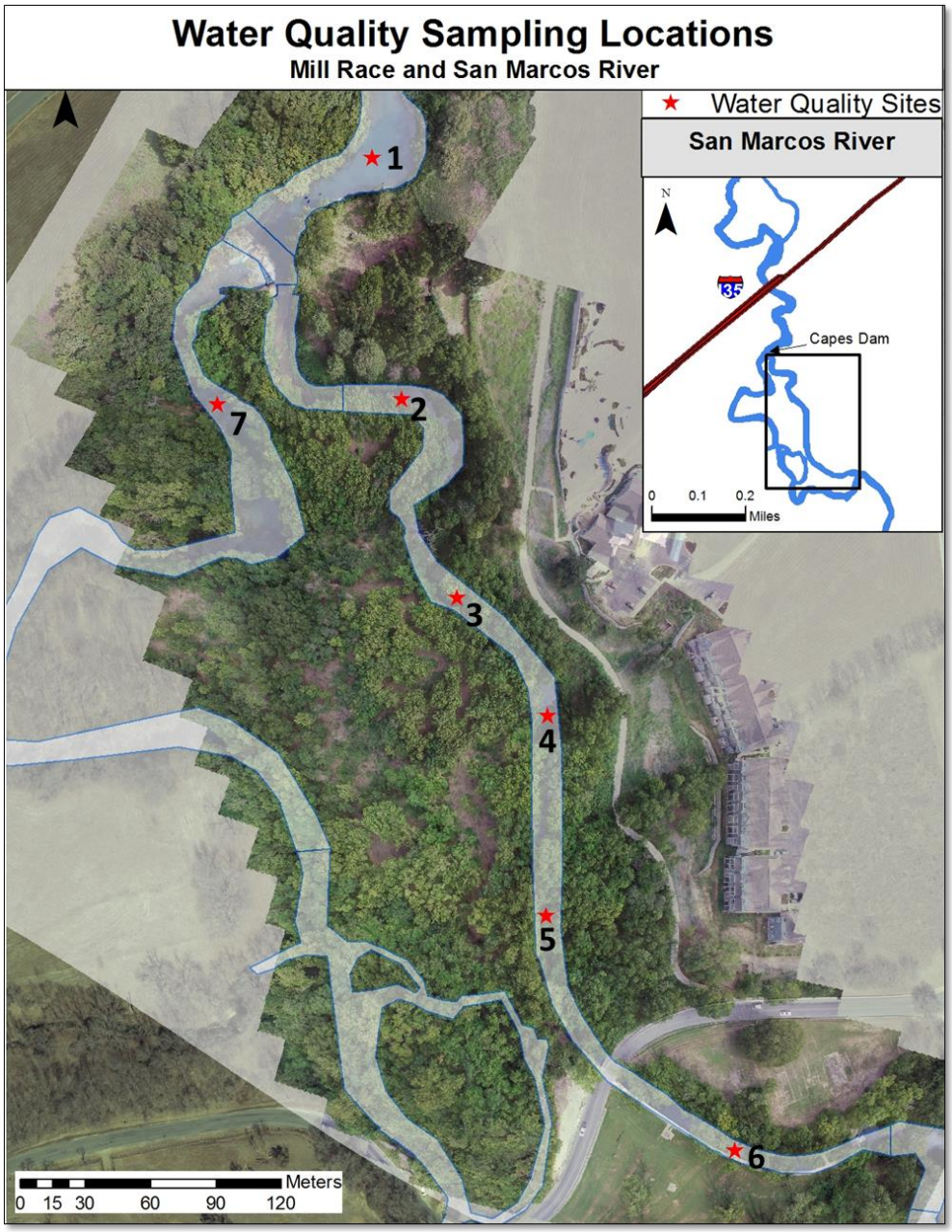

Figure 2. Water quality site map in the Mill Race and San Marcos River.

Aquatic vegetation

Aquatic vegetation coverage in the Mill Race was mapped on two days (8/11/2016, 8/19/2016) using a Trimble GeoXH with an external antenna (i.e., Zephyr). Aquatic vegetation patches were mapped with the polygon function and percentages of each vegetation species were identified within each patch. In areas with no aquatic vegetation, the dominant substrate type was recorded. Data were imported via GPS pathfinder and differentially corrected before being converted into an ArcGIS shapefile. The geometry calculator in ArcGIS was used to calculate area of vegetation polygons and used to estimate total aerial coverage of each vegetation species.

Identifying Seepage Extent

Obvious points of seepage near the Mill Race were mapped using a Trimble GeoXH and approximate discharge of larger seeps was estimated using a Marsh Mcbirney flowmate velocity meter and standard discharge estimation methods. The Mill Race discharge was measured at three locations using standard USGS procedures of measuring streamflow (http://water.usgs.gov/edu/streamflow2.html) to identify approximate seepage locations and longitudinal discharge characteristics in the Mill Race. Dye-sampling was conducted to confirm whether or not the Mill Race was the source of the seepage areas and not natural spring outflows. Working near the seepage locations, red food coloring dye was released into the Mill Race and water color in the seepage outflows was monitored.

Water mixing downstream of the Mill Race

Water quality parameters (temperature, conductivity, DO (mg/l), pH, and turbidity) were measured along 6 transects beginning upstream of the TPWD A.E. Woods hatchery outflow and continuing downstream past the Mill Race outfall (Figure 3). Measurements were taken on river right, mid channel, and river left. Current velocity (ft/s) at the

confluence of the Mill Race outfall and the San Marcos River was measured every three feet across the channel to assess water mixing between the two water sources using a Marsh Mcbirney flowmate velocity meter. Red food coloring dye was released at the confluence of the Mill Race outflow and the San Marcos River to visually document the mixing of water among the two sources.

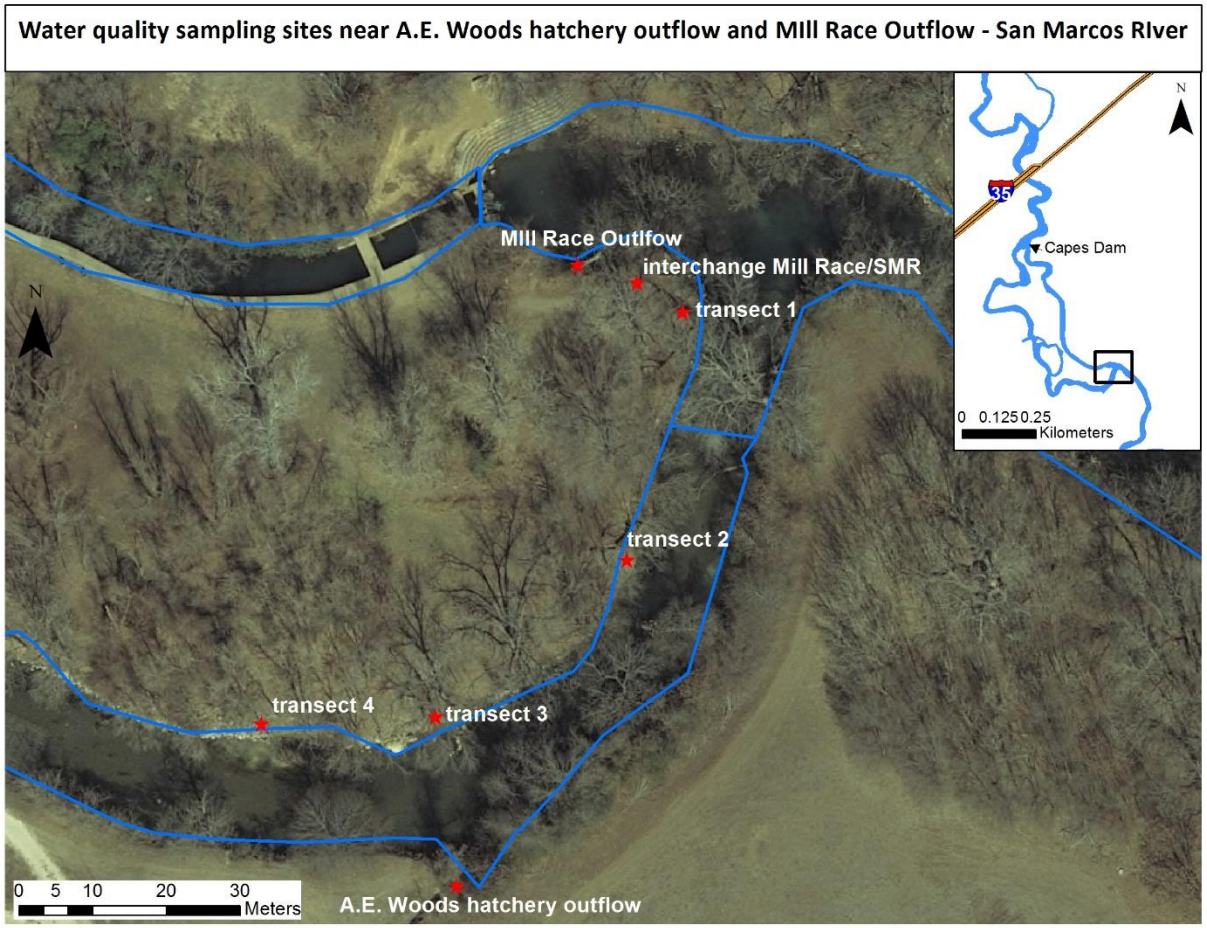

Figure 3. Transect locations to assess water quality mixing between TPWD A. E. Woods hatchery outflow and the San Marcos River.

Fish community and fountain darter assessment

Seining and underwater observation sampling techniques were used to assess the fish community and fountain darter numbers in the Mill Race on October 5 and 7, 2016 (Figure 4). Seine hauls and habitat measurements were completed among multiple transects starting

downstream and working in an upstream direction in the Mill Race. All available habitats were measured along each transect and seine hauls were placed adequate distance apart to minimize disturbing adjacent seine hauls. Fish were collected by either completing a 5 m downstream seine haul or a 5 m downstream substrate kick into the seine. Captured fish were identified, enumerated, and released. Current velocity (ft/s), depth, substrate type (i.e., silt, sand, gravel, cobble), and percent vegetative cover and type were recorded for each seine haul.

SCUBA surveys (i.e., underwater observations) were performed at two scales: mesohabitat surveys to document pelagic fishes and benthic transects used to document benthic-associated fishes. Mesohabitat surveys were conducted prior to benthic underwater transects with divers swimming parallel to each other and documenting fishes in their direct field of vision. In some instances, species were classified down to genus rather than species (i.e., sunfish - *Lepomis sp*.) because of difficulty in identifying morphologically distinguishing features during underwater observations. Benthic transects were completed by divers beginning at the downstream boundary of each transect and slowly swimming upstream 5 m guided by a PVC pole. Underwater lights were utilized in areas of dense vegetation and rocks. Fish in the diver's immediate field of vision were identified to lowest practical taxonomic group and enumerated.

Fish community was quantified by total number of individual's fish observations (total N) and the number of species (species richness) among all sampling techniques. Species were then assigned a gear type (i.e., seine, scuba mesohabitat, or scuba microhabitat) based on the gear type most efficient at quantifying the species (i.e, collected the most number of individuals). Assigning a gear type was necessary to more accurately calculate catch per unit effort for a species (CPUE, individuals/ area sampled) while excluding gear types with inefficient densities. Seines tend to underestimate densities of large body fishes, such as *Lepomis* (sunfish) but is more

effective in capturing small-bodied fishes such as minnows. For example, 18 (75%) of the 24 *Lepomis sp.* were observed during Scuba mesohabitat surveys and therefore assigned to the scuba-mesohabitat gear type to calculate CPUE.

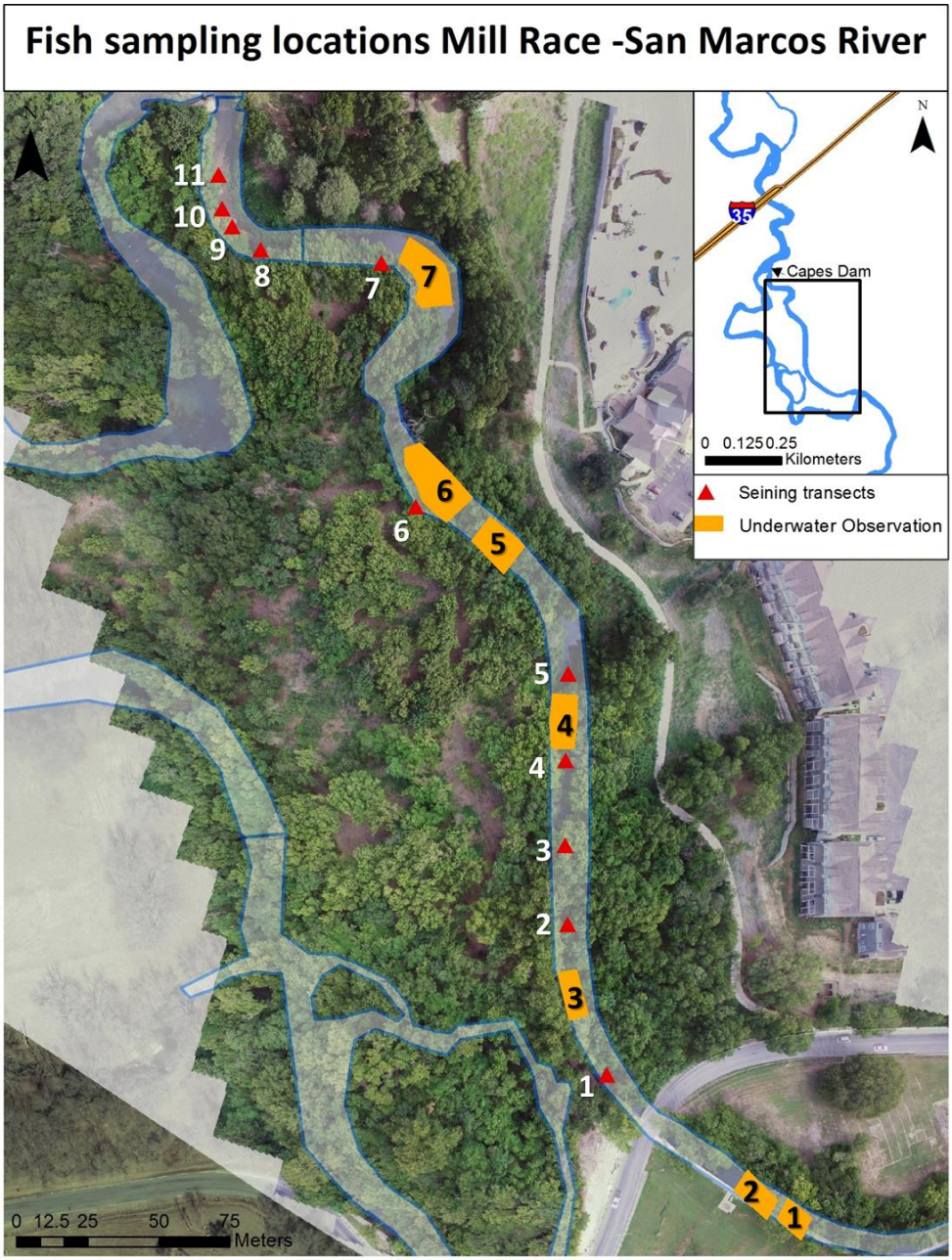

Figure 4. Fish sampling locations for seining (red triangles) and underwater observations (orange polygons) in the Mill Race – San Marcos River.

Recreation counts

Two game cameras were placed at locations near the juncture of Cape's Dam and the Mill Race from July – November 2016 (Figure 5). Cameras were placed facing the river allowing for the widest view possible and programmed to capture images once an hour for nine hours a day (dusk to dawn).

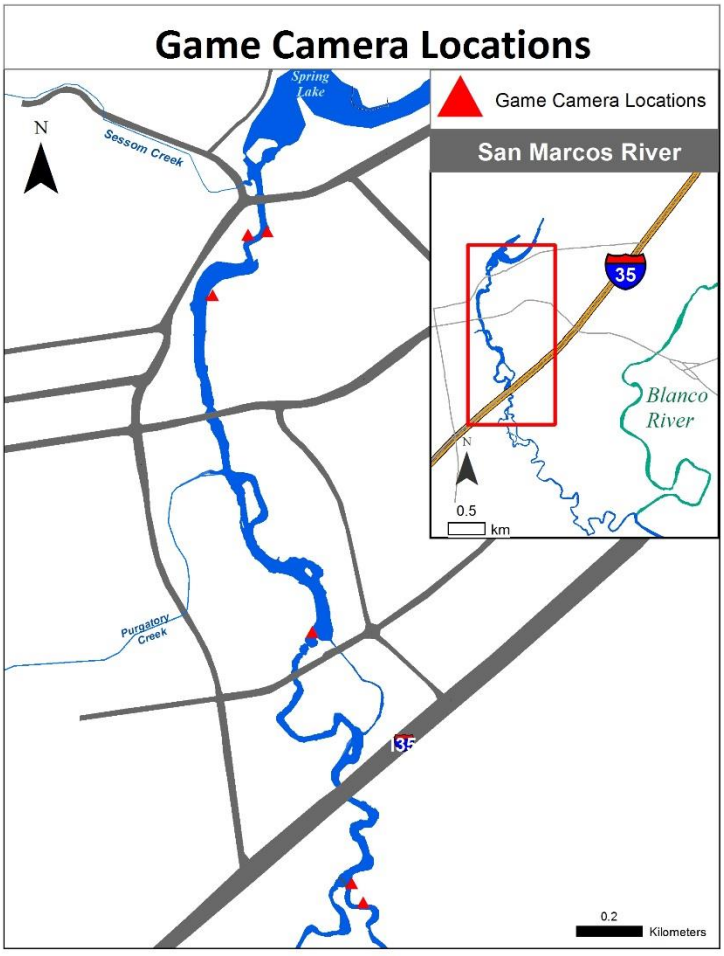

Figure 5. Game camera locations on the San Marcos River.

For reaches above Rio Vista Dam, images from 2013 and 2014 were used to assess recreation because they were the most complete period of record. Table 1 indicates

months available for use among all sites and Table 2 denotes reasons that resulted in periods of no images collected for the Cape's Dam-Mill Race area due to logistical causes (i.e. theft, vandalism, and equipment malfunction).

Table 1. Dates of recreation count sampling periods.

	Sewell		City Park		Rio Vista		Cape's Dam	Mill Race
Month	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2016**	**2016**
July						X		X
August							X	X
September	X		X				X	X
October					X		X	
November							X	

Table 2. Periods of data loss in the Cape'sCape's Dam-Mill Race Reach.

Date of Data Loss	Inoperable Camera	Reason
7/18-8/1	Cape's Dam	Camera Stolen
8/2-8/8	Cape's Dam	Memory Card Stolen
8/9-8/15	Mill Race	Memory Card Stolen
9/17-18	Cape's Dam	Vandalized with Vegetation
10/4-10/10	Mill Race	Memory Card Malfunction
10/22-11/22	Mill Race	Memory Card Malfunction
11/27-11/28	Cape's Dam	Vandalized with Tree

Each picture was reviewed and only individuals in contact with the river, or in a vessel in contact with the river, were counted. Recreation was divided into categories: vessel (kayaking, canoeing, etc.), tubing, and swimming. For tubes or vessels with multiple occupants, each occupant was counted individually in their respective group. Total recreation by category and average recreation use by day were calculated for the Dam and the Mill Race and compared to recreation use observed in the San Marcos River upstream of Rio Vista Dam.

Results

Surveying habitat and water quality parameters

A total of 342 in water topography points were collected in the upstream portion of the Mill Race. Initially, 220 topography points of the 342 points were collected but after the large rain event on September 26, 2016, an additional 142 points were collected to reflect the changes observed for the in-water topography. Twelve surface water elevation points were collected along the longitudinal profile of the Mill Race (Figure 6). Surface water elevation in the Mill Race showed minimal slope with only a slight drop at the start of the Mill Race (Table 3). Discharge in the Mill Race at time of measuring the surface water elevation was approximately 20.15 cfs and the San Marcos River discharge was 283 cfs.

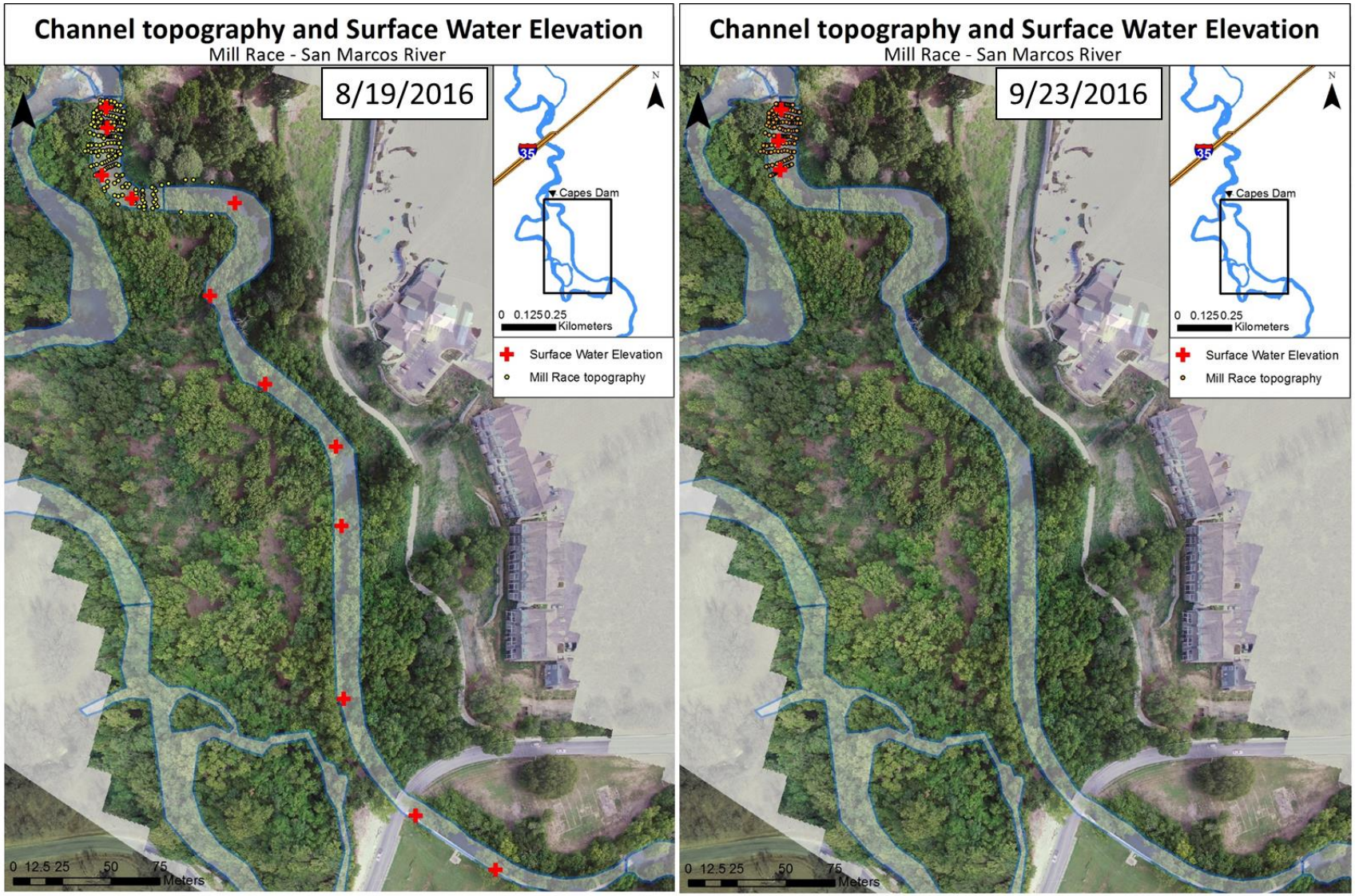

Figure 6. Channel topography and surface water elevations measured in the Mill Race (8/19/2016 and 9/23/2016).

Table 3. Surface Water Elevation in the Mill Race – San Marcos River (8/19/2016).

Distance from Dam (m) upstream	SWE (m)
0	168.400
10	168.385
35	168.380
55	168.380
110	168.380
166	168.380
220	168.380
270	168.380
311	168.380
400	168.380
470	168.380
520	168.380

Nine surface water elevation points were collected along the longitudinal profile upstream of Cape's Dam (Figure 7).

Figure 7. Surface water elevation points above the Cape's Dam and the Mill Race - San Marcos River (12/16/2016)

Surface water elevation in the San Marcos River showed minimal slope between IH35 and Cape's Dam. However, once upstream of IH35 (i.e., ~350 meters upstream of Cape's Dam), the surface water elevation sloped up considerably and marks the upstream extent of the back water from Cape's Dam (Table 4; Figure 8). This profile is consistent with the previously reported upstream extent of the backwater based on field measurement and simulated by the hydraulic modeling under the presence of Cape's Dam reported in Hardy and Raphelt (2015). Discharge in the San Marcos River at the time of measuring the surface water elevation was approximately 245 cfs. As would be expected from the fundamental properties of hydraulics of river channels, the upstream extent of the backwater would move progressively downstream under lower San Marcos River discharges (e.g., median flows ~ 175 cfs).

Table 4. Surface Water Elevation above Cape's Dam and the Mill Race – San Marcos River (12/16/2016).

Surface Water Elevation Location number (See Figure 7)	Distance from Dam (m)	Surface Water Elevation (m)
1	1.00	168.298
2	89.23	168.298
3	242.81	168.320
4	386.35	168.326
5	468.76	168.390
6	545.41	168.475
7	587.76	168.512
8	649.96	168.521
9	713.73	168.530

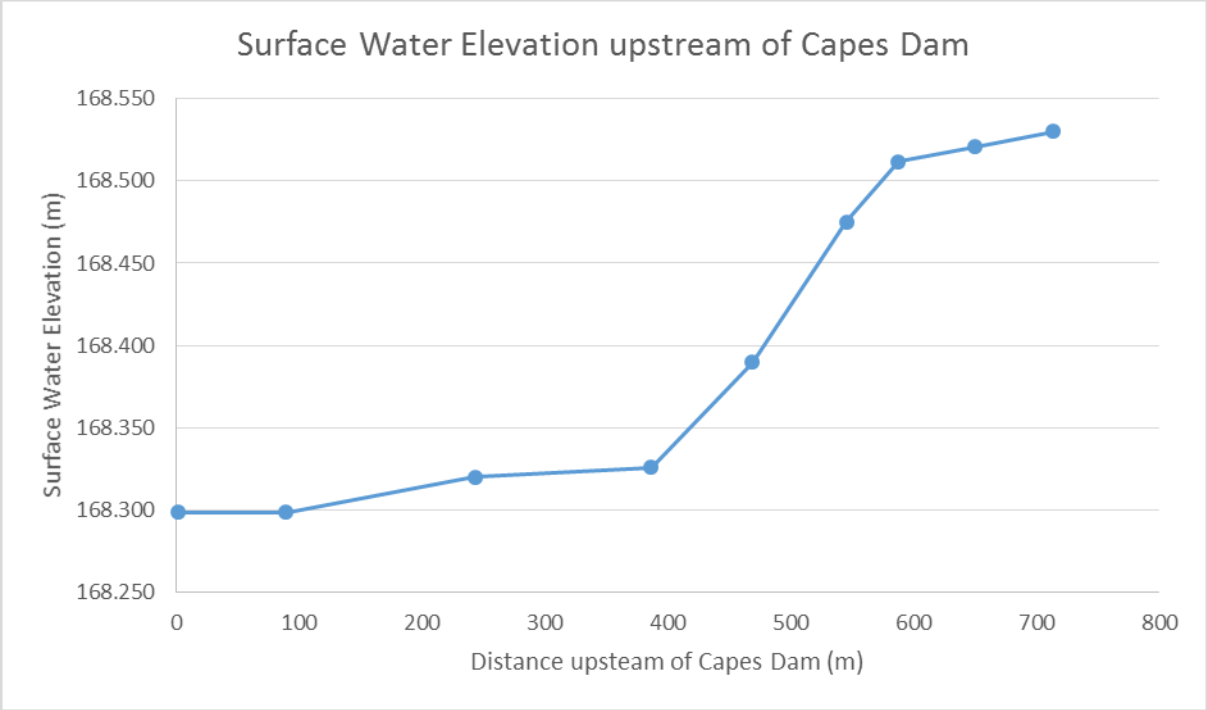

Figure 8. Surface water elevation points above Cape's Dam and the Mill Race - San Marcos River (12/16/2016)

Texas wild rice stands

A total of 126 Texas wild rice stands, covering approximately 237 m^2, were mapped upstream of Cape's Dam to the vicinity of the 'old walking bridge' in Ramon Lucio Park (Figures 9-12). Among the 126 Texas wild rice stands, 58 stands were observed in water depths less than 3 feet (1m) with the San Marcos River discharge of approximately 250 cfs. Of those 58 Texas wild rice stands, 42 were found in water depths less than 2 feet. Sixty-eight Texas wild rice stands were found in water depths greater than 3 feet. Only 16 of the 126 Texas wild rice stands were observed within the actual backwater extant of Cape's Dam (~ between IH-35 and

Cape's Dam), covering approximately 16 m^2 of stream bottom. No TWR were found in the Mill Race.

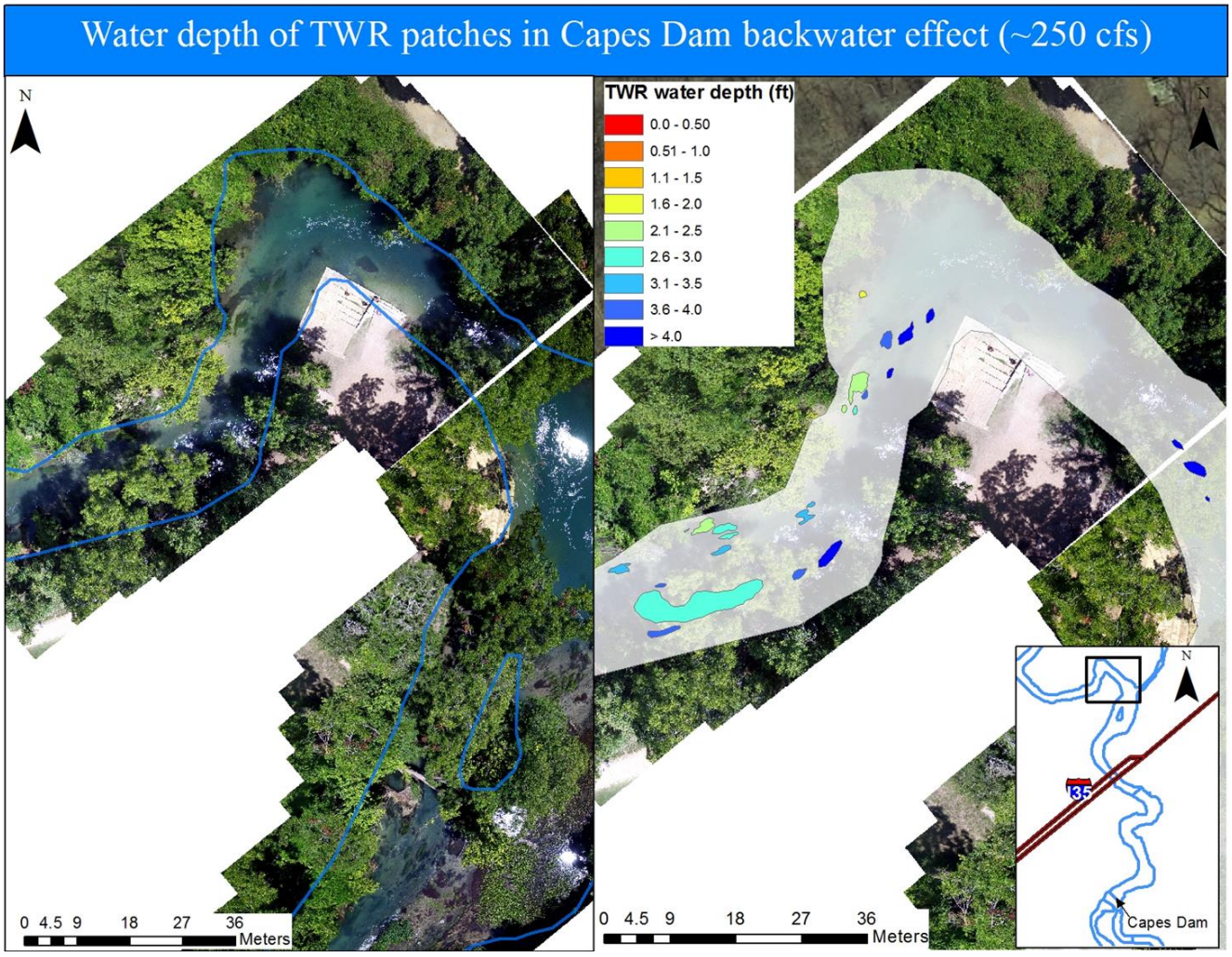

Figure 9. Texas wild rice stands and their observed water depths in the backwater extent of Cape's Dam (Sept 2016).

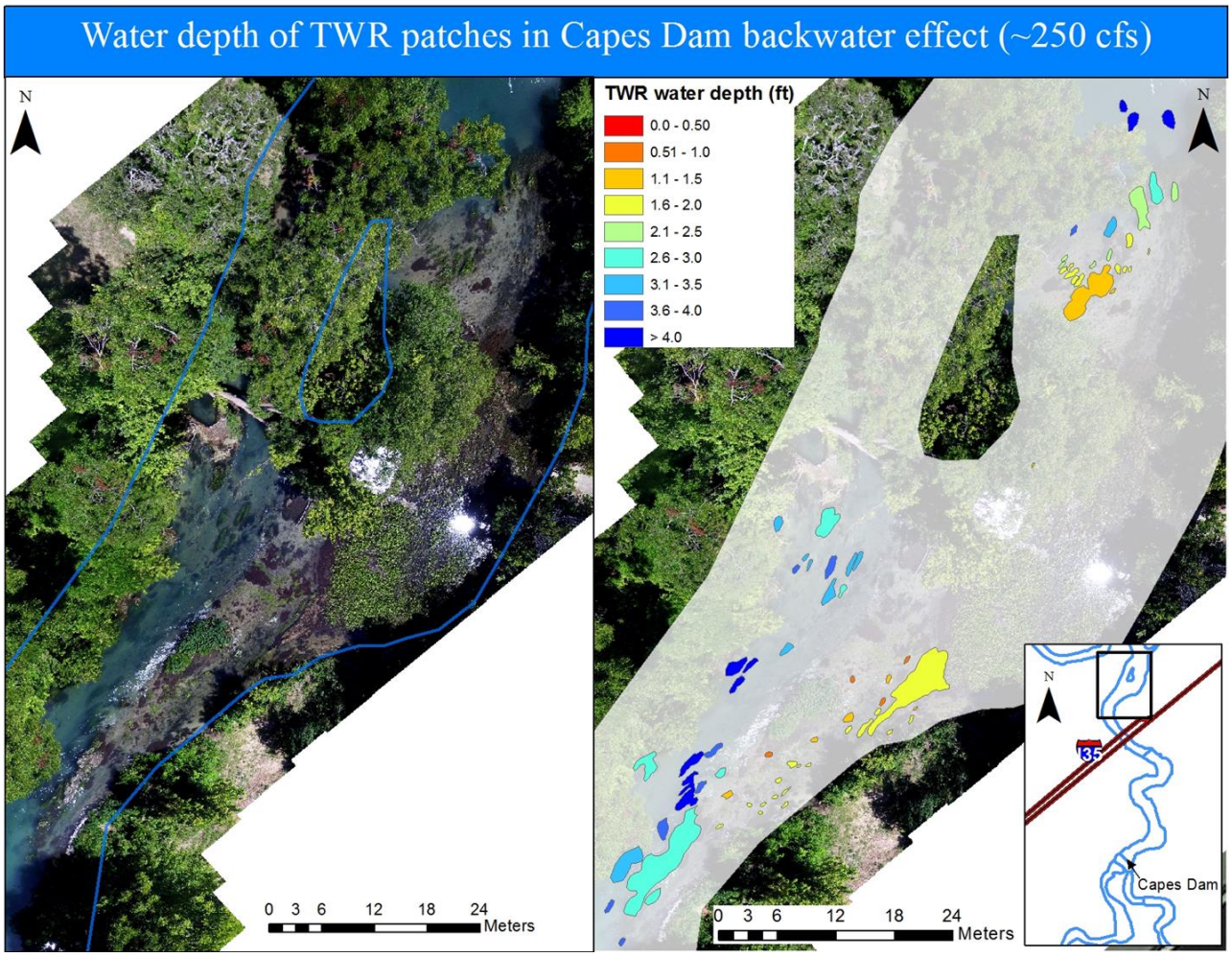

Figure 10. Texas wild rice stands and their observed water depths in the backwater extent of Cape's Dam (Sept 2016).

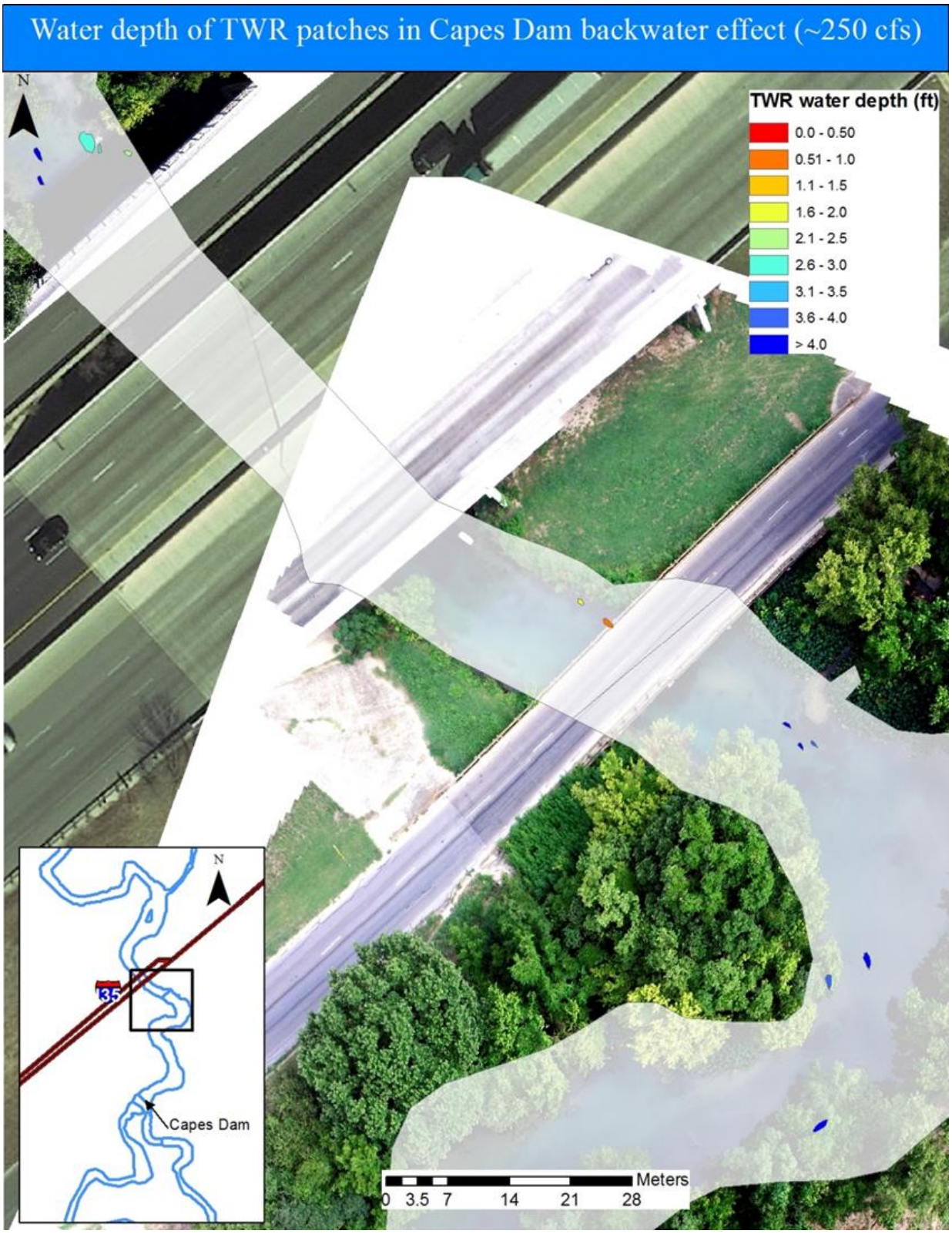

Figure 11. Texas wild rice stands and their observed water depths in the backwater extent of Cape's Dam (Sept 2016).

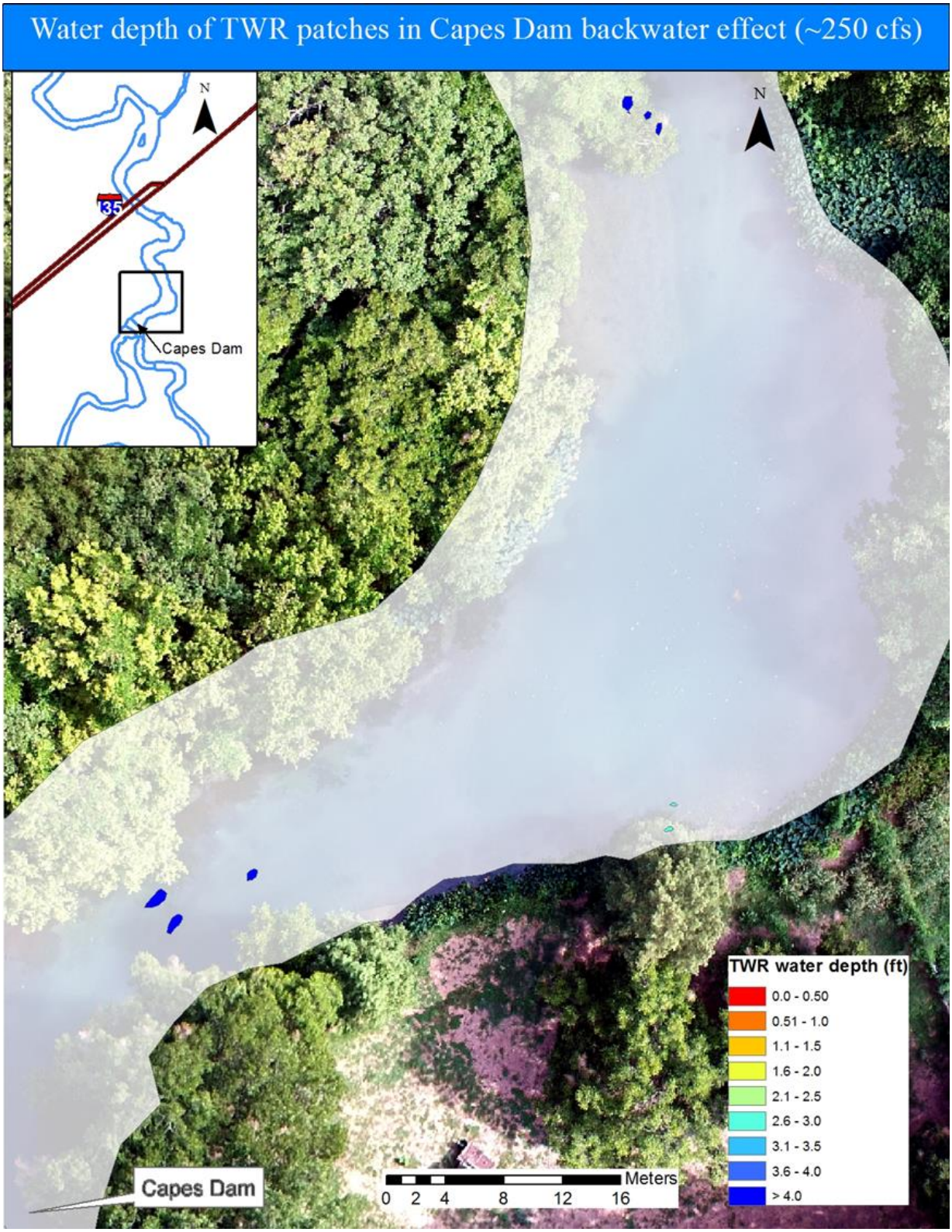

Figure 12. Texas wild rice stands and their observed water depths in the backwater extent of Cape's Dam (Sept 2016).

Water quality parameters

Water quality parameters taken on 08/29/2016, 10/5/2016, and 10/07/2016 are noted in Table 5. The range of turbidity observed in the Mill Race (1.12-6.97 NTU) was greater than in the San Marcos River (0.87-2.87 NTU). Dissolved oxygen generally decreased longitudinally in the Mill Race during all sampling periods (Figure 13) and is attributed to the lack of turbulent reaeration that is more reflective of conditions in the main channel of the San Marcos River. Other water quality parameters did not exhibit a longitudinal change within the Mill Race during these sampling periods.

Table 5. Water quality parameters for 08/29/2016, 10/5/2016, and 10/07/2016.

Monday, August 29, 2016										
	Water Quality									
	Dissolved Oxygen (mg/L)		Temperature (◦C)		Conductivity (µS/cm)		pH		Turbidity (NTU)	
Point	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	7.25	6.76	22.15	23.00	577.75	581.00	7.39	7.64	1.51	0.87
2	7.02	5.75	22.15	23.00	577.75	581.50	7.41	7.64	1.24	1.16
3	6.96	5.37	22.20	23.10	578.00	581.50	7.45	7.59	1.80	1.12
4	7.33	5.36	22.20	23.00	577.75	581.25	7.40	7.56	2.76	1.22
5	6.75	5.36	22.15	22.95	577.50	581.75	7.41	7.68	3.17	2.14
6	6.97	4.91	22.25	22.95	577.50	581.25	7.39	7.58	2.63	2.07
7	7.06	5.64	22.30	23.20	578.00	581.50	7.82	7.60	1.05	1.09
*AM measurements taken at 09:30, PM measurements taken at 13:30.										
Wednesday, October 5, 2016										
	Water Quality									
	Dissolved Oxygen (mg/L)		Temperature (◦C)		Conductivity (µS/cm)		pH		Turbidity (NTU)	
Point	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	9.15	9.40	22.36	23.40	591.60	592.20	7.81	7.85	2.07	2.35
2	8.66	9.19	22.55	23.44	591.65	591.80	7.80	7.85	2.22	2.71
3	7.96	8.91	22.43	23.47	592.20	592.60	7.78	7.84	5.45	4.08
4	7.66	8.96	22.18	23.35	592.10	592.30	7.76	7.85	4.67	4.07
5	7.34	8.32	22.09	22.90	592.05	592.75	7.77	7.80	6.97	6.79
6	7.13	8.05	22.13	23.09	591.55	592.20	7.76	7.78	5.30	6.60
7	8.84	8.94	22.49	23.43	591.20	590.85	7.83	7.90	2.61	2.87
*AM measurements taken at 09:30, PM measurements taken at 15:00										
Friday, October 7, 2016										
	Water Quality									
	Dissolved Oxygen (mg/L)		Temperature (◦C)		Conductivity (µS/cm)		pH		Turbidity (NTU)	
Point	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	9.19	9.35	22.69	22.99	591.25	590.80	7.80	7.82	2.48	1.84
2	8.80	9.00	22.80	23.04	591.80	590.75	7.81	7.86	3.69	5.03
3	8.29	8.94	22.60	23.10	594.00	590.80	7.87	7.85	3.50	2.61
4	8.08	8.98	22.36	23.06	591.50	590.85	7.84	7.85	4.39	3.34
5	7.66	8.71	22.18	22.94	591.85	591.15	7.78	7.85	5.35	3.96
6	7.44	8.40	22.20	22.79	591.60	591.50	7.79	7.79	4.60	4.45
7	9.09	8.93	22.72	22.98	590.80	590.00	7.84	7.88	2.46	2.41
*AM measurements taken at 09:00, PM measurements taken at 15:00.										

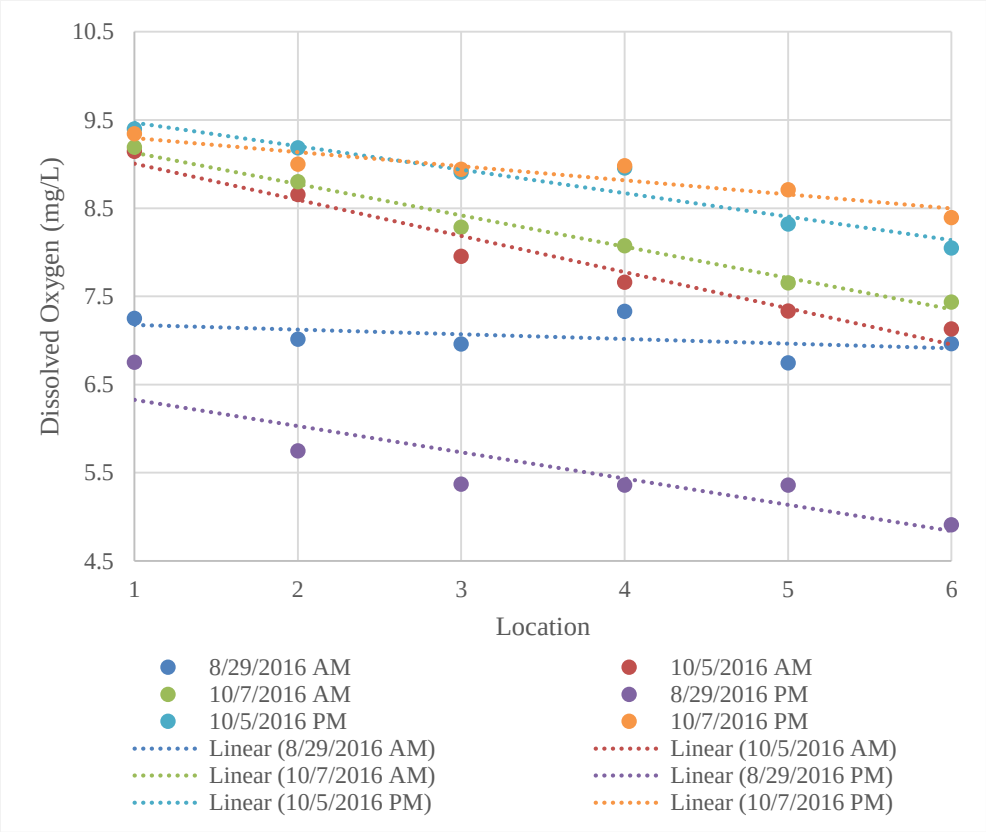

Figure 13. Observed profiles of dissolved oxygen (mg/L) in the Mill Race on 8/29/2016, 10/5/2016, and 10/7/2016.

Table 6 denotes photosynthetic active radiation (PAR) values and canopy closure for all sites on 08/15/2016. Canopy closure observed in center of the channel among sites in the San Marcos River (0%) was lower than the canopy cover found in the center channel among sites in the Mill Race (54-71%). Figure 14 illustrates the difference in the amount PAR reduction between the San Marcos River and the Mill Race. In general the rate of PAR reduction was greater in the Mill Race than the San Marcos River. Regression slopes for PAR reduction ranged from -0.19 to -0.35 in the San Marcos River whereas the slopes for PAR reduction ranged from -0.55 to -3.13 in the Mill Race (Table 7). Greater canopy closure, sun angle orientation, and water clarity likely attribute to the higher rates of PAR reduction in the Mill Race compared to the San Marcos River.

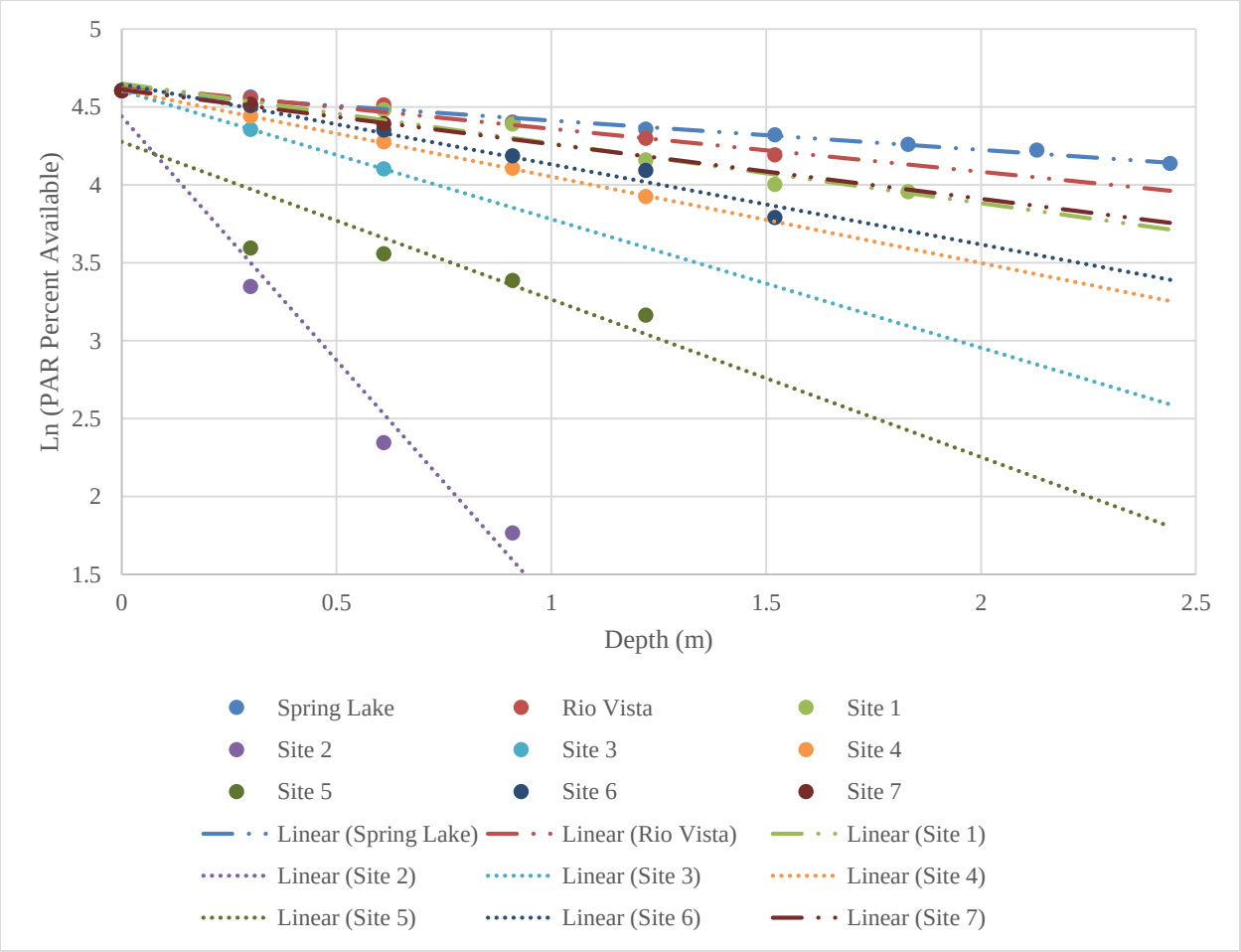

Figure 14. Percent PAR reduction among sites in the San Marcos River (– · ·) and the Mill Race (·····).

Table 6. Depth, canopy cover, light intensity, and the calculated extinction coefficient among sites in the San Marcos River and the Mill Race.

Depth (m)	**Spring Lake**		**Rio Vista**		**Site 1**		**Site 2**		**Site 3**		**Site 4**		**Site 5**		**Site 6**		**Site 7**	
	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)	Light Intensity (µmol m^{-2}s^{-1})	Extinction Coefficient (k)
Air	2,331	-	2,265	-	2,458	-	874	-	2,326	-	2,225	-	112	-	2,085	-	1,872	-
Interchange	1,926	-	2,039	-	2,030	-	718	-	2,136	-	2,022	-	55	-	1,293	-	1,690	-
0.30	1,849	0.136	1,940	0.166	1,836	0.335	204	4.194	1,665	0.830	1,716	0.547	20	3.372	1,174	0.322	1,547	0.295
0.61	1,705	0.200	1,859	0.152	1,795	0.202	75	3.703	1,291	0.825	1,456	0.538	19	1.717	1,003	0.416	1,365	0.350
0.91	1,573	0.222	1,655	0.229	1,636	0.237	42	3.120	Substrate		1,229	0.547	16	1.340	850	0.461	Substrate	
1.22	1,503	0.203	1,500	0.252	1,300	0.365	Substrate		-	-	1,025	0.557	13	1.182	775	0.420	-	-
1.52	1,448	0.188	1,350	0.271	1,110	0.397	-	-	-	-	Substrate		Substrate		572	0.537	-	-
1.83	1,362	0.189	Substrate		1,060	0.355	-	-	-	-	-	-	-	-	Detritus		-	-
2.13	1,315	0.179	-	-	Vegetation		-	-	-	-	-	-	-	-	-	-	-	-
2.44	1,205	0.192	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.74	Vegetation		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site Depth (m)	3.0		1.7		2.4		0.9		0.7		1.1		1.2		2.0		0.9	
Closure (%)	0		0		0		72		68		84		85		54		0	

Table 7. Linear regression equations and R^2 values for LN (Percent Par Reduction).

Site	Linear Regression Equation	R^2
Spring Lake	y = -0.1875x + 4.6006	R² = 0.9901
Rio Vista	y = -0.2767x + 4.6371	R² = 0.9712
Site 1	y = -0.3839x + 4.6501	R² = 0.9506
Site 2	y = -3.1308x + 4.4407	R² = 0.9751
Site 3	y = -0.555x + 4.6086	R² = 0.9996
Site 4	y = -0.8254x + 4.6047	R² = 1.0000
Site 5	y = -1.012x + 4.2764	R² = 0.7743
Site 6	y = -0.5148x + 4.6468	R² = 0.9695
Site 7	y = -0.3504x + 4.6108	R² = 0.992

Aquatic vegetation

Approximately 2,859 m^2 of aquatic vegetation was observed in the Mill Race in August 2016 (Table 8). Among vegetation species observed, the non-native *Hygrophila* was found to have the greatest aerial coverage (1,472 m^2), followed by *Cabomba* (1,052 m^2), and *Colocasia* (262 m^2). Vegetation cover accounted for roughly 56% of total stream bottom coverage of the Mill Race (Figure 15). Silt or sand substrate accounted for most of the open substrate areas in the Mill Race.

Table 8. Area (m^2), percent abundance and percent cover for aquatic vegetation species in the Mill Race – San Marcos River (Aug 2016).

Scientific Name	Common name	Area (m^2)	Abundance (%)	Cover (%)
Cabomba	Fanwort	1,052.21	36.80	20.53
Colocasia	Elephant ear	262.38	9.18	5.12
Ceratophyllum	Hornwort	7.040	0.25	0.14
Hygrophila	Dwarf hygro	1,472.28	51.50	28.73
Hydrilla	Esthwaite waterweed	11.16	0.39	0.22
Ludwigia	Primrose	0.84	0.03	0.02
Nasturium	Watercress	11.05	0.39	0.22
Terrestrial (Riparian)		42.00	1.47	0.82

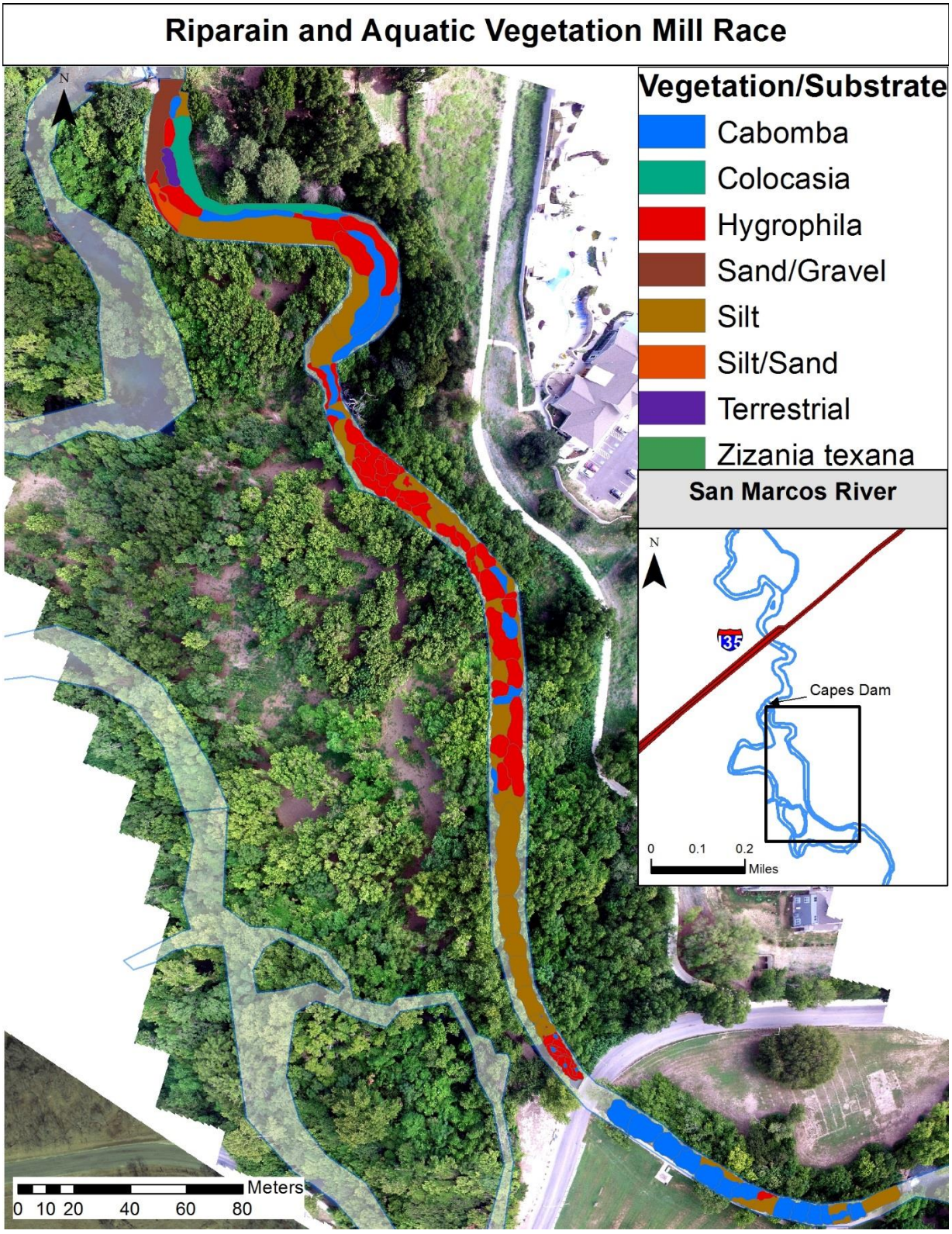

Figure 15. Vegetation and substrate coverage in the Mill Race (Aug 2016).

Identifying seepage extent

Two seepage outflow systems (denoted seepage System A and System B) were detected flowing in to the San Marcos River from the southwest region of Thompson's Island. Seepage outflow locations and discharge sampling locations (e.g. Mill Race Opening, Mill Race Upstream (of Cape's Road), Mill Race at Cape's Road.) are shown in Figure 16. Vibrant red hues were observed in both the System A and System B outflows within ten minutes of disbursing red-dye in the adjacent segment of the Mill Race just above Cape's Rd (see Figure 17). Observational red-dye testing confirmed the Mill Race to be the origin of seepage outflow for Systems A and B.

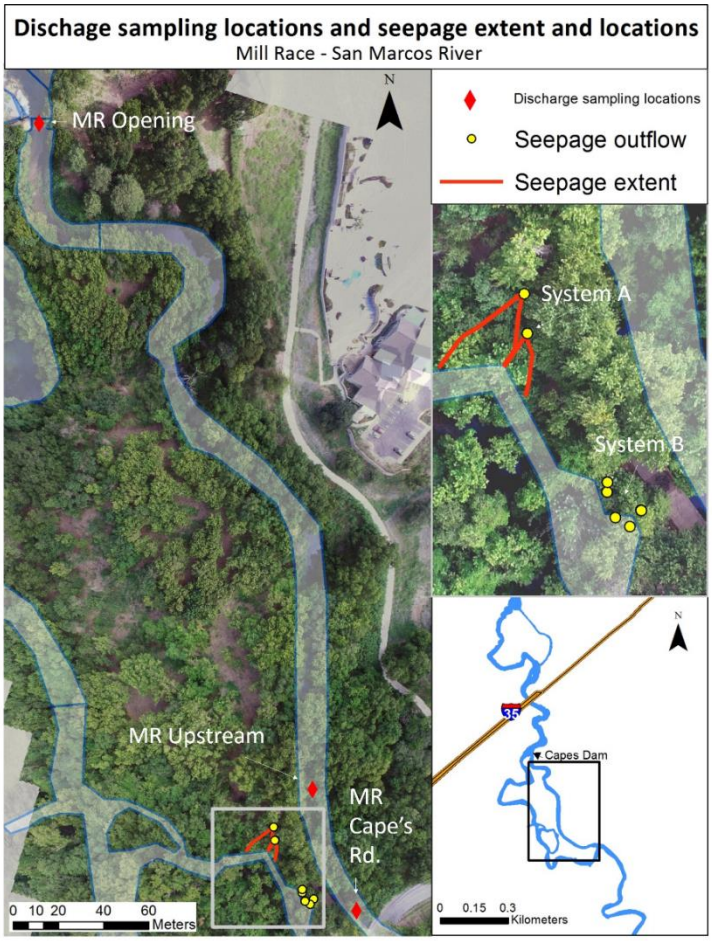

Figure 16. Discharge sampling and seepage extent sampling locations.

Figure 17. Seepage System A and B after the introduction of red dye in the Mill Race above Cape's Rd.

Figures 18 and 19 illustrate channel topography, water surface elevation, and current velocity for discharge sampling locations on 9/1/2016 and 09/23/206, respectively. Estimated discharge calculations for sampling locations are noted in Table 7. Estimated discharge at the Mill Race opening (MR Opening, 22.64 cfs and 21.07 cfs) varied <1 cfs from estimated discharge above seepage outflow (MR Upstream, 22.67 cfs and 21.36 cfs) on both 09/01/2016 and 09/23/2016. Estimated discharge above the seepage outflow (MR Upstream, 22.67 cfs and 21.34 cfs) was 11.99cfs greater than the estimated discharge below the seepage outflow (MR Cape's Rd., 9.23 cfs and 10.8 cfs) on average. As noted in Table 8, the estimated total discharge for seepage outflow Systems A and B was 12.49 cfs.

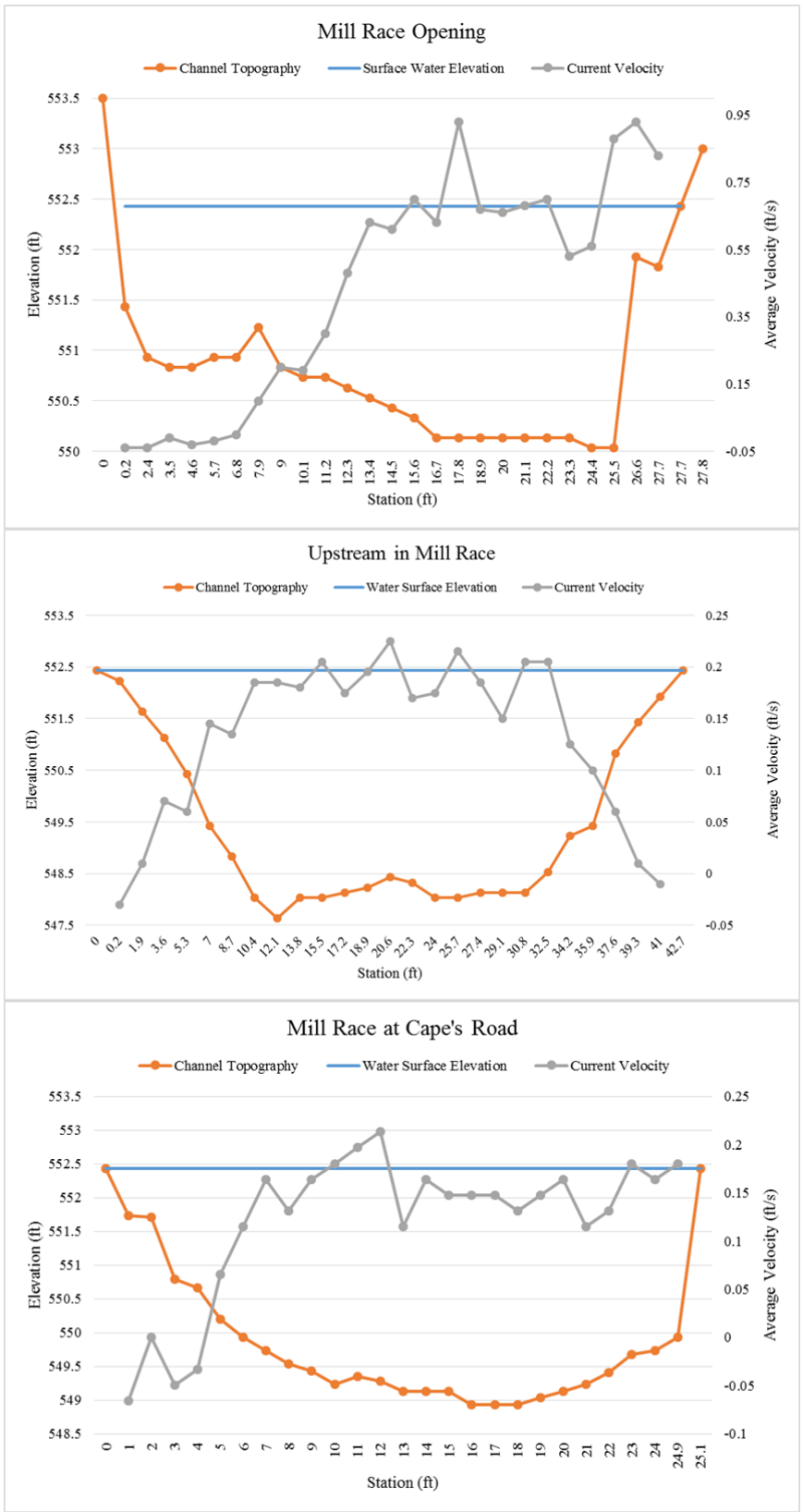

Figure 18. Channel topography, water surface elevation, and current velocity on 09/01/2016.

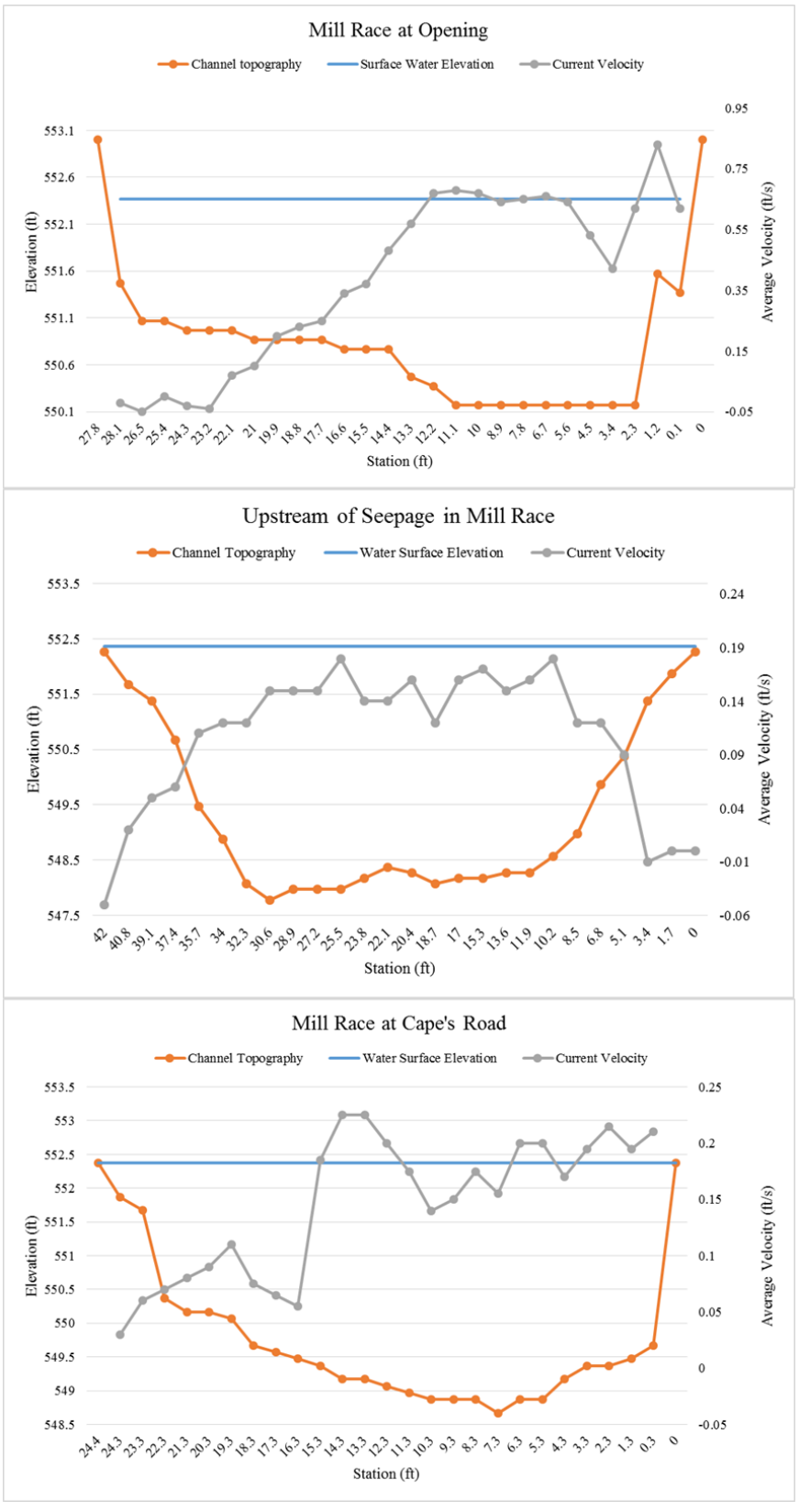

Figure 19. Channel topography, water surface elevation, and current velocity on 09/23/2016.

Table 9. Estimated discharge for seepage outflow locations.

Location	Date	Discharge
MR Cape's RD	9/1/2016	9.23
MR Upstream	9/1/2016	22.67
MR Opening	9/1/2016	22.64
MR Cape's RD	9/23/2016	10.8
MR Upstream	9/23/2016	21.34
MR Opening	**9/23/2016**	**21.07**

Location	Date	Discharge (cfs)
System A: Pt 1	08/24/2016	3.96
System A: Pt 2	09/01/2016	0.69
System B: Pt 1	09/01/2016	5.11
System B: Pt 2	09/01/2016	0.72
System B: Pt 3	08/24/20016	2.01
Total		12.49

Water mixing downstream of the Mill Race

Table 10 denotes the water quality parameters measured on October 12, 2016 along six transects beginning upstream of the TPWD A.E. Woods hatchery outflow and continuing downstream to the Mill Race outfall (refer to Figure 3 for transect locations). Water temperature was somewhat warmer (23.2°C) and conductivity was slightly lower (471.9µs/cm) in the A.E. Woods hatchery outflow when compared to the San Marcos River. However, by the location of Transect 2 (roughly 50m downstream of the outflow), water temperature and conductivity was consistent with San Marcos River water quality conditions along the entire transect. This is attributed to the fact that the A.E. Woods outflow represents a very small fraction of the total San Marcos flow with only minor differences in the measured water quality parameters. Water

temperature in the Mill Race outflow was slightly cooler with increased turbidity (4.5-8.62 NTU) compared to the San Marcos River main channel (Mean Turbidity 3.4 NTU).

Table 10. Water quality parameters measured along six transects beginning upstream of TPWD A. E. Wood hatchery outflow and continuing downstream to the Mill Race outfall (Oct 12, 2016).

Zone	PT	Water Quality				
		Dissolved Oxygen (mg/L)	Temperature (◦C)	Conductivity (µS/cm)	pH	Turbidity (NTU)
Mill Race Outflow	River Right	8.29	21.13	587.8	8	4.45
	Mid Point	8.28	21.13	588	8	8.62
	River Left	8.4	21.13	588	8	4.5
Interchange of Outflow and River	River Right	8.47	21.24	588.5	8	4.03
	Mid Point	8.61	21.5	588.2	7.9	3.53
	River Left	8.62	21.56	588.1	7.9	4.96
Transect 1 WQ	River Right	8.55	21.52	585.7	7.9	3.68
	Mid Point	8.43	21.47	588.8	7.9	3.28
	River Left	8.59	21.46	589.54	7.9	4.39
Transect 2 WQ	River Left	8.51	21.48	589.3	7.9	3.22
	Mid Point	8.52	21.5	588.1	7.9	3.4
	River Right	8.65	21.51	588	7.9	3.33
Transect 3 WQ	River Left	8.57	21.49	589.4	7.9	3.7
	Mid Point	8.5	21.5	589.4	7.8	3.31
	Interchange	8.34	21.7	575	7.9	3.33
	River Right	8.4	21.7	564	7.9	3.2
Outflow WQ	Mid-Outflow	8.04	23.2	471.9	8.3	3.26
Transect 4 WQ	River Left	8.49	21.53	589.2	7.9	3.12
	Mid Point	8.48	21.53	589.1	7.9	3.09
	River Right	8.48	21.53	589.1	7.9	3.2

Figure 20 illustrates the current velocities (ft/s) measured at the interface of the Mill Race outflow and the San Marcos River. Current velocities measurements were observed in both directions: current moving into the Mill Race outflow from the San Marcos River and current moving out into the San Marcos River from the Mill Race outflow. Figure 21 shows the mixing of the two water sources with the red dye spreading into the Mill Race outflow as well as into the San Marcos River. The current velocities measurements and dye testing suggests the interchange between the Mill Race outflow pool and the San Marcos River forms an eddy (swirling of water), which promotes mixing of two water sources. The spatial configuration of the channel

in the San Marcos River and these results suggest that the outfall pool would continue to exchange water from the main stem San Marcos River even if the Mill Race was not flowing.

Fish community and fountain darter assessment

The Mill Race consisted of shallow to moderate depths (0.1 – 6.0 ft) and slow to moderate current velocities (0.01 – 1.60 ft/s; Table 10). Habitat types were mostly runs (80%) and pools (15%) over predominantly silt substrate. Approximately 24% of the sampled areas contained submerged aquatic vegetation and woody debris was common among scuba sampled areas (27.6%).

Table 11. Mean (range) of physical parameters observed during fish sampling in the Mill Race (November 2016).

Physical Parameters	**Seine**	**Scuba**
Water depth (ft)	2.4 (0.1-4.5)	3.3 (1.5-6.0)
Current velocity (ft/s)	0.3 (0.01-1.6)	0.07 (0.01-0.16)
Substrate (%)		
Silt	65.5	89.7
Sand	18.5	0
Gravel	11	1.6
Cobble	2.5	8.4
Detritus	2.4	0.1
Aquatic vegetation cover (%)	24.9	23.8
Woody debris (%)	1.8	27.6

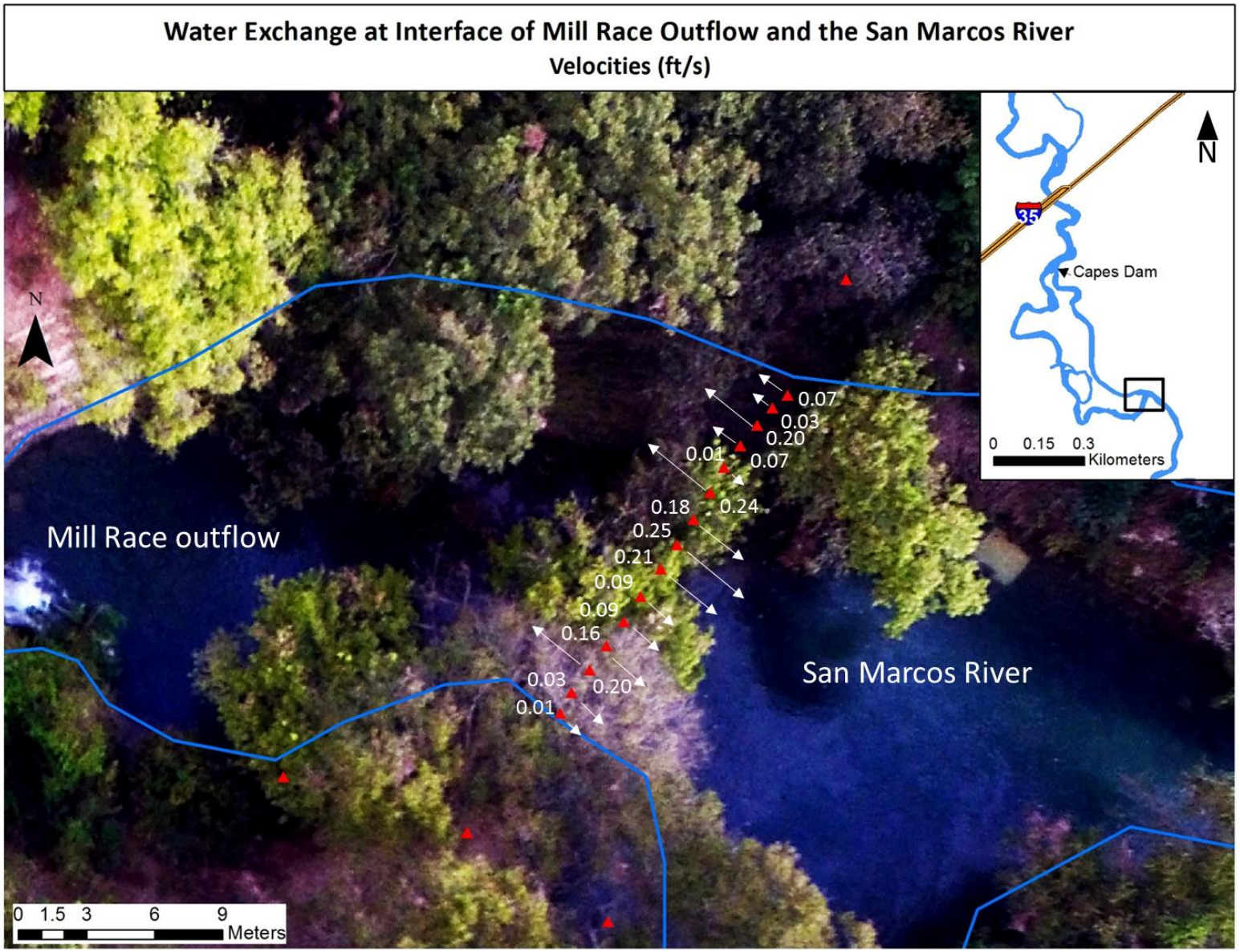

Figure 20. Current velocity (ft/s) measured at the interface of the Mill Race outflow and the San Marcos River (October 12, 2016).

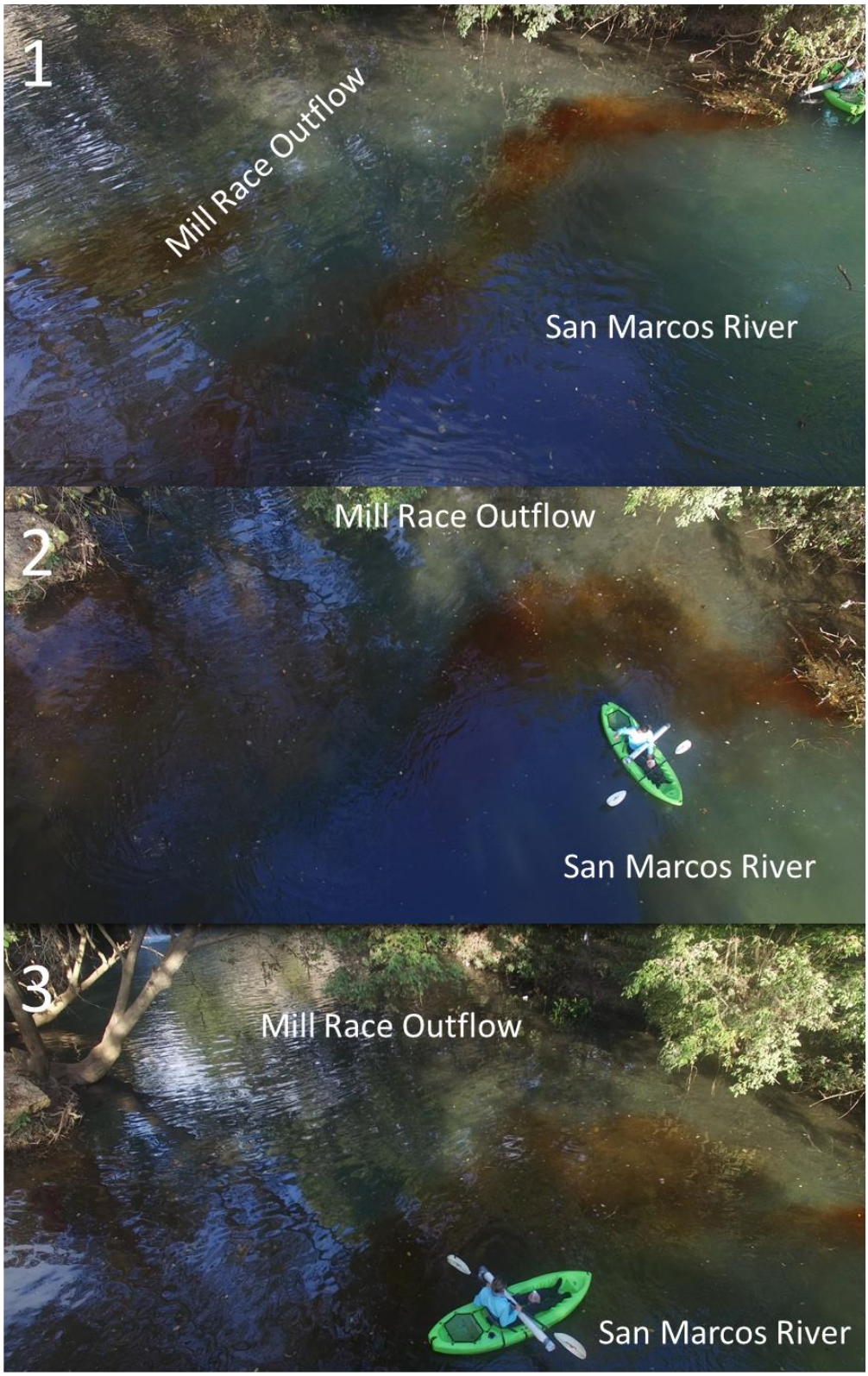

Figure 21. Images illustrating progression (1-3) of the red dye test to assess water mixing between the Mill Race Outflow and the San Marcos River.

A total of 649 individuals, representing 17 species, were collected in the Mill Race (Table 11). Among the 17 species collected, seven species (70 individuals out of 649 observed) are considered non-native (Kollaus et al. 2014). Species with highest CPUE (individuals/m^2 sampled) was *Gambusia* (0.767, 0.262) followed by *Hypostomus plecostomus* (0.150), and *Notropis amabilis* (0.129). *Gambusia sp.* accounted for over 66 percent of all fish collected. Thirteen individuals (0.031 CPUE) of *Etheostoma fonticola* (fountain darter) were collected during fish sampling in the Mill Race. Fountain darter were observed only in seining transects 7-11 and not observed further downstream within the Mill Race (refer to Figure 4 for transect locations). Given the extensive sampling and presence of aquatic vegetation, the results suggest that the Mill Race does not support substantial habitat use compared to the main stem San Marcos River. Higher water turbidity might have attributed to observing no individuals during Scuba (underwater observations). The thirteen fountain darters collected were observed in areas with water depths ranging from 0.1 – 2.1 feet and in mean column current velocities ranging from 0.03 – 0.54 ft/s. They were collected from areas with sand or silt substrate and in areas with 0% to 75% aquatic vegetation cover. Among the thirteen fountain darter collected, three individuals were observed in seine hauls with bare substrate but the remainder of individuals were observed in seine hauls containing greater than 40% vegetation coverage.

Table 12. Total number of observations (Total N), Most appropriate gear type per species, Total number of observations per gear type, and CPUE (individuals/ area sampled) per species in the Mill Race (Nov 2016). * denotes non-native species.

Scientific Name	Common Name	Total N	Gear type	N for gear type	CPUE (ind/m^2)
Dionda nigrotaeniata	Guadalupe roundnose minnow	4	Seine	4	0.009
Notropis amablis	Texas shiner	54	Seine	54	0.129
Moxostoma congestum	Gray redhorse	1	Seine	1	0.002
*Astyanax mexicanus**	Mexican tetra	3	Seine	3	0.007
*Hypostomus plecostomus**	Suckermouth catfish	33	Micro	24	0.150
Gambusia affinis	Mosquito fish	16	Seine	16	0.038
Gambusia geiseri	Big Springs gambusia	110	Seine	110	0.262
Gambusia sp.	Gambusia species	322	Seine	322	0.767
*Poecilia lattipina**	Sailfin molly	12	Seine	12	0.029
*Ambloplites rupestris**	Rockbass	1	Seine	1	0.002
Lepmois gulosus	Warmouth	1	Seine	1	0.002
Lepomis macrochirus	Bluegill sunfish	1	Seine	1	0.002
*Lepomis auritus**	Redbreast sunfish	19	Seine	18	0.043
Lepomis miniatus	Redspotted sunfish	17	Seine	17	0.040
Lepomis sp.	Sunfish species	24	Meso	18	0.015
Micropterua salmoides	Largemouth bass	16	Meso	9	0.008
Etheostoma fonticola	Fountain darter	13	Seine	13	0.031
*Cichlisoma cyanoguttatum**	Rio Grande cichlid	1	Seine	1	0.002
*Oreochromis aureus**	Blue tilapia	1	Seine	1	0.002
Total		649			
Number of Species		17			

Recreation counts

Table 13 and Figure 22 denote the total number of individuals per recreation type among sites across all periods reported. The total number of individuals observed in the Cape's Dam-Mill Race reach from July through November was 431. The total number of individuals observed in the Sewell Park-City Park-Rio Vista reach from July through November was 16,437.

Vessels accounted for the highest percentage of recreation activity in the Cape's Dam-Mill Race reach between July and November 2016 (57%), followed by swimmers (24%), and tubers (19%). Swimmers accounted for the highest percentage of recreation activity in the Sewell Park-City Park-Rio Vista reach between July and November 2016 (60%), followed by tubers (38%), and vessels (2%).

Table 13. Total number of individuals per recreation type among sites across all months of record.

Month	Site	Kayak	Tube	Swim	Monthly Total
July	Rio Vista 2014	141	5,760	8,703	14,604
	Mill Race 2016	59	44	28	131
August	Cape's Dam 2016	31	5	8	44
	Mill Race 2016	34	22	23	79
September	Sewell 2013	6	53	298	357
	City Park 2013	38	565	719	1,322
	Cape's Dam 2016	45	4	11	60
	Mill Race 2016	48	7	21	76
October	Rio Vista 2013	32	3	75	110
	Cape's Dam 2016	28	0	9	37
November	Cape's Dam 2016	1	0	3	4

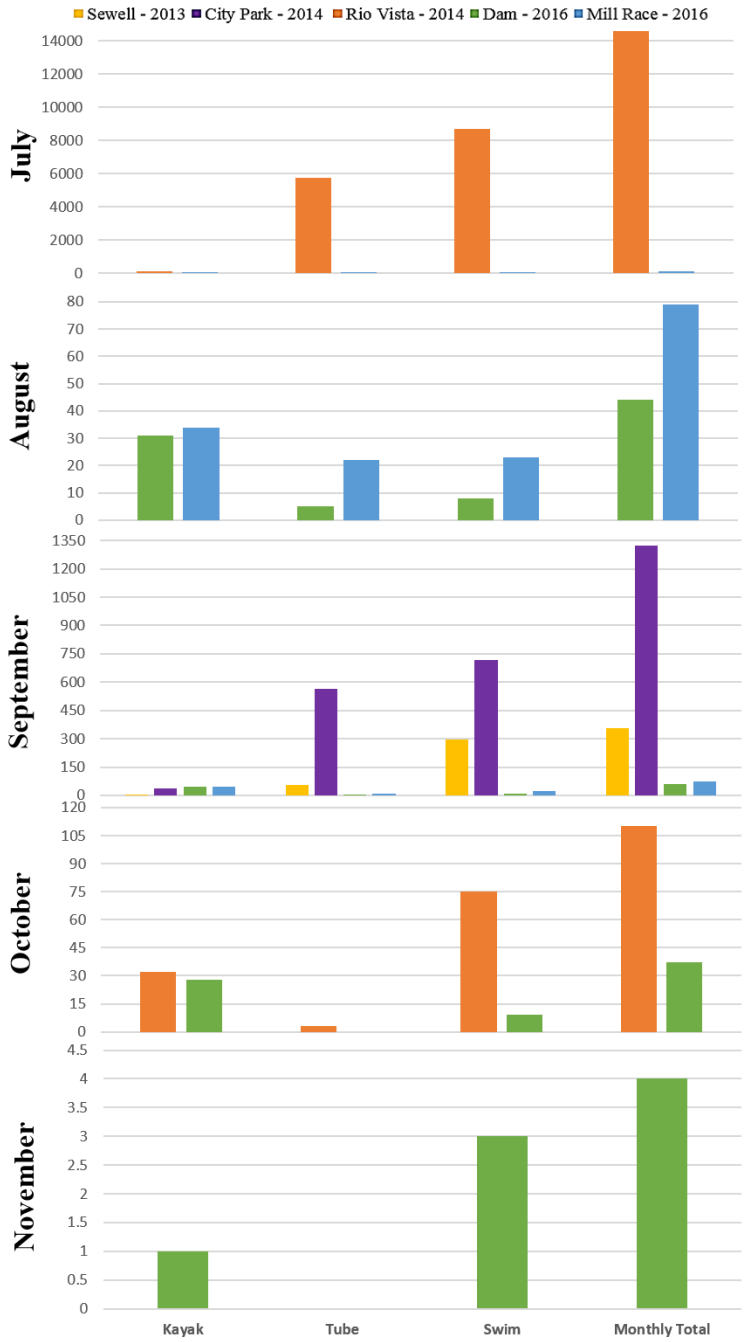

Figure 22. Total number of individuals per recreation type for each month captured by Sewell Park, City Park, Rio Vista Park, Dam, and Mill Race cameras.

Figure 23 illustrates the mean number of recreationists per weekday among months. Sundays in July provided the highest daily recreation mean for the Mill Race (24 individuals). Saturdays in July provided the highest daily recreation mean for Rio Vista (930

individuals). At Cape's Dam in November, the daily recreation mean was below 1 individual each day of the week.

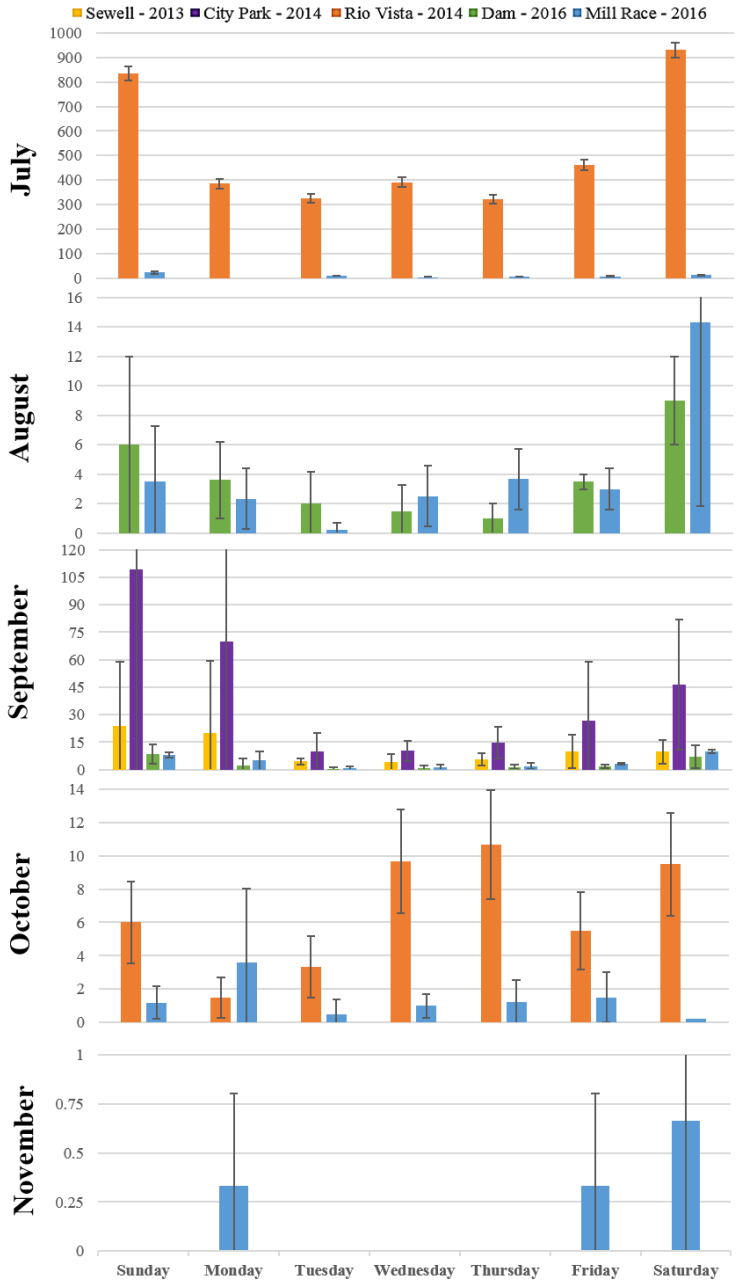

Figure 23. Mean and SD of recreation per weekday for all recreation types for each month captured by Sewell Park, City Park, Rio Vista Park, Dam, and Mill Race game cameras.