MEMO

To: Elizabeth A. Fazio-Hale, Riverbend Water Resources District

From: Bianca D. Whitaker, Arroyo Environmental Consultants, LLC

Date: January 28, 2019

Re: Volumetric & Sedimentation Survey Results

In July 2018, Arroyo Environmental Consultants, LLC, along with their partner firm Aqua Strategies Inc. (project team), were contracted to conduct a volumetric and sedimentation survey of Wright Patman Lake, Texas for Riverbend Water Resources District (RWRD). This document presents volumetric and sedimentation survey results, along with a brief description of methodologies in surveying, data collection, processing and analysis, quality controls measures and examples, and comparison of results to past surveys.

The project team collected bathymetric data for Wright Patman Lake between July 17, 2018 and August 23, 2018 with daily water surface elevations ranging from 225.82 to 226.69 feet above mean sea level (NGVD29; *USGS 07344200 Wright Patman Lk nr Texarkana, TX*).

Methodology

Survey methodology for this volumetric and sedimentation survey follows methods similar to those utilized by the Texas Water Development Board (TWDB). Bathymetric surveying was conducted using a Specialty Devices, Inc. (SDI) BSS+ single beam, multi-frequency (200kHz, 50kHz, 12kHz) sub-bottom profiling depth sounder integrated with a corrected GPS (global positioning system) unit. The same survey line layout pattern used by TWDB in 2010 was replicated in this 2018 survey. Data was collected with SDIDepth and Hypack Survey software (HYPACK) and processed and analyzed with Depthpic and Hydropick software packages.

Sediment cores were collected at selected points around the lake along survey lines with the SDI VibeCore system. Sediment cores were used to ground-truth the pre-impoundment depth (original lake depth before impoundment) by analyzing the sediment core samples for sediment thickness (depth), color, type, water content and presence of organic matter.

Interpolation methods utilized Hydrotools, SAGA and QGIS software to map the current surface and pre-impoundment surface throughout the lake. Elevation area capacity (EAC) tables (see Appendix A), as well as lake volume and sediment volume calculations, were generated from the interpolated data.

Results

The 2018 volumetric survey indicates Wright Patman Lake has a total reservoir capacity of 96,430 acre-feet and encompasses 17,907 surface acres at conservation pool elevation (220.6 feet above mean sea level, NGVD29; Table 1). Previous capacity estimates include the original design estimate in 1956 (158,000 acre-feet), the Texas Water Development Board's (TWDB) 1997 volumetric survey estimate (115,638 acre-feet as revised by TWDB), and the TWDB's 2010 volumetric survey estimate (97,927 acre-feet; Table 2). Table 1 provides lake volume, surface area, sedimentation volume and sedimentation rates at the different lake operating levels. Numbers are not provided for the April to May (227.5 feet above mean sea level, NGVD29) operating levels due to water levels below that elevation during the bathymetry survey.

TABLE 1. 2018 LAKE VOLUME AND SEDIMENTATION AT SEASONAL OPERATING LEVELS, LAKE BOUNDARY

Wright Patman Lake Volume and Sedimentation					
CPE	Elevation (ft NGVD29)	Current Capacity (acre-ft)	Current Surface Area (acres)	Sedimentation (acre-ft)[a]	Sedimentation Rate (acre-ft/yr)[a]
Nov - March	220.6	96,430	17,907	30,322	489
April - May	227.5	-	-	-	-
June - October	225.0[a]	193,695	25,426	-	-
October	221.2	107,491	19,025	31,835	513
Lake Boundary	226.28[a]	226,758	26,133	-	-

[a] Area, capacity and sediment thickness below elevation 224ft is based on echosounding data; for elevations above 224ft, area and capacity are extrapolated to the boundary.

Based on several methods for estimating sedimentation rates, Wright Patman Lake loses between 187 and 993 acre-feet of capacity per year due to sedimentation below conservation pool elevation (220.6 feet above mean sea level, NGVD29; Table 2 and Table 3). The project team determined the sedimentation rate to be 489 acre-feet per year based on the 2018 survey results. This sedimentation rate was determined from results of the 2018 survey, based upon years since impoundment (62 years) and volume of sediment (30,322 acre-ft) calculated to have accumulated since impoundment. Sedimentation rate can be calculated from the 2018 survey for each operating pool level to consider sediment accumulation up to the limits of 2018 survey data (Table 1). Previous sedimentation estimates were provided in the TWDB 1997 (TWDB 2003) survey report and the TWDB 2010 volumetric and sedimentation survey report. All lake volume comparisons between surveys are presented in Table 2.

Table 2 compares each survey to another survey, providing the volume difference between surveys, the volume difference as a percentage and the capacity loss rate for each comparison.

TABLE 2. COMPARISON OF LAKE VOLUME CALCULATIONS ON WRIGHT PATMAN LAKE

Comparison of Lake Volume Calculations					
Survey	Comparisons @ 220.6 ft NGVD29				
	Current Volume (acre-ft)				
	Comparison #1	Comparison #2	Comparison #3	Comparison #4	Comparison #5
Original design estimate	158,000	-	158,000	-	-
1997 TWDB Volumetric survey (revised)	-	115,638	-	115,638	-
2010 Volumetric survey	97,927	97,927	-	-	97,927
2018 Volumetric survey	-	-	96,430	96,430	96,430
Volume Difference (acre-ft)	60,073	17,711	61,570	19,208	1,497
Percent Volume Change	38.0%	15.3%	39.0%	16.6%	1.5%
Number of years (since impoundment)	54	13	62	21	8
Capacity loss rate (acre-ft/year)	1,112	1,362	993	915	187

Comparison of 2018 survey results to other studies developed using different methodologies should be made with caution due to inherent differences in methodology procedures. Comparison to the TWDB 2010 reported results are most suitable due to the fact that they are the only two surveys that include both a volumetric and sedimentation survey, and because data collection and analysis were conducted using comparable methods and equipment (Table 3). The 1997 survey included a volumetric result but did not include a sedimentation survey and is therefore not considered in the lake sedimentation comparison. Table 3 shows the total lake capacity (126,752 acre-ft) for the 2018 survey, calculated based on the preliminary lake volume calculation and the preliminary sediment volume calculation.

TABLE 3. COMPARISON OF LAKE SEDIMENTATION CALCULATIONS ON WRIGHT PATMAN LAKE

Comparison of Sedimentation Calculations		
Survey	Comparisons @ 220.6 ft NGVD29	
	Volume (acre-ft)	
	Comparison #6	Comparison #7
TWDB lake capacity estimate based on 2010 V&S survey	137,336	-
Lake capacity estimate based on 2018 V&S survey	-	126,752
2010 Volumetric survey	97,927	-
2018 Volumetric survey	-	96,430
2010 Sedimentation survey	39,409	-
2018 Sedimentation survey	-	30,322
Percent Sedimentation	28.7%	23.9%
Number of years (since impoundment)	54	62
Capacity loss rate (acre-ft/year)	730	489

A volumetric estimate from 1956 attributed to USACE was reported in the TWDB 2010 report; however, methodology information is not currently available to the project team and therefore not considered an appropriate comparison.

Quality Control/Quality Assurance Methods

The project team employed multiple methods of quality control/quality assurance (QA/QC) methods throughout the entire study process, from field data collection methods to data processing to final data comparisons. Examples of these methods are provided within this technical memo. The various QA/QC procedures include, but are not limited to the following: staff gage installation and verification of daily lake elevation, daily water velocity profile readings to calibrate and verify lake point depths, collection of sediment cores at multiple lake locations to ground truth the determination of pre-impoundment depth, visual inspection of mapped processed data points, comparison of processed data points collected on different days at the same location (Table 4), comparison of selected similar (collected along same pre-planned lines) cross-sections between 2010 and 2018 surveys (Appendix B: Figures 1 – 5), comparison of calculated lake volume and sediment volume between 2010 and 2018 surveys (Table 3), among other processed raw data checks.

Table 4 is an example of one of the many comparisons of data points in close proximity collected on different days of the 2018 survey. The last row provides the difference on one data point pair in the given parameters (x/y location, lake elevation, etc.). This comparison shows good internal consistency in data collection and processing methods throughout the 2018 survey.

TABLE 4. COMPARISON OF DATA POINTS

x	y	Lake Elevation (ft)	Current Surface (ft)	Pre-impoundment (ft)	Sediment Thickness (ft)	sdi_filename	Date	Time
3286915.078	7172755.257	226.2	217.27	215.88	1.39	18080221	8/2/18	48:02.1
3286914.962	7172755.189	226.23	217.21	215.85	1.36	18080129	8/1/18	16:41.5
0.116	**0.068**	**-0.03**	**0.06**	**0.03**	**0.03**			

Figures 1 through 5 in Appendix B provide a graphical view of comparisons conducted on one of the many pre-planned survey lines followed in both the 2010 TWDB and 2018 Arroyo surveys. Both surveys collected and processed lake current and pre-impoundment surfaces.

Figure 1 shows the comparison of the current surface of the lake in both surveys along one cross section. Overall, the current surface is similar in elevation over most of the cross section. However, differences are present and can be due to a variety of reasons: offset in the horizontal location of the data point (some points were up to 15 feet away from each other between the two surveys), and data processing differences (e.g. methodology of choosing the current surface can vary with the use of different software among different users), etc.

Figure 2 provides a comparison of the pre-impoundment surface of the lake in both surveys. Although some point comparisons are similar in elevation, which would be expected in the pre-impoundment elevations between surveys, there is a noticeable difference in these layers, particularly in deeper, possible thalweg (river bottom) areas. Some differences could be explained in point areas where the horizontal differences are greater (e.g. survey data points are over 10 feet apart between years). Larger differences in pre-impoundment elevations (original lake bottom) might be better explained by looking at differences in methodologies between surveys.

Figure 3 provides a view of a 2018 survey sediment layer along the cross section by showing both the current surface and pre-impoundment surface together.

Figure 4 provides a view of a 2010 survey sediment layer along the cross section by showing both the current surface and pre-impoundment surface together.

Figure 5 provides a comparison of the cross section of the sediment thickness for each survey. There are many spikes of greater sediment thickness along the 2010 survey line data than for the 2018 data. The variation of sediment thickness along this cross section implies differences in sediment accumulation estimates that warrant additional future study.

Conclusion

Results of the 2018 Arroyo Volumetric and Sedimentation Survey of Wright Patman Lake indicate a sedimentation or capacity loss rate (due to sedimentation) of 489 acre-ft/year over the life of the lake (1956 to present). This technical memo provides the final capacity and sedimentation numbers as well as a comparison to previous survey results.

The differences in pre-impoundment surface, sediment thickness calculations and sedimentation rates between the 2018 and 2010 surveys create a scientific dilemma in long-term water planning for the RWRD. Consistency amongst survey results would be ideal and would allow for more confidence in lake volume and sedimentation rate estimates.

Comprehensive QA/QC procedures on 2018 survey data and results by the project team support the results and conclusions presented above. However, preliminary investigations into the 2010 survey data identified several discrepancies within the 2010 survey which could account for significant variability between 2010 and 2018 survey results. This preliminary effort identifies enough concerns about processing and calculation techniques to warrant the opportunity to re-evaluate the 2010 survey more in-depth than what has been conducted for this project.

Re-evaluation of the 2010 survey may result in scientifically defensible revised 2010 lake volume and 2010 sedimentation rate estimates and provide RWRD with more reliable lake data for use in future water planning efforts.

REFERENCES

Texas Water Development Board (TWDB). 2012. Volumetric and Sedimentation Survey of Wright Patman Lake. https://www.twdb.texas.gov/surfacewater/surveys/completed/files/wrightpatman/2010-06/WrightPatman2010_FinalReport.pdf

Texas Water Development Board (TWDB). 2003. Volumetric Survey of Wright Patman Lake. https://www.twdb.texas.gov/surfacewater/surveys/completed/files/wrightpatman/1997-01/WPatman1997_FinalReport.pdf

United States Geological Survey (USGS). 2018. U.S. Geological Survey National Water Information System: Web Interface. *USGS 07344200 Wright Patman Lk nr Texarkana, TX.* https://waterdata.usgs.gov/tx/nwis/uv?site_no=07344200

APPENDIX A – ELEVATION-AREA-CAPACITY TABLES

TABLE 5. WRIGHT PATMAN LAKE ELEVATION-AREA TABLE

WRIGHT PATMAN LAKE
RESERVOIR AREA TABLE

July - August 2018
Volumetric & Sedimentation Survey
AREA IN ACRES

Seasonal pool elevations:

November 1 - March 31	220.6 feet
April 1 - May 31	227.5 feet
June 1 - October 4	225.0 feet
October 5 - October 31	221.2 feet

Elevation	Elevation Increment is ONE TENTH FOOT									
in FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
193							0.00	0.01	0.01	0.02
194	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.08
195	0.09	0.10	0.11	0.11	0.12	0.13	0.14	0.16	0.18	0.20
196	0.22	0.24	0.28	0.31	0.34	0.37	0.40	0.43	0.47	0.51
197	0.57	0.62	0.70	0.76	0.83	0.90	0.96	1.03	1.12	1.22
198	1.30	1.39	1.47	1.56	1.64	1.72	1.81	1.89	1.99	2.10
199	2.22	2.34	2.47	2.60	2.74	2.93	3.14	3.44	3.84	4.21
200	4.71	5.27	5.95	6.68	7.55	8.38	9.23	10.09	11.04	12.06
201	13.30	14.53	15.80	17.12	18.57	20.20	22.30	25.01	28.22	31.05
202	33.67	36.21	38.68	41.18	43.72	46.33	49.22	52.00	54.82	57.68
203	60.48	63.60	66.75	69.84	72.94	76.04	79.24	82.54	86.42	90.49
204	94.26	97.99	101.76	105.76	109.96	114.31	118.61	122.86	127.08	131.27
205	135.46	139.89	144.42	149.15	154.64	160.54	166.54	172.53	178.53	184.44
206	190.52	196.84	203.35	210.28	217.70	225.44	233.43	242.81	252.63	263.80
207	275.18	288.61	305.31	324.62	356.34	399.23	450.16	501.79	565.52	633.47
208	702.03	767.64	826.92	882.03	944.11	1,005.96	1,066.20	1,132.77	1,201.45	1,262.82
209	1,330.34	1,396.02	1,457.26	1,515.89	1,568.97	1,616.05	1,659.87	1,702.49	1,746.52	1,791.08
210	1,837.60	1,884.82	1,935.45	1,985.21	2,034.95	2,089.03	2,149.67	2,207.27	2,268.46	2,332.28
211	2,403.58	2,477.03	2,557.30	2,640.68	2,735.80	2,837.37	2,936.60	3,043.66	3,162.56	3,291.79
212	3,420.62	3,560.80	3,709.99	3,866.44	4,023.43	4,173.75	4,332.59	4,477.25	4,606.39	4,728.22
213	4,842.59	4,948.68	5,061.25	5,173.09	5,291.69	5,418.14	5,543.90	5,674.92	5,809.27	5,950.19
214	6,108.31	6,266.42	6,415.01	6,566.67	6,742.32	6,912.93	7,072.75	7,209.80	7,333.55	7,459.31
215	7,593.10	7,730.93	7,879.43	8,029.32	8,187.71	8,363.93	8,547.33	8,751.75	8,952.71	9,141.78
216	9,308.21	9,471.83	9,636.09	9,791.78	9,947.37	10,108.71	10,270.98	10,436.78	10,620.76	10,825.00
217	11,011.63	11,201.80	11,381.98	11,558.43	11,761.03	11,945.03	12,135.69	12,350.72	12,573.53	12,805.34
218	13,034.21	13,253.60	13,491.03	13,735.96	13,985.68	14,197.17	14,401.63	14,600.85	14,834.69	15,028.32
219	15,223.59	15,416.12	15,618.87	15,834.59	16,025.27	16,195.43	16,350.50	16,511.28	16,675.20	16,829.77
220	16,973.58	17,116.03	17,268.02	17,424.37	17,583.09	17,745.29	17,907.32	18,073.37	18,244.52	18,426.01
221	18,607.12	18,805.23	19,025.09	19,253.25	19,472.08	19,678.52	19,883.50	20,092.55	20,309.45	20,519.33
222	20,734.80	20,950.34	21,158.31	21,371.43	21,585.18	21,800.75	22,004.82	22,199.58	22,387.80	22,569.46
223	22,747.93	22,922.68	23,089.55	23,251.26	23,408.42	23,567.69	23,719.95	23,867.58	24,025.95	24,183.90
224	24,342.77	24,498.33	24,636.24	24,774.08	24,902.05	24,999.84	25,091.51	25,179.44	25,263.93	25,345.86
225	25,425.71	25,503.23	25,577.38	25,647.90	25,714.23	25,777.33	25,836.74	25,891.37	25,941.56	25,986.66
226	26,028.12	26,068.07	26,104.28							

TABLE 6. WRIGHT PATMAN LAKE ELEVATION-CAPACITY TABLE

WRIGHT PATMAN LAKE
RESERVOIR CAPACITY TABLE

July - August 2018
Volumetric & Sedimentation Survey
CAPACITY IN ACRE-FEET

Seasonal pool elevations:

November 1 - March 31	220.6 feet
April 1 - May 31	227.5 feet
June 1 - October 4	225.0 feet
October 5 - October 31	221.2 feet

Elevation in FEET	Elevation Increment is ONE TENTH FOOT									
	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
193							0.00	0.00	0.00	0.00
194	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05
195	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.16	0.18
196	0.20	0.22	0.25	0.28	0.31	0.35	0.38	0.43	0.47	0.52
197	0.57	0.63	0.70	0.77	0.85	0.94	1.03	1.13	1.24	1.36
198	1.48	1.62	1.76	1.91	2.07	2.24	2.42	2.60	2.79	3.00
199	3.21	3.44	3.68	3.94	4.20	4.49	4.79	5.12	5.48	5.88
200	6.33	6.83	7.38	8.01	8.72	9.52	10.40	11.37	12.42	13.58
201	14.84	16.23	17.75	19.39	21.18	23.11	25.24	27.60	30.26	33.22
202	36.46	39.95	43.70	47.69	51.94	56.44	61.21	66.27	71.62	77.24
203	83.15	89.35	95.87	102.70	109.83	117.28	125.05	133.13	141.58	150.42
204	159.66	169.28	179.26	189.64	200.42	211.64	223.29	235.36	247.86	260.77
205	274.11	287.87	302.09	316.76	331.94	347.70	364.06	381.01	398.56	416.71
206	435.46	454.82	474.84	495.51	516.90	539.06	562.00	585.79	610.56	636.39
207	663.33	691.48	721.17	752.63	786.54	824.22	866.68	914.20	967.64	1,027.50
208	1,094.33	1,167.84	1,247.68	1,333.10	1,424.37	1,521.87	1,625.48	1,735.39	1,852.24	1,975.45
209	2,105.12	2,241.48	2,384.16	2,532.87	2,687.16	2,846.46	3,010.28	3,178.39	3,350.82	3,527.68
210	3,709.11	3,895.22	4,086.18	4,282.25	4,483.23	4,689.38	4,901.32	5,119.14	5,342.90	5,572.88
211	5,809.60	6,053.59	6,305.31	6,565.14	6,833.81	7,112.51	7,401.18	7,700.09	8,010.27	8,332.95
212	8,668.59	9,017.50	9,381.01	9,759.77	10,154.26	10,564.14	10,989.35	11,429.99	11,884.30	12,350.90
213	12,829.66	13,319.23	13,819.61	14,331.36	14,854.55	15,390.00	15,938.09	16,499.07	17,073.29	17,661.25
214	18,264.08	18,882.89	19,516.91	20,165.98	20,831.30	21,514.21	22,213.69	22,928.06	23,655.15	24,394.74
215	25,147.17	25,913.42	26,693.85	27,489.30	28,300.00	29,127.48	29,973.01	30,837.51	31,722.77	32,627.62
216	33,550.38	34,489.38	35,444.65	36,416.22	37,403.11	38,405.87	39,424.80	40,460.06	41,512.81	42,585.40
217	43,676.95	44,787.98	45,917.08	47,064.52	48,229.46	49,415.47	50,619.36	51,843.40	53,089.43	54,358.22
218	55,650.22	56,964.76	58,301.40	59,662.87	61,048.87	62,458.39	63,888.83	65,338.01	66,810.31	68,303.41
219	69,816.28	71,348.70	72,900.19	74,472.97	76,065.81	77,677.22	79,305.19	80,947.12	82,606.70	84,282.12
220	85,971.80	87,676.86	89,396.10	91,130.20	92,880.50	94,646.91	96,430.13	98,228.60	100,044.90	101,877.90
221	103,729.76	105,599.32	107,491.27	109,405.31	111,342.35	113,299.45	115,277.64	117,276.43	119,296.99	121,337.53
222	123,400.85	125,484.77	127,589.75	129,716.18	131,864.23	134,033.74	136,224.33	138,433.86	140,664.02	142,912.03
223	145,177.78	147,461.80	149,761.64	152,079.57	154,411.67	156,760.87	159,125.13	161,504.84	163,900.66	166,310.26
224	168,736.27	171,178.04	173,634.06	176,106.22	178,589.26	181,084.82	183,590.17	186,103.53	188,624.86	191,155.61
225	193,694.86	196,241.67	198,793.78	201,356.59	203,924.88	206,498.98	209,079.72	211,667.17	214,257.65	216,853.47
226	219,455.57	222,059.51	224,668.34							

APPENDIX B – QA/QC FIGURES

FIGURE 1. COMPARISON OF 2018 AND 2010 CURRENT SURFACE CROSS SECTION

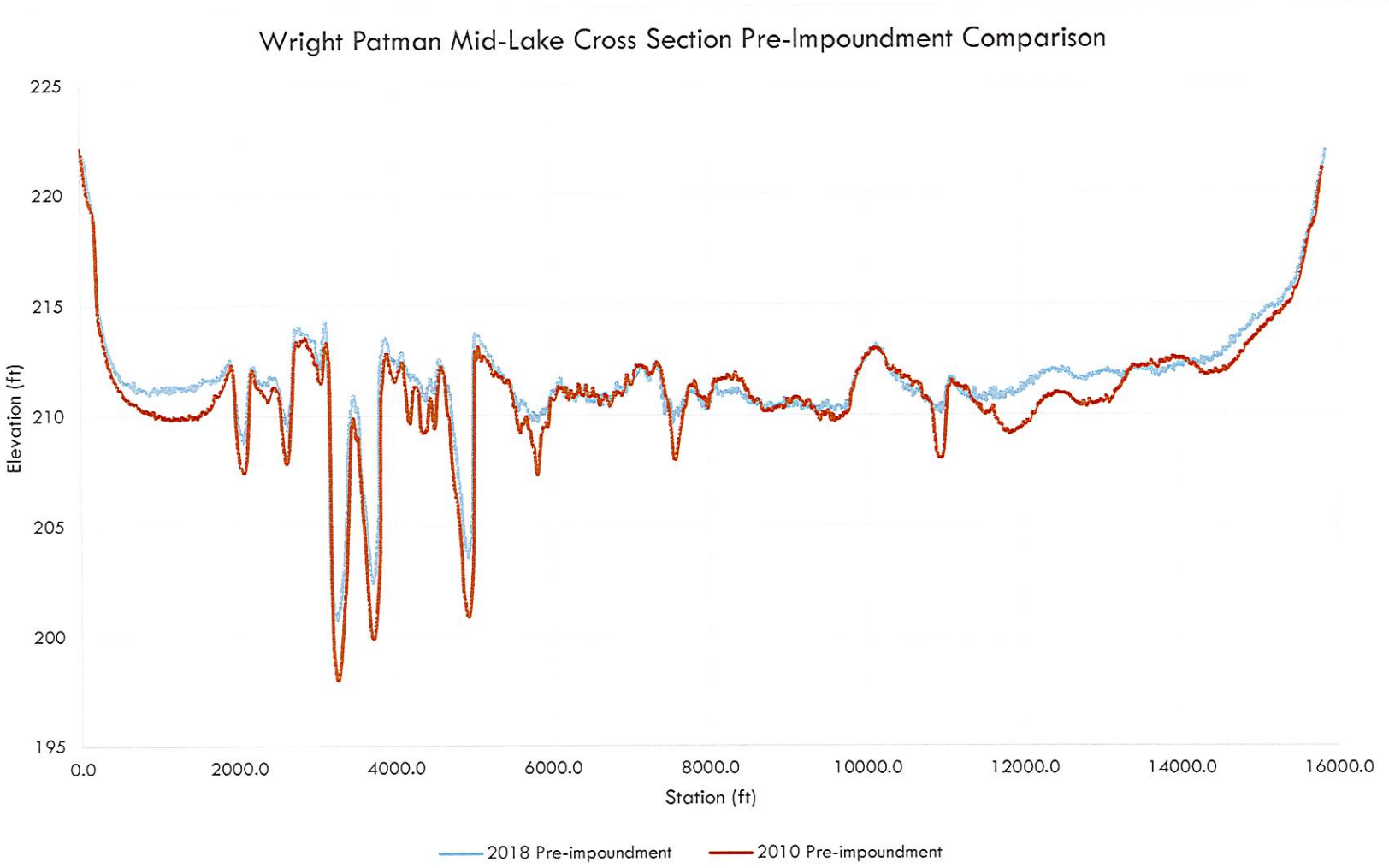

FIGURE 2. COMPARISON OF 2018 AND 2010 PRE-IMPOUNDMENT SURFACE CROSS SECTION

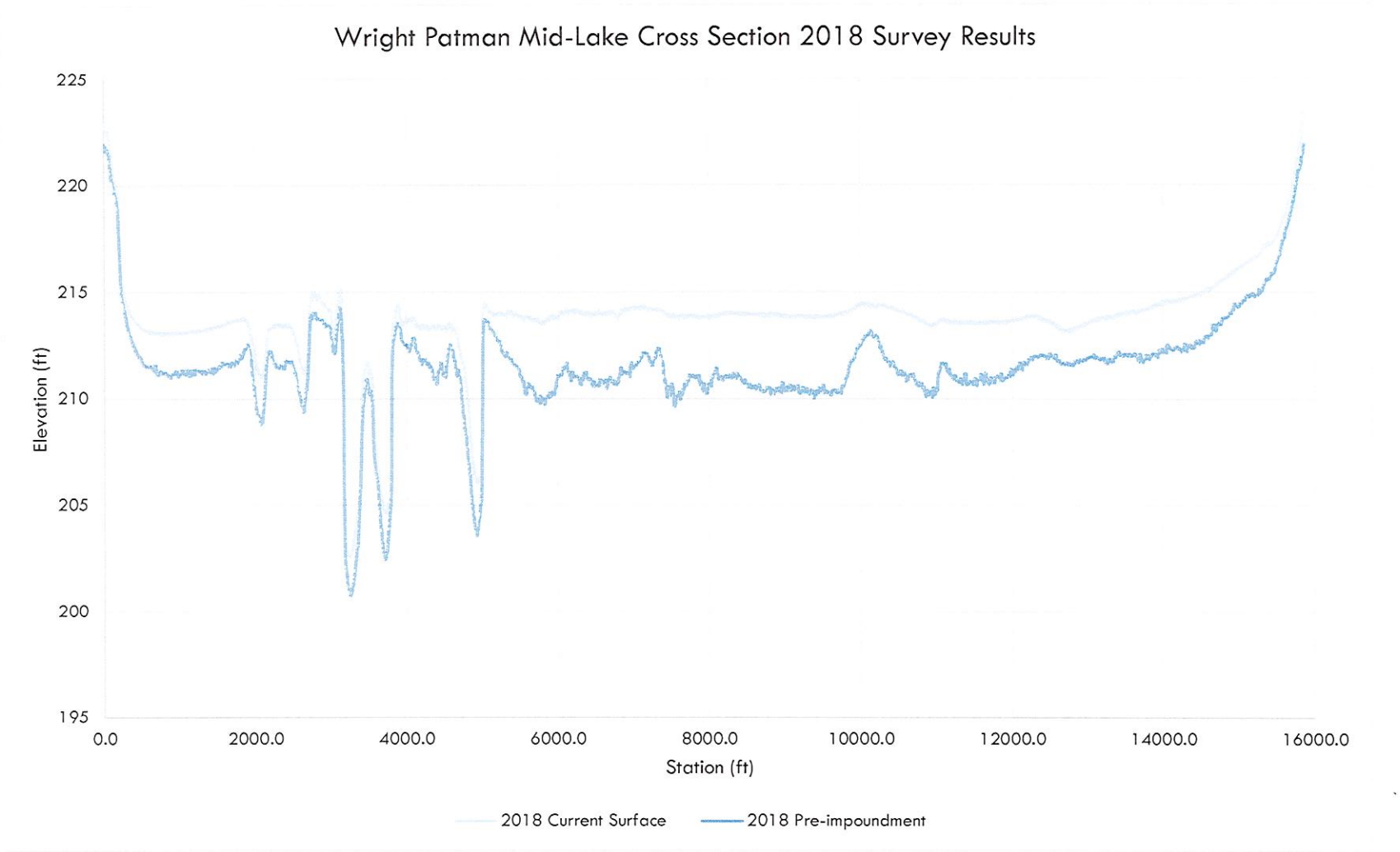

FIGURE 3. CROSS SECTION VIEW OF 2018 CURRENT AND PRE-IMPOUNDMENT SURFACES

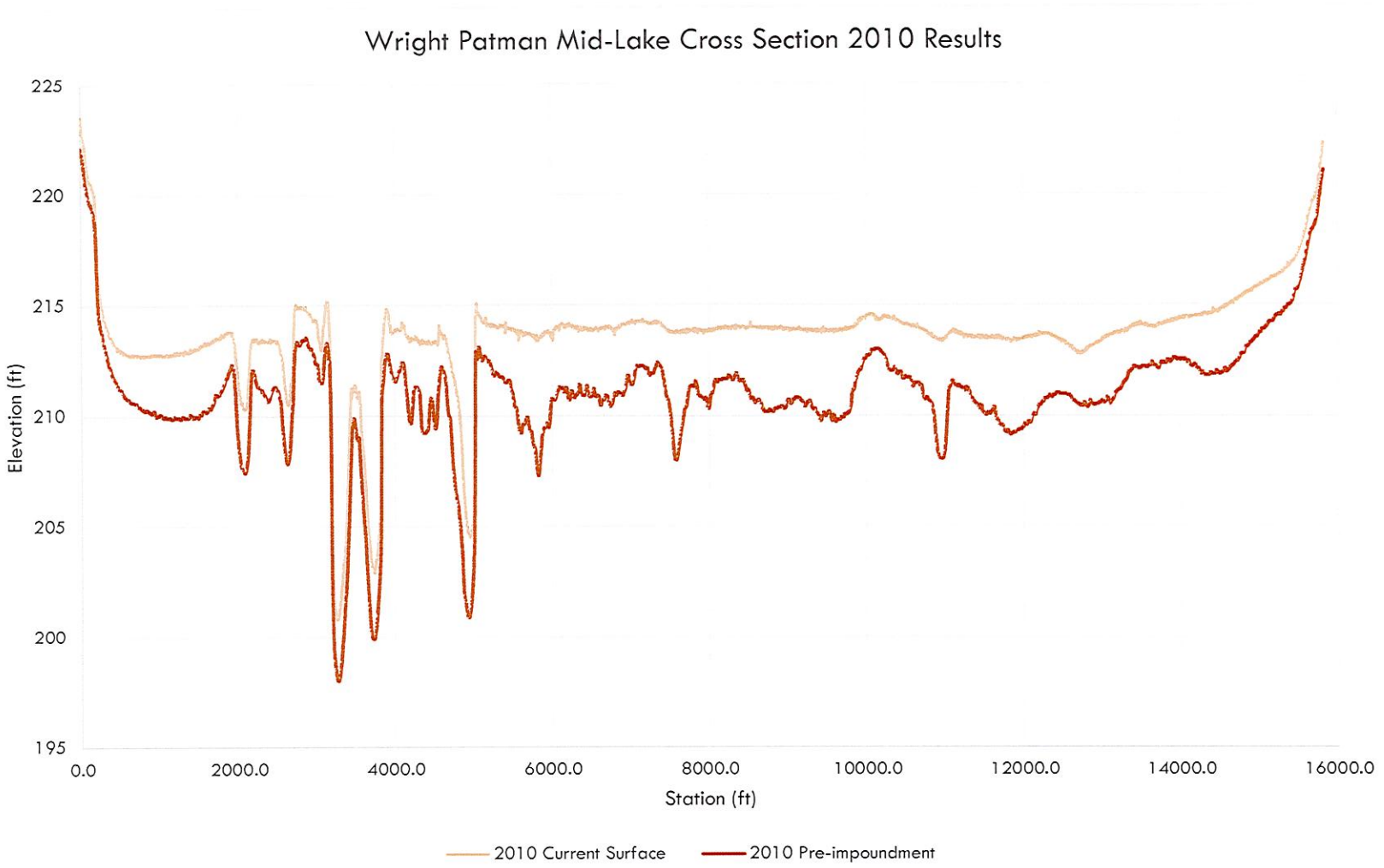

FIGURE 4. CROSS SECTION VIEW OF 2010 CURRENT AND PRE-IMPOUNDMENT SURFACES

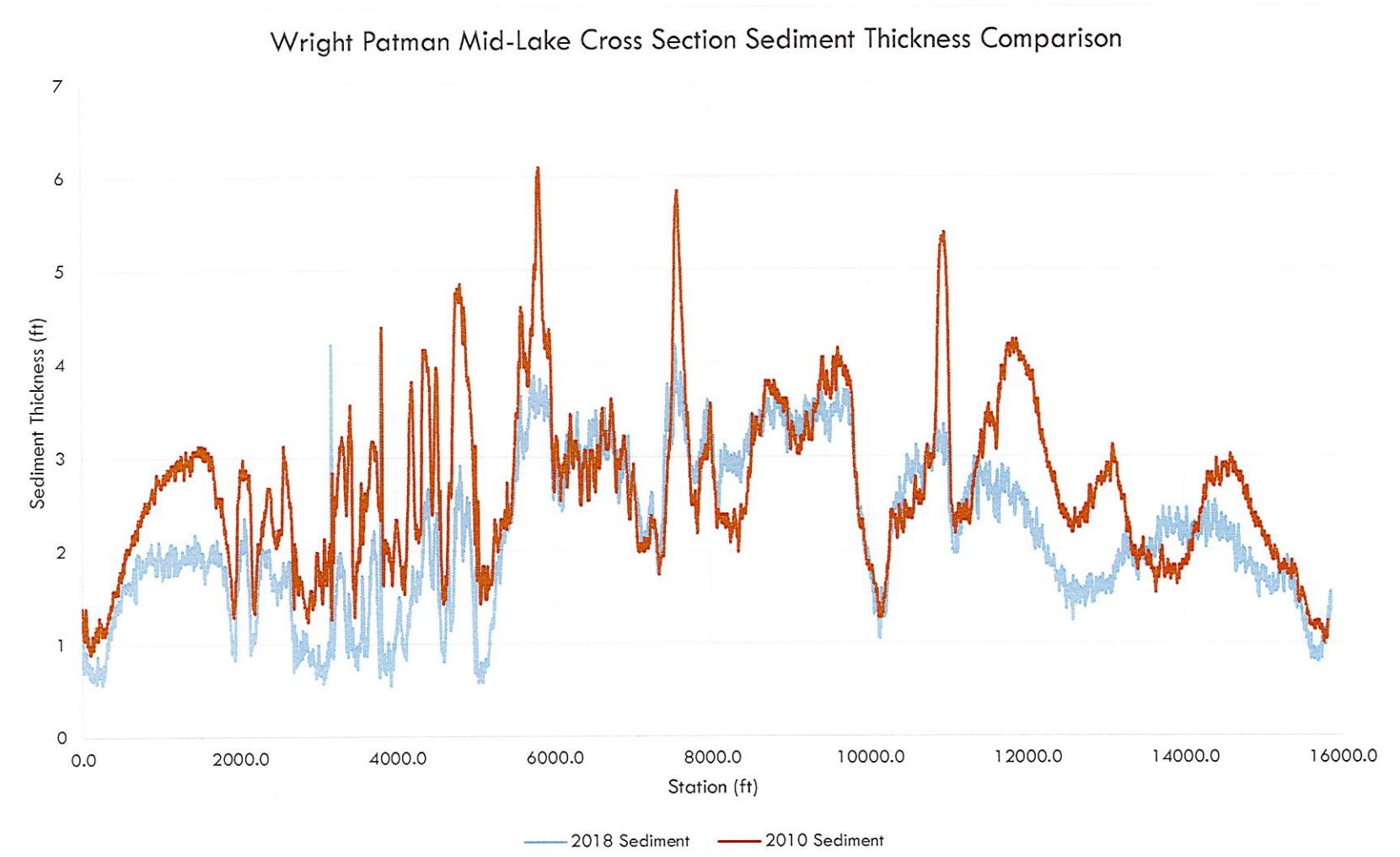

FIGURE 5. COMPARISON OF 2018 AND 2010 CALCULATED SEDIMENT THICKNESS ALONG CROSS SECTION