Lake Lucile Sediment Quality Sampling:

Spatial Extent of Impaired Sediment due to Outfall Stormwater Inputs

Prepared for: Alaska Department of Environmental Conservation

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Cover Photograph. Lake Lucile from the east outfall.

Acknowledgments: This project was conducted with support and assistance from Laura Eldred, DEC Project Manager, Jennifer Pennington, DEC Contract Manager and DEC funding through Contract No. 18-6002-12.

Table of Contents

Tables

Figures

1.0 Summary

Lake Lucile (also spelled Lucille) bed sediments were sampled to determine if select metal or hydrocarbon concentrations exceeded the biological screening criteria developed by the National Oceanic and Atmospheric Association (NOAA). The state of Alaska has not adopted freshwater sediment criteria in the state water quality standards at 18 AAC 70. The current recommendation from the Alaska Department of Environmental Conservation (ADEC) is to use the NOAA recommended biological criteria in the Screening Quick Reference Tables (SQuiRT). Results were evaluated relative to biological threshold effect levels (TEL) and biological probable effect levels (PEL) established in the NOAA SQuiRT.

Sampling sites were distributed around two stormwater outfalls, one located on the east basin and one in the west. Both outfalls discharge stormwater runoff from residential and commercial areas of Wasilla. Sediment samples were collected with a Ponar dredge and analyzed for concentrations of copper, lead, zinc, and polycyclic aromatic hydrocarbons (PAH). A total of 44 samples were collected; 28 samples were collected around the east outfall extending 502 m from the outfall, and 15 samples were collected around the west outfall extending out 172 m. One sample was collected from a reference site, located near the south shore away from both outfalls, in order to establish baseline concentration values.

Concentrations of all parameters were highest in samples collected closest to outfall discharge points. Adjacent to both the east and the west outfalls, concentrations of copper, zinc, and PAHs exceeded TEL values and concentrations of zinc also exceeded PEL values. Concentrations of lead approached, but were less than, the TEL and PEL values in all samples. Copper concentrations above detection limits showed the furthest spatial distribution of all pollutants analyzed. The estimated area of bed sediments with concentrations of at least one of the metal concentrations above TEL values was 4.4 acres around the east outfall and 1.1 acres around the west outfall.

2.0 Introduction

2.1. Background

The Matanuska-Susitna Borough and core areas of Wasilla have been the fastest growing regions in Alaska and among the fastest in the nation. As development increases, the concern for stormwater runoff pollution increases. Lake Lucile is located within the urban center of Wasilla and is adjacent to the George Parks Highway. Stormwater runoff from the commercial district of Wasilla discharges to Lake Lucile by means of two outfalls, which drain into the east and west sections of the lake (Figure 1). While stormwater transported by the east outfall is treated by infiltration until capacity is met, stormwater transported by the west outfall is directly discharged into the lake without treatment. Dissolved metals and PAHs (products of fuel combustion, motorized vehicle fluids, brakes and tires) adsorbed to sediment particles can be transported to Lake Lucile in stormwater runoff. Sediment delivery can increase when the capacity of physical treatment systems (sedimentation ponds and vegetated road swales) are exceeded. Concentrations of metals can increase in bed sediments exceeding thresholds for biological effects resulting in the impairment to designated uses. Contaminated stormwater is responsible for approximately one third of the impaired listings of assessed waters throughout the United States (USEPA 1991).

The National Oceanic and Atmospheric Administration (NOAA) delineates water quality criteria for heavy metal and total PAH concentrations in accordance with Screening Quick Reference Tables (SQuiRTs) (Buchman 2008, Table 1). SQuiRT critical levels are determined by evaluating biological effects, where concentrations causing a biological response are categorized as threshold effects levels (TEL) and probable effects levels (PEL). TELs are the concentration below which biological effects rarely occur, and PELs are the concentration above which biological effects are likely to occur.

Previous sampling conducted by the Alaska Department of Environmental Conservation (ADEC) in 1989 documented sediment concentrations of lead from 23,000 to 40,000 µg/kg near Lake Lucile's west outfall, and from 31,000 to 32,000 µg/kg near the east outfall (ADEC 1990). These concentrations were 3 or 4 times greater than those measured to obtain background concentrations near the lake outlet and near or above the TEL of 35,000 µg/kg (ADEC 1990). In 2011 and 2012, sediment lead concentrations ranged from 51,600 to 119,000 µg/kg near the east outfall; a substantial increase since 1989 and above PELs. Recent sampling in the Lake Lucile adjacent to the east outfall has also documented concentrations of zinc well above PELs, and copper and PAHs above TELs (Davis and Davis 2012; Davis et al. 2013 unpublished).

The most recent sampling efforts in 2011 and 2012 were limited in scope and not conducted at the west outfall, compared to a reference location, or evaluated for the spatial distribution of concentrations. If sediment bound metals are transported to the lake through these two outfalls, concentrations may decease proportionally with increasing distances from these sources. The spatial area of the lake sediments affected by high metal or hydrocarbon concentrations would be an indication of the extent of the problem and the likelihood of biological effects, and would inform management options.

Table 1. Sediment Threshold Effects Levels (TEL) and Probable Effect Levels (PEL) for select metals and PAH.

Parameter	TEL (µg/kg)	PEL (µg/kg)
Copper	35,700	197,000
Cadmium	37,300	90,000
Lead	35,000	91,300
Zinc	123,000	315,000
Total PAH	264.1	NA

2.2. Project Objectives

The project objective was to determine the spatial extent of metal and PAH concentrations in bed sediments proximal to the east and west outfalls, that exceed TEL and PEL.

3.0 METHODS

Sample collection, handling, preservation, and analyses followed a DEC approved Quality Assurance Project Plan.

3.1. Sampling dates

Initial sediment sampling was conducted on June 4, 2013. 27 samples were collected during the first sampling event. Results from this sampling were used to determine sampling locations for the second sampling event which occurred on June 20 and 21, 2013. 17 samples were collected during the second sampling event (Figure 2).

Initial sampling locations were distributed on a 100 m interval grid from the east outfall in order to determine the extent of contaminated sediments. Sampling locations were mapped in ArcGIS and were accessed by boat. Exact sampling locations were recorded with a handheld GPS receiver and triangulated to two points on the shore.

3.2. Sample collection

3.2.1. Water physical and chemical characteristics

Specific conductivity, pH, dissolved oxygen, and temperature were measured at each sampling location and on each sampling date. These parameters were measured to determine if there were locations of distinct differences in water chemistry that could indicate areas of groundwater discharge. Specific conductivity and pH were measured using a YSI 63 meter and probe. Dissolved oxygen concentration and percent saturation were measured using a YSI 550 meter and probe. Water temperature was measured using the YSI specific conductivity and dissolved oxygen meters at a depth of 0.5 meters.

Water depth was measured using a weighted, marked line deployed from the boat and measured at water surface.

3.2.2. Sediment samples

Sediment samples were collected using a Ponar dredge sampler. The sampler was rinsed in the lake three times at each sampling location prior to deployment. The sampler was released into the water column to submerge 15 cm into bottom sediments under the force of gravity. Once the sampler had settled into the bottom sediments, the messenger was released to trip the spring mechanism and close the dredge. The sampler was retrieved and the top opened to allow access to the sampler contents, which were observed for hydrocarbon sheen or odor. Clean, gloved hands collected sediment from the top 10 cm of the sample in a 250 ml glass bottle for metal and PAH analyses.

Samples were labeled by date, site name, analyses, and preservation. Samples were placed in a cooler with frozen gel-paks and were returned to the ARRI laboratory and refrigerated to maintain sample temperature at or below 4°C, before being shipped by FedEx to AM Test Incorporated in Kirkland, Washington for chemical analyses. Cooler temperature was kept at or below 4°C during shipment. All sediment samples were analyzed for concentrations of copper (Cu), lead (Pb) (SW-846 6010B) and Zinc (Zn) (SW-846 6020A). All samples on the initial sampling date and a subsample of those collected on the second sampling event were analyzed for PAH concentrations (EPA 8270).

3.3. Data analysis

Metal and total PAH sediment concentrations were compared with National Oceanic and Atmospheric Administration reference Screening Quick Reference Tables (SQuiRTs). Concentrations were also compared with 1989 DEC sampling results.

Project results were mapped in ArcMap to display the spatial distribution of metal concentrations and of total PAH concentrations. Total area exceeding the TEL values was estimated from the 2013 sampling results and plotted in ArcMap.

4.0 RESULTS AND DISCUSSION

All sampling was conducted following the procedures outlined in the QAPP. All sediment samples were stored, preserved, handled, and analyzed using approved methods and within the maximum allowable holding times. All laboratory precision measures from duplicates were less than 3%, well within the accuracy range of 20% established in the QAPP. All laboratory accuracy measures of known standards for metals were less the established range of 85 to 115%. Some of the individual accuracy of hydrocarbons exceeded this range with a maximum value of 120%. However, differences within this range would not result in a different interpretation of results.

Field replicates were obtained from two samples collected at the same location rather than a subdivision of a single sample. Therefore, field measures of precision represent the spatial variability in concentrations and the variability within a sample. Precision for individual samples and average precision is shown in Table 2. The differences between replicate samples collected reflect a combination of differences in metal concentrations in sediments separated either laterally or vertically. It is likely that concentrations of metals on bed sediments are not distributed evenly. Variability in the deposition of sediments could be due to differences in lake contours, macrophyte beds, and particle size. It is not uncommon for sediment metal concentrations to vary with depth. The Ponar sampler collected the top 15 cm of sediment and sample collection was from the top 10 cm of the Ponar sample. Therefore, if concentrations varied within the top 10 cm, these differences would be reflected in sample results.

Table 2. Precision of field replicates, expressed in terms of relative percent difference between replicate samples.

Site	Copper	Zinc	Lead	PAH
37 W	6 %	82 %	36 %	0 %
39 W	44 %	41 %	47 %	0 %
24 E	76 %	98 %	55 %	0 %
13 E	35 %	42 %	26 %	13 %
Average	40 %	66 %	41 %	3 %

4.1. Water physical and chemical characteristics

Water physical and chemical characteristics are reported in Table 3. Water depth at sampling locations ranged from 0.6 to approximately 5 m (Figure 3). Water temperatures were warm, ranging from 16 to 22°C. Measured pH values were also generally high, averaging 8.85 among all sample locations. These values, however, are similar to historic measures and likely related to a limestone substrate in portions of the lake (ADEC 1990).Dissolved oxygen was above saturation at all sampling sites, with a peak measurement of 153.3%. High saturation values can be attributed to photosynthesis within the lake, with samples collected around mid-day with clear to mostly overcast weather conditions. This may be related to outfall discharge through lake eutrophication, as believed to be true in previous studies (ADEC 1990). Weather prior to sampling dates were abnormally warm, with little to no rainfall before the time of sampling. The first sampling event had 6.1 mm of rainfall two days before the sampling event, preceded by 15 days of negligible rainfall (<1mm), as measured at the Palmer Municipal Airport. No measurable precipitation was recorded between sampling events. Dry conditions may have resulted in lower trace metals and PAH concentrations than if sampled after storm events.

Table 3. Lake Lucile physical and chemical characteristics measured during sediment sampling. In site name, “X” indicates replicate measures, and at site 13, initial sampling occurred on June 4, 2013 and the same location was resampled (13 b) on June 21, 2013.

Site	Location	Depth (m)	Temp (°C)	pH	Sp. Cond. (µS/cm)	D.O. (% Sat)	D.O. (mg/L)
1	Reference	1.45	16.5	9.50	312.1	112.2	10.77
3	West	0.92	16.9	8.92	300.7	124.5	11.93
4	West	1.20	17.0	8.89	298.4	124.6	11.72
5	West		17.0	8.87	299.0	123.8	11.86
6	West Outfall	0.74	16.9	9.11	302.9	116.5	10.86
7	East	3.68	16.4	8.96	316.7	116.3	10.90
8	East	4.23	16.2	9.02	317.6	116.4	11.21
9	East	3.40	16.9	9.87	318.8	119.4	11.28
10	East	4.88	16.5	9.01	317.5	117.0	11.31
11	East	4.42	16.2	9.09	320.2	118.0	11.36
12	East	3.40	15.8	8.82	320.6	116.0	11.23
13	East	3.22	16.9	9.74	319.1	116.1	11.10
13 X	East	3.50	16.9	9.74	319.1	116.1	11.10
13 b	East	3.00	21.8	8.55	266.7	147.0	12.85
14	East	2.94	16.5	9.20	316.4	118.1	11.15
15	East	4.55	16.2	9.21	321.3	121.2	11.62
16	East	2.85	15.7	8.88	329.0	113.1	10.93
17	East	1.84	15.8	8.82	321.9	115.5	11.18
18	East	2.35	16.8	9.49	315.0	116.9	11.10
19	East	2.39	16.6	9.29	324.2	121.2	11.55
20	East	3.50	15.9	8.90	336.2	113.9	11.05
21	East	1.25	22.5	8.12	272.9	135.7	11.72
22	East	1.15	15.6	8.68	326.4	115.1	11.39
23	East	1.01	16.4	9.11	337.7	126.8	12.15

Site	Location	Depth (m)	Temp (°C)	pH	Sp. Cond. (µS/cm)	D.O. (% Sat)	D.O. (mg/L)
24	East	1.38	15.8	8.71	340.4	120.5	11.94
24 X	East	1.38	15.8	8.71	340.4	120.5	11.94
25	East	0.97	15.6	8.61	345.1	116.8	11.31
26	East	0.64	15.4	8.58	327.3	113.3	11.12
27	East Outfall	0.83	15.0	7.78	341.3	104.4	10.32
32	East	0.95	22.0	8.15	280.1	138.0	11.89
33	East	1.00	21.8	8.05	289.5	126.4	11.01
34	East	0.75	22.1	7.86	291.1	120.2	10.56
35	East	1.25	22.7	7.94	278.0	135.7	11.78
36	West	1.15	20.9	8.82	260.9	152.9	13.52
37	West	0.75	21.1	8.90	257.2	149.6	13.79
37 X	West	0.75	21.1	8.90	257.2	149.6	13.79
38	West	0.90	21.1	8.74	260.4	151.8	13.49
39	West	0.75	21.0	8.98	252.4	151.7	13.49
39 X	West	0.75	21.0	8.98	252.4	151.7	13.49
40	West	2.05	21.4	8.94	251.7	149.0	13.25
41	West	1.35	21.1	8.85	260.6	151.0	13.38
42	West	2.30	21.5	8.88	251.9	147.1	13.03
43	West	1.50	21.4	8.96	251.8	151.8	13.42
44	West	2.45	21.5	8.97	249.6	153.3	13.50
Max.		4.88	22.7	9.87	345.1	153.3	13.79
Min.		0.64	15.0	7.78	249.6	104.4	10.32

4.2. Sediment Metals and PAH

The results of heavy metal and total PAH analysis are shown in Table 4 and Figures 4 through 11. TEL values were exceeded for at least 1 parameter at 10 sampling locations surrounding the outfalls. (Table 4). Site 13, however, showed anomalous high PAH values, inconsistent with nearby samples. The site was resampled during the second sampling event, with PAH values below detection limits, so was not included in subsequent area calculations of elevated PAH concentrations. Estimated areas with parameter concentrations above TEL values are reported in Table 5.

Copper analysis revealed five sites with concentrations above TEL values, although no site concentrations exceeded PEL values (Figures 4 and 5). The area with sediment copper concentrations above TEL values was estimated to be 16,597 m^2 (4.1 acres) near the east outfall and 4,590 m^2 (1.1 acres) near the west outfall. This was the largest estimated area around the west outfall of TEL value exceedances for all parameters analyzed. Sediment copper concentrations above detection limits also showed the broadest distribution of all analyzed parameters within Lake Lucile.

Zinc analysis revealed three sites with concentrations above TEL values and six sites with concentrations above PEL values (Figures 6 and 7). The largest area of estimated TEL value exceedances around the east outfall was due to concentrations of zinc at 18,033 m^2 (4.4 acres). The area of zinc TEL exceedances in the west basin was 1,340 m^2 (0.33 acres).

No sites were in exceedance of lead TEL or PEL values. The highest lead sample concentration, site 37, reported a value of 33,020 µg/kg, near the TEL value of 35,000 µg/kg. (Figures 8 and 9). Previous sampling conducted by ADEC in 1989 revealed lead concentrations between 23,000 and 40,000 µg/kg at the east outfall, which was greater than our results of 5,800 to 22,000 µg/kg near the east outfall. However, samples collected during storm events at the east outfall in August of 2011 were 119,000 µg/kg, which was above the PEL value, and 51,600 µg/kg on August 2, 2012 and 73,400 µg/kg on August 23, 2012, both of which were above the TEL value. ADEC 1989 results revealed lead concentrations between 31,000 and 33,000 µg/kg at the west outfall, whereas our result gave a range between 13,000 and 33,000 µg/kg near the west outfall.

Total PAH analysis revealed four sites above TEL values (Figures 10 and 11). Estimated area with sediment PAH concentrations above TEL values was 6,598 m^2 (1.6 acres) near the east outfall and 444 m^2 (0.11 acres) near the west outfall.

The reference site, (1), had low recorded values for all parameters. Site 37 and site 6, the nearest sites to the west outfall, recorded among the highest sediment concentrations for all tested parameters. The sites nearest the east outfall (site 25, site 27, and site 32) also had high recorded concentrations, some exceeding TEL and PEL values. In general, as distance from the outfall increased, concentrations decreased for all parameters. This suggests that sediment bound metals are transported to the lake by stormwater runoff through the two outfalls.

Because metals and PAHs are likely delivered to the lake during storm events that exceed the stormwater treatment capacity and overflow to outfalls, management options need to consider expansion of treatment facilities in order to reduce metal and PAH concentrations to levels within acceptable water quality standards. The likelihood of biological effects is increased with the prevalence of metal and PAH concentrations above the TEL values and is an even greater possibility with the results of some samples above the PEL values.

Table 4. Results of sediment sample analyses for each site sorted by site name. DL is detection limit. Site 1 R is the reference location on the south shore. Results in exceedance of TEL values are bolded. Results in exceedance of PEL values are bolded and asterisked. In site name, "X" indicates replicate measures, and at site 13, initial sampling occurred on June 4, 2013 and was resampled (13 b) on June 21, 2013.

Site	Location	Copper (µg/kg)	Zinc (µg/kg)	Lead (µg/kg)	PAH (µg/kg)
1	Reference	8,240	21,000	4,705	< DL
3	West	31,100	47,400	12,350	< DL
4	West	16,400	42,200	10,450	< DL
5	West	27,300	112,000	19,220	< DL
6	West Outfall	**43,100**	**460,000***	22,980	**1125.5**
7	East	19,600	60,100	10,480	< DL

Site	Location	Copper (µg/kg)	Zinc (µg/kg)	Lead (µg/kg)	PAH (µg/kg)
8	East	9,230	20,400	5,566	< DL
9	East	11,000	39,600	6,392	< DL
10	East	18,800	50,500	10,500	< DL
11	East	7,690	32,400	5,116	< DL
12	East	2,910	20,300	2,215	< DL
13	East	11,300	44,300	4,368	< DL
13 X	East	7,950	29,000	3,371	**302**
13 b	East				< DL
14	East	7,390	42,800	3,551	< DL
15	East	24,800	42,800	19,690	< DL
16	East	17,600	25,500	19,780	< DL
17	East	12,000	21,900	3,848	< DL
18	East	15,400	21,800	3,294	< DL
19	East	12,700	56,800	5,116	< DL
20	East	13,000	25,300	16,540	< DL
21	East	11,600	70,500	11,850	< DL
22	East	5,980	43,200	4,175	< DL
23	East	23,800	47,400	7,086	< DL
24	East	17,800	28,200	4,226	< DL
24 X	East	**39,400**	82,100	7,459	< DL
25	East	14,500	**159,000**	5,865	< DL
26	East	10,700	32,100	6,556	< DL
27	East Outfall	27,800	**428,000***	21,820	**1530**
32	East	33,100	**417,000***	21,220	< DL
33	East	**43,100**	**732,000***	27,680	**559.4**
34	East	30,900	**339,000***	20,340	< DL
35	East	26,800	**139,000**	18,450	< DL
36	West	29,200	103,000	22,650	< DL
37	West	**60,900**	**399,000***	33,020	< DL
37 X	West	**57,400**	**167,000**	22,830	< DL
38	West	32,900	89,500	13,420	< DL
39	West	9,800	23,100	4,824	< DL
39 X	West	15,400	34,900	7,771	< DL
40	West	21,200	46,800	11,900	< DL
41	West	28,500	55,200	13,400	< DL
42	West	17,100	35,400	9,211	
43	West	17,400	49,300	10,550	
44	West	15,900	33,000	4,884	

Table 5. Estimated area (m^2) in exceedance of TEL and PEL values for each parameter.

Parameter	Direction	TEL Exceedance Area (m^2)	PEL Exceedance Area (m^2)
Copper	West	4,590.0	0.0
Copper	East	16,597.4	0.0
Lead	West	0.0	0.0
Lead	East	0.0	0.0
PAH	West	443.5	N/A
PAH	East	6,597.6	N/A
Zinc	West	1,339.7	871.47
Zinc	East	18,033.4	8721.55

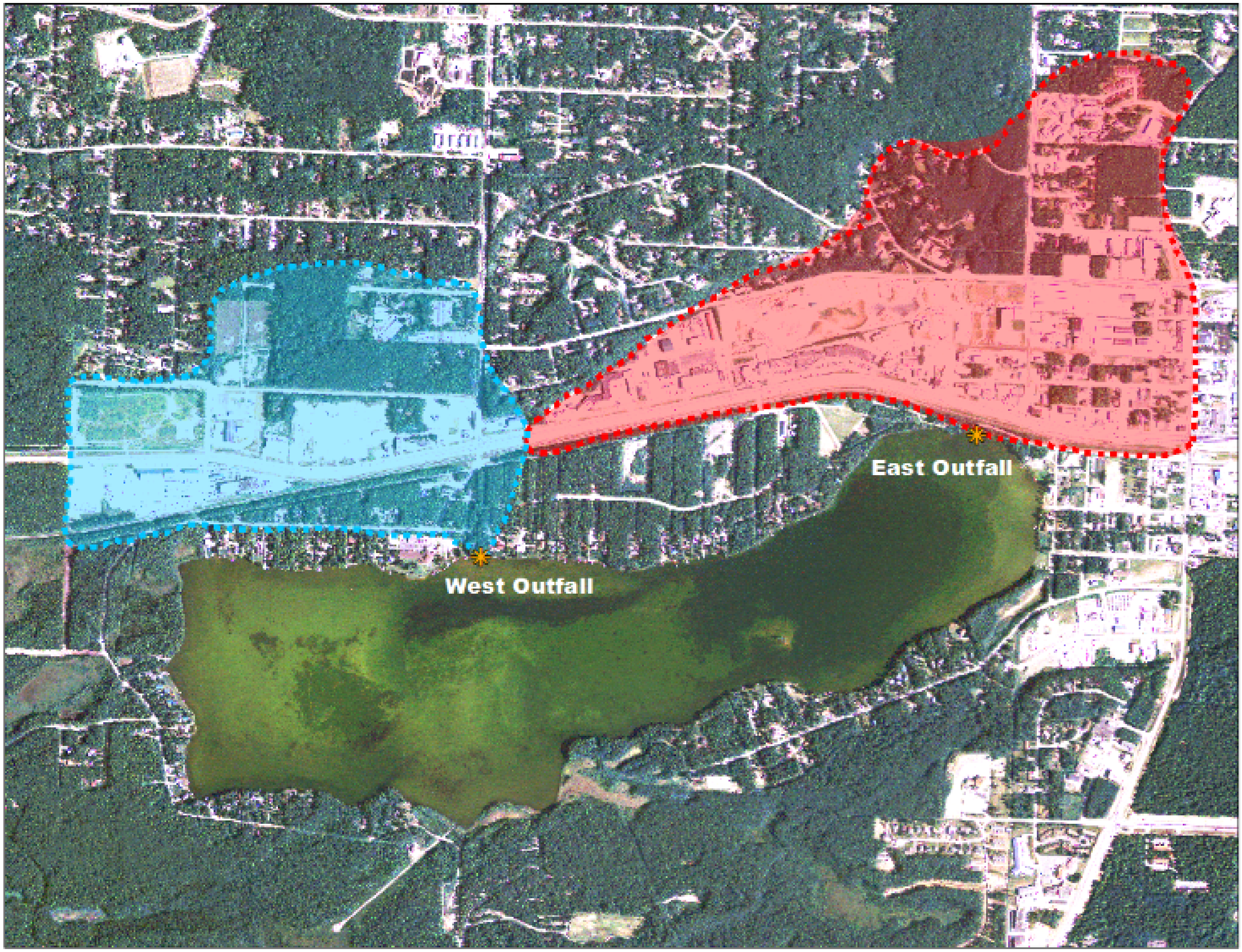

Figure 1. Aerial photograph of Lucile Lake and surrounding area showing estimated drainage area for east (309 acres) and west outfalls (212 acres).

Figure 2. Aerial photograph of Lucile Lake showing east and west outfall and grid sampling locations. Initial sampling points around the east outfall were on a 100 m grid. Samples around the west outfall were collected 25, 50, 100, and 150 m from the outfall.

Figure 3. Distribution of water depths at sampling locations.

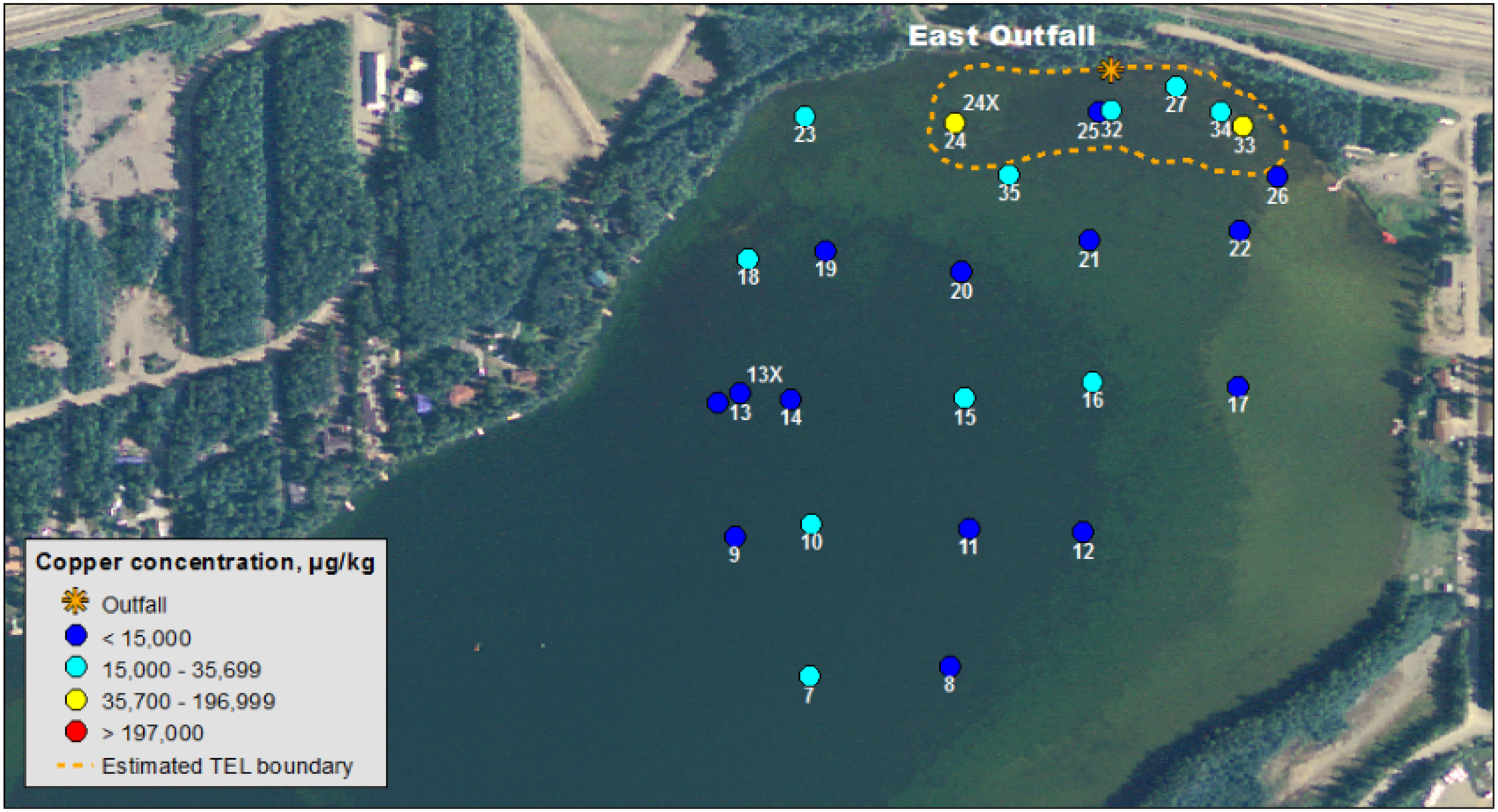

Figure 4. Distribution of bed sediment copper concentrations adjacent to the east outfall. Yellow markers indicate sites where concentrations exceed TEL values and red markers indicate sites that exceed PEL values. Dashed line is estimated area where copper concentrations are likely to exceed TEL values.

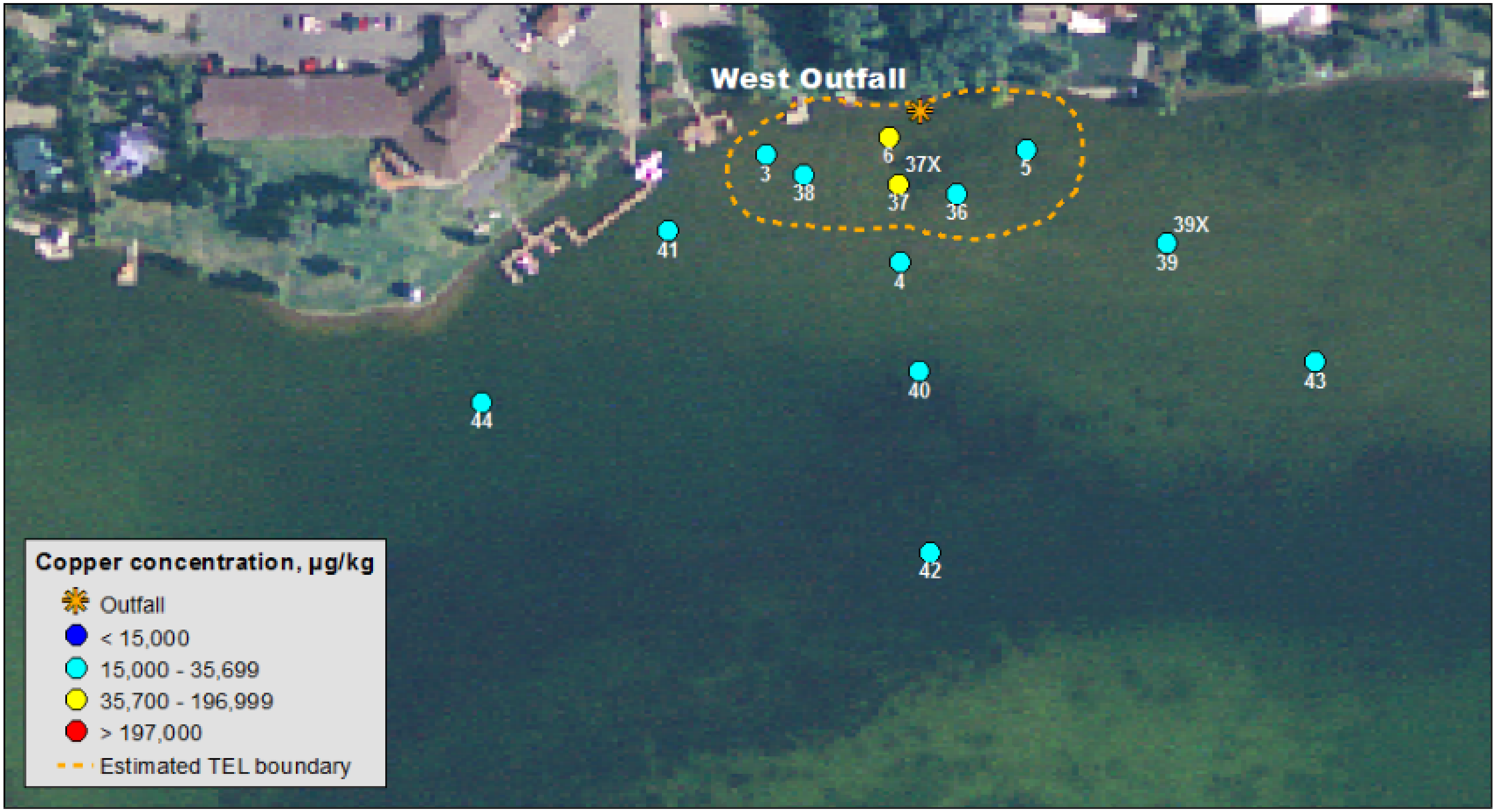

Figure 5. Distribution of bed sediment copper concentrations adjacent to the west outfall. Yellow markers indicate sites where concentrations exceed TEL values and red markers indicate sites that exceed PEL values. Dashed line is estimated area where copper concentrations are likely to exceed TEL values.

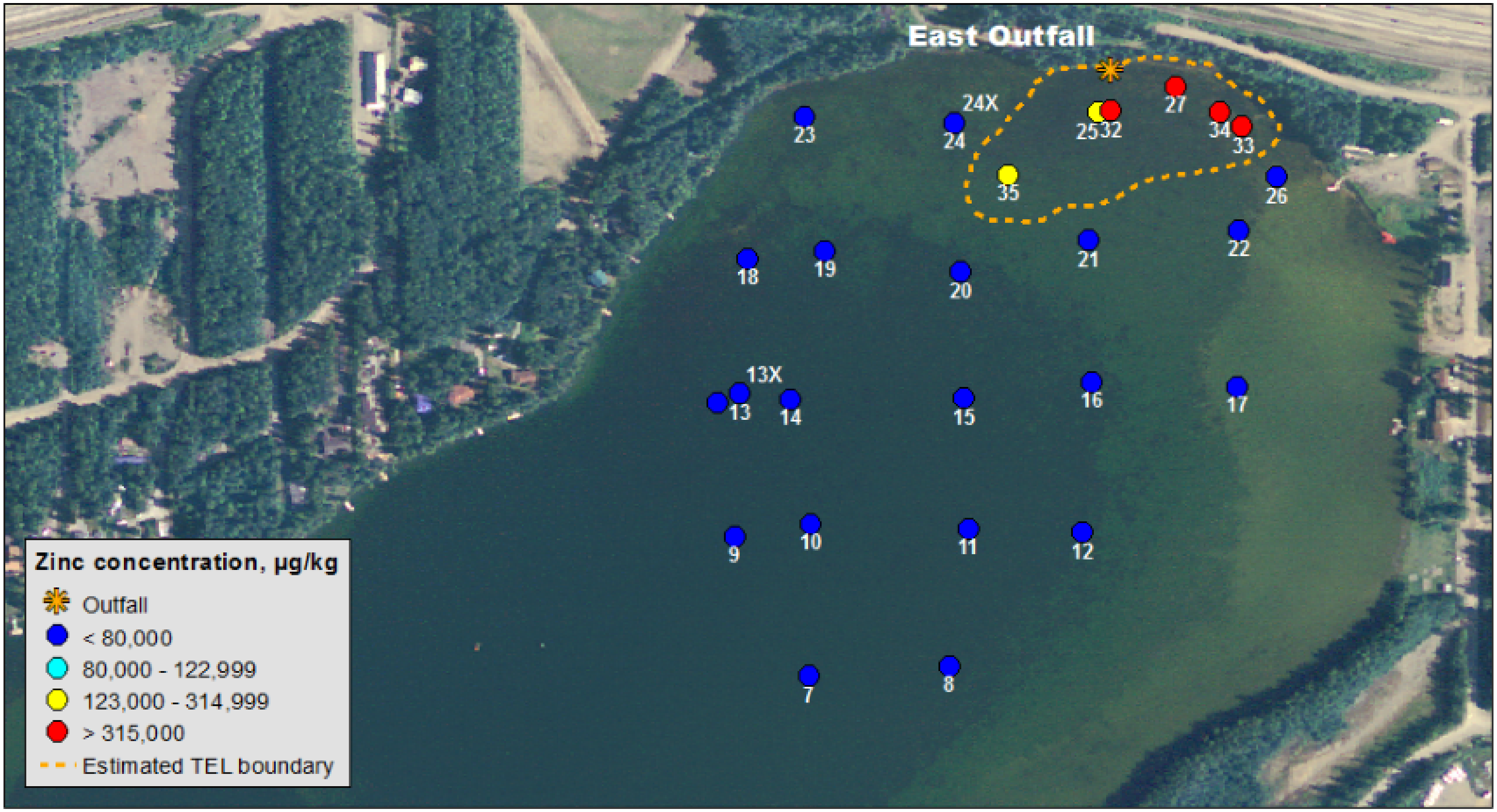

Figure 6. Distribution of bed sediment zinc concentrations adjacent to the east outfall. Yellow markers indicate sites where concentrations exceed TEL values and red markers indicate sites that exceed PEL values. Dashed line is estimated area where zinc concentrations are likely to exceed TEL values.

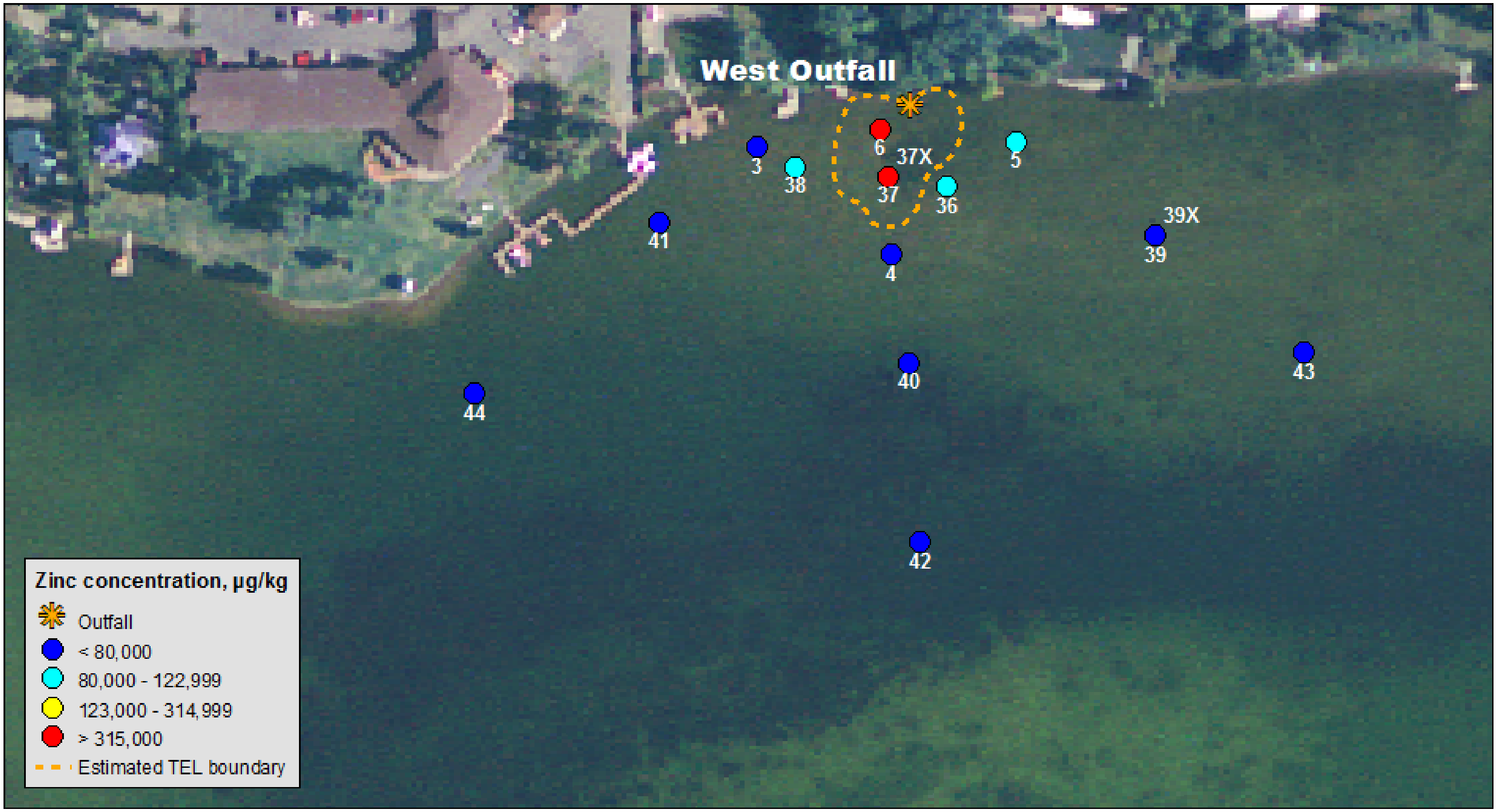

Figure 7. Distribution of bed sediment zinc concentrations adjacent to the west outfall. Yellow markers indicate sites where concentrations exceed TEL values and red markers indicate sites that exceed PEL values. Dashed line is estimated area where zinc concentrations are likely to exceed TEL values.

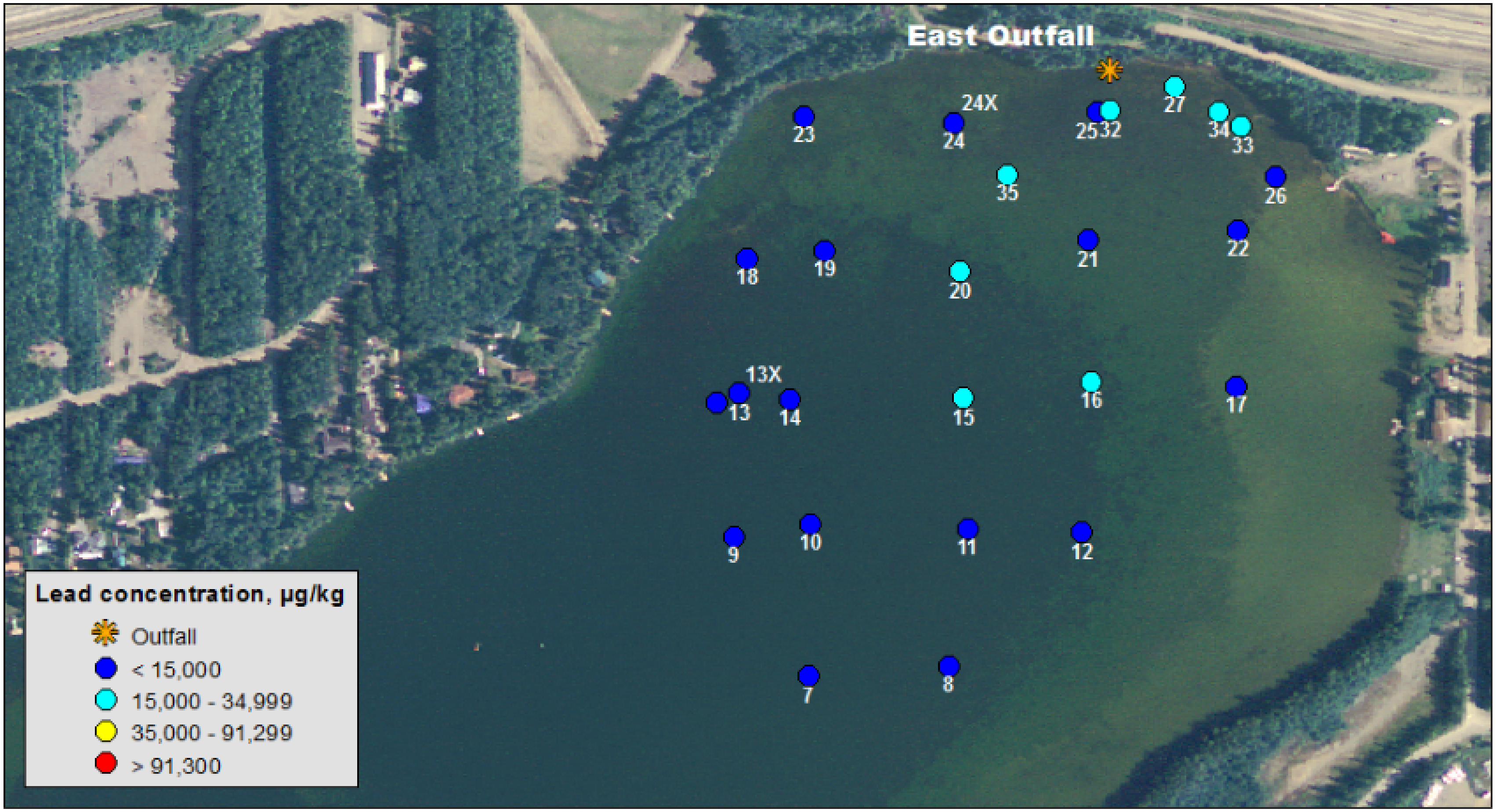

Figure 8. Distribution of lead sediment concentrations adjacent to the east outfall.

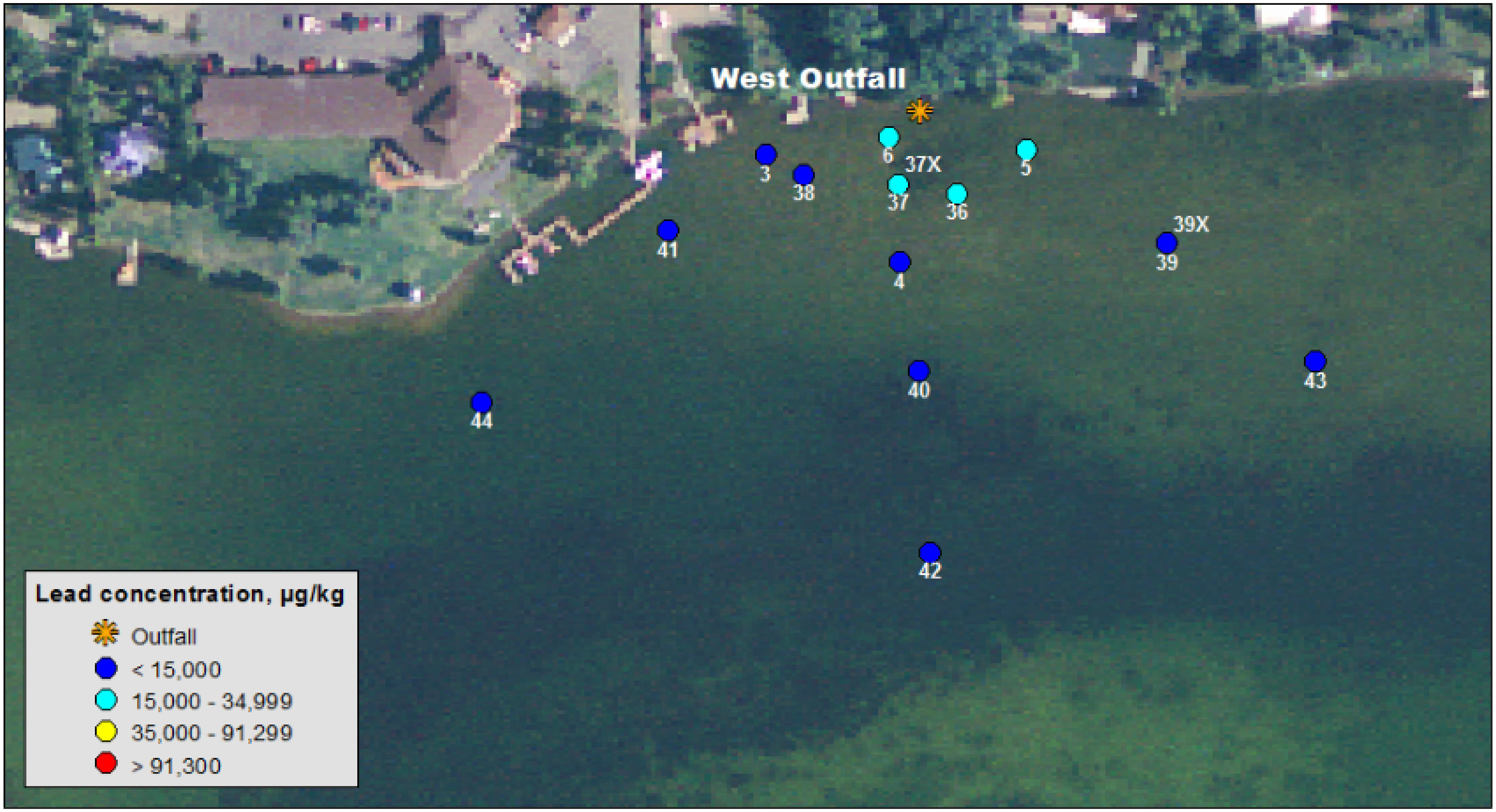

Figure 9. Distribution of bed sediment lead concentrations adjacent to the west outfall.

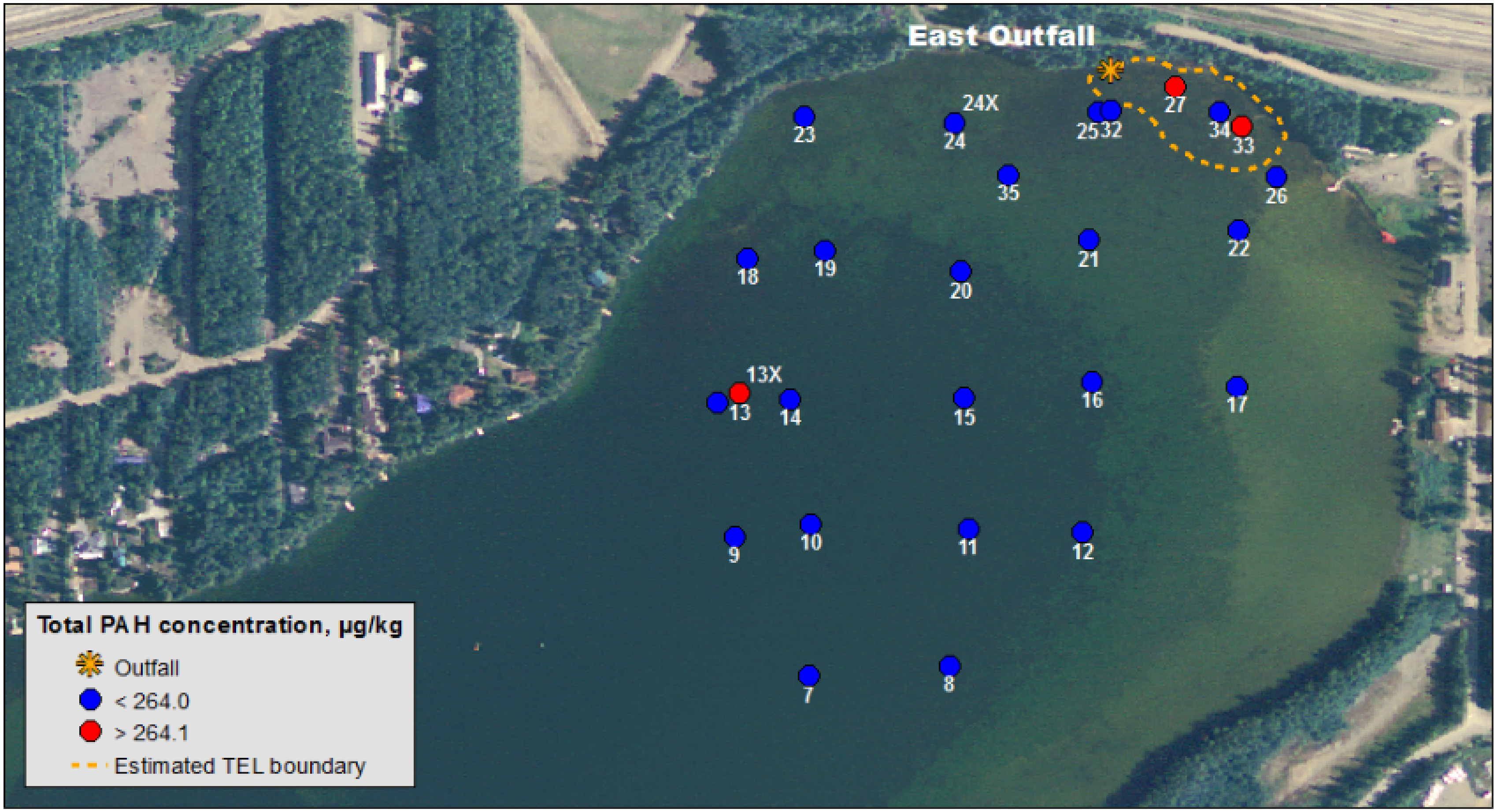

Figure 10. Distribution of bed sediment PAH concentrations adjacent to the east outfall. Red markers indicate sites where concentrations exceed TEL values. Dashed line is estimated area where PAH concentrations are likely to exceed TEL values.

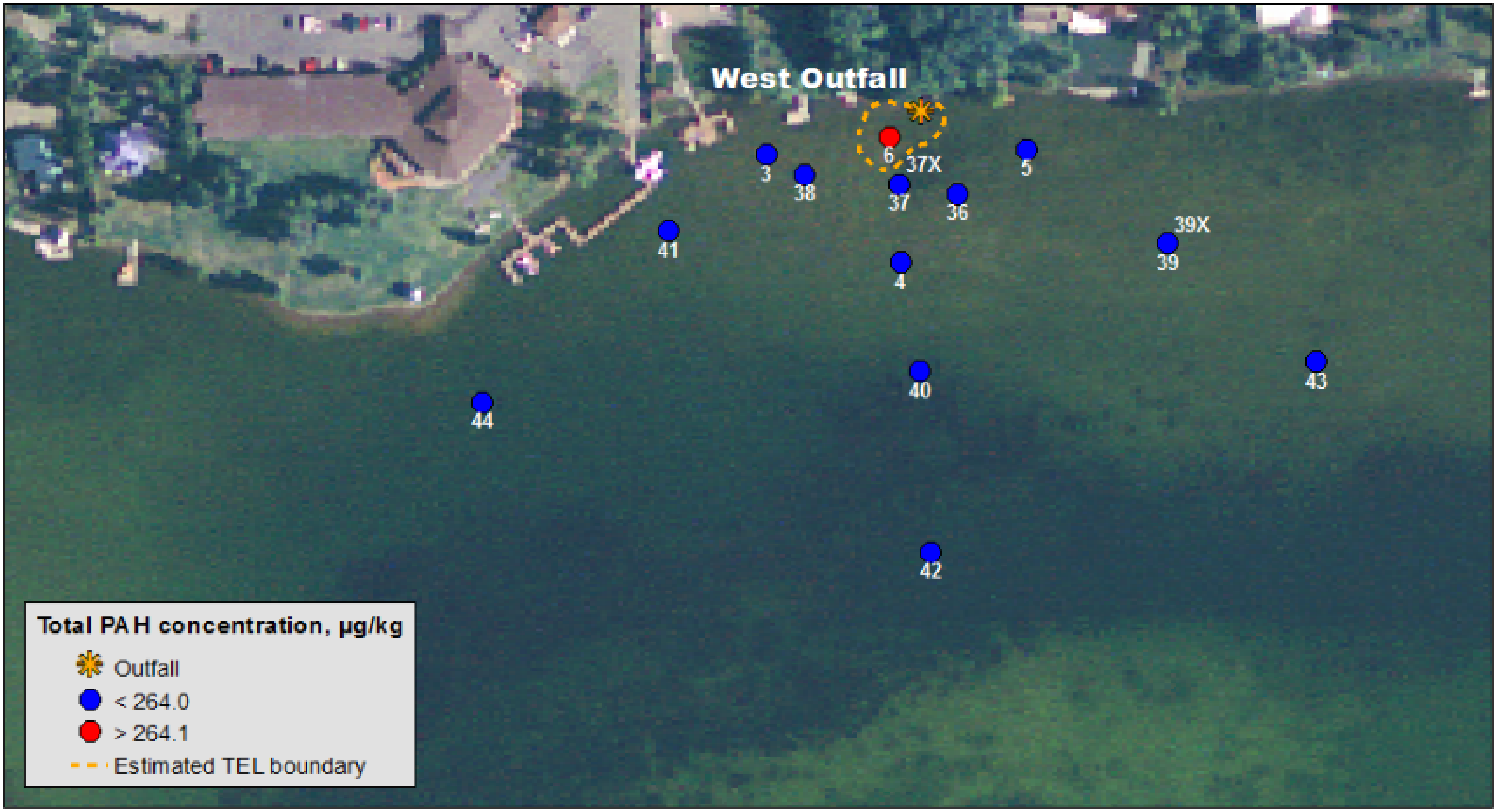

Figure 11. Distribution of bed sediment PAH concentrations adjacent to the west outfall. Red markers indicate sites where concentrations exceed TEL values. Dashed line is estimated area where PAH concentrations are likely to exceed TEL values.

5.0 References

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6.0 Appendix A. Site Photographs

Photograph 1. Lake Lucile east outfall.

Photograph 2. Lake Lucile west outfall.

Photograph 3. Ponar dredge sampler.

Photograph 4. Sediment collection from dredge sampler.

Photograph 5. Full sediment sample container.