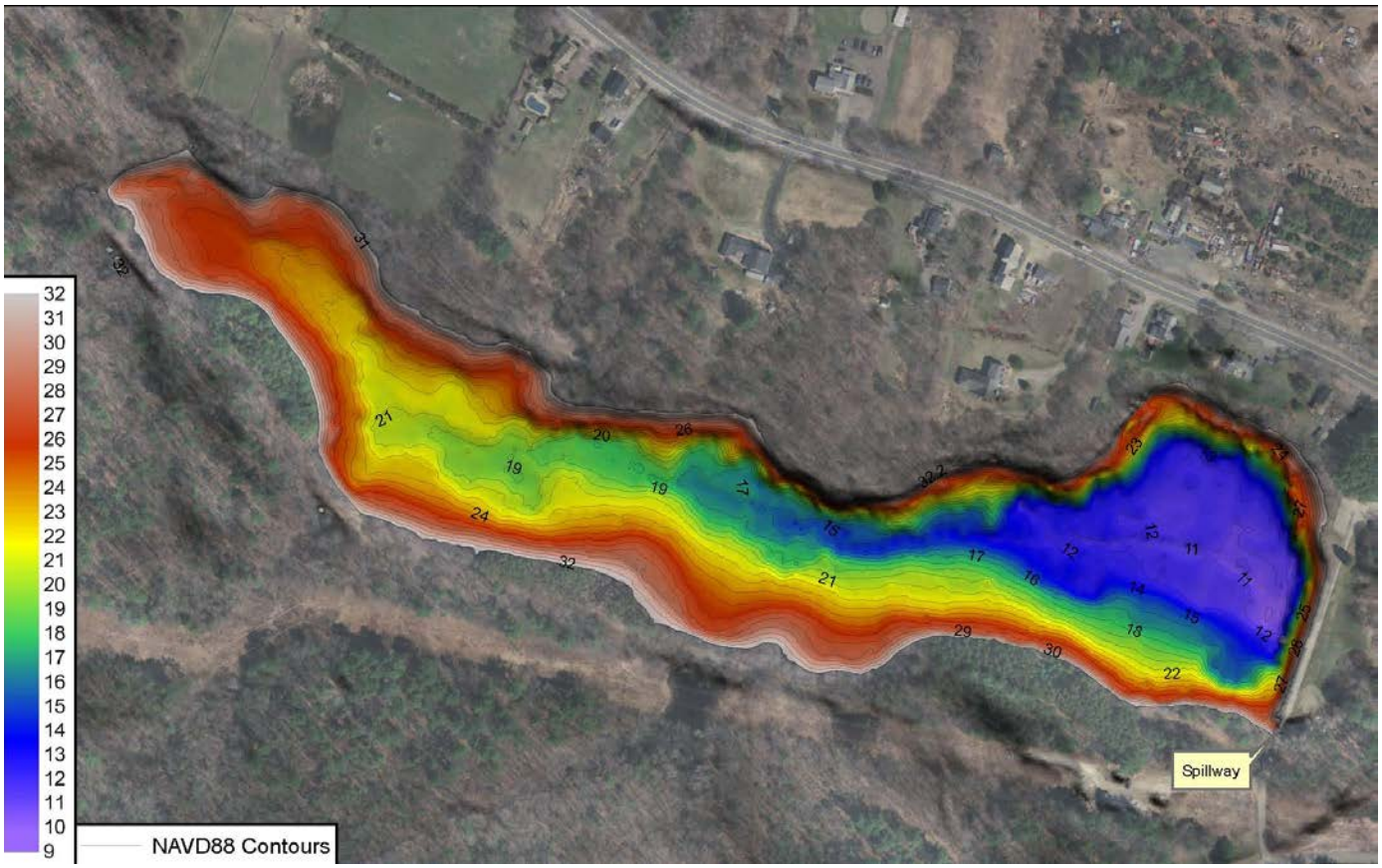
BATHYMETRIC AND SEDIMENT THICKNESS SURVEYS

DOW BROOK RESERVOIR
IPSWICH, MA



Dow Brook Reservoir Bathymetric Contour Map

Prepared for:

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Water Department
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1.0 INTRODUCTION

CR Environmental, Inc. (CR) performed bathymetric and geophysical surveys of the Dow Brook Reservoir in Ipswich, Massachusetts on May 17 - 18, 2018. The purpose of the survey was to calculate reservoir holding capacity, hypsographic relationships (e.g., area/volume) and to assess sediment accumulation.

2.0 ACQUISITION AND PROCESSING METHODS

2.10 Survey Vessel and Navigation

Surveys were conducted using CR's 12 foot aluminum skiff powered by an electric motor. The skiff was equipped with a small instrument enclosure and power supplies for computers and survey electronics.

Navigation for the survey was accomplished using a Hemisphere VS330 Real Time Kinematic Global Positioning System (RTK GPS). In fixed RTK mode, the horizontal accuracy of the system is approximately 1 centimeter with a vertical accuracy of approximately 2 cm. In Code Differential mode, horizontal accuracy is approximately 30 cm. Fixed RTK data were consistently obtained during the survey.

2.20 Bathymetric Survey Design and Instrumentation

The survey design consisted of transects oriented perpendicular to the major axis of the reservoir spaced 25 feet apart augmented by perpendicular quality control cross-line transects (Figure 1). Data accuracy was assessed through statistical comparison of soundings collected along primary and cross-line transects.

Soundings were collected using an Odom CV-100 echo sounder equipped with a 200-kHz 8-degree transducer. The minimum reliable sounding of this system is approximately 2 feet beneath the transducer, yielding defensible soundings at a minimum depth of approximately 2.5 feet beneath the water surface.

The RTK GPS and CV-100 echo sounder were interfaced to a shipboard computer running HYPACK 2015 hydrographic surveying software. During the survey, this system calculated X and Y positions in the desired grid system (MA State Plane, NAD83, US Foot), recorded the depth and navigation data, and provided a steering display for the vessel captain. HYPACK also depicted the progress of the survey using georeferenced imagery (e.g. orthophotos) as background files, ensuring that the survey areas were adequately insonified.

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Depth data were corrected for variations in water column sound velocity using profile data acquired with a YSI, Inc. Castaway conductivity and temperature profiler. Echo sounder draft was confirmed at the start and the survey by comparing echo sounder water depth measurements to absolute water depths obtained using the "bar check" method, in which a metal plate is lowered beneath the echo sounder's transducer to a known distance below the water surface. "Bar-check" calibrations were consistently accurate to within 0.10 feet throughout the surveys. Additional checks of sounding accuracy were obtained by comparisons of staff measurements with echo sounder readings. These comparisons consistently agreed to within 0.10 ft.

2.30 Sediment Thickness Survey Design and Methods

Sedimentation in the reservoir was assessed using a 10-kHz SyQwest Stratabox sub-bottom profiling (SBP) system. The SBP was interfaced to the RTK GPS and data were recorded along transects spaced 50-feet apart. Data were recorded in SEG-Y and ODC formats for post-processing.

3.0 DATA PROCESSING

3.10 Bathymetric Data Processing

Processing of reservoir depths consisted of the removal of outlying data points associated with water column interference (e.g., fish, gas, vegetation or debris), adjustment of depths for sound velocity variations, and conversion of raw depths (soundings) to NAVD88 elevations. Measured depths were converted to bottom elevations based on RTK NAVD88 water levels and observations of the water surface at the spillway. The basin was approximately 0.02 feet below the spillway full pool during the survey effort (Table 1). Processed sounding data were exported as ASCII comma delimited text files.

Georeferenced orthophotos and Light Detection and Ranging (LiDAR) terrain files surrounding the reservoir were obtained from USGS. LiDAR point data were reported relative to the NAVD88 vertical datum. LiDAR data were merged with CR's sounding data to generate seamless digital elevation models (DEMs) of the reservoir and surrounding terrestrial landscape. Inclusion of LiDAR data in the sounding database increased the accuracy of shoreline delineations and volume calculations.

A gridded surface was created from the merged elevation database of the reservoir using a 5 x 5 foot node density. A spectrum colored GeoTif image and contours were developed from the reservoir grid using a 1.0 foot contour interval. Contours have been digitally delivered in shapefile and DXF formats.

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Volumes and areas were calculated for the reservoir grid using 0.10 foot intervals. The ASCII bathymetric point data, grids, contours and GeoTIF visualizations have been provided as digital deliverables. Volumetric and hypsographic data have been delivered in tabular and graphical formats.

3.20 Sediment Sub-bottom Data Processing

Sub-bottom sonar data were processed using Chesapeake Technology SonarWiz software. Processing included digitization of the lakebed and application of moderate time-varied gain to improve detection capability. Profiles were exported as scaled JPEG images accompanied by SHP navigation files and a web-enabled inspection interface.

4.0 BATHYMETRIC SURVEY RESULTS

Bathymetric data for the reservoir were statistically analyzed to evaluate accuracy using U. S. Army Corps of Engineers methods (USACE, 2013. EM1110-2-1003). The USACE 95th percentile confidence interval (CI) recommendation for survey bias (cross-line repeatability) is +/- 0.2 feet and "resultant elevation/depth accuracy" of individual soundings is +/- 0.8 feet.

The observed water level at the Dow Brook Reservoir was 0.02 feet below the spillway, with a resultant elevation of 30.17 feet NAVD88 (Table 1). RTK GPS elevations and the spillway elevation reported on a 2008 design drawing provided by the Town of Ipswich agreed to within 0.04 feet. Cross-line statistics for the Dow Brook Reservoir dataset yielded a mean difference of 0.013 feet and a 95% CI uncertainty of 0.43 feet (SD = 0.22 feet).

The maximum depth of the Dow Brook Reservoir was 20.4 feet (9.8 feet NAVD88) and the average depth was 8.4 feet (21.8 feet NAVD88, Figure 2). The bed elevation adjacent to the western wall of the gatehouse was 11.9 feet NAVD88 (12.6 feet NGVD29). Volume calculations for the reservoir suggest a full pool capacity at the spillway of approximately 51.7 million gallons (Table 2, Figure 3). The volume with flashboards installed was calculated as approximately 60.96 million gallons. About 11- percent of the capacity is contained in the upper 1-foot of the basin below the spillway elevation.

A 1986 design drawing reports the elevation of the 14-inch gatehouse drain as 13 feet (+/-) NGVD29 (12.2 feet NAVD88). CR's survey data document a reservoir bed elevation of 11.9 feet NAVD88 on the western side of the gatehouse. These data suggest substantial burial of the drain pipe.

Digital echograms of sonar data documented minimal early growth aquatic vegetation within the reservoir.

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5.0 SEDIMENT SUB-BOTTOM RESULTS

The sub-bottom acoustic system penetrated greater than 25-feet of lakebed deposits in deeper portions of the reservoir (Figure 5). Profile data suggest 1-2 feet of post-construction sediment accumulation. Most of the sediment was suggested to have accumulated in deeper portions of the reservoir adjacent to the original course of Dow Brook. Glacial deposits as thick as 30 feet were observed beneath the original soil surface and were underlain by a strong reflector with characteristics suggestive of basal till or ledge.

Echograms recorded by the 200-kHz Odom echo sounder also suggested the widespread presence of approximately 1-2 ft of fine loose sediments in deeper portions of the basin.

6.0 QUALITY ASSURANCE/ QUALITY CONTROL

Data collected in the Dow Brook Reservoir on May 17-18, 2018 have been shown to comply with relevant promulgated USACE Performance Standards. CR merged these data with LiDAR data of similar vertical accuracy (i.e., +/- <0.5 feet at the 2-sigma confidence interval) to calculate full pool capacity and hypsography at 0.10 foot intervals.

CR has used all technically defensible approaches to minimize errors or biases in area or depth (elevation) calculations through the use of publically available terrestrial elevation data (e.g., LiDAR) to refine volume calculations by delineating the full pool area. CR's RTK GPS elevation measurements matched LiDAR values closely at the margins of the basin. RTK GPS and spillway elevations reported by the Town of Ipswich on design drawings also matched closely (i.e., <0.10 feet difference).

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REFERENCES

U.S. Army Corps of Engineers. 2013. *Engineering and Design Hydrographic Surveying*. EM1110-2-1003.

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TABLE 1

DOW BROOK RESERVOIR ELEVATION DATUMS
Ipswich, Massachusetts
(feet)

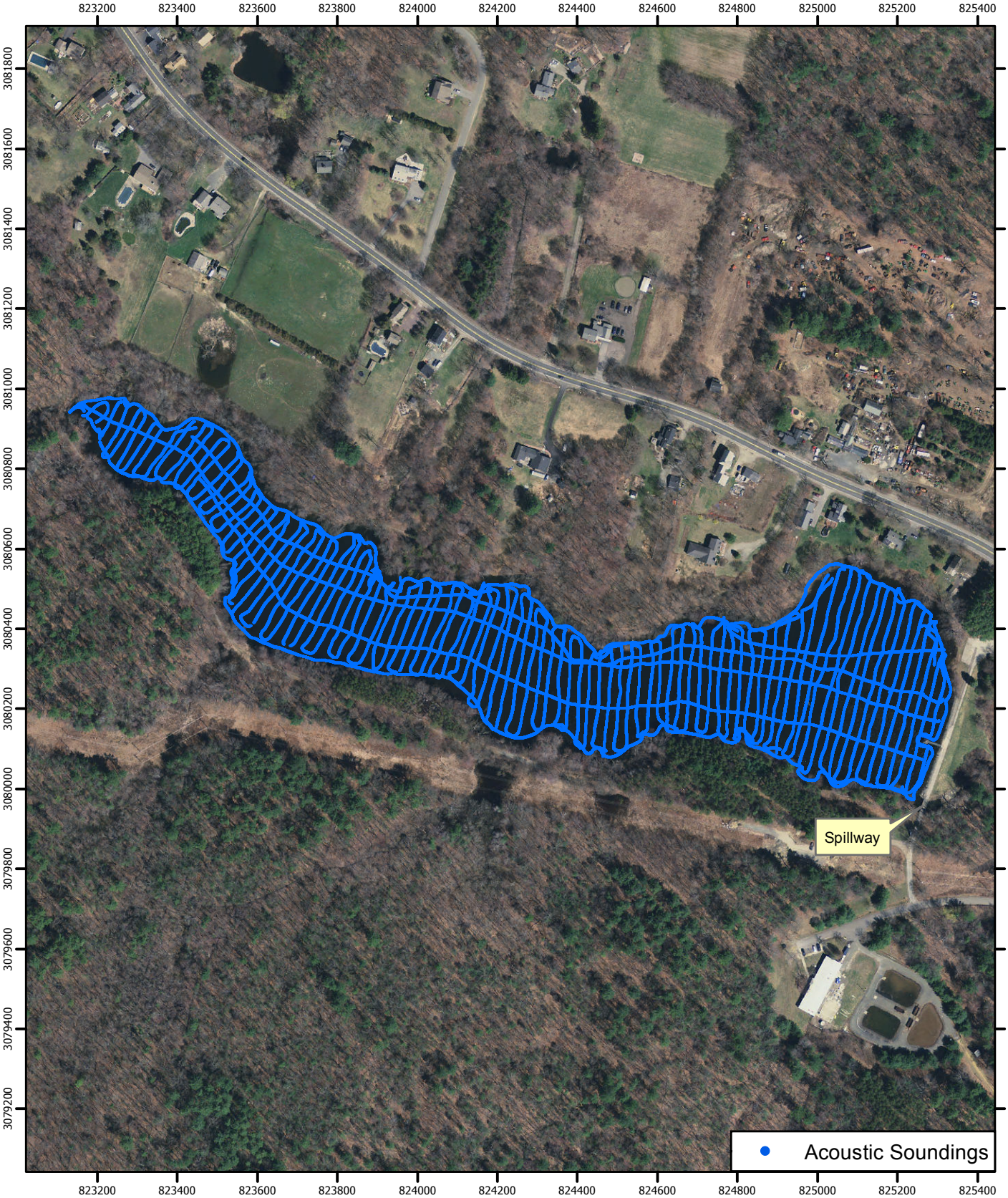
5/17/18 NAVD88 WS EL [1]	30.17
5/17/18 NGVD29 WS EL [2]	30.961
Spillway NGVD29 [3]	31
Spillway NAVD88 [2,3]	30.209
Top of Flashboards NGVD29 [3]	32.62
Top of Flashboards NAVD88 [2,3]	31.829
Monitoring Pt EL NAVD88 [4]	33.75

1. Average May 17, 2018 RTK GPS water surface elevation.
2. NAVD88 to NGVD29 conversion of +0.791 ft calculated using U.S. ACOE Corpscon V. 6.0.1.
3. Wright Pierce 2008 Drawing
4. Water surface was approximately 0.0.02 ft below spillway and 3.58 ft beneath the catwalk monitoring point on 5/17/2018.

TABLE 2

DOW BROOK RESERVOIR HYPSOGRAPHY
May 17, 2018

	NAVD88 EL (ft)	Water below Spillway (ft)	Water below Catwalk BM (in)	Volume (Gallons)	Planar Area (acres)
	32.83	*-2.63*	*19.8*	*62,976,000*	*18.62*
	32.1	-1.90	20.2	62,794,000	18.60
	32	-1.8	21.4	62,189,000	18.53
	31.9	-1.7	22.6	61,586,000	18.46
Top of Flashboards	31.8	-1.6	23.8	60,986,000	18.39
	31.7	-1.5	25.0	60,388,000	18.32
	31.6	-1.4	26.2	59,792,000	18.26
	31.5	-1.3	27.4	59,198,000	18.19
	31.4	-1.2	28.6	58,606,000	18.13
	31.3	-1.1	29.8	58,016,000	18.06
	31.2	-1.0	31.0	57,429,000	18.00
	31.1	-0.9	32.2	56,843,000	17.93
	31	-0.8	33.4	56,260,000	17.87
	30.9	-0.7	34.6	55,679,000	17.80
	30.8	-0.6	35.8	55,100,000	17.74
	30.7	-0.5	37.0	54,523,000	17.67
	30.6	-0.4	38.2	53,948,000	17.61
	30.5	-0.3	39.4	53,375,000	17.54
	30.4	-0.2	40.6	52,805,000	17.48
	30.3	-0.1	41.8	52,236,000	17.41
Spillway Full Pool	30.2	0.0	43.0	51,670,000	17.35
	30.1	0.1	44.2	51,105,000	17.28
	30	0.2	45.4	50,543,000	17.22
	29.9	0.3	46.6	49,983,000	17.15
	29.8	0.4	47.8	49,425,000	17.09
	29.7	0.5	49.0	48,869,000	17.02
	29.6	0.6	50.2	48,316,000	16.95
	29.5	0.7	51.4	47,764,000	16.89
	29.4	0.8	52.6	47,215,000	16.82
	29.3	0.9	53.8	46,668,000	16.75
	29.2	1.0	55.0	46,124,000	16.68
	29.1	1.1	56.2	45,581,000	16.61
	29	1.2	57.4	45,041,000	16.53
	28.9	1.3	58.6	44,504,000	16.46
	28.8	1.4	59.8	43,969,000	16.38
	28.7	1.5	61.0	43,436,000	16.30
	28.6	1.6	62.2	42,907,000	16.21
	28.5	1.7	63.4	42,380,000	16.12
	28.4	1.8	64.6	41,856,000	16.04
	28.3	1.9	65.8	41,335,000	15.94
	28.2	2.0	67.0	40,817,000	15.84
	28.1	2.1	68.2	40,302,000	15.74
	28	2.2	69.4	39,791,000	15.63
	27	3.2	81.4	34,867,000	14.58
	26	4.2	93.4	30,299,000	13.41
	25	5.2	105.4	26,139,000	12.20
	24	6.2	117.4	22,333,000	11.15
	23	7.2	129.4	18,878,000	10.05
	22	8.2	141.4	15,784,000	8.98
	21	9.2	153.4	13,052,000	7.76
	20	10.2	165.4	10,686,000	6.81
	19	11.2	177.4	8,612,000	5.93
	18	12.2	189.4	6,805,000	5.15
	17	13.2	201.4	5,225,000	4.53
	16	14.2	213.4	3,878,000	3.77
	15	15.2	225.4	2,741,000	3.22
	14	16.2	237.4	1,769,000	2.79
	13	17.2	249.4	924,000	2.34
	12	18.2	261.4	291,000	1.48
	11	19.2	273.4	32,000	0.27
	10	20.2	285.4	0	0.01



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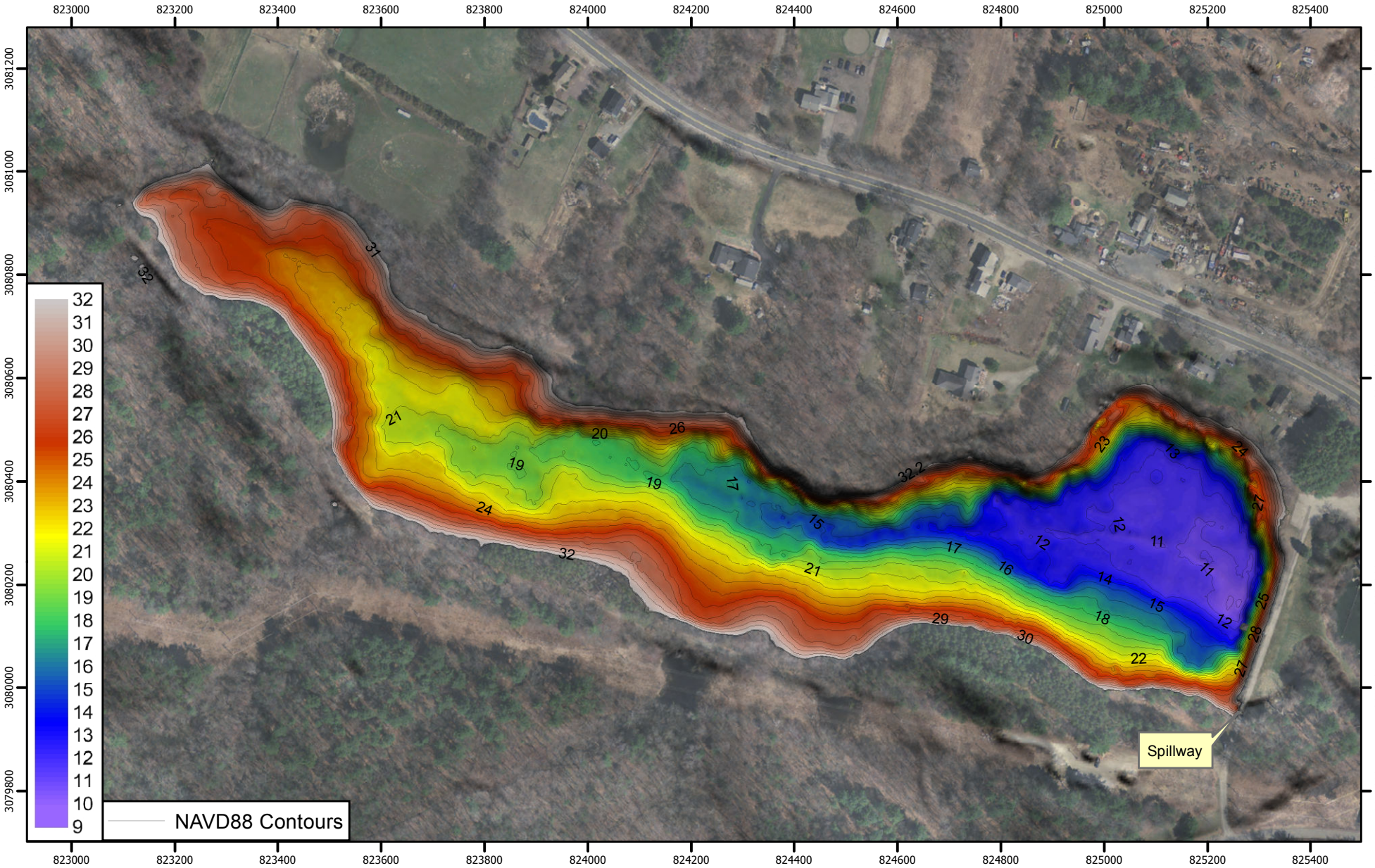
DOW BROOK RESERVOIR
SOUNDING DISTRIBUTION
Ipswich, Massachusetts

N
W E
S

NOTES:
1) Survey conducted May 17, 2018.
2) Grid MA State Plane, NAD 83, US Foot.

Feet
0 200 400

Figure 1



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DOW BROOK RESERVOIR BATHYMETRY
1.0-Foot NAVD88 Elevation Contours
Ipswich, Massachusetts

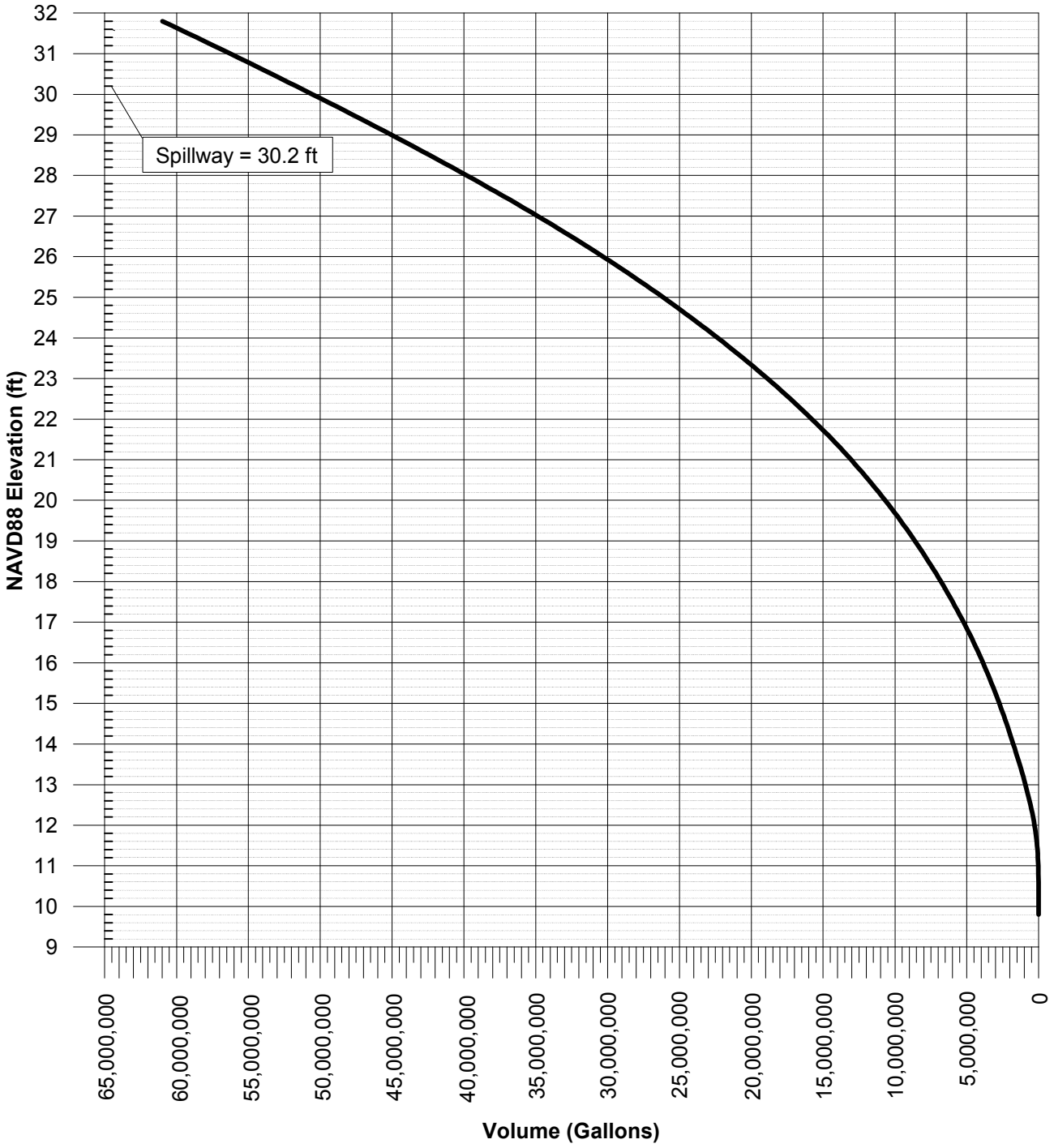
NOTES:
1) Survey conducted May 17, 2018.
2) Grid MA State Plane, NAD 83, US Foot.

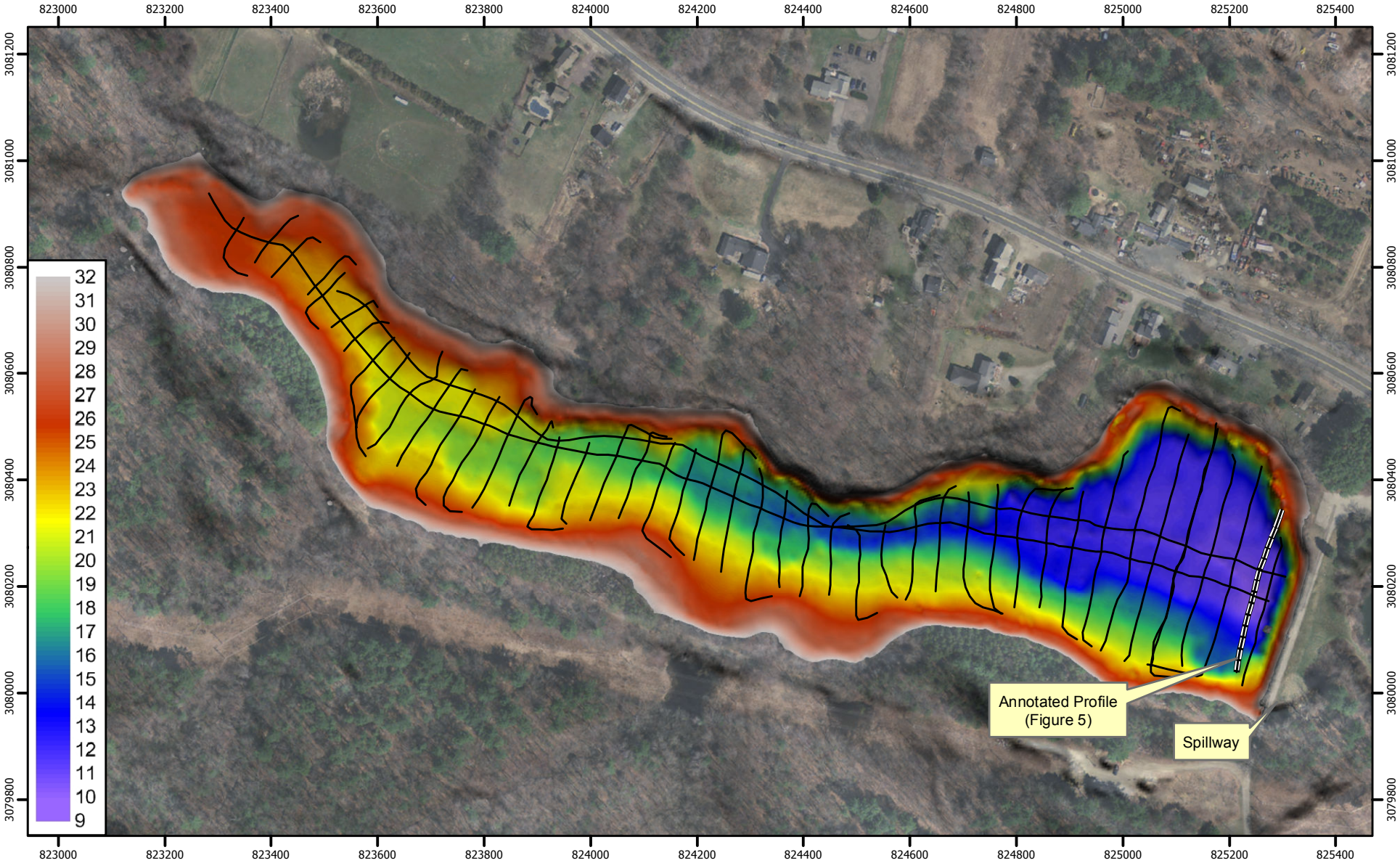
Feet
0 100 200

N W E S

Figure 2

FIGURE 3
DOW BROOK RESERVOIR CAPACITY CURVE
May 17, 2018





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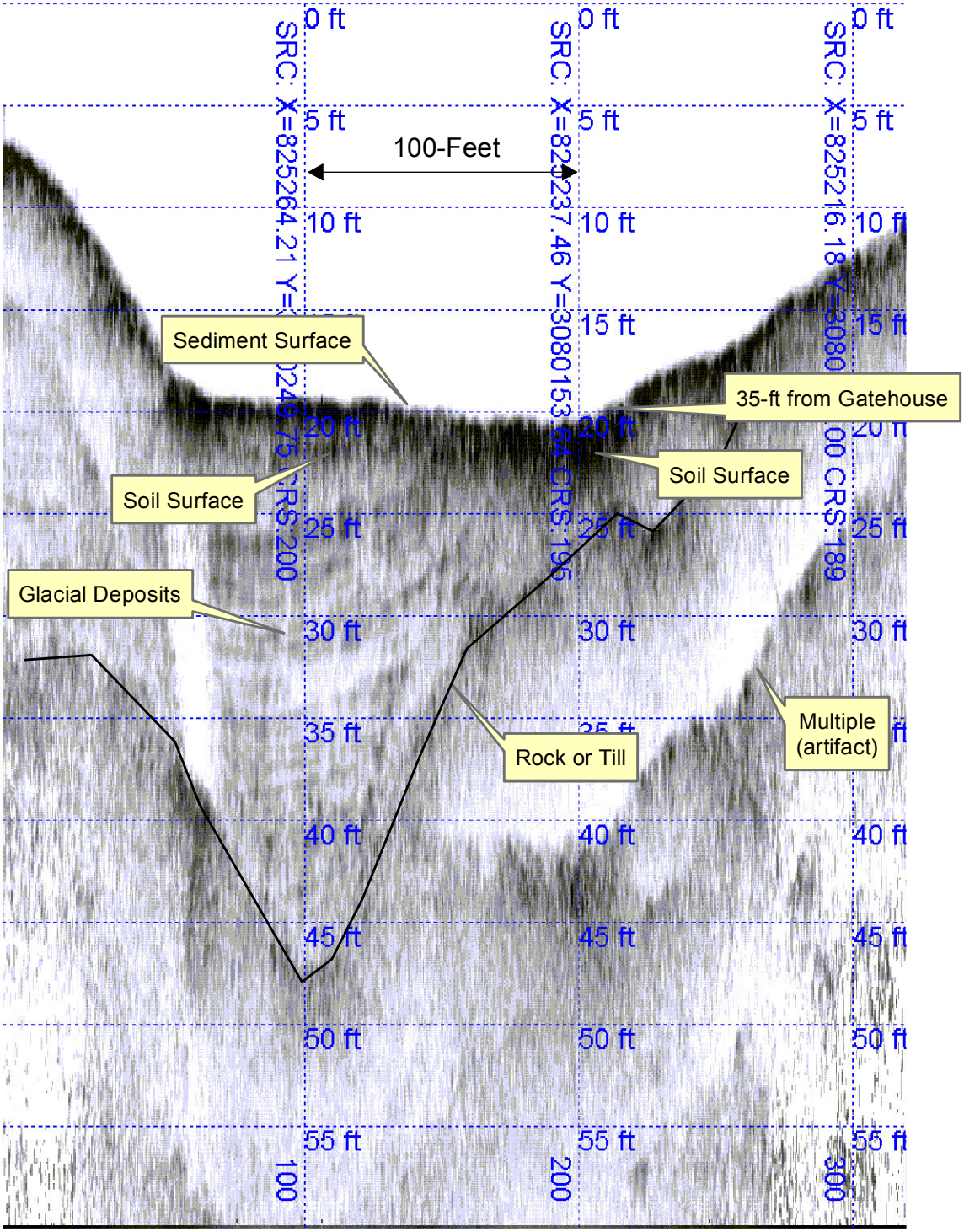
DOW BROOK RESERVOIR
10-kHz Sub-Bottom Sonar Transects
Ipswich, Massachusetts

N
W
E
S

NOTES:
1) Survey conducted May 18, 2018.
2) Grid MA State Plane, NAD 83, US Foot.

Feet
0 100 200

Figure 4



www.crenvironmental.com	DOW BROOK RESERVOIR 10-kHz Sub-Bottom Sonar Profile 1655 Adjacent to Gatehouse Ipswich, Massachusetts	N W E S
	NOTES: 1) Survey conducted May 18, 2018. 2) Grid MA State Plane, NAD 83, US Foot.	Figure 5