RECLAMATION

Managing Water in the West

Technical Report No. SRH-2013-07

Lake Isabel 2012 Reservoir Survey

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2012

ACKNOWLEDGMENTS

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) prepared and published this report for the United States Pike and San Isabel Forest Service (Service). The survey was conducted by Kent Collins and Ron Ferrari of the Sedimentation Group and Kurt Patrick and Cait Cuddihy of the Service in September 2012. Mike Hegler of the Service greatly assisted in getting the survey started. Kent Collins and Ron Ferrari of the Sedimentation Group consulted with Cait Cuddihy of the Service for study planning and field collection. Ron Ferrari completed the data processing to generate the 2012 topography and area-capacity values presented in this report. Kent Collins performed the technical peer review.

Mission Statements

The U. S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Reclamation Report

This report was produced by the Bureau of Reclamation's Sedimentation and River Hydraulics Group (Mail Code 86-68240), PO Box 25007, Denver, Colorado 80225-0007, www.usbr.gov/pmts/sediment/.

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Lake Isabel 2012 Reservoir Survey

prepared by

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Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Sedimentation and River Hydraulics Group
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Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240

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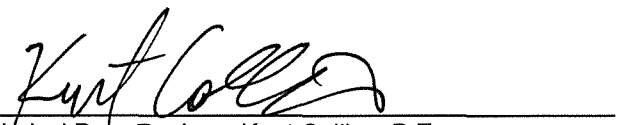
Lake Isabel 2012 Reservoir Survey

Lake Isabel Dam
San Isabel Forest
Colorado

1/17/2013

Prepared: Ronald L. Ferrari
Hydraulic Engineer,
Sedimentation and River Hydraulics Group 86-68240

Date



1/17/2013

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Introduction

Lake Isabel and Dam, on the Saint Charles River in Custer and Pueblo Counties in central Colorado, is about 30.5 miles southwest of Pueblo, 12 miles west of Colorado City and 8 miles northwest of Rye (Figure 1). The dam is located in the Southwest Quarter of Section 6 Township-24-South Range-68-West of the Sixth Principal Meridian. The dam and reservoir were completed in the 1930s and were originally used predominately as storage for CF&I Steel. Today, Lake Isabel, located in the San Isabel National Forest, provides fishing, hiking, and camping. The reservoir and recreation facilities are overseen by the Pike and San Isabel Forest Service (Service).

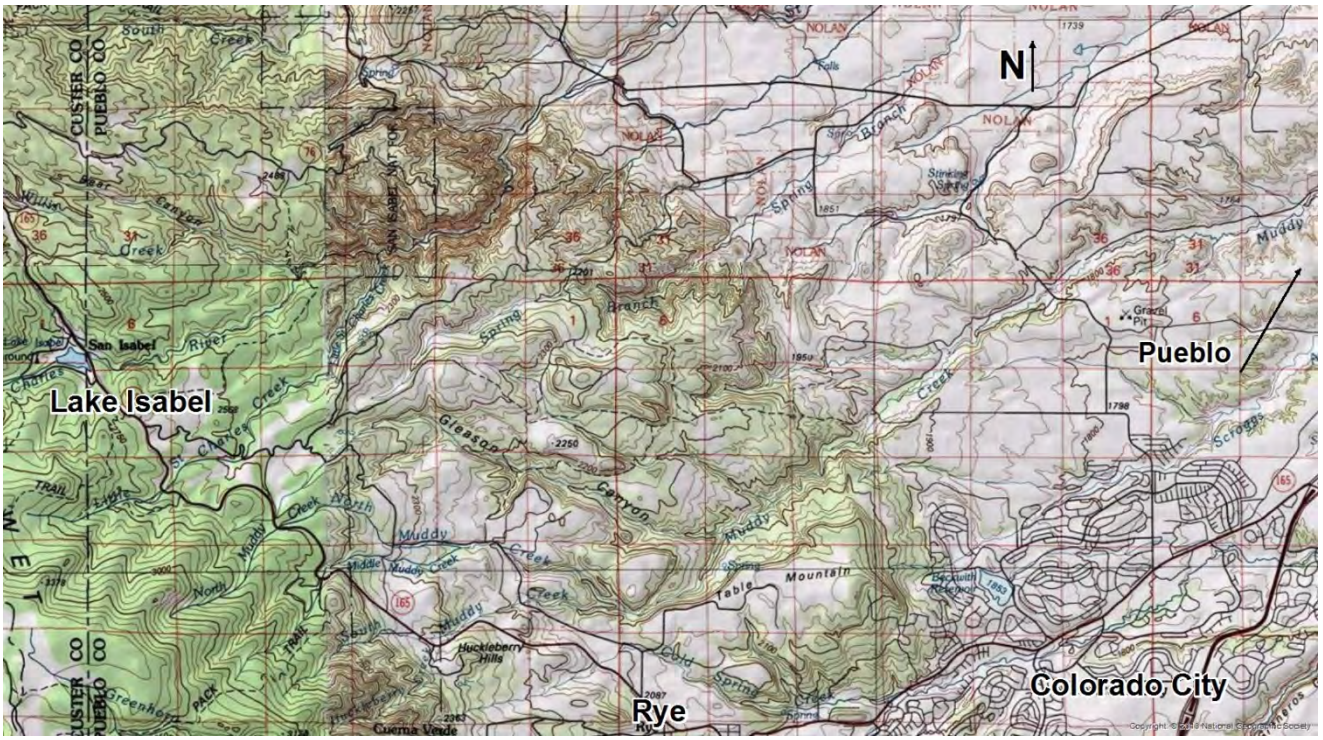

Figure 1 - General location of Lake Isabel in Colorado.

Lake Isabel Dam, originally called St. Charles Dam, is an earthen structure. The original reservoir and dam drawings along with the area and capacity tables show the vertical datum was tied to a local construction elevation that is around 40.5 feet lower than NAVD88. September 2012 measurements on top of the dam and

center line of the highway located the lowest section over the spillway near elevation 8,484.0[1].

According to original drawings and tables, the spillway crest elevation was 8,437.25 (project vertical datum) at gage height or reservoir depth 74.25, with high water at elevation 8,438.75 (project vertical datum) or gage height 75.75. The 2012 survey elevations were tied to NAVD88, geoid model 2012A (GEOID12A), with a measured spillway crest at elevation 8,477.7. NAVD88 elevations must be lowered 40.5 feet to match the original project datum elevations. Lake Isabel spillway is located near the left abutment of the dam and consists of a concrete overflow crest and outlet channel (Figure 2). The original invert of the outlet intake was at gage height 0.0 or elevation 8,363.0 on the project vertical datum or elevation 8,403.5 adjusted to NAVD88.

Figure 2 - Lake Isabel spillway looking upstream or west from top of the dam.

[1] Elevations in feet. All elevations based on the North American Vertical Datum of 1988 (NAVD88) using geoid model 2012A. To match the original project vertical data reduce the NAVD88 elevations around 40.5 feet. The current gage is set at 3.29 feet at spillway crest elevation 8,477.7 (NAVD88).

Control Survey Data Information

Prior to the 2012 hydrographic survey, the National Geodetic Survey (NGS) monument "Lorelei" was located and used as the base station for the GPS survey. The following NGS description was used to locate the point:

"STATION LOCATED AT LAKE ISABEL IN SEC 7, T 24 S, R 68 W, 6P.M. TO REACH THE STATION FROM THE JUNCTION OF INTERSTATE 25 AND S.H.165 TAKE EXIT 74. GO WEST ALONG S.H. 165 17.3 MI (27.8 KM) TO THE ENTRANCE OF THE SAN ISABEL NATIONAL FOREST-LAKE ISABEL WORK CENTER, CONTINUE WEST ALONG S.H. 165 0.01 MI (0.02 KM) TO THE STATION ON THE RIGHT AT MILEPOST 19.0. STATION MARK IS A NGS BRASS HORIZONTAL CONTROL DISK SET IN A ROCK OUTCROP FLUSH WITH THE GROUND AND IS LOCATED 19.1 M (62.7 FT) EAST OF THE CENTERLINE OF S.H. 165, 5.4 M (17.7 FT) EAST OF A WOOD RAIL FENCE AND 17.0 M 55.8 FT) NORTH OF THE ENTRANCE GATE TO THE WORK CENTER."

The published NGS elevation for "Lorelei" was rounded to the nearest foot. The ellipsoid and geoid height, computed using the 2009 geoid model, were used to calculate the initial coordinates for the base during the three day September 2012 RTK GPS survey.

For the 2012 survey, a control network was established using the on-line positioning user service (OPUS) to establish the horizontal and vertical control of point "Lorelei" that was used for the hydrographic survey. OPUS is operated by the NGS and allows users to submit GPS data files that are processed with known point data to determine positions and elevations relative to the national control network using GEOID12A. The three-day average was used to compute the coordinates at "Lorelei" that became the base information for this study. All September 2012 measured coordinates were shifted to match this control point and network. From the "Loarelei" base, additional control points were set around the reservoir, Figure 3. The horizontal control was established in Colorado state plane South coordinates, NAD83, in feet. Unless noted, all elevations and computations presented in this report are referenced to NAVD88 (GEOID12A).

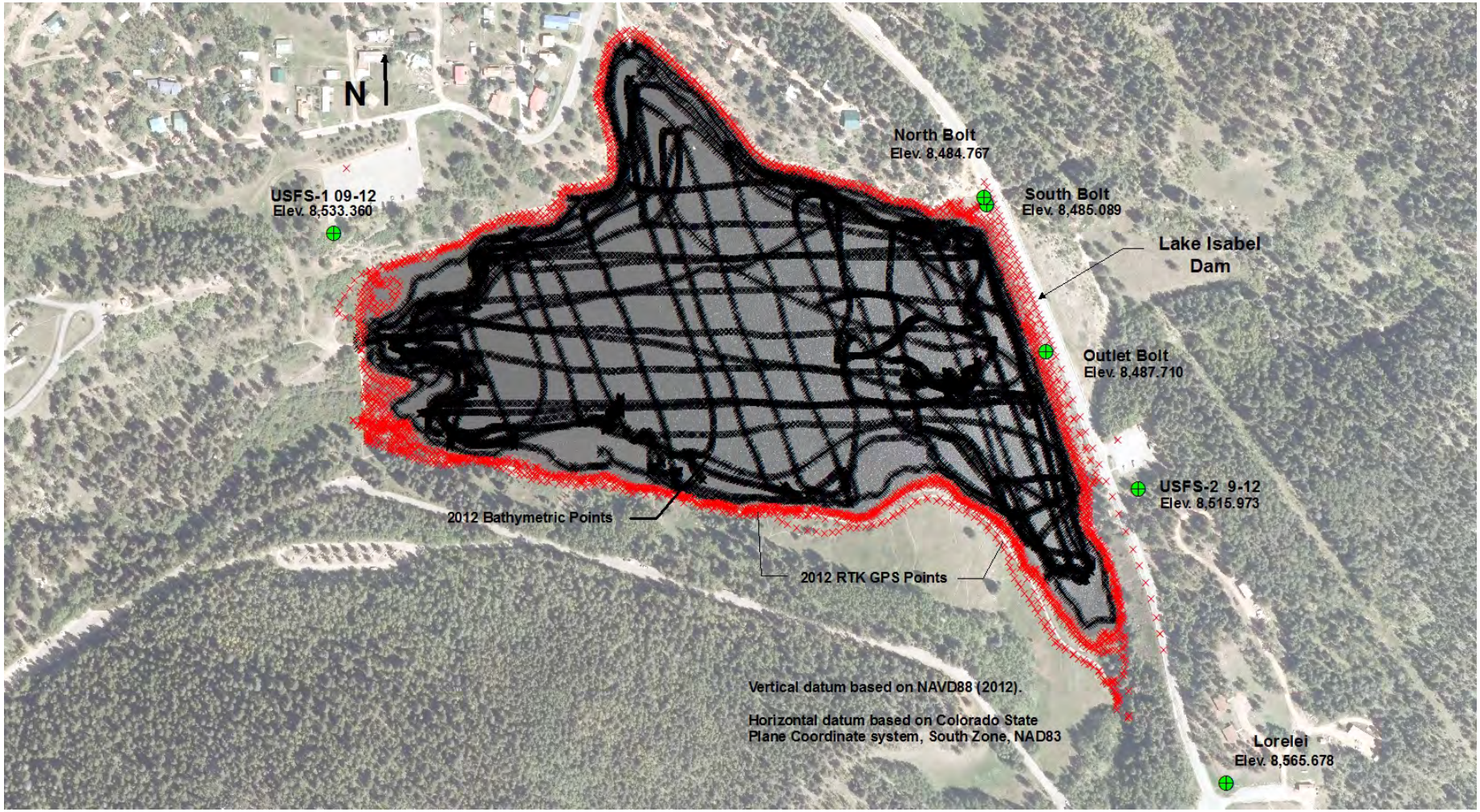

Figure 3 - Lake Isabel control points and 2012 data points.

Following are the control point coordinates used or established during the September 2012 Lake Isabel hydrographic survey, Figures 4 through 10.

NGS point "Lorelei"

East	3,130,272.167
North	1,479,033.526
Elevation	8,565.678

USFS-1 09-12

East	3,127,878.516
North	1,480,507.671
Elevation	8,533.360

USFS-2 09-12 (aluminum cap over rebar)

East	3,130,036.410
North	1,479,822.138
Elevation	8,515.973

Figure 4 - USFS-1 09-12: Aluminum cap on rebar.

Figure 5 - USFS-1 09-12.

Figure 6 - USFS-1 09-12.

Figure 7 - USFS-2 09-12: Aluminum cap on rebar

The following control coordinates were collected on the center of the southeast and northeast bolts of the spillway channel railing and on the center of a bolt on the outlet works. The RTK GPS survey rod was set on the center of these bolts with no mark set.

South Bolt

East	3,129,627.995
North	1,480,584.995
Elevation	8,485.089

North Bolt

East	3,129,620.582
North	1,480,603.525
Elevation	8,484.767

Outlet Bolt

East	3,129,787.099
North	1,480,190.410
Elevation	8,487.710

Figure 8 - Center of southeast bolt of spillway channel rail.

Figure 9 - Center of northeast bolt of spillway channel rail.

Figure 10 - Center of bolt on outlet gate pad.

Hydrographic Survey, Equipment, and Method of Collection

Bathymetric Survey Equipment

The bathymetric survey equipment was mounted on two different boats for the Lake Isabel survey: one a 9-foot cataraft powered by an electric trolling motor used to measure shallow depths along the shoreline (Figure 11); and the other a shallow draft, jet powered vessel for the deeper water in the main reservoir body. The hydrographic systems included a GPS receiver with a built-in radio, depth sounder, helmsman display for navigation, computer, and hydrographic system software for collecting the underwater data. All equipment was powered by on-board batteries. The shore equipment included a second GPS receiver with an external radio. The shore GPS receiver and antenna were mounted on a survey tripod over the known datum point “Lorelei” with a 12-volt battery providing power.

Figure 11 - Vessel used to collect depth data along the shoreline of Lake Isabel.

The Sedimentation and River Hydraulics Group uses RTK GPS with the major benefit being precise heights measured in real time to monitor water surface elevation changes. The RTK GPS system employs two receivers that track the same satellites simultaneously. The basic outputs from a RTK receiver are precise 3-D coordinates in latitude, longitude, and height with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically. The output is on the GPS WGS-84 datum that the hydrographic collection software converted into Colorado's state plane south coordinates, NAD83, in feet.

Lake Isabel bathymetric survey was conducted on September 24 and 25 of 2012 at water surface elevation 8,476.1. The bathymetric survey was conducted using sonic depth recording equipment interfaced with RTK GPS that measured the sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved along grid lines established to cover the reservoir. The survey vessel's guidance system provided directions to the boat operator to assist in maintaining a course along these predetermined lines. Data was also collected along the shoreline of the reservoir. As each line was traversed, the depth and position data were recorded on a laptop computer hard drive or GPS controller for subsequent processing. The survey vessels were steered away from specific areas of the reservoir with thick bottom vegetation growth to prevent collection of erroneous depth measurements, Figure 12. The water surface elevations recorded by RTK

GPS measurements were used to convert the sonic depth measurements to lake-bottom elevations tied to NAVD88 (GEOID12A). Final processing of the collected data resulted in around 24,400 points, Figure 3.

The 2012 underwater data was collected using a depth sounder that was calibrated by adjusting the speed of sound through the water column which varies with density, salinity, temperature, turbidity, and other conditions. The data was digitally transmitted to the collection systems through Bluetooth or RS-232 serial ports. The large vessel depth sounder also produced analog charts of the measured depths. These charts were analyzed during post-processing, and when the charted depths indicated a difference from the computer recorded bottom depths, the computer data files were modified. Additional information on collection and analysis procedures is outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

Figure 12 - Submerged weeds within Lake Isabel.

Above Water Data

The 2012 survey of Lake Isabel focused on the collection of the bathymetric or underwater data that was accessible by the survey vessel and RTK GPS topographic shots collected by walking the shoreline around the reservoir. The topographic shots concentrated on mapping the water's edge around the entire reservoir along with surveying up the slope away from the reservoir. To add detail at various elevations, orthographic aerial photos collected in 2005, 2009, and 2011 were downloaded from the United States Department of Agriculture (USDA) data web site (USDA, 2010). Unfortunately, the 2011 aerial was the only image that was clear enough, flown near the spillway crest elevation of 8,477.7, to develop a complete contour around the reservoir by digitizing the water's edge. When compared to the 2012 RTK GPS topographic shots, it was determined the 2011 aerial would require a horizontal shift to match features such as the spillway crest, highway, and water's edge. The water's edge was adequately mapped by the 2012 survey so the 2011 water's edge data were not needed and were not shifted. The 2011 aerial image was used only as a background photo for presentation purposes in this report.

As shown on Figure 3, there were areas of the reservoir where limited RTK GPS topographic points were collected. These areas include coves and the upper reservoir area with limited access due to tall vegetation and steep terrain that limited GPS collection. To allow topographic development of Lake Isabel in these areas, portions of USGS quad contours labeled 8,480 and 8,520 were digitized and used as breaklines during map development. The USGS quad contours, tied to National Geodetic Vertical Datum (NGVD29), were shifted to elevations 8,484.3 and 8,524.3 respectively to match NAVD88.

Reservoir Area and Capacity

Topography Development

This section discusses the methods used for generating topographic contours for Lake Isabel. The data sources included the 2012 hydrographic and topographic surveys, and the contours digitized from the USGS quad maps. The 2012 bathymetric and RTK GPS topographic surveys were the base data sets for contour development in the main portion of the reservoir for the normal operating range up to about elevation 8,479. As previously mentioned, USGS quad contours at elevations 8,484.3 and 8,524.3, were used as breaklines to allow contour development where limited RTK GPS topographic data was collected.

The data was processed into a triangulated irregular network (TIN) used to develop 1-foot contours referenced vertically to NAVD88 (GEOID12A). For

readability purposes the topography in this report is presented as 2-foot contours, Figure 13. A TIN is a set of adjacent non-overlapping triangles computed from irregularly spaced points with x,y horizontal coordinates and z elevation values. A TIN is designed to deal with continuous data such as elevations. ArcGIS uses a method known as Delaunay's criteria for triangulation where triangles are formed among all data points within a breakline polygon or clip. The method requires that a circle drawn through the three nodes of a triangle will contain no other point, meaning that each data point is connected to its nearest two neighbors to form a triangle, preserving all the data points. The TIN method is described in more detail in the ArcGIS user's documentation (ESRI, 2006).

In preparation for developing the TIN, two polygons were created to enclose the data sets. One polygon enclosed all the data for complete contour development of the study area. The second polygon ran along the alignment of the dam and spillway crest for computing the reservoir surface areas and resulting volumes presented in this report. These polygons, not assigned an elevation, were used as a hard boundary for the 2012 developed contours, allowing mapping only within the hardclip polygon by preventing interpolation outside it.

Contours for Lake Isabel were developed from the TIN generated within ArcGIS. The linear interpolation option of the ArcGIS TIN and CONTOUR commands was used to generate contours from the Lake Isabel TIN. For presentation purposes, the developed contours were slightly smoothed and contour lines less than 50 feet long were removed. The reservoir contour topography at 2-foot intervals is presented in Figures 14 through 18 from elevation 8,408.0 through elevation 8,486.0. The developed 8,406.0 contour line was less than 50 feet in length and was removed during the smoothing process. The developed 1-foot contours and collected point data are available digitally on the Sedimentation Group's web site (Reclamation, 2012).

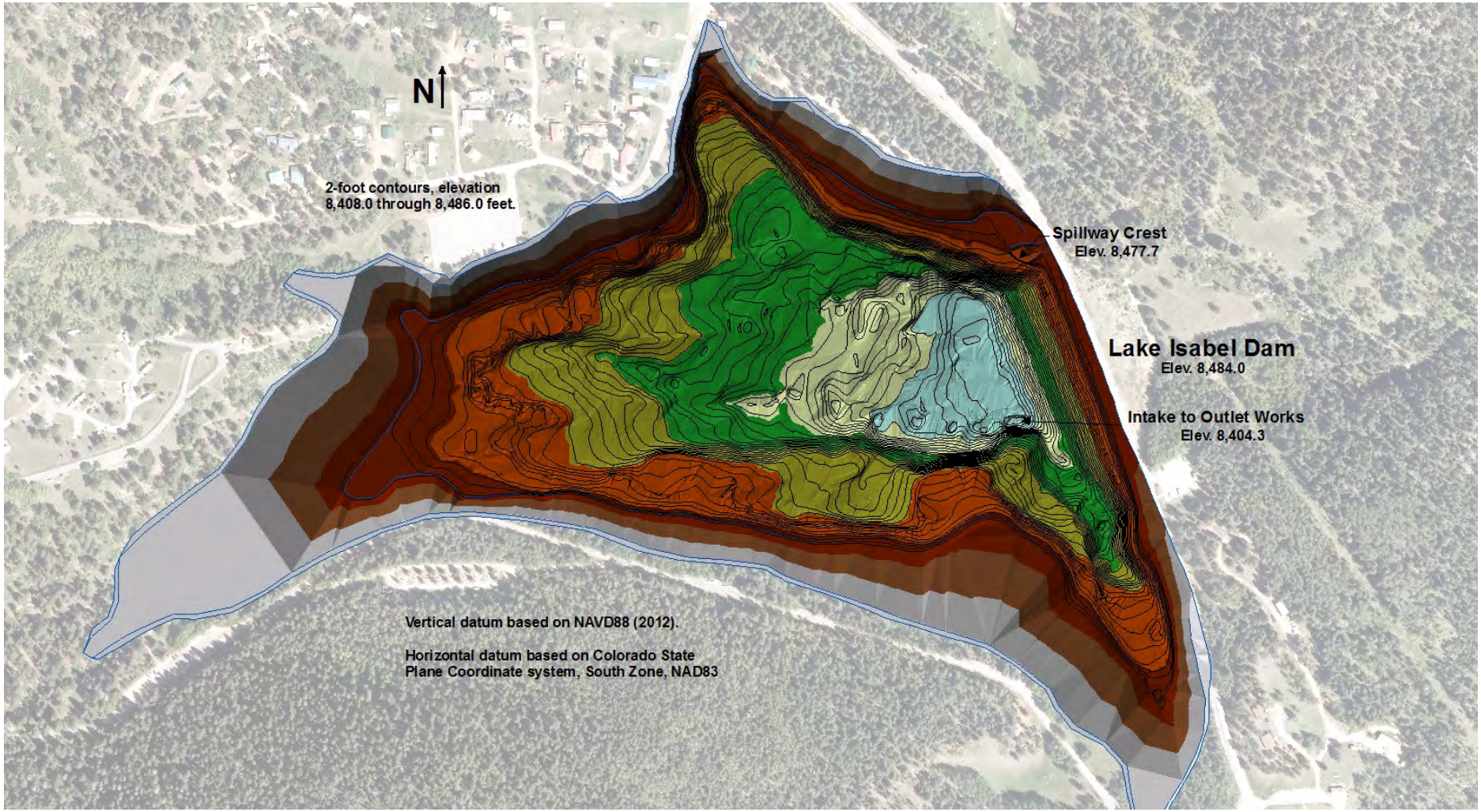

Figure 13 - Lake Isabel developed TIN.

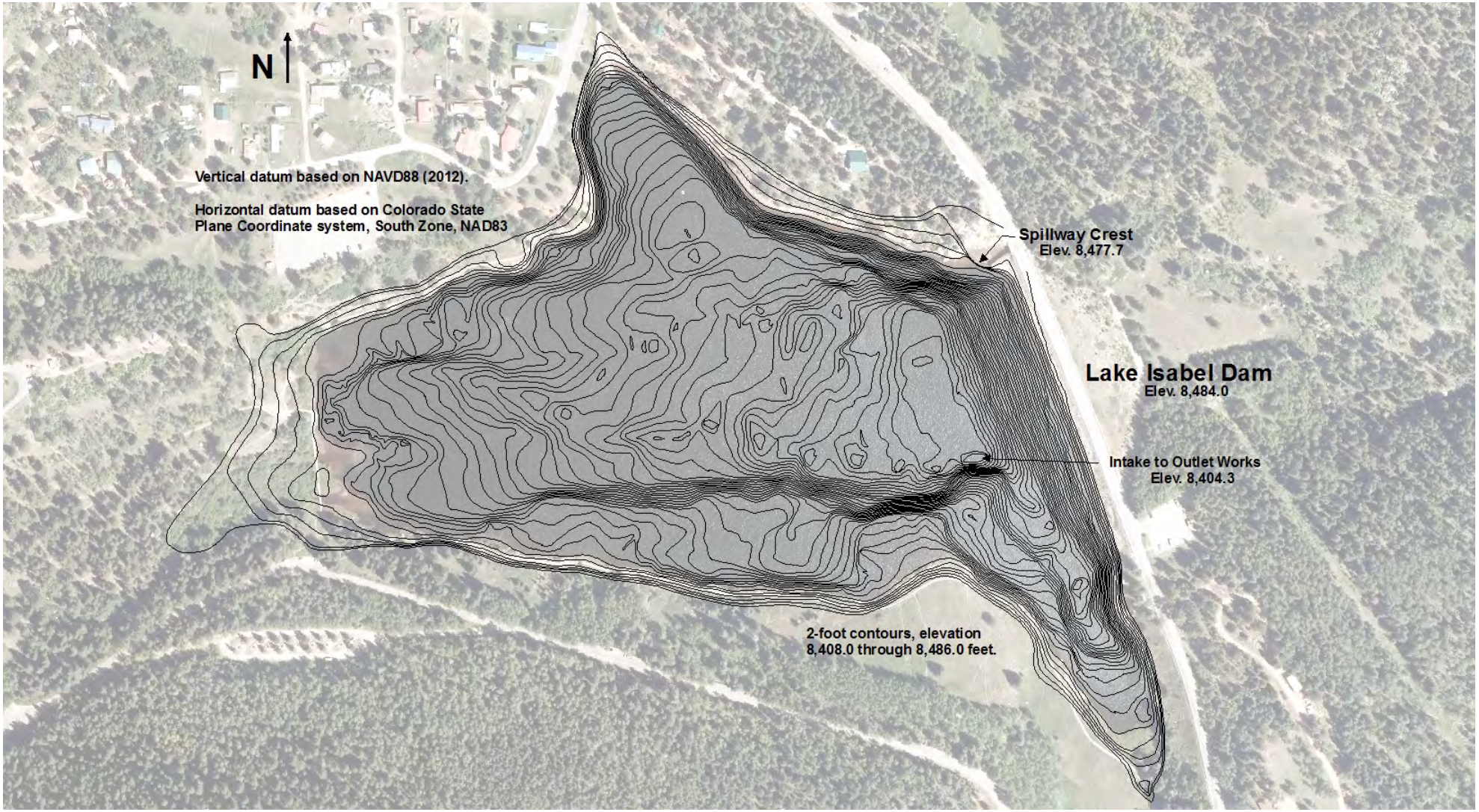

Figure 14 - Lake Isabel topography, 2-foot contours, elevation 8,408.0 through 8,486.0 (map 1 of 5).

Figure 15 - Lake Isabel topography, 2-foot contours, elevation 8,408.0 through 8,486.0 (map 2 of 5).

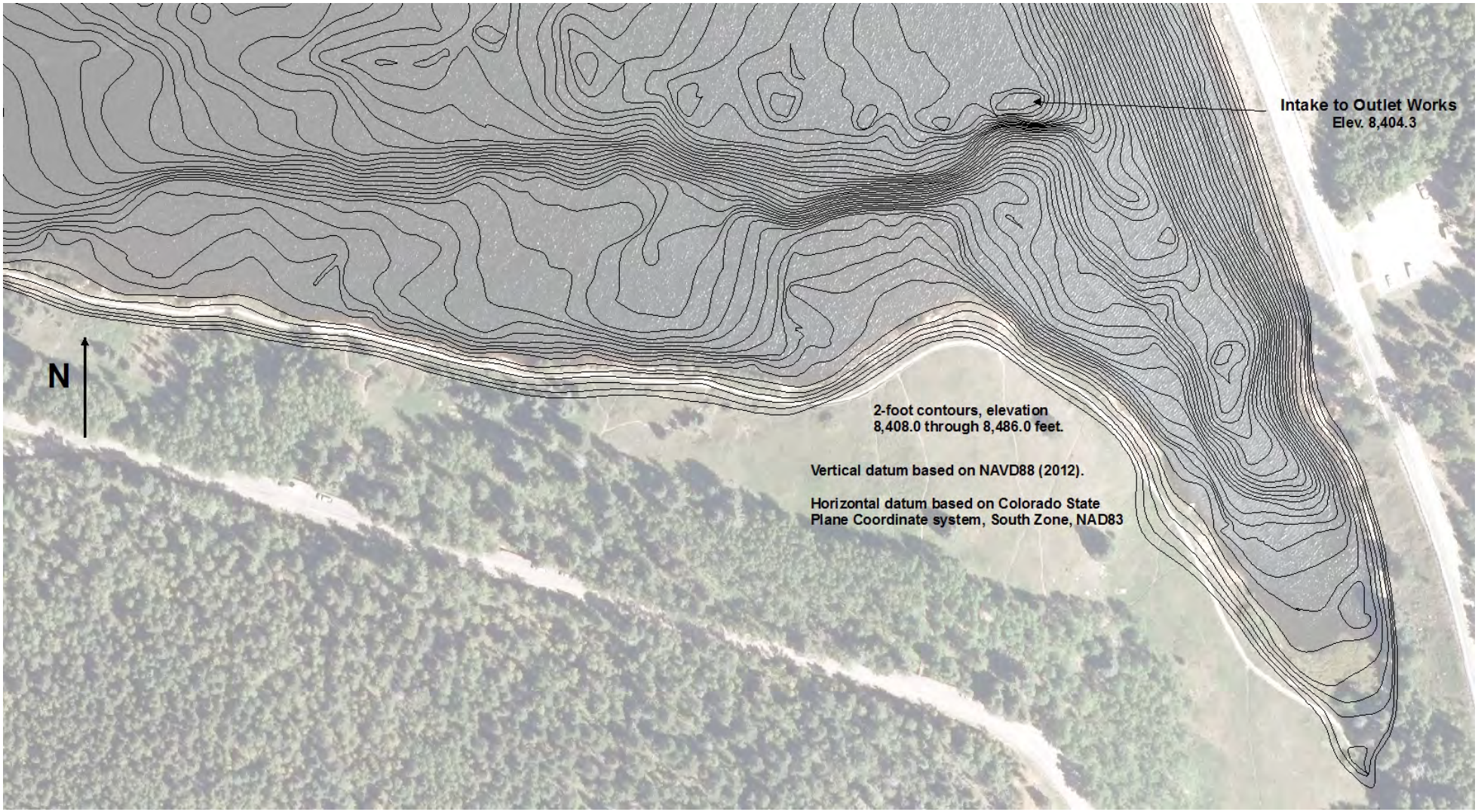

Figure 16 - Lake Isabel topography, 2-foot contours, elevation 8,408.0 through 8,486.0 (map 3 of 5).

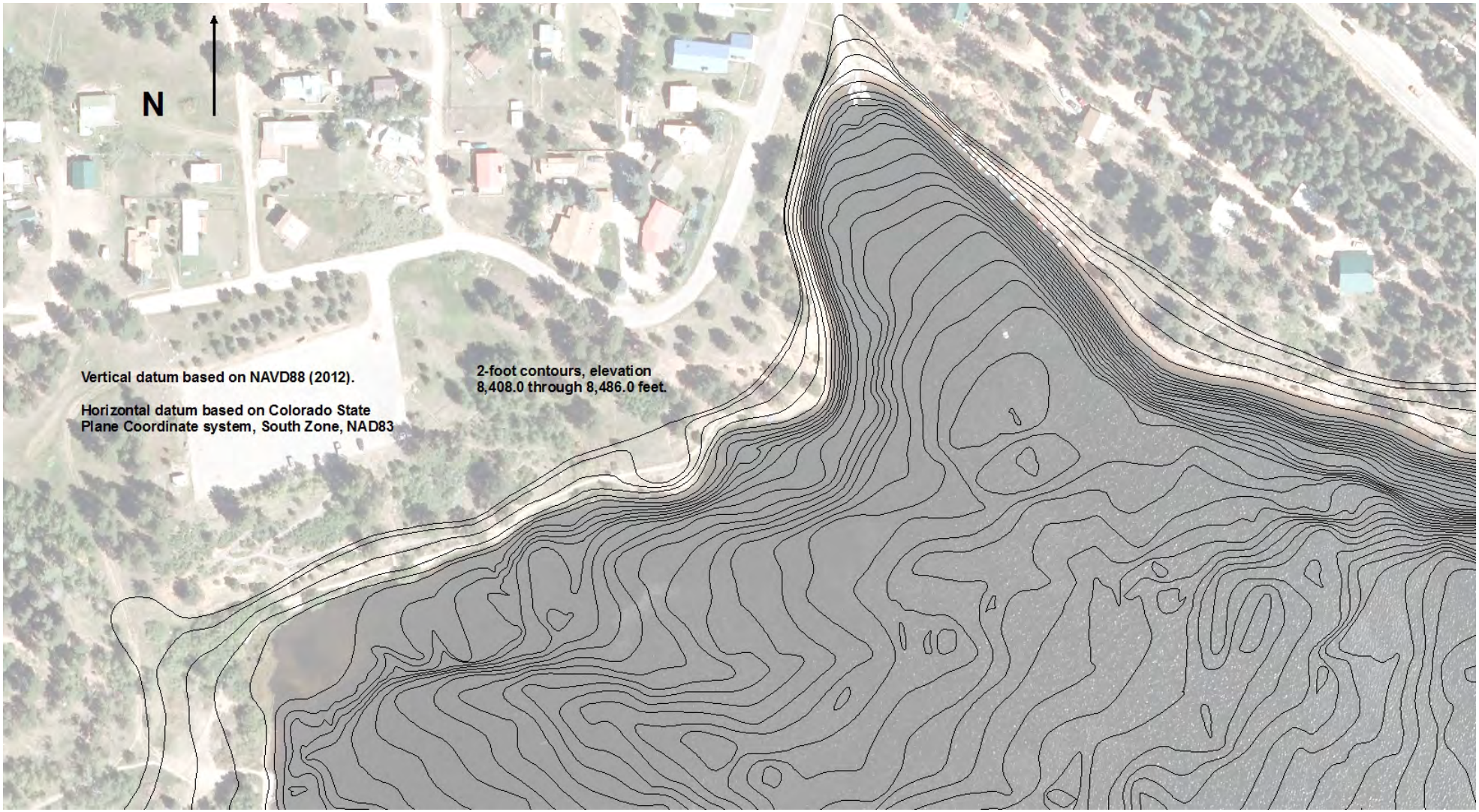

Figure 17 - Lake Isabel topography, 2-foot contours, elevation 8,408.0 through 8,486.0 (map 4 of 5).

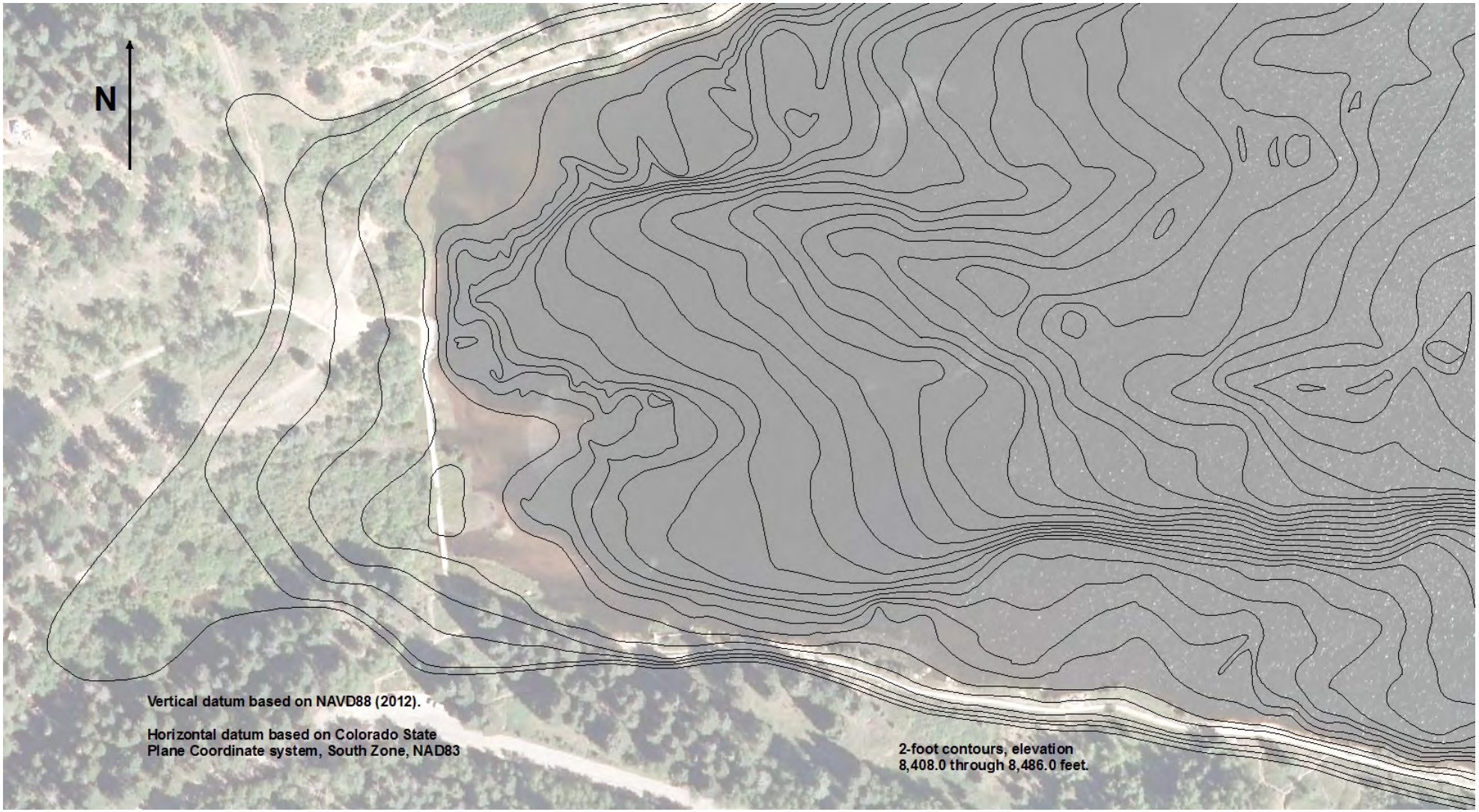

Figure 18 - Lake Isabel topography, 2-foot contours, elevation 8,408.0 through 8,486.0 (map 5 of 5).

2012 Lake Isabel Surface Area Methods

Using ArcGIS commands, 2012 surface areas for Lake Isabel were computed at 2- and 5-foot increments directly from the reservoir TIN from minimum elevation 8,405.0 to elevation 8,486.0. These computed areas provided information for developing the area-capacity tables.

2012 Lake Isabel Storage Capacity Methods

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Bureau of Reclamation, 1985). The ACAP program computes the area and capacity at user-defined elevation increments from 0.01 to 1.0 foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit. The error limit was set at 0.000001 for Lake Isabel. The capacity equation is then used over the full range of intervals fitting within the allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from basic area curve over that interval) is utilized until it exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Through differentiation of the capacity equations, which are of second order polynomial form, final area equations are derived:

$$y = a_1 + a_2x + a_3x^2$$

where:
- y = capacity
- x = elevation above a reference base
- a_1 = intercept
- a_2 and a_3 = coefficients

Results of the Lake Isabel area and capacity computations are listed in the appendix at the end of this report as 0.1 foot elevation increments. A description of the computations and coefficients output from the ACAP program is included with these tables. As of September 2012, at spillway crest elevation 8,477.7, the surface area was 35.7 acres with a total capacity of 969.8 acre-feet. The tables were extended to elevation 8,484.0, the maximum elevation of the reservoir before it would overtop the dam at its lowest point (located directly over the spillway structure).

Lake Isabel Surface Area and Capacity Results

This section provides 2012 surface area and capacity results for Lake Isabel. The developed area and capacity tables at 0.1 foot increments are attached in the appendix of this report and are also available as a separate report in 1, 0.1, and 0.01-foot increments (Reclamation, 2012b). The 2012 results are presented as area and capacity curves in Figure 19. For operation purposes, the current staff gage is set at 3.29 feet at spillway crest elevation 8,477.7.

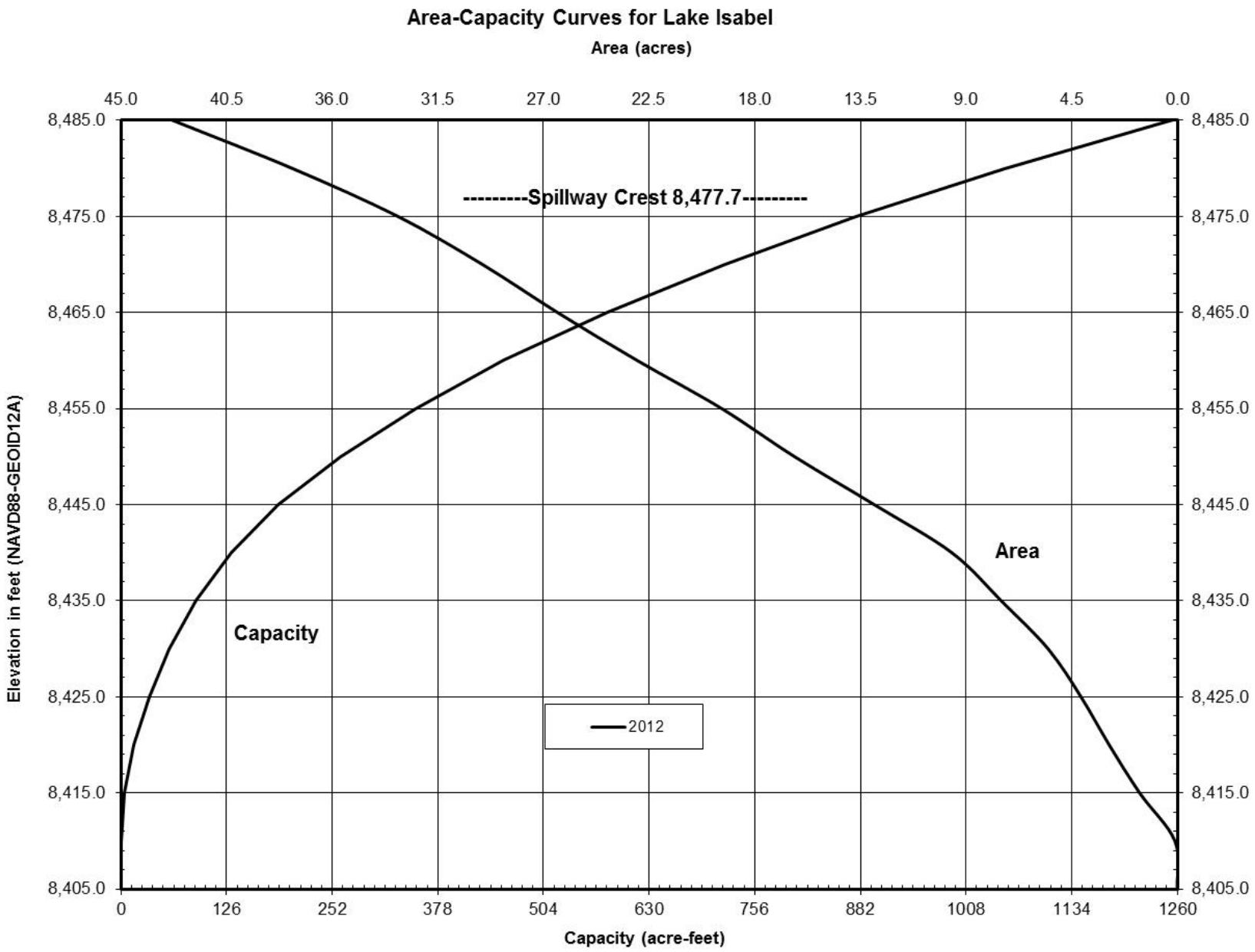

Figure 19 - Lake Isabel area and capacity plots.

Summary and Conclusions

This Reclamation report presents the results of the September 2012 survey of Lake Isabel . The primary objectives of the survey were to gather data needed to:

- develop reservoir topography; and
- compute area-capacity relationships

A control survey was conducted using the online positioning user service (OPUS) and RTK GPS to confirm the horizontal and vertical control network near the reservoir for the hydrographic survey. OPUS is operated by the NGS and allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The GPS base was set over the NGS monument "Lorelei" and provided continuous radio link throughout the hydrographic survey.

The study's horizontal control was in feet, Colorado south state plane coordinates, in NAD83. The vertical control, in US survey feet, was tied to NAVD88, geoid model 2012A (GEOID12A). Unless noted, all elevations in this report are referenced to NAVD88 (GEOID12A).

The September 2012 hydrographic survey was conducted at reservoir elevation 8,476.1, measured by RTK GPS. The bathymetric survey used sonic depth recording equipment interfaced with a RTK GPS for determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along grid lines covering Lake Isabel. The positioning system provided information to allow the boat operator to maintain a course along these grid lines, except areas where dense bottom vegetation prevented the survey boat from accessing. These areas were limited and did not significantly effect underwater contour development.

The above-water topography was determined from RTK GPS measurements that were collected at the same time as the bathymetric survey, and digitized contours from USGS quad maps. Above-water data acquisition consisted primarily of walking the shoreline, collecting topographic points along the water's edge and up the slope from the reservoir body. Due to vegetation and the steep slope of the topography, there were areas of the reservoir where RTK GPS measurements were not obtained. To allow complete contour development to the top of the dam (elevation 8,484.0) in these limited access areas, digitized breaklines were developed from portions of the USGS quad contour lines around the reservoir. These breaklines were only used in limited areas of the reservoir to complete topography above the main operating range of the reservoir up to elevation 8,479.

To eliminate the need for the USGS quad breaklines, a detailed aerial survey of the reservoir would be required.

The 2012 Lake Isabel topographic map is a combination of the digitized USGS quad map contours, the 2012 topographic survey, and the 2012 hydrographic survey data, all tied to the vertical datum NAVD88 (GEOID12A). The 2012 data set was the main component for the topographic development. A computer program was used to generate the 2012 topography and resulting reservoir surface areas at predetermined contour intervals from the combined reservoir data from top of dam elevation 8,484.0 and below. The 2012 area and capacity tables were produced by a computer program (ACAP) that calculated area and capacity values at prescribed elevation increments using the measured contour surface areas and a curve-fitting technique. The tables are located in the appendix.

The original Lake Isabel capacity table showed a gage height of 0.0 at elevation 8,363.0 (project vertical datum) and a gage height of 74.25 at the spillway crest, elevation 8,437.25 (project vertical datum). The original first computed surface area was at gage height 3.0 or elevation 8,366.0 (project vertical datum) corresponding to a depth of 71.25 feet. The original capacity at the spillway crest was 981.0 acre-feet.

The September 2012 survey measured the minimum reservoir bottom at elevation 8,405.0 with first computed surface area at elevation 8,406.0. The September 2012 computed capacity was 969.8 acre-feet at spillway crest elevation 8,477.7. From the first measured surface area, elevation 8,406.0, to spillway crest elevation 8,477.7, the reservoir depth is 71.7 feet. This is admittedly a rough comparison, but it appears there has been little to no loss of reservoir depth over the years of operation since dam closure. The study did measure a capacity loss of 11.2 acre-feet or 1.1 percent of the original. If the intake to the outlet works is located on the bottom of the reservoir, it appears any material that deposits near this area is flushed downstream. The capacity change could be due to sediment deposition in the upper reservoir, as seen in Figure 3, along with the differences in survey and computation methods.

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Appendix

LAKE ISABEL AREA AND CAPACITY TABLES

EQUATIONS --> AREA = A2 + X*(A3 + A3)

$$\text{--> CAPACITY} = A3*X^2 + A2*X + A1$$

WHERE X = THE DIFFERENCE BETWEEN THE BASE ELEVATION AND A GIVEN ELEVATION. AREA IS IN ACRES AND CAPACITY IS IN ACRE-FEET

LAKE ISABEL
2012 AREA-CAPACITY TABLES

EQUATION NUMBER	ELEVATION BASE	CAPACITY BASE	COEFFICIENT A1(INTERCEPT)	COEFFICIENT A2(1ST TERM)	COEFFICIENT A3(2ND TERM)
1	8405.00	0	0.0000	0.0000	0.0025
2	8407.00	0	0.0100	0.0100	0.0050
3	8408.00	0	0.0250	0.0200	0.0125
4	8410.00	0	0.1150	0.0700	0.1900
5	8412.00	1	1.0150	0.8300	0.1400
6	8414.00	3	3.2350	1.3900	0.1050
7	8416.00	6	6.4350	1.8100	0.1300
8	8418.00	10	10.5750	2.3300	0.1450
9	8420.00	15	15.8150	2.9100	0.1250
10	8422.00	22	22.1350	3.4100	0.1150
11	8424.00	29	29.4150	3.8700	0.1250
12	8425.00	33	33.4100	4.1200	0.1300
13	8426.00	37	37.6600	4.3800	0.1425
14	8428.00	46	46.9900	4.9500	0.1275
15	8430.00	57	57.4000	5.4600	0.1800
16	8432.00	69	69.0400	6.1800	0.2100
17	8434.00	82	82.2400	7.0200	0.2300
18	8435.00	89	89.4900	7.4800	0.2200
19	8436.00	97	97.1900	7.9200	0.2125
20	8438.00	113	113.8800	8.7700	0.2175
21	8440.00	132	132.2900	9.6400	0.2600
22	8442.00	152	152.6100	10.6800	0.3600
23	8444.00	175	175.4100	12.1200	0.4000
24	8445.00	187	187.9300	12.9200	0.4150
25	8446.00	201	201.2650	13.7500	0.3525
26	8448.00	230	230.1750	15.1600	0.2775
27	8450.00	261	261.6050	16.2700	0.2950
28	8452.00	295	295.3250	17.4500	0.3225
29	8454.00	331	331.5150	18.7400	0.3400
30	8455.00	350	350.5950	19.4200	0.3300
31	8456.00	370	370.3450	20.0800	0.3575
32	8458.00	411	411.9350	21.5100	0.3700
33	8460.00	456	456.4350	22.9900	0.3525
34	8462.00	503	503.8250	24.4000	0.3400
35	8464.00	553	553.9850	25.7600	0.3200
36	8465.00	580	580.0650	26.4000	0.3700
37	8466.00	606	606.8350	27.1400	0.3150
38	8468.00	662	662.3750	28.4000	0.2875
39	8470.00	720	720.3250	29.5500	0.3375
40	8472.00	780	780.7750	30.9000	0.3875
41	8474.00	844	844.1250	32.4501	0.3999
42	8475.00	876	876.9750	33.2500	0.3901
43	8476.00	910	910.6150	34.0300	0.4775
44	8478.00	980	980.5850	35.9400	0.4450
45	8480.00	1054	1054.2450	37.7200	0.4375
46	8482.00	1131	1131.4351	39.4700	0.4575
47	8484.00	1212	1212.2051	41.3001	0.7499
48	8485.00	1254	1254.2551	42.8000	0.2850
49	8486.00	1297	1297.3401	43.3700	0.2725

The current staff gage is set at 3.29 feet at spillway crest elevation 8,477.7.

LAKE ISABEL (ACAP92) COMPUTED
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2012 AREA-CAPACITY TABLES 7:59:47

THE AREA TABLE IS IN ACRES THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8405	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8406	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8407	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8408	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8409	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
8410	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4
8411	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8
8412	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1
8413	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.4
8414	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.6	1.6
8415	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.8
8416	1.8	1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0
8417	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3
8418	2.3	2.4	2.4	2.4	2.4	2.5	2.5	2.5	2.6	2.6
8419	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9
8420	2.9	2.9	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1
8421	3.2	3.2	3.2	3.2	3.3	3.3	3.3	3.3	3.4	3.4
8422	3.4	3.4	3.5	3.5	3.5	3.5	3.5	3.6	3.6	3.6
8423	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.8	3.8
8424	3.9	3.9	3.9	3.9	4.0	4.0	4.0	4.0	4.1	4.1
8425	4.1	4.1	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.4
8426	4.4	4.4	4.4	4.5	4.5	4.5	4.6	4.6	4.6	4.6
8427	4.7	4.7	4.7	4.8	4.8	4.8	4.8	4.9	4.9	4.9
8428	4.9	5.0	5.0	5.0	5.1	5.1	5.1	5.1	5.2	5.2
8429	5.2	5.2	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4
8430	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.8
8431	5.8	5.9	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1
8432	6.2	6.2	6.3	6.3	6.3	6.4	6.4	6.5	6.5	6.6
8433	6.6	6.6	6.7	6.7	6.8	6.8	6.9	6.9	6.9	7.0
8434	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.4
8435	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9
8436	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.3
8437	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7
8438	8.8	8.8	8.9	8.9	8.9	9.0	9.0	9.1	9.1	9.2
8439	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6
8440	9.6	9.7	9.7	9.8	9.8	9.9	10.0	10.0	10.1	10.1
8441	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6
8442	10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.2	11.3	11.3
8443	11.4	11.5	11.5	11.6	11.7	11.8	11.8	11.9	12.0	12.0
8444	12.1	12.2	12.3	12.4	12.4	12.5	12.6	12.7	12.8	12.8

LAKE ISABEL (ACAP92) COMPUTED
11/ 5/2012
2012 AREA-CAPACITY TABLES 7:59:47

THE AREA TABLE IS IN ACRES THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8445	12.9	13.0	13.1	13.2	13.3	13.3	13.4	13.5	13.6	13.7
8446	13.8	13.8	13.9	14.0	14.0	14.1	14.2	14.2	14.3	14.4
8447	14.5	14.5	14.6	14.7	14.7	14.8	14.9	14.9	15.0	15.1
8448	15.2	15.2	15.3	15.3	15.4	15.4	15.5	15.5	15.6	15.7
8449	15.7	15.8	15.8	15.9	15.9	16.0	16.0	16.1	16.2	16.2
8450	16.3	16.3	16.4	16.4	16.5	16.6	16.6	16.7	16.7	16.8
8451	16.9	16.9	17.0	17.0	17.1	17.2	17.2	17.3	17.3	17.4
8452	17.5	17.5	17.6	17.6	17.7	17.8	17.8	17.9	18.0	18.0
8453	18.1	18.2	18.2	18.3	18.4	18.4	18.5	18.5	18.6	18.7
8454	18.7	18.8	18.9	18.9	19.0	19.1	19.1	19.2	19.3	19.4
8455	19.4	19.5	19.6	19.6	19.7	19.7	19.8	19.9	19.9	20.0
8456	20.1	20.2	20.2	20.3	20.4	20.4	20.5	20.6	20.7	20.7
8457	20.8	20.9	20.9	21.0	21.1	21.2	21.2	21.3	21.4	21.4
8458	21.5	21.6	21.7	21.7	21.8	21.9	22.0	22.0	22.1	22.2
8459	22.2	22.3	22.4	22.5	22.5	22.6	22.7	22.8	22.8	22.9
8460	23.0	23.1	23.1	23.2	23.3	23.3	23.4	23.5	23.6	23.6
8461	23.7	23.8	23.8	23.9	24.0	24.0	24.1	24.2	24.3	24.3
8462	24.4	24.5	24.5	24.6	24.7	24.7	24.8	24.9	24.9	25.0
8463	25.1	25.1	25.2	25.3	25.4	25.4	25.5	25.6	25.6	25.7
8464	25.8	25.8	25.9	26.0	26.0	26.1	26.1	26.2	26.3	26.3
8465	26.4	26.5	26.5	26.6	26.7	26.8	26.8	26.9	27.0	27.1
8466	27.1	27.2	27.3	27.3	27.4	27.5	27.5	27.6	27.6	27.7
8467	27.8	27.8	27.9	28.0	28.0	28.1	28.1	28.2	28.3	28.3
8468	28.4	28.5	28.5	28.6	28.6	28.7	28.7	28.8	28.9	28.9
8469	29.0	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.4	29.5
8470	29.6	29.6	29.7	29.8	29.8	29.9	30.0	30.0	30.1	30.2
8471	30.2	30.3	30.4	30.4	30.5	30.6	30.6	30.7	30.8	30.8
8472	30.9	31.0	31.1	31.1	31.2	31.3	31.4	31.4	31.5	31.6
8473	31.7	31.8	31.8	31.9	32.0	32.1	32.1	32.2	32.3	32.4
8474	32.4	32.5	32.6	32.7	32.8	32.8	32.9	33.0	33.1	33.2
8475	33.2	33.3	33.4	33.5	33.6	33.6	33.7	33.8	33.9	34.0
8476	34.0	34.1	34.2	34.3	34.4	34.5	34.6	34.7	34.8	34.9
8477	35.0	35.1	35.2	35.3	35.4	35.5	35.6	**35.7**	35.7	35.8
8478	35.9	36.0	36.1	36.2	36.3	36.4	36.5	36.6	36.7	36.7
8479	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.5	37.5	37.6
8480	37.7	37.8	37.9	38.0	38.1	38.2	38.2	38.3	38.4	38.5
8481	38.6	38.7	38.8	38.9	38.9	39.0	39.1	39.2	39.3	39.4
8482	39.5	39.6	39.7	39.7	39.8	39.9	40.0	40.1	40.2	40.3
8483	40.4	40.5	40.6	40.7	40.8	40.8	40.9	41.0	41.1	41.2
8484	41.3									

LAKE ISABEL (ACAP92) COMPUTED
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2012 AREA-CAPACITY TABLES 7:59:47

THE CAPACITY TABLE IS IN ACRE FEET THE ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8405	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8406	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8407	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8408	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
8409	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
8410	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3
8411	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.8	0.9	0.9
8412	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
8413	2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	3.0	3.1
8414	3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4	4.6
8415	4.7	4.9	5.1	5.2	5.4	5.6	5.7	5.9	6.1	6.3
8416	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
8417	8.4	8.6	8.8	9.0	9.2	9.4	9.7	9.9	10.1	10.3
8418	10.6	10.8	11.0	11.3	11.5	11.8	12.0	12.3	12.5	12.8
8419	13.0	13.3	13.6	13.8	14.1	14.4	14.7	15.0	15.2	15.5
8420	15.8	16.1	16.4	16.7	17.0	17.3	17.6	17.9	18.2	18.5
8421	18.9	19.2	19.5	19.8	20.1	20.5	20.8	21.1	21.5	21.8
8422	22.1	22.5	22.8	23.2	23.5	23.9	24.2	24.6	24.9	25.3
8423	25.7	26.0	26.4	26.8	27.1	27.5	27.9	28.3	28.6	29.0
8424	29.4	29.8	30.2	30.6	31.0	31.4	31.8	32.2	32.6	33.0
8425	33.4	33.8	34.2	34.7	35.1	35.5	35.9	36.4	36.8	37.2
8426	37.7	38.1	38.5	39.0	39.4	39.9	40.3	40.8	41.3	41.7
8427	42.2	42.7	43.1	43.6	44.1	44.6	45.0	45.5	46.0	46.5
8428	47.0	47.5	48.0	48.5	49.0	49.5	50.0	50.5	51.0	51.5
8429	52.1	52.6	53.1	53.6	54.2	54.7	55.2	55.8	56.3	56.9
8430	57.4	57.9	58.5	59.1	59.6	60.2	60.7	61.3	61.9	62.5
8431	63.0	63.6	64.2	64.8	65.4	66.0	66.6	67.2	67.8	68.4
8432	69.0	69.7	70.3	70.9	71.5	72.2	72.8	73.5	74.1	74.8
8433	75.4	76.1	76.8	77.4	78.1	78.8	79.5	80.2	80.8	81.5
8434	82.2	82.9	83.7	84.4	85.1	85.8	86.5	87.3	88.0	88.7
8435	89.5	90.2	91.0	91.8	92.5	93.3	94.1	94.8	95.6	96.4
8436	97.2	98.0	98.8	99.6	100.4	101.2	102.0	102.8	103.7	104.5
8437	105.3	106.2	107.0	107.8	108.7	109.5	110.4	111.3	112.1	113.0
8438	113.9	114.8	115.6	116.5	117.4	118.3	119.2	120.1	121.0	121.9
8439	122.9	123.8	124.7	125.6	126.6	127.5	128.5	129.4	130.4	131.3
8440	132.3	133.3	134.2	135.2	136.2	137.2	138.2	139.2	140.2	141.2
8441	142.2	143.2	144.2	145.3	146.3	147.3	148.4	149.4	150.5	151.5
8442	152.6	153.7	154.8	155.8	156.9	158.0	159.1	160.3	161.4	162.5
8443	163.6	164.8	165.9	167.1	168.3	169.4	170.6	171.8	173.0	174.2
8444	175.4	176.6	177.9	179.1	180.3	181.6	182.8	184.1	185.4	186.6

LAKE ISABEL (ACAP92) COMPUTED
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2012 AREA-CAPACITY TABLES 7:59:47

THE CAPACITY TABLE IS IN ACRE FEET THE ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8445	187.9	189.2	190.5	191.8	193.2	194.5	195.8	197.2	198.5	199.9
8446	201.3	202.6	204.0	205.4	206.8	208.2	209.6	211.1	212.5	213.9
8447	215.4	216.8	218.3	219.7	221.2	222.7	224.2	225.7	227.2	228.7
8448	230.2	231.7	233.2	234.7	236.3	237.8	239.4	240.9	242.5	244.0
8449	245.6	247.2	248.8	250.4	251.9	253.5	255.1	256.7	258.4	260.0
8450	261.6	263.2	264.9	266.5	268.2	269.8	271.5	273.1	274.8	276.5
8451	278.2	279.9	281.6	283.3	285.0	286.7	288.4	290.1	291.8	293.6
8452	295.3	297.1	298.8	300.6	302.4	304.1	305.9	307.7	309.5	311.3
8453	313.1	314.9	316.7	318.6	320.4	322.2	324.1	325.9	327.8	329.6
8454	331.5	333.4	335.3	337.2	339.1	341.0	342.9	344.8	346.7	348.7
8455	350.6	352.5	354.5	356.5	358.4	360.4	362.4	364.4	366.3	368.3
8456	370.3	372.4	374.4	376.4	378.4	380.5	382.5	384.6	386.6	388.7
8457	390.8	392.9	395.0	397.1	399.2	401.3	403.4	405.5	407.6	409.8
8458	411.9	414.1	416.3	418.4	420.6	422.8	425.0	427.2	429.4	431.6
8459	433.8	436.0	438.3	440.5	442.8	445.0	447.3	449.6	451.9	454.1
8460	456.4	458.7	461.0	463.4	465.7	468.0	470.4	472.7	475.1	477.4
8461	479.8	482.2	484.5	486.9	489.3	491.7	494.1	496.5	499.0	501.4
8462	503.8	506.3	508.7	511.2	513.6	516.1	518.6	521.1	523.6	526.1
8463	528.6	531.1	533.6	536.1	538.7	541.2	543.7	546.3	548.8	551.4
8464	554.0	556.6	559.1	561.7	564.3	566.9	569.6	572.2	574.8	577.4
8465	580.1	582.7	585.4	588.0	590.7	593.4	596.0	598.7	601.4	604.1
8466	606.8	609.6	612.3	615.0	617.7	620.5	623.2	626.0	628.7	631.5
8467	634.3	637.1	639.9	642.6	645.4	648.3	651.1	653.9	656.7	659.5
8468	662.4	665.2	668.1	670.9	673.8	676.6	679.5	682.4	685.3	688.2
8469	691.1	694.0	696.9	699.8	702.7	705.6	708.6	711.5	714.4	717.4
8470	720.3	723.3	726.2	729.2	732.2	735.2	738.2	741.2	744.2	747.2
8471	750.2	753.2	756.3	759.3	762.4	765.4	768.5	771.5	774.6	777.7
8472	780.8	783.9	787.0	790.1	793.2	796.3	799.5	802.6	805.7	808.9
8473	812.1	815.2	818.4	821.6	824.8	828.0	831.2	834.4	837.7	840.9
8474	844.1	847.4	850.6	853.9	857.2	860.5	863.7	867.0	870.3	873.7
8475	877.0	880.3	883.6	887.0	890.3	893.7	897.1	900.4	903.8	907.2
8476	910.6	914.0	917.4	920.9	924.3	927.7	931.2	934.7	938.1	941.6
8477	945.1	948.6	952.1	955.7	959.2	962.7	966.3	**969.8**	973.4	977.0
8478	980.6	984.2	987.8	991.4	995.0	998.7	1002.3	1006.0	1009.6	1013.3
8479	1017.0	1020.7	1024.4	1028.1	1031.8	1035.5	1039.2	1043.0	1046.7	1050.5
8480	1054.2	1058.0	1061.8	1065.6	1069.4	1073.2	1077.0	1080.9	1084.7	1088.5
8481	1092.4	1096.3	1100.1	1104.0	1107.9	1111.8	1115.7	1119.6	1123.6	1127.5
8482	1131.4	1135.4	1139.3	1143.3	1147.3	1151.3	1155.3	1159.3	1163.3	1167.3
8483	1171.4	1175.4	1179.5	1183.5	1187.6	1191.7	1195.8	1199.9	1204.0	1208.1
8484	1212.2									

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Reclamation and the Service surveyed Lake Isabel in September 2012 to develop updated reservoir topography and compute the present storage-elevation relationship (area-capacity tables). The bathymetric survey was conducted near water surface elevation 8,476.1 feet (NAVD88, GEOID12A) using sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided continuous sounding positions throughout the underwater portion of the reservoir covered by the survey vessels. The measured water surface on September 24, 2012, at gage reading 1.73, was elevation 8,476.13. The above-water geometry was obtained from RTK GPS topographic measurements and digitized 40-foot interval contours from United States Geological Survey (USGS) quad maps. All elevations are tied to the North America Vertical Datum of 1988 (NAVD88) using the 2012A geoid model. Except for control point information, all data presented in this report were rounded to the nearest tenth of a foot.

As of September 2012, at spillway crest elevation 8,477.7, the reservoir surface area was 35.7 acres with a capacity of 969.8 acre-feet.

15. SUBJECT TERMS

reservoir area and capacity/ sedimentation/ reservoir surveys/ global positioning system/ sounders/ contour area/ RTK GPS/

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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