DRAFT MEMORANDUM

Project No.: 120045-007-7c

November 18, 2014

To: Mike Kaputa, Chelan County Department of Natural Resources

cc: Tony Jantzer, Icicle Peshastin Irrigation District

From: **Carl M. Einberger, LHG**
Associate Hydrogeologist

Daniel R. Haller, PE
Senior Associate Engineer

Re: **Bathymetry and Topographic Survey of Upper Klonaqua Lake and Conceptual Release Options**

This memo presents results of a bathymetry and limited topographic survey of Upper Klonaqua Lake and conceptual options to allow water storage in the lake to be released and used by the Icicle Peshastin Irrigation District (IPID). Upper Klonaqua Lake is located in the Icicle Creek Sub-basin of WRIA 45 (Wenatchee Basin) and is used, along with several other area lakes, to augment water supply for Icicle and Peshastin Irrigation District (Figure 1). There are multiple competing demands for water in the Icicle Creek Sub-basin, and instream flows are often not met. Access to waters stored in Upper Klonaqua Lake may help to provide more reliable instream flows during critical times of year which would provide benefit to the IPID and other stakeholders with interests in Icicle Creek instream flows.

This work was completed by Aspect Consulting, LLC (Aspect) and Gravity Consulting LLC (Gravity) on behalf of the Chelan County Department of Natural Resources.

Description of Bathymetry and Topographic Survey

On September 20, 2014, Gravity mobilized survey equipment and an inflatable kayak via helicopter to Upper Klonaqua Lake for bathymetry and water level survey. For single-beam bathymetry data collection, Gravity paired a Sonarmite single-beam echosounder with a Trimble R10 (GNSS/GLONASS) Receiver to collect the data from the inflatable kayak. The survey team installed all equipment onto a two-pole mounted system with fixed offsets to balance weight and minimize offset errors. For water level and land surveying, Gravity mounted a Trimble R10 (GNSS/GLONASS) Receiver to a two-meter rover tripod. To obtain Real-Time Kinematic (RTK) precision with the survey, a base station was setup on the ridge between the lakes using a Trimble R8 (GNSS/GLONAA) Receiver.

After installation of base station, rovers and measurement of all vertical offsets, the survey team configured all hardware drivers for the referenced instruments in the Trimble Access survey software package. After operational testing on land with both roving receivers, the survey team began surveying the lake, shoreline and topographical features around the lake, including benchmark surveys. Vertical survey data resolution, as reported by the RTK fix, was found to be equal to or less than 0.08 feet accuracy.

Survey Operations

Between September 20 and 23, Gravity performed the surveys in and around the Upper Klonaqua Lake. These surveys included: bathymetry in the lake, waterline along the lake shore, historic high waterline, and topographical features around the lake.

From the inflatable kayak setup, the lake was surveyed around the parameter to about 1 foot water depth then at 75- to 100-foot transects along both the north-south and east-west lines. The land rover was then used to obtain the waterline measurement and historic highwater mark. Waterline measurements were obtained every 100 feet around the lake, where possible, including the island on the north end of the lake. There was minimal difference in the waterline measurement and historic high waterline. In most cases, this difference was around 1 foot. The land rover receiver was also used to survey the saddle between Upper and Lower Klonaqua Lakes. Obtaining a good RTK fix was difficult in some locations due to the thick tree cover.

In addition to the primary objective of surveying the Upper Klonaqua, Lower Klonaqua Lake was also surveyed at the waterline, the historic highwater mark, and with a single bathymetry transect to obtain maximum depth. Although basic information for Lower Klonaqua Lake was obtained as part of this study, a comprehensive detailed bathymetry survey for Lower Klonaqua Lake was not performed, and therefore storage volumes in that lake must still be estimated with a potentially wide margin of error.

Data Processing

Post-processing of the data was conducted in Trimble Access Survey software, Microsoft Excel and ArcGIS 10.2. Processing consisted of review and removal of anomalous data. Data points with no depth logged were removed. Overlapping data points were reviewed for accuracy. Additionally, data consisted of plotting data points in ArcGIS. Using the ArcGIS's 3D analyst extension, the data was used to create a Triangulated Irregular Network (TIN) coverage. From this data, surface area and volume was calculated. See Figure E for volume calculations.

All data has been reduced to North American Vertical Datum of 1988 elevations. The horizontal datum references the North American Datum of 1983, State Plane, Washington State North Zone 4601, Feet.

Survey Results and Conceptual Release Options

Bathymetry and Topographic Observations

Figure A illustrates the bathymetry in plan view with depth contours. Elevations of the lake range from a highwater line of 5,199.1 feet, to a minimum lakebed elevation of approximately 5,044 feet, and an associated maximum depth of approximately 154 feet. Along the western edge of the lake is a bedrock ridge that serves as barrier between the Upper and Lower Klonaqua Lakes. The outlet from the upper to the lower lake is located in the extreme northeast corner of the lake, where a small stream drains overflow from the lake through a wetland area, and then down the steep bedrock ridge to the lower lake.

Figure B presents a northern and a southern cross-sectional profiles extending general west-to-east through the lake. The profiles illustrate that significantly more lakebed topography is present in the northern portion of the lake and approaching the area of the outlet at the northeast corner of the

lake. Figure C illustrates the measured bathymetry from a three-dimensional perspective. The bedrock ridge separating the two lakes is clearly evident along the right side of the depiction.

At the request of Tony Janzter of IPID, Gravity prepared a series of two- and three- dimensional water level elevation plots (Figures D and D2) to illustrate the nature of potential drawdown in Upper Klonaqua Lake using 10-foot increments. These data allow water volumes to be calculated that could be obtained for release from the lake. Volume calculations are summarized on Figure E and presented in more detail below. The difference in water level elevations between the upper and lower lake was measured at 115.8 feet.

Potential Release Volumes

The IPID holds an adjudicated water right for storage and release of a total of 2,500 acre-feet/year (afy) for the combined Upper and Lower Klonaqua Lakes system. Currently, the IPID is only able to release from Lower Klonaqua Lake. One estimate of capacity for Lower Klonaqua indicates that approximately 1,920 acre-feet (af) of useable storage may be available in that lake[1], however additional survey is necessary in order to verify that number. The amount of additional water available through drawdown of Upper Klonaqua Lake is summarized in the following table, based on the 10-foot drawdown increments evaluated by Gravity (Figure E):

Drawdown (feet)	Water Level Elevation (feet)	Release Volume Available (AF)
Baseline (Surveyed Water Level on 9/14)	5,198.1	-
10	5,188.1	613.4
20	5,178.1	1,146.2
30	5,168.1	1,621.1
40	5,158.1	2,053.4
50	5,148.1	2,448.2

Conceptual Release Options

Three conceptual options are under consideration by IPID for allowing access to water stored in Upper Klonaqua Lake and convey it to Lower Klonaqua Lake and from there through the existing system to Icicle Creek and IPID uses:

- **Siphoning.** Siphoning involves the use of a pipe for hydraulic conveyance over an intermediate high point by gravity using differential pressure between a reservoir surface

[1]Source of Usable Storage Capacity Data: Spreadsheet calculations of estimated stage-storage relationships for Alpine Lakes attached to email communication from Martin Walther, Ecology Dam Safety Office, October 10, 2012.

and an outlet. While it may be possible to implement a siphon to achieve some additional drawdown potential, the maximum siphon lift at the high lake elevations is limited, and is likely on the order of 10 to 15 feet. Siphoning also has inherent operation and maintenance issues associated with initiating and maintaining a siphon. Appropriate infrastructure, including a priming pump and generator, are some of the considerations for a detailed feasibility study and design of a siphoning option.

- **Pumping.** Pumping would involve the installation of either a permanent or semi-permanent facility at the lake to lift the water over the land between the two lakes. Submersible pumps or vertical turbine pumps could provide the greatest potential drawdown but would require on-site power generation (likely diesel generator). End-suction, engine driven pumps could also be utilized, but would allow for lesser drawdown (similar to siphon limitations) and would provide limited benefit beyond submersible pump or siphoning options. Fuel consumption with a pumping option would be a significant consideration. For example, a 10 cubic feet per second (cfs) pumping system with 50-foot lift capacity may require a 60 kW diesel generator. A generator this size would have a fuel consumption of over 100 gallons of diesel per day. Other fairly significant potential environmental impacts would need to be considered and evaluated with this option including noise, emissions, spill/leak potential, etc. Physical operation of the pump, including labor, would also need to be considered.
- **Tunneling.** A tunnel option would involve drilling and blasting through the bedrock outcrop between the upper and lower lakes. The tunnel could then be equipped with an automated gate valve to control releases to the lower lake. Based on the bathymetry survey, the preferred location for tunneling would be along the southern portion of the bedrock ridge, where the slope of the lakebed is steep and is not affected by the high bedrock which is apparent in the northeast portion of the lake.

Any of the above options would require detailed feasibility studies, and design and permitting analyses.

Potential Project Benefits

Release of additional storage from Upper Klonaqua Lake could help meet the Guiding Principles adopted by the Icicle Workgroup, such as additional instream flow augmentation and additional domestic/municipal supply. For example, assuming a 60-day release scenario to correspond with late summer/fall flows in Icicle Creek, approximately 5 to 20 cfs in flow benefits could be achieved for the following storage release scenarios:

Drawdown (feet)	Release Volume (Acre-Feet)	60-Day Flow Benefit (cfs)
10	613	5.2
20	1,146	9.6
30	1,621.1	13.6
40	2,053.4	17.3
50	2,448.2	20.6

Limitations

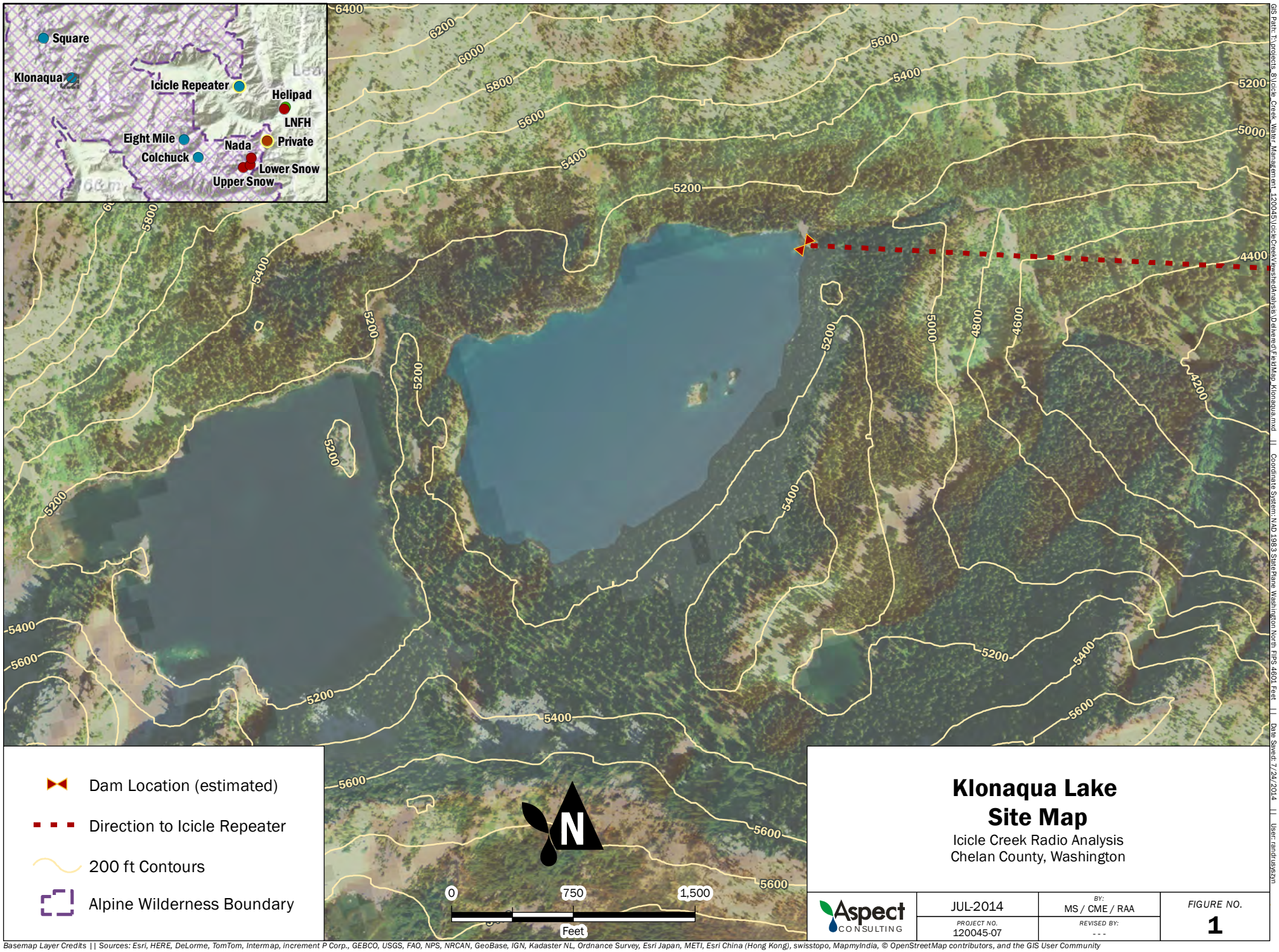
Work for this project was performed for Chelan County Department of Natural Resources (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Attachments

Figure 1 – Klonaqua Lake Site Map
Figure A – Upper Klonaqua Lake Bathymetry Elevation Grid with Depth Contours (prepared by Gravity Consulting LLC)
Figure B – Upper Klonaqua Lake Bathymetry Elevation Profile Sections (prepared by Gravity Consulting LLC)
Figure C – Upper Klonaqua Lake 3D Bathymetry Elevation Grid (prepared by Gravity Consulting LLC)
Figure D – Upper Klonaqua Lake 3D & 2D Water Level Elevations (prepared by Gravity Consulting LLC)
Figure D2 – Upper Klonaqua Lake 3D & 2D Water Level Elevations (prepared by Gravity Consulting LLC)
Figure E – Upper Klonaqua Lake Volume Calculations (prepared by Gravity Consulting LLC)

V:\120045 Chelan County\Deliverables\Upper Klonoqua Lake Conceptual Review Memo\Draft 11-18-14\Upper Klonaqua Lake Conceptual Review Draft Memo.docx



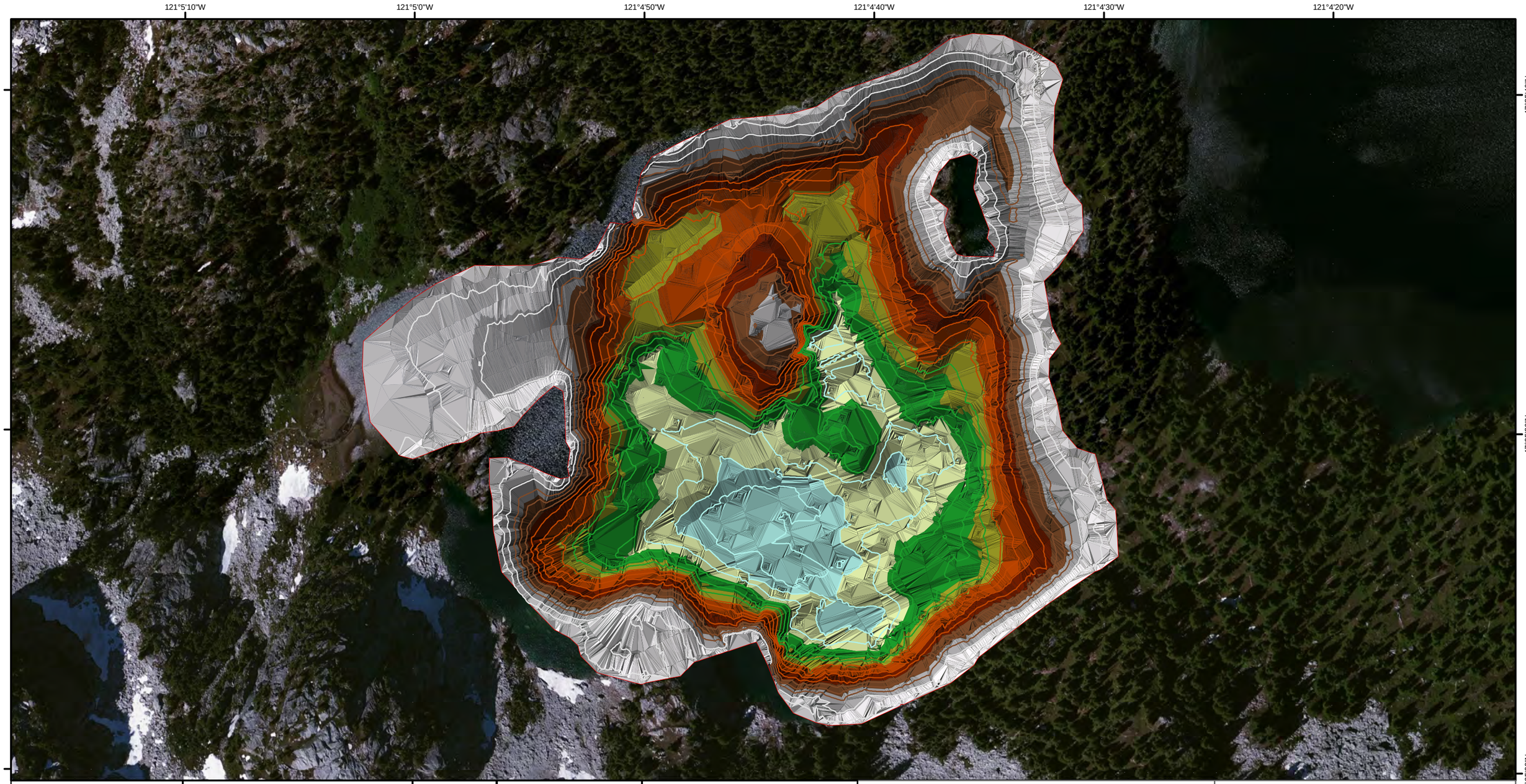
Klonaqua Lake Site Map

Icicle Creek Radio Analysis
Chelan County, Washington

Aspect CONSULTING	JUL-2014	BY: MS / CME / RAA	FIGURE NO.
	PROJECT NO. 120045-07	REVISED BY: - - -	1

GIS Path: T:\projects_8\Icicle Creek Water Management_120045\IcicleCreekViewshedAnalysis\Delivered\FieldMap_Klonaqua.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 7/24/2014 || User: randriusszyn

Basemap Layer Credits || Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Elevation - Feet

- 5181.107 - 5198.418
- 5163.797 - 5181.107
- 5146.486 - 5163.797
- 5129.176 - 5146.486
- 5111.865 - 5129.176
- 5094.555 - 5111.865
- 5077.244 - 5094.555
- 5059.934 - 5077.244
- 5042.623 - 5059.934

Depth Contours

- 0 -27 ft
- 28 -57 ft
- 58 - 97 ft
- 98 - 127 ft
- 128 - 156 ft

PROJECTION: NAD 1983 StatePlane Washington North FIPS 4601 Feet

0 100 200 400 600 800 Feet

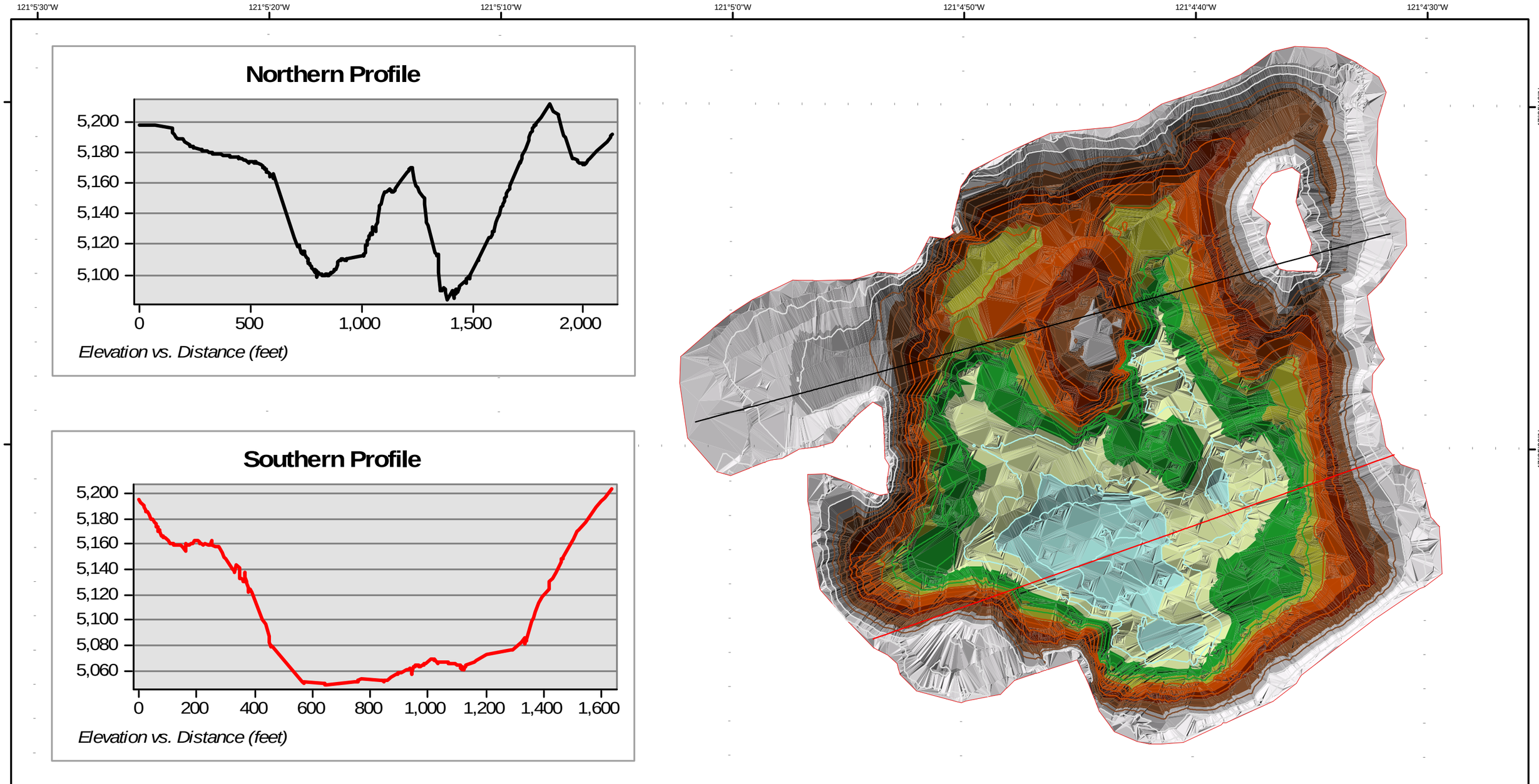
N

Figure A
Upper Klonaqua Lake Bathymetry
Elevation Grid with Depth Contours

GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

VERSION: A01
DRAWN: RM
CHECKED:
APPROVED:



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- 5146.486 - 5163.797
- 5129.176 - 5146.486
- 5111.865 - 5129.176
- 5094.555 - 5111.865
- 5077.244 - 5094.555
- 5059.934 - 5077.244
- 5042.623 - 5059.934

Depth Contours

- 0 -27 ft
- 28 -57 ft
- 58 - 97 ft
- 98 - 127 ft
- 128 - 156 ft

PROJECTION: NAD 1983 StatePlane Washington North FIPS 4601 Feet

0 100 200 400 600 800 Feet

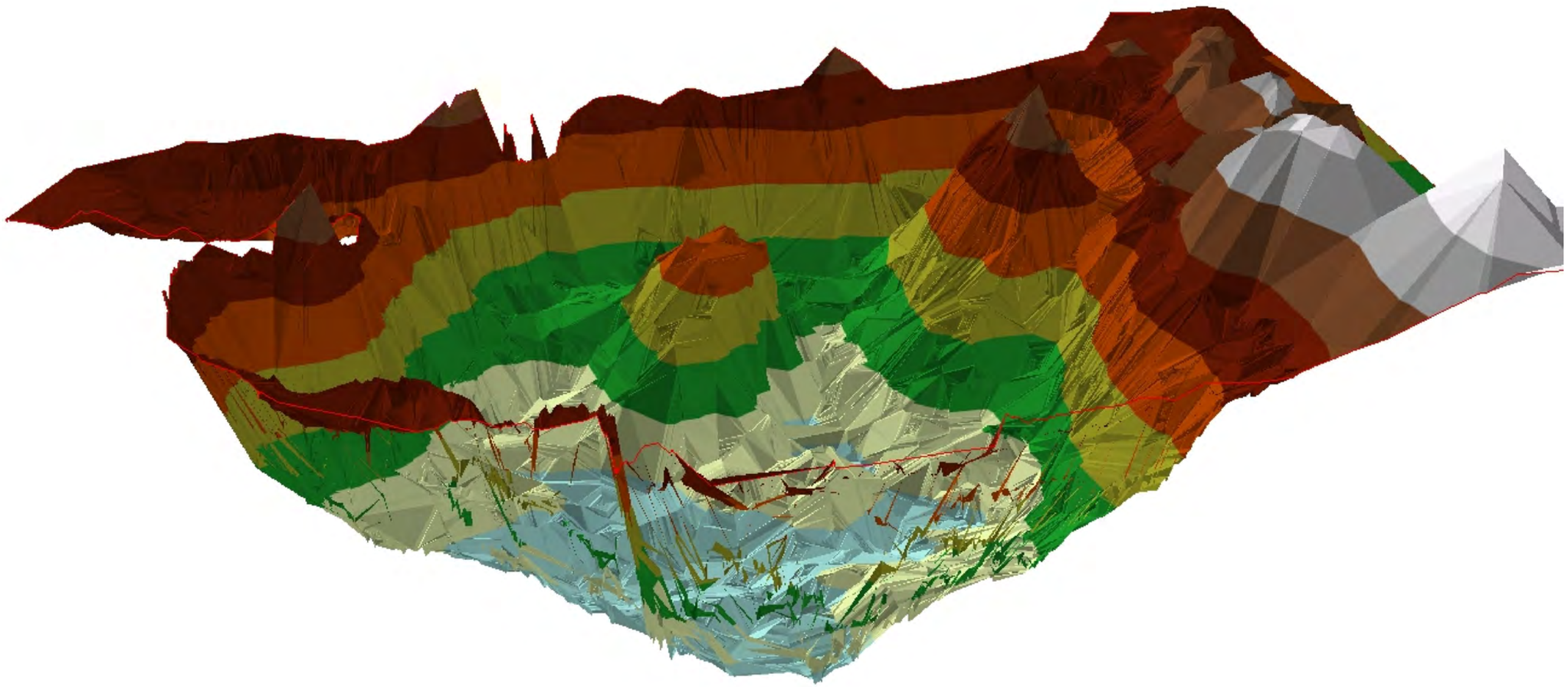
N

Figure B
Upper Klonaqua Lake Bathymetry
Elevation Profile Sections

GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

VERSION: A01
DRAWN: RM
CHECKED:
APPROVED:



Elevation - Feet

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- 5146.486 - 5163.797
- 5129.176 - 5146.486
- 5111.865 - 5129.176
- 5094.555 - 5111.865
- 5077.244 - 5094.555
- 5059.934 - 5077.244
- 5042.623 - 5059.934

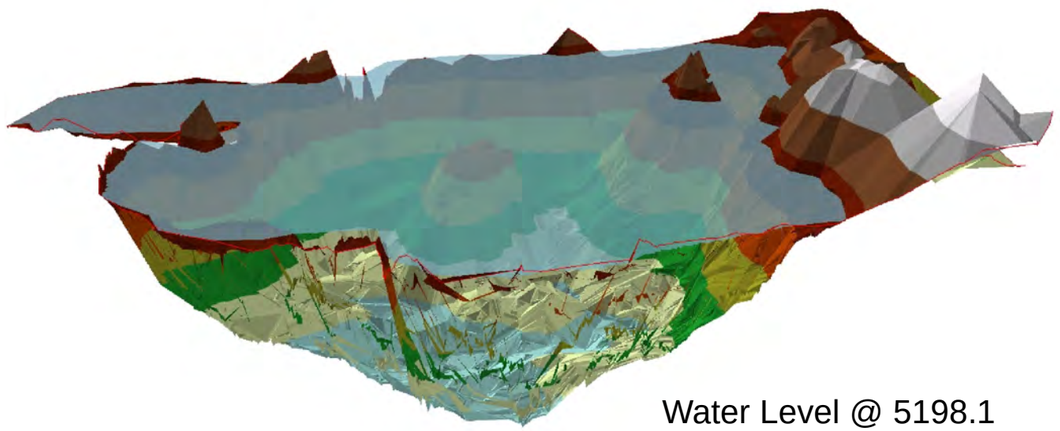
Note: 3D Image is not to scale.

Figure C
Upper Klonaqua Lake
3D Bathymetry Elevation Grid

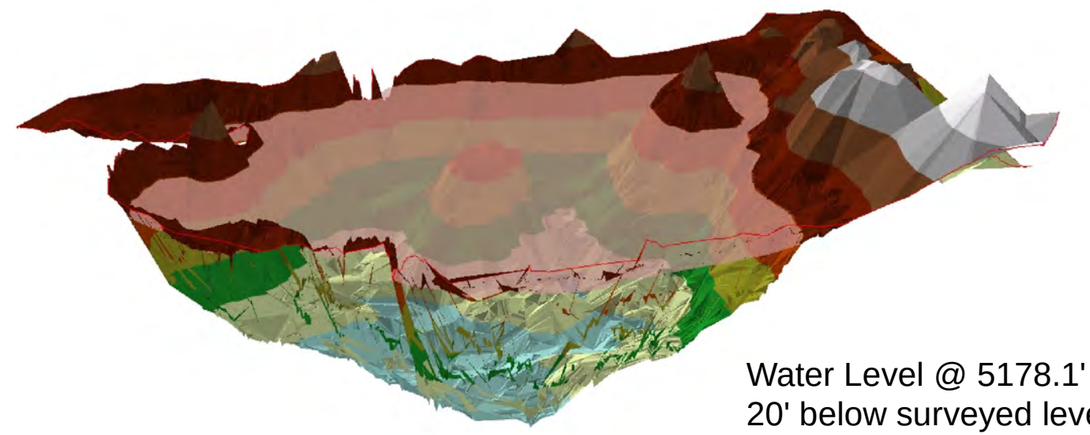
GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

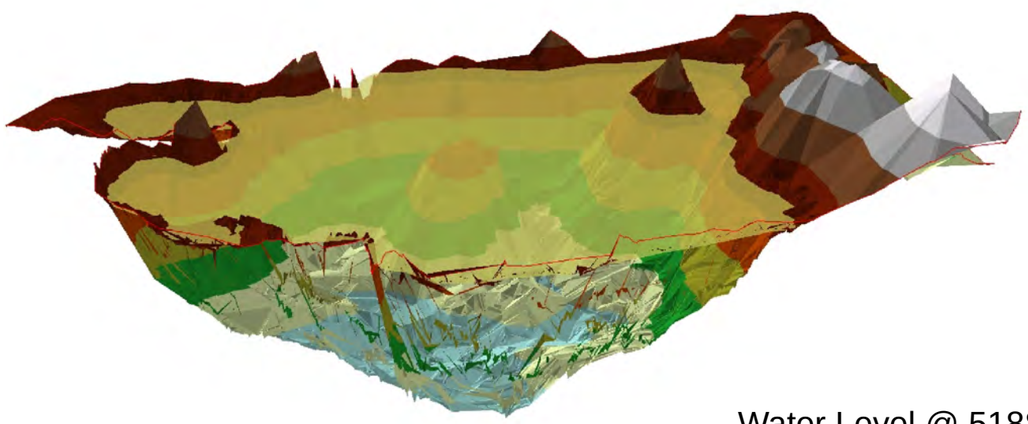
VERSION: A01
DRAWN: RM
CHECKED:
APPROVED:



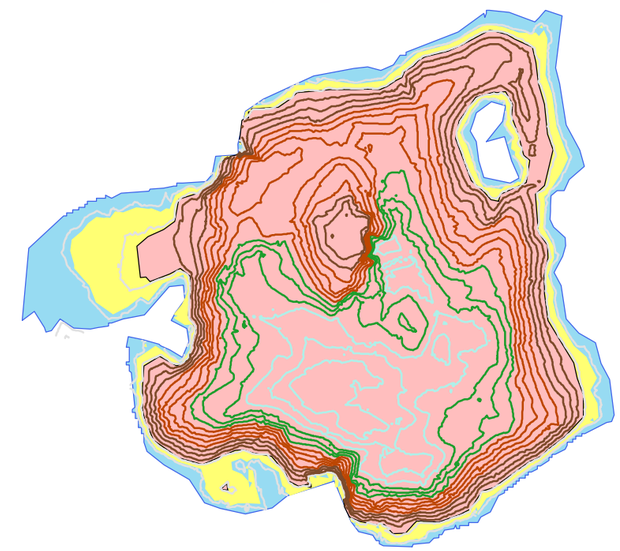
Water Level @ 5198.1
Surveyed Sept. 2014



Water Level @ 5178.1'
20' below surveyed level



Water Level @ 5188.1'
10' below surveyed level



2D Water Levels

Water Level Elevations

- Water Level @ 5198.1' (0' Below)
- Water level @ 5188.1' (10' Below)
- Water Level @5178.1' (20' below)

Depth Contours

- 0 -27 ft
- 28 -57 ft
- 58 - 97 ft
- 98 - 127 ft
- 128 - 156 ft

0 212.5 425 850 1,275 1,700 Feet

N

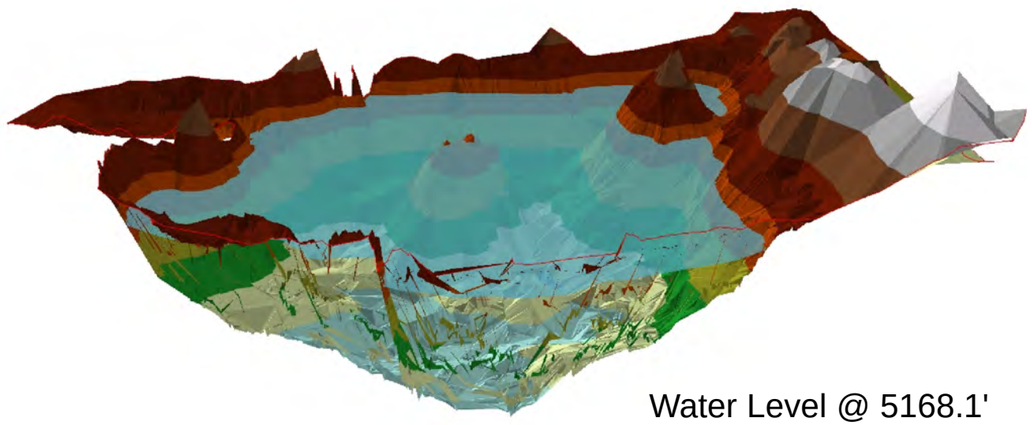
Scale is accurate for 2D map only.

Figure D Upper Klonaqua Lake
3D & 2D Water Level Elevations

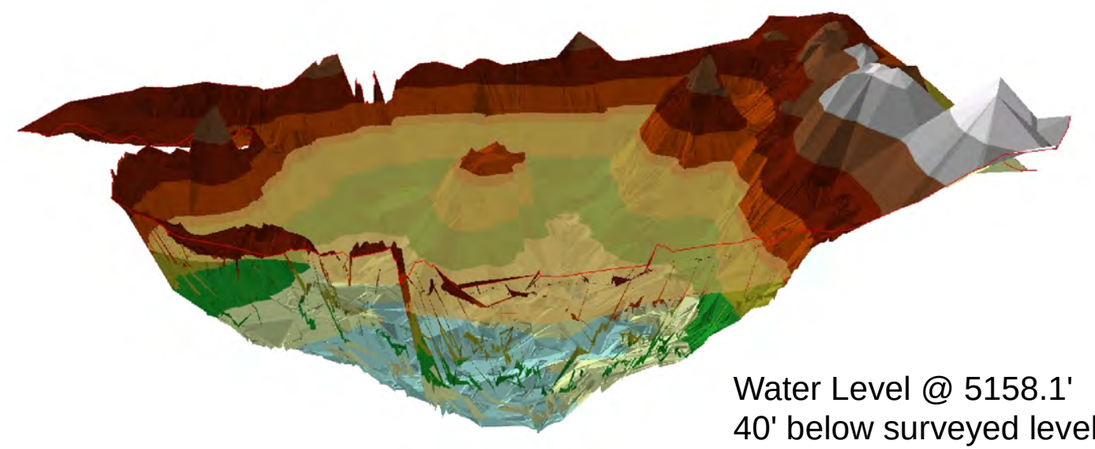
GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

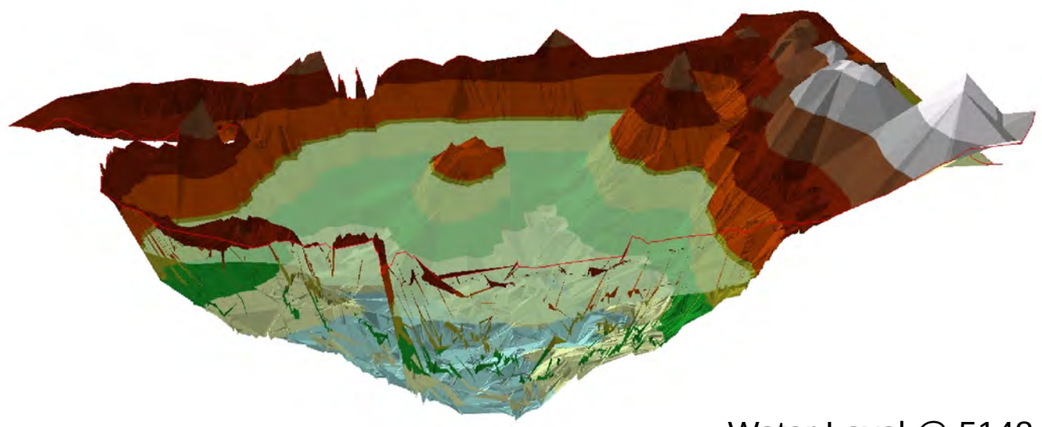
VERSION: A01
DRAWN: RM
CHECKED:
APPROVED:



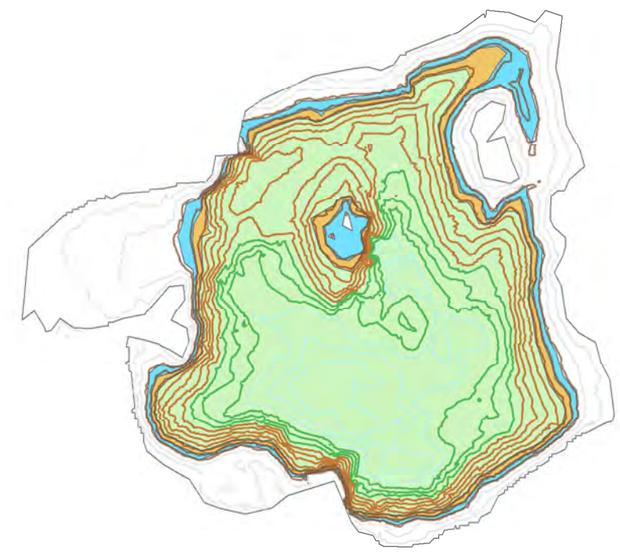
Water Level @ 5168.1'
30' below surveyed level



Water Level @ 5158.1'
40' below surveyed level



Water Level @ 5148.1'
50' below surveyed level



2D Water Levels

Water Level Elevations

- Present Water Level
- Water Level @5168.1' (30' below)
- Water Level @5158.1' (40' below)
- Water Level @5148.1' (50' below)

Depth Contours

- 0 -27 ft
- 28 -57 ft
- 58 - 97 ft
- 98 - 127 ft
- 128 - 156 ft

0 212.5 425 850 1,275 1,700 Feet

N

Scale is accurate for 2D map only.

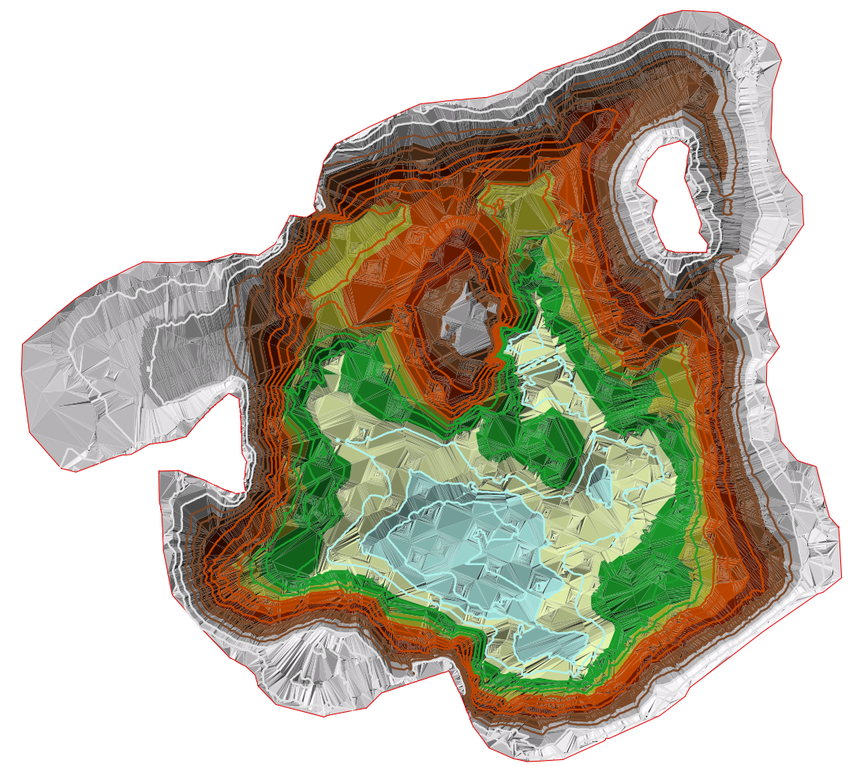
Figure D2 Upper Klonaqua Lake
3D & 2D Water Level Elevations

GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

VERSION: A01
DRAWN: RM
CHECKED:
APPROVED:

Water Level	Water Level (feet)	Volume (Cubic Feet)	Volume (Acre Feet)	Precent Reduction
Upper Lake Klonaqua				
Maximum Water Depth	154.0			
High Water Level	5199.1	194,040,985.41	4,454.57	
Surveyed Water Level (9/14)	5198.1	191,181,614.16	4,388.93	0.0%
10' Below Water Level	5188.1	164,463,976.49	3,775.57	14.0%
20' Below Water Level	5178.1	141,253,904.29	3,242.74	26.1%
30' Below Water Level	5168.1	120,565,610.32	2,767.81	36.9%
40' Below Water Level	5158.1	101,734,779.07	2,335.51	46.8%
50' Below Water Level	5148.1	84,536,978.00	1,940.70	55.8%
Lower Lake Klonaqua				
Water Level	5082.3		*Difference in Water*	
High Water Level	5101.9		*Levels between upper*	*115.8*
Maximum Water Depth	137.0		*lake and lower lake*	
Difference in Water Levels	19.6			



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Depth Contours

- 0 -27 ft
- 28 -57 ft
- 58 - 97 ft
- 98 - 127 ft
- 128 - 156 ft

PROJECTION: NAD 1983 StatePlane Washington North FIPS 4601 Feet

0 150 300 600 900 1,200 Feet

N

Figure E
Upper Klonaqua Lake
Volume Calculations

GRAVITY Consulting LLC

SCALE: See Scale Bar
SIZE: 11 x 17
PROJECT:
DATE: 10/03/2014

VERSION: A01
DRAWN: RM
CHECKED:
APPROVED: