Underwater Sonar Profiling Survey Of Westwood, Middle and Lower Chase Lakes for The City of Nanaimo

November 4th and 18th 2003

Prepared by
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Table of Contents

1. Introduction

At the request of Scott Pamminger of The City of Nanaimo, AquaCoustic Remote Technologies Inc. has completed a bathymetric survey of Westwood, Middle and Lower Chase Lakes. The purpose of the survey was:

- To gather bathymetry of the reservoir bottom; particularly adjacent to the dams.
- To calculate the volume of water held in the lakes.

AquaCoustic Remote Technologies Inc. was contacted because of their specialized equipment and experience in transitional sonar hydrographic surveys.

This report presents the results of the November 2003 sonar survey and provides a description of the methodology and limitations.

2. Company Background

The principals have over 30 years of experience in assessing underwater conditions. AquaCoustic is a company that specializes in the operation of remotely operated vehicles, the integration of specialized underwater sonar equipment, and the interpretation of the raw data. Utilizing a suite of software programs developed for this application, AquaCoustic can conduct surveys of underwater areas of concern, generate profiles, position underwater objects, and correlate this information to existing grids or coordinates.

The range of activities of this unique combination of equipment, technology, and personnel has included pipeline surveys, contour mapping, dredging profiles, positioning of underwater structures and volume measurements.

3. Scope of Work

The project required carrying out a reconnaissance effort, sonar profiling inspection of the below water area. This entailed profiling the entire lake bottom up to the lake surface. Particular emphasis was needed on the existing structures and the deepest part of the lakes.

A Side Scan sonar was used to gather bottom images around the dams. An underwater video system was also on site but was not used.

Post process the sonar profiling data to include pitch, roll and heading data, along with DGPS positioning.

Produce an AutoCAD drawing of each lake, including grids and contours.

Provide a hard copy report of the bottom features.

Provide a compact disk with the xyz data points on an AutoCAD R14 drawing.

4. Methodology

4.1 Instrumentation and Survey Operation

The profiling sonar survey equipment comprised the following:

- A digital scanning/profiling sonar head
- Imagenex sonar processor and positioning software
- Trimble Pro XRB DGPS system.
- 30 ft of data cable
- Pentium laptop computer for data acquisition
- Proprietary software for post-processing of the sonar data
- A base plate turn table
- Bubble type levelers
- Aluminum survey rods and stainless steel bracket for holding the sonar head and pitch and roll sensor.
- A pitch and roll sensor with heading; (data string is sent to the computer 10 times a second).

The sonar profiling was performed using an Imagenex Model 881A digital profiling sonar head attached to an aluminum sonar rod. The sonar head-to-rod connection consisted of a fabricated stainless steel L-bracket so that the axis of the sonar head was perpendicular to the axis of the sonar survey rod. The DGPS antenna was fastened on the top of the rod; this gave sub metre accuracy for XY positions. A pitch, roll and heading sensor was also attached to the rod; this gave pitch and roll information to 0.1 degree every 0.1 seconds.

The sonar survey was performed using a small aluminum boat supplied by the client. A wooden platform was attached to the front of the boat on the centre line. The base plate swivel was fastened to the wooden platform at the bow of the boat. The holding rod was then passed through a hole in the base plate so that the rod hung vertically from an attached collar. The holding rod was free to rotate and follow the boat track. The sonar head was fastened to the underwater end of the rod, approximately 3 inches below the water surface. The pitch, roll and heading sensor was attached to the rod and in line with the sonar head. A measurement from the sonar head to water level was obtained, this measurement was subtracted from the given water elevation. This gave us our Z value. The DGPS antenna was fastened on top of the rod; this gave us our XY position. The boat was navigated around the perimeter of the lake collecting sonar profiles. The successive tracks were offset approximately 10 to 20 metres towards the centre of the lake. The track separation was calculated using the reflective characteristics of the reservoir bottom and the depth of water as criteria.

At the start of the survey, the velocity of sound in the lake water was measured by performing a calibration check. The calibration check involved suspending a metal plate in the water at a known distance below the sonar head. The sonar software was used to measure the distance to the plate, and the velocity of sound in the local water was matched in the computer software so that the calculated depth shown and actual depth to the plate were equal. In general, the speed of sound of water was found to be about 1470m/s.

The DGPS survey tracks were tied into a control point surveyed in by the City of Nanaimo on each dam. The water elevation for each reservoir was set as given for the times involved.

Profiling data was collected using a narrow-beam sonar head sealed in a sonar enclosure. With this digital system, the frequency can be adjusted from 600 kHz to 1 MHz and the sound pulse can be lengthened or shortened. The sonar head, when positioned underwater, generates an acoustic pulse in a narrow cone. The sound footprint is approximately 3% of range or 3-ft diameter in 100 ft of water. A profile of the reservoir bottom is built as the sonar head mechanically steps about the longitudinal axis of the sonar enclosure. When the acoustic pulse hits a target, it bounces back and the echo appears as a data point recorded in terms of travel time. The depth is then calculated using the angle of the profile head relative to vertical, the speed of sound in water and the travel time. Depending on the angle of incidence of the acoustic pulse cone with the reservoir bottom, several echo returns are recorded. The profile data comprises first, intermediate and last returns of the acoustic pulse. For the work presented in this report, the centre return of the acoustic pulse was used for individual depth measurements. The accuracy is best when the pulse strikes the reservoir bottom at right angles. Accuracy diminishes as the angle of incidence of the pulse to the bottom diverges from 90°. Depth measurements are considered approximate when the angle of incidence with the ground is 45° and less. When operating within ±45°, the overall accuracy is considered to be better than 0.5% of range. Through the use of software programs this data is translated into XYZ positions and can be plotted in a variety of formats.

The survey was carried out on November 4^{th} and 18^{th} 2003

5. Survey Results

5.1 Westwood Lake

The following survey results represent the conditions on the date of the survey. The water surface elevation was 161.8 m

Overall, the total number of sonar survey points exceeded 361,000 data points.

The sonar settings were set to maximize the acoustic returns for the local conditions.

The calculated volume of the reservoir on the day of the survey was approximately 2,306,514 cubic metres.

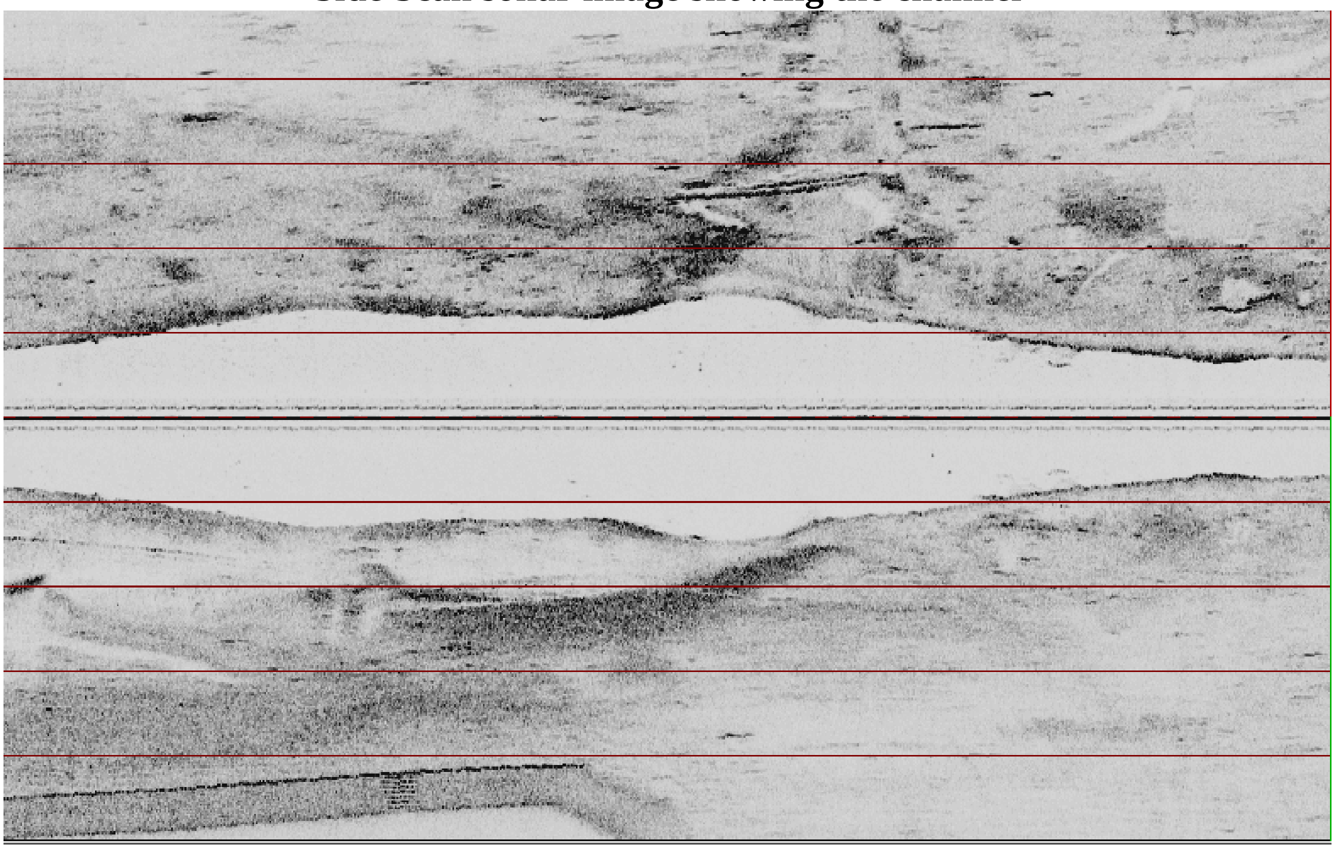
The survey of the reservoir was hampered somewhat by the submerged trees that were flooded when the reservoir was first built. This problem was mitigated by the rotating style head and we could gather data from either side of the boat. The survey speed was slowed for fear of hitting one of these submerged trees with the equipment.

The sonar data shows a straight ditch proceeding from the west side of the dam and traveling offshore. This depression is approximately 6 metres wide by approximately 1 to 2 metres deep. Other straight line depressions are also observed in the lake bottom. These may have been drainage ditches before the reservoir was flooded. The deepest part of the lake is in front of the dam.

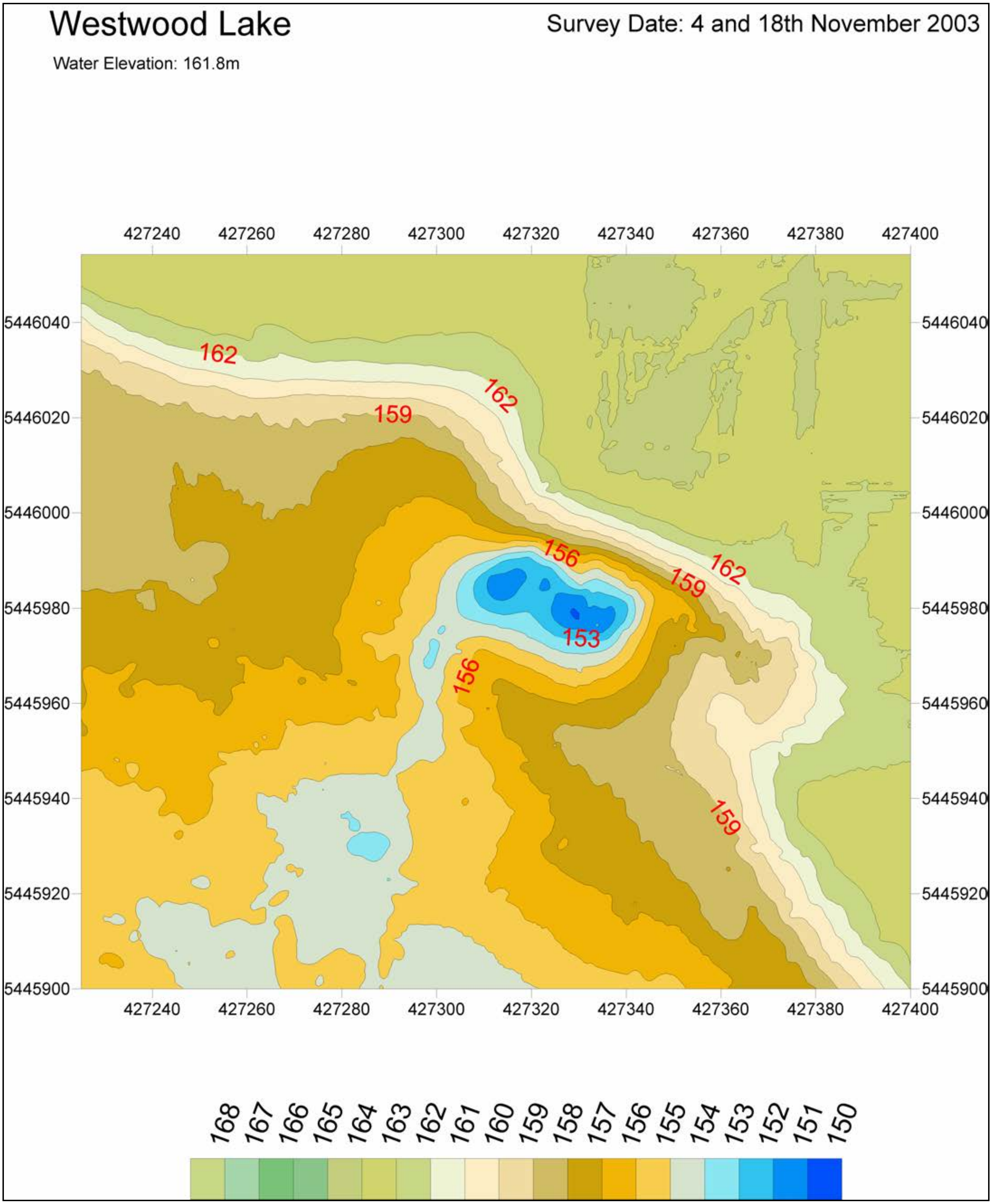
A slight dishing effect of the data at the outer limits of the sonar profiles may occur. This is caused by the angle of incident of the acoustic signal. The effect is minimal and falls well within the accepted norms at the ranges used on this survey.

The Side Scan images of the area in front of the dam indicates soft sediment and some waterlogged timber debris. On the west side of the dam by the boat launch, there are indications of a straight depression in line with the above mentioned depression leading offshore. There is also a possible channel leading out from the deep area of the dam into the lake. This channel shows up well in the contours.

Side Scan sonar image showing the channel



Looking directly down on area in front of dam, notice steps in foot of dam.


Westwood Lake
Survey Date: 4 and 18th November 2003
Water Elevation: 161.8m
427240 427260 427280 427300 427320 427340 427360 427380 427400
5446040 5446020 5446000 5445980 5445960 5445940 5445920 5445900
162
159
156
153
168 167 166 165 164 163 162 161 160 159 158 157 156 155 154 153 152 151 150

5.2 Middle Chase Lake

The following survey results represent the conditions on the date of the survey. The water surface elevation was 86.478 m

Overall, the total number of sonar survey points exceeded 22,000 data points.

The sonar settings were set to maximize the acoustic returns for the local conditions.

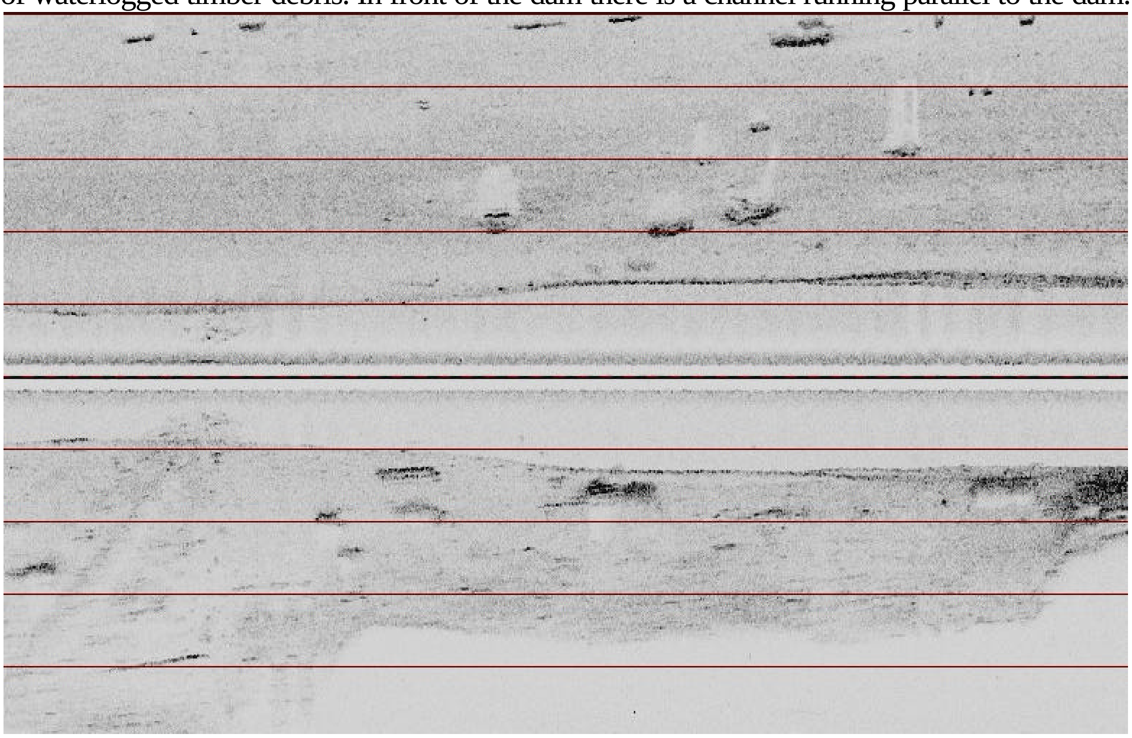
The calculated volume of the reservoir on the day of the survey was approximately 111,009 cubic metres.

The survey of the reservoir was hampered somewhat by the submerged trees that were flooded when the reservoir was first built. This problem was mitigated by the rotating head sonar system and we could gather data from either side of the boat. The survey speed was slowed for fear of hitting one of these submerged trees with the equipment.

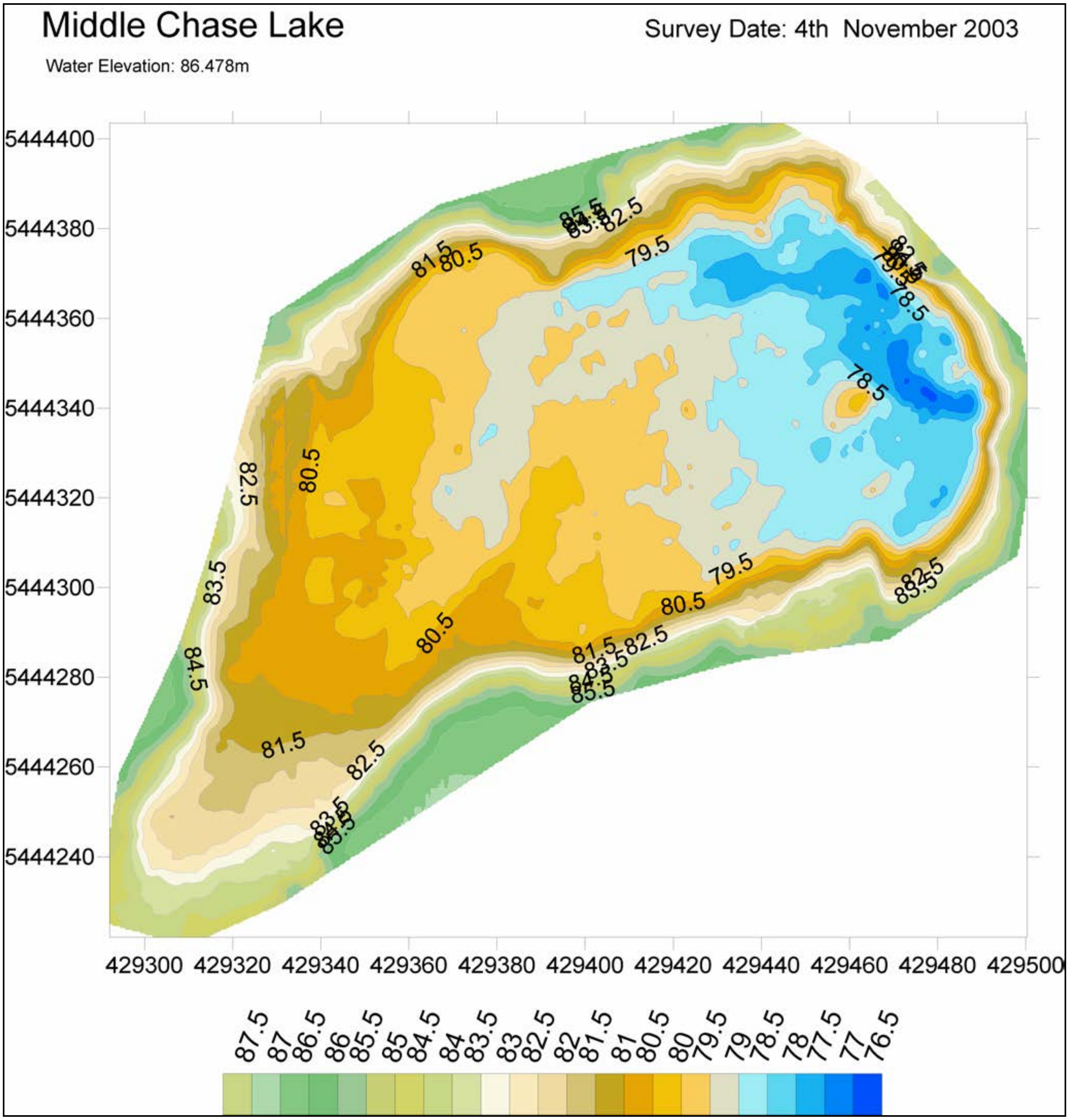
The sonar data shows a channel in front of and parallel to the spill way. The deepest part of the lake is in front of the dam.

A slight dishing effect of the data at the outer limits of the sonar profiles may occur. This is caused by the angle of incident of the acoustic signal. The effect is minimal and falls well within the accepted norms at the ranges used on this survey.

The Side Scan images of the area in front of the dam indicate rock outcrops with soft sediment and a small number of waterlogged timber debris. In front of the dam there is a channel running parallel to the dam.



Possible pipe from south side of lake.


Middle Chase Lake
Survey Date: 4th November 2003
Water Elevation: 86.478m
5444400
5444380
5444360
5444340
5444320
5444300
5444280
5444260
5444240
429300 429320 429340 429360 429380 429400 429420 429440 429460 429480 429500
87.5 87 86.5 86 85.5 85 84.5 84 83.5 83 82.5 82 81.5 81 80.5 80 79.5 79 78.5 78 77.5 77 76.5

5.3 Lower Chase Lake

The following survey results represent the conditions on the date of the survey. The water surface elevation was 71.804 m

Overall, the total number of sonar survey points exceeded 30,000 data points.

The sonar settings were set to maximize the acoustic returns for the local conditions.

The calculated volume of the reservoir on the day of the survey was approximately 121,640 cubic metres.

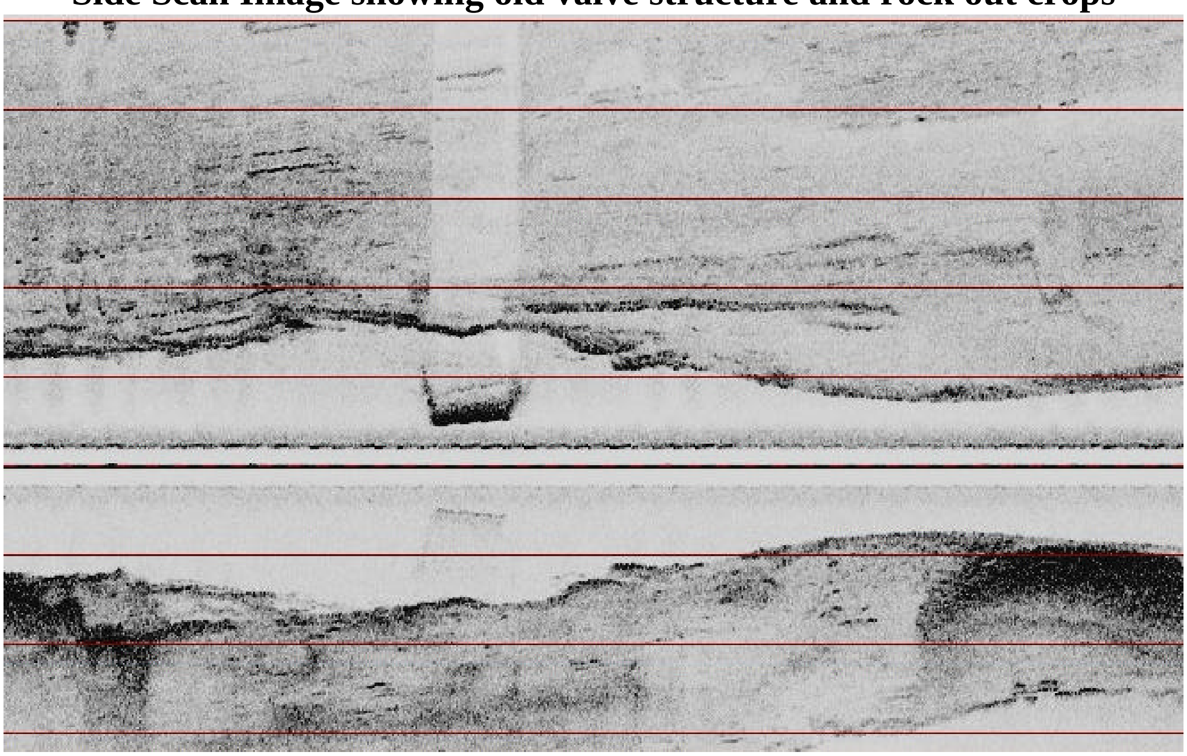
The survey of the reservoir was hampered somewhat by the submerged trees that were flooded when the reservoir was first built. This problem was mitigated by the rotating head sonar system and we could gather data from either side of the boat. The survey speed was slowed for fear of hitting one of these submerged trees with the equipment.

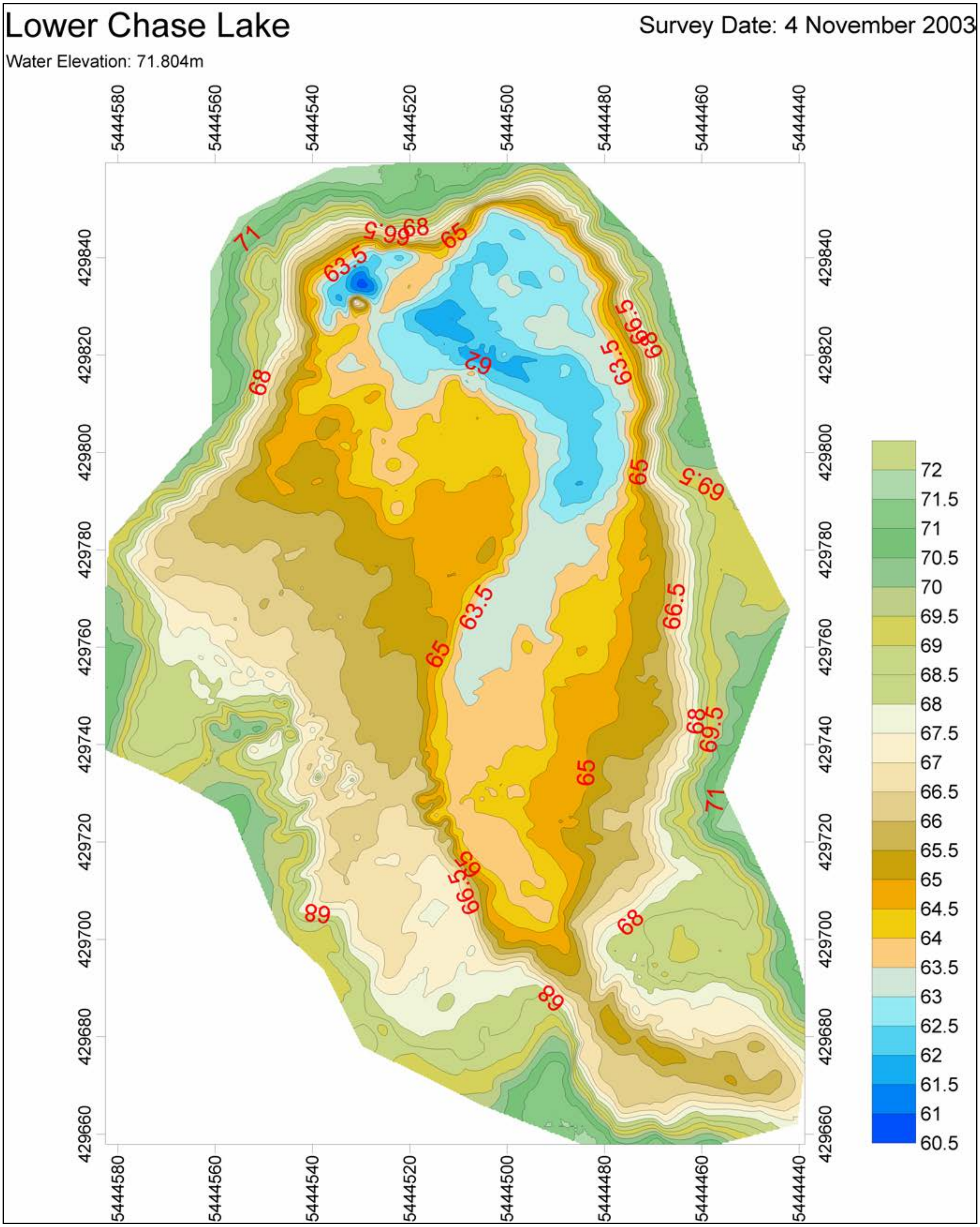
The sonar data shows the deepest part of the lake is in front of the dam.

A slight dishing effect of the data at the outer limits of the sonar profiles may occur. This is caused by the angle of incident of the acoustic signal. The effect is minimal and falls well within the accepted norms at the ranges used on this survey.

The Side Scan images of the area in front of the dam indicate rock outcrops and soft sediment and a small number of waterlogged timber debris. In front of the dam there is a channel running parallel to the dam.

Side Scan Image showing old valve structure and rock out crops





Lower Chase Lake
Survey Date: 4 November 2003
Water Elevation: 71.804m
5444580
5444560
5444540
5444520
5444500
5444480
5444460
5444440
429840
429820
429800
429780
429760
429740
429720
429700
429680
429660
72
71.5
71
70.5
70
69.5
69
68.5
68
67.5
67
66.5
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
61
60.5

6. Summary of Results

Some of the shallow water profiles show aquatic vegetation and log debris; 95% of this was processed out of the data. In some areas we could not get close to shore and collect profile data because of the submerged logs and tree stumps. The volume of the lakes was calculated from the actual water level given for the day of the survey for each lake. For positioning, the DGPS signal was very strong overall, except for a small area in Middle Chase Lake. The City of Nanaimo surveyed in control points for each lake; these are tied into the sonar survey. Due to time constraints, a reconnaissance effort survey was conducted; a more detailed survey is recommended for some areas that were identified in the report.

7. Limitations

The distance to a given surface may be determined accurately based on the acoustic travel times. Underwater sound velocity is dependent on water temperature, depth and salinity. An underestimate of the sound velocity would produce distances that are too shallow, the reverse occurs with an overestimate of sound velocity. In addition there are approximations inherent in fitting a theoretical model to real world data. Some errors may occur in gridding between data along discrete survey traverses.

The nature and composition of bottom features identified in sonar surveys cannot be absolutely determined by inspection of the data. Several indicators such as reflector strength, diffraction patterns, smoothness of reflectors and reflector relief may provide insight into features.

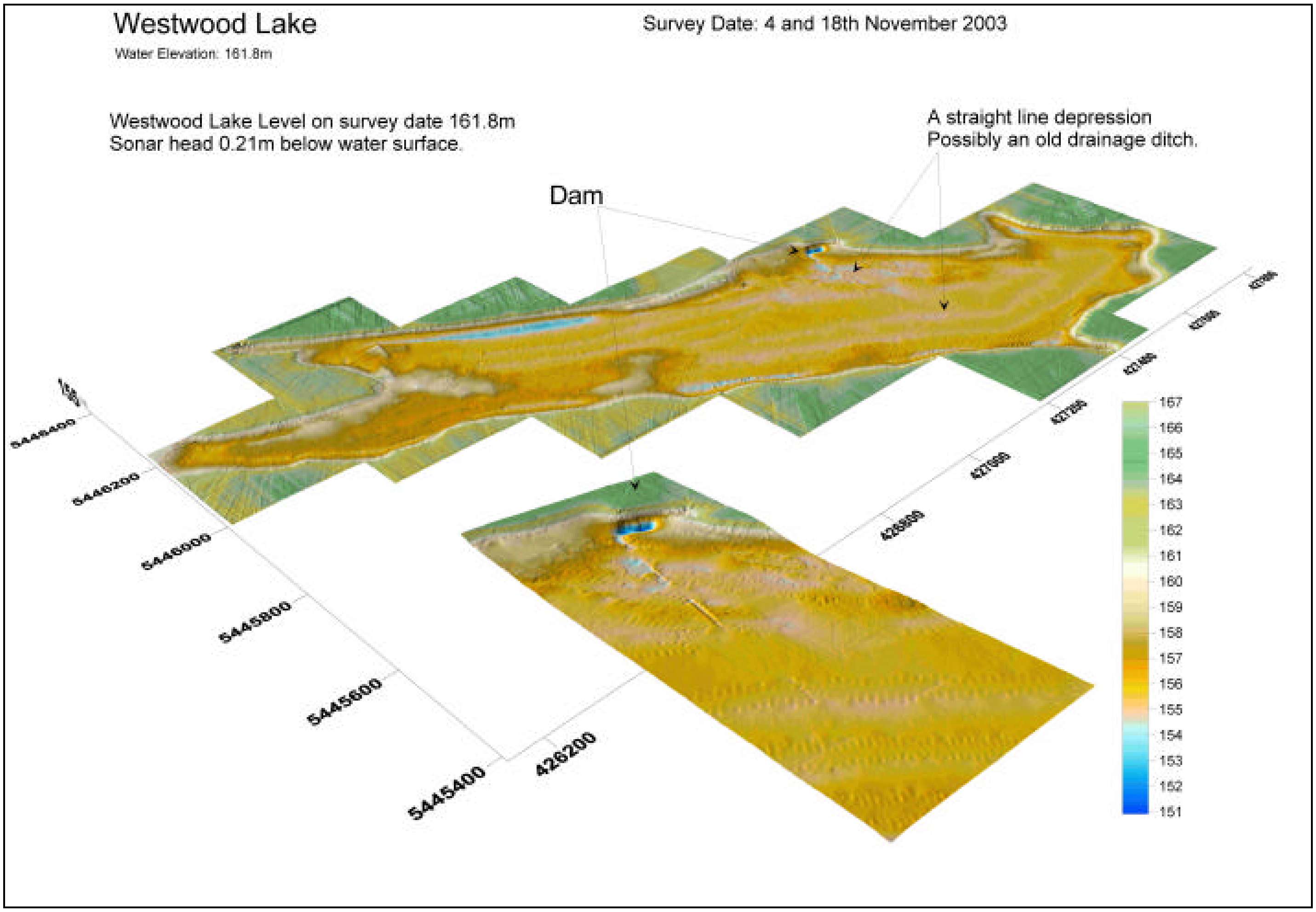
The information in this report is based upon sonar measurements and field procedures, and our interpretation of the data. The information is based upon our estimate of conditions considering the geophysical and all other information available to us. The results are interpretive in nature and are considered to be a reasonably accurate presentation of underwater conditions, within the limitations of the methodology employed.

Respectfully submitted,

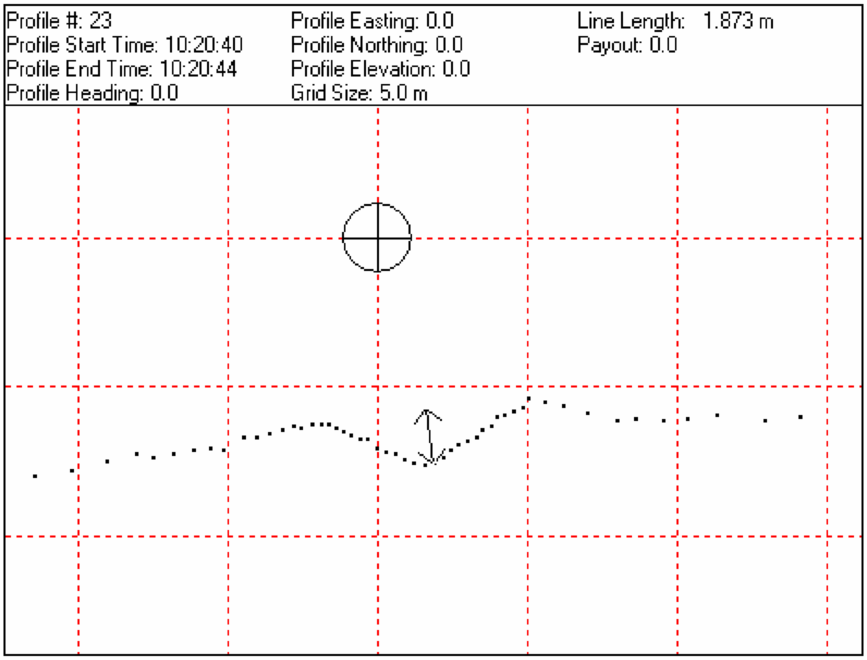
Michael Blackshaw

Plan view of Westwood Lake

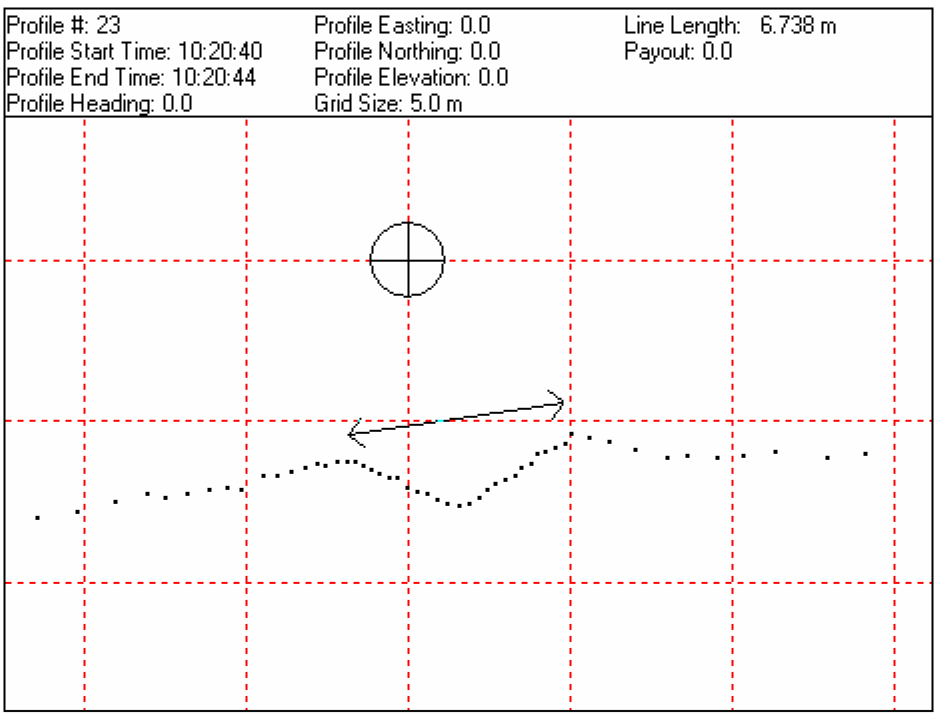
Gridded surface rendering of Westwood Lake



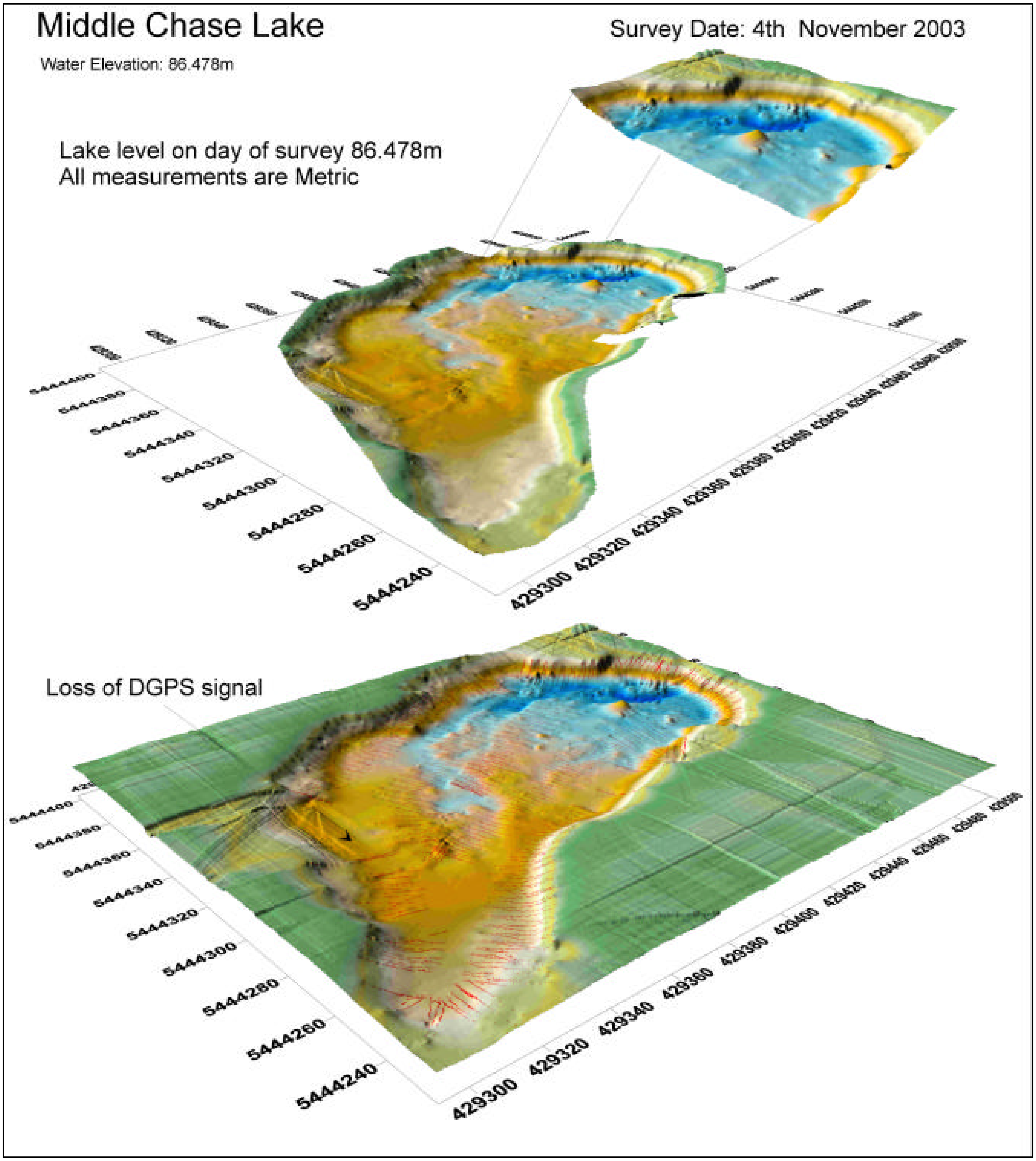
Westwood Lake
Sonar profile data across depression showing 1.873 m depth

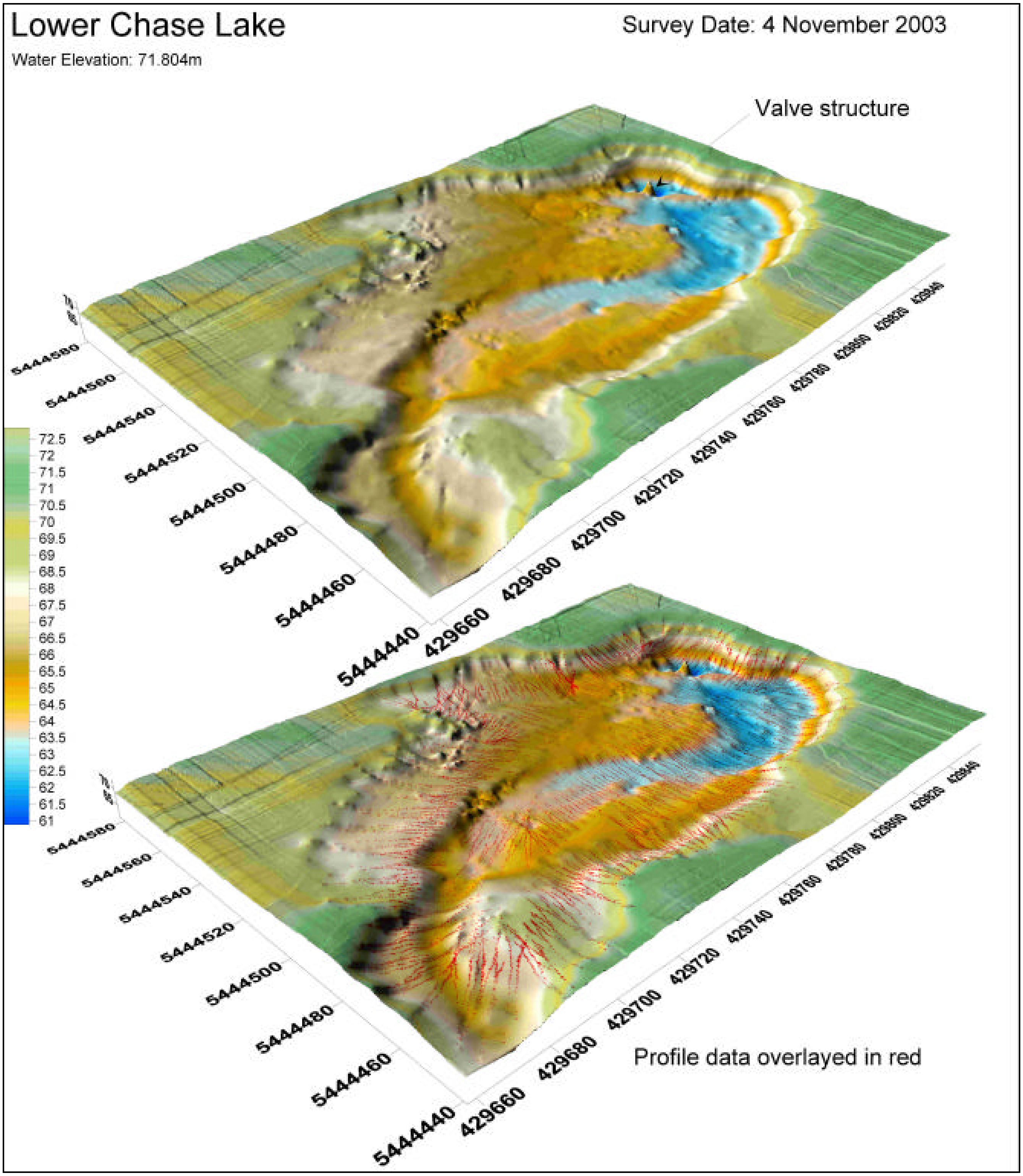


Sonar profile data across depression showing 6.738 m width



Plan view of Middle and Lower Chase Lakes


Middle Chase Lake
Survey Date: 4th November 2003
Water Elevation: 86.478m
Lake level on day of survey 86.478m
All measurements are Metric
Loss of DGPS signal
5444400
5444380
5444360
5444340
5444320
5444300
5444280
5444260
5444240
429300
429320
429340
429360
429380
429400
429420
429440
429460
429480
429500


Lower Chase Lake
Survey Date: 4 November 2003
Water Elevation: 71.804m
Valve structure
72.5
72
71.5
71
70.5
70
69.5
69
68.5
68
67.5
67
66.5
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
61
5444580
5444560
5444540
5444520
5444500
5444480
5444460
5444440
429660
429680
429700
429720
429740
Profile data overlayed in red

Photographs

The photograph on the left shows the sonar base plate with vertical holding rod with DGPS antenna. The sonar head is attached to the bottom of the rod, 0.21m below the water surface.

The photograph above and to the left shows the dam at Westwood Lake.

The photograph below shows the dam at Lower Chase Lake