

# Summary of the 2015-2016 Bathymetry and Sub-bottom Data Review and Stage Storage Curve Development for the Faro Mine Remediation Project

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| PROJECT NUMBER:  | 673709.20.01.01.02.03.DI.RB                                                                                                                                                                                                                                                                                                                                                       |
| FIELD PLAN NAME: | CH2M RFP 660403-010 Hydrographic (Bathymetry) and Sub-bottom Profiling Survey issued September 16, 2015<br>Aurora's Project Execution Plan (Dated October 5, 2015)<br>CH2M Scope of Work - 2016 Hydrographic (Bathymetry) and Sub-bottom Profiling Survey issued September 16, 2015<br>Aurora's Proposal – 2016 Hydrographic and Sub-Bottom Profiling Survey (Dated June 7, 2016) |

This technical memorandum (TM) presents a summary of CH2M HILL Canada Limited's (CH2M's) technical review of the bathymetry fieldwork performed by Aurora Geosciences in 2015 and 2016 for the Cross Valley Dam (CVD) Pond and the Intermediate Dam (ID) Pond in 2016. A companion report, *Summary of Fiscal Year 2015 and 2016 Field Investigations– Cross Valley Dam and Intermediate Dam Pond Field Data* (CH2M, August 2016c), documents the field investigation activities, and Appendix F, *Geotechnical Data Analyses Report*, to the *Final Comprehensive Data Road Map report (CDRM)* (CH2M, August 2016n) discusses the findings of the investigation. Updates of stage storage curves for the CVD Pond and the ID Pond were prepared by CH2M based on the Aurora bathymetry data combined with the Faro Mine Light Detection and Ranging (LiDAR) terrain surface.

At the request of the Government of Yukon (YG), as part of this work CH2M also prepared a simple Excel calculation spreadsheet for each the CVD and ID Ponds, as well as Faro, Grum and Vangorda Pits. These spreadsheets provide an estimation of the stored volume and available storage capacity given a specified pond or pit water elevation. In addition, the updated stage storage curves have been incorporated into the water management tool version of the GoldSim model.

## Aurora Geosciences Bathymetry and Sub-bottom Field Work

Aurora conducted the bathymetry and sub-bottom profiling fieldwork in 2015 and 2016. They performed the CVD Pond fieldwork at the end of October 2015 and did some additional work in mid-June of 2016. The ID Pond fieldwork was performed in mid-June 2016. In October of 2015 the CVD Pond work was ended prematurely because of the pond freezing over. Additional quality control (QC) checks were planned for the CVD Pond in June 2016 but were not completed because of high wind conditions that forced the crew off the pond.

The Aurora Geosciences work program consisted of the following:

- Bathymetric data capture for both ponds using multi-beam technology and single-beam technology for QC checks and supplemental data. Both data capture technologies were coupled with Real-Time

Kinematic (RTK) global positioning system (GPS) tied to the onsite permanent control network as specified in Standard Operating Procedure (SOP) MSR006, *Geographic Land Surveying and Field Surveying Procedures* (CH2M, March 2012g) for position and elevation.

- Sub-bottom profile geophysical data capture for both ponds. This technology was also coupled with RTK GPS tied to the Faro Mine control network for position and elevation.
- Office reduction and analysis of the captured bathymetry and sub-bottom profile data.
- The production of various deliverables based on the office reduction and analysis of their captured data, including the following:
  - Bathymetry-based pond bottom surfaces for each pond in an Environmental Sciences Research Institute (ESRI)-compatible, one-half metre (m) cell size grid format.
  - A contour map for each pond showing the below water pond surface contours at 0.25-m contour intervals. Figures 1 and 2 show the bathymetry survey contours.
  - ESRI compatible 1-m cell size sub-bottom thickness surfaces for the sub-bottom features identified during the data capture.
  - Various computer-aided design/dxf, geographic information system (GIS), and text format files to show the sub-bottom profiles, and QC checks performed.
- A comprehensive report (one for each pond) describing the technologies, equipment, and procedures used and QC checks performed are provided in Attachment 1, Aurora Geosciences CVD Pond Bathymetry and Sub-bottom Profile Report, and Attachment 2, Aurora Geosciences ID Pond Bathymetry and Sub-Bottom Profile Report. The reports include discussions and interpretations of the bathymetry and sub-bottom profile data and the accuracies attained together with figures, descriptions, and explanations of the various deliverables. Data files prepared by Aurora are provided on the external hard drive prepared for project close-out, and a combined bathymetry and LiDAR surface developed by CH2M for interpolation of the stage storage capacity curves is provided electronically as ESRI GRID format source files with this TM.

The primary Aurora Geosciences deliverables used to generate the combined bathymetry and Faro Mine LiDAR surfaces used to update the CVD Pond and ID Pond stage storage curves were the ESRI-compatible grid format files named CVD\_pondBottom\_Elevation\_0.5\_esri.flt and ID pond elevation.flt.

For the sub-bottom profile data, the primary Aurora Geosciences deliverables used to generate sub-bottom elevation surfaces were ESRI-compatible thickness grids named FeatureB.flt, FeatureC.flt, FeatureD.flt, FeatureE.flt, FeatureF.flt, and FeatureG.flt for the CVD Pond. For the ID Pond, the delivered thickness grids were named Feature 1 Thickness.flt and Feature 2 Thickness.flt

## CH2M Technical Review of the Aurora Bathymetry and Sub-bottom Report and Deliverables and Stage Storage Curve Development

CH2M reviewed the reports and the bathymetry data provided by Aurora. The bathymetry data was reviewed for its area of coverage, data format, and accuracy. The data were then combined with existing Faro Mine LiDAR terrain data to produce a surface for use in the development of the updated stage storage curves.

## CH2M Review of Aurora Bathymetry and Sub-bottom Deliverables

Bathymetry survey accuracy is described in the reports prepared by Aurora and discussed in this report. Weather conditions did not permit some of the planned QC work efforts to be completed. If bathymetry data with greater accuracy is required for future uses, additional QC review checks that could be performed are presented in the Conclusion and Recommendations section of this TM.

The Aurora Geosciences reports provide accuracy reporting primarily based on equipment manufacturer specifications and processing software output rather than independent field surveyed QC checks. Their GPS base station was setup on Faro Mine control point 2010-P5. The published coordinate and elevation values were used.

An ESRI terrain dataset was created and augmented in late 2012 with the Laberge bathymetry data in the Faro Pit area. Several Microstation Inroads DTMs were also created at the same time representing the same DTM data. This combined original LiDAR data and Laberge bathymetry data is referred herein as the Faro Mine LiDAR terrain surface. As an accuracy check, CH2M compared the Aurora deliverables to the Faro Mine LiDAR terrain surface.

In the following subsections, tables are presented showing the accuracy comparisons for the various Aurora Geosciences bathymetry and RTK surveys. Observations about the CVD Pond and ID Pond accuracy tables are also provided.

### Cross Valley Dam Pond

LiDAR data and aerial photos of the Faro Mine Complex were acquired by BGC Engineering and Terra Remote Sensing Inc. for YG. This data was acquired in October 2011, with a proprietary camera and LiDAR system mounted in the same aircraft; the photography and LiDAR were acquired simultaneously. The approximate water surface elevation in the CVD Pond at the time of the LiDAR data collection was 1,027.0 m, whereas the approximate water surface elevation at the time of Aurora's bathymetry survey was 1,028. 679 m. The pond spill elevation based on the LiDAR terrain surface is 1,030.66 m.

Figures 2 and 3 show the final LiDAR and bathymetry areas and the locations of various accuracy check points for the CVD Pond. These check points are the locations for the points included in the accuracy calculation table (Table 1).

Table 1. CVD Pond Bathymetry Accuracy Checks

| Description                      | CVD Pond RTK<br>Shoreline Points<br>minus LiDAR | CVD Pond Lead<br>Line Points minus<br>Multi-Beam Bathy | CVD Pond Multi-<br>Beam Bathy minus<br>LiDAR | CVD Pond Single<br>Beam minus Multi-<br>Beam Bathy |
|----------------------------------|-------------------------------------------------|--------------------------------------------------------|----------------------------------------------|----------------------------------------------------|
| Number of Check Points           | 111                                             | 5                                                      | 144                                          | 829                                                |
| Minimum Elevation Difference (m) | -0.332                                          | -0.351                                                 | -1.662                                       | -1.549                                             |
| Maximum Elevation Difference (m) | 0.530                                           | -0.114                                                 | 0.976                                        | 1.480                                              |
| Average Elevation Difference (m) | -0.064                                          | -0.225                                                 | 0.179                                        | 0.117                                              |
| Median Elevation Difference (m)  | -0.069                                          | -0.214                                                 | 0.154                                        | 0.164                                              |
| Standard Deviation               | 0.142                                           | 0.109                                                  | 0.365                                        | 0.358                                              |
| RMSE (m)                         | 0.155                                           | 0.245                                                  | 0.405                                        | 0.377                                              |
| Accuracy at 95% (m)              | 0.304                                           | 0.480                                                  | 0.794                                        | 0.739                                              |

Notes:

% = percent

RMSE = Root mean square error

## Intermediate Dam Pond

The LiDAR data for the ID Pond area was also acquired by BGC Engineering and Terra Remote Sensing Inc. for YG in October 2011. The approximate water surface elevation in the ID Pond at the time of the LiDAR data collection was 1,043.60 m, whereas the approximate water surface elevation at the time of Aurora's bathymetry survey was 1,045.976 m. The pond-spill elevation based on the LiDAR terrain surface is 1047.70 m.

Figure 4 shows the final LiDAR (green) and bathymetry (blue) areas and the locations of various accuracy check points for the ID Pond. The check points are the locations for the points included in the accuracy calculation tables (Tables 2 and 3).

**Table 2. ID Pond Bathymetry Accuracy Checks**

| Description                      | ID Pond RTK Shoreline Points minus LiDAR | ID Pond Lead Line Points minus Multi-Beam Bathy | ID Pond Multi-Beam Bathy minus LiDAR | ID Pond Single Beam minus Multi-Beam Bathy |
|----------------------------------|------------------------------------------|-------------------------------------------------|--------------------------------------|--------------------------------------------|
| Number of Check Points           | 203                                      | 25                                              | 485                                  | 2,968                                      |
| Minimum Elevation Difference (m) | -0.515                                   | -1.579                                          | -0.482                               | -0.896                                     |
| Maximum Elevation Difference (m) | 0.858                                    | 0.836                                           | 1.123                                | 1.690                                      |
| Average Elevation Difference (m) | -0.115                                   | -0.259                                          | -0.015                               | 0.174                                      |
| Median Elevation Difference (m)  | -0.131                                   | -0.292                                          | -0.031                               | 0.034                                      |
| Standard Deviation (m)           | 0.181                                    | 0.453                                           | 0.134                                | 0.373                                      |
| RMSE (m)                         | 0.214                                    | 0.514                                           | 0.135                                | 0.411                                      |
| Accuracy at 95% (m)              | 0.419                                    | 1.007                                           | 0.264                                | 0.806                                      |

**Table 3. Additional ID Pond Bathymetry Accuracy Checks**

| Description                      | ID Pond RTK Shoreline Extension Points minus LiDAR | ID Pond Lead Line Points minus LiDAR | ID Pond Single Beam Bathy minus LiDAR |
|----------------------------------|----------------------------------------------------|--------------------------------------|---------------------------------------|
| Number of Check Points           | 98                                                 | 24                                   | 10,082                                |
| Minimum Elevation Difference (m) | -0.346                                             | -0.716                               | -1.327                                |
| Maximum Elevation Difference (m) | 0.267                                              | 0.113                                | 1.166                                 |
| Average Elevation Difference (m) | -0.067                                             | -0.262                               | -0.069                                |
| Median Elevation Difference (m)  | -0.081                                             | -0.238                               | -0.037                                |
| Standard Deviation               | 0.125                                              | 0.183                                | 0.246                                 |
| RMSE (m)                         | 0.141                                              | 0.318                                | 0.255                                 |
| Accuracy at 95% (m)              | 0.276                                              | 0.623                                | 0.500                                 |

Observations about the CVD Pond and ID Pond accuracy tables are as follows:

1. With a relative vertical accuracy of  $\pm 0.3$  m, the elevation differences for the RTK shots for the CVD shoreline points and the ID Pond shoreline extension points are similar but a little higher than industry standard expectations based on accuracies that can be achieved using RTK GPS technology. The ID Pond shoreline RTK points have a slightly lower relative accuracy at  $\pm 0.4$  m.
2. The lead-line checks for the CVD Pond bathymetry and against the ID Pond LiDAR in the overlap area, where LiDAR data was available within the ID Pond bathymetry area, are similar but the lead-line comparisons within the ID Pond bathymetry area are larger.
3. Based on Aurora Geosciences evaluation of the multi-beam bathymetry compared to the single-beam bathymetry and based on CH2M's comparison of the multi-beam and single-beam bathymetry compared to the LiDAR surface for the ID Pond, the ID Pond bathymetry surface looks reasonable and has a relative accuracy of approximately  $\pm 0.3$  m relative to the Faro Mine LiDAR terrain surface. For the CVD Pond, a similar accuracy is expected because Aurora used the same equipment and procedures. The overlap between LiDAR and bathymetry has a much narrower band of area, with the larger overlap areas in very shallow areas where the accuracy of the multi-beam data is lower. Consequently, the calculated accuracy relative to the Faro Mine LiDAR terrain surface is approximately  $\pm 0.8$  m.
4. The comparison between the multi-beam elevations and the single-beam elevations are similar in both ponds.

## Conclusion and Recommendations

Except as specifically noted, the bathymetry pond bottom surfaces look reasonable and likely have a relative accuracy of approximately  $\pm 0.3$  m relative to the Faro Mine LiDAR terrain surface for the majority of their areas. Depending on the accuracy requirements for future projects that will rely on the bathymetry data, additional independent QC surveys and checks may be desirable for further analysis and confirmation of the accuracy of the bathymetry surfaces.

If tighter accuracy confirmation is desired, additional QC surveys and checks are recommended as follows:

1. Set up on the Faro Mine control network monument used by Aurora Geosciences and observe two other network monuments to confirm the elevation of the control point used by Aurora Geosciences has not been disturbed.
2. Perform Total Station or GPS surveys at x,y locations for previous Aurora Geosciences shoreline and shoreline extension RTK shots around each pond (at least 20 shots per pond) to confirm the elevations and accuracy of their RTK surveys.
3. For the ID Pond, independently survey the elevation of the daily check point described in the Aurora Geosciences report and compare the elevation generated by Aurora.
4. Field survey profiles along the shoreline of the CVD Pond from 15 m horizontally outside of the 1,027 elevation contour line to 15 m horizontally into the pond below the 1,027 above elevation contour. Compare these to the Faro Mine LiDAR terrain surface and the Aurora Geosciences bathymetry surfaces. Weather conditions did not permit this data to be collected during the field survey.
5. Capture single-beam bathymetry for three north and south profiles spaced equal distance apart in the CVD Pond to compare with the Aurora multi-beam bathymetry surface. Weather conditions did not permit this data to be collected during the field survey.

6. Perform checks to determine if the bathymetry areas shown in Figure 3 on the northern end of the CVD Pond are truly higher than the Faro Mine LiDAR terrain surface or if the bathymetry data in this area needs to be revised.
7. Complete field survey profiles for 15 m horizontally toward and into the ID Pond area at the shoreline extension points surveyed by Aurora Geosciences. Compare these data to the Faro Mine LiDAR terrain surface and the Aurora Geosciences bathymetry surface.

## Stage Storage Curve Updates

The assumptions, process, and tools used to combine the Aurora bathymetry with the Faro Mine LiDAR terrain data to develop a combined bathymetry and LiDAR terrain surface that will update the stage storage curves is provided in this section. Two separate methods, ESRI Grid method and ESRI Terrain triangle method, were used to create combined ground and bathymetry surface models, and to cross check the calculations for the stage storage curves.

## Development of Combined Bathymetry and LiDAR Surface Models

Based on accuracies achievable from the bathymetry and LiDAR technologies, the Faro Mine LiDAR terrain data is assumed to be more accurate than the bathymetry data because of the following:

- The bathymetry data was clipped down to the area within the Faro Mine LiDAR terrain surface below the apparent water surface elevation (WSEL) at the time of the LiDAR data capture. Bathymetry data below the apparent WSEL was used to replace data currently in the Faro Mine LiDAR terrain data surface and LiDAR data above the WSEL was retained for the combined LiDAR and bathymetry surface. The combined surfaces were developed in two formats. One as a one-half m ESRI grid surface consistent with the one-half m bathymetry grid surface provided by Aurora and the other as an ESRI terrain surface using the gridded point data from the Aurora bathymetry surface and point and break line data from the Faro Mine LiDAR terrain data set.
- The Faro Mine LiDAR terrain surface was reviewed to determine the apparent WSEL at the time the LiDAR data was captured. Based on a review of the CVD Pond WSEL at the time of the LiDAR, data capture was determined to be 1,027.0 m and the ID Pond WSEL was determined to be 1,043.6 m (see Figures 2 and 4). The Faro Mine LiDAR terrain file was contoured within the two pond areas to develop the bathymetry clip area as discussed in the preceding bullet. Some editing of the clip areas based on these contours was performed because of a minor lack of flatness in the terrain surface because of the accuracy of the LiDAR data.
- The spill elevation for the two ponds was generated by contouring the Faro Mine LiDAR surface in the vicinity of the ponds to determine the highest elevation, where a closed contour was retained fully within the ponds. For the CVD Pond, the LiDAR terrain surface spill elevation was determined to be 1,030.66 m and for the ID Pond the LiDAR spill elevation was determined to be 1,047.70 m. These elevations compare well with the Challenger field survey elevations of 1,030.65 for the CVD Pond spill elevation and 1047.76 for the ID Pond spill elevation.
- A 0.5 m ESRI grid surface consistent in cell size and alignment with the clipped Aurora bathymetry surface was generated from the Faro Mine LiDAR Terrain surface, with the outer limits of the 0.5 m LiDAR terrain grid surface limited to the pond spill elevation contour areas. This clipping was done to ensure that additional extraneous volumes outside of the ponds would not be added to the volumes.
- The clipped bathymetry grid and the clipped LiDAR terrain grid were then combined using the ESRI Grid Mosaic tool, giving the bathymetry grid precedence over the LiDAR grid. Since the bathymetry grid was clipped to the apparent LiDAR WSEL, the resultant combined surface is

bathymetry data below the apparent WSEL, and LiDAR data above the apparent WSEL. This step provided 0.5 m cell size combined bathymetry and LiDAR grid surface used to update the stage storage curves.

- For the combined ESRI Terrain format surface, which was used as a check on the grid surface volume calculations, a new terrain surface limited to the spill elevations for the pond areas were generated. The spill elevation polygons were used as the limiting boundary areas for the terrain files by adding them as the boundary edge break lines for the individual pond terrains. This was done to prevent the addition of extraneous volumes outside of the ponds to the volumes. Existing terrain point data within the apparent WSEL areas were removed from the terrain data and replaced with bathymetry data points from the Aurora-provided bathymetry grid files. Since the bathymetry data was clipped to the apparent LiDAR WSEL, the resultant combined terrain surface is bathymetry data below the apparent WSEL, and LiDAR data above the apparent WSEL. This step provided the combined bathymetry/LiDAR ESRI terrain surface used to update the stage storage curves.

### Calculation of the Updated Stage Storage Curves

The stage storage curves were calculated using an ESRI ArcMap GIS volume calculation tool based on the combined ESRI Grid and checked separately using the ESRI Terrain surfaces previously described. The specific tool used was the Surface Volume tool, which is one of the Functional Surface tools within the three dimension (3D) Analyst Tools set in ArcToolbox. At the request of YG, the volumes were calculated at 10 centimetres (cm) (0.1 m) intervals from the bottom of the ponds to the spill elevation.

Volumes were calculated using both the 0.5 m combined grid surfaces and from the pond-specific terrain surfaces. The volumes from the grid and terrain calculations were compared as a QC check. Volumes compared favorably with less than 1 percent difference in the volumes.

The stage (elevation) versus storage curves are shown in Figures 4 and 5. A simple excel calculation spreadsheet for the CVD Pond is provided in Attachment 3, which includes curve plots and the stage and storage table in 10 cm elevation increments. The spreadsheet calculates the approximate stored volume and available storage capacity given a specified pond water elevation, using linear interpolation. Attachment 4 provides the water management tool version of the GoldSim model, incorporating the updated stage storage curves.

### Sub-bottom Features

Aurora Geosciences delivered sub-bottom thickness contours, thickness grids in ESRI compatible grid format, and thickness cross-sections for the sub-bottom features. For the CVD Pond, six sub-bottom features were identified, Features B through G. For the ID Pond, two sub-bottom features were identified, Features 1 and 2. The contours and thickness grids for the CVD Pond are fairly complete for all features for their area of coverage, but for the ID Pond, the bottom of Feature 2 was not discernible by Aurora Geosciences in the middle area of the pond so there is a significant gap in the Feature 2 data in that area.

The compared plots show the CVD Pond sub-bottom cross-section plot provided by Aurora Geosciences agrees well with the sub-bottom cross-section plots created by CH2M, by converting the thickness grids to depth surfaces.

The thickness grid depth cross-sections and elevation grid files were developed from the Aurora Geosciences feature thickness grids. The sub-bottom elevation surfaces were created by using ESRI grid math tools to subtract the first sub-bottom thickness grid from the finalized bathymetry surface grid and then by subtracting subsequent lower sub-bottom thickness grids from the resultant next-higher sub-bottom elevation surface grid. This methodology for creating the thickness depth and elevation grids was based on thickness grid files discussed with Aurora Geosciences.

Similar to the CVD Pond, the comparison plots show the Aurora ID Pond sub-bottom cross-section plot agrees well with their sub-bottom cross-section plots generated by CH2M from the thickness grids converted to elevation grid surfaces.

## Conclusion and Recommendations

The different sub-bottom-survey features represent layers beneath the ponds with different reflective properties. Only the uppermost features, Feature B in the CVD Pond and Feature 1 in the ID Pond, appear to correlate reasonably with material layers identified in the ConeTec borings and CPT soundings. The Feature B reflective layer in the CVD Pond approximately correlates to observed sludge deposits. The Feature 1 reflective layer in the ID Pond appears to represent tailings and loosely settled soil deposits. The estimated interpretations of the sub-bottom profiling is further discussed in the Comprehensive Design Road Map Report (CH2M, August 2016n).

## Other Stage Storage Curve Updates Not Associated with the Aurora Geosciences Work

Three-stage storage curve updates are not associated with the Aurora Geosciences work. They are the updates for Faro Pit, Vangorda Pit, and Grum Pit. The work performed to update these stage storage curves is described herein.

### Faro Pit Stage Storage Curve Update

The stage storage curve for Faro Pit was calculated similar to CVD Pond and ID Pond stage storage curves. The 2012 CH2M and Laberge bathymetry and hydrographic data (CH2M, March 2013i) for Faro Pit had already been combined into the overall Faro Mine LiDAR data terrain file.

Using the Faro Mine LiDAR terrain surface, it was determined that the pit crest for the Faro Pit was elevation 1,173.6 m. Similar to the CVD Pond and ID Pond process, the terrain data was limited to the pit crest boundary around the Faro Pit lake and generated a specific terrain file limited to the pit crest for use in the volume calculations. A 0.5-m grid surface was also generated from the combined Faro Mine LiDAR terrain file that was clipped to the pit crest elevation contour.

The ESRI Surface Volume tool was used to calculate volumes for both the grid and terrain versions of the combined surface. As described earlier, this tool is one of the Functional Surface tools within the 3D Analyst Tools set in ArcToolbox. Per the request of YG, the volumes were calculated at 10-cm (0.1-m) intervals from the bottom of the pond to the spill elevation.

Volumes were calculated from both the 0.5 m combined grid surface and from the pond specific terrain surface and compared as a quality control check. Volumes compared favorably with less than one percent difference in the volumes after the first 3-m from the bottom of the pond to less than two-hundredths of a percent difference thereafter for increasing elevations.

The updated Faro Pit stage (elevation) versus storage curve is shown in Figure 11. A simple excel calculation spreadsheet for the Faro Pit is provided in Attachment 3, which includes a curve plot and the stage and storage table in 10 cm elevation increments. The spreadsheet calculates the approximate stored volume and available storage capacity given a specified pit water elevation, using linear interpolation. Attachment 4 provides the water management tool version of the GoldSim model, incorporating the updated stage storage curves.

The original topographic dataset, including the 2011 LiDAR, the 2012 high and low altitude aerial photography and associated 3D Stereo digital terrain model (DTM) data extraction is described in the *Mapping Development, Faro Mine Remediation Project* TM (CH2M, March 2013i).

In July and August of 2016, the prior ESRI terrain data set was updated as described in the technical section with the 2015-2016 Aurora Geosciences bathymetry data sets for the CVD and ID Ponds. This ESRI terrain geodatabase is named `Faro_Terrain_201607.gdb`. A summary of the component data sets are as follows:

- Aurora Geosciences bathymetry data sets
  - `CVD_Bathy_Clippped` – CVD Aurora Bathymetry data clipped into the LiDAR
  - `IDP_Bathy_Clippped` – ID Aurora Bathymetry data clipped into the LiDAR
- Faro low and high altitude aerial 3D Stereo DTM data:
  - `Faro_High_Auto_Cor`
  - `Faro_High_Breaks`
  - `Faro_High_Control`
  - `Faro_High_Edge`
  - `Faro_Low_Breaks`
  - `Faro_Pity_Bathy_20121118` - Laberge Bathymetry
  - `Gov_DEM_Cloud_Areas`
- LiDAR data sets:
  - `LAS_Faro_North`
  - `LAS_Faro_Pit_main`
  - `LAS_Haul_rd_central`
  - `LAS_Haul_rd_north`
  - `LAS_Rose_Cr_north`
  - `LAS_Tailings_area_clipped2` - LiDAR data with data within the Faro Pit/Laberge, Aurora Geosciences/CVD and ID bathymetry areas removed
  - `LAS_Vangorda_East`
  - `LAS_Vangorda`
  - `LAS_Vangorda_West`

A copy of these files are provided with the project mapping files on an external hard drive transferred to YG and INAC as part of CH2M's MSA close-out in August 2016.

## Vangorda and Grum Stage Storage Curve Updates

The Vangorda and Grum stage storage curve updates were not developed from the existing Faro Mine LiDAR terrain surface data. The volume-capacity curve for the Vangorda Pit was estimated using data presented in the Integrated and Comprehensive Abandonment Plan (RGC, 1996) for the volume of water below the pit lake level and meshed with the topography generated from the 2003 aerial photography (SRK, July 2007). The Grum Pit storage capacity below elevation 1,230 m is from the *2011 Annual Environmental Monitoring and Activities Report – Faro, YT* (Golder, February 2011).

The current stage storage curve values, at 10-cm elevation increments are simple spreadsheet interpolations from the previous 1-m stage storage curve values. Using this interpolation methodology does not increase the accuracy of the volumes.

The updated Vangorda and Grum stage (elevation) versus storage curves are shown in Figures 12 and 13. A simple excel calculation spreadsheet for the Vangorda and Grum Pits are provided in Attachment 3, which includes curve plots and the stage and storage table in 10-cm elevation increments. The spreadsheet calculates the approximate stored volume and available storage capacity given a specified pit water elevation using linear interpolation.

## References

- Aurora Geosciences. August 2016a. *Draft Technical Report Hydrographic and Sub-Bottom Profiling Survey – Cross Valley Dam Pond*. Prepared for CH2M HILL Canada Limited. August 22. (Attachment 1 to the *Summary of the 2015-2016 Bathymetry and Sub-Bottom Data Review and Stage Storage Curve Development for the Faro Mine Remediation Project*.)
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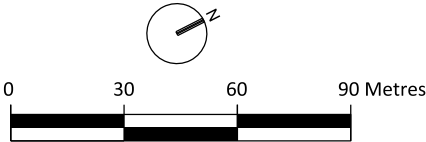
Figures



LEGEND

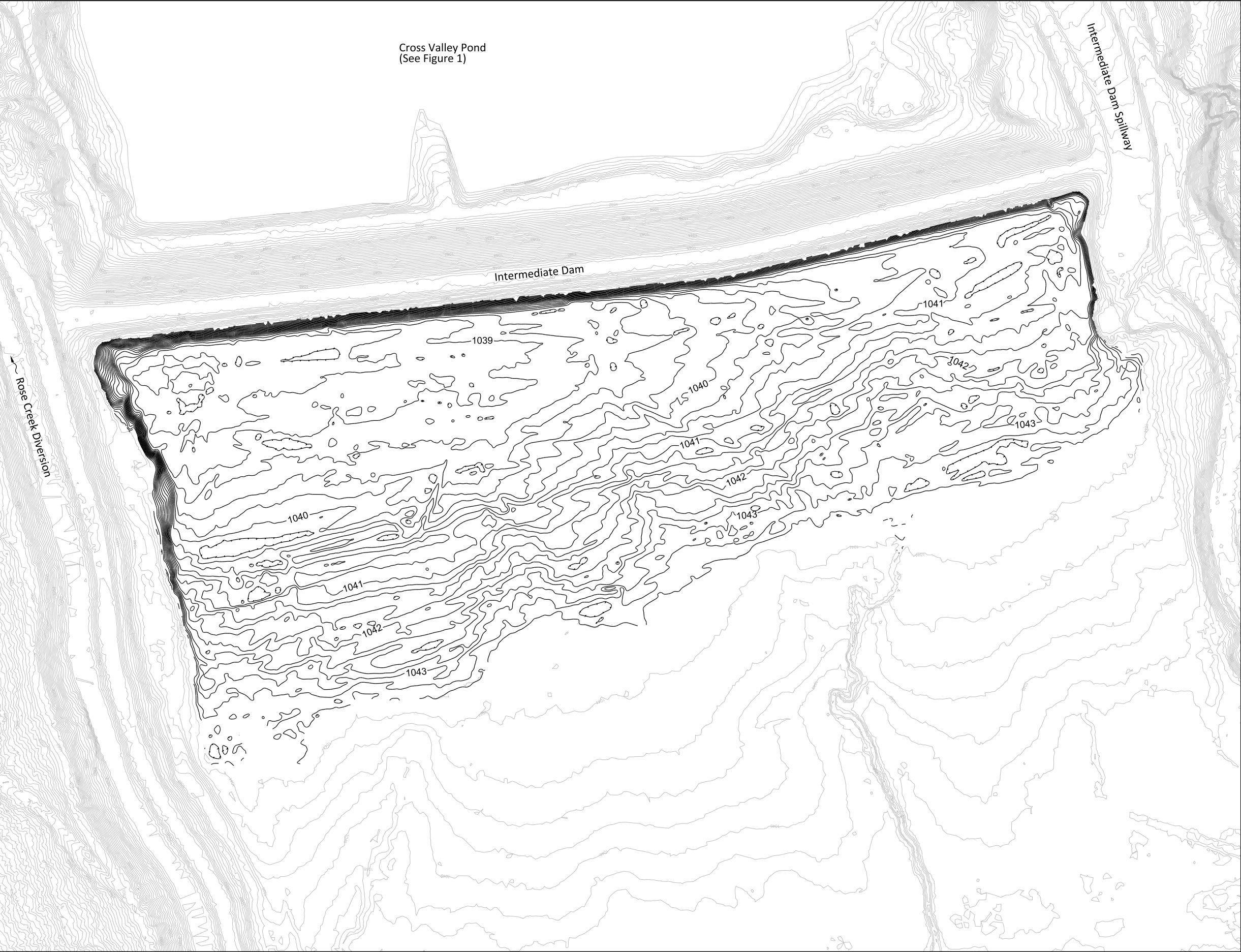
2011 LiDAR Survey Contours  
(50cm Interval), Note 1

Bathymetry Survey  
Contours (1 m interval shown for clarity), Note 2



- Notes:
1. Contours shown were prepared by Critigen Corporation from LiDAR dated Oct. 2011.
  2. Bathymetry Contours shown were prepared by Aurora Geosciences based on survey dated October 2015 and some additional work dated June 2016.

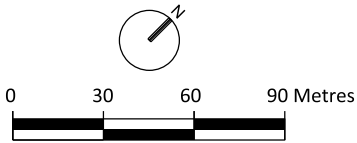
Figure 1  
Cross Valley Pond Bathymetry Survey  
**Faro mine Remediation Project**  
Faro Mine Remediation Project



LEGEND

2011 LiDAR Survey Contours  
(50cm Interval), Note 1

Bathymetry Survey  
Contours (25cm interval), Note 2



- Notes:
1. Contours shown were prepared by Critigen Corporation from LiDAR dated Oct. 2011.
  2. Bathymetry Contours shown were prepared by Aurora Geosciences based on survey dated October 2015 and some additional work dated June 2016.

Figure 2  
Intermediate Dam Pond Bathymetry Survey  
**Faro Mine Remediation Project**  
Faro Mine Remediation Project



Legend

- CVD Pond Lead Line Points
- CVD Pond Single Beam Points
- × CVD Pond Multi-Beam/LiDAR Check Points
- CVD Pond RTK Shoreline Points
- Apparent LiDAR WSEL (1,027.0 meters)
- CVD Pond Spill Elevation (1,030.66 meters)

Clipped Aurora Bathymetry Surface



Clipped Faro Mine LiDAR Terrain Surface



Figure 3  
CVD Pond Bathymetry and Faro Mine  
LiDAR Data Areas  
Faro Mine Remediation Project



**Legend**

- LiDAR Spill Elevation  
(CVP\_Contour\_1030p66)
- Faro LiDAR 1,027m Apparent Water at  
time of LiDAR capture  
(CVP\_Contour\_1027)

**Aurora Bathymetry Elevs above  
1,027**

|          |                     |
|----------|---------------------|
|          | 1,028.01 - 1,028.57 |
|          | 1,027.51 - 1,028.00 |
|          | 1,027.01 - 1,027.50 |
| No Color | 1,013.87 - 1,027.00 |



**Figure 4**  
**CVD Pond Bathymetry Elevations**  
**higher than Faro Mine LiDAR Data**  
*Faro Mine Remediation Project*



Legend

- ID Pond Lead Line Points (Bathy Check)
- ID Pond Lead Line Points (LiDAR Check)
- ID Pond RTK Shoreline Extension Points (LiDAR Che
- ID Pond Single Beam Points (LiDAR Check)
- ID Pond Single Beam Points (Multi-Beam Check)??
- ID Pond Multi-Beam/LiDAR Check Points
- IDP\_ShoreLineMeasured\_Pts
- Apparent LiDAR WSEL (1,043.60 meters)
- ID Pond Spill Elevation (1,047.70 meters)
- Clipped Aurora Bathymetry Surface
- Clipped Faro Mine LiDAR Terrain Surface

Figure 5  
ID Pond Bathymetry and Faro Mine  
LiDAR Data Areas  
Faro Mine Remediation Project

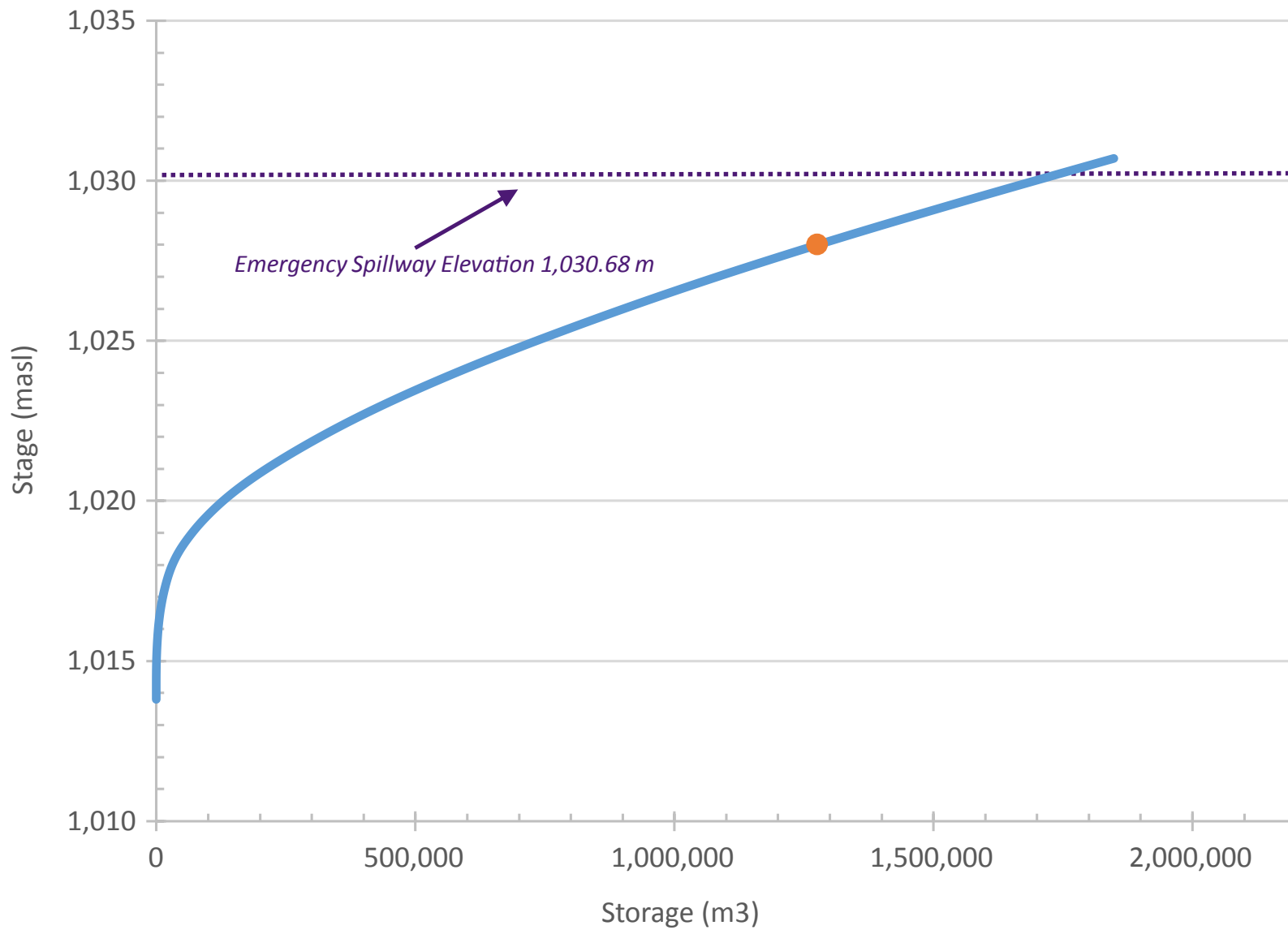


**Figure 6**  
**CVD Pond Stage Storage Curve**  
*Faro Mine Remediation Project*

Note: 1,030.66 m emergency spillway elevation from LiDAR

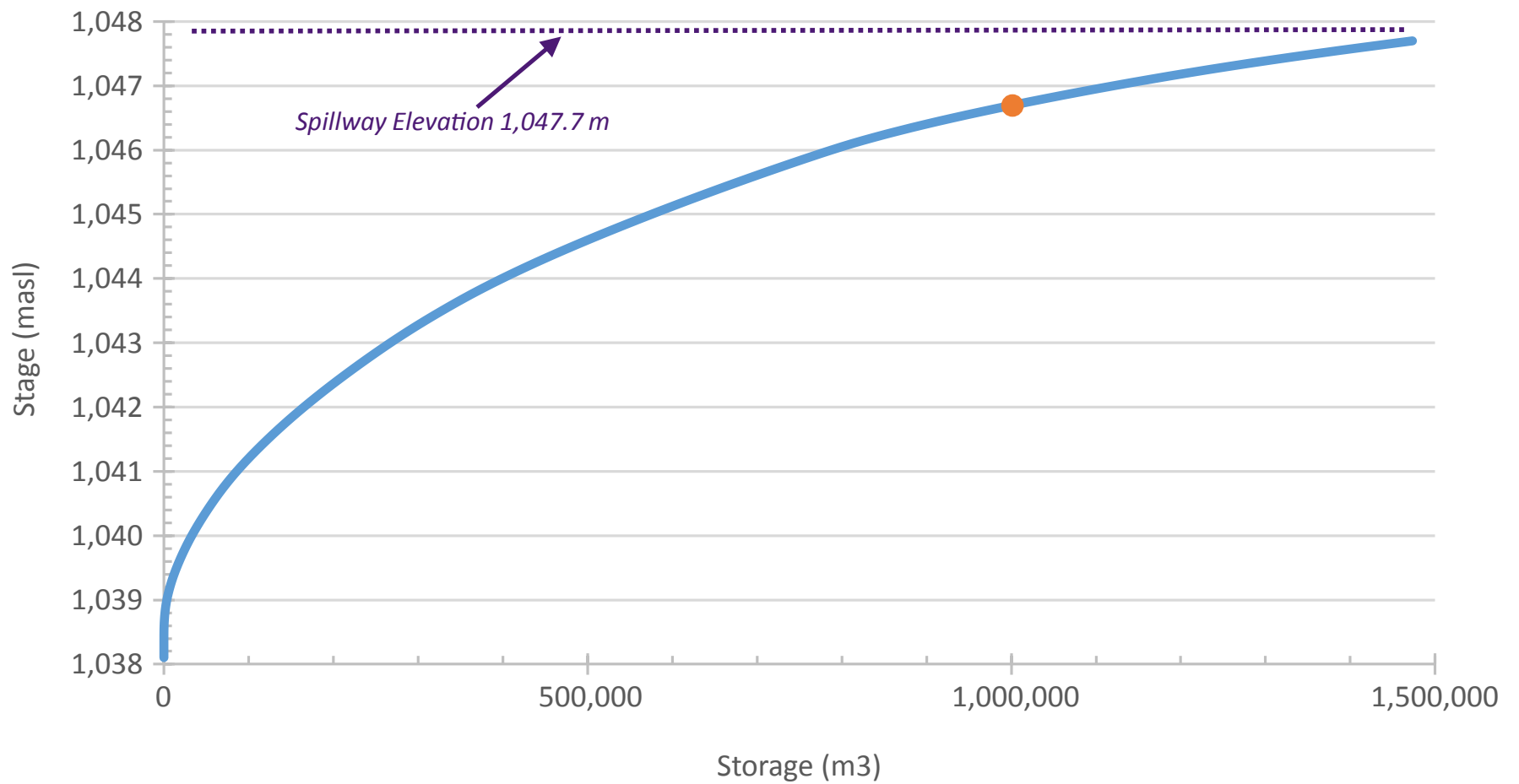


**Figure 7**  
**ID Pond Stage Storage Curve**  
*Faro Mine Remediation Project*



**Legend**

- CVD Pond Lead Line Points
- CVD Pond Single Beam Points
- × CVD Pond Multi-Beam/LiDAR Check Points
- CVD Pond RTK Shoreline Points
- Apparent LiDAR WSEL (1,027.0 meters)
- CVD Pond Spill Elevation (1,030.66 meters)

**Sub-Bottom Feature B**

- Thickness (m)**
- -0.095 - 0.000 (suspect areas)
  - 0.001 - 5.621

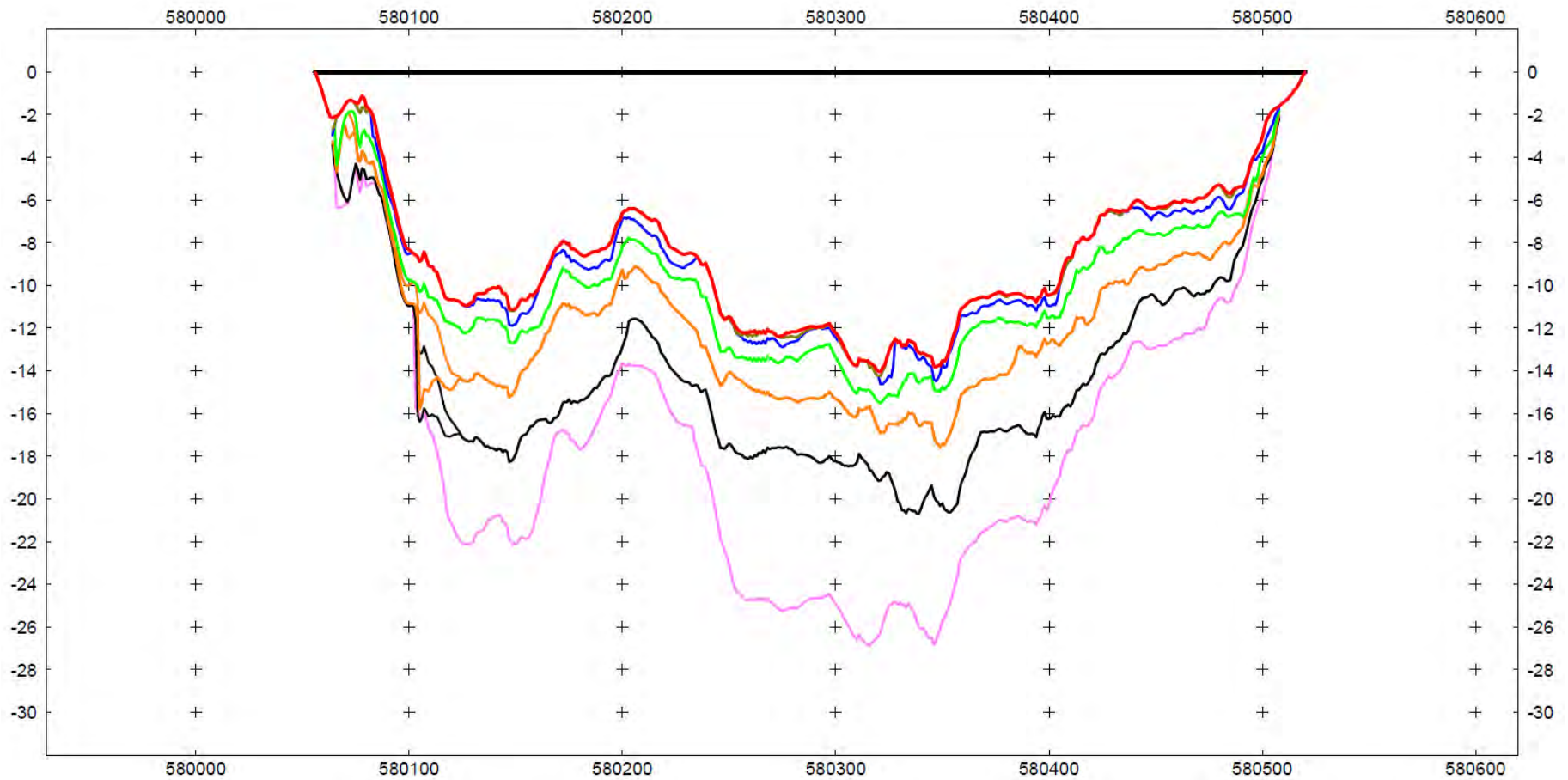
**Clipped Aurora Bathymetry Surface**



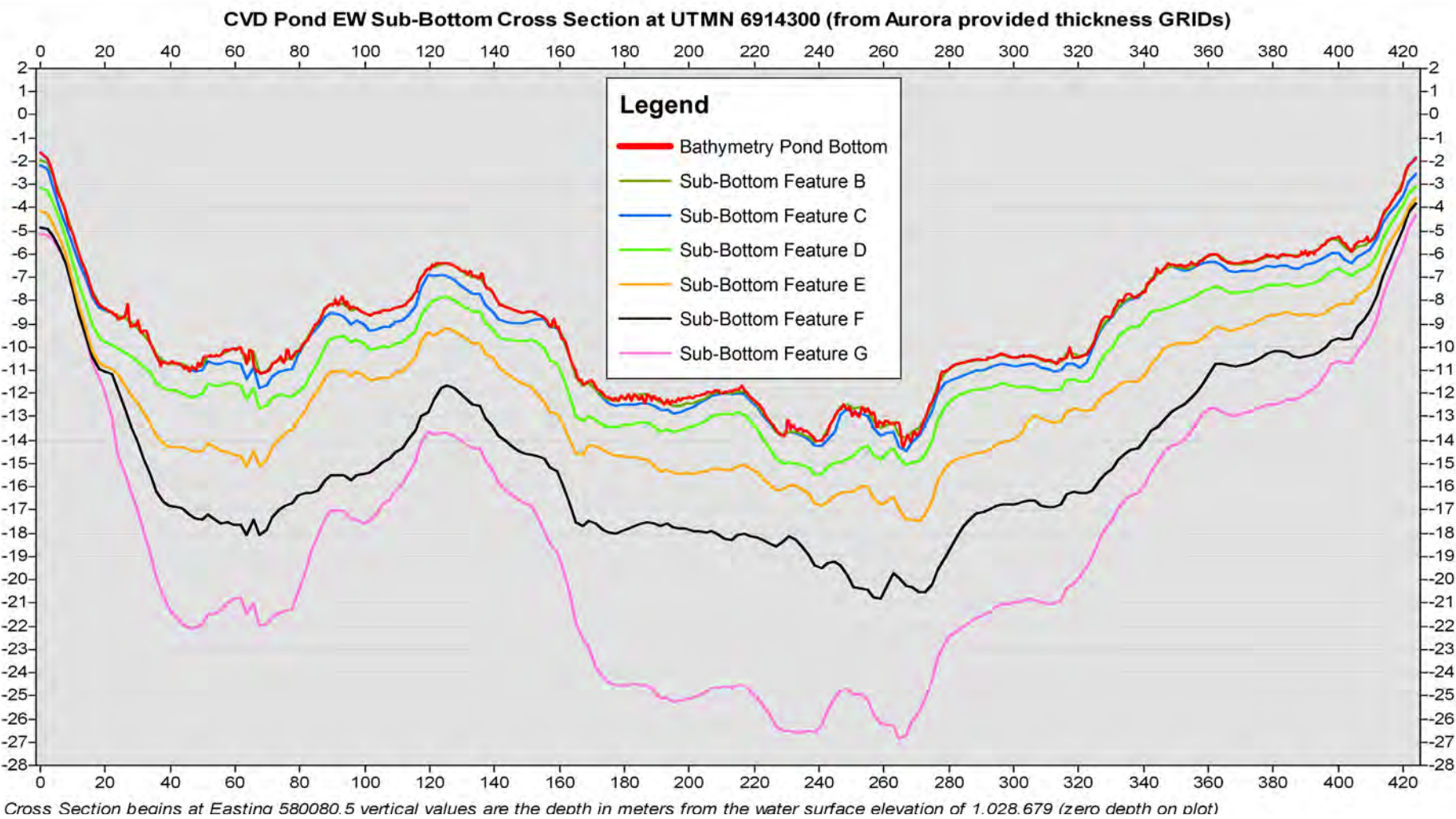
**Clipped Faro Mine LiDAR Terrain Surface**



**Figure 8**  
**CVD Pond Sub-Bottom Area of Coverage**  
**and Negative Thickness Areas**  
*Faro Mine Remediation Project*

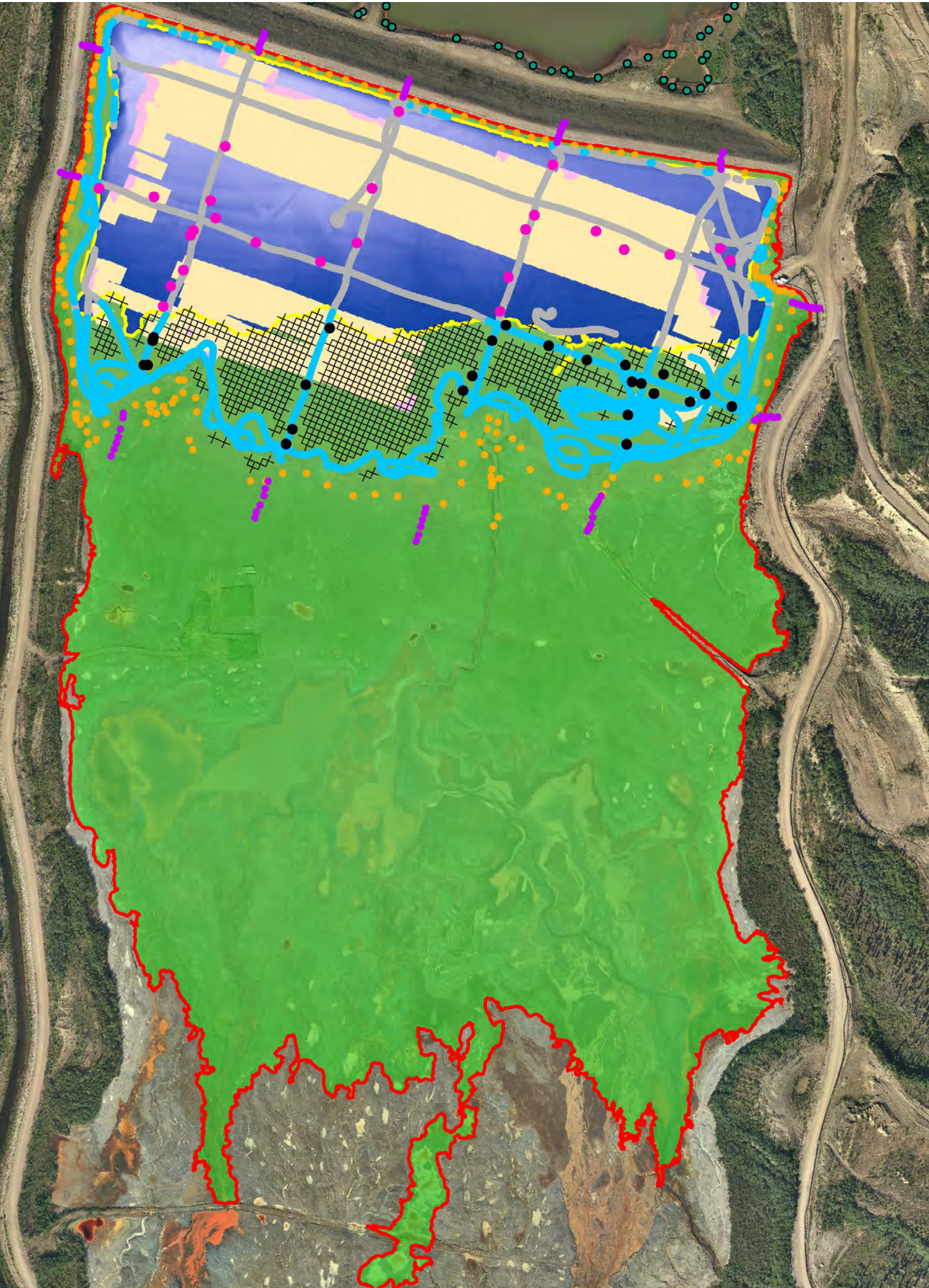


Aurora delivered sub-bottom cross-section plot at section UTMN 6914300



GIS profile plot of sub-bottom thickness GRID data converted to depths at section UTMN 6914300

Figure 9  
Comparison of CVD Pond Sub-Bottom Features  
at section UTMN 6914300s  
Faro Mine Remediation Project



**Legend**

- ID Pond Lead Line Points (Bathy Check)
- ID Pond Lead Line Points (LiDAR Check)
- ID Pond RTK Shoreline Extension Points (LiDAR Check)
- ID Pond Single Beam Points (LiDAR Check)
- ID Pond Single Beam Points (Multi-Beam Check)??
- × ID Pond Multi-Beam/LiDAR Check Points
- IDP\_ShoreLineMeasured\_Pts
- Apparent LiDAR WSEL (1,043.60 meters)
- ID Pond Spill Elevation (1,047.70 meters)

**Sub-Bottom Feature 2**

- Thickness (m)**
- -2.366 - 0.000
  - 0.001 - 13.980

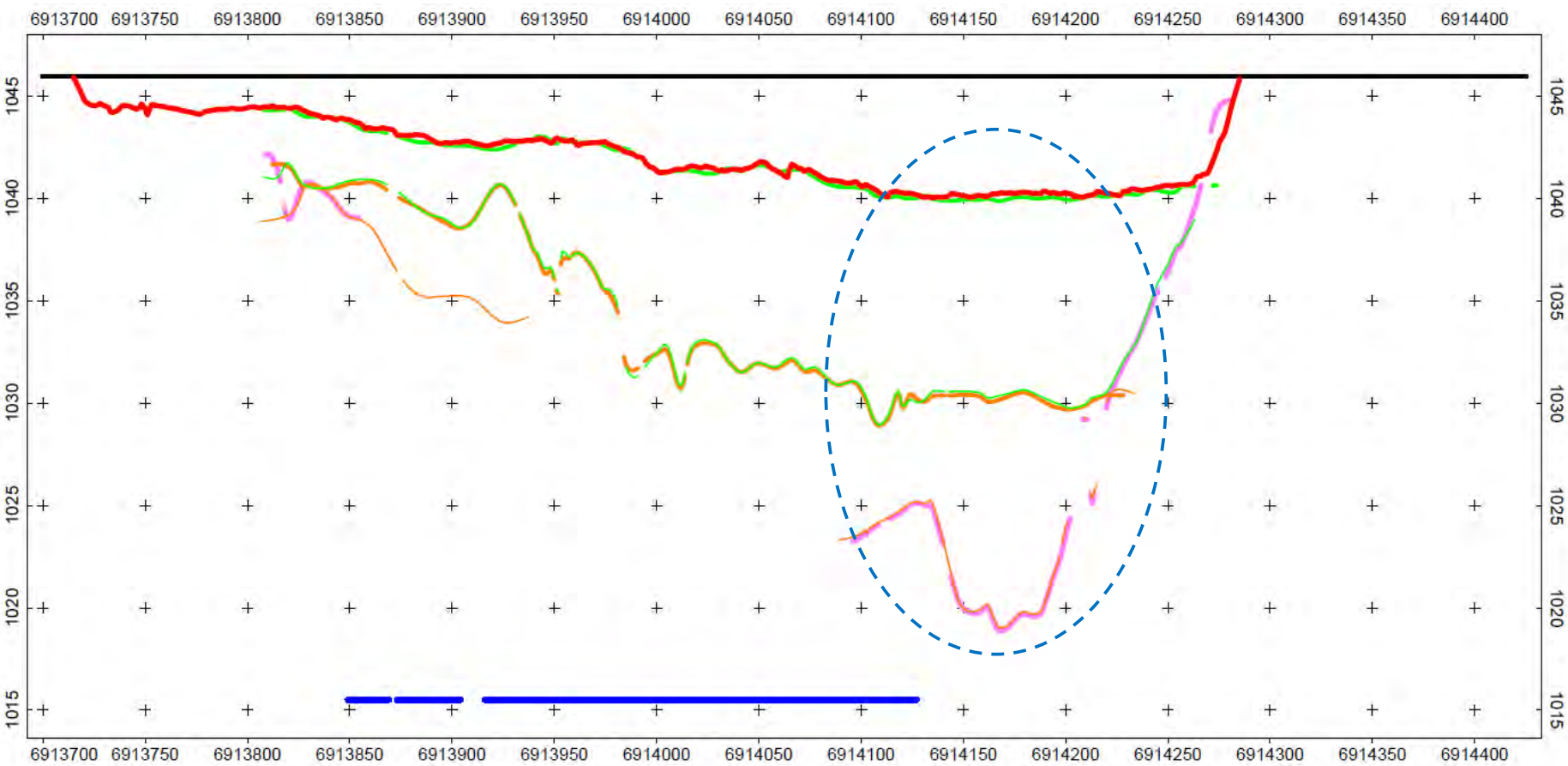
**Clipped Aurora Bathymetry Surface**



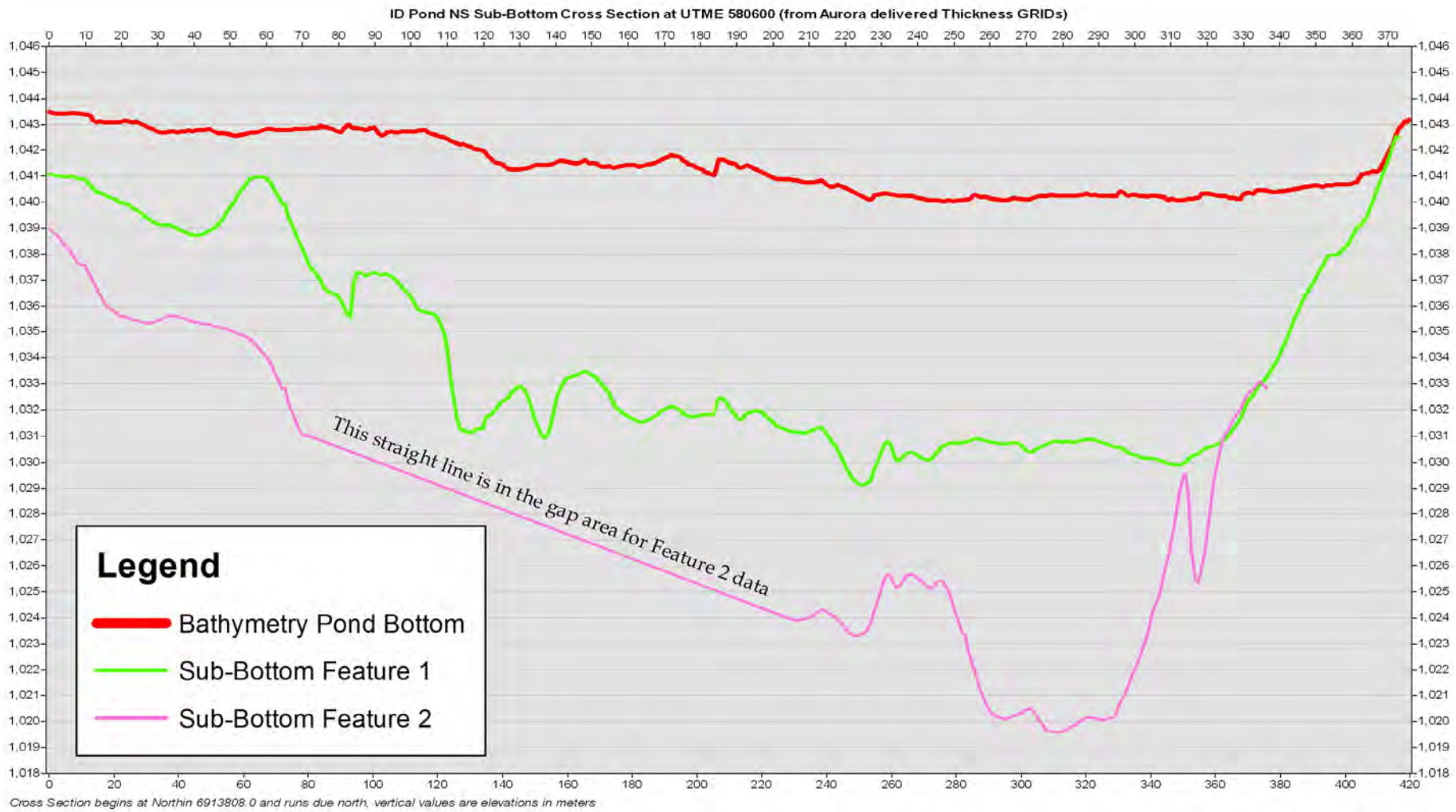
**Clipped Faro Mine LiDAR Terrain Surface**



**Figure 10**  
**ID Pond Sub-Bottom Area of Coverage**  
**and Negative Thickness Areas**  
*Faro Mine Remediation Project*



Aurora delivered sub-bottom cross-section plot at section UTME 580600



GIS profile plot of sub-bottom thickness grid data converted to depths at section UTME 580600

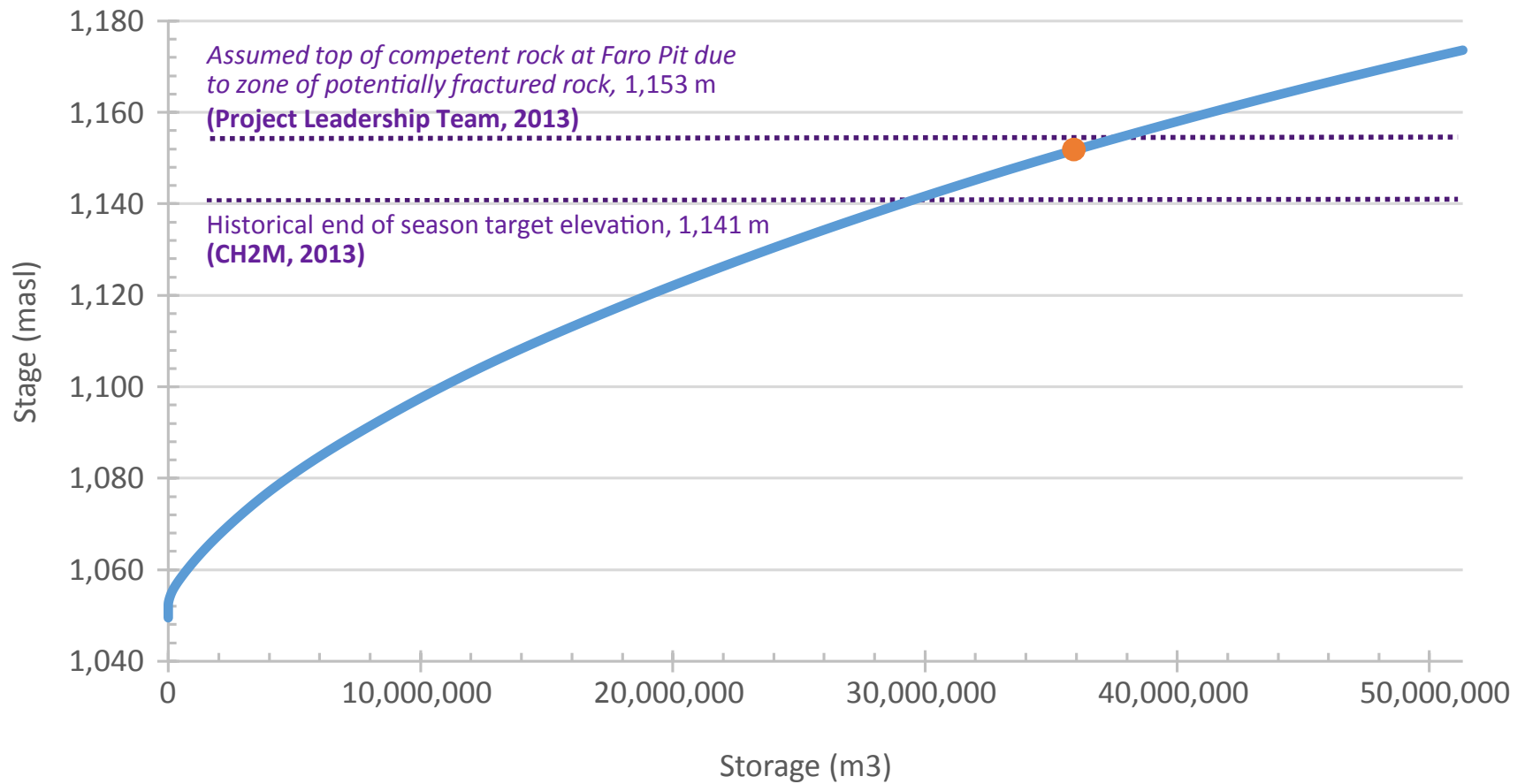


**Figure 12**  
**Faro Pit Stage Storage Curve**  
Faro Mine Remediation Project

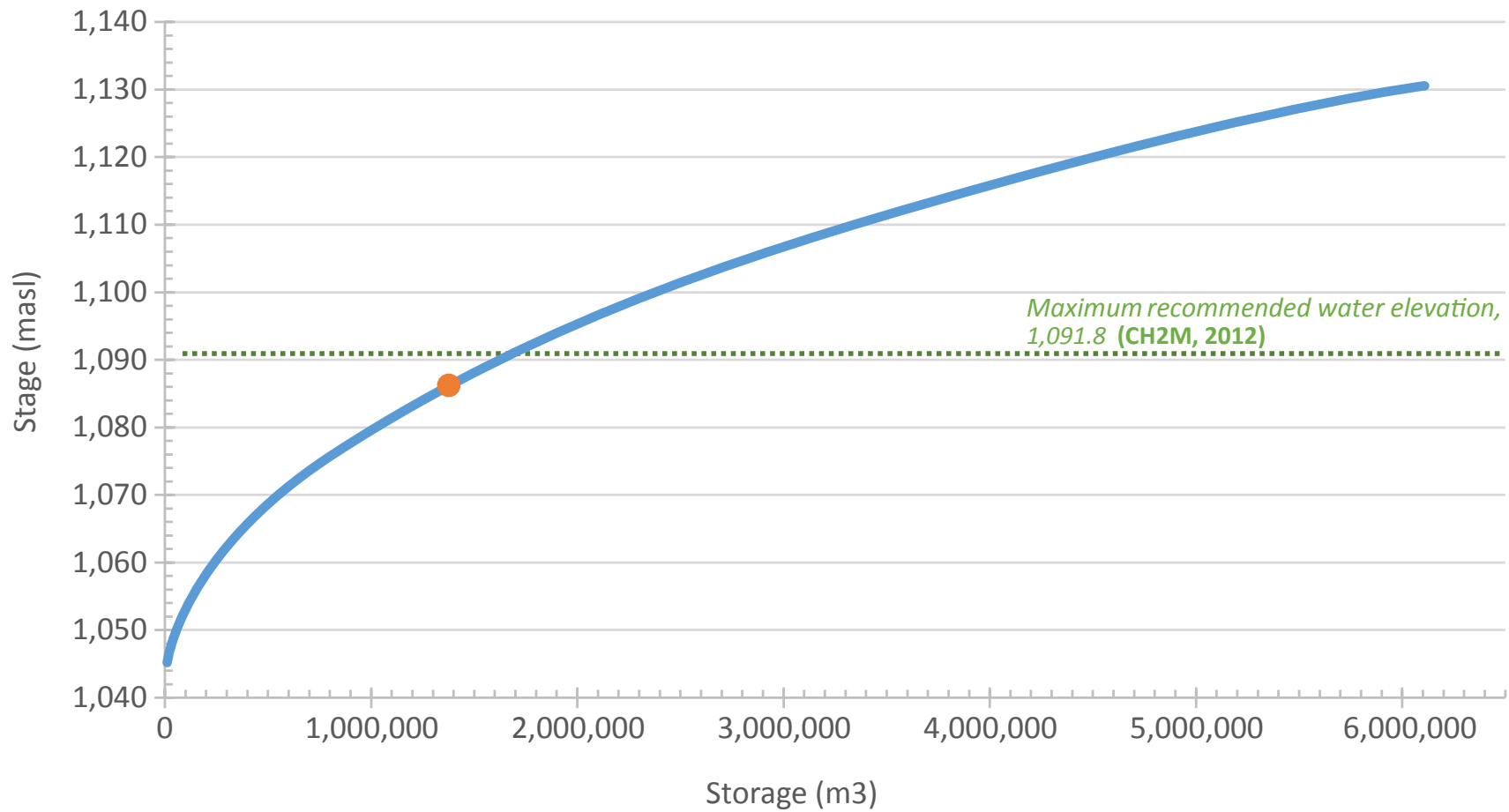


**Figure 13**  
**Vangorda Pit Stage Storage Curve**  
*Faro Mine Remediation Project*

Note: Based on interpolated 1-meter interval historic bathymetric data and not site lidar.

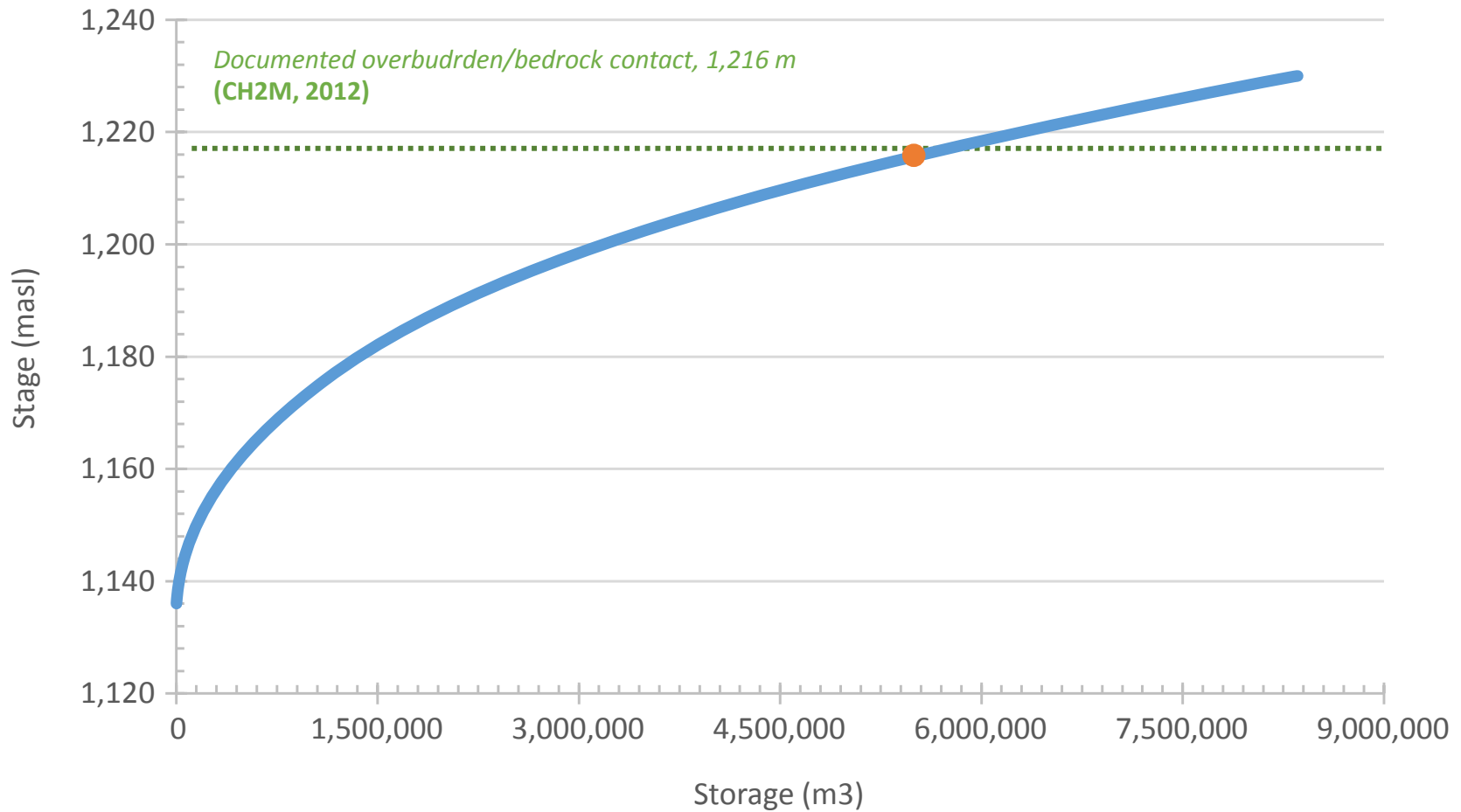


**Figure 14**  
**Grum Pit Stage Storage Curve**  
*Faro Mine Remediation Project*

Note: Based on interpolated 1-meter interval historic bathymetric data and not site lidar.

Attachment 1  
Aurora Geosciences CVD Pond  
Bathymetry and Sub-bottom  
Profile Report

---

**Hydrographic and Sub-Bottom Profiling Survey – Cross Valley Dam Pond**

NTS: 105K/06,      Faro Mining Complex, Yukon Territory, Canada

WORK PERFORMED:  
October 20 – 27, 2015

Prepared for:



Prepared by:



**DRAFT TECHNICAL REPORT**  
**Hydrographic and Sub-Bottom Profiling Survey – Cross Valley Dam Pond**

Effective Date: August 22, 2016

Prepared for:  
**CH2M Hill Canada Limited**  
**Whitehorse, YT Y1A 4N2**

Prepared by:  
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**Shawn Scott**

## TABLE OF CONTENTS

|          |                                                          |           |
|----------|----------------------------------------------------------|-----------|
| <b>1</b> | <b>INTRODUCTION .....</b>                                | <b>1</b>  |
| <b>2</b> | <b>LOCATION &amp; ACCESS .....</b>                       | <b>1</b>  |
| <b>3</b> | <b>WORK PROGRAM .....</b>                                | <b>2</b>  |
| 3.1      | BATHYMETRIC SURVEY .....                                 | 3         |
| 3.1.1    | <i>Equipment.....</i>                                    | 4         |
| 3.1.2    | <i>Survey Specifications &amp; Field Procedures.....</i> | 5         |
| 3.1.3    | <i>Data Processing .....</i>                             | 8         |
| 3.1.4    | <i>Products .....</i>                                    | 12        |
| 3.2      | SUB-BOTTOM SURVEY .....                                  | 13        |
| 3.2.1    | <i>Equipment.....</i>                                    | 13        |
| 3.2.2    | <i>Survey Specifications &amp; Field Procedures.....</i> | 14        |
| 3.2.3    | <i>Data Processing .....</i>                             | 15        |
| 3.2.4    | <i>Sub-bottom Products .....</i>                         | 19        |
| 3.3      | QUALITY CONTROL CHECKS .....                             | 20        |
| 3.3.1    | <i>Common Transects .....</i>                            | 20        |
| 3.3.2    | <i>Lead-line comparisons .....</i>                       | 24        |
| 3.3.3    | <i>Daily check-ins .....</i>                             | 24        |
| <b>4</b> | <b>DISCUSSION AND INTERPRETATION .....</b>               | <b>27</b> |
| 4.1      | BATHYMETRY .....                                         | 27        |
| 4.2      | SUB-BOTTOM .....                                         | 28        |

## LIST OF FIGURES

|                                                                                                  |    |
|--------------------------------------------------------------------------------------------------|----|
| FIGURE 1: LOCATION MAP OF THE CVD POND WITHIN THE FARO MINE AREA. ....                           | 2  |
| FIGURE 2: SURVEYS ON CVD POND. ....                                                              | 3  |
| FIGURE 3: UNIVERSAL MOUNTING POLE WITH THREE GPS ANTENNAE AND SUBSEA MOTION SENSOR VISIBLE. .... | 6  |
| FIGURE 4: POSITION QUALITY OF GPS SOLUTIONS DURING MULTI-BEAM BATHYMETRY ACQUISITION. ....       | 9  |
| FIGURE 5: HEIGHT QUALITY OF GPS SOLUTIONS DURING MULTI-BEAM BATHYMETRY ACQUISITION. ....         | 9  |
| FIGURE 6: AVERAGE ACOUSTIC WATER VELOCITY PROFILE. ....                                          | 11 |
| FIGURE 7: POSITION QUALITY OF GPS SOLUTIONS DURING SUB-BOTTOM PROFILING ACQUISITION. ....        | 15 |
| FIGURE 8: HEIGHT QUALITY OF GPS SOLUTIONS DURING SUB-BOTTOM PROFILING ACQUISITION. ....          | 16 |
| FIGURE 9: EXAMPLE OF INTRODUCED ROUGHNESS TO THE SUB-BOTTOM DATASET.....                         | 18 |
| FIGURE 10: HISTOGRAM OF DIFFERENCE BETWEEN SINGLE-BEAM AND MULTI-BEAM SURVEYS.....               | 20 |
| FIGURE 11: SINGLE-BEAM COMMON TRANSECTS SURVEYED IN 2016 AND SHORELINE FROM 2015. ....           | 20 |
| FIGURE 12: COMMON SINGLE-BEAM AND MULTI-BEAM TRANSECTS 1, 2 AND 3.....                           | 22 |
| FIGURE 13: COMMON SINGLE-BEAM AND MULTI-BEAM TRANSECTS 4, 5 AND 6.....                           | 23 |
| FIGURE 14: HISTOGRAMS OF THE DIFFERENCED GRIDS FROM MULTI-BEAM CONTROL POINTS.....               | 25 |
| FIGURE 15: MORNING SUB-BOTTOM DATA AT THE FLAGGED CONTROL POINT .....                            | 26 |
| FIGURE 16: AFTERNOON SUB-BOTTOM DATA AT THE FLAGGED CONTROL POINT .....                          | 26 |
| FIGURE 17: BATHYMETRY OF CVD POND.....                                                           | 28 |
| FIGURE 18: L4 SUB-BOTTOM PROFILE. ....                                                           | 29 |

|                                                                                       |    |
|---------------------------------------------------------------------------------------|----|
| FIGURE 19: FEATURE B THICKNESS WITH BATHYMETRY CONTOURS .....                         | 30 |
| FIGURE 20: L26 SUB-BOTTOM PROFILE. . . . .                                            | 31 |
| FIGURE 21: BATHYMETRY CONTOURS WITH FEATURE D THICKNESS COLOUR CONTOUR UNDERLAY. .... | 32 |

## LIST OF TABLES

|                                                                      |    |
|----------------------------------------------------------------------|----|
| TABLE 1: ESTIMATED ACCURACY OF SINGLE-BEAM HORIZONTAL POSITION. .... | 10 |
| TABLE 2: LEAD-LINE MEASUREMENTS AT CVD POND. ....                    | 24 |

## LIST OF APPENDICES

|                   |                           |
|-------------------|---------------------------|
| APPENDIX I.....   | PROJECT LOG               |
| APPENDIX II.....  | EW AND NS CROSS-SECTIONS  |
| APPENDIX III..... | EDGE TECH JSF FILE FORMAT |

## 1 INTRODUCTION

Aurora Geosciences Ltd. was retained by CH2M Hill Canada Limited to conduct bathymetric and sub-bottom profiling of the Cross Valley Dam (CVD) and Intermediate Dam (ID) ponds at the Faro Mine, Faro, Yukon Territory. Only the multi-beam bathymetry and sub-bottom surveys on the CVD Pond were completed during the 2015 survey due to the onset of cold weather and subsequent formation of ice, rendering further boat work on the ponds impossible. Work on the Intermediate Dam pond was completed in June 2016 and is described in a separate report. The single-beam bathymetry was completed on the CVD Pond in June 2016 along with some supporting RTK measurements.

Complete coverage of the CVD Pond bathymetry was obtained through a multi-beam sonar investigation, coupled with a supplemental single-beam sonar survey in shallow areas, and RTK-GPS survey (to define the shoreline). The survey revealed greater depths toward the North as well as Western side of the pond, producing a maximum depth of 14.68 metres.

Acoustic sub-bottom profiling was also completed on the pond with a line spacing of 10m.

All geographic locations in this report are relative to North American Datum 1983 (CSRS) and all elevations are orthometric heights relative to the HT2 geoid. Non-geodetic coordinates are expressed in Universal Transverse Mercator Zone 8N metric coordinates. All measurements are expressed in the metric SI system.

## 2 LOCATION & ACCESS

The crew was based in the town of Faro, YT for the duration of the project and accessed the CVD Pond daily by truck and then by 16-foot aluminum boat. The pond is approximately 15 kilometers north-northwest of the town of Faro; Figure 1 is a map of the CVD Pond within the Faro Mine area.

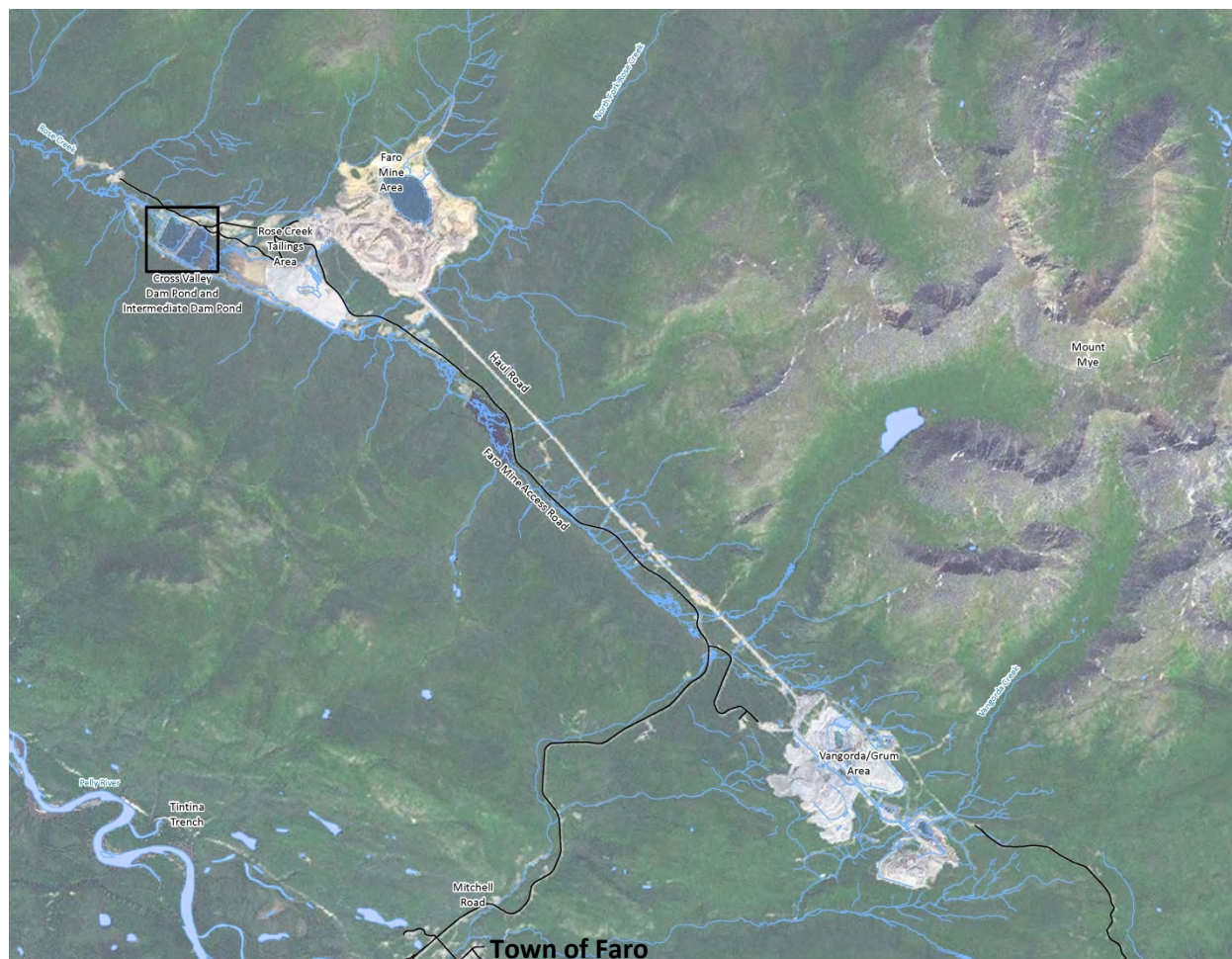


**Figure 1: Location map of the CVD pond within the Faro Mine area. Map is from the CH2M Hill Agreement 10201-7-100723. The distance from the Town of Faro to the CVD Pond is approximately 15 km.**

### 3 WORK PROGRAM

This section describes the October 2015 and June 2016 work programs conducted at the CVD Pond. A bathymetric survey was completed comprising of multi-beam sonar, selected areas of single-beam sonar, selected lead-line measurements and RTK-GPS survey both for shoreline definition and for single-beam line extensions to allow comparison to existing topographic data; this is described in Section 3.1. A sub-bottom survey was completed using a 4-24 kHz chirped acoustic signal; this is described in Section 3.2. Figure 2 shows the line-path of the multi-beam bathymetry (yellow), 2015 single-beam bathymetry (black), sub-bottom profiling (red) and RTK shoreline survey points (blue symbols). A complete project log detailing the work performed by the Aurora Geosciences field crew is in Appendix I.

QA/QC of the surveys is examined in Section 3.3.

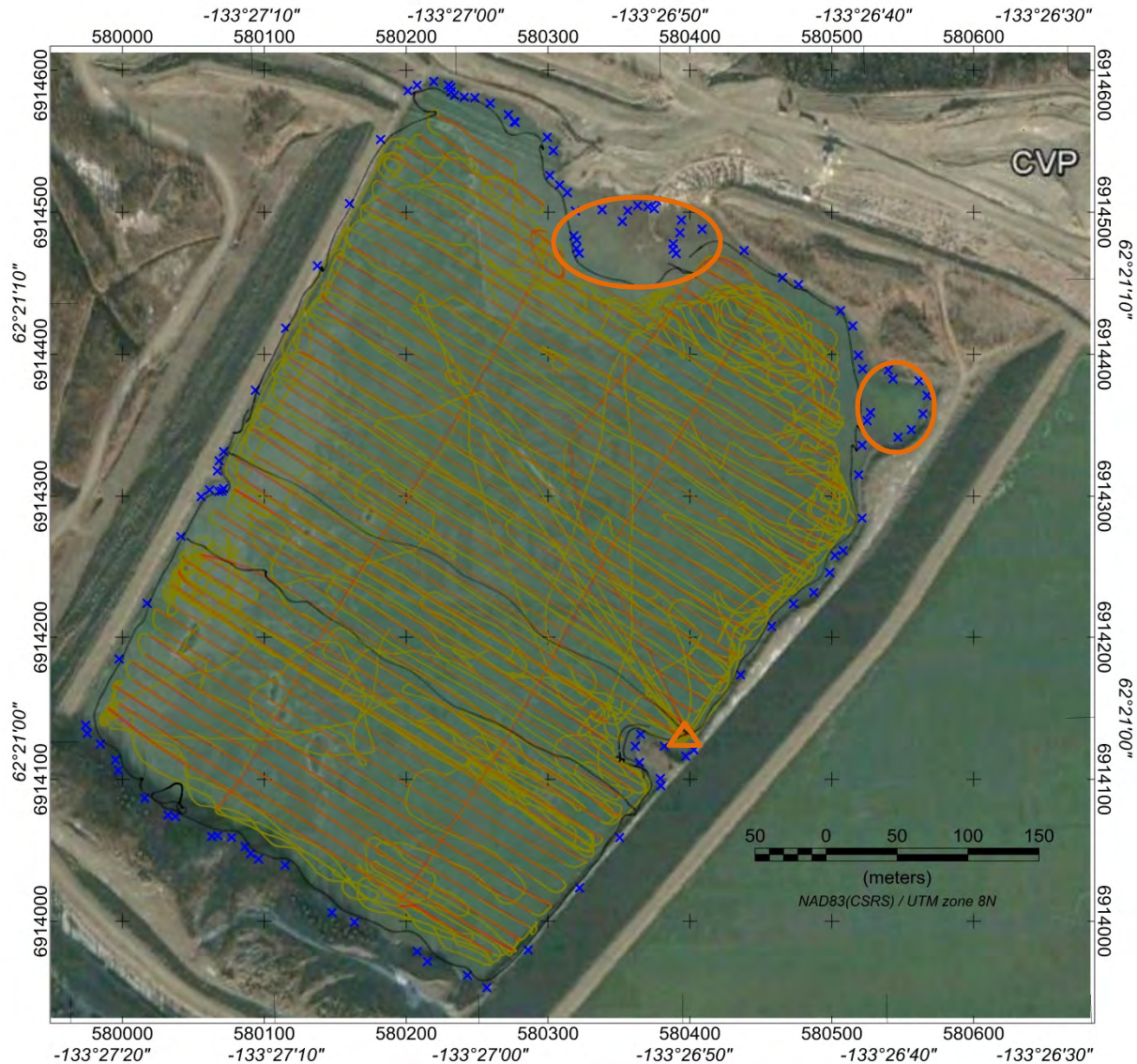


**Figure 2: Surveys on CVD Pond.** Yellow shows the path of the multi-beam bathymetry, red of the sub-bottom profiling, black of the 2015 single-beam bathymetry and the blue symbols are the shore GPS measurements. The location of the CVP monument used for a GPS base is shown in the north-east corner. Areas shown in orange are shallow water where no data were collected. Daily check-in location is shown by the orange triangle.

### 3.1 Bathymetric Survey

The multi-beam bathymetric survey provides an extremely high resolution depth database of the CVD Pond, with a data density of approximately 3.6 cm. Positional data were determined through an RTK GPS streaming data to the multi-beam system, with the GPS base station set up at the nearby CVP control point. The shoreline was also surveyed using RTK GPS, to both define the areal limit of the pond and to measure the water elevation. A single-beam sonar survey supplemented the multi-beam survey in shallow water, though with a much lower data density. There are two areas on the north side of the pond that were not surveyed using either method due to the very shallow water, as well as obstacles in

the water (rocks, metallic debris). In addition, two traverses of the pond were done using the single-beam survey, to compare with the multi-beam dataset.

The single-beam survey was a lower priority than the planned multi-beam and sub-bottom surveys of the Intermediate Dam Pond (not completed). However, due to the daily tear down time of the multi-beam equipment, the crew was able to collect some single-beam data on the CVD Pond in 2015 without any impact on production of multi-beam or sub-bottom data collection despite this not conforming to the stated priority.

Multi-beam data collection was completed and single-beam data collection was partially completed at CVD Pond in 2015 and six traverses of the pond were done using the single-beam survey in 2016 to compare with the multi-beam dataset. No bathymetric data were collected at the Intermediate Dam Pond due to the onset of cold weather and ice formation in 2015.

### **3.1.1 Equipment**

The crew was equipped with the following instruments and equipment:

|                     |   |                                                          |
|---------------------|---|----------------------------------------------------------|
| Equipment:          | 1 | VS101 Hemisphere GPS box s/n: AA1129-14928-00016         |
|                     | 2 | A21 Hemisphere GPS sensors s/n: 7179, 7169               |
|                     | 1 | Digibar S water velocity sensor s/n: 4714                |
|                     | 1 | MB1 multi-beam sonar head s/n: 206                       |
|                     | 1 | RTAI real time appliance s/n: 220083                     |
|                     | 1 | Digibar V water velocity sensor (sonar head) s/n: 5683   |
|                     | 1 | IMU S-108 Subsea Motion Sensor s/n: 4078                 |
|                     |   | Miscellaneous multi-beam cables, brackets and equipment  |
|                     | 1 | Trimble GeoExplorer XT2008                               |
|                     | 1 | Garmin GPSmap 527                                        |
|                     | 1 | Airmar SS510 smart transducer                            |
|                     |   | Miscellaneous single-beam cables, brackets and equipment |
|                     | 1 | Leica GS15 sensor rover s/n 1502720                      |
|                     | 1 | Leica GS14 sensor base s/n 2806121                       |
|                     | 1 | Leica CS15 controller s/n 2907005                        |
|                     | 1 | Pac Crest ADL Vantage Pro Radio s/n 13086191             |
|                     | 1 | Pac Crest Radio s/n 1301949                              |
|                     |   | Miscellaneous GPS cables, tripods and equipment          |
| Communications:     | 4 | VHF handheld radios                                      |
|                     | 1 | DeLorme InReach                                          |
| Vehicles & Vessels: | 1 | Flat deck truck                                          |
|                     | 1 | Truck Trailer                                            |
|                     | 1 | Arctic Cat ATV                                           |
|                     | 1 | 16ft aluminium boat                                      |
|                     | 1 | Inflatable Zodiac rescue boat                            |
|                     | 1 | 6 HP outboard motor                                      |
|                     | 1 | 2 HP electric motor                                      |
| Safety:             | 4 | Government certified personal floatation devices (PFDs)  |
|                     | 2 | ATV helmets                                              |
|                     | 4 | Hard hats                                                |

|                       |     |                                                    |
|-----------------------|-----|----------------------------------------------------|
|                       | 100 | Nitrate gloves                                     |
|                       | 9   | Tyvek suits                                        |
|                       | 8   | Safety glasses                                     |
|                       | 4   | High Visibility Vests                              |
|                       | 2   | Fire extinguisher                                  |
|                       | 2   | Level 2 First aid kit                              |
|                       | 4   | Spare paddles                                      |
|                       | 2   | 15m floating rope                                  |
|                       | 2   | Bailers                                            |
| Computers & Software: | 1   | Laptop with Edgetech Discover Sub-Bottom 4.0       |
|                       | 1   | Laptop with HyPack 2015, SonarWiz 6                |
|                       | 1   | Laptop with Image, SMC IMU Config, Digibar Pro 3.0 |
| Other                 | 20  | 6 mil plastic garbage bags                         |
|                       | 1   | Pressure washer                                    |
|                       | 1   | Water tank                                         |
|                       | 1   | Office box                                         |
|                       | 1   | Geophysical Toolbox                                |

### 3.1.2 Survey Specifications & Field Procedures

All manufacturer and model information for equipment referenced in this section can be found in Section 3.1.1.

#### 3.1.2.1 RTK GPS

A GPS base station was established daily with the Leica GS14 antenna over the permanent control marker 2010-P5 at CVP. As this primary control monument was suitable for all areas of the CVD pond, a secondary control network was not established.

For the 2016 points, the published position for 2010-P5 was inadvertently not programmed into the GPS base prior to starting work in the field and an arbitrary position was therefore used the first day. For consistency the arbitrary base position was used throughout the 2016 survey and all RTK data were corrected by a post-survey datum shift to align the base with the published position.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. This base location was broadcast continuously via radio to the Leica GS15 rover so that a phase-corrected RTK solution was being transferred to the multi-beam equipment via NMEA string at all times during multi-beam sonar collection.

Point RTK positions with the Leica GS15 antenna were taken along the shoreline to constrain the gridding of the water depths in the shallows and to provide a measure of the water-surface elevation. Where the shoreline is straight, station spacing is nominally 50 m, with decreasing station spacing as required to capture smaller scale shoreline features; these points are shown as blue crosses in Figure 2.

In 2016, point RTK positions were also recorded as rough extensions of all single-beam lines, extending roughly 15 m back from the shoreline.

Also in 2016, RTK positions were taken during single-beam collection and matched to the single-beam data by time-stamp.

### **3.1.2.2 Multi-Beam Sonar**

An Odom Teledyne MB1 multi-beam echo-sounder was used for the collection of primary bathymetric data from all areas of the CVD Pond, in areas with water depths greater than approximately 1 m. The sonar head was equipped with a sensor that monitored changes in water velocity from fluctuations in water temperature and purity. A motion sensor was also used to monitor the heave, pitch and roll of the boat. The later was calibrated each morning to account for slight variations in crew weight as well as position. A Hemisphere marine GPS unit with two widely spaced antennae, positioned perpendicular to the sonar head (parallel to the axis of the vessel), provided precision bearings at all times. The Leica GS15 rover with a radio link to a base antenna was attached 1.09 metres directly above the sonar head to provide high accuracy positional data. The part of the system above water is shown in Figure 3.



**Figure 3: Universal mounting pole with three GPS antennae and subsea motion sensor visible.**

Each day the MB1 sonar head, RTK sensor and all secondary control instruments were bolted to the same place on a universal mounting pole, ensuring constant registration relative to the boat across multiple days of surveying. Data from all instruments were fed to an Odom Real Time Appliance for time registration and for interfacing with laptop computers.

A pair of onboard computers was used to control and monitor the instruments, while simultaneously recording data. One laptop, equipped with Odom Image, monitored the sonar head and water velocity sensor. The second laptop, equipped with Hypack 2015, recorded all data and plotted results allowing for real time feedback on quality and coverage.

The crew conducted a series of control tests at the beginning and end of each day. A control station was established at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) by the suspension of a survey flag over the pond shown by the orange triangle in Figure 2; GPS and multi-beam sonar data were recorded for a minimum of 30 seconds during check-ins at this control station. Patch test data were recorded during normal data collection each day to correct potential errors arising from mounting variations as well as pitch, roll and yaw motion. Patch test corrections generated by the Hypack software were negligible and were not applied to the final data set. Water velocity data were collected by a second water velocity sensor independent of the sonar head that was lowered to the pond floor, producing a water velocity profile for the full depth of the pond with data points collection every 10 cm. 12 casts were attempted in various locations to assess any spatial variability of the acoustic velocity.

The MB1 sonar head operated at 170-220 kHz and is capable of recording a 120° swath which, over flat terrain, is approximately 4 x the water column depth. As a quality control measure to account for variations in the pond floor and potential noise near the edge of the swath, the crew aimed for an initial 33% overlap in data, with occasional insufficient overlap to be cleaned up at the end of the survey. These were identified in preliminary processing and all were successfully in-filled on the final day of surveying resulting in a complete contiguous dataset. Data was collected across the full 120° swath with a total of 512 beams and preserved in the raw files. In practice, the useful data swath was approximately 80° and the pond was, in general, much shallower than expected, resulting in many extra passes to ensure complete data coverage. As another quality control measure, the Hypack software was configured so as to not log any data if a phase-corrected RTK signal was not present. Occasional drops in RTK signal quality due to temporary loss of radio-link therefore created data gaps obvious to the operator during data collection and were immediately rectified by a repeat pass over the affected area for complete coverage.

Line spacing for the multi-beam survey was variable, although initial passes follow the same bearing (122°) as the intended sub-bottom lines. Target boat speed was approximately 3 knots, though care was taken in shallower areas to protect the sensitive equipment.

### **3.1.2.3 Single-Beam Sonar**

The single-beam bathymetry survey was conducted to fill in data voids in shallow water where use of the multi-beam transducer was not practical. Fill-ins were done along the entire perimeter of the Cross Valley Dam Pond and attempts were made to fill in shallow areas at the north and north-east edges of the pond. These shallow areas proved to be unnavigable even for the inflatable zodiac, which was used instead of the 14-ft vessel for the 2015 single-beam survey.

In 2015, only two EW reference lines were surveyed to create a secondary control database against which to measure the multi-beam bathymetry data, the other planned reference lines were not completed due to the onset of winter and ice on the pond. For consistency, all six of the planned lines were surveyed in 2016 and the 2015 lines were not used in the analysis. Four of these lines spanned the width of the pond at a bearing of approximately 122° and set 100 m apart. The two other lines spanned the length of the pond at a bearing of 30° and were spaced 150 m apart.

Data were collected at a 1 second interval with data from the Airmar SS510 transducer. The transducer operates at a frequency of 200 kHz with a beam width of 9°. Target boat speed was 2 knots in open water but speeds in potentially shallow areas were lower.

In 2015, data from the Trimble Geoexplorer GPS antenna and the Airmar transducer were streamed to the Trimble GeoXT controller for storage. The vertical offset between the GPS antenna and the transducer was 1.1 m. There was no horizontal offset.

In 2016, data from the Airmar transducer were streamed to the Trimble GeoXT controller for storage and were georeferenced using data from the RTK-GPS Leica GS15 rover. A 17 second offset was applied to the single-beam sonar data prior to time-stamp matching to account for the different time convention (GPS versus UTC time) used by each instrument. The vertical offset between the GPS antenna and the transducer was 1.44 m. There was no horizontal offset.

#### **3.1.2.4 Lead-Line Measurements**

In 2016, lead-line measurements were taken to create a tertiary database against which to measure the other bathymetric data, however because of an impending shortage of safety personnel at the Faro Mine area, the lead-line survey was cut short and only six points were measured on the CVD Pond.

A best effort was made to make the measurement when the lead-line was plumb but the survey vessel was not anchored during the measurements and there was significant drift from high winds at the time of the lead-line survey so some bias towards longer measurements because of the angled line is expected. Additionally, the operators often observed significant muck on the lead-line after retrieval so the weight may have been penetrating some centimeters beyond the mudline as measured by the sonar data.

### ***3.1.3 Data Processing***

#### **3.1.3.1 RTK-GPS**

For the 2016 portion of the survey, the use of an arbitrary initial reference point required that a datum shift be applied to all raw data to reposition the base station to the published position of 2010-P5. All points were shifted -2.005 m N, 1.733 m E and elevation was shifted -6.501 m.

Data were logged to the Leica receiver, exported to csv files and then edited to correct labelling or entry errors; the raw daily base and rover files, as well as the exported rover files are included with the data package of this report. The 2015 positional quality is shown in Figure 4 and the 2015 height quality in Figure 5 as reported by the Leica Geo Office software package from the raw rover files (with no post-processing); both have a 95% confidence level well below 10 cm. The effective positional and height quality is better than the histograms portray because, as indicated in Section 3.1.2.2, the multi-beam unit was configured so as to not log any data if a phase-corrected RTK signal from the base was not present. On a handful of occasions the RTK radio link was down, but the operator noticed the data gap while surveying and immediately re-surveyed the missing section with RTK corrected positional and height data. These data nevertheless remain in the GPS database shown in Figure 4 and Figure 5.

The position and height data for Oct 21 were mistakenly not independently recorded on the GPS rover and are therefore not included in the histograms. However, as the operator did not see any data gaps during collection, these data are known to be of good quality.

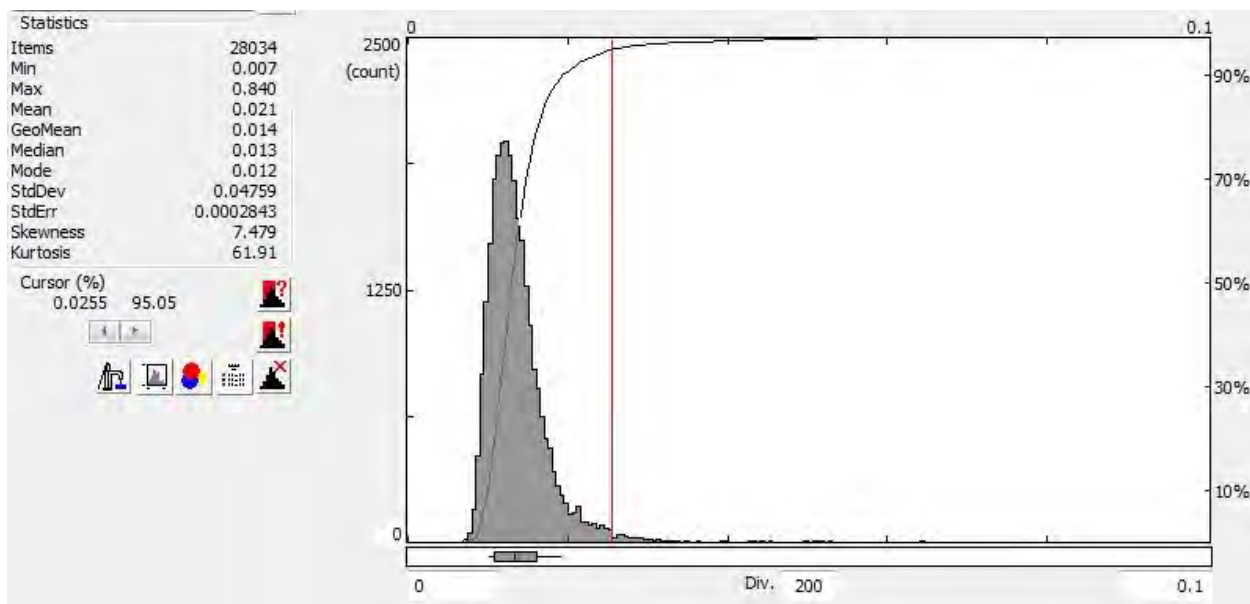


**Figure 4: Position quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the position quality is at 0.026 m.**

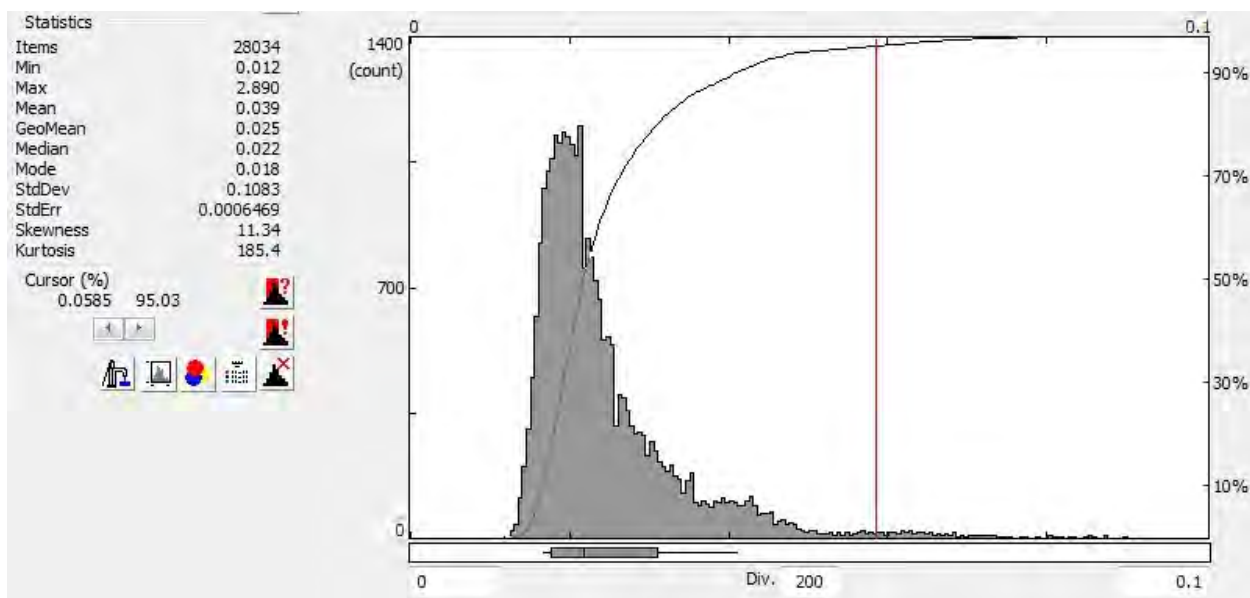


**Figure 5: Height quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the height quality is at 0.059 m.**

### 3.1.3.2 Single-Beam Sonar

For the 2015 survey, base GPS data were exported to RINEX format and processed with Trimble Pathfinder software to obtain a differentially corrected position. The Trimble Geoexplorer GPS used with the single-beam sonar was not equipped with an RTK radio link to the base; the solutions are therefore not phase corrected and the accuracy is significantly less than those of the multi-beam sonar; an estimate of horizontal accuracy for the 4956 positions as reported by the Pathfinder software is shown in Table 1.

**Table 1: Estimated accuracy of single-beam horizontal position.**

| <b>Estimated<br/>accuracy range</b> | <b>Percentage<br/>of points</b> |
|-------------------------------------|---------------------------------|
| 0 – 5 cm                            | 0%                              |
| 5 – 15 cm                           | 0%                              |
| 15 – 30 cm                          | 66.87%                          |
| 30 – 50 cm                          | 33.05%                          |
| 0.5 – 1 m                           | 0.06 %                          |
| 1 – 2 m                             | 0.02 %                          |

The base location used for the Pathfinder correction is taken from the average measured position of the GPS base and is reported in the processing log file. A datum shift of 0.432 m (north), 4.171 m (east) and -9.260 (elevation) was applied to correct the base station to the published location of point CVP 2010-P5. Acoustic water velocity was assumed to be 1500 m/s during acquisition and this is corrected to 1426 m/s, a measured average velocity for the pond (Section 3.1.3.3 and Figure 6).

For the 2016 data, RTK GPS data were exported and matched by timestamp to the single-beam data with a time-shift of 17 seconds to account for a GPS to UTC time datum adjustment.

In 2016, pond bottom elevations were calculated by subtracting depths derived from the single-beam from the elevation of the single-beam sonar head as measured by the RTK GPS. In 2015, pond bottom elevations were calculated by subtracting depths derived from the Hypack software from the average elevation of the shoreline as measured by the RTK GPS (1028.6792 m).

### 3.1.3.3 Multi-beam Sonar

Multi-beam sonar data were processed using Hypack's Hysweep 64-bit Editor. Beam angle limits of 40 degrees were imposed on both port and starboard sides for all data, with lower limits being applied where deemed necessary by visual inspection. An over/under filter and a Savitzky-Golay filter were applied to highlight and remove potentially erroneous data. All data were then visually inspected in batches of 1000 swaths or less. Single spike anomalies and areas of high noise were removed. In general, the data collected at the widest angle from the sonar head were unreliable and discarded.

Secondary instrumentation data were also inspected and areas where high heave, pitch, roll or speed were recorded, were removed from the dataset. Water velocity data were inspected, showing little variation across time and location. Averaged values from 4 casts were used to create a water velocity profile from 0 m to 14 m, shown in Figure 6. Values from this profile are applied to all data and recorded depths were adjusted accordingly in the Hypack software.

Pond bottom elevations were calculated by subtracting depths derived from the Hypack software from the average elevation of the shoreline as measured by the RTK GPS (1028.6792 m).

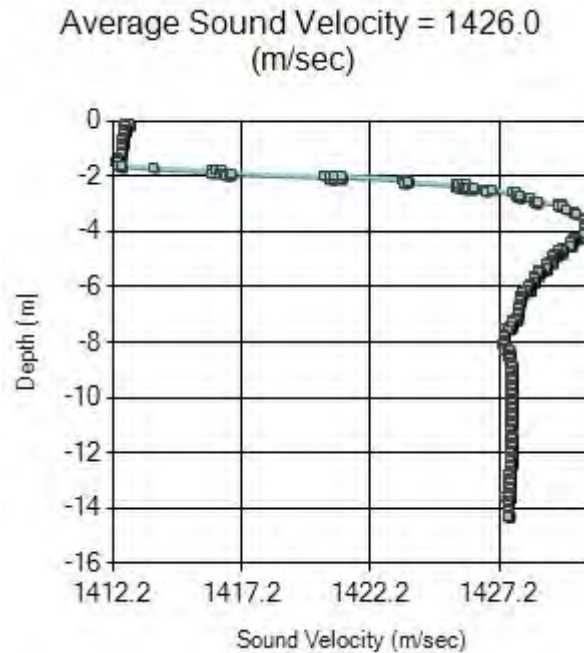


**Figure 6: Average acoustic water velocity profile.**

Multi-beam data collected on October 23<sup>rd</sup> and 24<sup>th</sup> were subject to time shift errors by malfunctions in the RTAI real-time appliance. These errors were not detectable from the Hypack software used for data collection and were only evident during post-processing. From discussions of this malfunction with the instrument supplier, the appropriate solution to correct the issue is to individually correct each time entry.

Time stamps assigned by the RTAI appear in the raw logging files as an incrementing value representing the number of seconds since midnight. Whenever the time shift error occurred, this time stamp value would suddenly decrease while other data continued to be logged correctly at regular intervals with correct times. Data from all sources would be logged in chronological order in the same file regardless of any time stamp error, making it possible to identify and calculate the value of any time shift. A script was written to create a new log file for each time shift error and adjust erroneous time stamps to match the nearest correct time stamp (usually every 0.050 - 0.100 seconds.) A total of 19 errors were corrected in data collected October 23<sup>rd</sup>, and 30 errors in data collected on October 24<sup>th</sup>.

RTK GPS points taken at 95 shoreline locations adjacent to the surveyed area were assigned a depth of 0 m and used to interpolate a full shoreline. Orthometric heights are recorded for these shoreline locations. This shoreline data was integrated with all multi-beam and single-beam bathymetry data to

create all grids and contour files associated with this pond. Gridded bathymetry data were created using a 0.5 m cell size and windowed to exclude points outside of the RTK GPS surveyed perimeter created by the gridding algorithm. No filters were applied to the final bathymetry grids. All 25 cm and 50 cm contours were made after 3 passes of a 3x3 Hanning filter on the bathymetry grid.

### 3.1.4 Products

#### Folder / File

#### Description

|                                                               |                                                                                                                                                                                                     |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Raw data/Multi-beam/Raw/*.hsx                                 | Raw multi-beam data in Hypack Raw format                                                                                                                                                            |
| Raw data/Single-beam /*.obs                                   | Raw single-beam data in GeoXT format, with supporting files for both 2015 and 2016 CVD surveys.                                                                                                     |
| Raw data/Multi-beam/Time Edit/*.hsx                           | Time error-corrected data in Hypack Raw format                                                                                                                                                      |
| Raw data/GPS/Base/*.m00 and Rover/*.m00                       | Base and rover GPS data from Oct 21-24 are associated with bathymetry and shoreline data in Leica m00 format. Data from June 17 are associated with single-beam bathymetry and on-shore extensions. |
| Processed data/GPS/CVD Pond shoreline/*.csv and *.txt         | Corrected shoreline rover GPS data in ASCII formats.                                                                                                                                                |
| Processed data/GPS/Daily Surveying/*.csv and *.txt            | Corrected rover GPS data in ASCII formats. Data from Oct 21-24 are associated with multi-beam data.                                                                                                 |
| Processed data/GPS/CVD shoreline extensions/*.xyz             | Corrected rover GPS data in ASCII formats.                                                                                                                                                          |
| Processed data/GPS/Daily check-ins/*.csv and *.txt            | Corrected rover GPS data in ASCII formats. Data from Oct 21-24 are associated with multi-beam data.                                                                                                 |
| Processed data/GPS/channels.txt                               | Description of columns for ASCII GPS files.                                                                                                                                                         |
| Processed data/Lead-line/CVD lead lines.xyz                   | Lead-line data for CVD pond, collected in 2016.                                                                                                                                                     |
| Processed data/Lead-line/channels.txt                         | Description of columns for ASCII lead-line file.                                                                                                                                                    |
| Processed data/Multi-beam/bathymetry final.xyz                | Master ASCII database of all final bathymetry data in depth of water.                                                                                                                               |
| Processed data/Single-beam/CVD single-beam secondary data.xyz | Master ASCII database of all secondary control single-beam data from common transect lines.                                                                                                         |
| Processed data/Single-beam/channels.xyz                       | Description of cloumns for ASCII single-beam data.                                                                                                                                                  |
| Processed data/Multi-beam/feature channels.txt                | Description of columns for ASCII final bathymetry and secondary control databases.                                                                                                                  |

|                                                                                                 |                                                                                                       |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Processed data/Multi-beam/water velocity profile.vel                                            | Master ASCII database of averaged water velocity profiles.                                            |
| Processed data/Multi-beam/*checkins.xyz                                                         | ASCII database of all bathymetry check-in data.                                                       |
| Processed data/Multi-beam/0.5m elevation rasterized/ESRI/CVD_pondBottom_Elevation_0,5_esri.flt* | ESRI raster grid at 0.5 m cell size with supporting files.                                            |
| Processed data/Multi-beam/0.5m elevation rasterized/ESRI/CVD_pondBottom_Elevation_0,5.grd       | Geosoft raster grid at 0.5 m cell size with supporting files.                                         |
| Processed data/Multi-beam/500 25cm contours.dxf                                                 | 1:500 scale 25cm contours of depth, with a 3 pass 3x3 Hanning filter in AutoCAD version12 DXF format  |
| Processed data/Multi-beam/1250 50cm contours.dxf                                                | 1:1250 scale 50cm contours of depth, with a 3 pass 3x3 Hanning filter in AutoCAD version12 DXF format |
| Figures/Bathymetry 500.pdf                                                                      | 1:500 scale map with gridded bathymetry (depth) data and 25cm contours in PDF format                  |
| Figures/Bathymetry 1250.pdf                                                                     | 1:1250 scale map with gridded bathymetry (depth) data and 50cm contours in PDF format                 |

## 3.2 Sub-Bottom Survey

Acoustic sub-bottom data collection was completed at CVD Pond, but no sub-bottom data were collected at the Intermediate Dam Pond in 2015 due to the cold temperatures and ice formation. This was completed in 2016 and is described in a separate report. The data were collected at lines with 10 m spacing. The coverage is slightly less complete than the bathymetric data set due to survey restrictions in shallow water from the sub bottom instrument as illustrated in Figure 2.

### 3.2.1 Equipment

The crew was equipped with the following instruments and equipment:

|                 |   |                                                   |
|-----------------|---|---------------------------------------------------|
| Equipment:      | 1 | EdgeTech SB-424 towfish s/n: 38803                |
|                 | 1 | Edgetech 3100P sub-bottom topside unit s/n: 38688 |
|                 | 1 | Leica GS15 sensor rover s/n 1502720               |
|                 | 1 | Leica GS14 sensor base s/n 2806121                |
|                 | 1 | Leica CS15 controller s/n 2907005                 |
|                 | 1 | Pac Crest ADL Vantage Pro Radio s/n 13086191      |
|                 | 1 | Pac Crest Radio s/n 1301949                       |
|                 |   | Miscellaneous GPS cables, tripods and equipment   |
| Communications: | 4 | VHF handheld radios                               |
|                 | 1 | DeLorme InReach                                   |
| Vehicles:       | 1 | Flat deck truck                                   |
|                 | 1 | Truck Trailer                                     |
|                 | 1 | Arctic Cat ATV                                    |

|                       |     |                                                         |
|-----------------------|-----|---------------------------------------------------------|
|                       | 1   | 16ft aluminium boat                                     |
|                       | 1   | Inflatable Zodiac rescue boat                           |
|                       | 1   | 6 HP outboard motor                                     |
|                       | 1   | 2 HP electric motor                                     |
| Safety:               | 4   | Government certified personal floatation devices (PFDs) |
|                       | 2   | ATV helmets                                             |
|                       | 4   | Hard hats                                               |
|                       | 100 | Nitrile gloves                                          |
|                       | 9   | Tyvek suits                                             |
|                       | 8   | Safety glasses                                          |
|                       | 4   | High Visibility Vests                                   |
|                       | 2   | Fire extinguisher                                       |
|                       | 2   | Level 2 First aid kit                                   |
|                       | 4   | Spare paddles                                           |
|                       | 2   | 15m floating rope                                       |
|                       | 2   | Bailers                                                 |
| Computers & Software: | 1   | Laptop with Edgetech Discover Sub-Bottom 4.0            |
| Other:                | 20  | 6 mil plastic garbage bags                              |
|                       | 1   | Pressure washer                                         |
|                       | 1   | Water tank                                              |
|                       | 1   | Office box                                              |
|                       | 1   | Geophysical Toolbox                                     |

### 3.2.2 Survey Specifications & Field Procedures

#### 3.2.2.1 RTK GPS

A GPS base station was established daily over the permanent control marker 2010-P5 at CVD. As this primary control monument was suitable for all areas of the CVD pond, a secondary control network was not established.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. This base location was broadcast continuously via radio to the rover so that a phase-corrected RTK solution was being transferred to the sub-bottom equipment via NMEA string at all times during data collection.

#### 3.2.2.2 Sub-bottom Profiling

Sub-bottom profiling was performed along 54 lines running 122° west to east across the pond, and along 3 perpendicular tie-lines for cross reference. Survey line spacing was 10 m with tie-lines being profiled at uneven spacing, in an attempt to profile different features that appeared during the initial passes.

Target boat speed was approximately 3 knots and attempts were made to maintain constant speeds in an effort to avoid distorting produced images.

The Edgetech SB-424 towfish, 3100P topside unit and Discover software were used to collect all sub-bottom data. The SB-424 is capable of outputting a variety of FM chirps, each of which was tested before surveying began. Of the chirps tested, it was decided that the highest range of frequencies available (4-24kHz) provided the best resolution; whereas limiting the signal to lower frequencies seemed to offer no significant advantage with regard to depth of penetration.

### 3.2.3 Data Processing

#### 3.2.3.1 RTK

Data were logged to the Leica receiver and exported to csv files; both raw daily base and rover files, in addition to the exported rover files, are included with the data package of this report. The positional quality is shown in Figure 7 and the height quality in Figure 8 as reported by the Leica Geo Office software package from the raw rover files (with no post-processing); both have a 95% confidence level well below 10 cm.

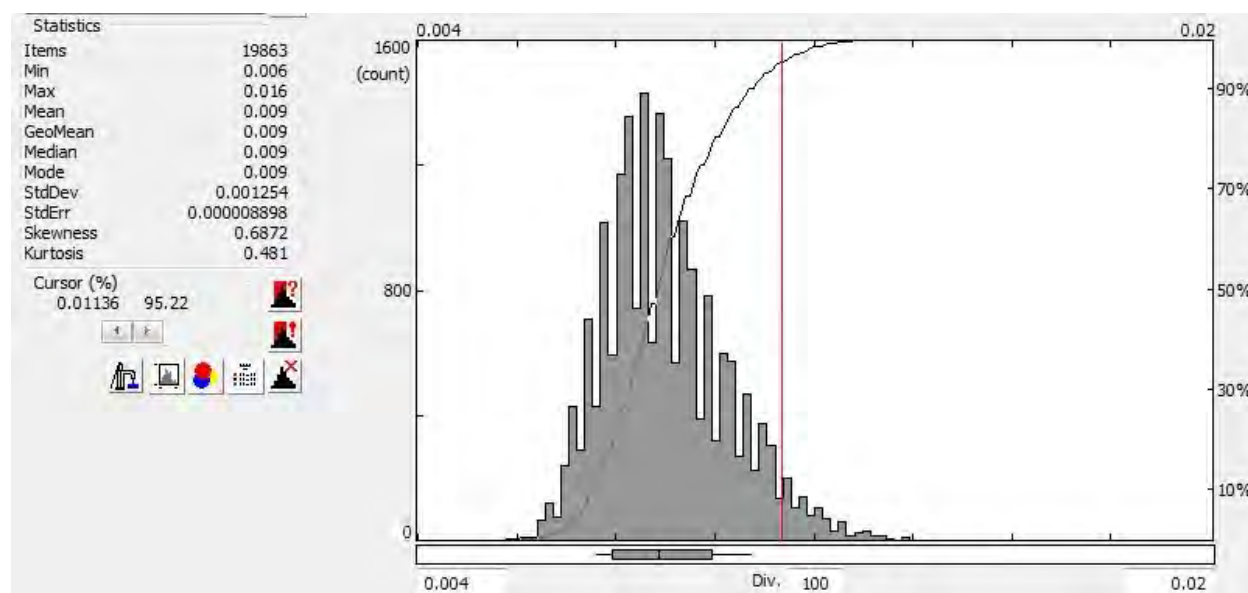


Figure 7: Position quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the position quality is at 0.011 m.

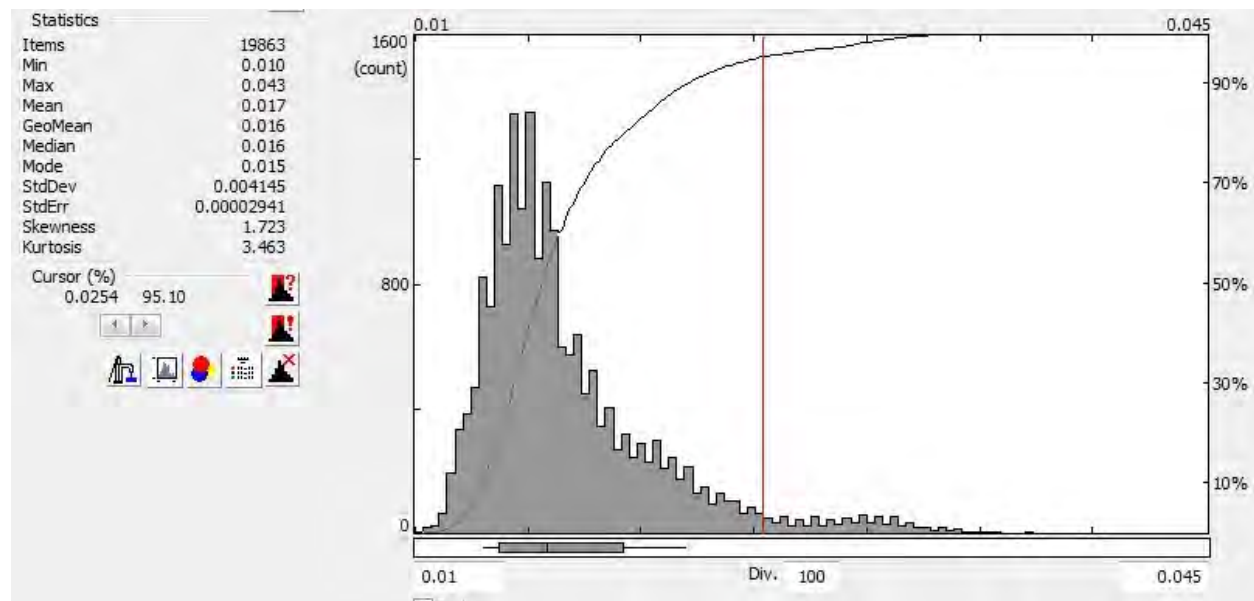


**Figure 8: Height quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the height quality is at 0.025 m.**

### 3.2.3.2 Sub-Bottom

Initial processing of sub-bottom profiles was performed with SonarWiz 6. User gain controls were adjusted to increase the visibility of responses at depth and have a minimal impact on near surface responses. Once set, this gain was applied universally across all lines allowing for objective comparisons between them. Auto-detection of the pond bottom was used but was insufficiently accurate. All features, including the pond bottom, were drawn in after visual inspection. Features were first drawn on the 3 perpendicular tie-lines. The depths of these features were then plotted to all sonargrams and used only as visual cues to calibrate the drawing of all subsequent features. Tie-line feature depths were not included in the final dataset.

### Definitions of Features

Feature A – this is the mudline, first signal to return indicating the bottom of the water column.

Feature B – There are two main divisions for Feature B. The first is a package of layered sediment, with each individual layer typically 25 cm thick. On the north side of the pond, the thickest package of layered sediment outlines a well-defined pit. The layers are not always well defined – sometimes because the layer is too thin and only a single non-reflective layer is being imaged, but also sometimes because the response grades from well-defined layers to a more homogeneous mass sitting on top of Feature C (see below). It's possible that a single thin layer of high reflectance material similar to Feature C is not detectable, and therefore is included in the thickness of Feature C.

Line 44 shows many of these features from the north end of the pond, while Line 4 shows similar features from the south end of the pond. There is another pit-like feature imaged in Line 4, but it is not visible on the two adjacent lines.

The second division included in Feature B is more irregular layers sitting on top of Feature C. These are more common in the middle of the pond and are typified by the response on Line 35.

There are only a few cases where multiple instances of Feature B are stacked. An example of this on the west end of Line 3.

Feature C – This is a high reflectance layer that underlays large areas of the pond. There is a rough correlation between high thickness of Feature C and shallower water. The difference between Feature C and Feature D is subtle.

Feature D – This is very similar to Feature C, but has a mottled texture with very small irregular areas of lower reflectance. Lineaments of high thickness of Feature D tend to follow bathymetric relief; on steeper slopes, Feature C tends to be absent resulting in a greater thickness of Feature D. This supports the interpretation that Feature C represents fines which slough off on the steeper slopes. Examples of this are the scarps in the southeast corner of the pond, in the middle of the pond (Lines 21-28) and all along the western edge of the pond.

There are also greater thicknesses of Feature D in between the two spits protruding into the ponds on lines 18, 19 and 20.

Feature E – This feature outlines all areas where the high reflectance of features C and D is no longer present but enough reflectance to outline some texture remains.

Feature F – This feature represents areas where no textured reflectance is discernable but some traces of the signal are still being reflected. When present above other features, it clearly outlines a lack of a returning signal. When present below all other features, it is an arbitrarily chosen limit specific to the gain settings used during data processing, where the plotted response still appears more gray than blank. Because the gain settings were kept constant on all sonograms, the relative thickness of this layer at depth could be representative of the rate of signal attenuation.

Feature G – This feature represents all areas that show weaker responses than feature F. With the gain settings used during data processing, this feature appeared more white or blank than gray. The lower limit of this feature is always the first multiple from the mudline (Feature A) which is generally quite strong and masks any deeper responses.

### **Export and Processing of Features**

The features described above were identified on a line-by-line basis and images of each EW line with the interpreted features are included with this report. Features were validated through cross-referencing with the NS lines but no feature lines were drawn on the NS lines. The data on the EW lines were exported to an ASCII master database and AutoCAD v12 DXFs with all the interpreted features that were produced for each line. As no core or velocity data were available at the time of processing, the velocities of all layers are assumed to be 1500 m/s upon export and all data downstream of the export are in metres. The data should be transformed back to the time domain and all depths and thicknesses re-calculated once further data become available.

To calculate the thickness of each feature the distance to the feature defined above it is extracted from the master database. Feature A is the first arrival of the pulse and represents the mudline; this feature is present in all sub-bottom data. Several of the features are interleaved and to obtain a total thickness, the sub-features (e.g. B1 and B2) are summed. The summed feature thicknesses are exported to ASCII and are gridded with a minimum curvature algorithm and a cell size of 2.0 m, which is an appropriate cell-size for 10 m line-spacing. Grids are provided in both Geosoft and ESRI formats. Contours for each feature are made at 10 cm intervals and are exported in AutoCAD v12 DXF format.

### Cross-Sections

Cross-sections were produced at 50 m intervals for the pond in both the east-west and north-south directions. A database was developed for each cross-section with 1m resolution and the final bathymetric database is sampled to obtain the pond bottom along the cross-section.

The down-line sub-bottom data interval is 0.25 – 0.30 m and the line spacing is approximately 10m. Many of the features are sparsely distributed over the pond and therefore a Triangular Irregular Network (TIN) method is used with linear interpolation between TIN points to sample each sub-feature along the cross-sections. This ensures no gridding artifacts from sparse data, typical of other gridding algorithms, are sampled into the cross-sections. Nevertheless, line-to-line features that run obliquely to the line direction and that are small relative to the lines spacing of 10 m, have artifacts in between the lines. This is particularly apparent on the cross-section at 6914100 N.

The bathymetric dataset is superior to that defined by Feature A in the sub-bottom data and the depth of each sub-feature relative to Feature A is more robust than the absolute depth. Therefore the depth of each sub-feature is calculated below Feature A and then this depth is subtracted from the bottom, determined by the bathymetric survey (so as to use the higher quality dataset). This method does transfer some small scale roughness imaged in the bathymetry survey to the lower resolution sub-bottom layers. An example is shown in Figure 9, where the circles area illustrates the roughness introduced into the cross-section. Although the left-hand panel (L27.jpg) is oblique to the right-hand panel (6414350.pdf), the excerpts circled in blue are approximately coincident.

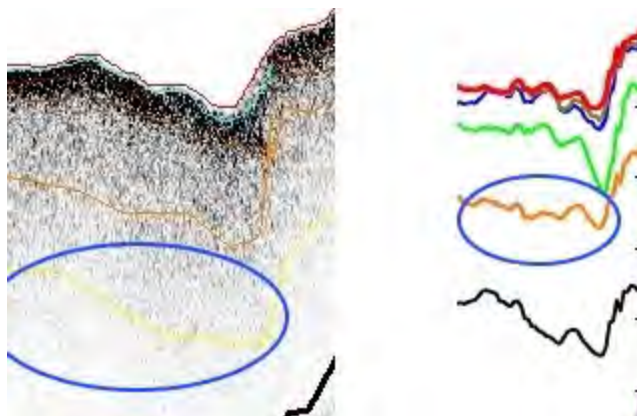


**Figure 9: Example of introduced roughness to the sub-bottom dataset. The left-hand panel is an interpreted section (L27.jpg), the right-hand panel is a cross-section (6914350.pdf) with introduced small scale roughness.**

### 3.2.4 Sub-bottom Products

The following files and figures are appended to this report:

| Folder / File                                                         | Description                                                                                                 |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Raw data/Sub-Bottom/*.jsf                                             | Sub-bottom data by line in EdgeTech jsf format (see Appendix III).                                          |
| Raw data/Sub-Bottom/on-water control CVP/*.jsf                        | Sub-bottom raw data at the on-water control point.                                                          |
| Raw data/Sub-Bottom/faro freq tests/*.jsf                             | Sub-bottom on-site tests with different waveforms.                                                          |
| Raw data/GPS/Base/*.m00 and Rover/*.m00                               | Base and rover GPS data from Oct 25 are associated with sub-bottom data in Leica m00 format.                |
| Processed data/GPS/Daily Surveying/*.csv and *.txt                    | Corrected rover GPS data in ASCII formats. Data from Oct 25 are associated with sub-bottom data.            |
| Processed data/GPS/Daily check-ins/*.csv and *.txt                    | Corrected rover GPS data in ASCII formats. Data from Oct 25 are associated with sub-bottom data.            |
| Processed data/GPS/channels.txt                                       | Description of columns for ASCII GPS files.                                                                 |
| Processed data/Sub-bottom/Interpreted sub-bottom - depth.xyz          | Master ASCII database of all interpreted sub-bottom features in depth from mudline.                         |
| Processed data/Sub-bottom/Interpreted sub-bottom - elevation.xyz      | Master ASCII database of all interpreted sub-bottom features in elevations.                                 |
| Processed data/Sub-bottom/ channels.txt                               | Description of columns for ASCII master sub-bottom database.                                                |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/Feature_*.xyz   | Calculated thickness of each sub-bottom feature.                                                            |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/channels.txt    | Description of columns for ASCII feature thickness.                                                         |
| Processed data/Sub-bottom/Feature thickness/DXF contours/Feature*.dxf | Contour of feature thickness (interval of 0.1 m) in AutoCAD version12 DXF format.                           |
| Processed data/Sub-bottom/Feature thickness/ESRI grids                | Raster grid at 2 m cell size of feature thickness.                                                          |
| Processed data/Sub-bottom/Feature thickness/Geosoft grids             | Raster grid at 2 m cell size of feature thickness.                                                          |
| Processed data/Sub-bottom/Images                                      | Images of processed data for every line with interpreted layers in jpg format.                              |
| Processed data/Sub-bottom/Line-by-line DXFs                           | Interpreted layers in AutoCAD version12 DXF format.                                                         |
| Figures/Cross-sections/DXFs                                           | EW and NS cross-sections with bathymetry and interpreted sub-bottom layers in AutoCAD version12 DXF format. |
| Figures/Cross-sections/PDFs                                           | EW and NS cross-sections with bathymetry and interpreted sub-bottom layers in PDF format.                   |

### 3.3 Quality Control Checks

#### 3.3.1 Common Transects

Six transects were completed across the pond in 2016 with the single-beam transducer to create a dataset suitable for comparison with the multi-beam data. These six lines represent 1504 single-beam readings which, on average, are 0.2 m shallower than the multi-beam data for the same location and have a maximum difference of 2.24 m (Figure 10). The transect paths are shown in Figure 11 while the transect data are shown in Figure 12 and Figure 13.

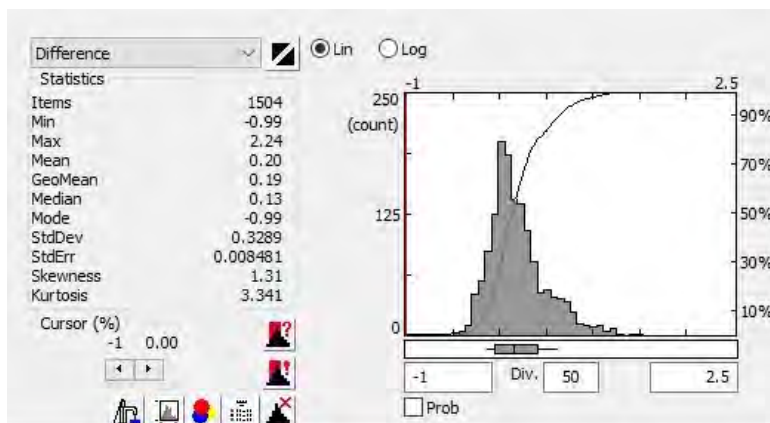


Figure 10: Histogram of difference between single-beam and multi-beam surveys.

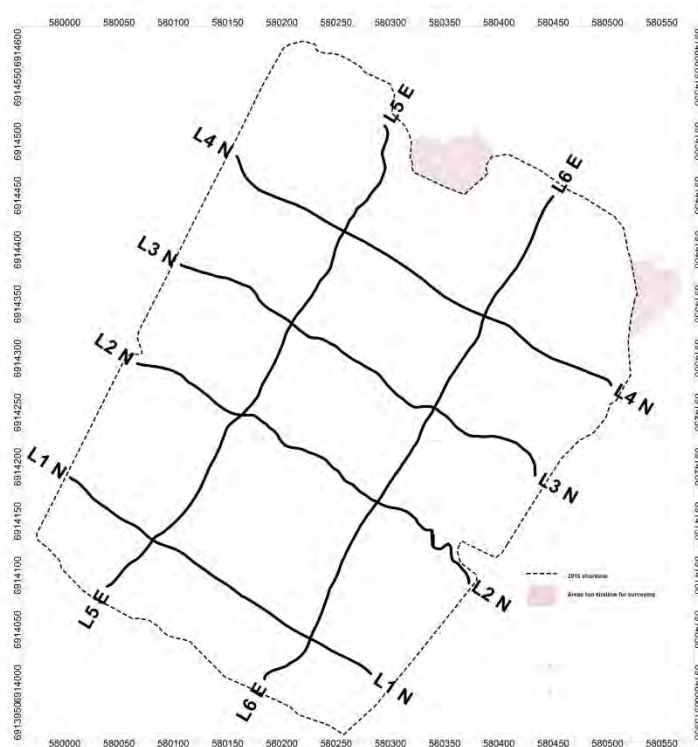


Figure 11: Single-beam common transects surveyed in 2016 and shoreline from 2015.

The purpose of the single-beam data collection is to provide an independent check (in addition to the lead-line dataset) on the multi-beam data. The distribution of the differences shows a bias towards deeper measurements for the multi-beam but also has positive skewness, indicating a larger range on the positive end (Figure 10). Examination of transects shown in Figure 12 show that many of these positive outliers, circled in blue, are not random; they often occur where the pond bottom has a steep gradient.

One possible explanation for this systematic difference is that in an area of steep bottom topography, the footprint of the sonar will cover a wide range of depths. The multi-beam system is calibrated with a pair of GPS antenna for heading determination and pitch, roll and heave detectors. Although the beam width is larger than the single beam (120° versus 9°), the multi-beam operates with 512 beams over the 120° instead of a single beam over 9°. The wider footprint per beam and the lack of heading and motion detectors on the single-beam instrumentation means there is greater ambiguity in imaging a dipping subsurface. The observed discrepancy between the datasets would be consistent with the single-beam taking the earliest reflection as bottom.

The area at the junction of transects 4 and 6 shows higher variability in the single-beam data than the multi-beam data. The fact that this high variability is observed in two perpendicular transects argues against an instrument malfunction cause; the reason for the effect is unknown.

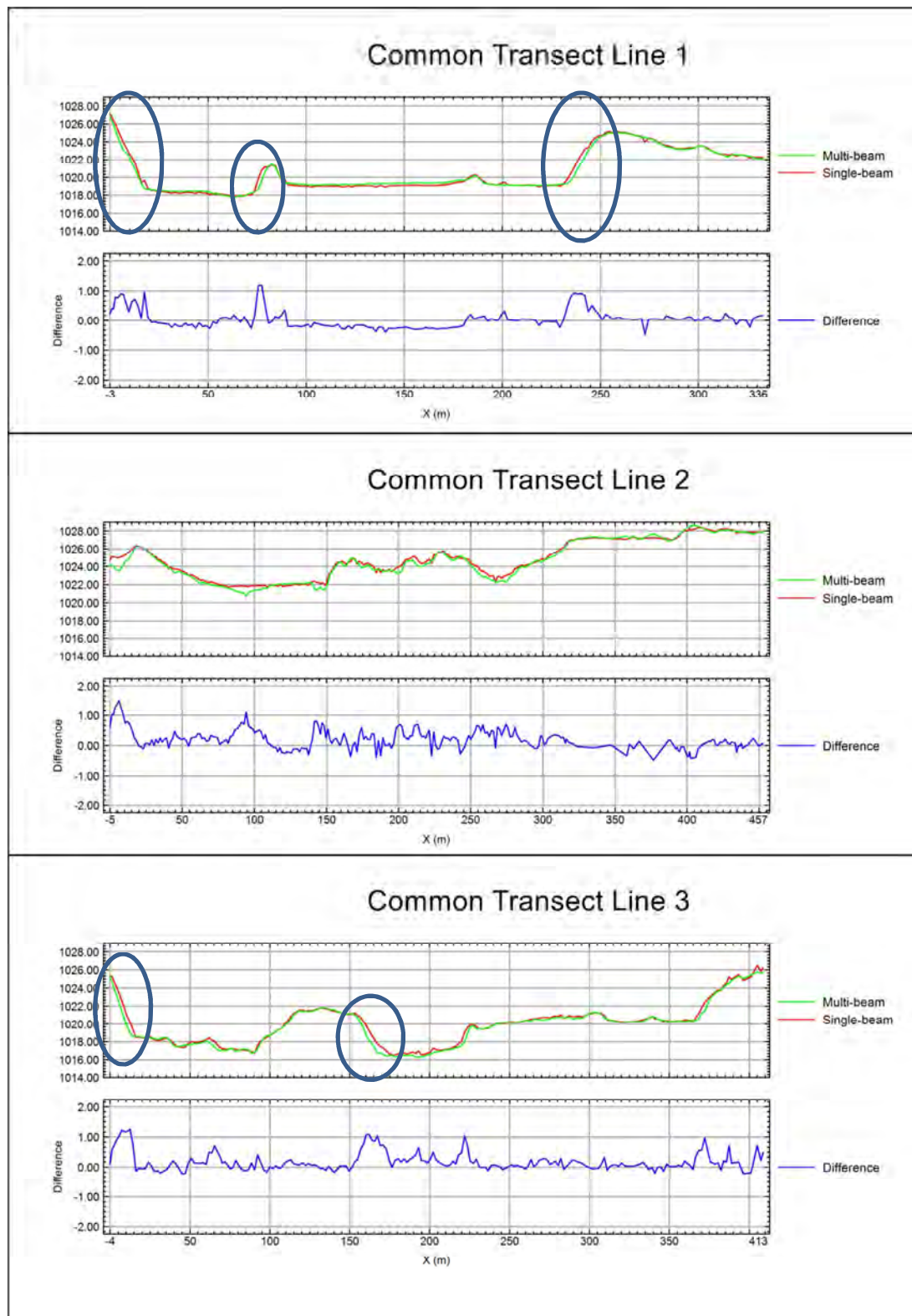


**Figure 12: Common single-beam and multi-beam transects 1, 2 and 3, showing pond bottom elevation (top panel) and single-beam / multi-beam difference (bottom panel). Blue ellipses show areas of steep bottom gradient and where a systematic difference between single-beam and multi-beam depth is observed.**

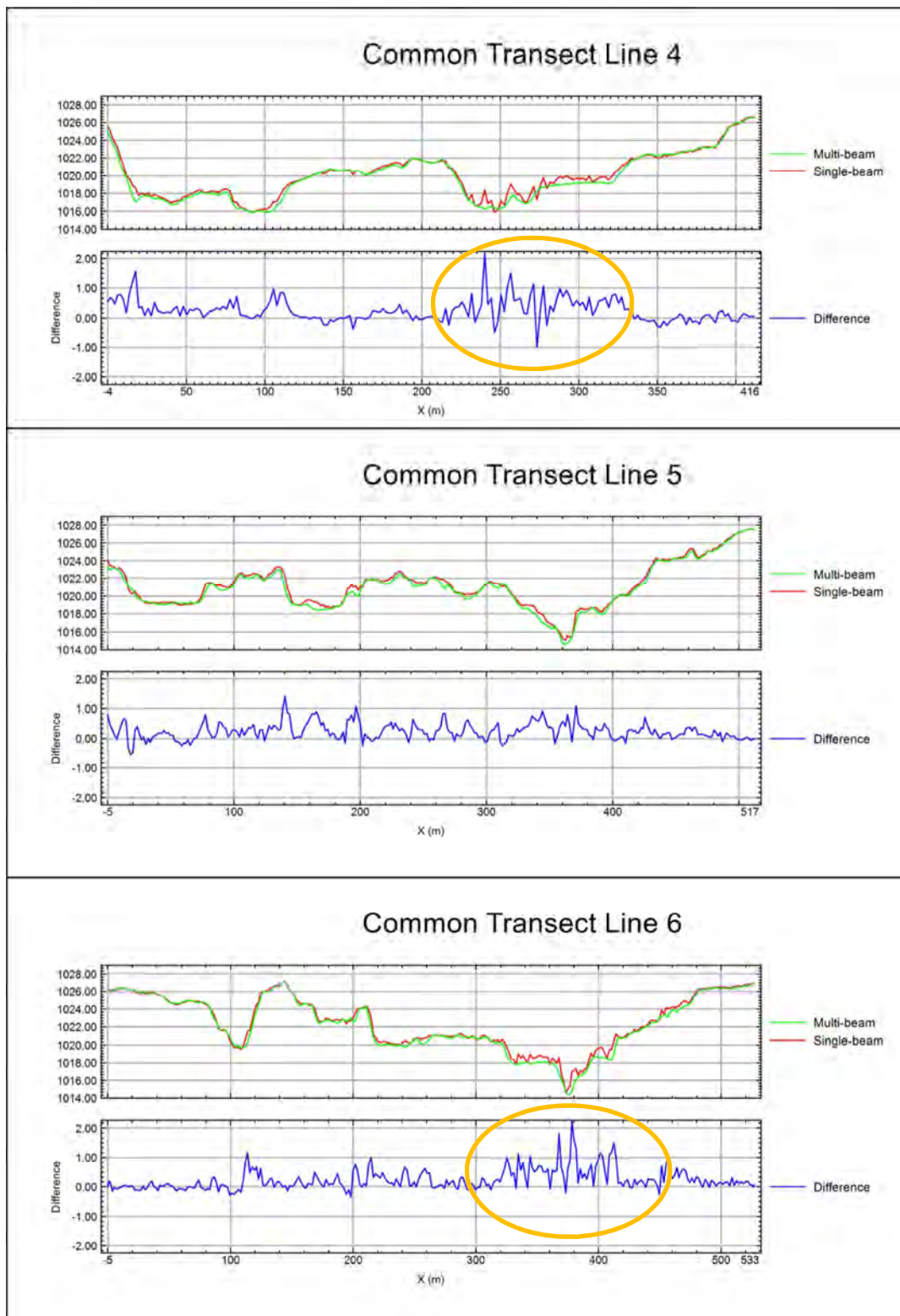


Figure 13: Common single-beam and multi-beam transects 4, 5 and 6, showing pond bottom elevation (top panel) and single-beam / multi-beam difference (bottom panel). The orange ellipses show an area of single-beam roughness, near the junction of transects 4 and 6.

### 3.3.2 Lead-line comparisons

Six lead-line measurements were made at CVD pond in 2016 and are detailed in Table 2 – the full planned lead-line dataset was not collected because the site safety officer could no longer remain on site and a premature demobilization of the Aurora crew was required. The lead-line points were not sufficiently close to the single-beam lines to allow a direct comparison.

**Table 2: Lead-line measurements at CVD Pond. UTM coordinates are in NAD83 (CSRS) datum and elevations are metres above the HT2 geoid.**

| Point | UTM Easting (m) | UTM Northing (m) | Water Depth (m) | Lead-line derived bottom elevation (m) | Sonar derived bottom elevation (m) | Difference (m) |
|-------|-----------------|------------------|-----------------|----------------------------------------|------------------------------------|----------------|
| CVD 1 | 580316.7        | 6914146          | 7.4             | 1022.6632                              | 1022.7132                          | -0.05          |
| CVD 2 | 580346.1        | 6914133          | 2.7             | 1027.3632                              | 1028.1116                          | -0.75          |
| CVD 3 | 580128.9        | 6914267          | 8.2             | 1021.8632                              | 1022.1312                          | -0.27          |
| CVD 4 | 580167          | 6914246          | 8.4             | 1021.6632                              | 1021.907                           | -0.24          |
| CVD 5 | 580245.5        | 6914213          | 7.4             | 1022.6632                              | 1022.8937                          | -0.23          |
| CVD 6 | 580279.8        | 6914180          | 6               | 1024.0632                              | 1023.9936                          | 0.07           |

It should be noted that the greatest discrepancy at CVD 2 is in shallow water. Because the water elevation when the lead-line measurements were collected in 2016 is much higher than when the sonar data were collected in 2015, the water would have been too shallow for the multi-beam equipment and the sonar derived depth at CVD 2 is either an interpolation between shore line and single-beam point or single-beam point and multi-beam point and is therefore subject to much greater error than the other points.

Ignoring CVD 2, the mean difference is nevertheless biased negative (-0.14 m) which indicates the lead-line measurements are in general deeper than the multi-beam measurements. This bias is in part due to the methodology as the boat was not anchored while taking the measurements and was drifting significantly in the wind. Efforts to take the best data possible were made, but the lead-lines were to not vertical at the time of measurement which would explain the deep bias. Also adding to the deep bias of the lead-line measurements, based on the observations of ubiquitous and thick mud on the weighted part of the line, it was clear that the bottom of ID pond is very soft in places and the weight would have had significant penetration.

### 3.3.3 Daily check-ins

GPS, multi-beam and sub-bottom data were collected during QA/QC check-ins at the beginning and end of each day. A control station was established at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) by the suspension of a survey flag over the pond shown by the orange triangle in Figure 2; GPS and multi-beam sonar data were recorded for a minimum of 30 seconds during check-ins at this control station. Although not exemplary as a control station, this was deemed the best option that would be accessible by the survey vessel. The topography and geometry of the shoreline did not offer many

suitable options to set up the control flag and consequently the water depth of chosen check-in site was shallower than ideal.

To allow meaningful comparison from day to day, the full range of the sonar swath was windowed to a small section (approximately 1 X 0.1 m) that was common to several days. Although small, this area does compare on the order of 125 individual multi-beam measurements which is sufficient for statistical analysis. The depths were gridded and then differenced to an arbitrary reference (the first day). The statistics of the differenced grids are instructive to the repeatability of the survey and are shown in Figure 14 for the days with sufficient overlap for good statistical analysis.

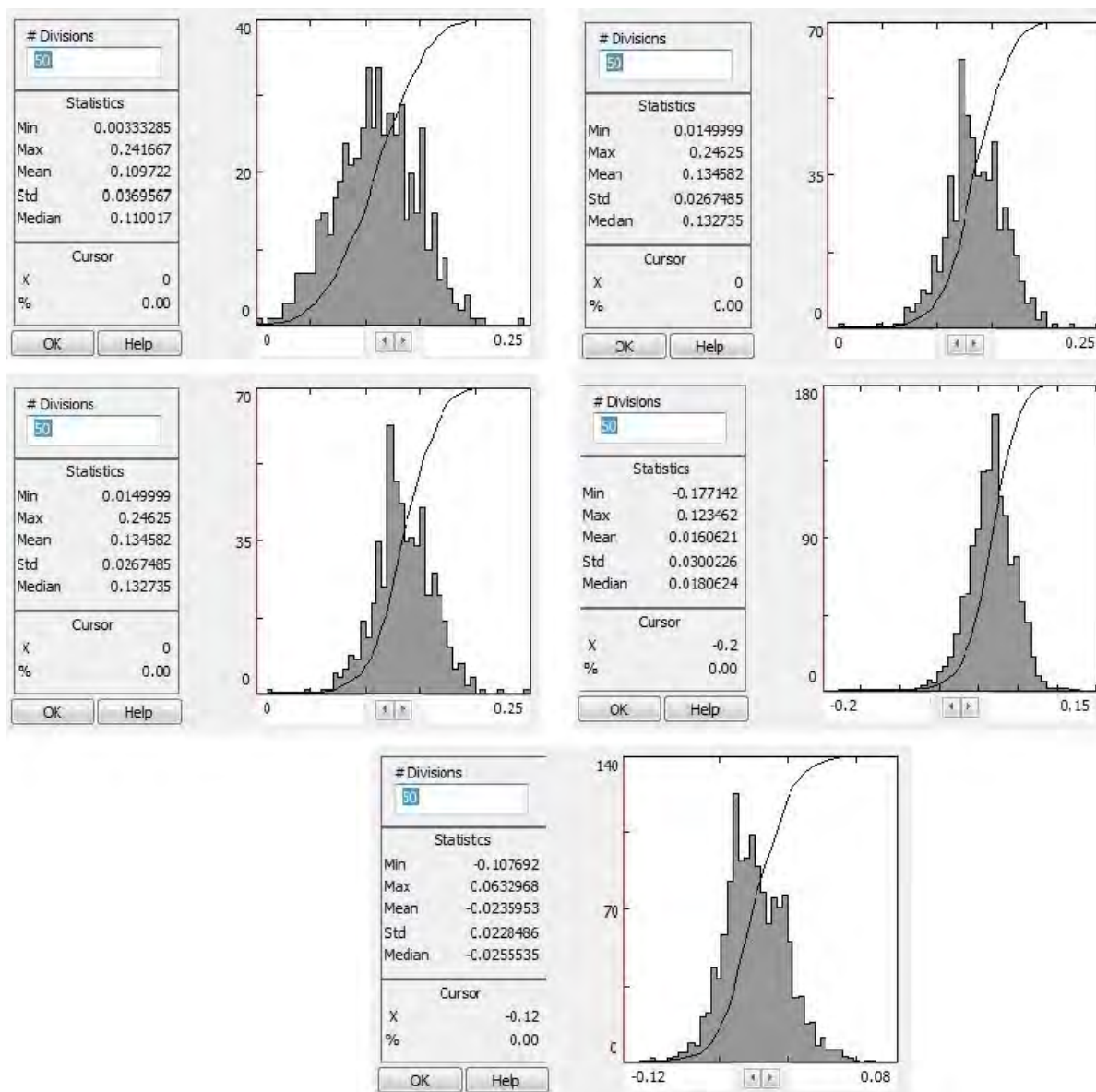


Figure 14: Histograms of the differenced grids from multi-beam control points.

The mean difference between the reference control point and individual repeats at that control point vary from a few centimeters to 13.4 centimeters. The standard deviation of the differenced grids is more consistent at 2 – 4 cm. This indicates that the 95% confidence level, which is approximately 2 standard deviations, is on the order of 6 cm. The larger datum shifts between the individual control readings are interpreted to be variations in the water elevation and not a representative measure of survey error. Variation of the water elevation was not measured systematically throughout the survey however there was approximately a 10 cm water elevation change in between Oct 21 and Oct 23 when two suites of shoreline measurements were taken, consistent with the above interpretation.

The sub-bottom control point data, taken at the same location and same methodology as the multi-beam data, from the single day of surveying are shown in Figure 15 (morning) and Figure 16 (afternoon). Qualitatively, the responses are equivalent, demonstrating proper equipment function.

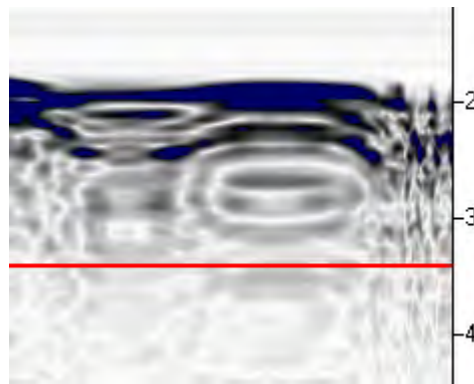


**Figure 15: Morning sub-bottom data at the flagged control point at 580395, 6914126 (NAD83 UTM Zone 8N coordinates) .**

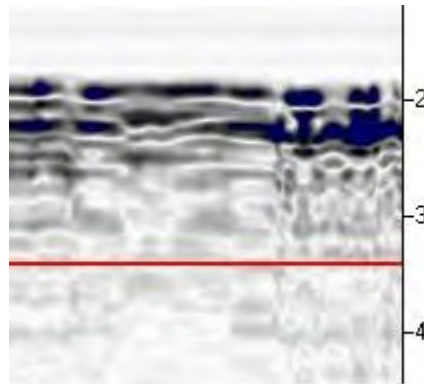


**Figure 16: Afternoon sub-bottom data at the flagged control point at 580395, 6914126 (NAD83 UTM Zone 8N coordinates).**

## 4 DISCUSSION AND INTERPRETATION

### 4.1 Bathymetry

The mean elevation of the shoreline during the 2015 survey is 1028.679 m (orthometric height above the HT2 geoid) with a standard deviation of 4.6 cm (n=111).

The total volume of water in the CVD Pond during the 2015 survey, given a shoreline at 1028.679 m, is 1,413,045.8 cubic metres. There is no allowance in this calculation for the water in the shallow areas where no data were collected, but a rough estimate indicated that this extra amount of water would be a small amount, on the order of 0.25% of the total pond volume.

The multi-beam sonar survey provides a very high resolution dataset of the water depth shown in Figure 17. The maximum depth of the pond is 14.68m in the northern part of the pond. There are several lineaments of sharp relief, interpreted to reflect dikes or pits that were part of the design of CVD pond, prior to its flooding.

Agreement was generally good between the lead-line depths, single-beam transects and the multi-beam data, providing confidence in the data veracity of all three products. The notable exceptions are depth mismatches between the single-beam and multi-beam in areas of high pond bottom slope and one area of the pond where high variability is noted in the single-beam dataset. The multi-beam system is designed to account for slope in the calculation of depths while the single-beam is a simpler system that likely takes the first (i.e. most shallow) reflector and this would explain the discrepancy. Because of the more advanced instrumentation and strategy to account for such topography, the multi-beam is the preferred dataset.

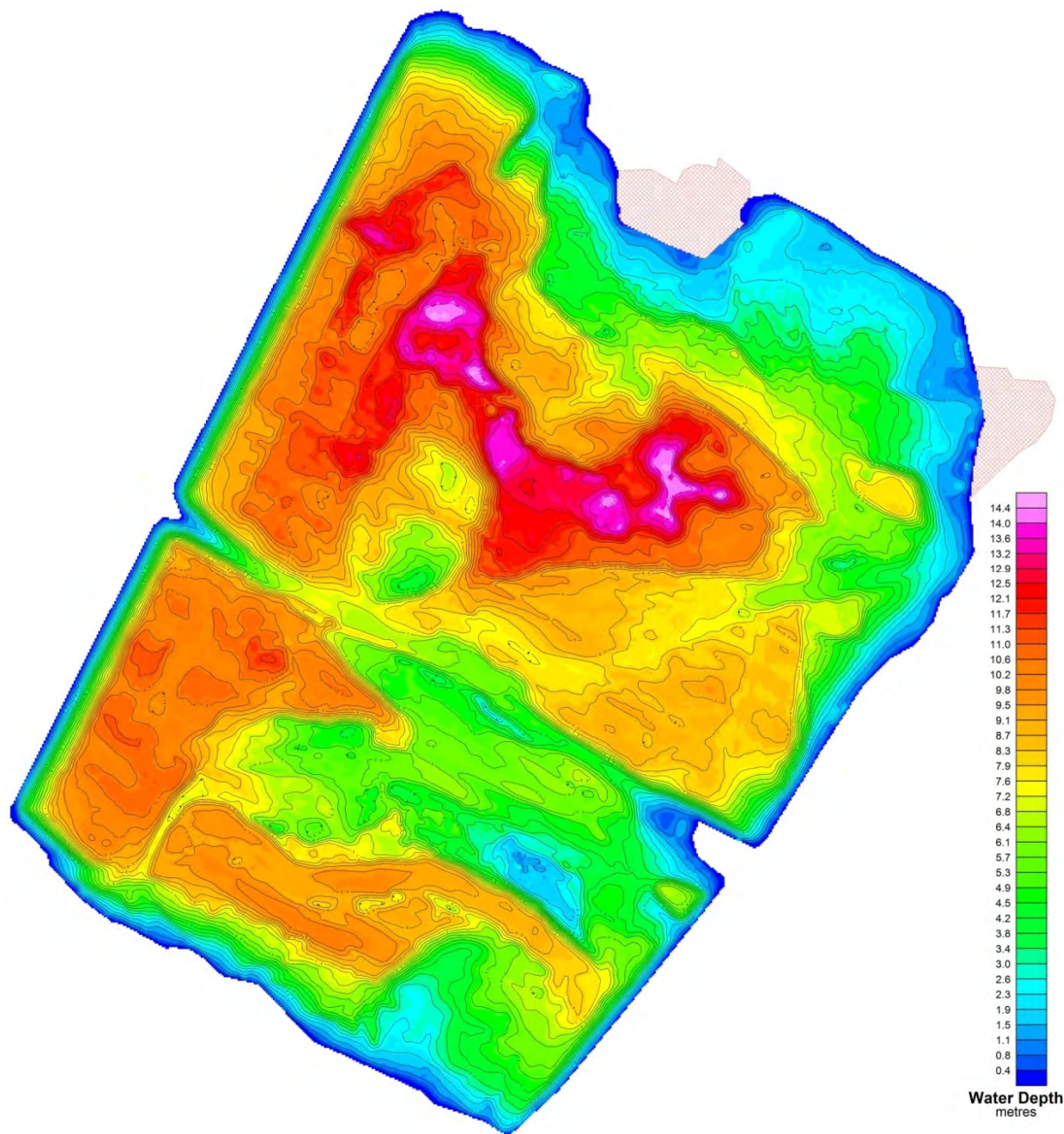


Figure 17: Bathymetry of CVD Pond.

## 4.2 Sub-bottom

The sub-bottom data of the CVD pond is markedly different from that of the ID pond where thick packages of the equivalent of Feature B are ubiquitously imaged. Additionally a distinct reflector is often seen below the Feature B equivalent at the ID pond while this was not observed at CVD pond. Both datasets support an interpretation of Feature B representing tailings but the nature of Features C through G are not clear and, with the hindsight of the data from the ID pond, calls into question whether

they represent real manifestations of sub-bottom variation at all. The two subsurface logs obtained in the winter of 2015-2016 do not lend themselves to drawing conclusion on these features

Despite the ambiguity of the interpretation of the sub-bottom data at CVD a few comments can be made from the sections as well as from examination of the bathymetric data with the sub-bottom data.

The layered material which defines Feature B is well correlated with bounding escarpments, particularly in the south of the pond as seen in Figure 19 and . These features appear to represent a constructed pit where layers of sediment (fines from the polishing mill) were settled.

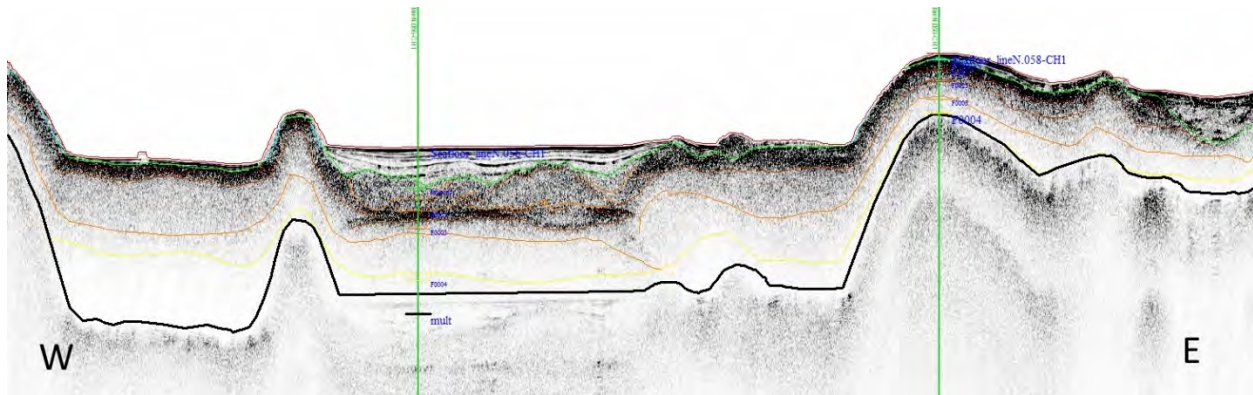


**Figure 18: L4 sub-bottom profile. The trace of this profile is shown as a red line in Figure 19.**

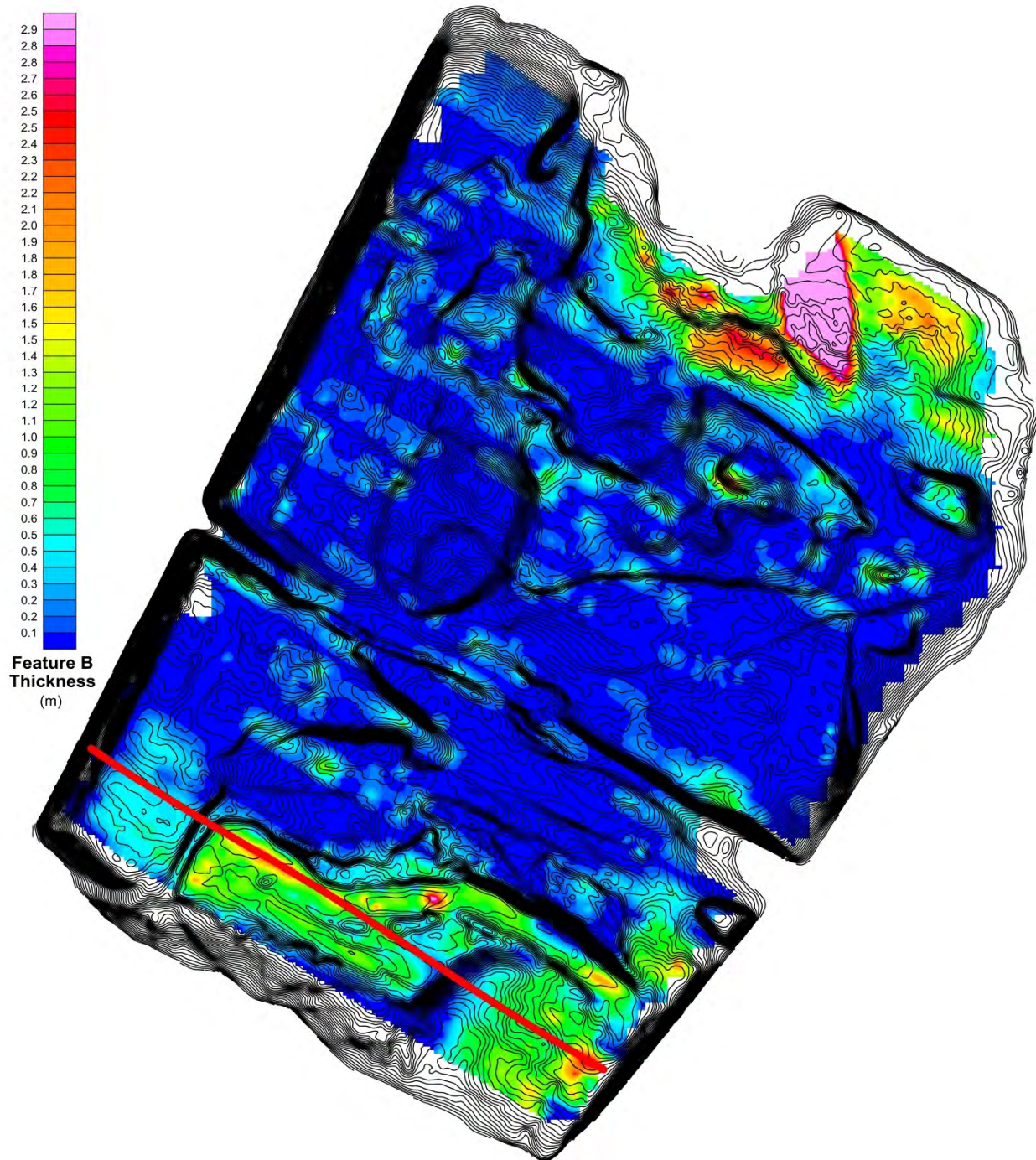


**Figure 19: Feature B thickness with bathymetry contours. The red line shows the trace of L4, the profile of which is Figure 18.**

Feature D thickness, the color contour in Figure 21, is well correlated with steep slopes. Figure 20 shows the profile for L26 which is drawn as a red line in Figure 21. On the slopes, the character of the response changes and does not have the layer of very high amplitude reflectance, prevalent in most of the

section. Because of the lack of this high reflectance layer, represented by Feature C, Feature D thickens here. The interpretation is that Feature C represents finer material which has sloughed off the steeper slopes, leaving only the coarser material represented by Feature D. This interpretation should be verified with ground data.

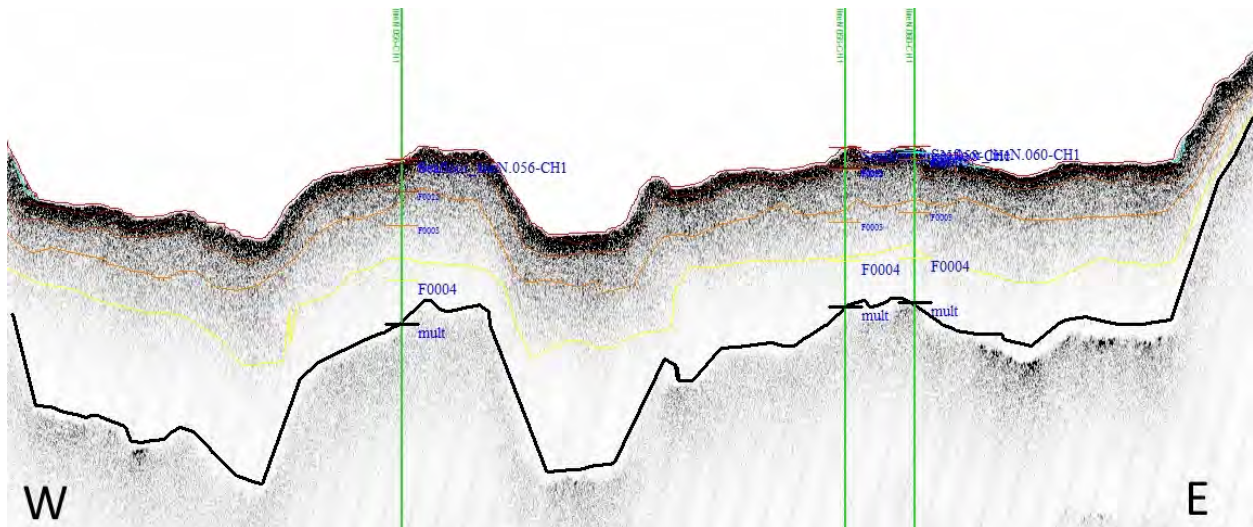


Figure 20: L26 sub-bottom profile. The trace of this profile is shown as a red line in Figure 21.

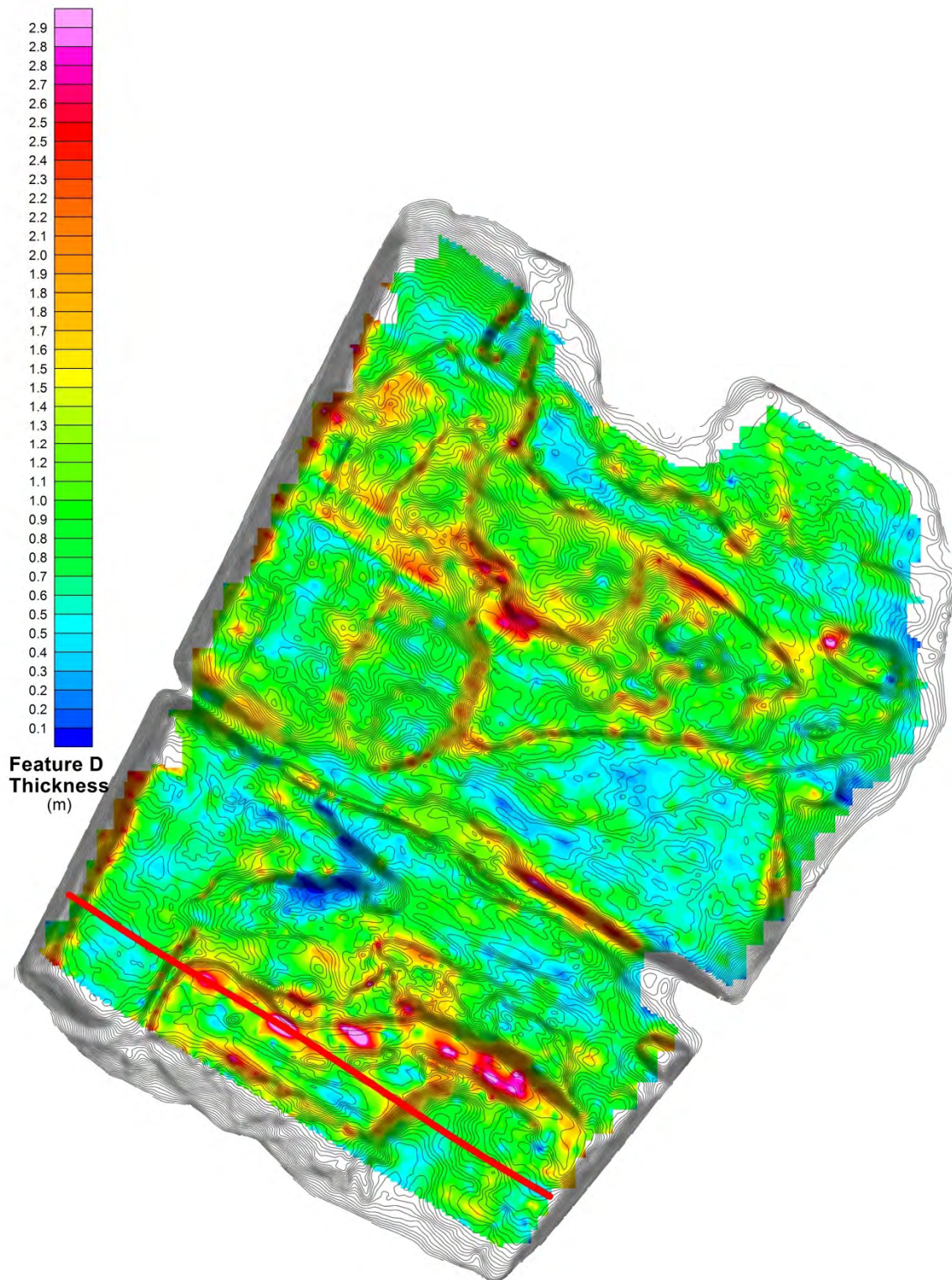


**Figure 21: Bathymetry contours with Feature D thickness colour contour underlay. The red line shows the trace of L26, the profile of which is Figure 20.**

Ground Penetrating Radar (GPR) is a complementary technique to acoustic sub-bottom profiling; GPR relies on a contrast in dielectric constant to image different sub-bottom material while the acoustic profiler depends on velocity and density contrasts. The depth of penetration of GPR may be limited, particularly in conductive environments.

The acoustic profiling data acquisition is slow and sometimes impossible to collect in shallow water. While this was not a serious problem at CVD, the Intermediate Dam Pond has a significant portion of the pond that is very shallow. A GPR survey on the ice may be an economical alternative / complement to shallow acoustic sub-bottom profiling, particularly when the ice is frozen directly to the pond bed; GPR coupling to the bed is maximized in the absence of a strong ice-water reflective interface.

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Dave Hildes, P.Geo., Ph. D.  
Geophysicist

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Shawn Scott,  
Geophysical Technician

**Appendix I**

**Project Log**

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[illegible]



## Production Summary

|                               | CVP<br>Multi-beam                   | CVP<br>Single-beam | CVP<br>Sub-bottom | Intermediate<br>Multi-beam | Intermediate<br>Single-beam | Intermediate<br>Sub-bottom |
|-------------------------------|-------------------------------------|--------------------|-------------------|----------------------------|-----------------------------|----------------------------|
| Estimate percentage completed | 100                                 | 30                 | 100               | 0                          | 0                           | 0                          |
| Tue 20-Oct-2015               | mobe and orientation                |                    |                   |                            |                             |                            |
| Wed 21-Oct-2015               | 25                                  |                    |                   |                            |                             |                            |
| Thu 22-Oct-2015               | 35                                  |                    |                   |                            |                             |                            |
| Fri 23-Oct-2015               | 30                                  | 30                 |                   |                            |                             |                            |
| Sat 24-Oct-2015               | 10                                  |                    |                   |                            |                             |                            |
| Sun 25-Oct-2015               |                                     |                    | 100               |                            |                             |                            |
| Mon 26-Oct-2015               | 0                                   | 0                  | 0                 | 0                          | 0                           | 0                          |
| Tue 27-Oct-2015               | shoreline RTK GPS points and demobe |                    |                   |                            |                             |                            |

## Faro Bathymetry and Sub-Bottom

**DATE:**

October-20-15

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type                       | Contractor/Renter | Hrs or units |
|----------------------------|-------------------|--------------|
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 0            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 0            |
| ATV & trub trailer         | AGL               | 0            |

### Crew

| Position     | Contractor        | Hrs or units |
|--------------|-------------------|--------------|
| Geophysicist | Dave Hildes       | 10           |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |

### Comments

#### Weather

Clear turning to slightly overcast. +5 in Whitehorse

### Notes (production comments, incidents, other)

Mobilized to Faro from Whitehorse via truck around 7:30am and completed hazard assessment. Arrived in Faro around noon, grabbed a bite to eat and then completed the TES orientation and safety orientation with Robin. Completed a site visit with Robin later in the afternoon and logistics planning.

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-21-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 0            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 0            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Dave Hildes       | 10           |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |

| Comments                                    |
|---------------------------------------------|
| Weather                                     |
| Snow in the morning. Clear in the afternoon |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 8am</p> <p>Set up through the morning. Initial set up and unloading took longer than what is anticipated for daily set up.</p> <p>Calibration of instruments and intial tests in the early afternoon.</p> <p>Multibeam surveying started at approximately 14:45 and ended at 16:40.</p> <p>No issues with data aquisition and early progress is encouraging.</p> <p>Approximately 25% of CVP is completed.</p> <p>All equipment and apparell cleaned with safe water and equipment packed at end of day by 18:00. Must prepare to leave earlier in future days to avoid a late checkout at CH2MH office.</p> <p>Dave Hildes demobed at the end of the day and is no longer on site.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-22-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 0            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 0            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

| Comments                                                                                   |
|--------------------------------------------------------------------------------------------|
| Weather                                                                                    |
| Snow in the morning again, rain in the afternoon. One sliver of sun in the late afternoon. |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 800am</p> <p>Reviewed boating AHA and FLRA with Robin.</p> <p>Day was spent continuing multi-beam surveying on the CVP.</p> <p>Networking issues with instruments caused an hour's delay when we first set out.</p> <p>Most of the data acquisition was in shallow water, requiring many, many passes to get good coverage.</p> <p>RTK coverage failed momentarily at the end of the day, the issue was resolved in time for a last qc checkpoint reading.</p> <p>Checked out at 540pm.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-23-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 0            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 1            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

| Comments                                      |
|-----------------------------------------------|
| Weather                                       |
| Snow in the morning yet again, sunny by noon. |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 800am</p> <p>On the water by 1030am. Started the day by continuing the multibeam bathymetry but RTA had wasn't able to connect until an hour later. Did a sound velocity cast and check-in with RTK while waiting. Finished most of the multibeam with a bit of cleanup to be done tomorrow. In order to maximize our efficiency without risking a late checkout at the CH2MHill office, we completed the labour intensive tear down work early. With the time left before we needed to be off site, we collected RTA GPS data along the shore of the CVP and also collected some single beam data with the zodiac along the perimeter where it is too shallow for the large boat.</p> <p>Checked out of CH2MHill at 550pm.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-24-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 0            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 1            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

| Comments                                                      |
|---------------------------------------------------------------|
| Weather                                                       |
| Cloudy to start the day and then sunny through the afternoon. |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 800am</p> <p>On the water by 945am. Continued problems waiting for the RTA to warm up. Spent most of the day doing detail work to ensure full coverage for the multibeam survey. Spent some time at the end of the day trying to prepapre for sub-bottom survey for tomorrow.</p> <p>Continued problems connecting to the Digibar -S sound velocity probe, managed two complete casts but spent much more time attempting to read data from it. Tried again to access shallow areas to the north of the pond but again struck a large rock. Had the same problem there the day before in the zodiac and have found no safe solution to surveying there. Checked out of CH2MHill at 550pm.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-25-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 1            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 1            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

| Comments                                                 |
|----------------------------------------------------------|
| Weather                                                  |
| Sunny and clear. Cold though, ice on edges of the water. |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 800am</p> <p>On the water by 930am.</p> <p>Set up the sub-bottom and tested several lines repeatedly with different frequency chirps. Ran survey all day with few problems.</p> <p>Finished the day with little time to spare but completed the sub-bottom survey on the Cross Valley Dam.</p> <p>Checked out of CH2MHill at 555pm.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-26-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 1            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 1            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

| Comments                                                                       |
|--------------------------------------------------------------------------------|
| <b>Weather</b>                                                                 |
| Sunny all day but significantly colder. Ice fully covering both ponds all day. |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Safety Meeting at CH2MHill office at 800am</p> <p>Arrived at ponds to discover they were both completely covered in ice. Contacted CH2MHill and notified them of the problem, saying we would carry on preparing to work in hopes of the ice melting. We continued to monitor the ice thickness and maintained close contact with Robin and Robert of CH2MHill, who felt it was unsafe to attempt to launch a boat on either pond. The ice did not melt and we were advised to consider today a weather day and return ready to work in the morning, should conditions allow.</p> |

## Faro Bathymetry and Sub-Bottom

|              |               |
|--------------|---------------|
| <b>DATE:</b> | October-27-15 |
|--------------|---------------|

|                     |
|---------------------|
| <b>PREPARED BY:</b> |
| Shawn Scott         |

| LOGISTICS                  |                   |              |
|----------------------------|-------------------|--------------|
| Type                       | Contractor/Renter | Hrs or units |
| Truck                      | AGL               | 1            |
| Trailer                    | AGL               | 1            |
| Boat                       | AGL               | 1            |
| Sub-bottom 424             | Rental            | 1            |
| Multibeam MB1 & controller | Rental            | 1            |
| Single Beam                | AGL               | 1            |
| ATV & trub trailer         | AGL               | 1            |

| Crew         |                   |              |
|--------------|-------------------|--------------|
| Position     | Contractor        | Hrs or units |
| Geophysicist | Darrell Epps      | 10           |
| Technician   | Shawn Scott       | 10           |
| Field Hand   | Hannah Warrington | 10           |
|              |                   |              |

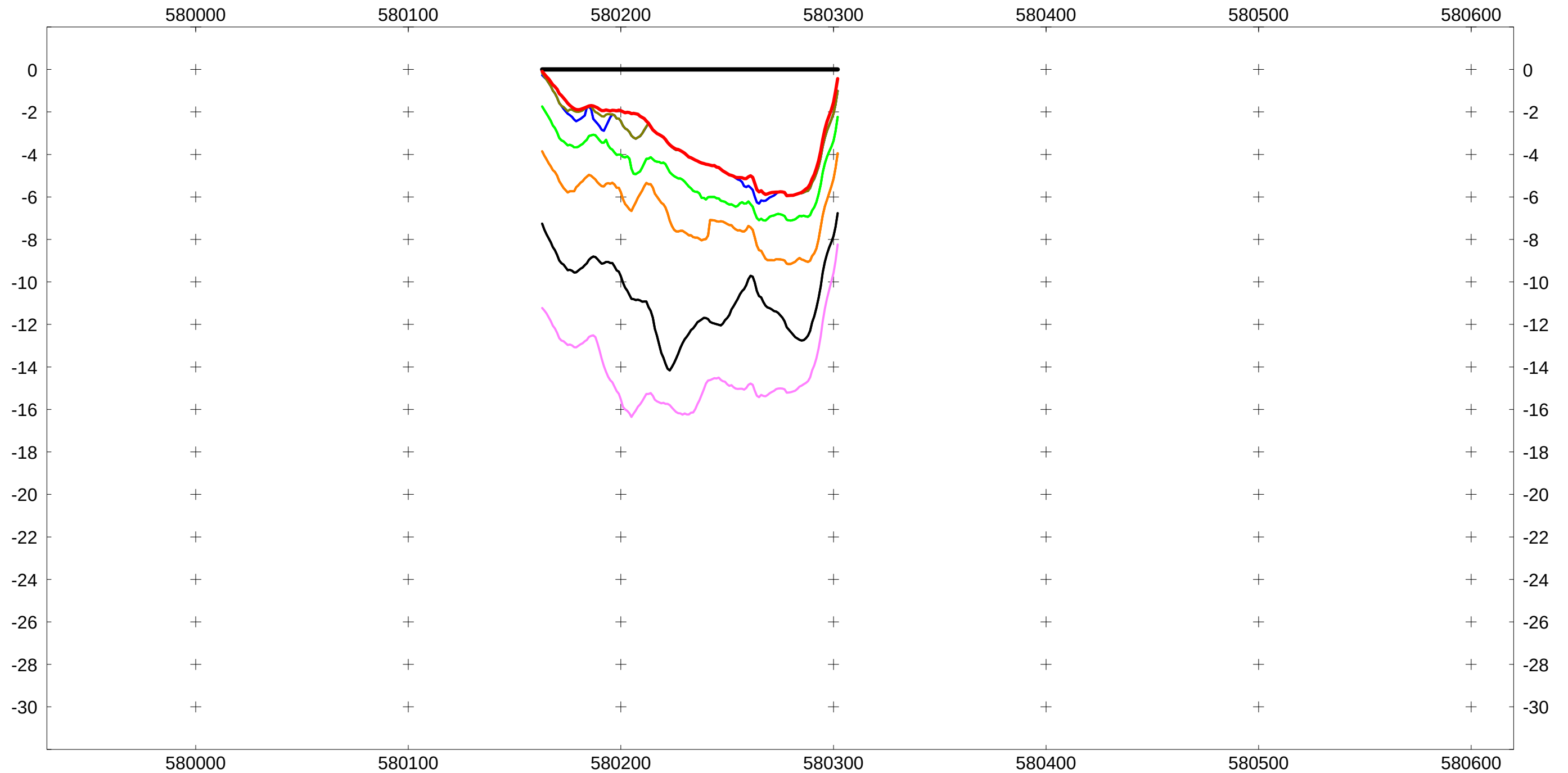
| Comments                                    |
|---------------------------------------------|
| Weather                                     |
| overcast and temperature hovering around -5 |

| Notes (production comments, incidents, other)                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The weather stayed below zero overnight and the short term forecast calls for more of the same. Discussions between CH2M Hill and Aurora Geosciences determined that the survey could not proceed any longer due to the ice on the ponds and that the data collection/field work would be ended. Collected some shoreline RTK-GPS points in the morning and then left site around 11am. Loaded up equipment and instruments after lunch and demobilized via truck back to Whitehorse around 3pm. |

## Appendix II

### Cross-sections

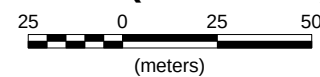
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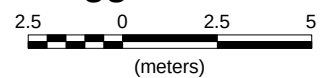
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

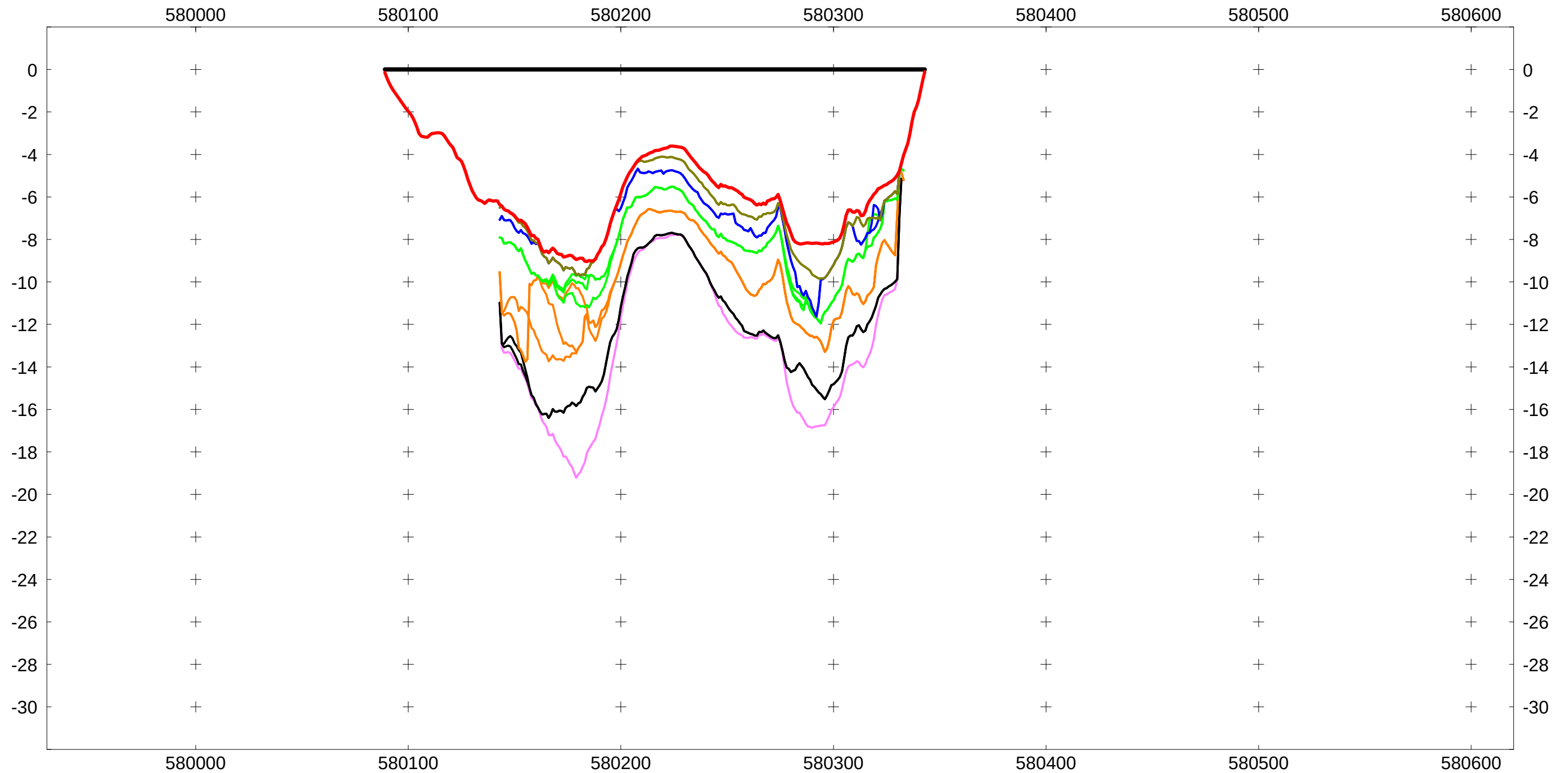
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914000**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

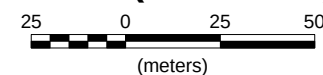
**AURORA GEOSCIENCES LTD.**



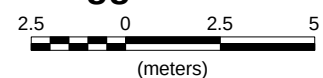
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

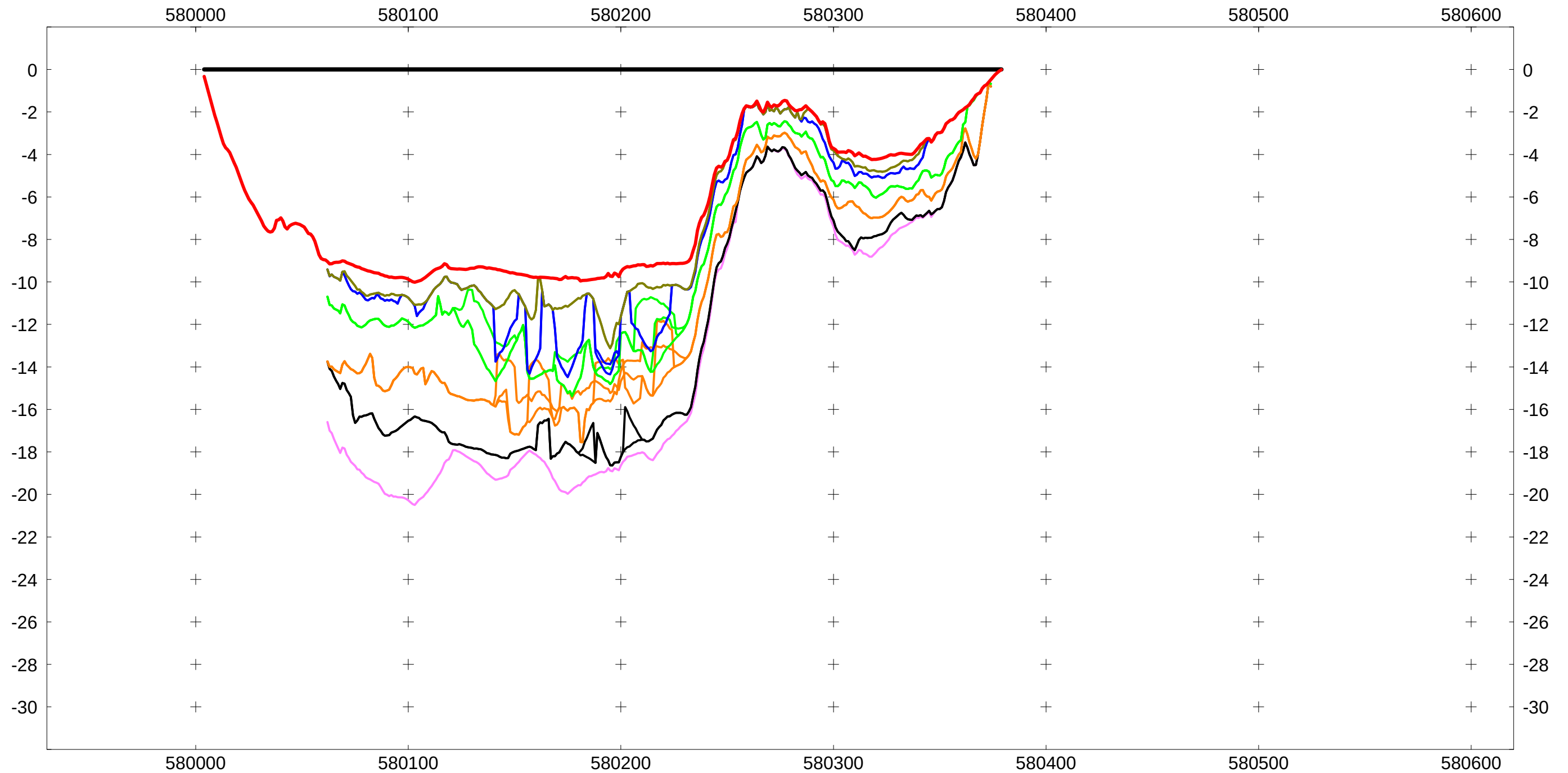
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914050**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

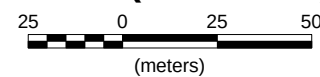
**AURORA GEOSCIENCES LTD.**



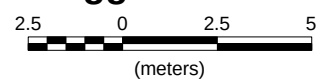
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

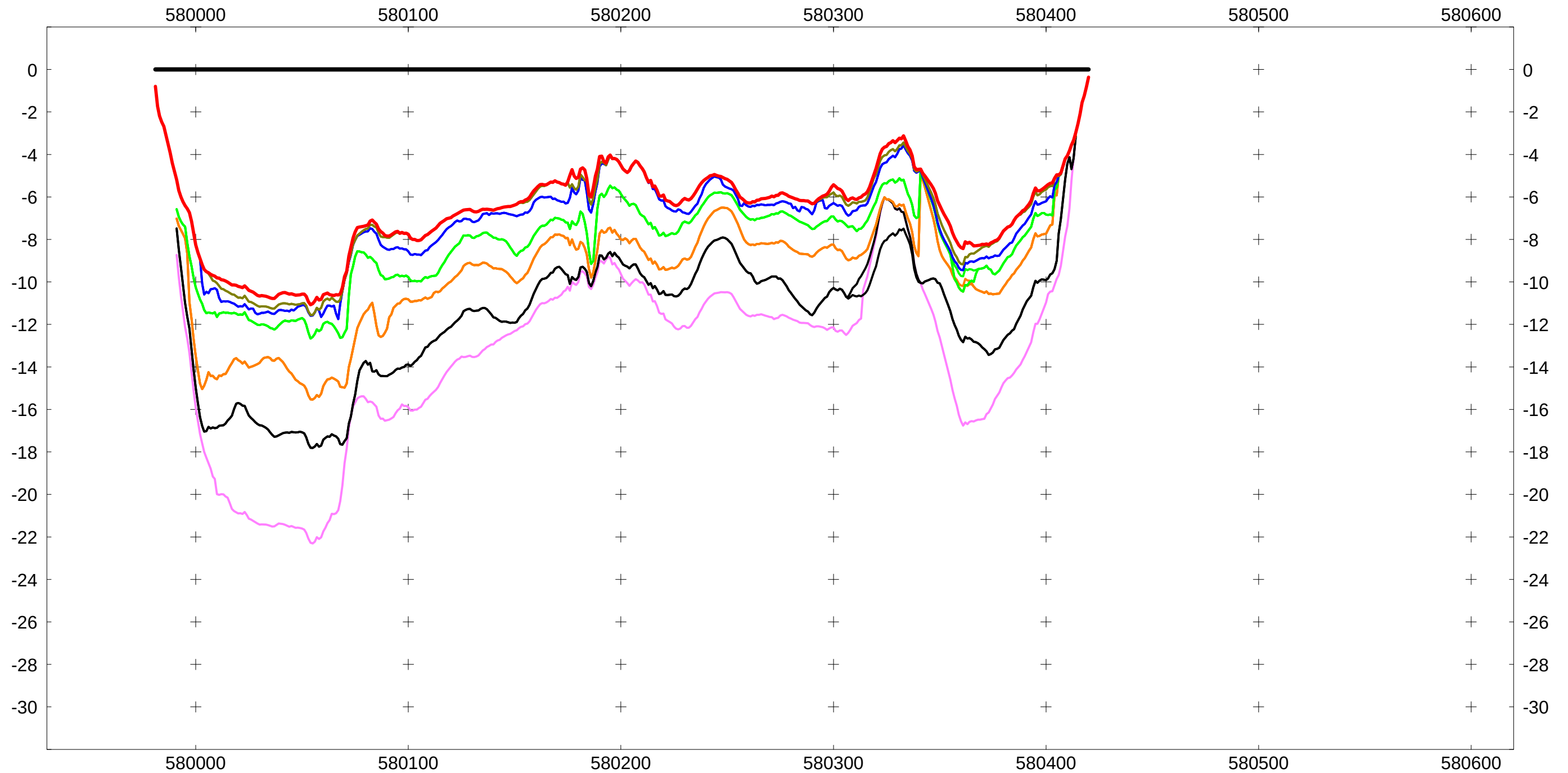
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914100**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

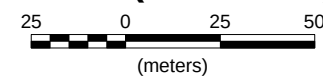
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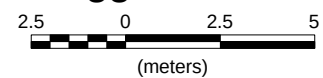
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G :

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

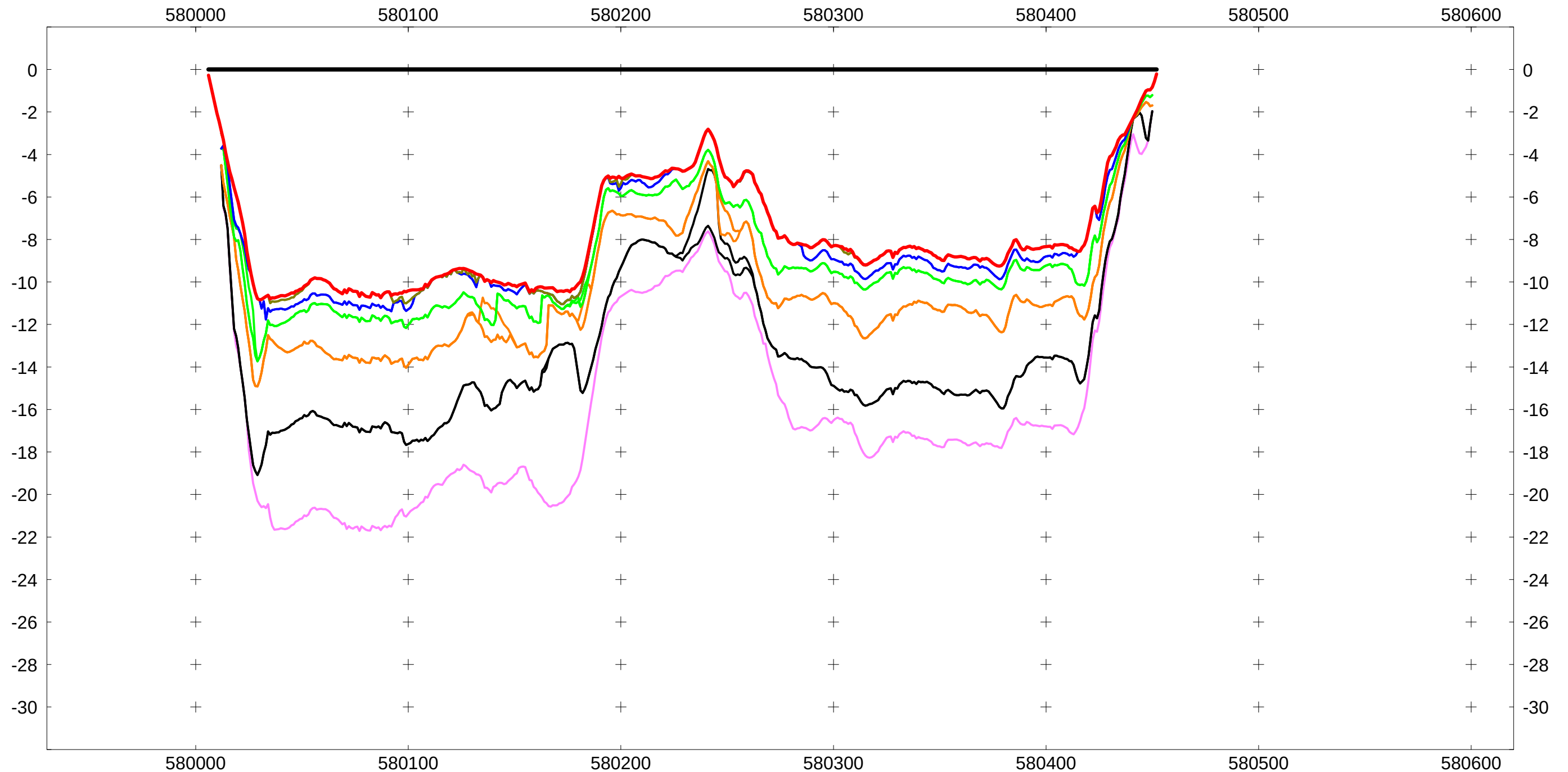
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914150**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

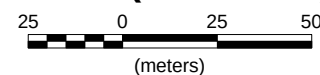
**AURORA GEOSCIENCES LTD.**



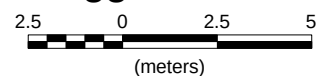
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

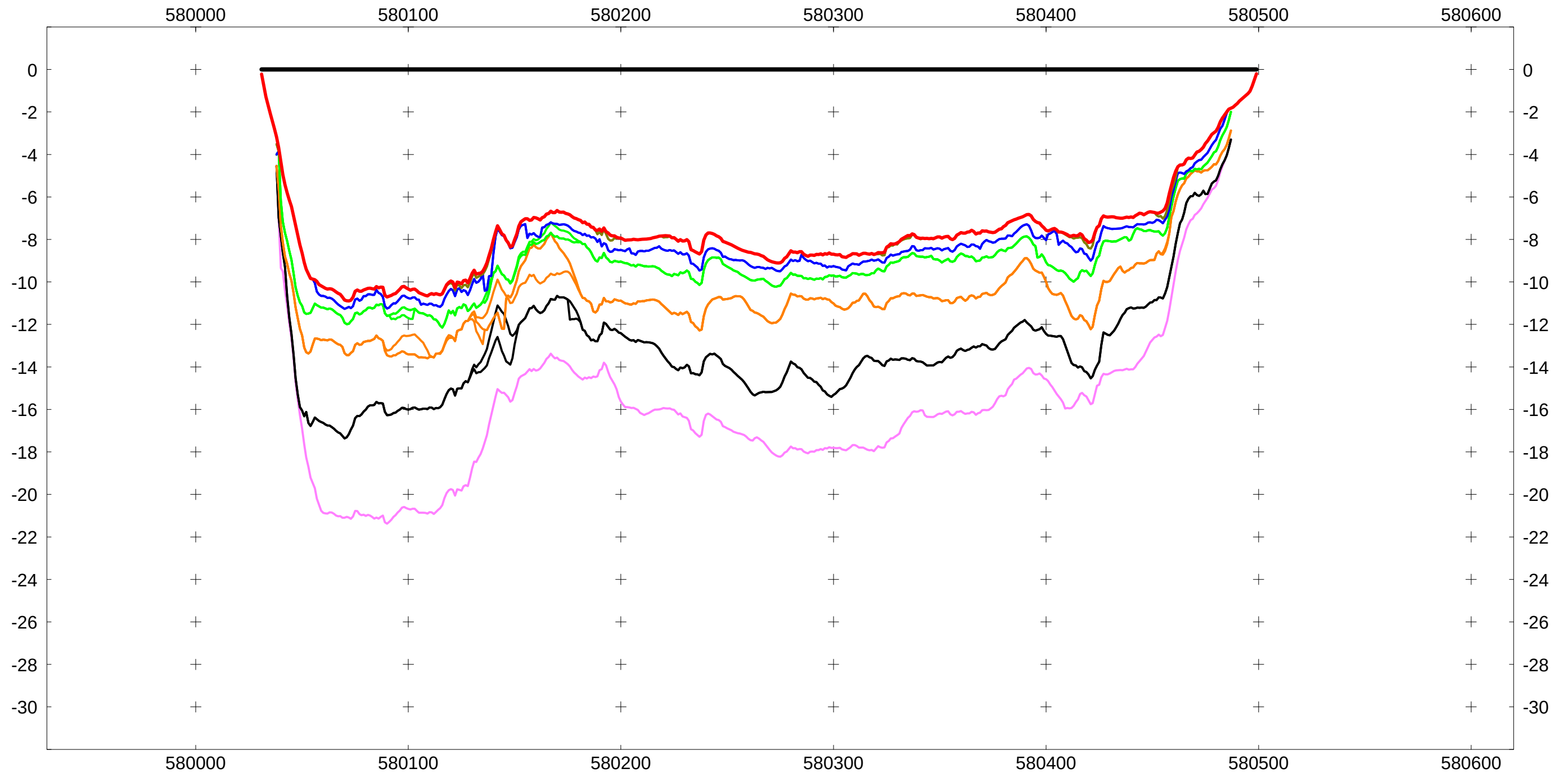
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914200**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

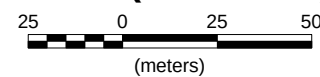
**AURORA GEOSCIENCES LTD.**



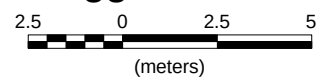
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

**CH2M HILL LTD.**

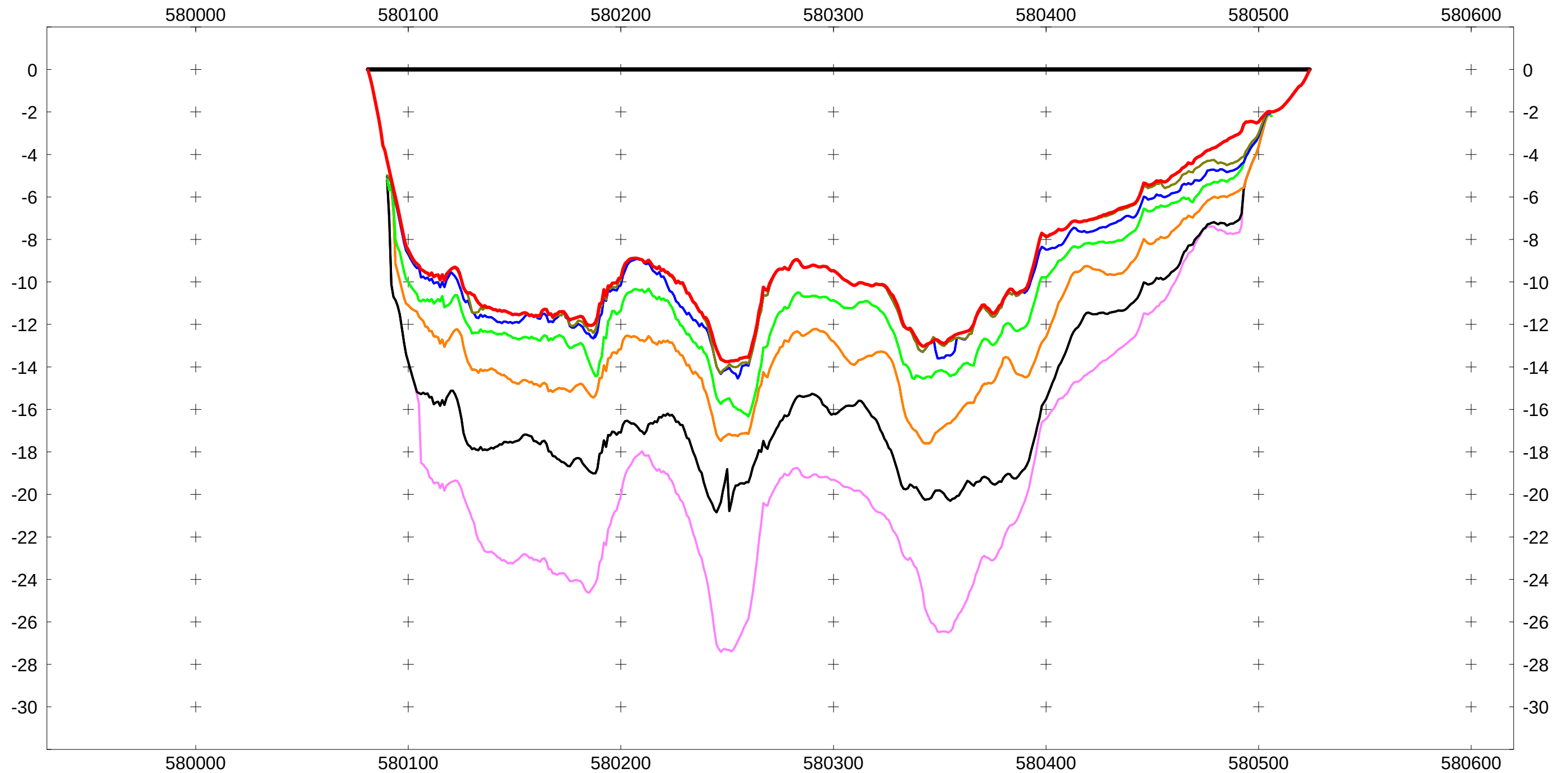
**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914250**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

**AURORA GEOSCIENCES LTD.**

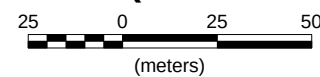




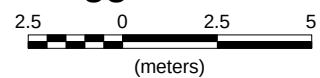
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

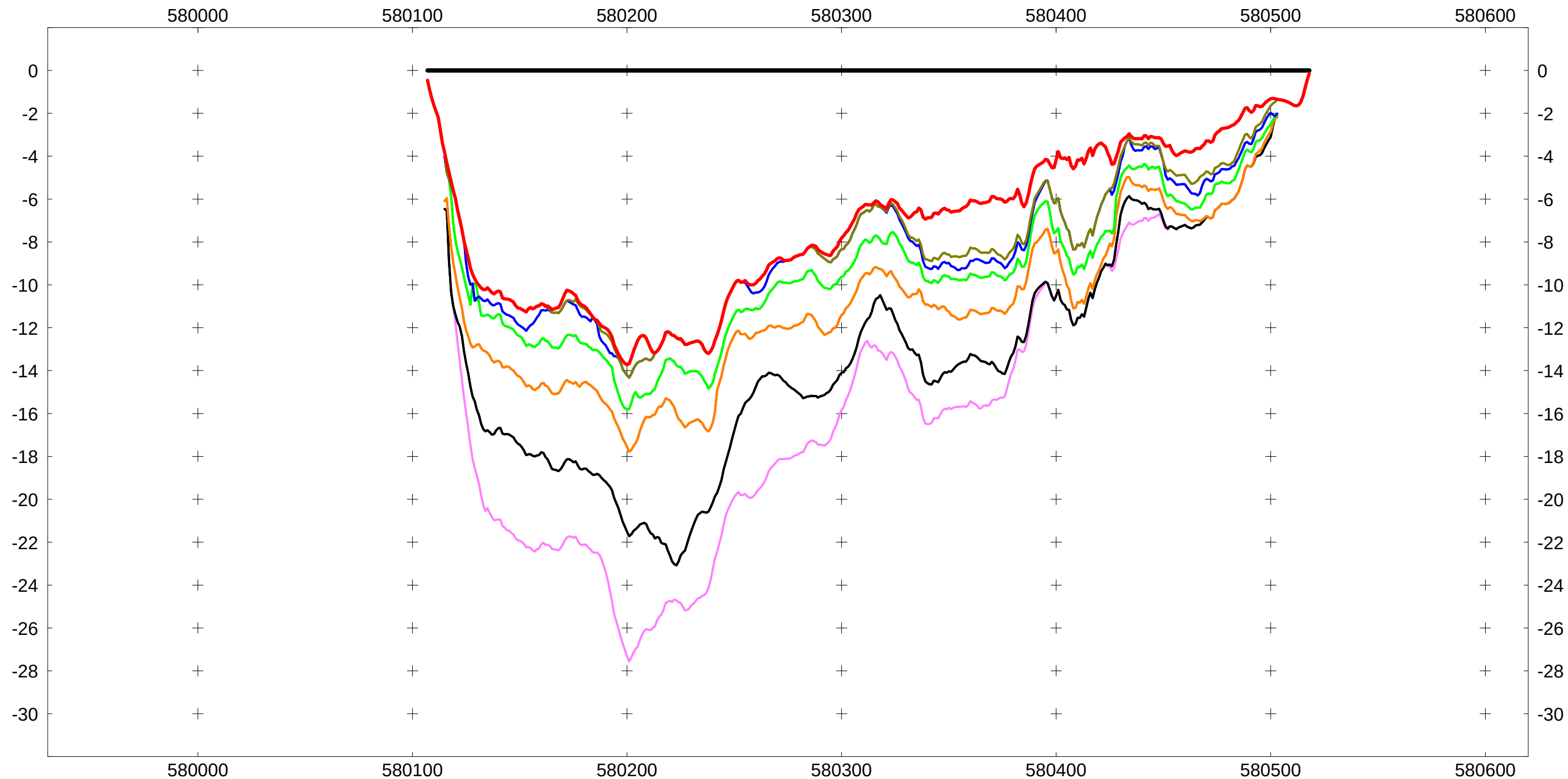
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914350**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

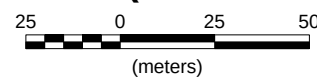
**AURORA GEOSCIENCES LTD.**



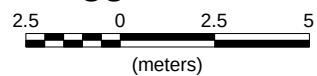
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

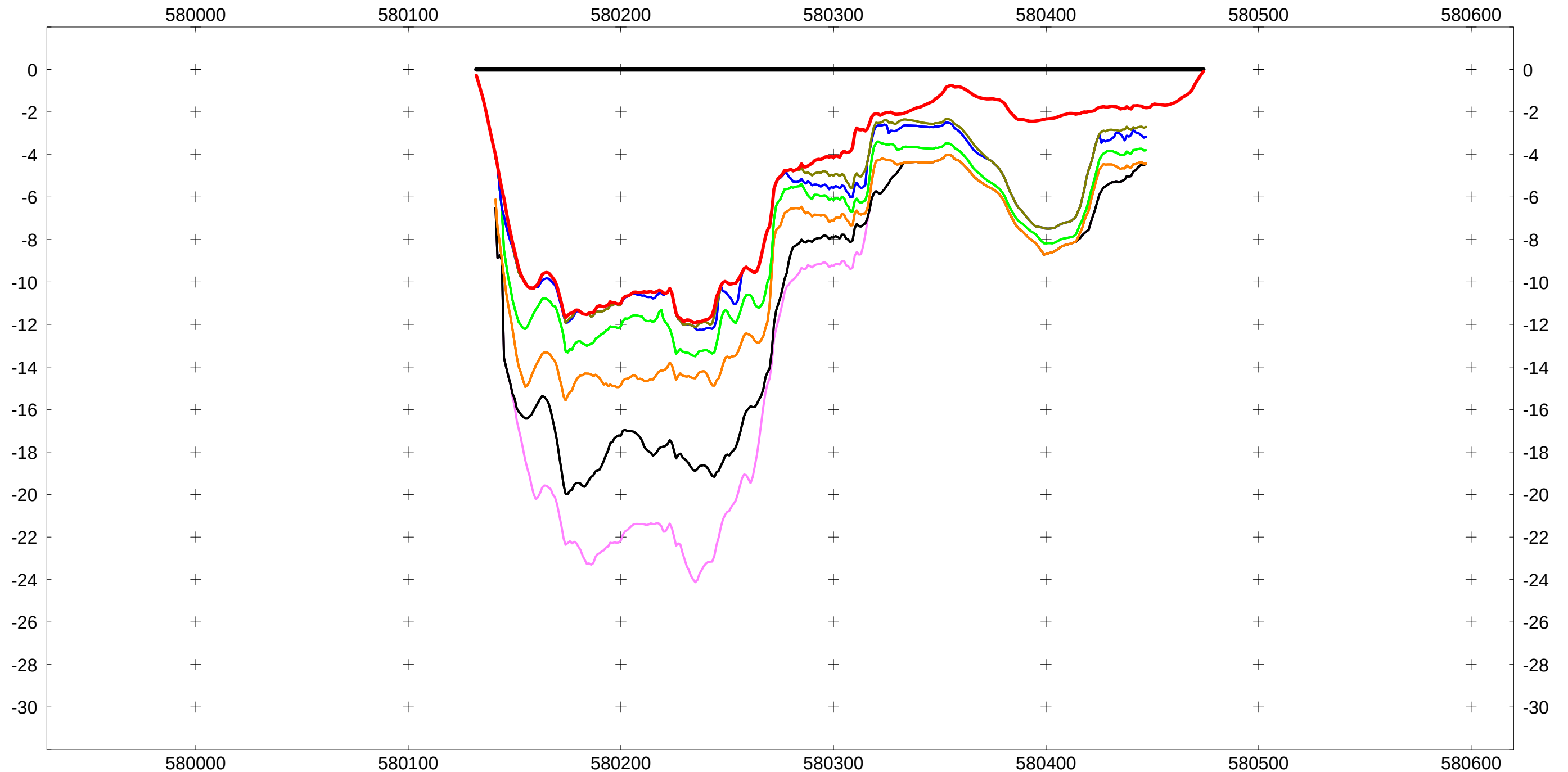
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914400**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

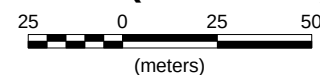
**AURORA GEOSCIENCES LTD.**



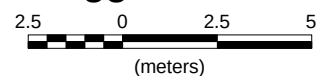
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

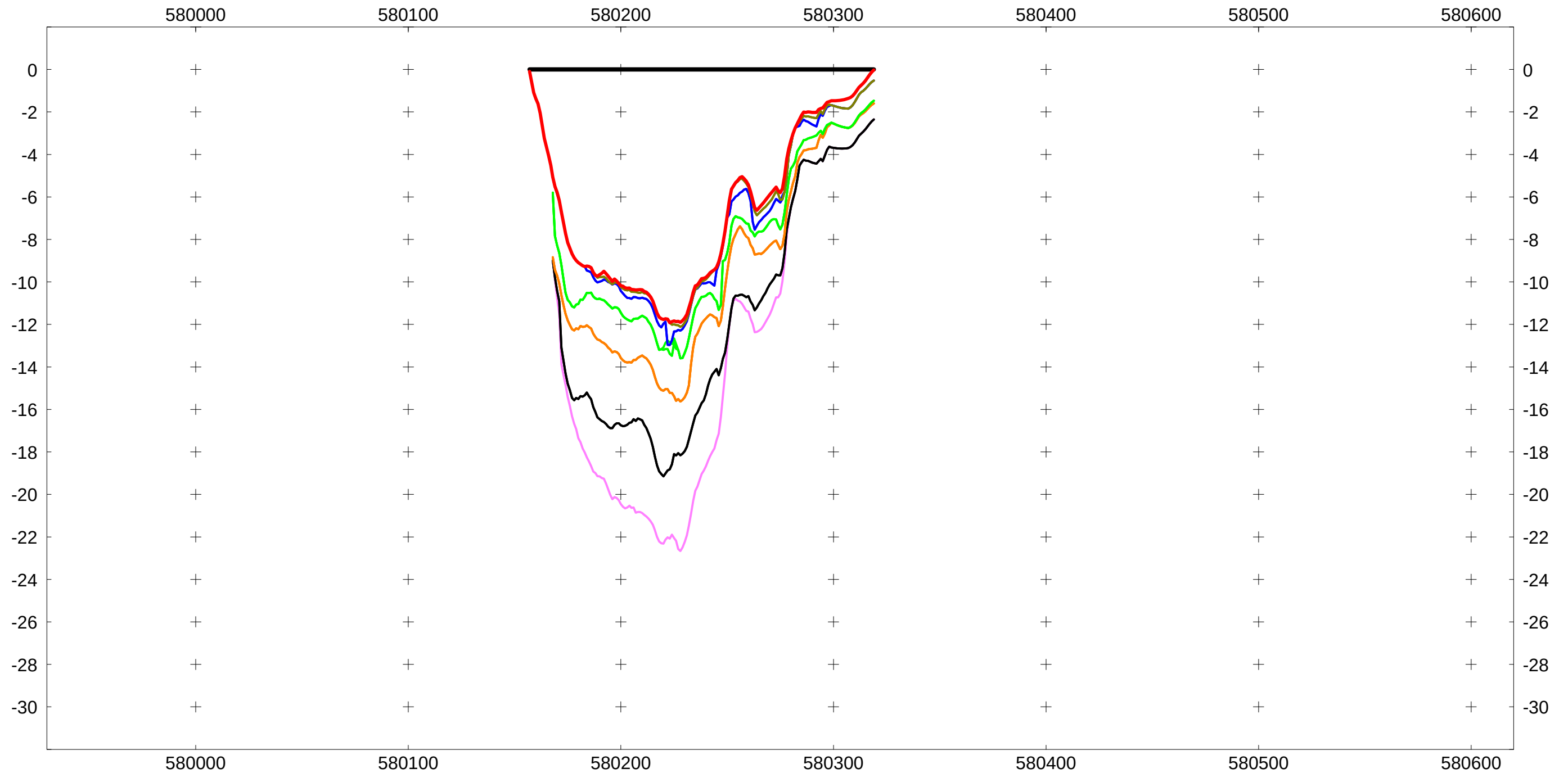
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914450**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

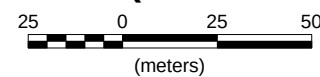
**AURORA GEOSCIENCES LTD.**



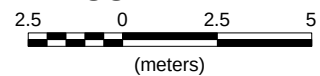
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

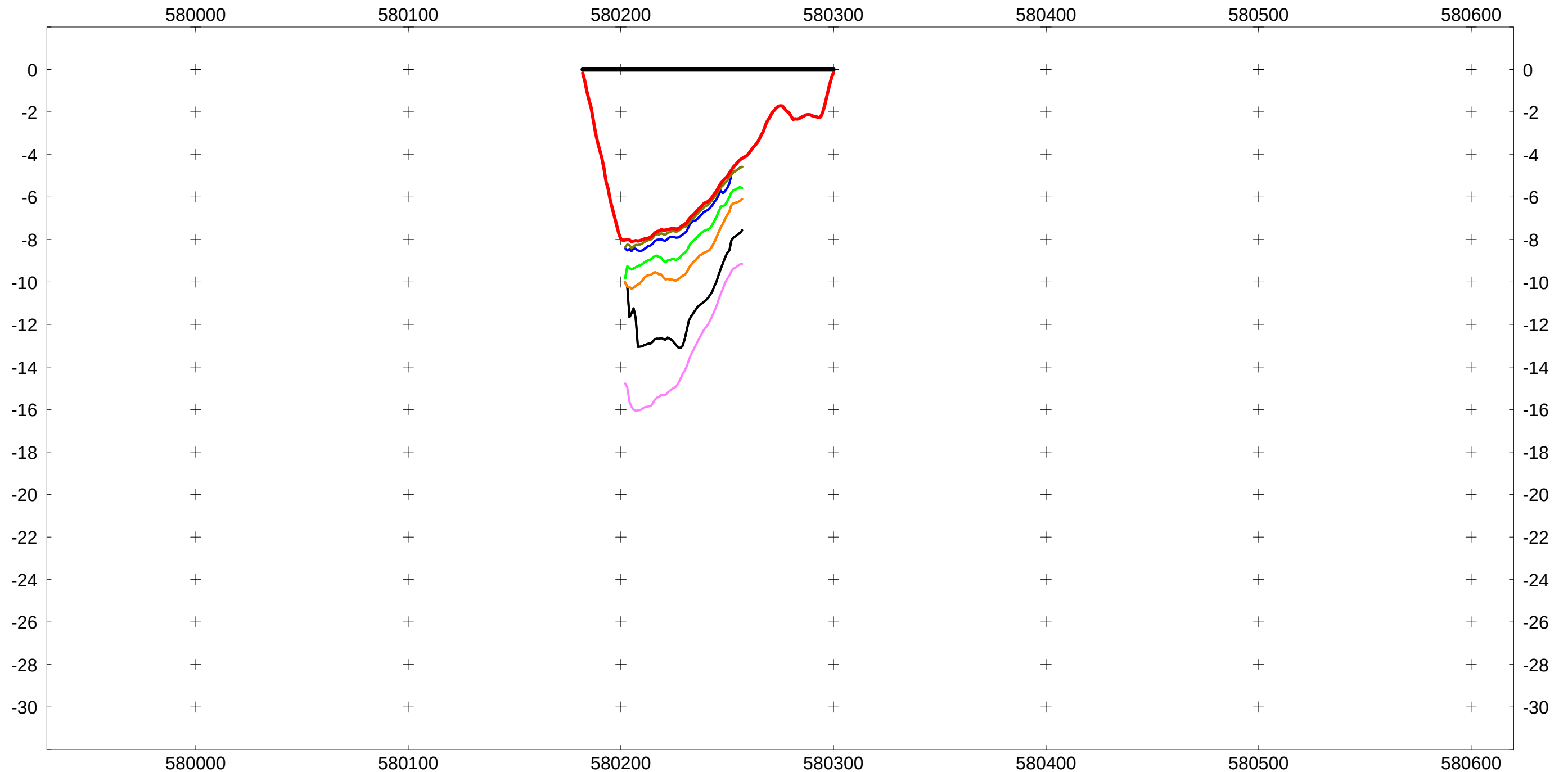
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914500**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

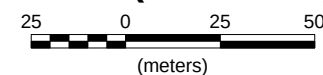
**AURORA GEOSCIENCES LTD.**



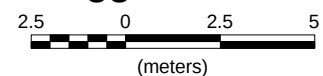
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Easting

Y-AXIS - Depth relative  
to Water Surface

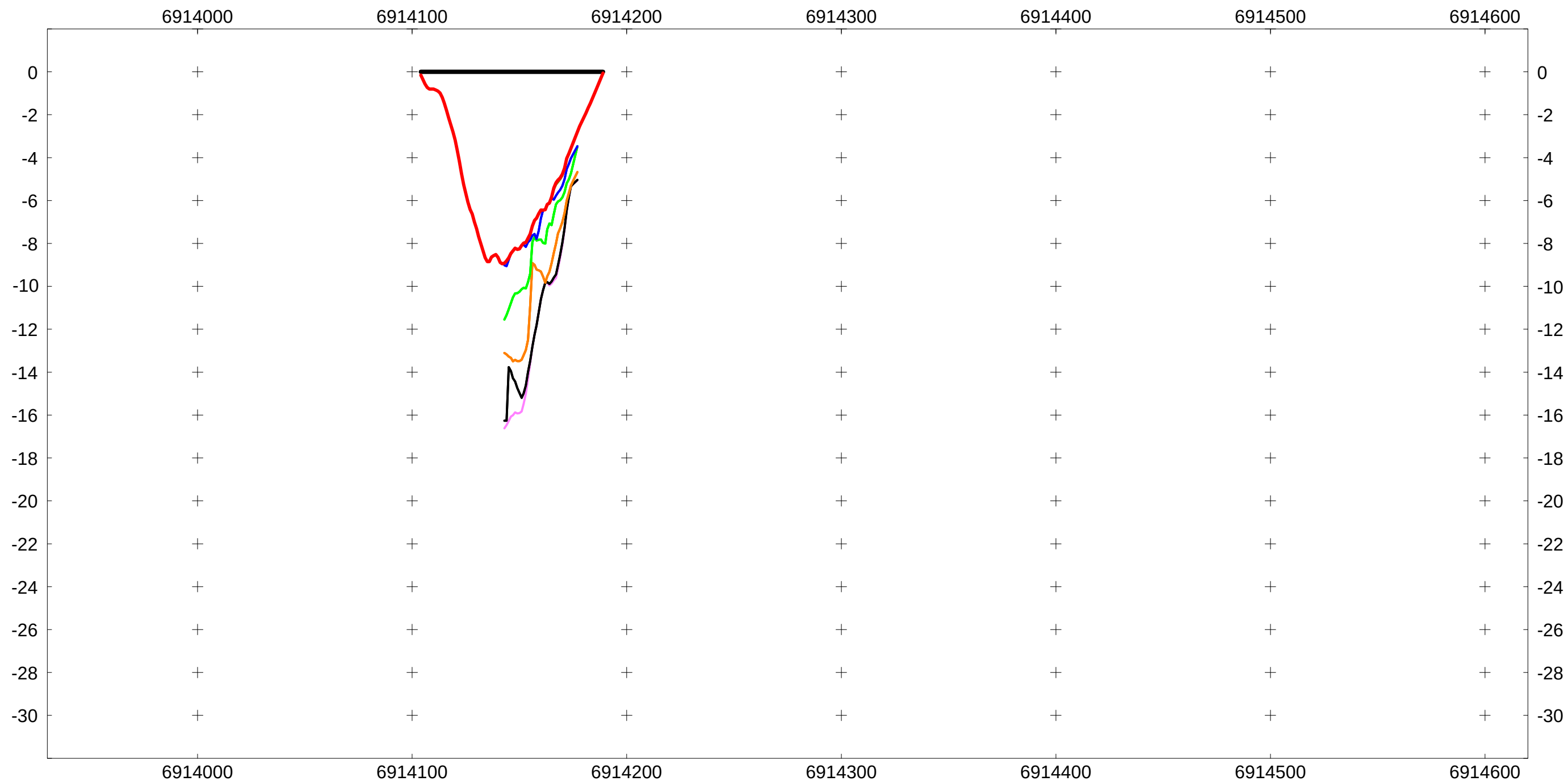
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914550**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

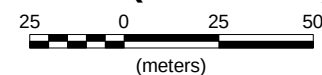
**AURORA GEOSCIENCES LTD.**



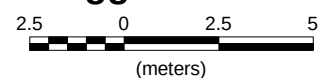
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

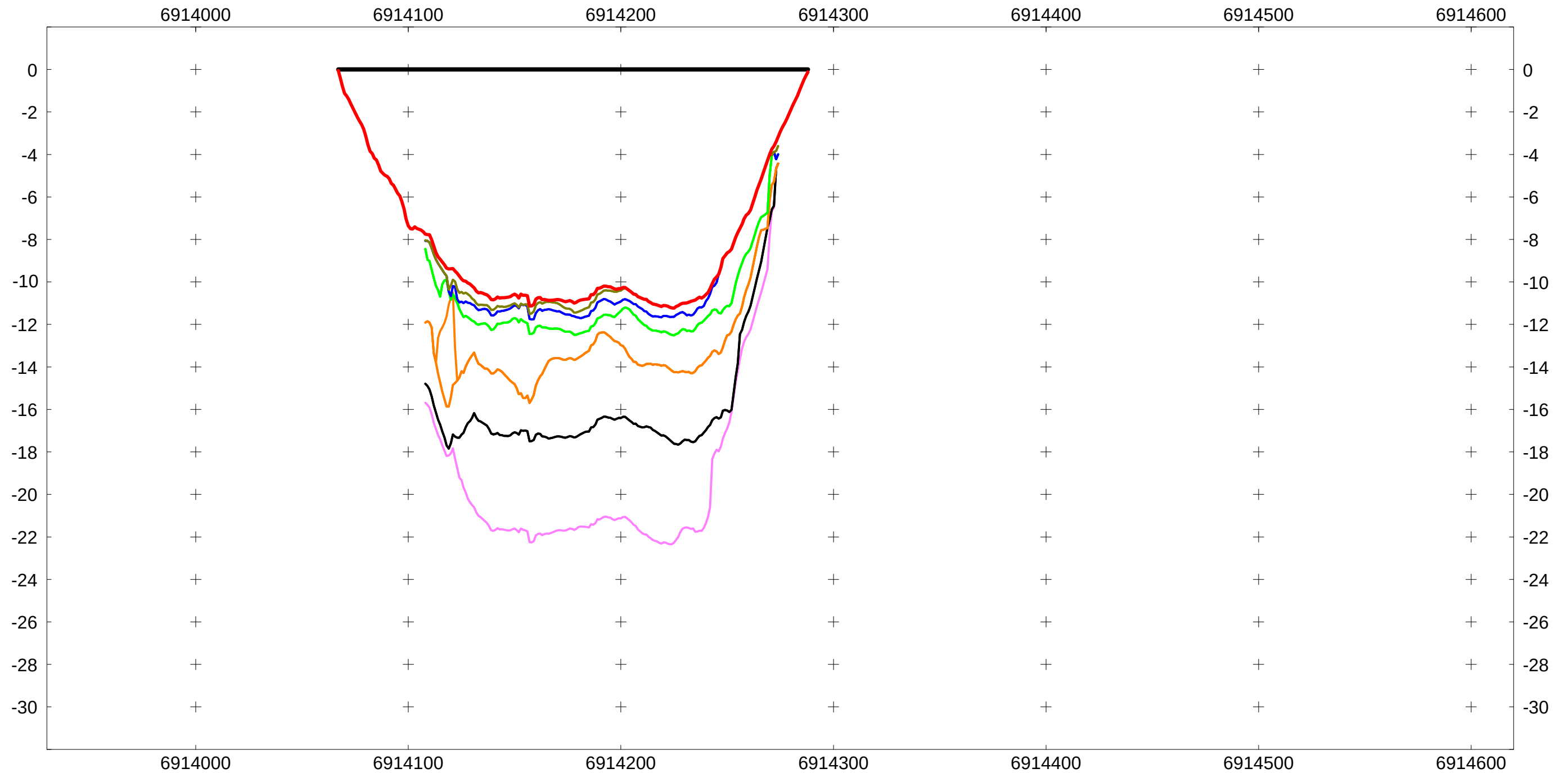
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580000**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

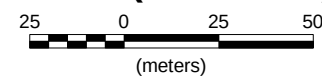
**AURORA GEOSCIENCES LTD.**



## LEGEND

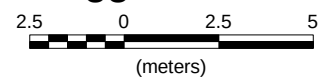
Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Scale (vertical)  
exaggeration X10



Y-AXIS - Depth relative  
to Water Surface

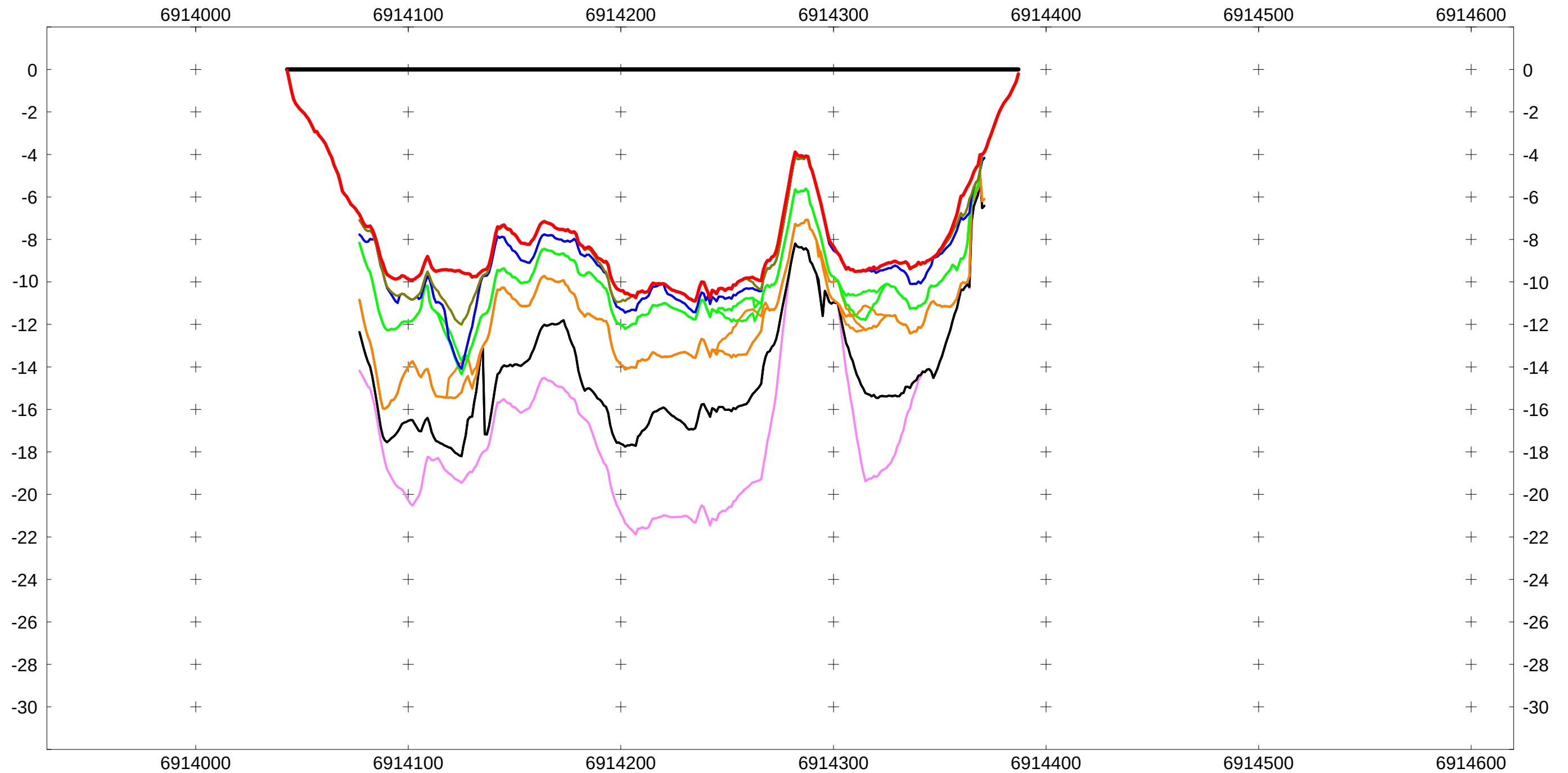
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580050**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

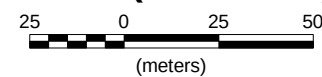
**AURORA GEOSCIENCES LTD.**



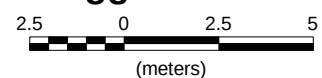
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

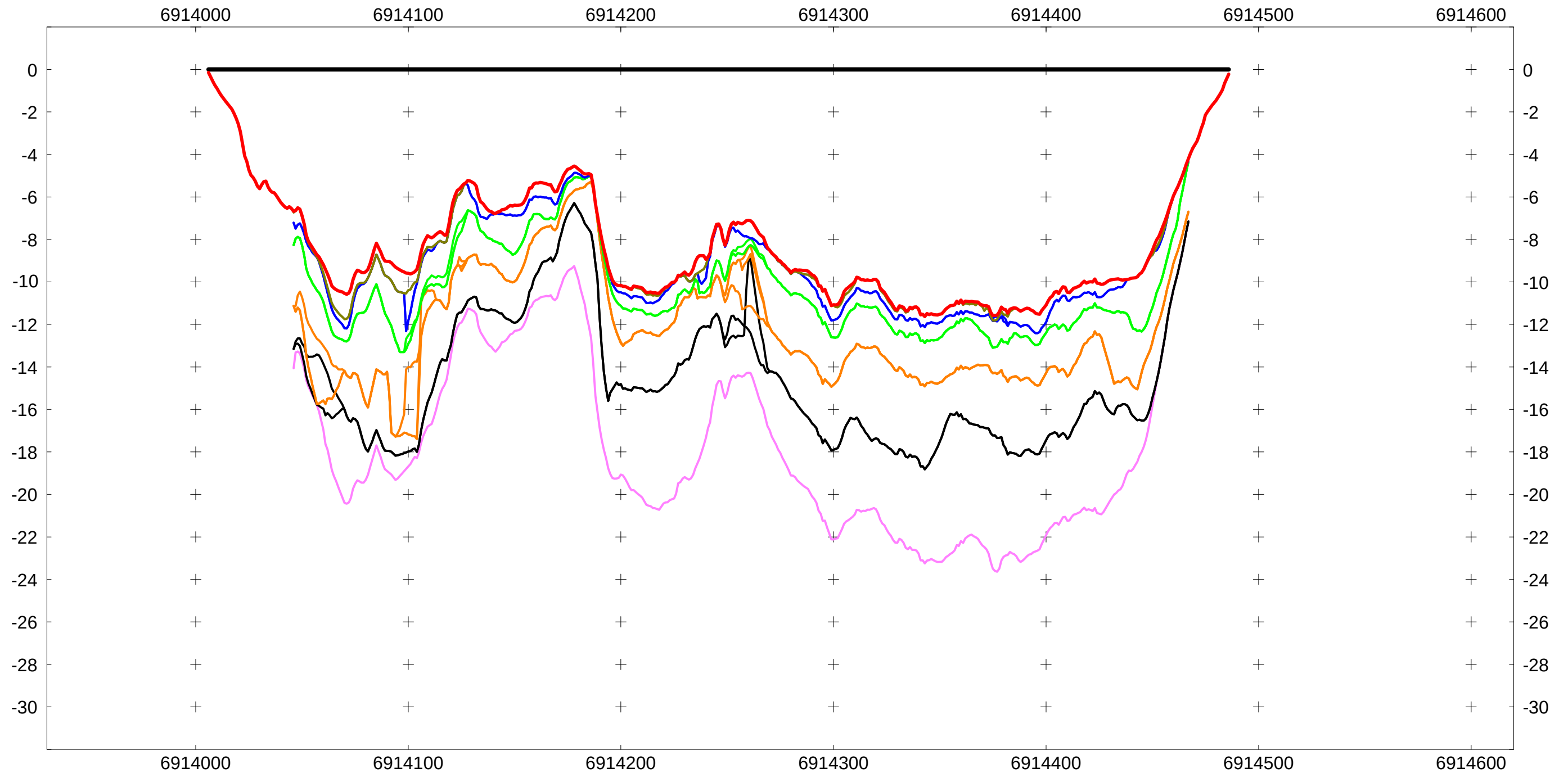
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580100**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

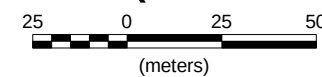
**AURORA GEOSCIENCES LTD.**



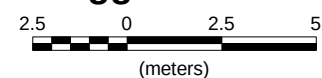
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

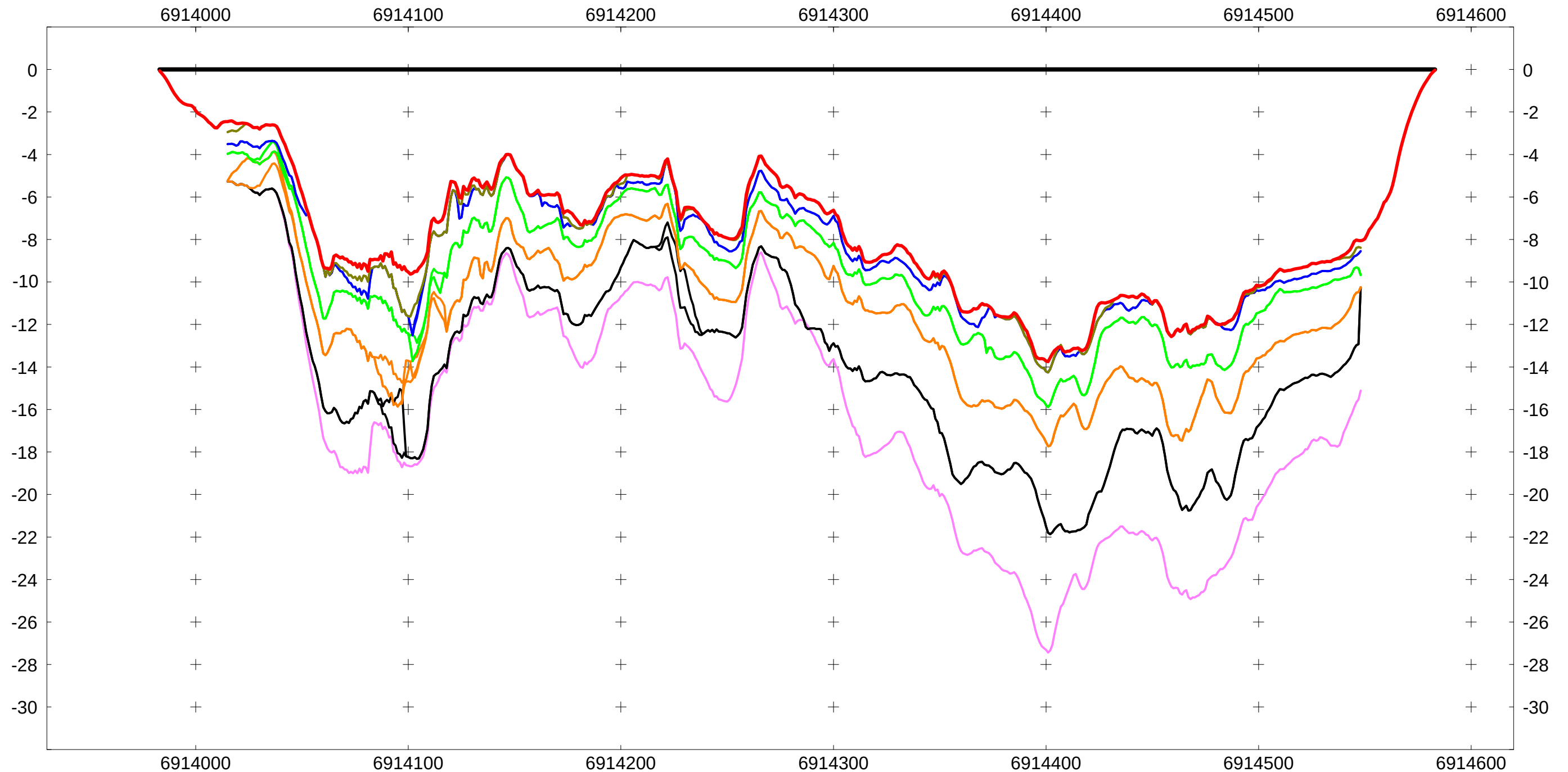
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580150**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

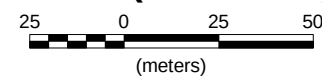
**AURORA GEOSCIENCES LTD.**



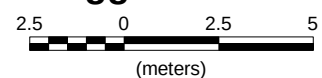
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

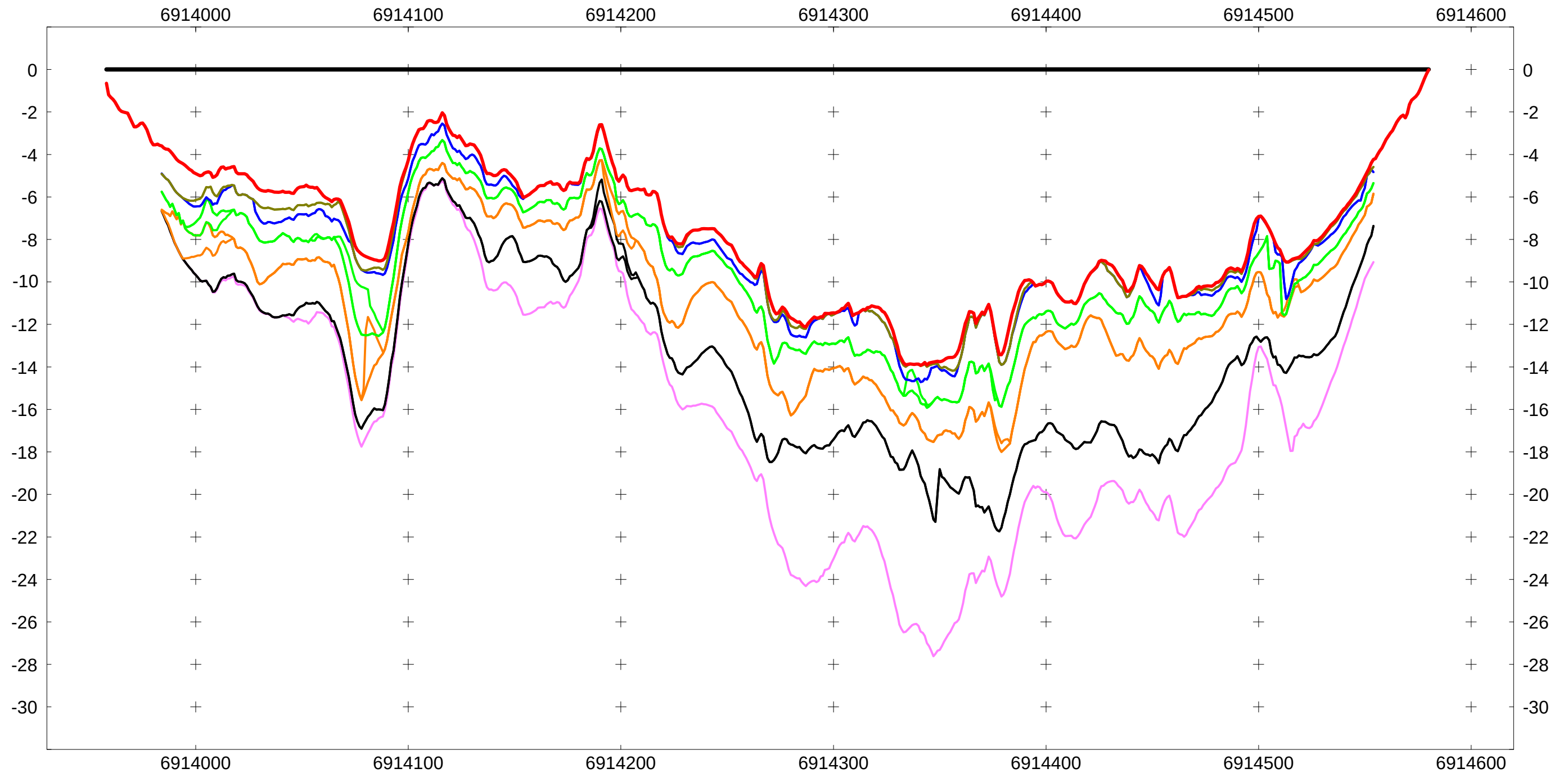
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580200**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

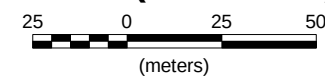
**AURORA GEOSCIENCES LTD.**



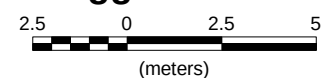
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

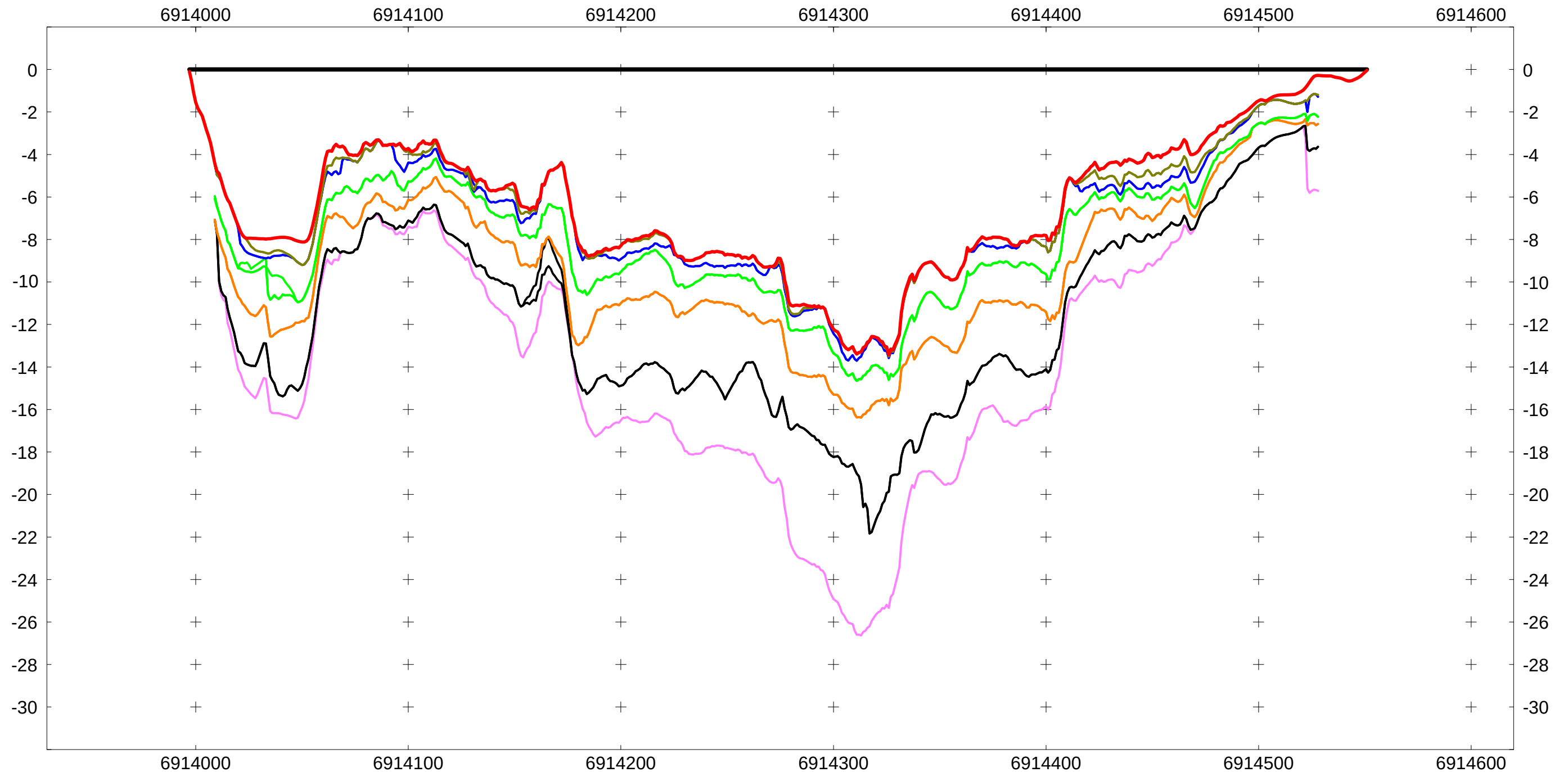
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580250**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

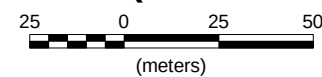
**AURORA GEOSCIENCES LTD.**



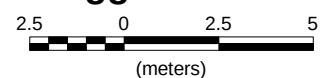
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

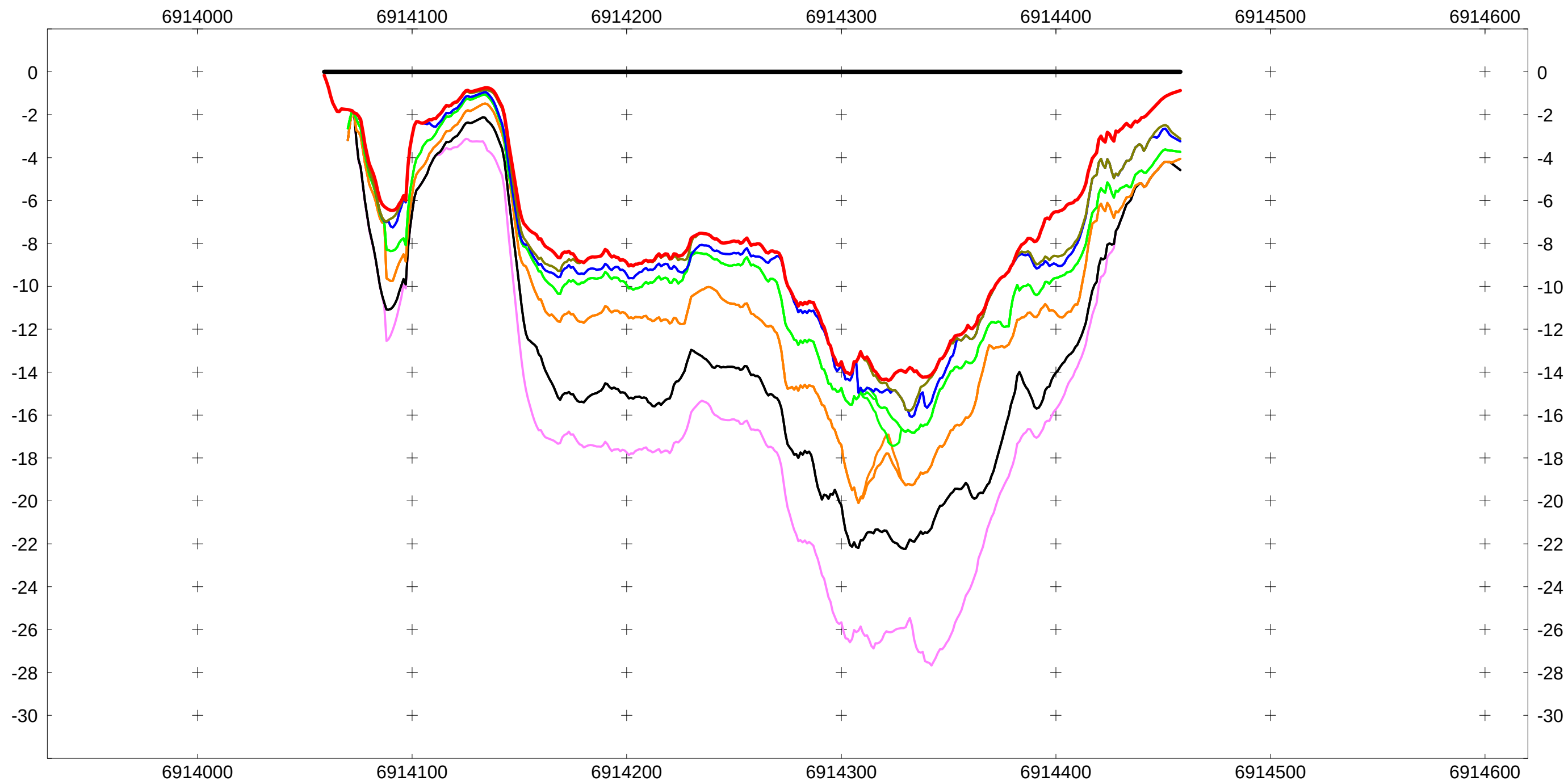
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580300**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

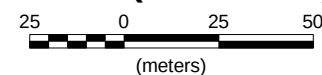
**AURORA GEOSCIENCES LTD.**



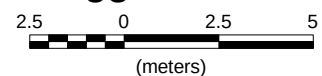
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

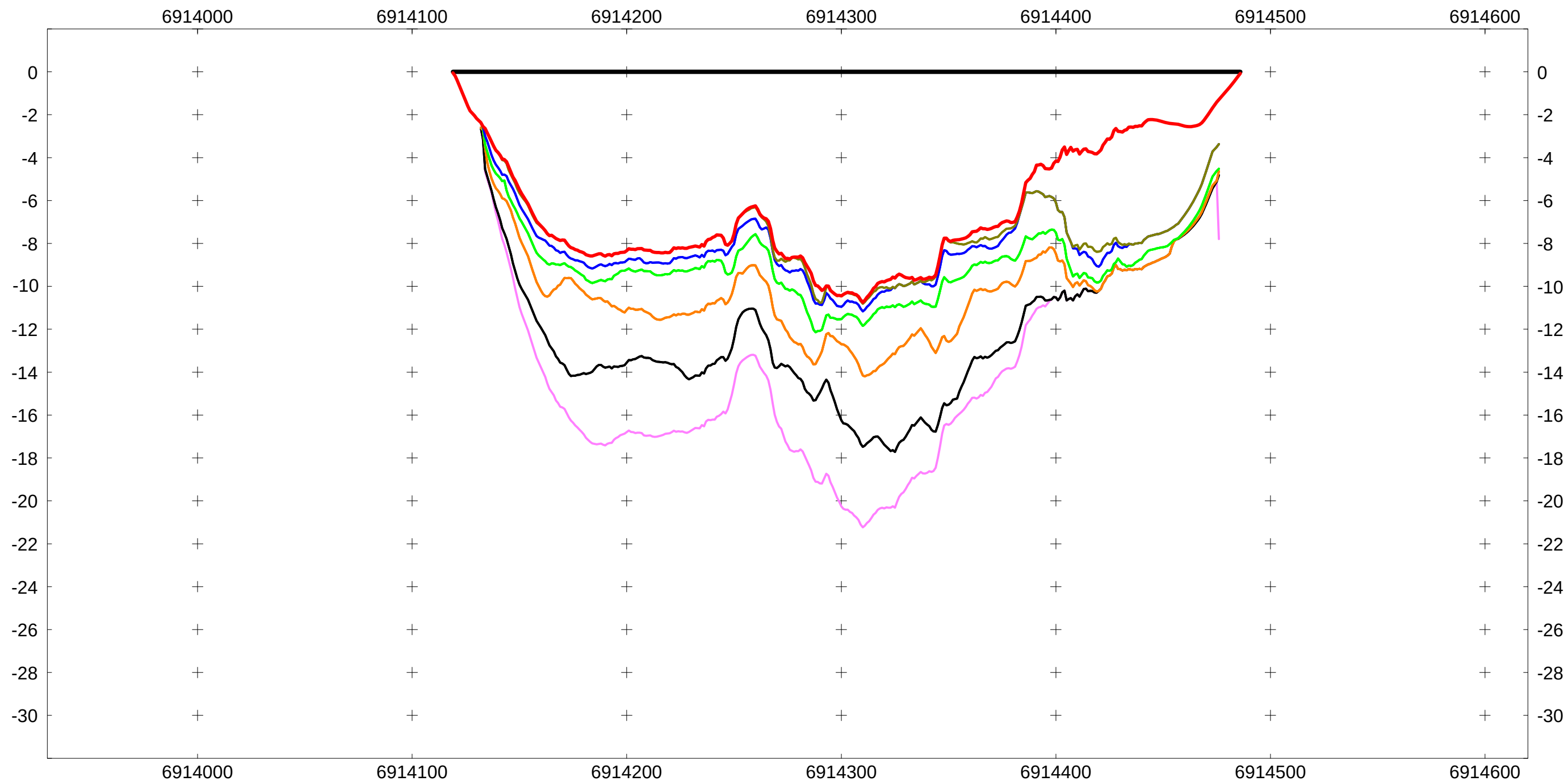
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580350**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

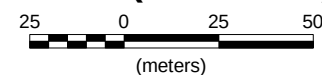
**AURORA GEOSCIENCES LTD.**



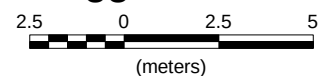
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

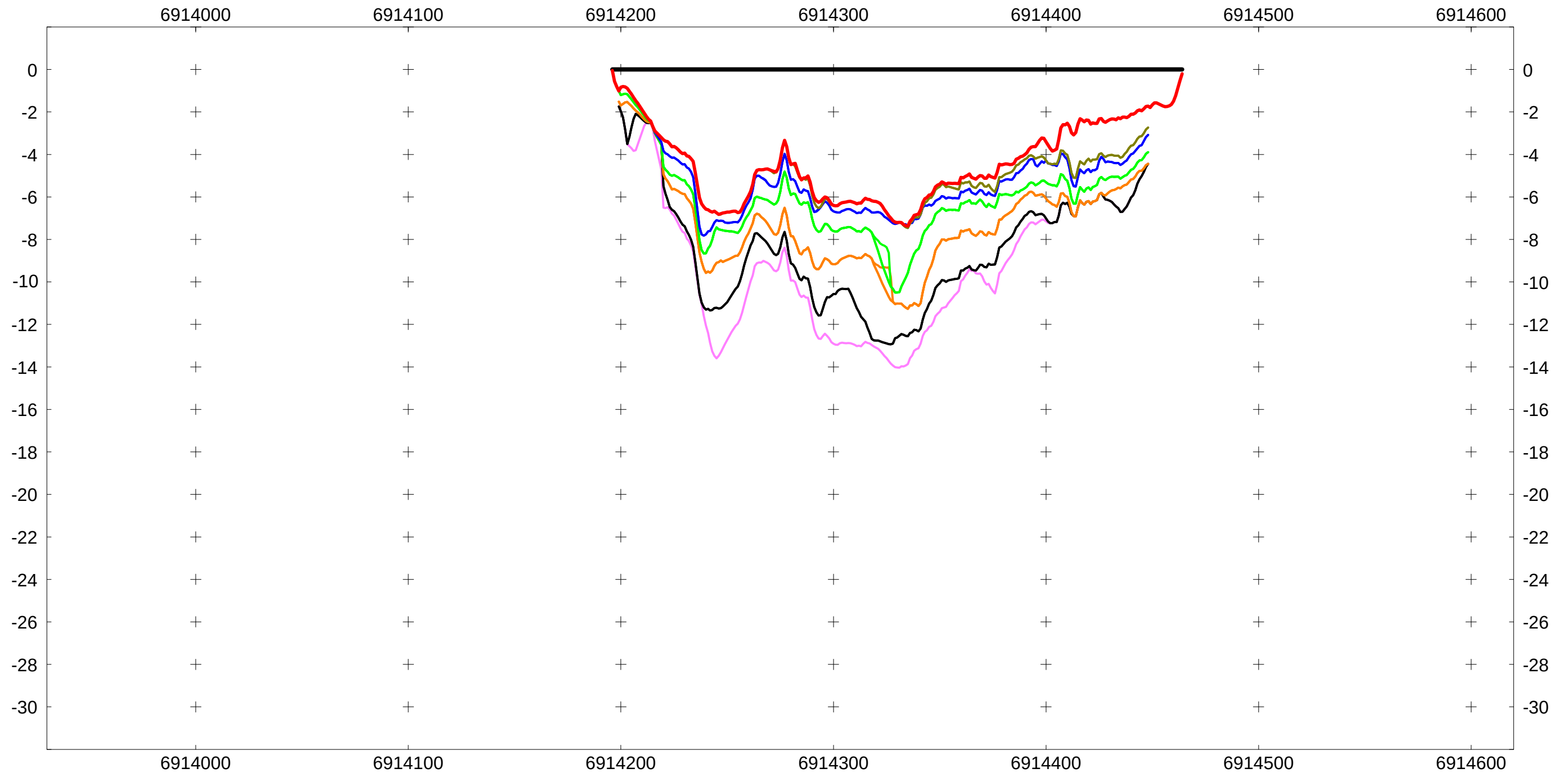
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580400**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

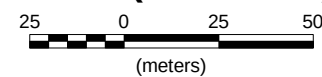
**AURORA GEOSCIENCES LTD.**



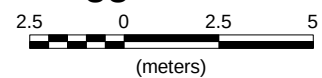
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

Scale (horizontal)



Scale (vertical)  
exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

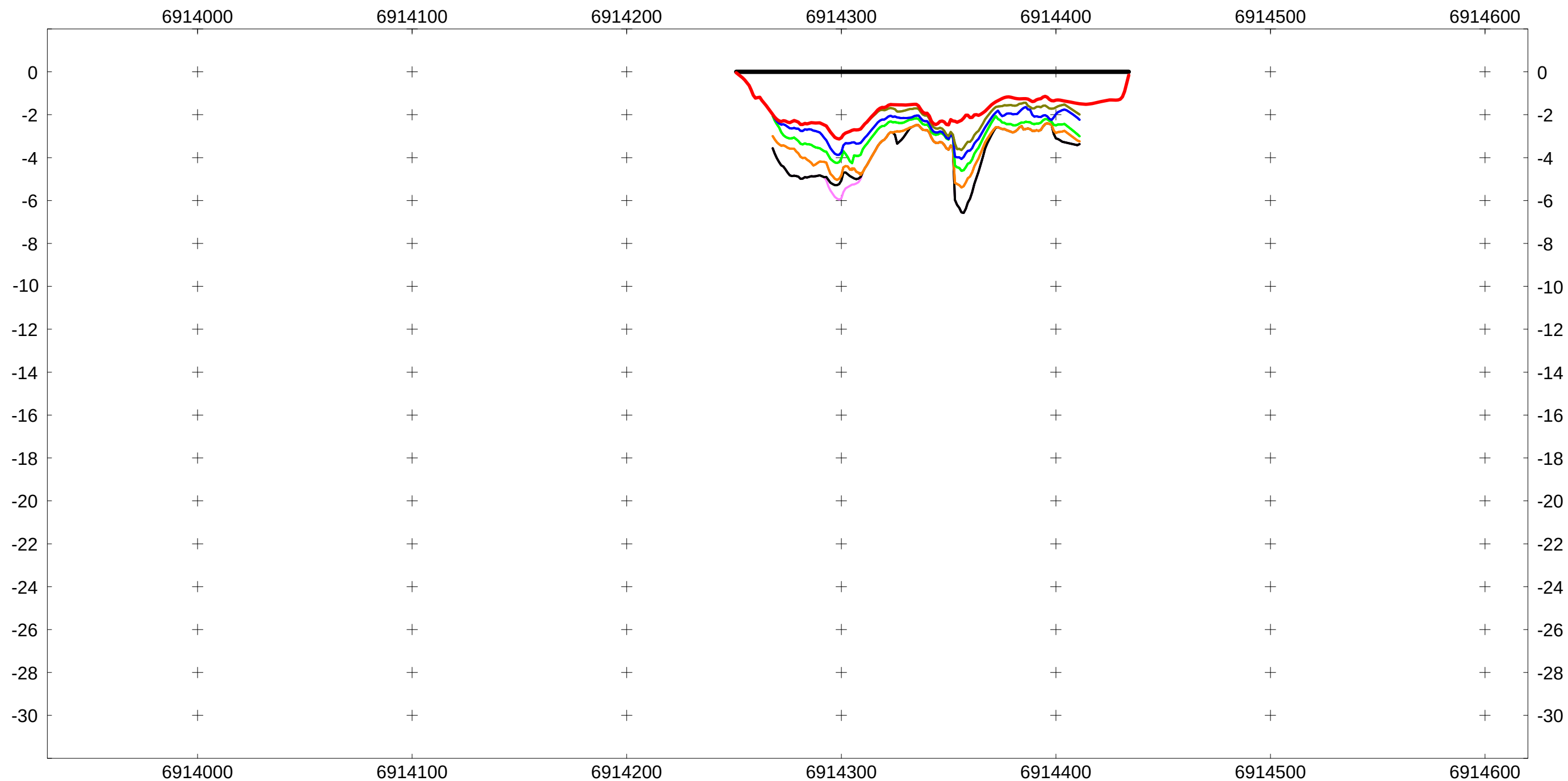
**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580450**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

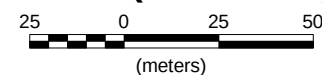
**AURORA GEOSCIENCES LTD.**



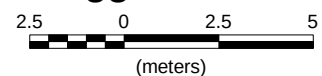
## LEGEND

Water :   
Bottom :   
Feature B :   
Feature C :   
Feature D :   
Feature E :   
Feature F :   
Feature G : 

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Depth relative  
to Water Surface

**CH2M HILL LTD.**

**CROSS VALLEY DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580500**

Surveyed Oct 20-26, 2015  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS & DE  
Map drawn: Dec 10, 2015  
NAD83 UTM Zone 8N

**AURORA GEOSCIENCES LTD.**

## Appendix III

EdgeTech jsf format

---

# ***EDGETECH SONAR DATA FILE FORMAT***

## **DESCRIPTION OF THE EDGETECH (.jsf) FILE FORMAT**

**Document No. 990-0000048-1000**

***Revision: 1.8 / October 2009***



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## TABLE OF CONTENTS

|                                                                |    |
|----------------------------------------------------------------|----|
| INTRODUCTION .....                                             | 3  |
| C/C++ Code Example for Reading a JSF File .....                | 4  |
| 16-Byte Message Header .....                                   | 4  |
| Message Type 80: Sonar Data Message (segydefs.h) .....         | 6  |
| Navigation data .....                                          | 8  |
| Pulse Information.....                                         | 9  |
| CPU Time .....                                                 | 9  |
| Weighting Factor .....                                         | 10 |
| Orientation Sensor Data.....                                   | 10 |
| User defined area from 180-239 .....                           | 11 |
| NMEA Navigation Data .....                                     | 11 |
| Other User Defined Data .....                                  | 11 |
| Sonar Trace Data .....                                         | 12 |
| Message Type 82: Side Scan Data Message (sidescandefs.h) ..... | 13 |
| Computer date / time data acquired .....                       | 14 |
| Auxiliary sensor information .....                             | 14 |
| Sonar Trace Data .....                                         | 14 |
| Message Type 2020: Pitch Roll Data.....                        | 15 |
| Message Type 2002: NMEA String.....                            | 16 |
| Message Type 2060: Pressure Sensor Reading.....                | 16 |
| Message Type 2080: Doppler Velocity Log Data (DVL).....        | 16 |
| Message Type 2090: Situation Message .....                     | 17 |
| Message Type 182: System Information Message.....              | 19 |

## **INTRODUCTION**

EdgeTech topsides by default record in JSF file format, which consists of a set of messages. Each message begins with a 16-byte header which indicates the type of data to follow and its size. Different types of data will have different message numbers (Message Type field). Sonar data is recorded on a per-channel basis. Therefore, for a single frequency side-scan system there will be two messages per ping – one for port (channel 0) and one for starboard (channel 1). Other types of sensors (such as pitch roll) will have their own message numbers as well, and will similarly have a single message per reading set. A typical file might have the following:

- Header1:    Sonar Data for Subsystem SSL and channel 0 (Port Side)
  - Sonar Data Header for Message 1 (Ping number 1, Port, Time Stamp)
  - Sonar Data for Message 1 (16-bit integers – one per sample)
- Header2:    Sonar Data for Subsystem SSL and channel 1 (Starboard Side)
  - Sonar Data Header for Message 2 (Ping number 1, Starboard, Time Stamp)
  - Sonar Data for Message 2 (16-bit integers – one per sample)
- Header3:    Pitch Roll reading
  - Serial Device Standard Header (Time Stamp)
  - Pitch Roll Data Structure
- Header4:    Sonar Data for Subsystem SB
  - Sonar Data Header for Message 4 (Ping number 1, Time Stamp)
  - Sonar Data for Message 4 (16-bit integer pairs – one pair per sample)

Since data is stored in a binary format, the byte ordering of 16-bit and 32-bit values is important. JSF uses little endian (Intel) format for binary data where the least significant bytes are stored first. This is the native format for Intel x86 computers such as the IBM PC and compatibles. If data is read on a big endian machine (such as most Sun Workstations), you will need to byte reverse the data so that the 2 bytes of a 16-bit value are flipped, and the 4 bytes of a 32-bit value are flipped (Bytes 0, 1, 2, 3 become Bytes 3, 2, 1, 0).

EdgeTech topsides often have an option to limit the size of created files, and will generate a sequence of files for a long data run. In this case, the concatenation of these files will yield a valid JSF file for a longer run time if desired.

This document describes the messages of common interest to those processing JSF files. It is not intended to be a complete description of all valid messages.

## C/C++ Code Example for Reading a JSF File

Here is a C code example for reading an entire JSF file.

```
void readFile(char *fileName)
{
    FILE *fid;
    int i;
    SonarMessageHeaderType hdr; /* Basic 16-byte message header */

    fid = fopen(fileName, "rb");
    if (fid == NULL) return;

    while(!feof(fid))
    {
        if (fread(&hdr, sizeof(hdr), 1, fid) != 1)
            break;
        if (hdr.startOfMessage != SONAR_MESSAGE_HEADER_START)
        {
            printf("Invalid file format\n");
            break;
        }
        for(i = 0; i < hdr.byteCount; i++)
        {
            if (getc(fid) == EOF)
            {
                printf("Invalid file format\n");
                break;
            }
        }
        printf("Message Type %d\n", hdr.sonarMessage);
    }
    fclose(fid);
}
```

Details of data structure of the types of messages in a JSF file are described below.

### **16-Byte Message Header**

A JSF file is a collection of messages, and every message in a JSF file begins with a sixteen byte long header. It identifies the type and size of the message, as well as the originating subsystem and channel.

| Byte Offsets | Description                                                                                                            | Size   |
|--------------|------------------------------------------------------------------------------------------------------------------------|--------|
| 0 – 1        | Marker for the Start of Header (always 0x1601)                                                                         | UINT16 |
| 2            | Version number of protocol used (e.g.10)                                                                               | UINT8  |
| 3            | Session Identifier                                                                                                     | UINT8  |
| 4 – 5        | Message Type (e.g. 80 = Sonar Trace Data)                                                                              | UINT16 |
| 6            | Command Type<br>2 = Normal data source                                                                                 | UINT8  |
| 7            | Subsystem Number<br>0 = Sub-bottom<br>20 = Single or Lower Frequency Side Scan<br>21 = Higher Frequency Side Scan      | UINT8  |
| 8            | Channel for a Multi-Channel Subsystem<br>For Side Scan Subsystems, 0 = Port, 1 = Starboard<br>For Serial Ports: Port # | UINT8  |
| 9            | Sequence Number                                                                                                        | UINT8  |
| 10 – 11      | Reserved                                                                                                               | UINT16 |
| 12 – 15      | Size of following Message in Bytes                                                                                     | UINT32 |

Every message header begins (bytes 0 - 1) with a 0x1601 start of a message header marker. This serves as a sanity check during file processing.

The Protocol level (byte 2) indicates which revision of this specification was used to write that message. Messages of differing protocol levels may be interspersed in the same file. Maintaining backward compatibility in the public interface is a priority. Protocol level changes involve additional messages or changes to the non-public portion of the interface.

The session identifier (byte 3) is used for internal routing and can be ignored.

The Message Type field (bytes 4 - 5) defines the type of data to follow. Some data formats of interest are detailed in the following sections. If the Message Type field contains an unwanted or unknown (i.e. not defined below) type, use the Size of the message (bytes 12 – 15) to skip over the data to the next Message Header.

The message protocol is used for command and control as well as data. The command type field (byte 6) while of interest during real time operation can normally be ignored when reading JSF files.

The subsystem number (byte 7) is used to determine the source of the data. Common subsystem assignments are as follows:

- Sub-bottom data - 0
- Single frequency sidescan data - 20

---

|                                                    |       |
|----------------------------------------------------|-------|
| Lower frequency data of a dual frequency sidescan  | - 20  |
| Higher frequency data of a dual frequency sidescan | - 21  |
| Raw serial data                                    | - 100 |
| Parsed serial data                                 | - 101 |

The channel (byte 8) is zero for single channel (most sub-bottom) systems. For most sidescan systems, it is zero for port and one for starboard. For serial port data the channel number is the logical port number, which often differs from the physical COM port in use. The sequence number (byte 9) and reserved fields (bytes 10 - 11) can normally be ignored when reading JSF files.

The byte count (bytes 12 – 15) is the number of bytes until the next start of message header. This is the amount of additional data to read if processing the current message, or the amount of data to skip over if the current message is not of interest.

### **Message Type 80: Sonar Data Message (jsfdefs.h)**

The Sonar Data Message consists of a single ping (receiver sounding period) of data for a single channel (such as Port Side Low Frequency Side-Scan). Standard sidescan sub-systems have two channels of data, port and starboard. Standard sub-bottom sub-systems have a single channel of data. Data files with higher channel counts exist. Which fields have data present depends on the system used and data acquisition procedures. This message may contain data from multiple non-acoustic sensors. Non-acoustic data contained in this message will often not be time interpolated. EdgeTech strongly recommends that if high positional or situational accuracy is required that the individual sensor messages be processed. Otherwise, this may be the only message that will need to be interpreted in a JSF file. Validity flags indicate which auxiliary fields are populated. By convention, if a value is not present the field is set to 0.

A Sonar Data Message consists of a 240-byte header, which is very similar to a traditional SEG Y header, and the actual acoustic sample data follows the header. This 240-byte header described below:

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                             | Size      |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Ping Time in seconds [since the start of time based on time() function] (1/1/1970) (added in protocol version 8) <sup>1</sup>                                                                                                                                                                                                                                           | INT32     |
| 4 – 7        | Starting Depth (window offset) in samples<br>- usually zero                                                                                                                                                                                                                                                                                                             | UINT32    |
| 8 – 11       | Ping Number (increments with each ping)                                                                                                                                                                                                                                                                                                                                 | UINT32    |
| 12 – 15      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 2 |
| 16 – 17      | MSBs – Most Significant Bits – High order bits to extend 16 bit unsigned short values to 20 bits. The 4 MSB bits become the most significant portion of the new 20 bit value.<br>Bits 0 - 3 – start frequency<br>Bits 4 - 7 – end frequency<br>Bits 8 – 11 – samples in this packet<br>Bits 12 – 15 – reserved<br>(added in protocol version 10)(see description below) | UINT16    |
| 18 – 27      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 5 |
| 28 – 29      | ID Code (always 1)<br>1 = Seismic Data                                                                                                                                                                                                                                                                                                                                  | INT16     |
| 30 – 31      | Validity Flag (See mapping below)                                                                                                                                                                                                                                                                                                                                       | UINT16    |
| 32 – 33      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | UINT16    |
| 34 – 35      | Data Format<br>0 = 1 short per sample - Envelope Data<br>1 = 2 shorts per sample - Analytic Signal Data, (Real, Imaginary)                                                                                                                                                                                                                                              | INT16     |
| 36 – 37      | Distance from Antenna to Tow point in Centimeters, Aft +<br>(Fish Aft = +)                                                                                                                                                                                                                                                                                              | INT16     |
| 38 – 39      | Distance from Antenna to Tow Point in Centimeters, Starboard<br>+ (Fish to Starboard = +)                                                                                                                                                                                                                                                                               | INT16     |
| 40 – 43      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 2 |

The Most Significant Bits fields are used to extend sixteen bit integers to twenty bits.

These are added as needed when the range of possible values exceeds what can be stored in a sixteen bit integer. The simplest way to use these additional bits is to treat the value as a 32 bit integer, the existing value becomes the least significant 16 bits, the MSB field becomes the next most significant 4 bits with the most significant 12 bits set to zeros.

<sup>1</sup> NOTE: For protocol revisions 7 and before this field was always zero.

## Validity flags bitmap:

- Bit 0: Lat Lon or XY valid
- Bit 1: Course valid
- Bit 2: Speed valid
- Bit 3: Heading valid
- Bit 4: Pressure valid
- Bit 5: Pitch roll valid
- Bit 6: Altitude valid
- Bit 7: Reserved
- Bit 8: Water temperature valid
- Bit 9: Depth valid
- Bit 10: Annotation valid
- Bit 11: Cable counter valid
- Bit 12: KP valid
- Bit 13: Position interpolated

**Navigation Data**

This is most often the position at the last navigation fix. See the time NMEA Navigation Data fields for the time of the fix. On most systems, position is not time interpolated and should not be used for mosaicing or other processing requiring high accuracy positioning. Validity flags indicate whether these fields are valid and interpolated. The representation of the navigation data depends on the coordinate-units field. For Latitude / Longitude representations, a positive value designates east of the Greenwich Meridian or north of the equator.

| Byte Offsets | Description                                                                                                                        | Size       |
|--------------|------------------------------------------------------------------------------------------------------------------------------------|------------|
| 44 – 47      | Kilometer of pipe (see bytes 30-31)                                                                                                | FLOAT32    |
| 48 – 79      | Reserved – <b>Do not use</b>                                                                                                       | INT16 x 16 |
| 80 – 83      | X in millimeters or decimeters or<br>Longitude in Minutes of Arc / 10000<br>(see bytes 30-31 and 88-89)                            | INT32      |
| 84 – 87      | Y in millimeters or decimeters or<br>Latitude in 0.0001 Minutes of Arc<br>(see bytes 30-31 and 88-89)                              | INT32      |
| 88 – 89      | Coordinate Units<br>1 = X, Y in millimeters<br>2 = Longitude, Latitude in minutes of arc times $10^{-4}$<br>3 = X, Y in decimeters | INT16      |

## Pulse Information

This data describes the transmitted pulse characteristics, as well as sampling parameters.

| Byte Offsets | Description                                                                                                                               | Size       |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 90 – 113     | Annotation String (ASCII Data)                                                                                                            | UINT8 x 24 |
| 114 – 115    | Number of data samples in this packet<br>See bytes 16 – 17 for MSB information<br>Note: Very large sample sizes require multiple packets. | UINT16     |
| 116 – 119    | Sampling Interval in Nanoseconds                                                                                                          | UINT32     |
| 120 – 121    | Gain Factor of ADC                                                                                                                        | UINT16     |
| 122 – 123    | User Transmit Level Setting (0 – 100) percent                                                                                             | INT16      |
| 124 – 125    | Reserved – <b>Do not use</b>                                                                                                              | INT16      |
| 126 – 127    | Transmit pulse starting frequency in decahertz (daHz)<br>(units of 10Hz)<br>See bytes 17 – 18 for MSB information                         | UINT16     |
| 128 – 129    | Transmit pulse ending frequency in decahertz<br>(daHz)(units of 10Hz)<br>See bytes 16 – 17 for MSB information                            | UINT16     |
| 130 – 131    | Sweep Length in milliseconds                                                                                                              | UINT16     |
| 132 – 135    | Pressure in milliPSI (1 unit = 1/1000 PSI)<br>(see bytes 30-31)                                                                           | INT32      |
| 136 - 139    | Depth in millimeters (if not = 0) (see bytes 30-31)                                                                                       | INT32      |
| 140 – 141    | Sample Freq of the data in hertz, modulo 65536 NOTE *                                                                                     | UINT16     |
| 142 – 143    | Outgoing pulse identifier                                                                                                                 | UINT16     |
| 144 – 147    | Altitude in millimeters (If bottom tracking valid)<br>0 implies not filled (see bytes 30-31)                                              | INT32      |
| 148 - 155    | Reserved – <b>Do not use</b>                                                                                                              | INT32 x 2  |

NOTE\* : For all data types EXCEPT RAW (Data Format = 2) this is the Sampling Frequency of the data. For RAW data, this is one-half the Sample Frequency of the data ( $F_s/2$ ). All values are modulo 65536. Use this in conjunction with the Sample interval (Bytes 114-115) to calculate correct sample rate.

## CPU Time

The time that the Acoustic data was recorded. The time of the start of the ping of data represented by the following trace data is the Ping Time.

The Ping Time in seconds since 1/1/1970, (in the same time base as the device messages that follow), is contained in bytes 0-3. The millisecondsToday field (bytes 200-203), MODULO 1000, will yield the milliseconds in current second, compatible with the time stamp of the device messages. This time stamp is only valid for data recorded in Protocol Revision 8 and above.

The Ping Time can also be determined from the Year, Day, Hour, Minute and Seconds as per bytes 156 to 165. Thus provides 1 second level accuracy and resolution. For higher resolution (milliseconds) use the Year, and Day values of bytes 156 to 159, and then use the milliSecondsToday value of bytes 200-203 to complete the timestamp. System time is set to UTC, regardless of time zone. This time format is backwards compatible with all older Protocol Revisions.

These 2 time stamps are equivalent and identical.

| Byte Offsets | Description                                           | Size  |
|--------------|-------------------------------------------------------|-------|
| 156 – 157    | Year (e.g. 2009) (see Bytes 0-3) (Should not be used) | INT16 |
| 158 – 159    | Day (1 – 366) (Should not be used)                    | INT16 |
| 160 – 161    | Hour (see Bytes 200-203) (Should not be used)         | INT16 |
| 162 – 163    | Minute (Should not be used)                           | INT16 |
| 164 – 165    | Second (should not be used)                           | INT16 |
| 166 – 167    | Time Basis (always 3)                                 | INT16 |

## **Weighting Factor**

The trace data is transmitted as sixteen bit integers in block floating point format per message. This saves bandwidth and storage space while preserving dynamic range. The weighting factor MUST BE applied to each of the sixteen bit integer values to restore the original floating point value.

| Byte Offsets | Description                                               | Size  |
|--------------|-----------------------------------------------------------|-------|
| 168 – 169    | Weighting Factor N (Signed Value!)<br>Defined as $2^{-N}$ | INT16 |
| 170 – 171    | Number of pulses in the water                             | INT16 |

## **Orientation Sensor Data**

These fields contain useful information about the attitude of the sonar sensor. The Compass heading will be magnetic heading of the towfish. If a Gyro sensor is properly interfaced to the Discover Topside acquisition unit, with a valid NMEA HDT message, this field will contain the Gyro heading, relative to true north

| Byte Offsets | Description                                                              | Size   |
|--------------|--------------------------------------------------------------------------|--------|
| 172 – 173    | Compass Heading (0 to 360 ) in units of 1/100 degree (see bytes 30-31)   | UINT16 |
| 174 – 175    | Pitch: Scale by 180 / 32768 to get degrees, + = bow up (see bytes 30-31) | INT16  |
| 176 – 177    | Roll: Scale by 180 / 32768 to get degrees, + = port up (see bytes 30-31) | INT16  |
| 178 – 179    | Tow fish electronics Temperature, in unit of 1/10 <sup>th</sup> degree C | INT16  |

## **Miscellaneous Data**

| Byte Offsets | Description                                                   | Size   |
|--------------|---------------------------------------------------------------|--------|
| 180 – 181    | Reserved – <b>Do not use</b>                                  | INT16  |
| 182 – 183    | Trigger Source<br>0 = Internal<br>1 = External<br>2 = Coupled | INT16  |
| 184 – 185    | Mark Number<br>0 = No Mark                                    | UINT16 |

## **NMEA Navigation Data**

These fields contain the time of the last position fix. If the position data is interpolated this will be the same as the CPU and ping time.

| Byte Offsets | Description      | Size  |
|--------------|------------------|-------|
| 186 – 187    | Hour (0 – 23)    | INT16 |
| 188 – 189    | Minutes (0 – 59) | INT16 |
| 190 – 191    | Seconds (0 – 59) | INT16 |
| 192 – 193    | Course           | INT16 |
| 194 – 195    | Speed            | INT16 |
| 196 – 197    | Day (1 – 366)    | INT16 |
| 198 – 199    | Year             | INT16 |

## **Other Miscellaneous Data**

| Byte Offsets | Description                                                                                                                                        | Size     |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 200 – 203    | Milliseconds today (since midnight) (use in conjunction with Year / Day to get time of Ping)                                                       | UINT32   |
| 204 – 205    | Maximum Absolute Value of ADC samples in this packet                                                                                               | UINT16   |
| 206 – 207    | Reserved – Do not use                                                                                                                              | INT16    |
| 208 – 209    | Reserved – Do not use                                                                                                                              | INT16    |
| 210 – 215    | Sonar Software Version Number - ASCII                                                                                                              | INT8 x 6 |
| 216 – 219    | Initial Spherical Correction Factor<br>(Useful for multi-ping / deep application) * 100                                                            | INT32    |
| 220 – 221    | Packet Number<br>Each ping starts with packet 1                                                                                                    | UINT16   |
| 222 – 223    | 100 times the A/D Decimation Factor. Data is normally sampled at a high Rate. Digital filters are applied to precisely limit the signal bandwidth. | INT16    |
| 224 – 225    | Decimation Factor after the FFT                                                                                                                    | INT16    |
| 226 – 227    | Water Temperature in units of 1/10 degree C<br>(see bytes 30-31)                                                                                   | INT16    |
| 228 – 231    | Layback in meters                                                                                                                                  | FLOAT32  |
| 232 – 235    | Reserved – Do not use                                                                                                                              | INT32    |
| 236 – 237    | Cable Out in decimeters (see bytes 30-31)                                                                                                          | UINT16   |
| 238 – 239    | Reserved – Do not use                                                                                                                              | UINT16   |

## Sonar Trace Data

Sonar trace data follows the 240-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 114-115) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding Message Header byte count, (bytes 12 –15) less the header size of 240.

Each of the data sample values then needs to be scaled by the weighting factor thus:

ScaledDatasample = datasample \*  $2^{(-N)}$ . (NOTE Sign !)

Future expansions of this data format will use floating point values to represent samples, and will result in other valid values for Data Format (bytes 34-35). Data readers will be more robust if this data section is skipped over if the Data Type does not match the 4 values presented here.

## **Message Type 82: Side Scan Data Message (sidescandefs.h)**

Side-Scan Data Messages are no longer used and only described here for historical reasons. While configuring a sonar to generate these messages is still possible, new systems are not configured in that manner. If your sonar is storing Side-Scan Data Messages the configuration should be changed to store Sonar Data Messages instead. Side-Scan Data Messages are never stored by Discover, and are only encountered in data stored by sonar. This data is almost always compressed rendering it unusable without further processing. A Side-Scan Data Message is similar to a Sonar Data Message. It contains the exactly the same acoustic data. While the Side Scan Data Message was intended for Side Scan data, it can also be used for Sub-bottom data. The system configuration determines which type of data is actually stored. Each Side Scan Data Message has an 80 byte header, the content of which is defined below. As with Sonar Data Messages, unused fields should be set to 0.

| Byte Offsets | Description                                                                                                                                                                                                                          | Size   |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| 0 – 1        | Subsystem (0 .. n)                                                                                                                                                                                                                   | UINT16 |
| 2 – 3        | Channel Number (0 .. n)                                                                                                                                                                                                              | UINT16 |
| 4 – 7        | Ping number (increments with each ping period)                                                                                                                                                                                       | UINT32 |
| 8 – 9        | Packet number (1..n) Each ping starts with packet 1                                                                                                                                                                                  | UINT16 |
| 10 – 11      | TriggerSource (0 = internal, 1 = external)                                                                                                                                                                                           | UINT16 |
| 12 – 15      | Samples in this packet                                                                                                                                                                                                               | UINT32 |
| 16 – 19      | Sample interval in ns of stored data                                                                                                                                                                                                 | UINT32 |
| 20 – 23      | Starting Depth (window offset) in samples                                                                                                                                                                                            | UINT32 |
| 24 – 25      | Weighting Factor : Defined as $2^{-N}$ volts                                                                                                                                                                                         | INT16  |
| 26 – 27      | Gain factor of ADC                                                                                                                                                                                                                   | UINT16 |
| 28 – 29      | Maximum absolute value for ADC samples for this packet                                                                                                                                                                               | UINT16 |
| 30 – 31      | Range Setting (in decameters) (meters times 10)                                                                                                                                                                                      | UINT16 |
| 32 – 33      | Unique pulse identifier                                                                                                                                                                                                              | UINT16 |
| 34 – 35      | Mark Number (0 = no mark)                                                                                                                                                                                                            | UINT16 |
| 36 – 37      | Data format<br>0 = 1 short per sample - envelope data the total number of bytes of data to follow is 2 * samples<br>1 = 2 shorts per sample - stored as real(1), imag(1), the total number of bytes of data to follow is 4 * samples | UINT16 |
| 38           | Number of simultaneous pulses in the water                                                                                                                                                                                           | UINT8  |
| 39           | Reserved – <b>Do not use</b>                                                                                                                                                                                                         | UINT8  |

## Computer date / time data acquired

| Byte Offsets | Description           | Size   |
|--------------|-----------------------|--------|
| 40 – 43      | Milliseconds today    | UINT32 |
| 44 – 45      | Year                  | INT16  |
| 46 – 47      | Day of year (1 – 366) | UINT16 |
| 48 – 49      | Hour of day (0 – 23)  | UINT16 |
| 50 – 51      | Minute (0 – 59)       | UINT16 |
| 52 – 53      | Second (0 – 59)       | UINT16 |

## Auxiliary sensor information

| Byte Offsets | Description                                            | Size      |
|--------------|--------------------------------------------------------|-----------|
| 54 – 55      | Compass heading in minutes (0 – 360) x 60              | UINT16    |
| 56 – 57      | Pitch Scale by 180 / 32768 to get degrees, + = bow up  | INT16     |
| 58 – 59      | Roll Scale by 180 / 32768 to get degrees, + = port up  | INT16     |
| 60 – 61      | Heave (centimeters)                                    | INT16     |
| 62 – 63      | Yaw (minutes)                                          | INT16     |
| 64 – 67      | Pressure in units of 1/1000 PSI                        | UINT32    |
| 68 – 69      | Temperature in units of 1/10 of a degree Celsius       | INT16     |
| 70 – 71      | Water Temperature in units of 1/10 of a degree Celsius | INT16     |
| 72 – 75      | Altitude in millimeters (or -1 if no valid reading)    | INT32     |
| 76 – 79      | Reserved – <b>Do not use</b>                           | UINT8 x 4 |

## Sonar Trace Data

Sonar trace data follows the 80-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 12-15) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding 16 byte Message Header byte count, (bytes 12 –15) less the header size of 80. Each of the data sample values then needs to be scaled by the weighting factor thus:

$\text{ScaledDataSample} = \text{datasample} * 2^{-(N)}$

## **Message Type 2020: Pitch Roll Data**

A pitch roll message consists of a single reading from a pitch roll sensor such as a Seatex MRU, TSS or Octans device. Not all devices provide all data for the defined structure. Use the validity flags to determine which fields are populated.

| Byte Offsets | Description                                                                                                                                                                                               | Size      |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Time in seconds (since the start of time based on time() function) (1/1/1970)                                                                                                                             | INT32     |
| 4 – 7        | Milliseconds in the current second                                                                                                                                                                        | INT32     |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                                                                                                              | UINT8 x 4 |
| 12 – 13      | Acceleration in x: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 14 – 15      | Acceleration in y: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 16 – 17      | Acceleration in z: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 18 – 19      | Rate Gyro in x: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 20 – 21      | Rate Gyro in y: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 22 – 23      | Rate Gyro in y: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 24 – 25      | Pitch Multiply by $(180.0 / 32768.0)$ to get Degrees<br>Bow up is positive                                                                                                                                | INT16     |
| 26 – 27      | Roll: Multiply by $(180.0 / 32768.0)$ to get Degrees<br>Port up is positive                                                                                                                               | INT16     |
| 28 – 29      | Temperature in units of 1/10 of a degree Celsius                                                                                                                                                          | INT16     |
| 30 – 31      | Device specific info. This is device specific info provided for Diagnostic purposes                                                                                                                       | UINT16    |
| 32 – 33      | Estimated Heave in millimeters                                                                                                                                                                            | INT16     |
| 34 – 35      | Heading in units of 0.01 Degrees (0...360)                                                                                                                                                                | UINT16    |
| 36 – 39      | Data valid flags<br>Bit 0: ax<br>Bit 1: ay<br>Bit 2: az<br>Bit 3: rx<br>Bit 4: ry<br>Bit 5: rz<br>Bit 6: pitch<br>Bit 7: roll<br>Bit 8: heave<br>Bit 9: heading<br>Bit 10: temperature<br>Bit 11: devInfo | INT32     |
| 40 – 43      | Reserved – <b>Do not use</b>                                                                                                                                                                              | INT32     |

## **Message Type 2002: NMEA String**

A NMEA String consists of a time stamp followed by a NMEA string as read from a GPS, Gyro or other device. Each message is a single NMEA string excluding the <CR>/<LF>.

| Byte Offsets           | Description                               | Size                    |
|------------------------|-------------------------------------------|-------------------------|
| 0 – 3                  | Time in seconds since 1970                | INT32                   |
| 4 – 7                  | Milliseconds in the current second        | INT32                   |
| 8                      | Source, 1 = Sonar, 2 = Discover, 3 = ETSI | INT8                    |
| 9 – 11                 | Reserved – <b>Do not use</b>              | UINT8 x 3               |
| 12 – To Message Length | NMEA string data                          | INT8 x remaining length |

## **Message Type 2060: Pressure Sensor Reading**

If a pressure sensor is present in the system these messages will be in the data stream.

A single pressure sensor reading is provided, along with a time-stamp. While pressure sensors can be configured in different units, the default is PSI absolute.

| Byte Offsets | Description                                                                                                            | Size        |
|--------------|------------------------------------------------------------------------------------------------------------------------|-------------|
| 0 – 3        | Time in seconds (since the start of time based on time() function).                                                    | INT32       |
| 4 – 7        | Milliseconds in the current second.                                                                                    | INT32       |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                           | UNIT8 x 4   |
| 12 – 15      | Pressure in units of 1/1000th of a PSI                                                                                 | INT32       |
| 16 – 19      | Temperature in units of 1/1000th of degree Celsius.                                                                    | INT32       |
| 20 – 23      | Salinity in Parts Per Million                                                                                          | INT32       |
| 24 – 27      | Data valid flags:<br>Bit 0: pressure<br>Bit 1: temp<br>Bit 2: salt PPM<br>Bit 3: conductivity<br>Bit 4: sound velocity | INT32       |
| 28 – 31      | Conductivity in micro-Siemens per cm                                                                                   | INT32       |
| 32 – 35      | Velocity of Sound in mm per second                                                                                     | INT32       |
| 36 – 75      | Reserved – <b>Do not use</b>                                                                                           | INT 32 x 10 |

## **Message Type 2080: Doppler Velocity Log Data (DVL)**

This is data from a DVL (if fitted) and often includes velocity and altitude readings.

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Size      |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Time in seconds (since the start of time based on time() function).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT32     |
| 4 – 7        | Milliseconds in the current second.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT32     |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | UINT8 x 4 |
| 12 – 15      | Flags. Indicates which values are present.<br>Bit 0: X, Y Velocity present<br>Bit 1: 1 => Velocity in ship coordinates<br>0 => Earth coordinates<br>Bit 2: Z (Vertical Velocity) present<br>Bit 3: X, Y Water Velocity present<br>Bit 4: Z (Vertical Water Velocity) present<br>Bit 5: Distance to bottom present<br>Bit 6: Heading present<br>Bit 7: Pitch present<br>Bit 8: Roll present<br>Bit 9: Temperature present<br>Bit 10: Depth present<br>Bit 11: Salinity present<br>Bit 12: Sound velocity present<br>-----<br>Bit 31: Error detected | UINT32    |
| 16 – 31      | 4 Integers: Distance to bottom in cm for up to 4 beams.<br>A 0 value indicates an invalid or non-existing reading.                                                                                                                                                                                                                                                                                                                                                                                                                                 | INT32 x 4 |
| 32 – 33      | X Velocity with respect to the bottom in mm / second<br>Positive => Starboard or East.<br>-32768 indicates an invalid reading.                                                                                                                                                                                                                                                                                                                                                                                                                     | INT16     |
| 34 – 35      | Y Velocity: Positive => Forward or North (mm/second)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | INT16     |
| 36 – 37      | Z Vertical Velocity: Positive => Upward (mm/second)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT16     |
| 38 – 39      | X Velocity with respect to a water layer in mm / second<br>Positive => Starboard or East                                                                                                                                                                                                                                                                                                                                                                                                                                                           | INT16 x 3 |
| 40 - 41      | Y Velocity: Positive => Forward or North                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |           |
| 42 - 43      | Z Vertical Velocity: Positive => Upward                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
| 44 - 45      | Depth from depth sensor in decimeters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | UINT16    |
| 46 - 47      | Pitch -180 to +180 degree (units = 0.01 of a degree) + Bow up                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | INT16     |
| 48 - 49      | Roll -180 to +180 degrees (units = 0.01 of a degree) + Port up                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | INT16     |
| 50 - 51      | Heading: 0 to 360 degrees (in units of 0.01 of a degree)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | UINT16    |
| 52 - 53      | Salinity in 1 part per thousand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | UINT16    |
| 54 - 55      | Temperature in units of 1/100 of a degree Celsius                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | INT16     |
| 56 - 57      | Sound velocity in meters per second                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT16     |
| 58 - 71      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | INT16 x 7 |

## **Message Type 2090: Situation Message**

A situation message is a composite of several motion / position sensors. This message is not commonly used. The detailed data structure is shown below:

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Size     |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 0 - 3        | Time in seconds (since the start of time based on time() function).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | INT32    |
| 4 - 7        | Milliseconds in the current second.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | INT32    |
| 8 - 11       | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | INT8 x 4 |
| 12 - 15      | <p>Validity Flags<br/>Validity Flags indicate which of the following fields are valid. If the corresponding bit is set the field is valid.</p> <p>Bit 0 : microsecondTimestamp<br/>           Bit 1 : latitude<br/>           Bit 2 : longitude<br/>           Bit 3 : depth<br/>           Bit 4 : heading<br/>           Bit 5 : pitch<br/>           Bit 6 : roll<br/>           Bit 7 : XRelativePosition<br/>           Bit 8 : YRelativePosition<br/>           Bit 9 : ZRelativePosition<br/>           Bit 10 : XVelocity<br/>           Bit 11 : YVelocity<br/>           Bit 12 : ZVelocity<br/>           Bit 13 : NorthVelocity<br/>           Bit 14 : EastVelocity<br/>           Bit 15 : downVelocity<br/>           Bit 16 : XAngularRate<br/>           Bit 17 : YAngularRate<br/>           Bit 18 : ZAngularRate<br/>           Bit 19 : XAcceleration<br/>           Bit 20 : YAcceleration<br/>           Bit 21 : ZAcceleration<br/>           Bit 22 : latitudeStandardDeviation<br/>           Bit 23 : longitudeStandardDeviation<br/>           Bit 24 : depthStandardDeviation<br/>           Bit 25 : headingStandardDeviation<br/>           Bit 26 : pitchStandardDeviation<br/>           Bit 27 : rollStandardDeviation</p> | UINT32   |
| 16 - 19      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | UINT x 4 |
| 20 - 27      | Microsecond timestamp, us since 12:00:00 am GMT, January 1, 1970                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | UINT64   |
| 28 - 35      | Double float: Latitude in degrees, north is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | FLOAT64  |
| 36 - 43      | Double float: Longitude in degrees, east is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | FLOAT64  |
| 44 - 51      | Double float: Depth in meters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | FLOAT64  |
| 52 - 59      | Double float: Heading in degrees                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | FLOAT64  |
| 60 - 67      | Double float: Pitch in degrees, bow up is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | FLOAT64  |
| 68 - 75      | Double float: Roll in degrees, port up is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | FLOAT64  |
| 76 - 83      | Double float: X, forward, relative position in meters, surge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | FLOAT64  |
| 84 - 91      | Double float: Y, starboard, relative position in meters, sway                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | FLOAT64  |

|           |                                                                           |             |
|-----------|---------------------------------------------------------------------------|-------------|
| 92 - 99   | Double float: Z, downward, relative position in meters, heave             | FLOAT64     |
| 100 - 107 | Double float: X, forward, velocity in meters per second                   | FLOAT64     |
| 108 - 115 | Double float: Y, starboard, velocity in meters per second                 | FLOAT64     |
| 116 - 123 | Double float: Z, downward, velocity in meters per second                  | FLOAT64     |
| 124 - 131 | Double float: North velocity in meters per second                         | FLOAT64     |
| 132 - 139 | Double float: East velocity in meters per second                          | FLOAT64     |
| 140 - 147 | Double float: Down velocity in meters per second                          | FLOAT64     |
| 148 - 155 | Double float: X angular rate in degrees per second, port up is positive   | FLOAT64     |
| 156 - 163 | Double float: Y angular rate in degrees per second, bow up is positive    | FLOAT64     |
| 164 - 171 | Double float: Z angular rate in degrees per second, starboard is positive | FLOAT64     |
| 172 - 179 | Double float: X, forward, acceleration in meters per second per second    | FLOAT64     |
| 180 - 187 | Double float: Y, starboard, acceleration in meters per second per second  | FLOAT64     |
| 188 - 195 | Double float: Z, downward, acceleration in meters per second per second   | FLOAT64     |
| 196 - 203 | Double float: Latitude standard deviation in meters                       | FLOAT64     |
| 204 - 211 | Double float: Longitude standard deviation in meters                      | FLOAT64     |
| 212 - 219 | Double float: Depth standard deviation in meters                          | FLOAT64     |
| 220 - 227 | Double float: Heading standard deviation in degrees                       | FLOAT64     |
| 228 - 235 | Double float: Pitch standard deviation in degrees                         | FLOAT64     |
| 236 - 243 | Double float: Roll standard deviation in degrees                          | FLOAT64     |
| 244 - 275 | Reserved – Do not use                                                     | UINT16 x 16 |

## **Message Type 182: System Information Message**

The system information message contains details of the system used to acquire data. This message is normally present at the beginning of a JSF file, and may be repeated if configuration parameters change.

| Byte Offsets | Description                                            | Size  |
|--------------|--------------------------------------------------------|-------|
| 0 - 3        | System Type                                            | INT32 |
| 4 - 7        | Reserved – Do not use                                  |       |
| 8 - 11       | Version Number of Sonar Software used to generate data | INT32 |
| 12 - 19      | Reserved – Do not use                                  |       |
| 20 - 23      | Serial Number of Tow Vehicle used to collect data      | INT32 |
| 24 - End     | Reserved – Do not use                                  |       |

The size of the System Information Message is subject to change as more detailed information is may be added in future versions of the software. The byte count in the

message header should be used to determine the total size of the structure and get to the next message in the file.

The System Type is the major type of system used to collect data. To date, the following system types are defined:

| System Type Number | Description                                                        |
|--------------------|--------------------------------------------------------------------|
| 1                  | 2xxx Series, Combined Sub-Bottom / Side Scan with SIB Electronics  |
| 2                  | 2xxx Series, Combined Sub-Bottom / Side Scan with FSIC Electronics |
| 4                  | 4300-MPX (Multi-Ping)                                              |
| 5                  | 3200-XS, Sub-Bottom Profiler with AIC Electronics                  |
| 6                  | 4400-SAS, 12-Channel Side Scan                                     |
| 7                  | 3200-XS, Sub Bottom Profiler with SIB Electronics                  |
| 11                 | 4200 Limited Multipulse Dual Frequency Side Scan                   |
| 14                 | 3100-P, Sub Bottom Profiler                                        |
| 16                 | 2xxx Series, Dual Side Scan with SIB Electronics                   |
| 17                 | 4200 Multipulse Dual Frequency Side Scan                           |
| 18                 | 4700 Dynamic Focus                                                 |
| 19                 | 4200 Dual Frequency Side Scan                                      |
| 20                 | 4200 Dual Frequency non Simultaneous Side Scan                     |
| 21                 | 2200-MP Combined Sub-Bottom / Dual Frequency Multipulse Side Scan  |
| 23                 | 4600 Bathymetric System                                            |
| 128                | 4100, 272 /560A Side Scan                                          |

Attachment 2  
Aurora Geosciences ID Pond  
Bathymetry and Sub-bottom  
Profile Report

---

**Hydrographic and Sub-Bottom Profiling Survey – Intermediate Dam Pond**

NTS: 105K/06,      Faro Mining Complex, Yukon Territory, Canada

WORK PERFORMED:  
June 10-18, 2016

Prepared for:



Prepared by:



**TECHNICAL REPORT**  
**Hydrographic and Sub-Bottom Profiling Survey – Intermediate Dam Pond**

Effective Date: August 12, 2016

Prepared for:  
**CH2M Hill Canada Limited**  
**Whitehorse, YT Y1A 4N2**

Prepared by:  
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## TABLE OF CONTENTS

|          |                                                          |           |
|----------|----------------------------------------------------------|-----------|
| <b>1</b> | <b>INTRODUCTION .....</b>                                | <b>1</b>  |
| <b>2</b> | <b>LOCATION &amp; ACCESS .....</b>                       | <b>1</b>  |
| <b>3</b> | <b>WORK PROGRAM .....</b>                                | <b>2</b>  |
| 3.1      | BATHYMETRIC SURVEY .....                                 | 4         |
| 3.1.1    | <i>Equipment.....</i>                                    | 4         |
| 3.1.2    | <i>Survey Specifications &amp; Field Procedures.....</i> | 5         |
| 3.1.3    | <i>Data Processing .....</i>                             | 8         |
| 3.1.4    | <i>Bathymetry Products .....</i>                         | 12        |
| 3.2      | SUB-BOTTOM SURVEY .....                                  | 14        |
| 3.2.1    | <i>Equipment.....</i>                                    | 14        |
| 3.2.2    | <i>Survey Specifications &amp; Field Procedures.....</i> | 15        |
| 3.2.3    | <i>Data Processing .....</i>                             | 16        |
| 3.2.4    | <i>Sub-bottom Products .....</i>                         | 20        |
| 3.3      | QUALITY CONTROL CHECKS.....                              | 21        |
| 3.3.1    | <i>Common Transects .....</i>                            | 21        |
| 3.3.2    | <i>Daily check-ins .....</i>                             | 27        |
| <b>4</b> | <b>DISCUSSION AND INTERPRETATION .....</b>               | <b>31</b> |
| 4.1      | BATHYMETRY .....                                         | 31        |
| 4.2      | SUB-BOTTOM .....                                         | 32        |
| 4.2.1    | <i>Alignment with Cone Penetration Soundings .....</i>   | 34        |

## LIST OF FIGURES

|                                                                                                                                                                   |    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| FIGURE 1: LOCATION MAP OF THE INTERMEDIATE DAM POND WITHIN THE FARO MINE AREA. ....                                                                               | 2  |
| FIGURE 2: SURVEYS ON INTERMEDIATE POND. ....                                                                                                                      | 3  |
| FIGURE 3: UNIVERSAL MOUNTING POLE WITH THREE GPS ANTENNAE AND SUBSEA MOTION SENSOR VISIBLE. ....                                                                  | 6  |
| FIGURE 4: POSITION QUALITY OF GPS SOLUTIONS DURING MULTI-BEAM BATHYMETRY ACQUISITION. ....                                                                        | 9  |
| FIGURE 5: POSITION QUALITY OF GPS SOLUTIONS DURING SINGLE-BEAM BATHYMETRY ACQUISITION. ....                                                                       | 9  |
| FIGURE 6: HEIGHT QUALITY OF GPS SOLUTIONS DURING MULTI-BEAM BATHYMETRY ACQUISITION. ....                                                                          | 10 |
| FIGURE 7: HEIGHT QUALITY OF GPS SOLUTIONS DURING SINGLE-BEAM BATHYMETRY ACQUISITION. ....                                                                         | 10 |
| FIGURE 8: AVERAGE ACOUSTIC WATER VELOCITY PROFILE. ....                                                                                                           | 12 |
| FIGURE 9: POSITION QUALITY OF GPS SOLUTIONS DURING SUB-BOTTOM PROFILING ACQUISITION. ....                                                                         | 16 |
| FIGURE 10: HEIGHT QUALITY OF GPS SOLUTIONS DURING SUB-BOTTOM PROFILING ACQUISITION. ....                                                                          | 17 |
| FIGURE 11: SONARGRAM SHOWING HOMOGENOUS FEATURE (FEATURE 2), UNDER CLEARLY LAYERED SEDIMENT (FEATURE 1) AND ABOVE A<br>DEFINED BOTTOM FEATURE (FEATURE 5).. ....  | 19 |
| FIGURE 12: HISTOGRAM OF DIFFERENCE BETWEEN SINGLE-BEAM AND MULTI-BEAM READINGS.....                                                                               | 21 |
| FIGURE 13: COMMON SINGLE-BEAM AND MULTI-BEAM TRANSECTS, SHOWING POND BOTTOM ELEVATION (TOP PANEL) AND SINGLE-BEAM<br>/ MULTI-BEAM DIFFERENCE (BOTTOM PANEL). .... | 23 |
| FIGURE 14: HISTOGRAM OF DIFFERENCE BETWEEN LEAD-LINE MEASUREMENTS AND MULTI-BEAM READINGS. ....                                                                   | 24 |

|                                                                                                                                                                                             |    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| FIGURE 15: HISTOGRAM OF DIFFERENCE BETWEEN LEAD-LINE MEASUREMENTS AND SINGLE-BEAM READINGS.....                                                                                             | 25 |
| FIGURE 16: COMMON LEAD-LINE MEASUREMENTS ALONG SINGLE-BEAM TRANSECTS AND COMPARISONS WITH MULTI-BEAM DATA,<br>SHOWING POND BOTTOM ELEVATION (TOP PANEL) AND DIFFERENCES (BOTTOM PANEL)..... | 26 |
| FIGURE 17: SHORELINE ELEVATION. ....                                                                                                                                                        | 29 |
| FIGURE 18: HISTOGRAMS OF THE DIFFERENCED GRIDS FROM MULTI-BEAM DAILY CHECK-INS AS DESCRIBED IN SECTION 3.1.2.2.....                                                                         | 30 |
| FIGURE 19: SONARGRAMS OF FROM THE SUB-BOTTOM CONTROL PASSES. ....                                                                                                                           | 31 |
| FIGURE 20: INTERMEDIATE DAM POND ELEVATION OF POND BOTTOM.....                                                                                                                              | 32 |
| FIGURE 21: THICKNESS OF INTERPRETED FEATURE 1.....                                                                                                                                          | 33 |
| FIGURE 22: THICKNESS OF INTERPRETED FEATURE 2.....                                                                                                                                          | 34 |
| FIGURE 23: SOUNDING LOG CH-16-201-CP16 TO THE NEAREST POINT ON A 2-D AXIS SONOGRAM .....                                                                                                    | 35 |
| FIGURE 24: SOUNDING LOGS FROM CP19 AND CP15 SHOW REFUSAL ABOVE INTERPRETED BEDROCK SURFACE. ....                                                                                            | 36 |

## LIST OF TABLES

|                                                                       |    |
|-----------------------------------------------------------------------|----|
| TABLE 1: RTK GPS DATA FROM CHECK-IN CONTROL ADJACENT TO ID POND. .... | 27 |
| TABLE 2: RTK GPS WATER ELEVATION DATA OF THE ID POND.....             | 28 |

## LIST OF APPENDICES

|                   |                          |
|-------------------|--------------------------|
| APPENDIX I.....   | PROJECT LOGS             |
| APPENDIX II.....  | EW AND NS CROSS-SECTIONS |
| APPENDIX III..... | EDGETEC JSF FILE FORMAT  |

## 1 INTRODUCTION

Aurora Geosciences Ltd. was retained by CH2M Hill Canada Limited to conduct bathymetric and sub-bottom profiling of the Cross Valley Dam Pond and the Intermediate Dam Pond at the Faro Mine, Faro, Yukon Territory. Primary surveys of the Cross Valley Dam Pond were completed in October 2015 when the onset of cold weather rendered further boat work on the ponds impossible. The focus of this report is the bathymetric and sub-bottom surveying completed on the Intermediate Dam Pond in June, 2016.

Complete coverage of the Intermediate Dam Pond bathymetry was obtained through a multi-beam sonar investigation, coupled with a supplemental single-beam sonar survey in shallow areas, and a RTK-GPS survey to define the shoreline. The survey revealed greater depths toward the southwestern side of the pond, producing a maximum depth of 7.32 metres.

Acoustic sub-bottom profiling was also completed on the pond with a nominal line spacing of 5m.

All geographic locations in this report are relative to North American Datum 1983 (CSRS) and all elevations are orthometric heights relative to the HT2 geoid. Non-geodetic coordinates are expressed in Universal Transverse Mercator Zone 8N metric coordinates. All measurements are expressed in the metric SI system.

## 2 LOCATION & ACCESS

The crew was based in the town of Faro, YT for the duration of the project and accessed the Intermediate Dam Pond daily by truck and then by 16-foot aluminum boat. The pond is approximately 15 kilometers north-northwest of the town of Faro; Figure 1 is a map of the Intermediate Dam Pond within the Faro Mine area.



**Figure 1: Location map of the Intermediate Dam Pond within the Faro Mine area. Map is from the CH2M Hill Agreement 10201-7-100723. The distance from the Town of Faro to the Intermediate Dam Pond is approximately 15 km.**

### 3 WORK PROGRAM

This section describes the June 2016 work program conducted at the Intermediate Dam Pond. A bathymetric survey was completed comprising of multi-beam sonar, selected areas of single-beam sonar, selected lines of lead-line measurements and RTK-GPS survey both for shoreline definition and for single-beam line extensions to allow comparison to existing topographic data; this is described in Section 0. A sub-bottom survey was completed using a 4-24 kHz chirped acoustic signal; this is described in Section 3.2. Figure 2 shows the line-path of the multi-beam bathymetry (yellow), single-beam bathymetry (black), sub-bottom profiling (red) and RTK shoreline survey points (blue crosses). A complete project log detailing the work performed by the Aurora Geosciences field crew is in Appendix I.

QA/QC of the surveys is examined in Section 3.3.

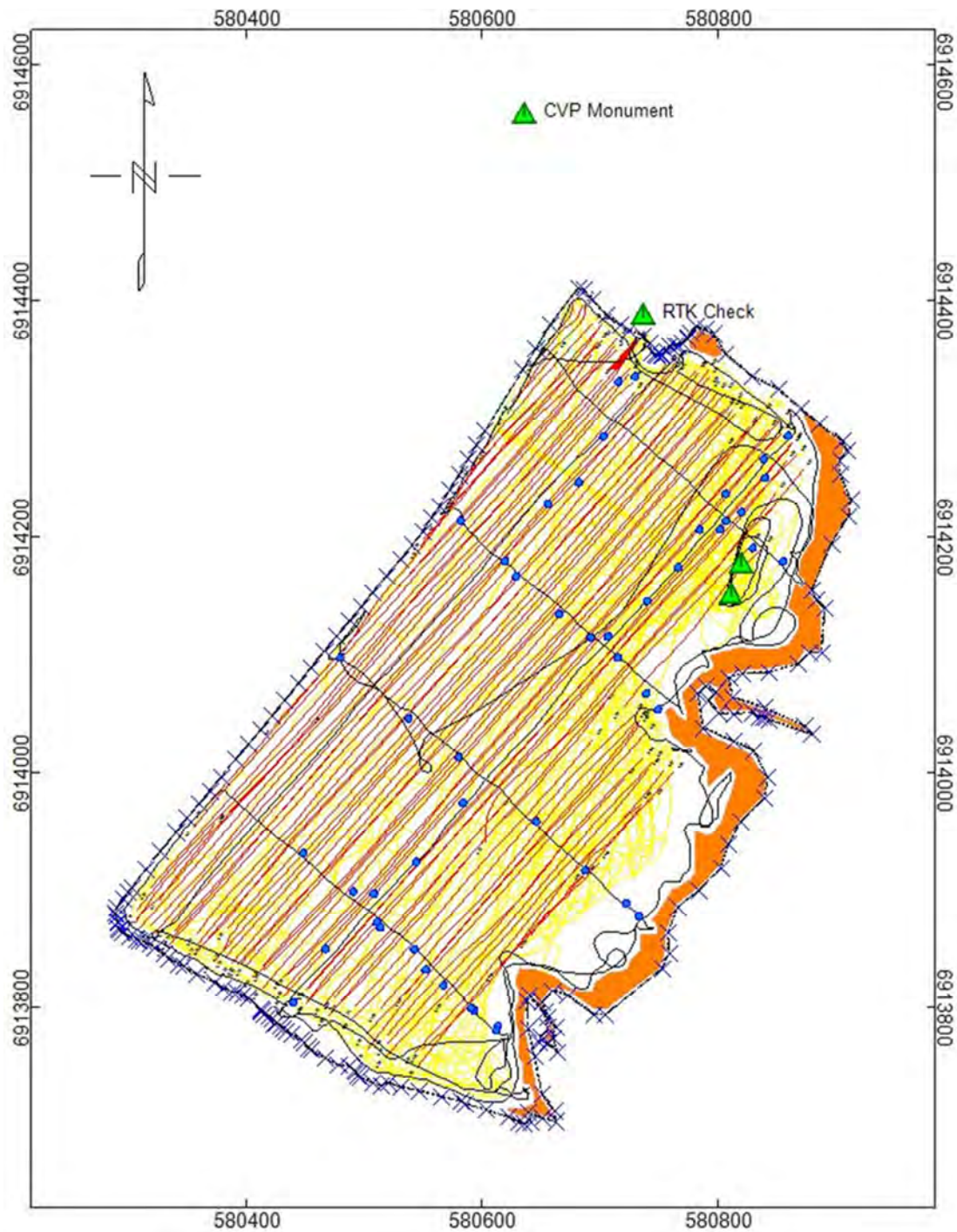


**Figure 2: Surveys on the Intermediate Dam Pond.** Yellow shows the path of the multi-beam bathymetry, red of the sub-bottom profiling, black of the single-beam bathymetry, blue circles are the lead-line measurements and the blue x-symbols are the shore GPS measurements. The location of the CVP monument used for a GPS base is shown in the northwest corner. Areas shown in orange are shallow water where no data were collected. Daily multi-beam and sub-bottom check-in locations at 580819E, 6914176N & 580810E, 6914150N (NAD83 UTM Zone 8N) as described in Section 3.1.2.2 are shown by the green triangles. An RTK daily check-in point at 580736E, 6914386N (NAD83 UTM Zone 8N) as described in Section 3.1.2.1 is also shown by a green triangle.

### 3.1 Bathymetric Survey

The multi-beam bathymetric survey provides an extremely high resolution depth database of the Intermediate Dam Pond, with a data density of approximately 3.6 cm. Positional data were determined through an RTK GPS streaming data to the multi-beam system, with the GPS base station set up at the nearby CVP control point. The shoreline was also surveyed using RTK GPS, to define the areal limit of the pond. Water elevation was measured twice daily with RTK GPS. A single-beam sonar survey supplemented the multi-beam survey in shallow water, though with a much lower data density. There are small areas on the southeastern side of the pond that were not surveyed using either method due to the very shallow water. In addition, six traverses of the pond were done using the single-beam survey, to compare with the multi-beam dataset.

#### 3.1.1 Equipment

The crew was equipped with the following instruments and equipment:

|                     |     |                                                          |
|---------------------|-----|----------------------------------------------------------|
| Equipment:          | 2   | ANTCOM G3ANT GPS Antennas s/n: 346853,346854             |
|                     | 1   | Minos X velocity sensor s/n: 30337                       |
|                     | 1   | MB1 multi-beam sonar head s/n: 206                       |
|                     | 1   | RTAI real time appliance s/n: 220083                     |
|                     | 1   | Digibar V water velocity sensor (sonar head) s/n: 5683   |
|                     | 1   | Coda F-175 motion sensor s/n: F70012                     |
|                     |     | Miscellaneous multi-beam cables, brackets and equipment  |
|                     | 1   | Trimble GeoExplorer XT2008                               |
|                     | 1   | Garmin GPSmap 527                                        |
|                     | 1   | Airmar SS510 smart transducer                            |
|                     |     | Miscellaneous single-beam cables, brackets and equipment |
|                     | 1   | Leica GS15 sensor rover s/n 1502720                      |
|                     | 1   | Leica GS14 sensor base s/n 2802696                       |
|                     | 1   | Leica CS15 controller s/n 2907005                        |
|                     | 1   | Pac Crest ADL Vantage Pro Radio s/n 13086191             |
|                     | 1   | Pac Crest Radio s/n 1301949                              |
|                     |     | Miscellaneous GPS cables, tripods and equipment          |
|                     | 1   | 50m lead-line and reel                                   |
| Communications:     | 4   | VHF handheld radios                                      |
|                     | 1   | SAT phone                                                |
| Vehicles & Vessels: | 1   | Flat deck truck                                          |
|                     | 1   | Truck Trailer                                            |
|                     | 1   | Arctic Cat ATV                                           |
|                     | 1   | 16ft aluminum boat                                       |
|                     | 1   | Inflatable Zodiac rescue boat                            |
|                     | 1   | 6 HP outboard motor                                      |
|                     | 1   | 20 HP outboard motor                                     |
| Safety:             | 4   | Government certified personal floatation devices (PFDs)  |
|                     | 2   | ATV helmets                                              |
|                     | 4   | Hard hats                                                |
|                     | 200 | Nitrile gloves                                           |
|                     | 12  | Tyvek suits                                              |

|                       |    |                                                    |
|-----------------------|----|----------------------------------------------------|
|                       | 8  | Safety glasses                                     |
|                       | 4  | High Visibility Vests                              |
|                       | 2  | Fire extinguisher                                  |
|                       | 2  | Level 2 First aid kit                              |
|                       | 4  | Spare paddles                                      |
|                       | 2  | 15m floating rope                                  |
|                       | 2  | Bailers                                            |
| Computers & Software: | 1  | Laptop with Edgetech Discover Sub-Bottom 4.0       |
|                       | 1  | Laptop with HyPack 2015, SonarWiz 6                |
|                       | 1  | Laptop with Image, SMC IMU Config, Digibar Pro 3.0 |
| Other                 | 20 | 6 mil plastic garbage bags                         |
|                       | 1  | Pressure washer                                    |
|                       | 1  | Water tank                                         |
|                       | 1  | Office box                                         |
|                       | 1  | Geophysical Toolbox                                |

### 3.1.2 Survey Specifications & Field Procedures

All manufacturer and model information for equipment referenced in this section can be found in Section **Error! Reference source not found.**.

#### 3.1.2.1 RTK GPS

A GPS base station was established daily with the Leica GS14 antenna over the permanent control marker 2010-P5 at CVD. The published position for 2010-P5 was inadvertently not programmed into the GPS base prior to starting work in the field and an arbitrary position was therefore used the first day. For consistency the arbitrary base position was used throughout the survey and all RTK data were corrected by a post-survey datum shift to align the base with the published position. The initial (arbitrary) reference point recorded by the base station was broadcast continuously via radio to the Leica GS15 rover so that a phase-corrected RTK solution was being transferred to the multi-beam bathymetric equipment via NMEA string at all times during data collection. The use of this initial reference point requires a datum shift be applied to all raw data.

An RTK check-in point was established on the northwest end of the ID pond at 580736E, 6914386N (NAD83 CSRS Epoch 2002 UTM Zone 8N) and measurements were taken there once or twice daily. The daily check-in values are provided in Section 3.3.2.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. The post-survey datum shift applied was to align the arbitrary base position to this accepted position.

Point RTK positions with the Leica GS15 antenna were taken along the shoreline to constrain the gridding of the water depths in the shallows and to provide a measure of the water-surface elevation. Where the shoreline is straight, station spacing is at minimum 50 m, with decreasing station spacing as

required to capture smaller scale shoreline features; these points are shown as blue crosses in Figure 2. Point RTK positions were also recorded as extensions of all single-beam check lines, extending roughly 15 m back from the shoreline.

RTK positions were taken during single-beam collection and matched to the single-beam data by time-stamp.

### **3.1.2.2 Multi-Beam Sonar**

An Odom Teledyne MB1 multi-beam echo-sounder was used for the collection of primary bathymetric data from all areas of the Intermediate Pond, in areas with water depths greater than approximately 1 m. The sonar head was equipped with a sensor that monitored changes in water velocity from fluctuations in water temperature and purity. A motion sensor was also used to monitor the heave, pitch and roll of the boat. The latter was calibrated each morning to account for slight variations in crew weight as well as position. An Antcom marine GPS unit with two widely spaced antennae, positioned perpendicular to the sonar head (parallel to the axis of the vessel), provided precision bearings at all times. The Leica GS15 rover with a radio link to a base antenna was attached 1.345 metres directly above the sonar head to provide high accuracy positional data. The part of the system above water is shown in Figure 3.



**Figure 3: Universal mounting pole with three GPS antennae and subsea motion sensor visible.**

Each day the MB1 sonar head, RTK sensor and all secondary control instruments were bolted to the same place on a universal mounting pole, ensuring constant registration relative to the boat across multiple days of surveying. Data from all instruments were fed to an Odom Real Time Appliance for time registration and for interfacing with laptop computers.

A pair of onboard computers was used to control and monitor the instruments, while simultaneously recording data. One laptop, equipped with Odom Image, monitored the sonar head and water velocity

sensor. The second laptop, equipped with Hypack 2015, recorded all data and plotted results allowing for real time feedback on quality and coverage.

The crew conducted a series of control tests at the beginning and end of each day. Control stations, shown by green triangles in Figure 2, were established at 580819E, 6914176N & 580810E, 6914150N (NAD83 UTM Zone 8N) by driving poles into the pond floor. GPS and multi-beam sonar data were recorded while traversing north to south, from pole to pole. The purpose was to collect data at the same physical location, guided by the poles, multiple times to establish the repeatability of the multi-beam data.

Patch test data were collected over flat areas and slopes to correct potential errors arising from mounting variations as well as pitch, roll and yaw motion. Water velocity data were collected by a second water velocity sensor independent of the sonar head that was lowered to the pond floor, producing a water velocity profile for the full depth of the pond with data points collection every 10 cm.

The MB1 sonar head operates at 170-220 kHz and is capable of recording a 120° swath which, over flat terrain, is approximately 4 x the water column depth. As a quality control measure to account for variations in the pond floor and potential noise near the edge of the swath, the crew aimed for an initial 33% overlap in data, with occasional insufficient overlap. Secondary passes were completed as necessary to fill in gaps caused by fluctuations in pond depth identified in preliminary processing and all were successfully in-filled aside from the shallow southeast edge of the pond resulting in an almost complete contiguous dataset. Data were collected across the full 120° swath with a total of 512 beams and preserved in the raw files. In practice, the useful data swath was approximately 80° and the pond was shallow enough to require many extra passes to ensure complete data coverage. As a further quality control measure, the Hypack software was configured so as to not log any data if a phase-corrected RTK signal was not present. Occasional drops in RTK signal quality therefore created data gaps requiring further passes for complete coverage.

Line spacing for the multi-beam survey was variable, although initial passes follow the same bearing (41°) as the intended sub-bottom lines. Target boat speed was approximately 3 knots, though care was taken in shallower areas to protect the sensitive equipment.

### **3.1.2.3 Single-Beam Sonar**

The single-beam bathymetry survey was conducted to fill in data voids in shallow water where use of the multi-beam transducer was not practical. Attempts to fill in shallow areas at the southeastern edge of the pond were met with limited success because of the extreme shallowness of the pond there.

Six reference lines were also surveyed to create a secondary control database against which to measure the multi-beam bathymetry data. Four of these lines spanned the width of the pond, at a bearing of approximately 131° and set 150 m apart. The two other lines spanned the length of the pond at a bearing of 41°, were spaced 175 m apart and coincided with two of the sub-bottom profiling lines.

Data were collected at a 1 second interval with data from the Airmar SS510 transducer. The transducer operates at a frequency of 200 kHz with a beam width of 9°. Target boat speed was 2 knots in open

water but speeds in potentially shallow areas were lower. Data from the Airmar transducer were streamed to the Trimble GeoXT controller for storage and were georeferenced using data from the RTK-GPS Leica GS15 rover. A 17 second offset was applied to the single-beam sonar data prior to time-stamp matching to account for the different time convention (GPS versus UTC time) used by each instrument. The vertical offset between the GPS antenna and the transducer was 1.44 m. There was no horizontal offset.

#### **3.1.2.4 Lead-Line Measurements**

Lead-line measurements were taken to create a tertiary database against which to measure the other bathymetric data. Forty nine points were measured around the ID pond with an effort to collect points along the single-beam traverses to create three coincident datasets.

A best effort was made to make the measurement when the lead-line was plumb but the survey vessel was not anchored during the measurements and there was significant drift from high winds at the time of the lead-line survey so some bias towards longer measurements because of the angled line is expected. Additionally, the operators often observed significant muck on the lead-line after retrieval so the weight may have been penetrating some centimeters beyond the mudline as measured by the sonar data.

### ***3.1.3 Data Processing***

#### **3.1.3.1 RTK-GPS**

The use of an arbitrary initial reference point required that a datum shift be applied to all raw data to reposition the base station to the published position of 2010-P5. All points were shifted -2.005 m N, 1.733 m E and elevation was shifted -6.501 m.

Data were logged to the Leica receiver and exported to csv files; the raw daily base and rover files, as well as the exported rover files are included with the data package of this report. The positional quality is shown in Figure 4 (multi-beam) & Figure 5 (single-beam) and the height quality in Figure 6 (multi-beam) & Figure 7 (single-beam) as reported by the Leica Geo Office software package from the raw rover files with no post-processing; all have a 95% confidence level well below 10 cm. The effective positional and height quality for the multi-beam collection is better than the histograms portray because, as indicated in Section 3.1.2.2, the multi-beam unit was configured so as to not log any data if a phase-corrected RTK signal from the base was not present. Some data with no RTK link remain in the database despite not being used by the multi-beam system. These are typically at the end of the file and likely represent recording while putting away equipment.

Baseline and DOP data were obtained by post-processing with Leica Geo Office. Although the base station was operating correctly and RTK corrections were being received on June 17, the file of the GPS readings did not record properly on the base. The consequence is that some meta-products for the GPS (baseline and DOP information) is not available for June 17.

Water level and data from RTK check-ins are discussed below in Section 3.3.2.

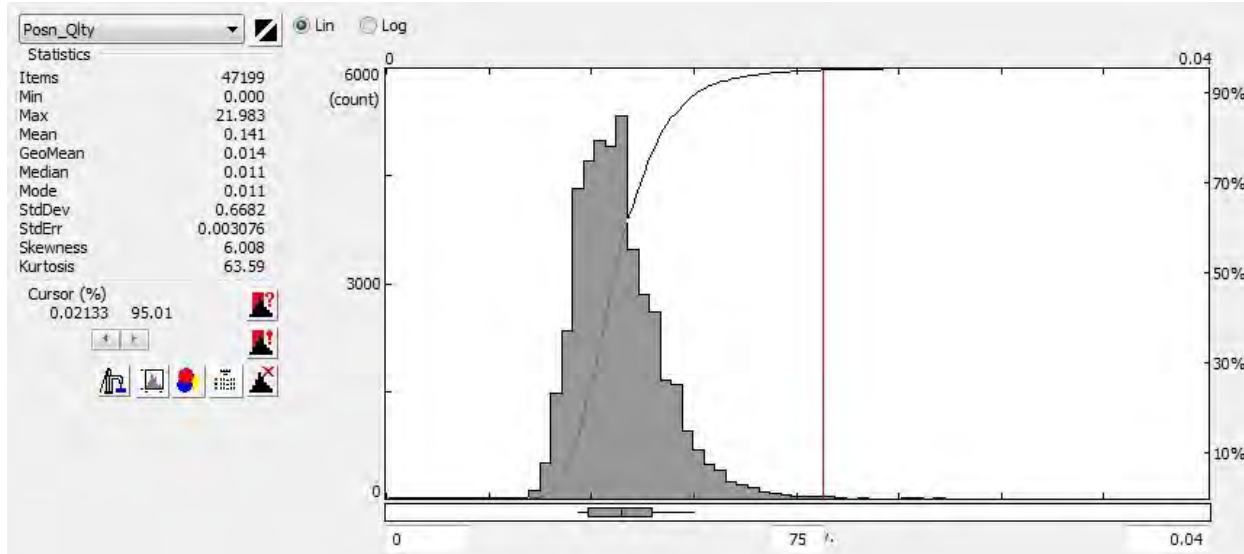


**Figure 4: Position quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the position quality is at 0.021 m.**

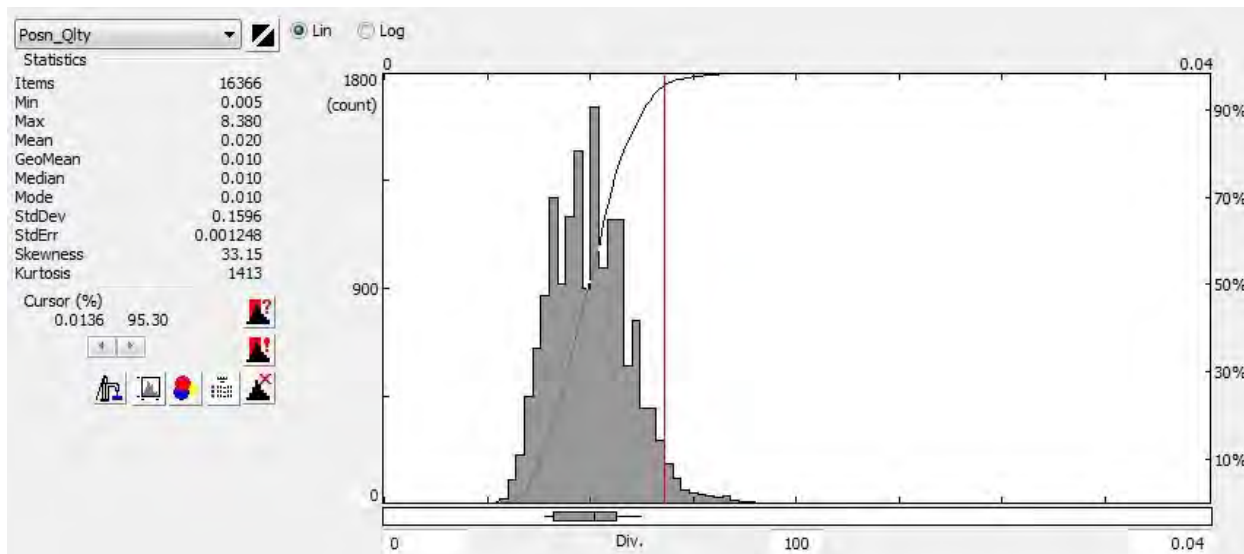


**Figure 5: Position quality of GPS solutions during single-beam bathymetry acquisition. The red line shows the 95% of the position quality is at 0.014 m.**

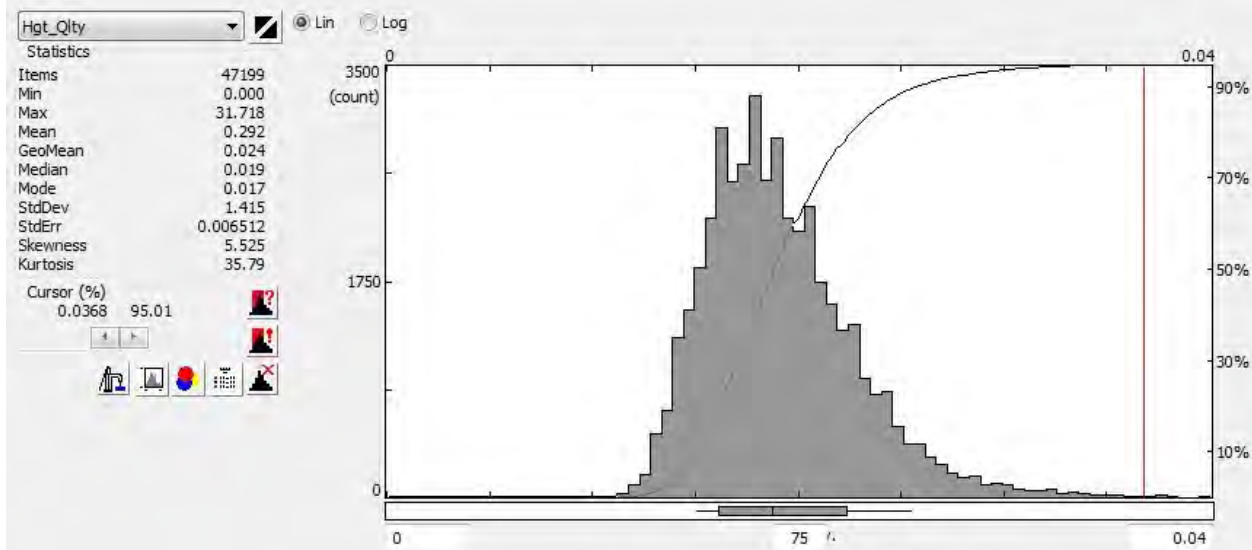


**Figure 6: Height quality of GPS solutions during multi-beam bathymetry acquisition. The red line shows the 95% of the height quality is at 0.037 m.**

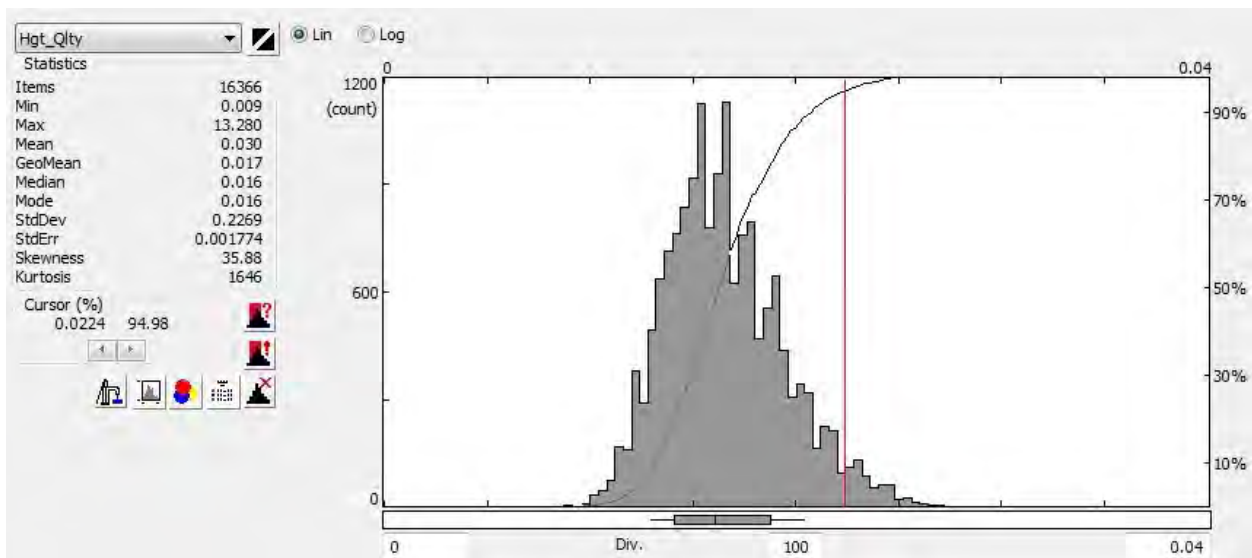


**Figure 7: Height quality of GPS solutions during single-beam bathymetry acquisition. The red line shows the 95% of the height quality is at 0.022 m.**

### 3.1.3.2 Single-Beam Sonar

RTK GPS data were exported and matched by timestamp to the single-beam data with a time-shift of 17 seconds to account for a GPS to UTC time datum adjustment.

Acoustic water velocity was assumed to be 1500 m/s during acquisition and this is corrected to 1455 m/s, a measured average velocity for the pond (Section 3.1.3.3 and Figure 8).

Pond bottom elevations were calculated by subtracting depths derived from the single-beam from the elevation of the single-beam sonar head as measured by the RTK GPS. Water elevation measurements and shoreline measurements were not used in the pond bottom elevation determination wherever sonar data were collected.

#### **3.1.3.3 Multi-beam Sonar**

Multi-beam sonar data were processed using Hypack's Hysweep 64-bit Editor. Beam angle limits of 40 degrees were imposed on both port and starboard sides for all data, with lower limits being applied where deemed necessary by visual inspection. An over/under filter and a Savitzky-Goalay filter were applied to highlight and remove potentially erroneous data. All data were then visually inspected in batches of 1000 swaths or less. Single spike anomalies and areas of high noise were removed. In general, the data collected at the widest angle from the sonar head were unreliable and discarded.

Secondary instrumentation data were also inspected and areas where high heave, pitch, roll or speed were recorded, were removed from the dataset. Water velocity data were inspected, showing little variation across time and location. Averaged values from 4 casts were used to create a water velocity profile from 0 m to 7 m, shown in Figure 8. Values from this profile are applied to all data and recorded depths were adjusted accordingly in the Hypack software.

Pond bottom elevations were calculated by subtracting depths derived from the Hypack software from the average elevation of the multi-beam sonar head as measured by the RTK GPS (1045.490 m). Water elevation measurements and shoreline measurements were not used in the pond bottom elevation determination wherever sonar data were collected.

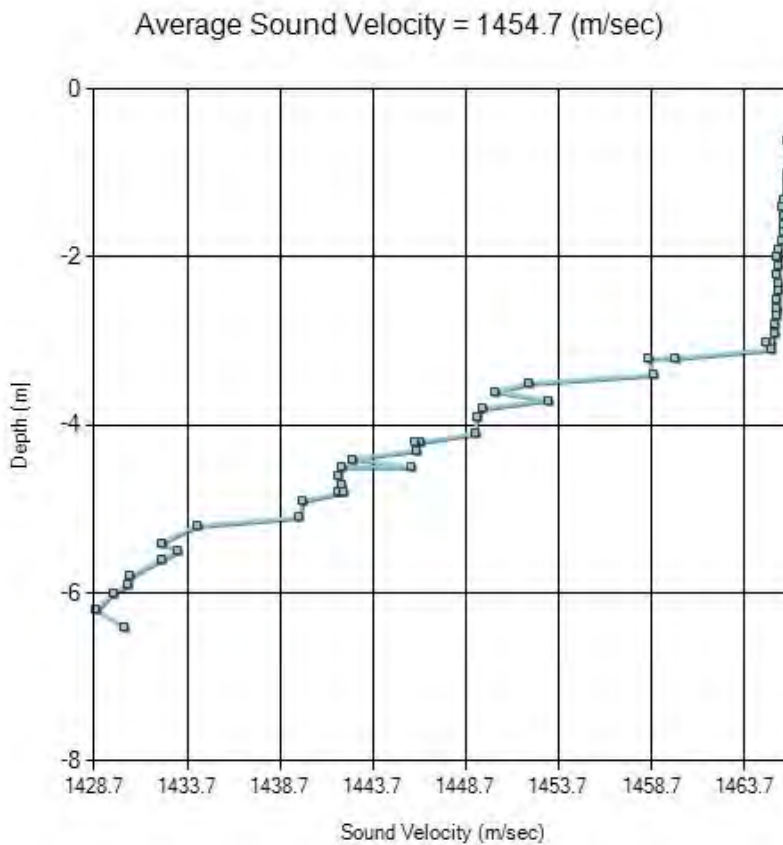


**Figure 8: Average acoustic water velocity profile.**

RTK GPS points taken at 203 shoreline locations adjacent to the surveyed area were used to interpolate a full shoreline. Orthometric heights are recorded for these shoreline locations. This shoreline data was integrated with all multi-beam and single-beam bathymetry data to create all grids and contour files associated with this pond. Gridded bathymetry data were created using a 0.5 m cell size and windowed to exclude points outside the RTK GPS surveyed perimeter created by the gridding algorithm. No filters were applied to the final bathymetry grids. All 25 cm and 50 cm contours were made after 3 passes of a 3x3 Hanning filter on the bathymetry grid.

### **3.1.4 Bathymetry Products**

The following files and figures are appended to this report

| <b>Folder / File</b>                    | <b>Description</b>                                                                               |
|-----------------------------------------|--------------------------------------------------------------------------------------------------|
| Raw data/Multi-beam/Raw/*.hsx           | Raw multi-beam data in Hypack Raw format                                                         |
| Raw data/Single-beam /*.obs             | Raw single-beam data in GeoXT format, with supporting files                                      |
| Raw data/GPS/Base/*.m00 and Rover/*.m00 | Base and rover GPS data from June 12&13 are associated with multi-beam data in Leica m00 format. |

|                                                                                       |                                                                                                                                                               |
|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Processed data/GPS/*.csv                                                              | GPS data in ASCII formats with baseline information, DOP values, positional quality. Data from June 12&13 are associated with multi-beam data.                |
| Processed data/GPS/channels.txt                                                       | Description of columns for ASCII GPS files.                                                                                                                   |
| Processed data/Bathymetry/ID pond elevation_complete.xyz                              | Master ASCII database of all final bathymetry data, combined with single beam and shore-line RTK Expressed in project coordinates, not water depth..          |
| Processed data/Bathymetry/0.5m rasterized/ID pond elevation_0.5.xyz                   | Rasterized version of the complete bathymetric data at 0.5 m cell size in ASCII format.                                                                       |
| Processed data/Bathymetry/0.5m rasterized/ID pond elevation.flt                       | Rasterized version of the complete bathymetric data at 0.5 m cell size in ESRI float raster grid format.                                                      |
| Processed data/Bathymetry/0.5m rasterized/ID pond elevation with shore extensions.flt | Rasterized version of the complete bathymetric data at 0.5 m cell size in ESRI float raster grid format including the extensions onto the shore.              |
| Processed data/Bathymetry/ID pond lead-lines.xyz                                      | Master ASCII database of all lead-line measurements.                                                                                                          |
| Processed data/Bathymetry/ID pond shoreline extensions.xyz                            | Master ASCII database of elevations measured on the shore located as extensions to the single-beam data lines..                                               |
| Processed data/Bathymetry/ID pond shoreline interpolation.xyz                         | Master ASCII database of the shoreline measurements, rasterized to 1 m.                                                                                       |
| Processed data/Bathymetry/ID pond shoreline measured.xyz                              | Master ASCII database of all shoreline measurements.                                                                                                          |
| Processed data/Bathymetry/ID pond single-beam.xyz                                     | Master ASCII database of all single-beam data including secondary control from common transect lines and data in water too shallow for the multi-beam survey. |
| Processed data/Multi-beam/feature channels.txt                                        | Description of columns for ASCII pond elevation databases.                                                                                                    |
| Processed data/Bathymetry/water velocity profile.vel                                  | Master ASCII database of averaged water velocity profiles.                                                                                                    |
| Processed data/Bathymetry/ID pond elevation contous_500.dxf                           | 1:500 scale 25cm contours of depth, made from the 0.5 raster pond elevation with a 7 passes of a 3x3 Hanning filter in AutoCAD version12 DXF format.          |
| Processed data/Bathymetry/ID pond elevation contous_1500.dxf                          | 1:1500 scale 25cm contours of depth, made from the 0.5 raster pond elevation with a 7 passes of a 3x3 Hanning filter in AutoCAD version12 DXF format .        |
| Figures/ID pond bottom elevation 500.pdf                                              | 1:500 scale map with gridded mudline elevation and 25 cm contours in PDF format                                                                               |
| Figures/ID pond bottom elevation 1250.pdf                                             | 1:1250 scale map with gridded mudline elevation and 25 cm contours in PDF format                                                                              |

## 3.2 Sub-Bottom Survey

Acoustic sub-bottom data collection was completed at Intermediate Dam Pond with a nominal line spacing of 5 metres. The coverage is slightly less complete than the bathymetric data set due to survey restrictions in shallow water from the sub-bottom instrument as illustrated in Figure 2.

### 3.2.1 Equipment

The crew was equipped with the following instruments and equipment:

|                       |     |                                                         |
|-----------------------|-----|---------------------------------------------------------|
| Equipment:            | 1   | EdgeTech SB-424 towfish s/n: 38803                      |
|                       | 1   | Edgetech 3100P sub-bottom topside unit s/n: 38688       |
|                       | 1   | Leica GS15 sensor rover s/n 1502720                     |
|                       | 1   | Leica GS14 sensor base s/n 2802696                      |
|                       | 1   | Leica CS15 controller s/n 2907005                       |
|                       | 1   | Pac Crest ADL Vantage Pro Radio s/n 13086191            |
|                       | 1   | Pac Crest Radio s/n 1301949                             |
|                       |     | Miscellaneous GPS cables, tripods and equipment         |
| Communications:       | 4   | VHF handheld radios                                     |
|                       | 1   | SAT phone                                               |
| Vehicles:             | 1   | Flat deck truck                                         |
|                       | 1   | Truck Trailer                                           |
|                       | 1   | Arctic Cat ATV                                          |
|                       | 1   | 16ft aluminium boat                                     |
|                       | 1   | Inflatable Zodiac rescue boat                           |
|                       | 1   | 6 HP outboard motor                                     |
|                       | 1   | 2 HP electric motor                                     |
| Safety:               | 4   | Government certified personal floatation devices (PFDs) |
|                       | 2   | ATV helmets                                             |
|                       | 4   | Hard hats                                               |
|                       | 100 | Nitrile gloves                                          |
|                       | 9   | Tyvek suits                                             |
|                       | 8   | Safety glasses                                          |
|                       | 4   | High Visibility Vests                                   |
|                       | 2   | Fire extinguisher                                       |
|                       | 2   | Level 2 First aid kit                                   |
|                       | 4   | Spare paddles                                           |
|                       | 2   | 15m floating rope                                       |
|                       | 2   | Bailers                                                 |
| Computers & Software: | 1   | Laptop with Edgetech Discover Sub-Bottom 4.0            |
| Other:                | 20  | 6 mil plastic garbage bags                              |
|                       | 1   | Pressure washer                                         |
|                       | 1   | Water tank                                              |
|                       | 1   | Office box                                              |
|                       | 1   | Geophysical Toolbox                                     |

### **3.2.2 Survey Specifications & Field Procedures**

#### **3.2.2.1 RTK GPS**

A GPS base station was established daily with the Leica GS14 antenna over the permanent control marker 2010-P5 at CVD. The published position for 2010-P5 was inadvertently not programmed into the GPS base prior to starting work in the field and an arbitrary position was used the first day. For consistency the arbitrary base position was used throughout the survey and all RTK data were corrected by a post-survey datum shift to align the base with the published position. The initial (arbitrary) reference point recorded by the base station was broadcast continuously via radio to the Leica GS15 rover so that a phase-corrected RTK solution was being transferred to the sub-bottom equipment via NMEA string at all times during data collection. The use of this initial reference point requires a datum shift be applied to all raw data.

An RTK check-in point was established on the north-west end of the ID pond at 580736E, 6914386N (NAD83 CSRS Epoch 2002 UTM Zone 8N) and measurements were taken there once or twice daily. The daily check-in values are provided in Section 3.3.2.

As per the published *Survey Standards for Faro Mine Closure* included with CH2M Hill Agreement 10201-7-100723, the coordinates for the antenna established at 2010-P5 are 6914557.921 N, 580635.174 E (NAD83 CSRS Epoch 2002, UTM Zone 8 coordinates with a CSF of 0.999505) with an orthometric height above the HT2 Geoid Model of 1060.480 m. The post-survey datum shift applied was to align the arbitrary base position to this accepted position.

#### **3.2.2.2 Sub-bottom Profiling**

Sub-bottom profiling was performed along 75 lines running 41° across the pond, and along 6 perpendicular tie-lines for cross reference. Survey line spacing was 5 m with tie-lines being profiled at uneven spacing, in an attempt to profile different features that appeared during the initial passes. Target boat speed was approximately 3 knots and attempts were made to maintain constant speeds in an effort to avoid distorting produced images.

The Edgetech SB-424 towfish, 3100P topside unit and Discover software were used to collect all sub-bottom data. The SB-424 is capable of outputting a variety of FM chirps, each of which was tested before surveying began. Of the chirps tested, it was decided that the highest range of frequencies available (4-24 kHz) provided the best resolution; whereas limiting the signal to lower frequencies seemed to offer no significant advantage with regard to depth of penetration.

The crew conducted a series of control tests at the beginning and end of each day. Control stations, shown by green triangles in Figure 2, were established at 580819E, 6914176N & 580810E, 6914150N (NAD83 UTM Zone 8N) by driving poles into the pond floor. GPS and sub-bottom data were recorded while traversing north to south, from pole to pole. The purpose was to collect data at the same physical location, guided by the poles, multiple times to establish the repeatability of the sub-bottom data.

### 3.2.3 Data Processing

#### 3.2.3.1 RTK

The use of an arbitrary initial reference point required a datum shift be applied to all raw data to reposition the base station to the published position of 2010-P5. All points were shifted -2.005 m N, 1.733 m E and elevation was shifted -6.501 m.

Data were logged to the Leica receiver and exported to csv files; both raw daily base and rover files, in addition to the exported rover files, are included with the data package of this report. The positional quality is shown in Figure 9 and the height quality in Figure 10 as reported by the Leica Geo Office software package from the raw rover files with no post-processing; both have a 95% confidence level well below 10 cm.

Baseline and DOP data were obtained by post-processing with Leica Geo Office. Although the base station was operating correctly and RTK corrections were being received on June 17, the file of the GPS readings did not record properly on the base. The consequence of this is that some meta-products for the GPS (baseline and DOP information) are not available for June 17.

Water level and data from RTK check-ins are discussed below in Section 3.3.2.

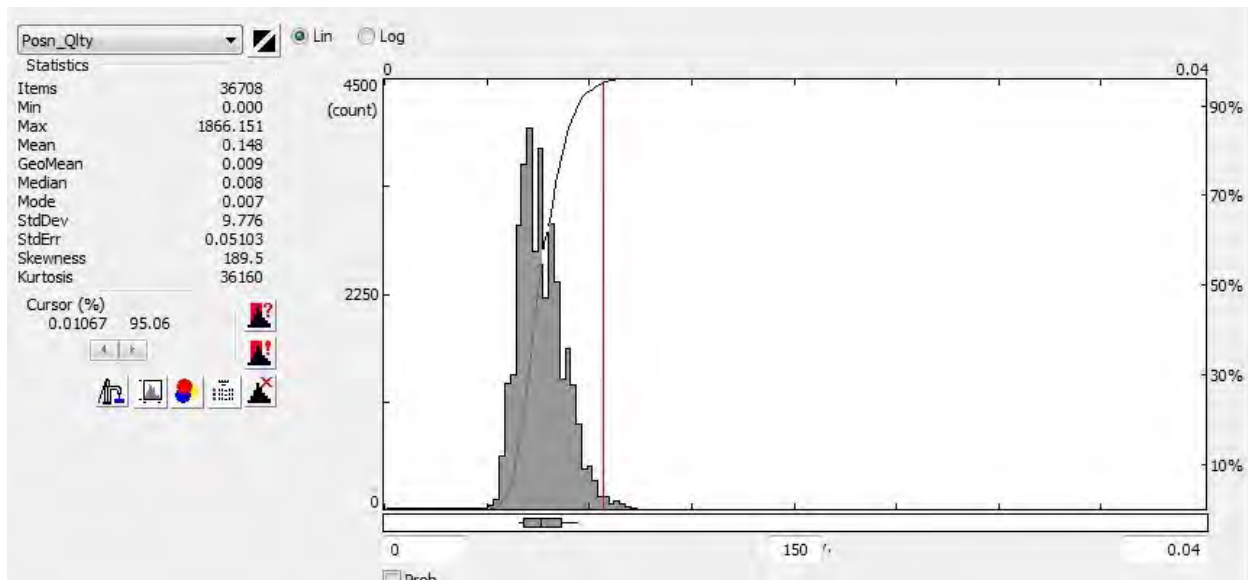


**Figure 9: Position quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the position quality is at 0.011 m.**

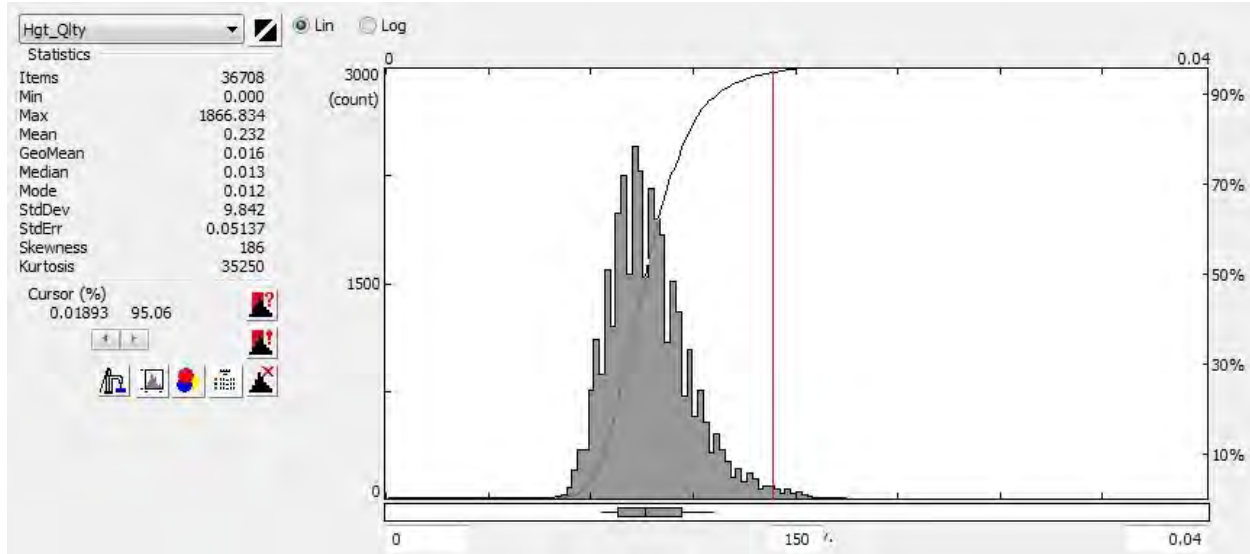


**Figure 10: Height quality of GPS solutions during sub-bottom profiling acquisition. The red line shows the 95% of the height quality is at 0.019 m.**

### 3.2.3.2 Sub-Bottom

Initial processing of sub-bottom profiles was performed with SonarWiz 6. User gain controls were adjusted to increase the visibility of responses at depth and have a minimal impact on near surface responses. Once set, this gain was applied universally across all lines allowing for objective comparisons between them. Auto-detection of the pond floor was used but was insufficiently accurate. All features, including the pond floor, were drawn in after visual inspection. Features were first drawn on the perpendicular tie-lines. The depths of these features were then plotted to all sonargrams and used only as visual cues to calibrate the drawing of all subsequent features. Tie-line feature depths were not included in the final dataset.

### Definitions of Features

**Feature 1U** – This is the upper limit of a package of layered sediment with each individual layer typically 25 cm thick. The layers are not always well defined – sometimes because the layer is too thin but also sometimes because the response grades from well-defined layers to a more homogeneous mass sitting on top of Feature 2 (see below). This feature likely represents layered tailings deposited in a tailings pond environment, which are expected to have strong horizontal layering resulting in high sonar reflectance as observed in Feature 1.

**Feature 1D** – This is the lower limit of Feature 1.

**Feature 2U** – This is the upper limit of a mostly homogeneous feature that show a markedly weaker response than the layered sediment of Feature 1. These areas are sometimes clearly delineated and sometimes are the result of a more gradual fading of response. They are always susceptible to being dominated by multiples of stronger reflectors higher in the stratigraphy and could simply represent a complete loss of signal at depth. Although the signal often appears greatly attenuated within Feature 2,

strong responses from underlying features such as interpreted bedrock are still occasionally seen. This feature likely represents the fluvial or glacio-fluvial quaternary sediments on bedrock. Although these deposits are not likely homogeneous, they are not be expected to have the strong horizontal layering that results in high sonar reflectance as seen in Feature 1.

Feature 2D – This is the lower limit of Feature 2. When this feature is present directly above Feature 5 it represents, with Feature 2U, the thickness of Feature 2. When not present (Feature 2U is underlain by Feature 4) the thickness of Feature 2 remains undefined.

Feature 4 – This feature is used to represent areas where no well-defined bottom layer is discernable. It is the opposite pair of Feature 5; wherever Feature 5 is not defined, Feature 4 is. As Feature 4 is defined by a lack of discernable response, the depths assigned are not reliable.

Feature 5 – This is a strong well defined layer with no apparent sediment layers below it, possibly representative of bedrock.

An example of a section with Features 1,2 & 5 in shown Figure 11.

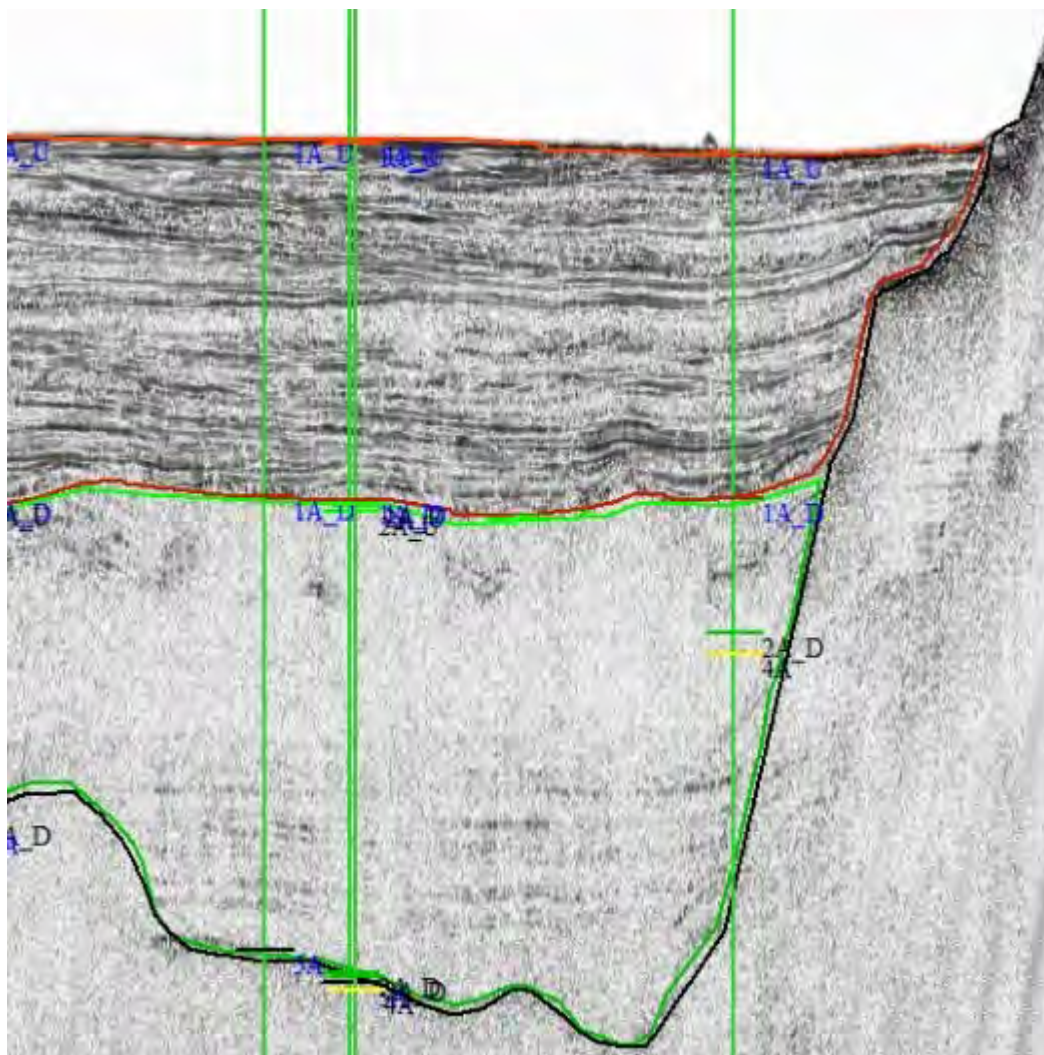


**Figure 11: Sonagram showing homogenous feature (Feature 2), under clearly layered sediment (Feature 1) and above a defined bottom feature (Feature 5). Vertical lines represent the location of tie lines.**

### **Export and Processing of Features**

The features described above were identified on a line-by-line basis and images of each line with the interpreted features are included with this report. Features were validated through cross-referencing with the six perpendicular tie-lines. The data on the NS lines were exported to an ASCII master database and AutoCAD v12 DXFs with all the interpreted features were produced for each line. The velocities of all layers are assumed to be 1500 m/s upon export and all data downstream of the export are in metres.

The feature thicknesses are exported to ASCII and are gridded with a minimum curvature algorithm and a cell size of 1.0 m, which is an appropriate cell size for 5 m line-spacing. Grids are provided in both ASCII and ESRI formats. Contours for each feature are made at 10 cm intervals and are exported in AutoCAD v12 DXF format.

### **Cross-Sections**

Cross-sections were produced at 50 m intervals for the pond in both the east-west and north-south directions. A database was developed for each cross-section with 1 m resolution and the final bathymetric database is sampled to obtain the pond bottom along the cross-section.

### 3.2.4 Sub-bottom Products

The following files and figures are appended to this report:

| Folder / File                                                                        | Description                                                                                                                                      |
|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Raw data/Sub-bottom/*.jsf                                                            | Sub-bottom data by line in EdgeTech jsf format (see Appendix III).                                                                               |
| Raw data/GPS/Base/*.m00 and Rover/*.m00                                              | Base and rover GPS data from June 14 & 15 are associated with sub-bottom data in Leica m00 format.                                               |
| Processed data/GPS/Daily Surveying/*.csv and *.txt                                   | GPS data in ASCII formats with baseline information, DOP values, positional quality. Data from June 14 & 15 are associated with sub-bottom data. |
| Processed data/GPS/channels.txt                                                      | Description of columns for ASCII GPS files.                                                                                                      |
| Processed data/Sub-bottom/Feature lines/ASCII/ID pond subbottom_all_Features.xyz     | Master ASCII database of all interpreted sub-bottom features.                                                                                    |
| Processed data/Sub-bottom/Feature lines/ASCII/ID pond subbottom_*.xyz                | ASCII Database of feature “*”.                                                                                                                   |
| Processed data/Sub-bottom/Feature lines/ASCII/Feature_lines_channels.txt             | Description of columns for ASCII sub-bottom databases.                                                                                           |
| Processed data/Sub-bottom/Line-by-line DXFs/*.dxf                                    | Interpreted sub-bottom features in AutoCAD version12 DXF format.                                                                                 |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/Feature_*.xyz                  | Calculated thickness of each sub-bottom feature.                                                                                                 |
| Processed data/Sub-bottom/Feature thickness/ASCII XYZ/Feature_thickness_channels.txt | Description of columns for ASCII feature thickness.                                                                                              |
| Processed data/Sub-bottom/Feature thickness/DXF contours/Feature*.dxf                | Contour of feature thickness (interval of 0.25 m) after 10 passes with a 3X3 Hanning filter in AutoCAD version12 DXF format.                     |
| Processed data/Sub-bottom/Feature thickness/ESRI grids                               | Raster grid at 1 m cell size of feature thickness in ARC float raster format.                                                                    |
| Processed data/Sub-bottom/Feature thickness/Geosoft grids                            | Raster grid at 1 m cell size of feature thickness in Geosoft grid format.                                                                        |
| Processed data/ID pond sonargrams/*.jpg                                              | Images of processed data for every line with interpreted layers in jpg format.                                                                   |
| Figures/Cross-sections/DXFs                                                          | EW and NS cross-sections (50 m spacing) with bathymetry and interpreted sub-bottom layers in AutoCAD version12 DXF format.                       |
| Figures/Cross-sections/PDFs                                                          | EW and NS cross-sections (50 m spacing) with bathymetry and interpreted sub-bottom layers in PDF format.                                         |

### 3.3 Quality Control Checks

#### 3.3.1 Common Transects

##### 3.3.1.1 Single-beam & Multi-beam

Six transects were completed across the pond with the single-beam transducer to create a dataset suitable for comparison with the multi-beam data. These 6 lines represent 1352 single-beam locations which, on average, are 0.02 m deeper than the multi-beam data for the same location and have a maximum absolute difference of 1.42 m (Figure 12). Transects are shown in Figure 13.

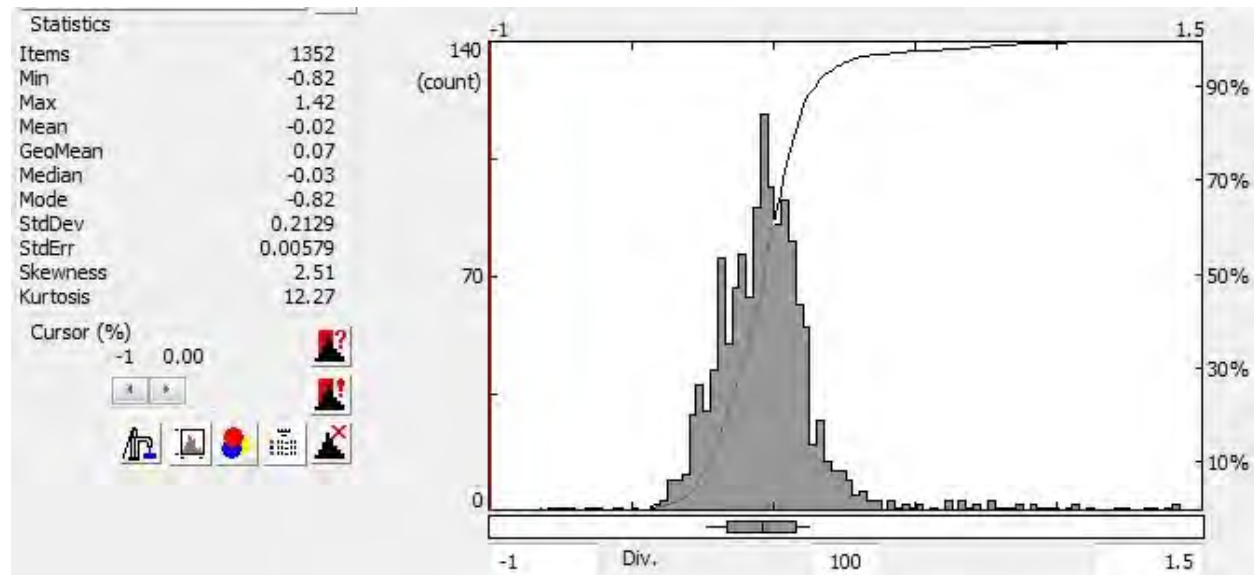


Figure 12: Histogram of difference between single-beam and multi-beam readings.

The purpose of the single-beam data collection is to provide an independent check (in addition to the lead-line dataset) on the multi-beam data. The distribution of the differences is centered close to zero but has a high kurtosis and skewness, indicating high level of outliers particularly on the positive end (Figure 12). Examination of transects shown in Figure 13 show that these outliers, circled in blue, are not random; they occur where the pond bottom has a steep gradient. When the outliers are rejected until the kurtosis is approximately equal to 3 (the kurtosis of a normal Gaussian distribution), the standard deviation is 0.16 m.

One possible explanation for this systematic difference is that in an area of steep bottom topography, the footprint of the sonar will cover a wide range of depths. The multi-beam system is calibrated with a pair of GPS antenna for heading determination and pitch, roll and heave detectors. Although the beam width is larger than the single beam (120° versus 9°), the multi-beam operates with 512 beams over the 120° instead of a single beam over 9°. The wider footprint per beam and the lack of heading and motion detectors on the single-beam instrumentation means there is greater ambiguity in imaging a dipping subsurface. The observed discrepancy between the datasets would be consistent with the single-beam taking the earliest reflection as bottom.

There was some corrugation in the raw multi-beam dataset that is likely a result of imperfect calibration or a calibration that was slipping in time. This was particularly apparent in the morning of the first day of collection, June 12<sup>th</sup>. Most of this artifact was successfully removed in post-processing, however there is a small residual effect that cannot be removed. An example of this residual corrugation, which has an amplitude of several decimeters, is shown by the orange ellipse in Figure 13. It should be noted that the residual corrugation is not systematically biased and averages to zero therefore calculations of the water volume in the pond will not be significantly affected.

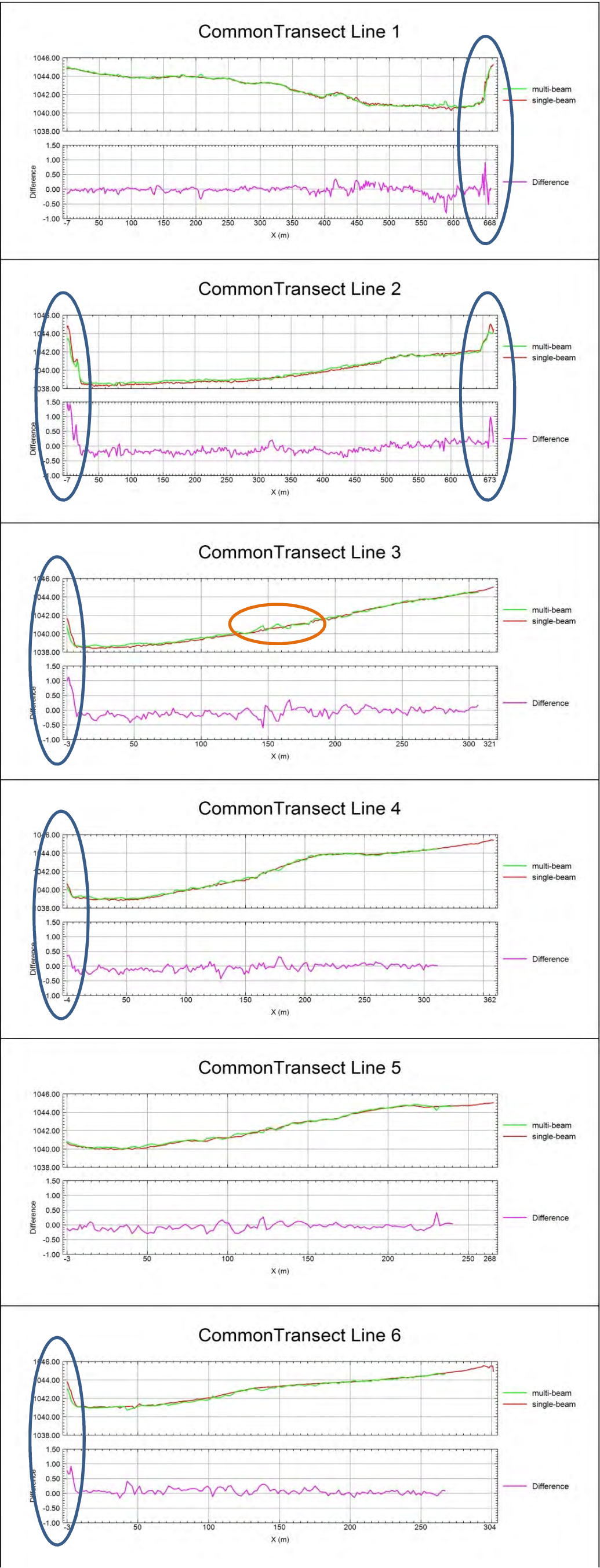


Figure 13: Common single-beam and multi-beam transects, showing pond bottom elevation (top panel) and single-beam / multi-beam difference (bottom panel). Blue ellipses show areas of steep bottom gradient and where a systematic difference between single-beam and multi-beam depth is observed. The orange ellipse shows an example of residual corrugation, likely caused by an imperfect calibration.

### 3.3.1.2 Lead-line comparisons

Preferentially along the same six single-beam transects, 49 lead-line measurements were taken and the histogram of the difference between the 49 lead-line and the multi-beam measurements is shown in Figure 14. Because of the nearly coincident lead-line measurements and single-beam measurements, comparisons can also be made between these two datasets and this is shown in Figure 15. The criterion for comparison was that the lead-line needed to be within 5 m of the single-beam reading. Both difference datasets are biased negative (-0.26 m and -0.31 m) which indicates the lead-line measurements are in general deeper than both the multi-beam and single-beam measurements. This bias is in part due to the methodology as the boat was not anchored while taking the measurements and was drifting significantly in the wind. Efforts to take the best data possible were made, but the lead-lines were to not vertical at the time of measurement which would explain the deep bias. Also adding to the deep bias of the lead-line measurements, based on the observations of ubiquitous and thick mud on the weighted part of the line, it was clear that the bottom of ID pond is very soft in places and the weight would have had significant penetration.

Despite the bias, the distribution is fairly well matched to a normal Gaussian distribution. No systematic difference is seen between the comparisons of lead-line and single-beam and lead-line and multi-beam (Figure 16).

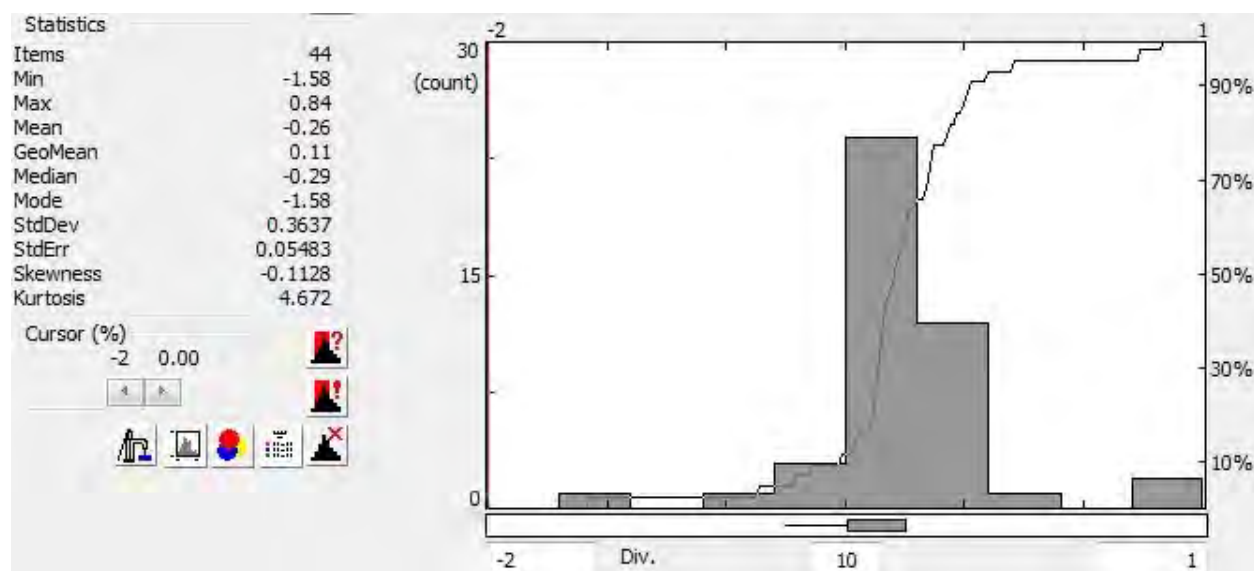


Figure 14: Histogram of difference between lead-line measurements and multi-beam readings.

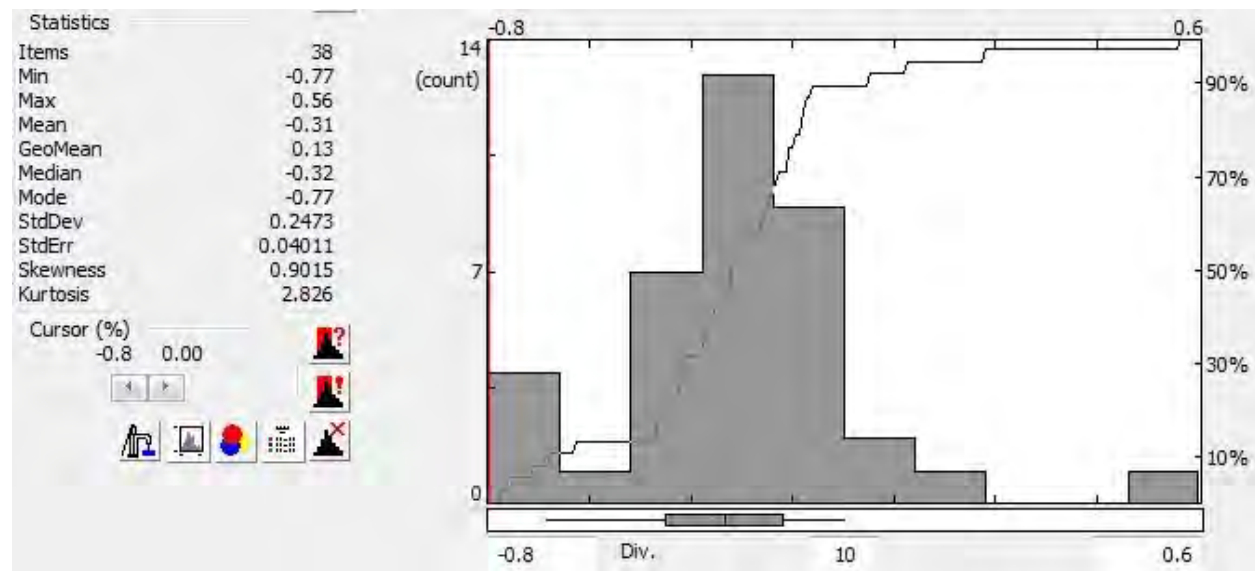


**Figure 15: Histogram of difference between lead-line measurements and single-beam readings.**

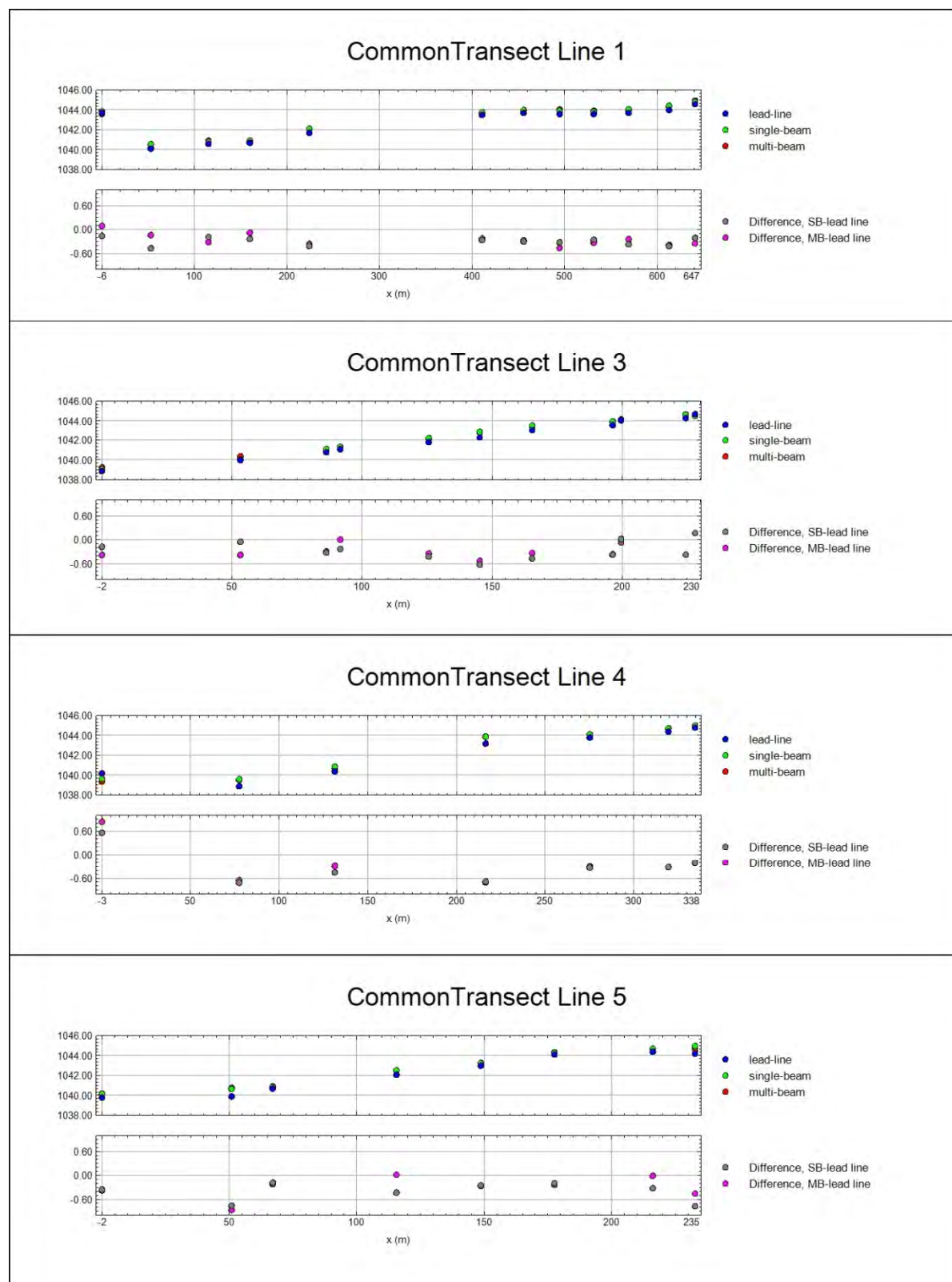


Figure 16: Common lead-line measurements along single-beam transects and comparisons with multi-beam data, showing pond bottom elevation (top panel) and differences (bottom panel).

### 3.3.2 Daily check-ins

#### 3.3.2.1 GPS Control

A distinct location (the north side of a protruding pipe) on the northwest side of the pond was chosen as a daily check-in station to directly test the consistency of the Leica RTK GPS system from which all positioning in the ID pond was measured. Measurements were taken once or twice a day and the results are tabulated in Table 1.

The repeatability of the elevation is within 3.5 cm with a standard deviation of 1.2 cm, while the repeatability of the easting and northing are 2.5 cm and 1.5 cm respectively while the standard deviations are 8 mm and 5 mm respectively.

**Table 1: RTK GPS data from check-in control adjacent to ID pond.**

| Date                 | Time     | Easting           | Northing           | Orthometric Height |
|----------------------|----------|-------------------|--------------------|--------------------|
| 2016-06-11           | 12:26:06 | 580736.109        | 6914386.867        | 1047.662           |
| 2016-06-12           | 7:49:15  | 580736.084        | 6914386.854        | 1047.664           |
| 2016-06-13           | 8:03:05  | 580736.085        | 6914386.859        | 1047.685           |
| 2016-06-13           | 16:20:57 | 580736.095        | 6914386.861        | 1047.679           |
| 2016-06-14           | 9:56:16  | 580736.089        | 6914386.863        | 1047.674           |
| 2016-06-14           | 15:51:57 | 580736.089        | 6914386.859        | 1047.679           |
| 2016-06-15           | 7:54:24  | 580736.087        | 6914386.862        | 1047.681           |
| 2016-06-15           | 16:02:09 | 580736.095        | 6914386.854        | 1047.697           |
| 2016-06-16           | 8:20:07  | 580736.086        | 6914386.859        | 1047.691           |
| 2016-06-17           | 9:53:52  | 580736.104        | 6914386.869        | 1047.689           |
| 2016-06-17           | 22:57:13 | 580736.100        | 6914386.862        | 1047.697           |
| <b>Mean</b>          |          | <b>580736.093</b> | <b>6914386.861</b> | <b>1047.682</b>    |
| <b>Range</b>         |          | <b>0.025</b>      | <b>0.015</b>       | <b>0.035</b>       |
| <b>Standard Dev.</b> |          | <b>0.008</b>      | <b>0.005</b>       | <b>0.012</b>       |

#### 3.3.2.2 ID pond water level

The water elevation of the ID pond was measured once or twice a day and the results are tabulated in Table 2.

The repeatability of the elevation is within 10.5 cm with a standard deviation of 2.6 cm; this range is much larger than that of the RTK check-in control but this variability reflects both measurement / system error and a true change in water elevation. The drop in water level is also seen in the shoreline elevations, shown in Figure 17, where the data on the left of the black line were collected on June 16 and the data on the right of the blackline were collected on June 17. The drop in ID pond water elevation by several centimetres is consistent with both datasets, although the drop in the shoreline

elevations is greater. The interpretation of why the shoreline elevation shows a greater drop is that most of the points measured on June 17<sup>th</sup> are from the eastern side of the pond where the mud was very soft and although best efforts were made to get the true pond surface elevation, there was penetration of the GPS pole into the mud, biasing the water elevation lower. A shoreline elevation of 1045.976 m, the average of all the shoreline measurements, was used in the shallow water interpolation between the most shallow sonar measurement (usually single-beam) and the shoreline. The change in water level noted on June 17<sup>th</sup> is not significant in the calculation of the pond bottom elevation because it only affects a small area (shallow water) and the true differences is not as great as the shoreline measurements indicate because of the bias introduced by penetration into the soft mud.

**Table 2: RTK GPS water elevation data of the ID pond.**

| Date                 | Time     | Orthometric Height |
|----------------------|----------|--------------------|
| 2016-06-11           | 12:28:12 | 1046.035           |
| 2016-06-12           | 7:52:01  | 1046.043           |
| 2016-06-13           | 8:04:55  | 1046.035           |
| 2016-06-13           | 16:19:53 | 1046.030           |
| 2016-06-14           | 15:49:33 | 1046.043           |
| 2016-06-14           | 15:50:43 | 1046.036           |
| 2016-06-15           | 7:57:02  | 1046.023           |
| 2016-06-15           | 16:04:26 | 1046.028           |
| 2016-06-16           | 8:23:58  | 1046.063           |
| 2016-06-17           | 9:56:10  | 1046.027           |
| 2016-06-17           | 22:58:44 | 1045.958           |
| <b>Mean</b>          |          | <b>1046.029</b>    |
| <b>Range</b>         |          | <b>0.105</b>       |
| <b>Standard Dev.</b> |          | <b>0.026</b>       |

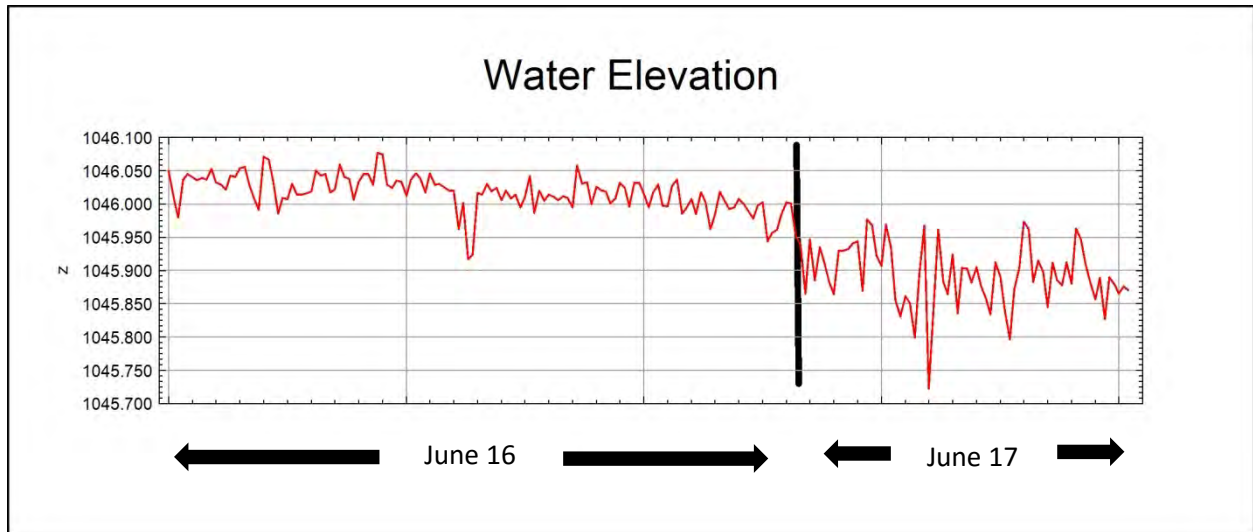


**Figure 17: Shoreline elevation. The vertical black line represents the break between the points collected on June 16<sup>th</sup> and 17<sup>th</sup>.**

### 3.3.2.1 Bathymetric check-ins

Multi-beam check-in data were collected as described in Section 3.1.2.2 at the start and end of every multi-beam survey day, creating a swath of data approximately 3.5 m wide and 40 m long. The data were gridded with a cell size of 10 cm giving between 8883 and 10143 common points for comparison. The mean difference between the reference control pass (morning pass of first day) and subsequent passes vary from 6 centimeters to 11 centimeters as shown in Figure 18. The standard deviation of the differenced grids is more consistent at 3.6 – 6.2 cm. This indicates that the 95% confidence level, which is approximately 2 standard deviations, is on the order of 9 cm.

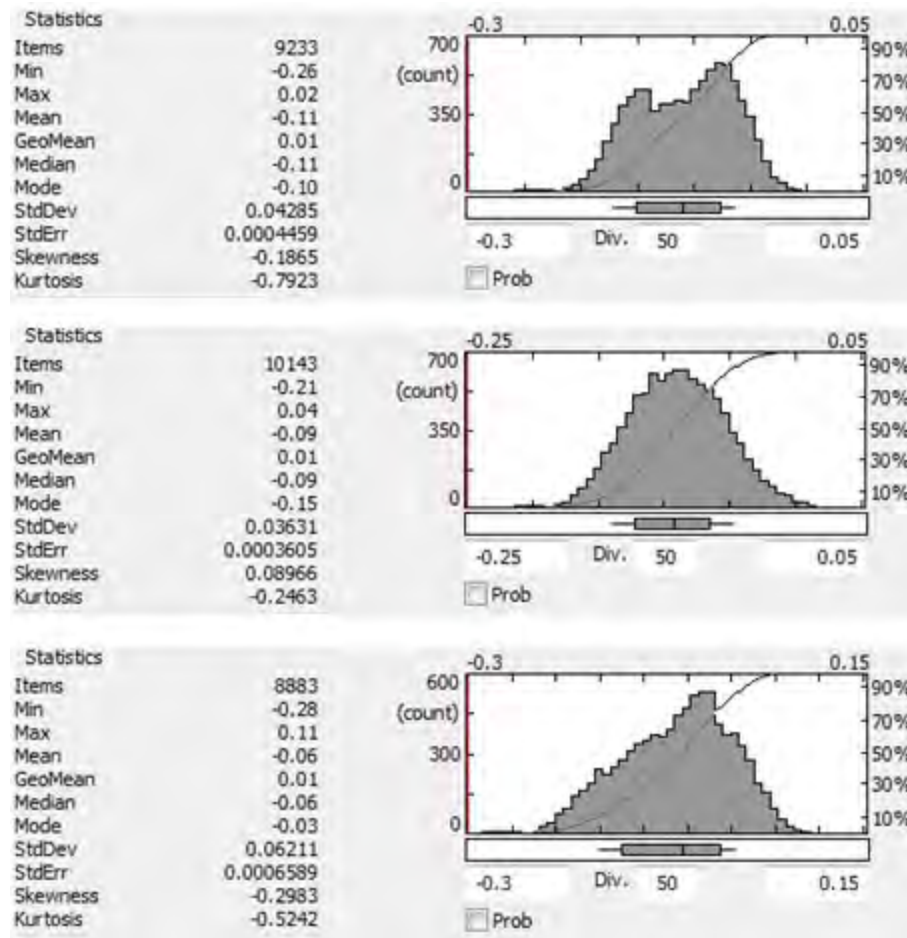


Figure 18: Histograms of the differenced grids from multi-beam daily check-ins as described in Section 3.1.2.2.

### 3.3.2.2 Sub-bottom check-ins

Sub-bottom check-in data were collected as described in Section 3.2.2.2 at the start and end of every sub-bottom survey day, the results of which are shown in Figure 19. No quantitative analysis was performed on these data, but the data are visually consistent between the 4 passes and as the interpreted features were identified visually from the sonagrams, this is an appropriate level of comparison. The control data demonstrates the sub-bottom equipment was in good working order prior to and immediately following the two days of surveying.

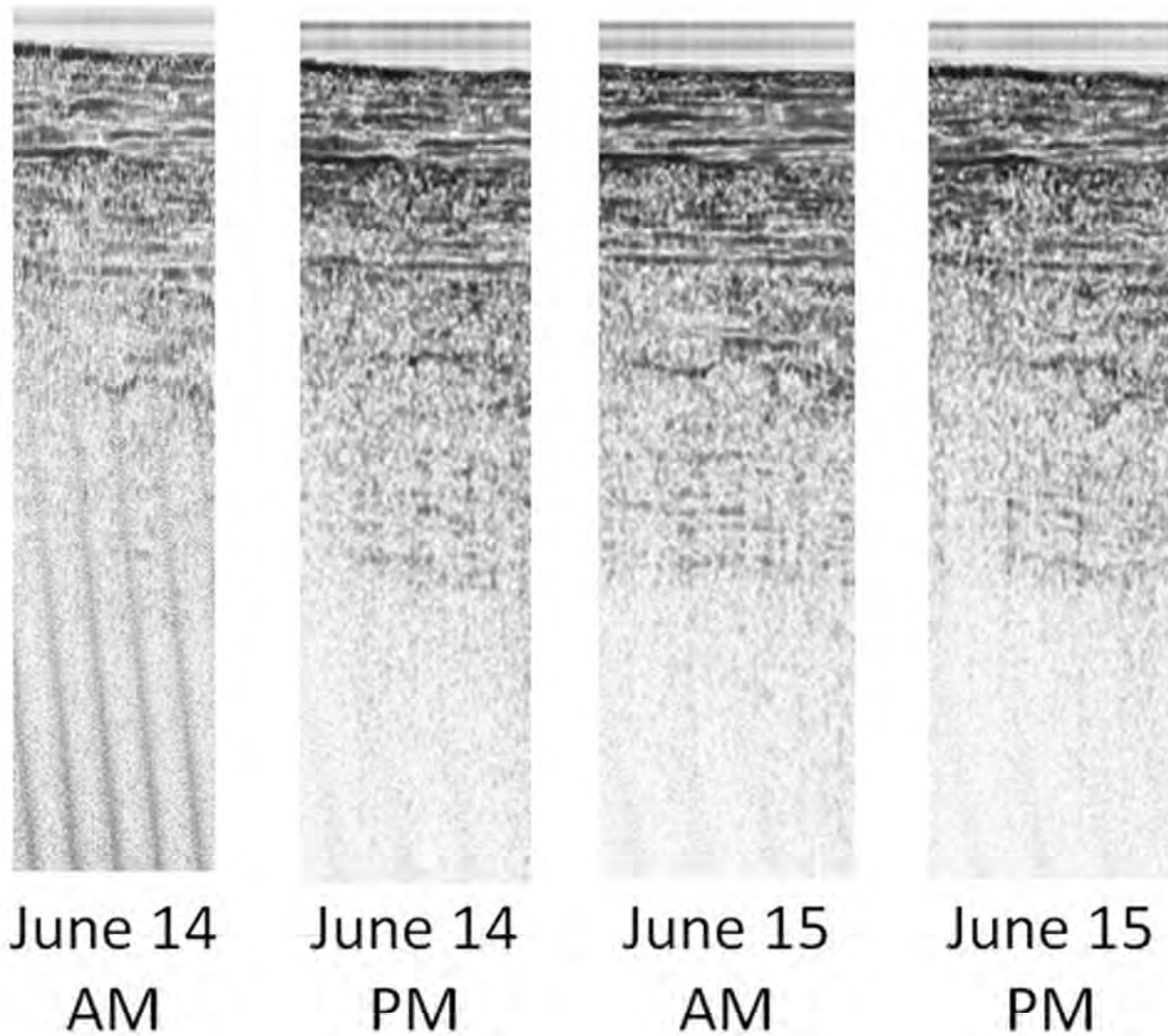


Figure 19: Sonargrams from the sub-bottom control passes.

## 4 DISCUSSION AND INTERPRETATION

### 4.1 Bathymetry

The multi-beam sonar survey provides a very high resolution dataset of the pond bottom as shown in Figure 20. The maximum depth of the pond is 7.8 m in the most western part of the pond. The pond bottom is mostly featureless and is dominated by shallowing slope to the east.

Agreement was generally good between the lead-line depths, single-beam transects and the multi-beam data, providing confidence in the data veracity of all three products. The notable exceptions are depth mismatches between the single-beam and multi-beam in areas of high pond bottom slope. The multi-

beam system is designed to account for slope in the calculation of depths while the single-beam is a simpler system that likely takes the first (i.e. most shallow) reflector and this would explain the discrepancy. Because of the more advanced instrumentation and strategy to account for such topography, the multi-beam is the preferred dataset.

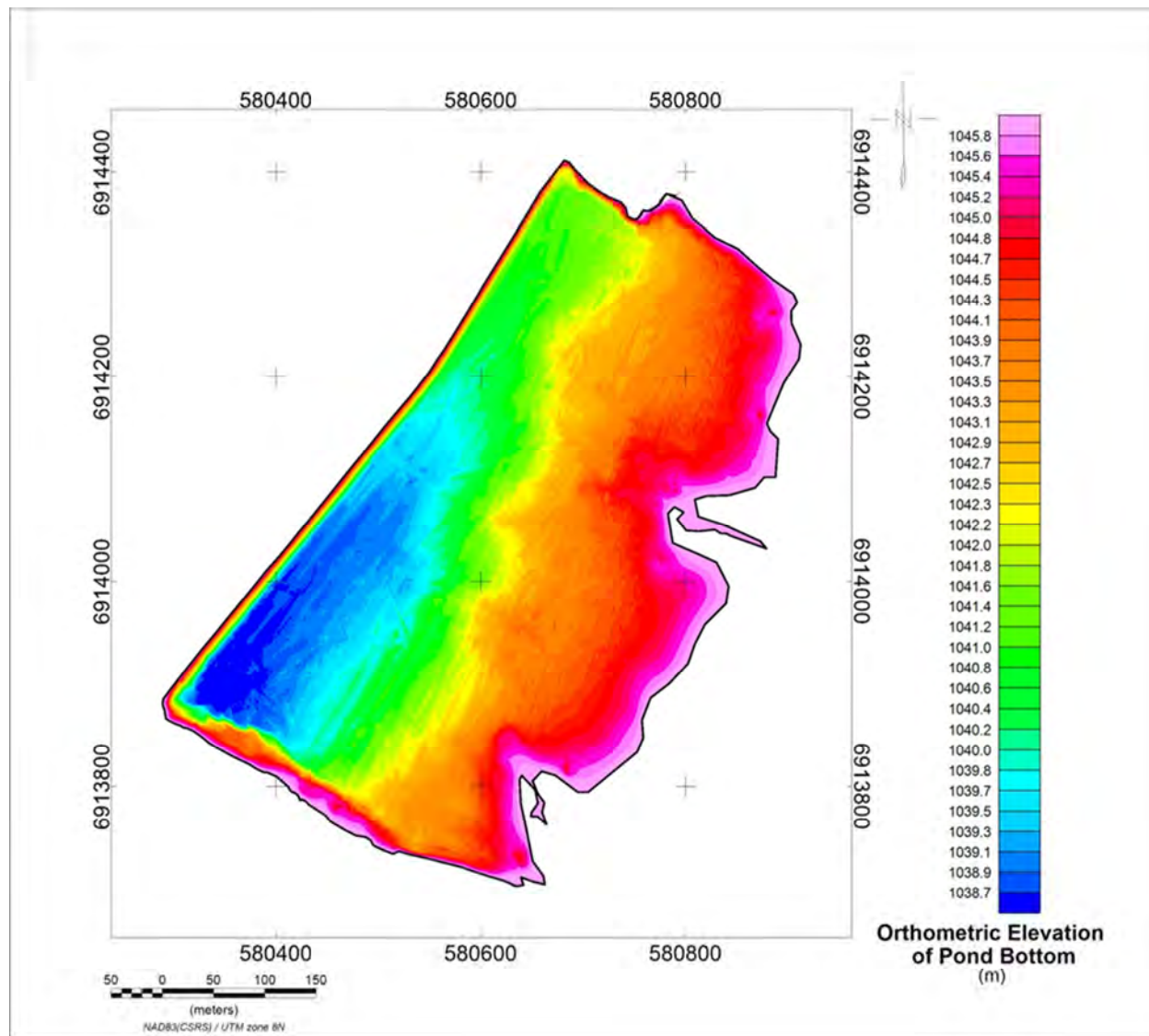


Figure 20: Intermediate Dam Pond elevation of pond bottom.

## 4.2 Sub-bottom

The Intermediate Dam Pond had many strong reflectors, some of which exhibited well-layered packages of sediment, interpreted to be tailings. A deeper reflector in much of the pond is identified and interpreted as bedrock. The thicknesses of Features 1 and 2 as defined above are shown in Figure 21 and Figure 22 respectively. The thickness of the features is greater on the western edge of the pond.

Feature 1, which is more robustly defined, is thickest in the northern part of the pond. The sections of pond with no thickness defined for Feature 2 is where no bottom of Feature 2 was identified.

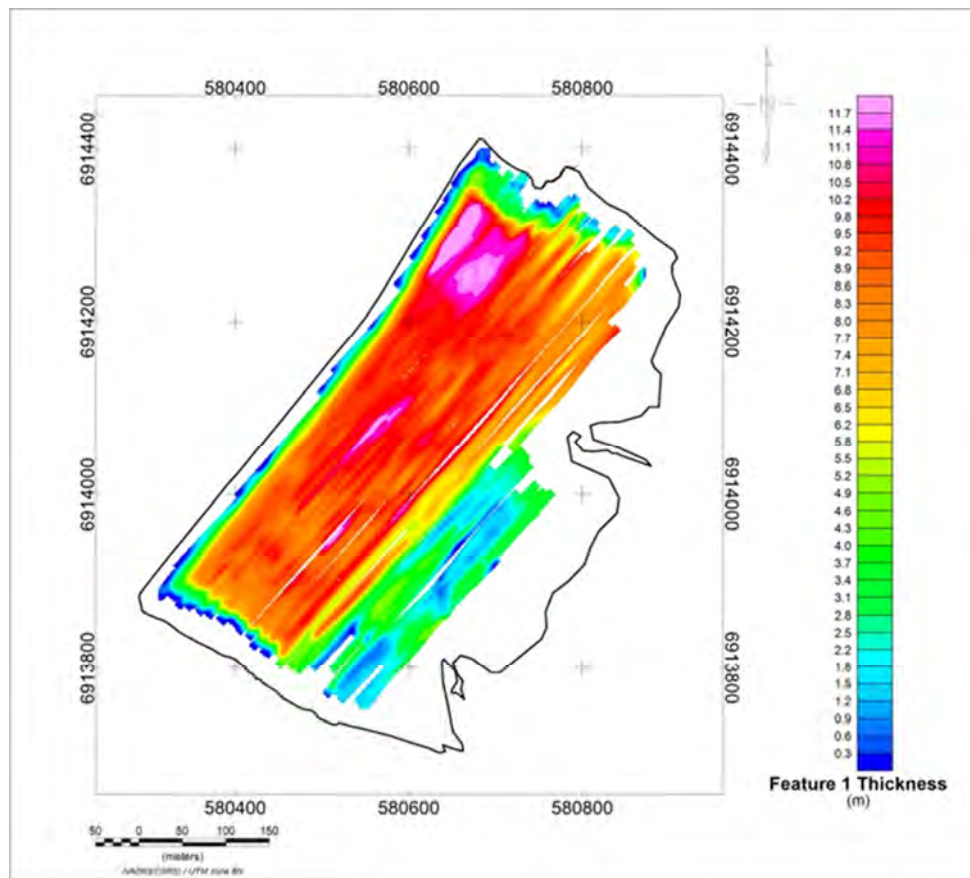


Figure 21: Thickness of interpreted Feature 1.

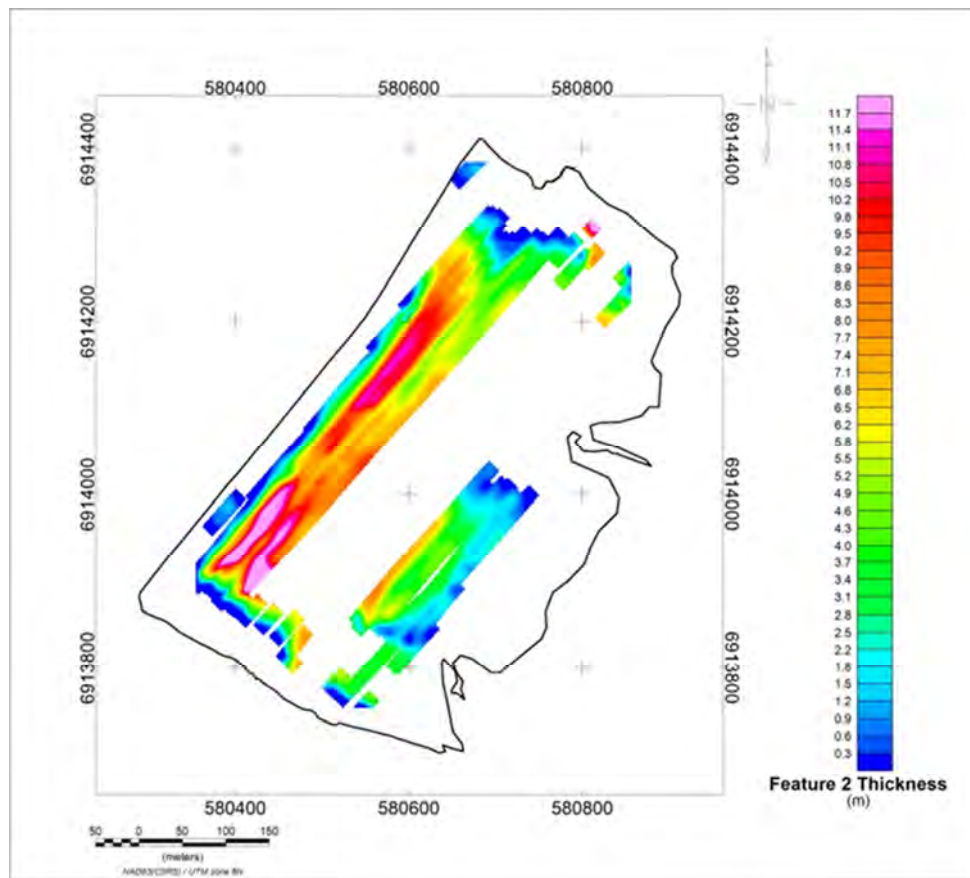


Figure 22: Thickness of interpreted Feature 2.

#### 4.2.1 Alignment with Cone Penetration Soundings

Attempts to corroborate data with logs from cone penetration tests were not successful. Two of the soundings (CP14 and CP17) were conducted in areas where the sub-bottom profile showed no detectable bottom. One of the soundings (CP16) hit refusal later than the sub-bottom interpretation predicted, however this sounding took place 4 m away from any profile and as seen in Figure 23 hit what appears to be a steep incline in the pond wall and is therefore subject to large error because of the extrapolated location. The three other soundings (CP15, CP17 & CP 19) registered refusal as shallower than the interpreted sub-bottom bedrock, an example of which is shown in Figure 24. The default velocity in the processing software is 1500 m/s but to raise the interpreted bottom up to the refusal depth from CP15, CP17 and CP19 requires a sonic velocity of 1290 m/s. This is too slow to be physically reasonable for a sonic velocity in mud.

An alternate interpretation would be to assume the base of the Feature 1 represents bedrock and refusal. However, this interpretation would require a sonic velocity of 2500 – 3000 m/s which is too high for a sonic velocity in mud. Additionally at the CVD pond, soundings show several metres of penetration before refusal with a complete absence of Feature 1 in the sonargrams.

Therefore the final interpretation of what the features represent and how they relate to the core penetration soundings remain ambiguous. Velocities were left at 1500 m/s for all images and data included with this report.

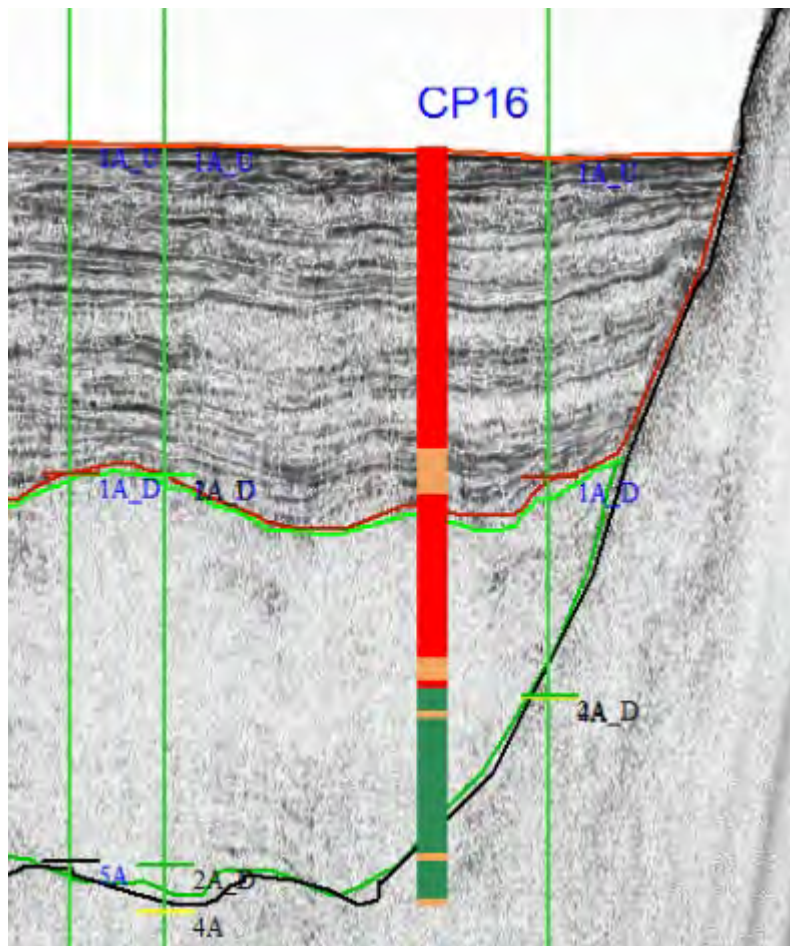


**Figure 23: Location of sounding log CH-16-201-CP16 extrapolated to the nearest point on a 2-D axis sonogram axis can create errors close to steep pond walls.**

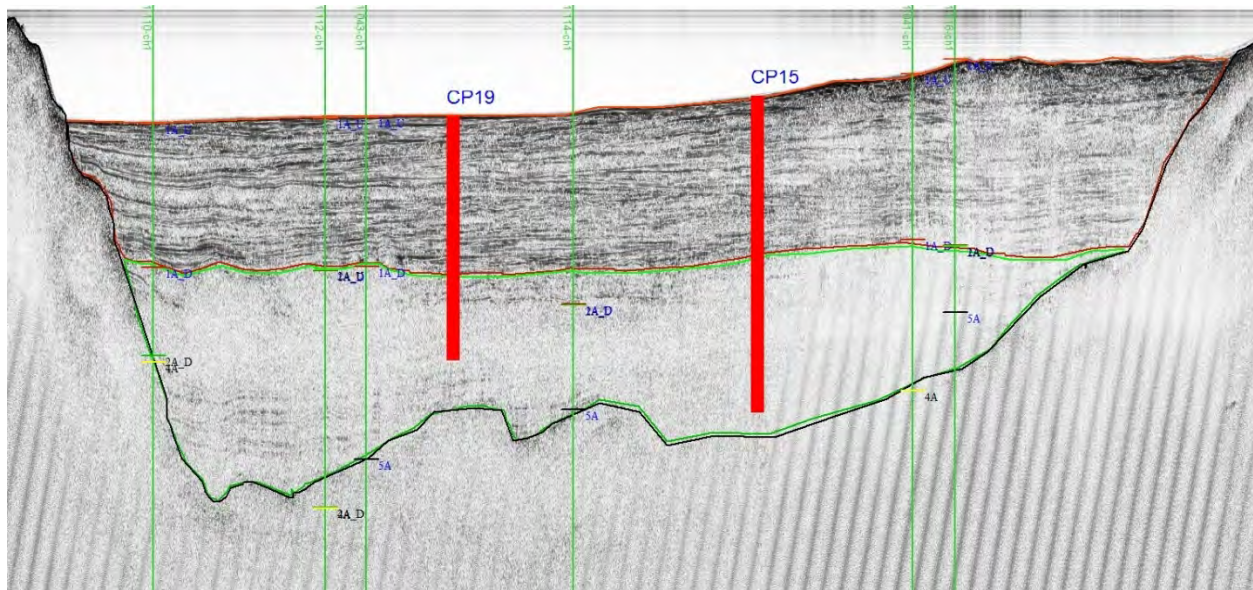


Figure 24: Sounding logs from CP19 and CP15 show refusal above interpreted bedrock surface.

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Dave Hildes, P.Geo., Ph. D.  
Geophysicist

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Shawn Scott,  
Geophysical Technician

**Appendix I**

**Project Log**

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**AURORA GEOSCIENCES**

| Weather Day       | PERSONNEL : 27 Person-Days BAD WEATHER : 0 Person-Weather Days DAYS ON THE JOB : 8 days |                         |                                    |                      |                                         |
|-------------------|-----------------------------------------------------------------------------------------|-------------------------|------------------------------------|----------------------|-----------------------------------------|
| weather day       | Men-Weather Days                                                                        | Shawn Scott             | Kel Sax                            | Sahara Dove          | Dave Hildes                             |
| *1/2 weather day* |                                                                                         |                         |                                    |                      |                                         |
| Current Job       | 0                                                                                       | 8                       | 7                                  | 9                    | 3                                       |
| '''               | *                                                                                       | Mobe                    |                                    | Mobe                 |                                         |
| Sat 11-Jun-2016   | *                                                                                       | Orientation, setup      | Orientation, setup                 | Orientation, setup   |                                         |
| Sun 12-Jun-2016   | *                                                                                       | Multi-beam              | Multi-beam                         | Safety               |                                         |
| Mon 13-Jun-2016   | *                                                                                       | Multi-beam              | Multi-beam                         | Safety               |                                         |
| Tue 14-Jun-2016   | *                                                                                       | Sub-bottom              | Sub-bottom                         | Safety               |                                         |
| Wed 15-Jun-2016   | *                                                                                       | Sub-bottom              | Sub-bottom                         | Safety               |                                         |
| Thu 16-Jun-2016   | *                                                                                       | Single-beam, lead lines | Single-beam, lead lines            | Safety and RTK       | Mobe                                    |
| Fri 17-Jun-2016   | *                                                                                       | Demobe                  | Single-beam, lead lines, tear down | Safety and tear down | Single-beam, lead lines, RTK, tear down |
| Sat 18-Jun-2016   | *                                                                                       |                         |                                    | Demobe               | Demobe                                  |
|                   |                                                                                         |                         |                                    |                      |                                         |
|                   |                                                                                         |                         |                                    |                      |                                         |
|                   |                                                                                         |                         |                                    |                      |                                         |
|                   |                                                                                         |                         |                                    |                      |                                         |



## CHM-16069-YT Faro Bathymetry 2016

|                        | IP Multi-beam (%) | IP Sub-bottom (%) | IP Single-beam (%) | IP Lead-lines (%) | IP RTK (%) | CVD Single Beam (%) | CVD Lead -ines (%) | CVD RTK (%) |
|------------------------|-------------------|-------------------|--------------------|-------------------|------------|---------------------|--------------------|-------------|
| <b>% Completed</b>     | <b>100</b>        | <b>100</b>        | <b>100</b>         | <b>100</b>        | <b>100</b> | <b>100</b>          | <b>18</b>          | <b>100</b>  |
| <b>Fri 10-Jun-2016</b> |                   |                   |                    |                   |            |                     |                    |             |
| <b>Sat 11-Jun-2016</b> |                   |                   |                    |                   |            |                     |                    |             |
| <b>Sun 12-Jun-2016</b> | 55                |                   |                    |                   |            |                     |                    |             |
| <b>Mon 13-Jun-2016</b> | 45                |                   |                    |                   |            |                     |                    |             |
| <b>Tue 14-Jun-2016</b> |                   | 60                |                    |                   |            |                     |                    |             |
| <b>Wed 15-Jun-2016</b> |                   | 40                |                    |                   | 20         |                     |                    |             |
| <b>Thu 16-Jun-2016</b> |                   |                   | 100                | 100               | 30         |                     |                    |             |
| <b>Fri 17-Jun-2016</b> |                   |                   |                    |                   | 50         | 100                 | 18                 | 100         |
| <b>Sat 18-Jun-2016</b> |                   |                   |                    |                   |            |                     |                    |             |



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Friday, June 10, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Sunny and warm.

### Notes (production comments, incidents, other)

Left Whitehorse at 6pm, arrived safe in Faro 10pm.



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Saturday, June 11, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Arrived on site at 9am. Had safety orientation with Parsons, then had a safety orientation and logistics meeting with Benn and Chuck at CH2M. Set up the site in the early afternoon, unloaded boat and gear. Set up boat for multibeam survey and set control station pins in place



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Sunday, June 12, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.

Day 1 of multibeam

7pm



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Monday, June 13, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.  
Multibeam day 2 some surveying cleaned equipment with pressure washer



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Tuesday, June 14, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

High winds at times, storm clouds with audible thunder for a short while in the afternoon.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.  
Sub-bottom day 1. 530pm



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Wednesday, June 15, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.  
Sub-bottom day 2. 630pm rtk shore



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Thursday, June 16, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.  
single beam survey lines, shallows, leadline, return gear via small's,  
clean gear, rtk shore



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Friday, June 17, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

### Notes (production comments, incidents, other)

Safety meeting at CH2M office at 730.  
moved to cvd, single beam survey lines, lead lines, rtk shore, rtk line extensions. GPS malfunction took several hours to hours, had to cut out most of the CVD lead lining to get the equipment out of the water and cleaned as there was to be no safety officer on-site tomorrow. Day went long to complete work.



## CHM-16069-YT Faro Bathymetry 2016

**DATE:**

Saturday, June 18, 2016

**PREPARED BY:**

Shawn Scott

### LOGISTICS

| Type | Contractor | Hrs or units |
|------|------------|--------------|
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |
|      |            |              |

### Comments

#### Weather

Mixed sun and cloud.

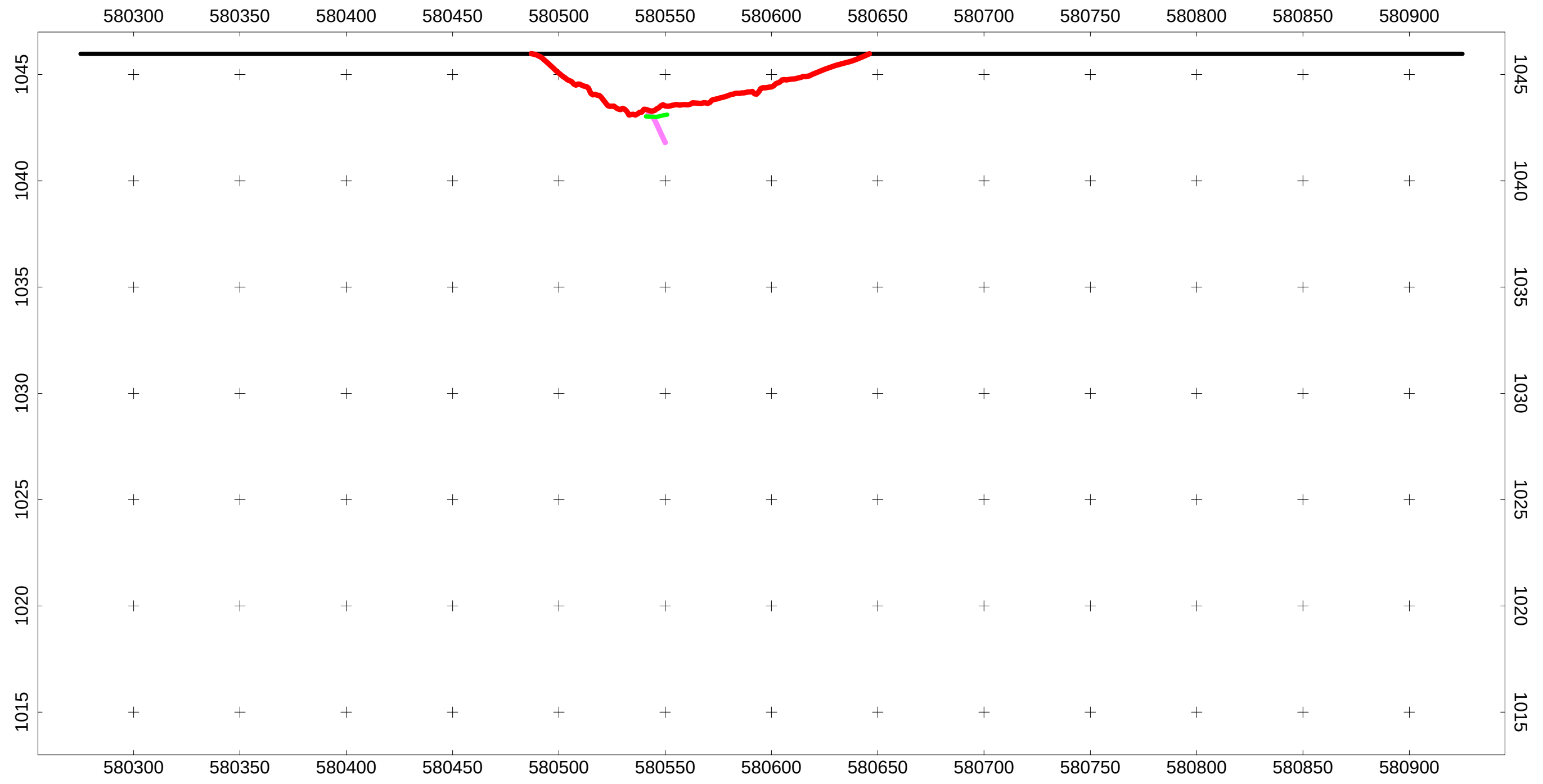
### Notes (production comments, incidents, other)

Crew demoblizes to Whitehorse.

## Appendix II

### Cross-sections

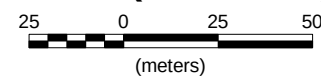
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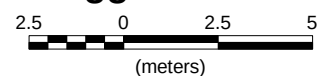
# LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

## Scale (horizontal)



## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

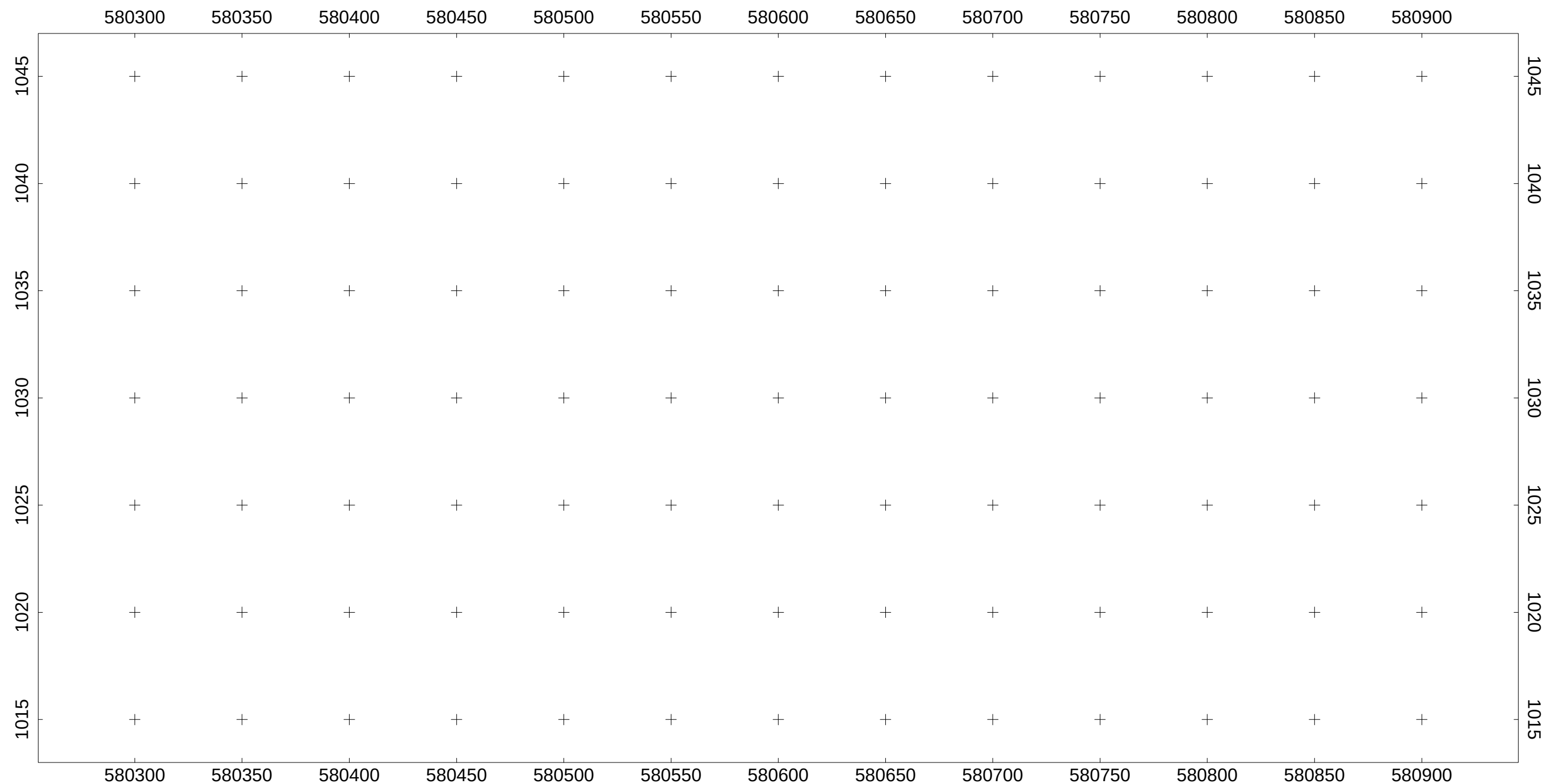
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6913750**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

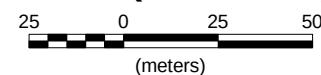
**AURORA GEOSCIENCES LTD.**



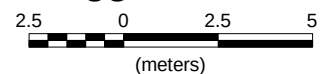
## LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

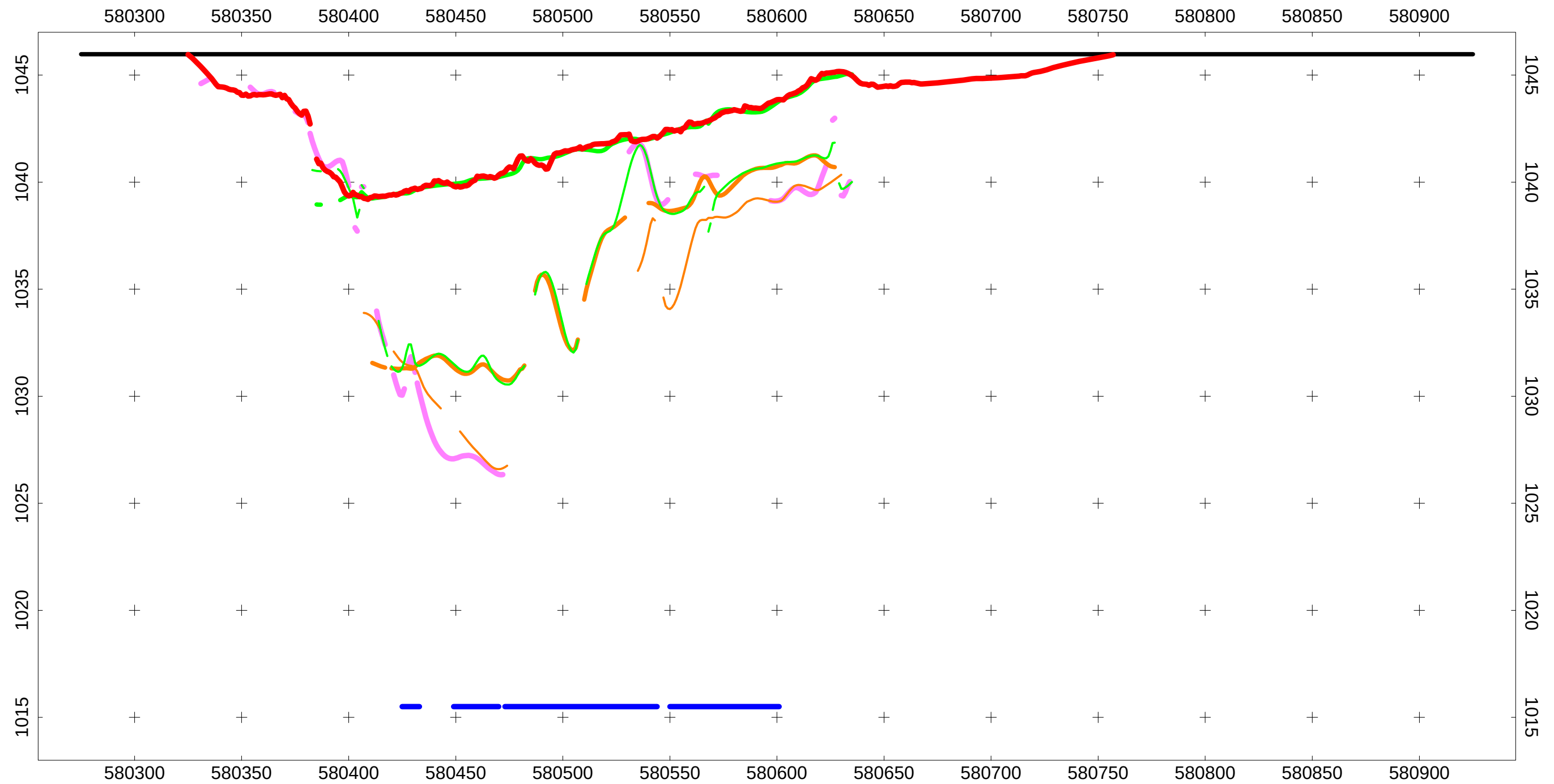
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6913800**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

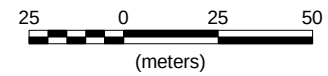
**AURORA GEOSCIENCES LTD.**



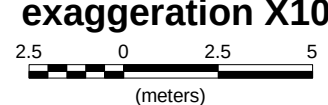
# LEGEND

- Water :
- Mudline :
- Feature 1 - Upper :
- Feature 1 - Lower :
- Feature 2 - Upper :
- Feature 2 - Lower :
- Feature 4 :
- Feature 5 :

## Scale (horizontal)



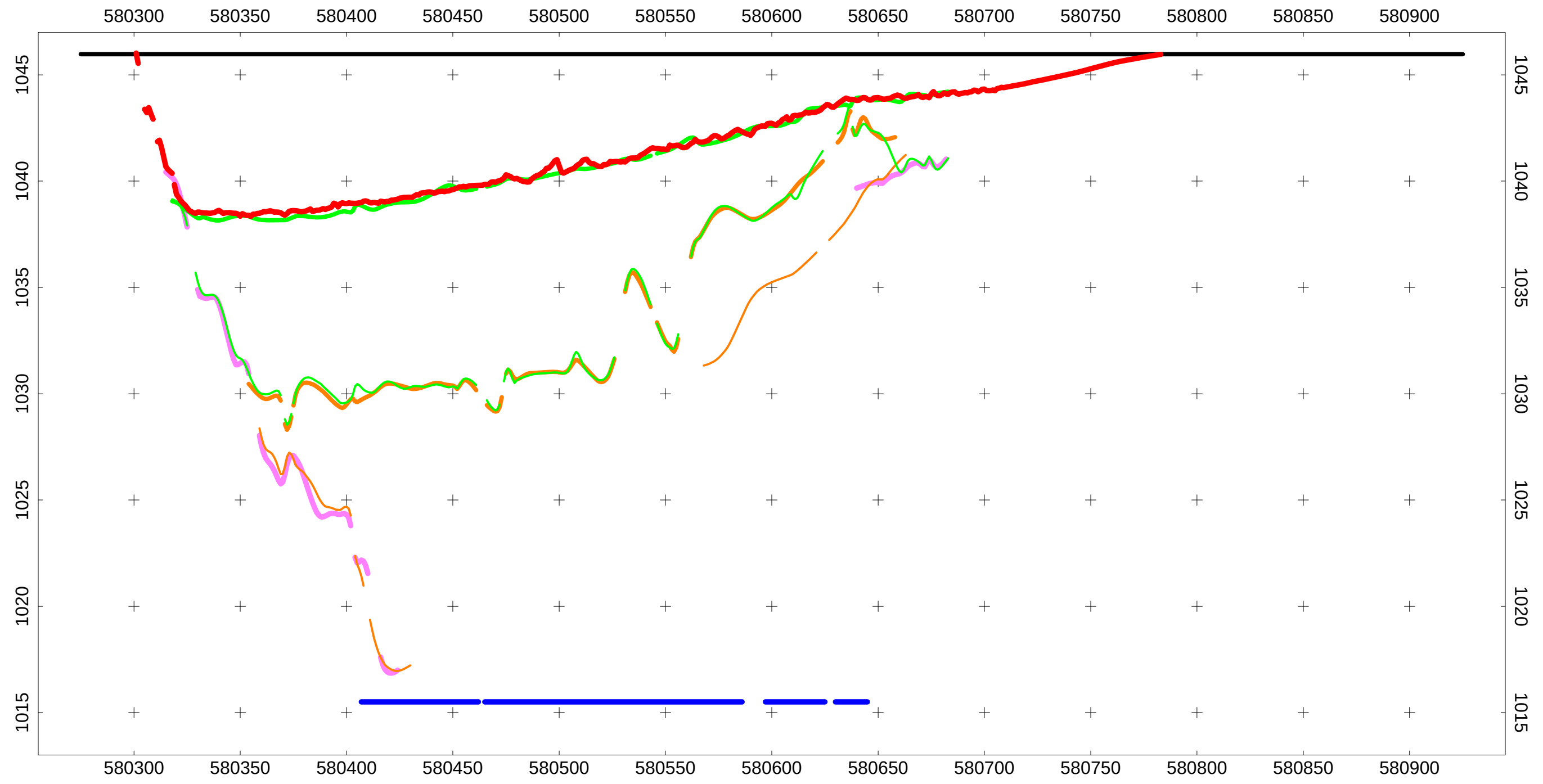
## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

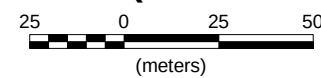
|                                                                                             |                                                                 |
|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| CH2M HILL LTD.                                                                              |                                                                 |
| INTERMEDIATE DAM POND<br>Bathymetric and Sub-Bottom Survey<br>Cross section at UTMN 6913850 |                                                                 |
| Surveyed Jun 11-18, 2016<br>Faro Mining Complex<br>NTS: 105k/06                             | Surveyed by: SS<br>Map drawn: Jul 27, 2016<br>NAD83 UTM Zone 8N |
| AURORA GEOSCIENCES LTD.                                                                     |                                                                 |



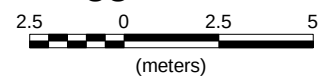
# LEGEND

- Water : ——
- Mudline : ——
- Feature 1 - Upper : ——
- Feature 1 - Lower : ——
- Feature 2 - Upper : ——
- Feature 2 - Lower : ——
- Feature 4 : ——
- Feature 5 : ——

## Scale (horizontal)



## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

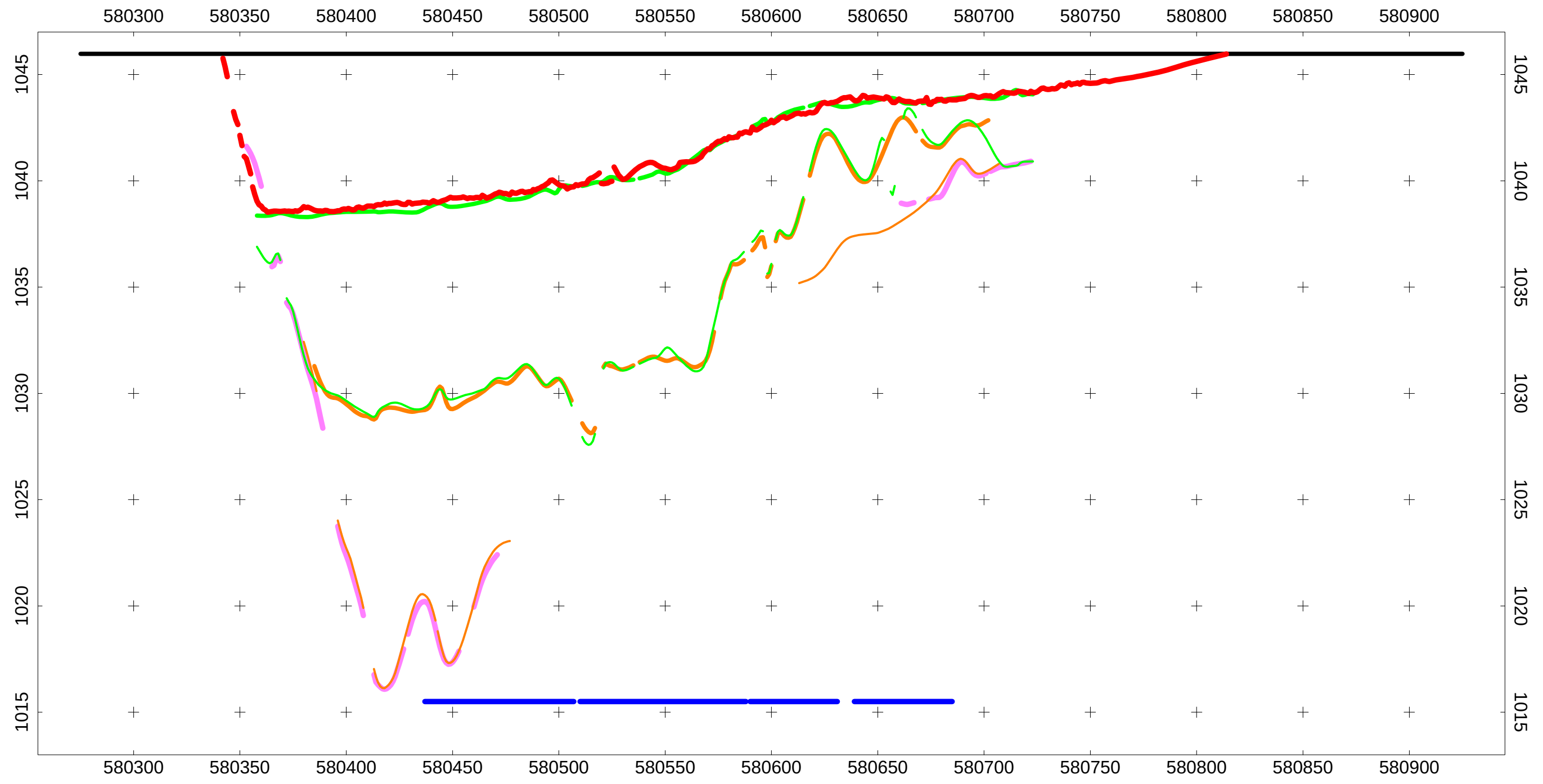
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6913900**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

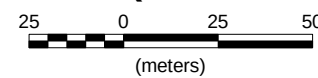
**AURORA GEOSCIENCES LTD.**



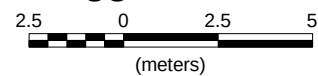
# LEGEND

- Water :
- Mudline :
- Feature 1 - Upper :
- Feature 1 - Lower :
- Feature 2 - Upper :
- Feature 2 - Lower :
- Feature 4 :
- Feature 5 :

## Scale (horizontal)



## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

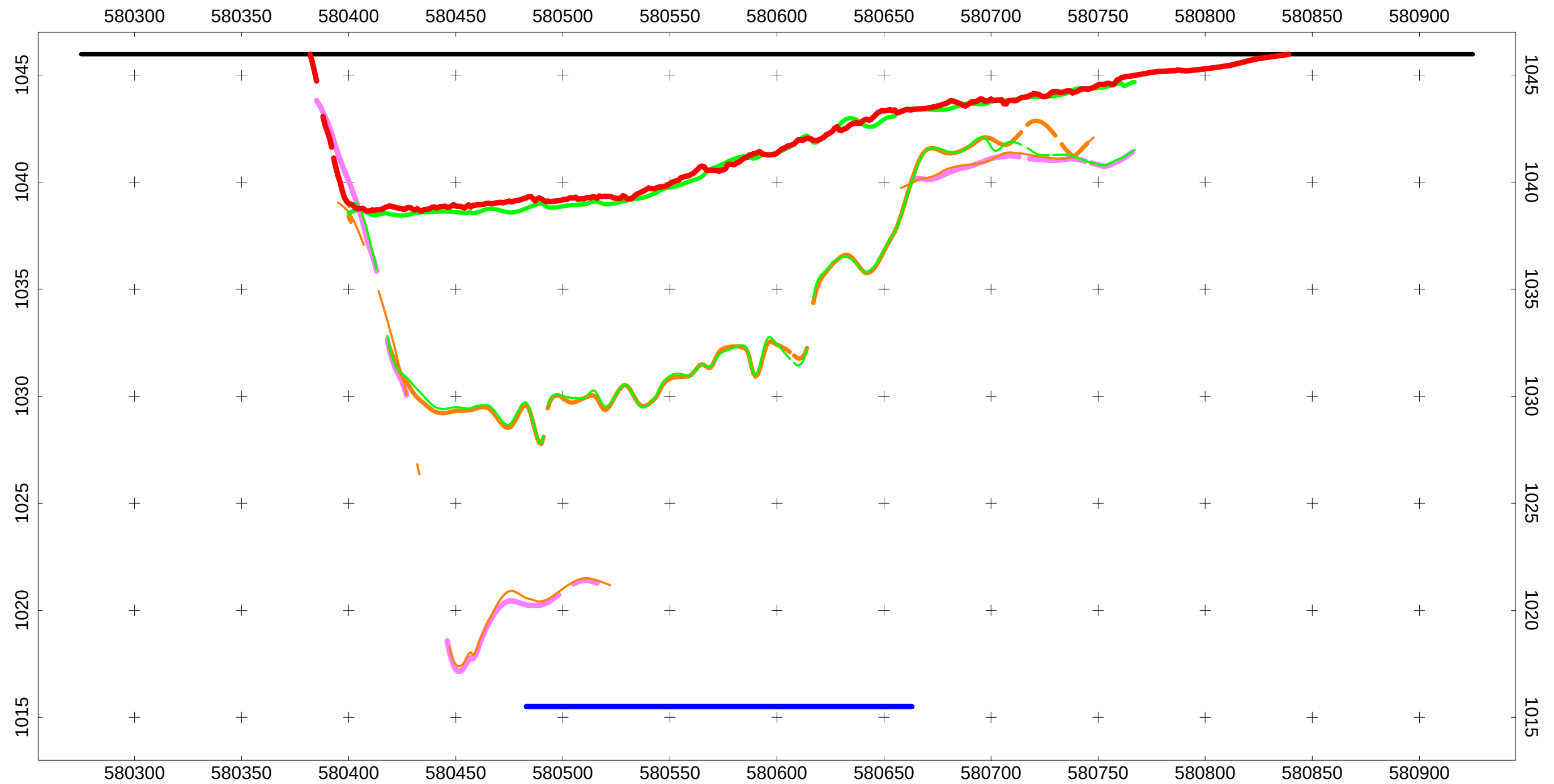
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6913950**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

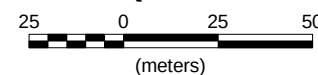
**AURORA GEOSCIENCES LTD.**



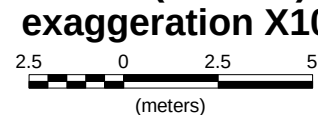
## LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

### Scale (horizontal)



### Scale (vertical)



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

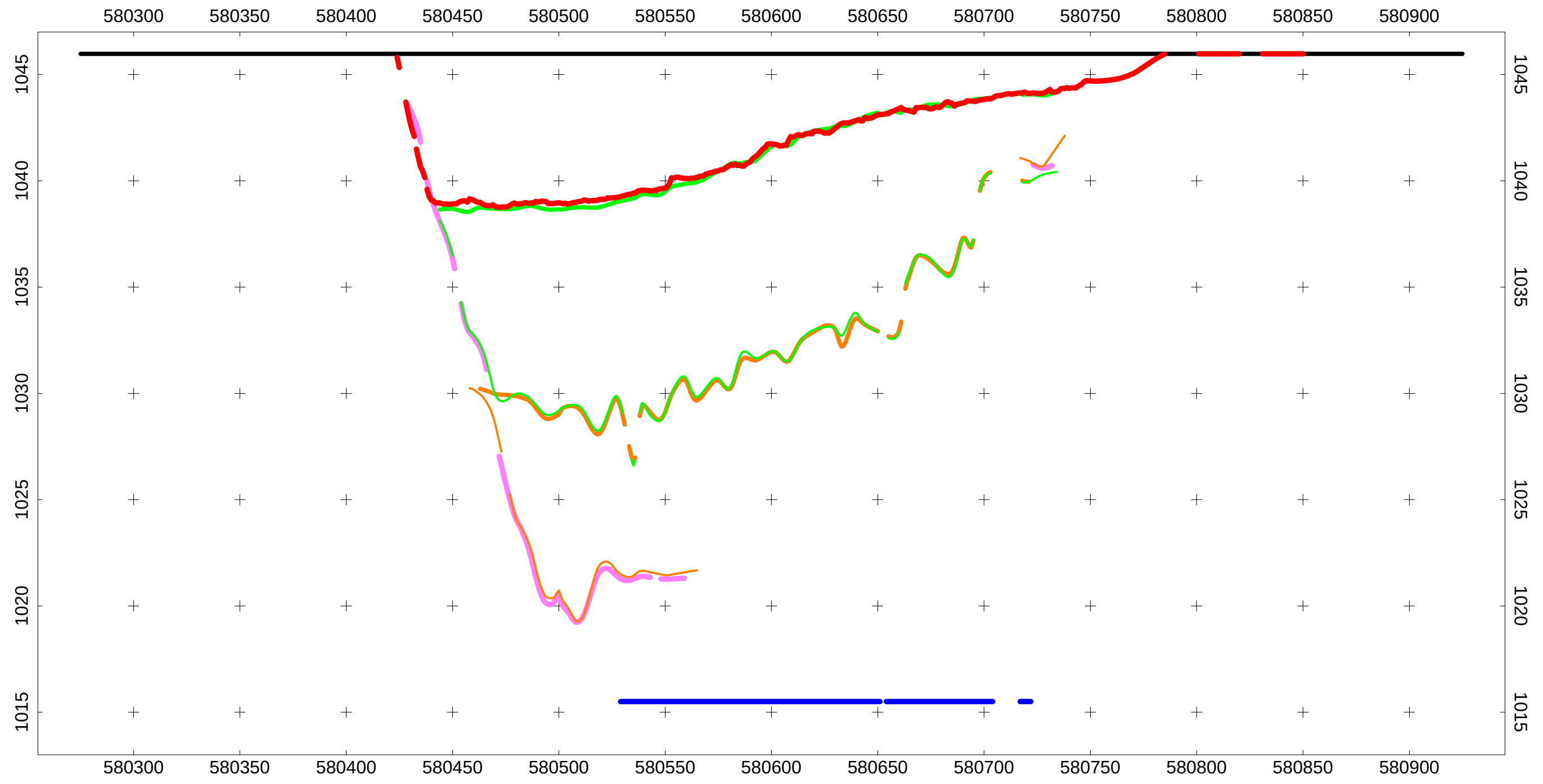
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914000**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

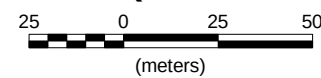
**AURORA GEOSCIENCES LTD.**



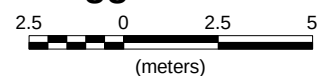
## LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

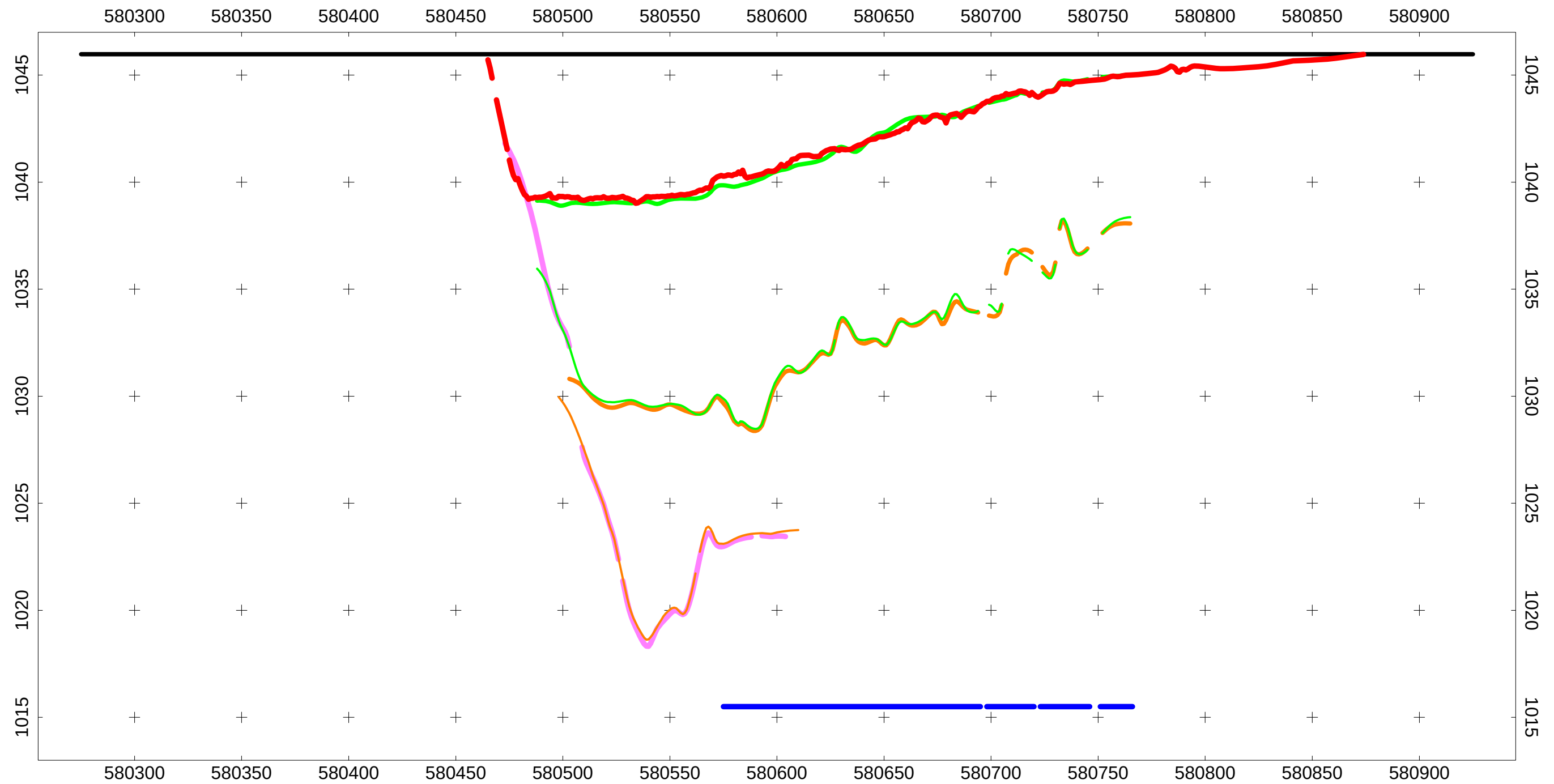
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTMN 6914050**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

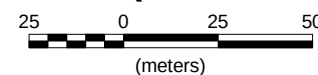
**AURORA GEOSCIENCES LTD.**



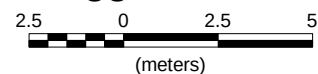
## LEGEND

- Water :
- Mudline :
- Feature 1 - Upper :
- Feature 1 - Lower :
- Feature 2 - Upper :
- Feature 2 - Lower :
- Feature 4 :
- Feature 5 :

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

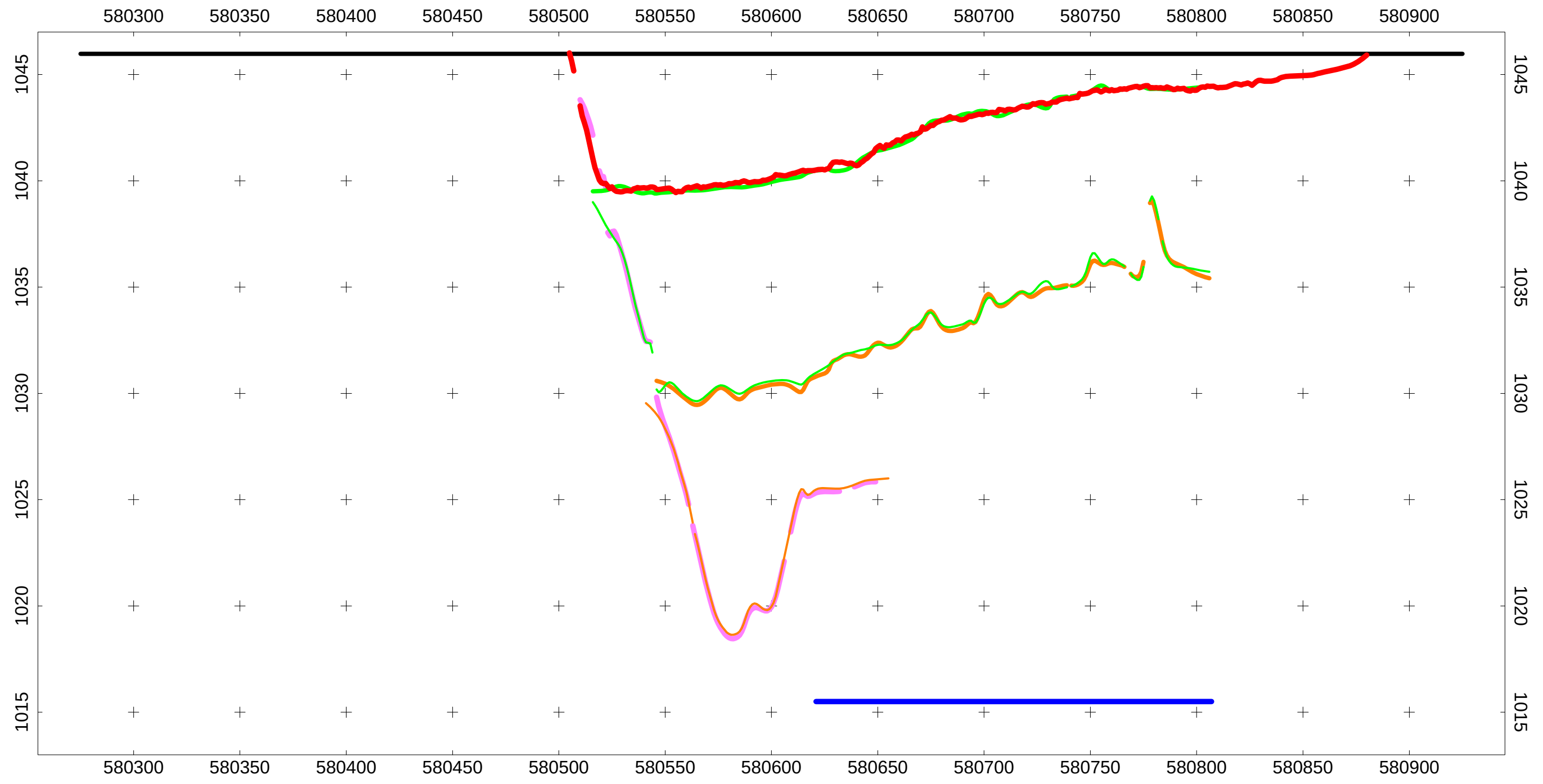
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914100**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

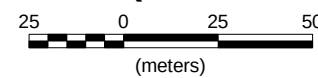
**AURORA GEOSCIENCES LTD.**



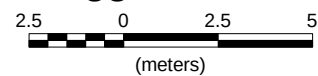
# LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

## Scale (horizontal)



## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

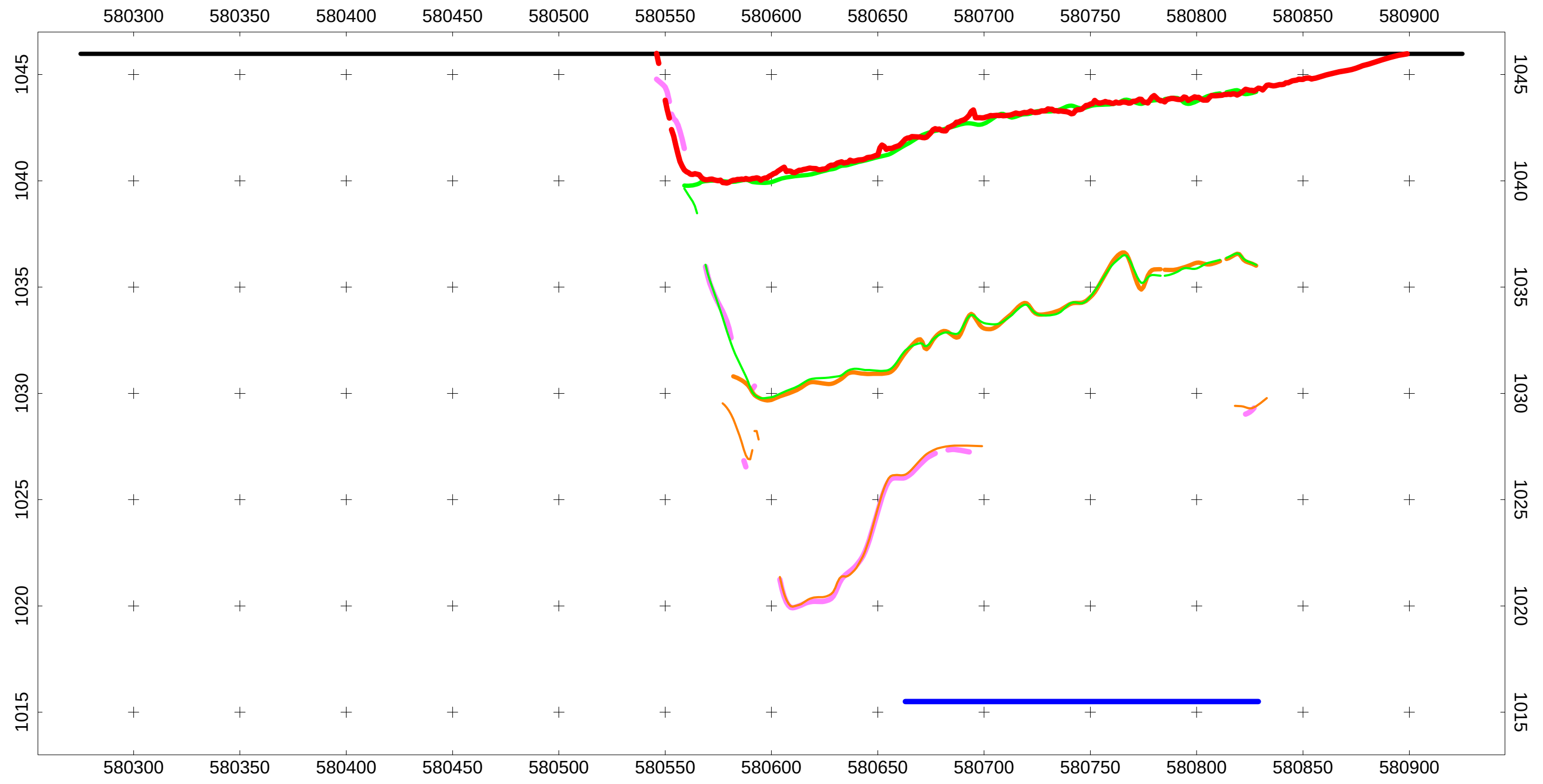
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914150**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

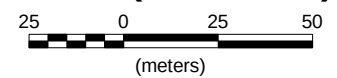
**AURORA GEOSCIENCES LTD.**



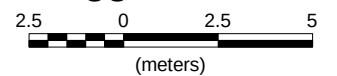
# LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

## Scale (horizontal)



## Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

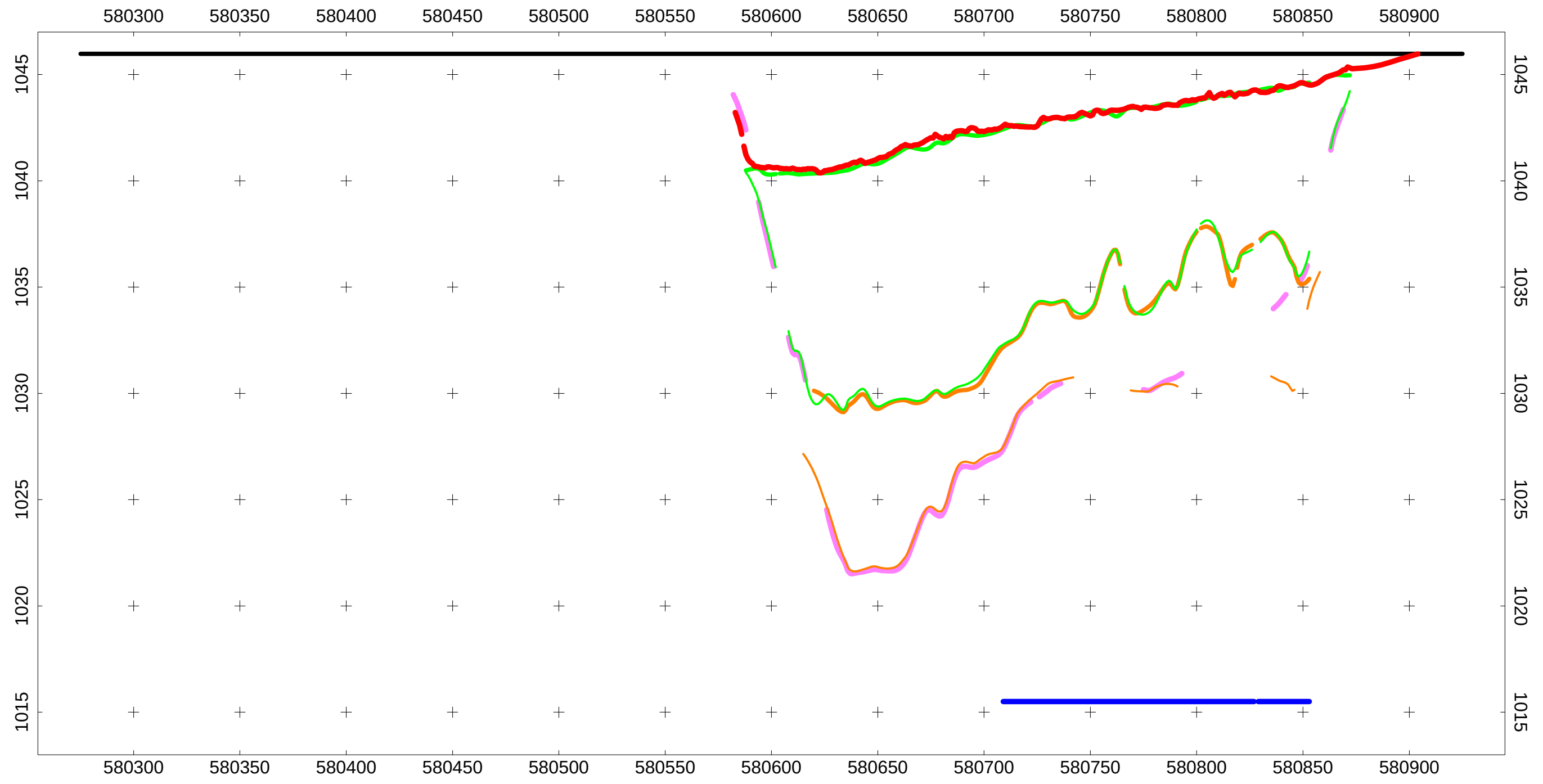
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914200**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

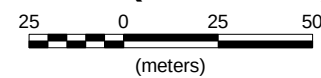
**AURORA GEOSCIENCES LTD.**



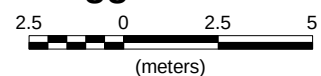
## LEGEND

- Water :
- Mudline :
- Feature 1 - Upper :
- Feature 1 - Lower :
- Feature 2 - Upper :
- Feature 2 - Lower :
- Feature 4 :
- Feature 5 :

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

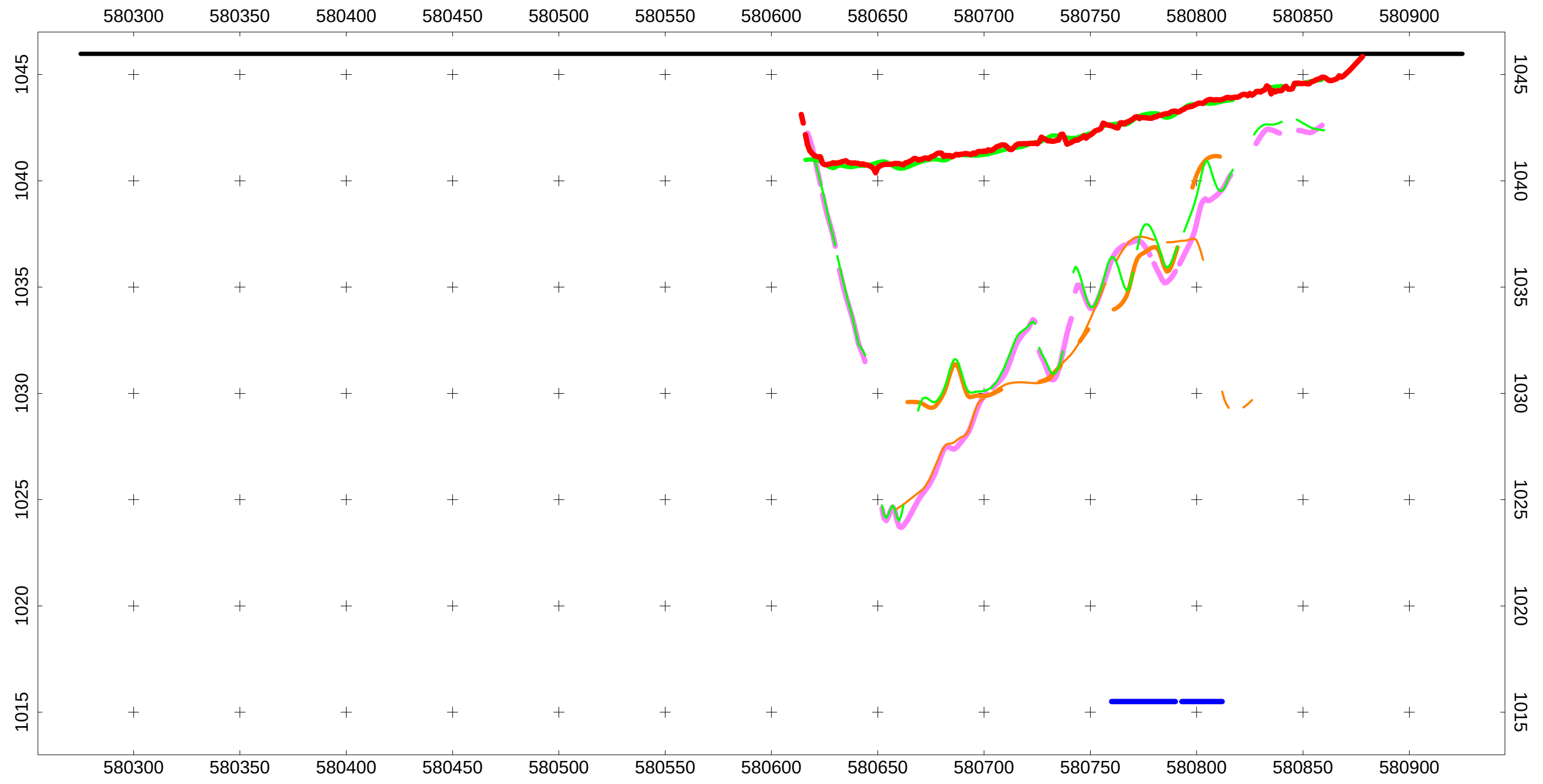
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914250**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

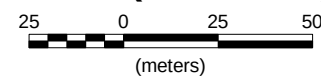
**AURORA GEOSCIENCES LTD.**



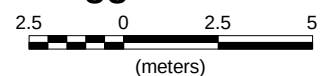
## LEGEND

- Water :
- Mudline :
- Feature 1 - Upper :
- Feature 1 - Lower :
- Feature 2 - Upper :
- Feature 2 - Lower :
- Feature 4 :
- Feature 5 :

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

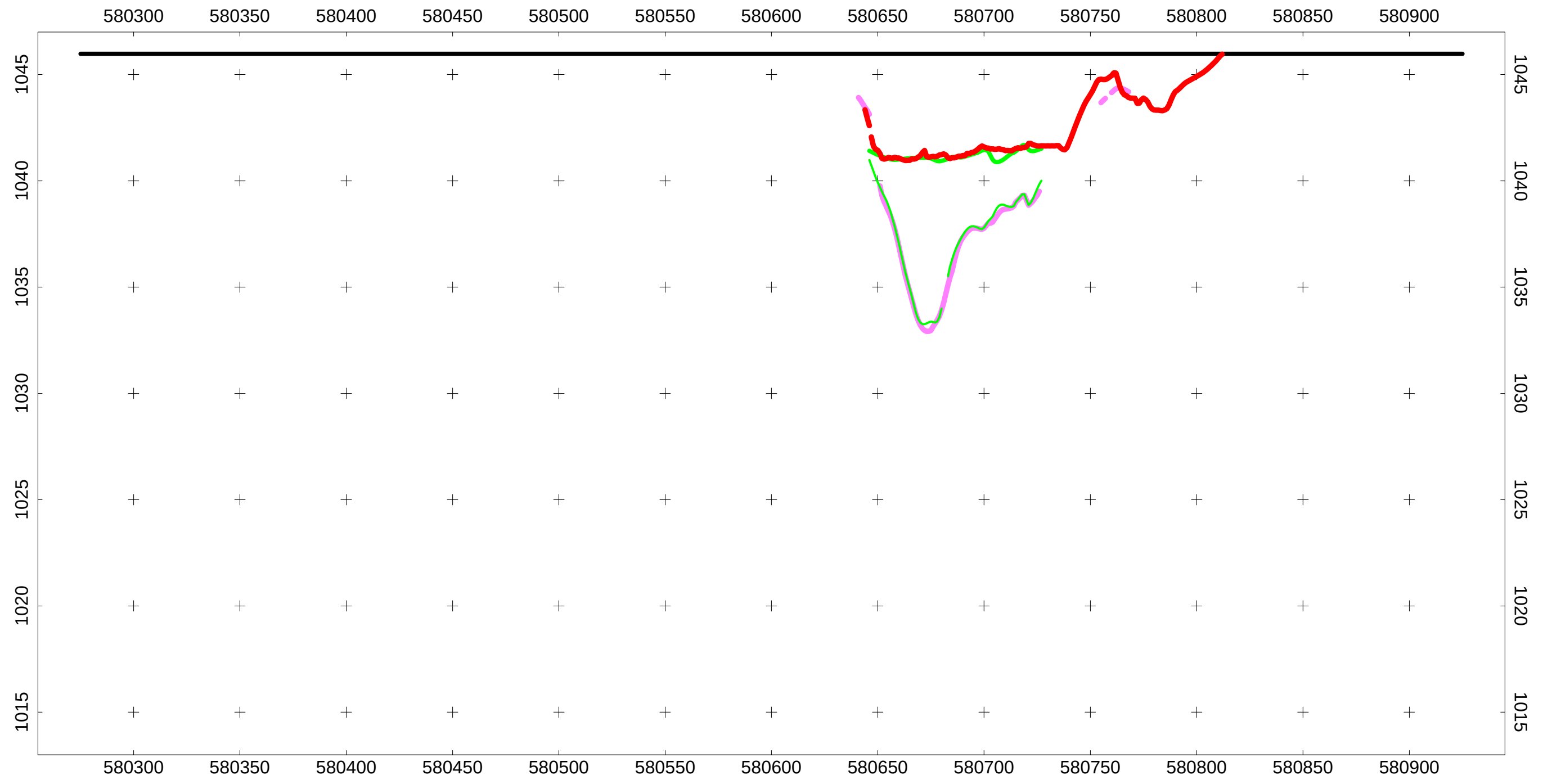
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914300**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

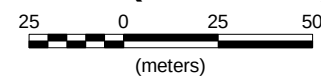
**AURORA GEOSCIENCES LTD.**



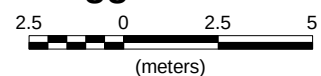
## LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

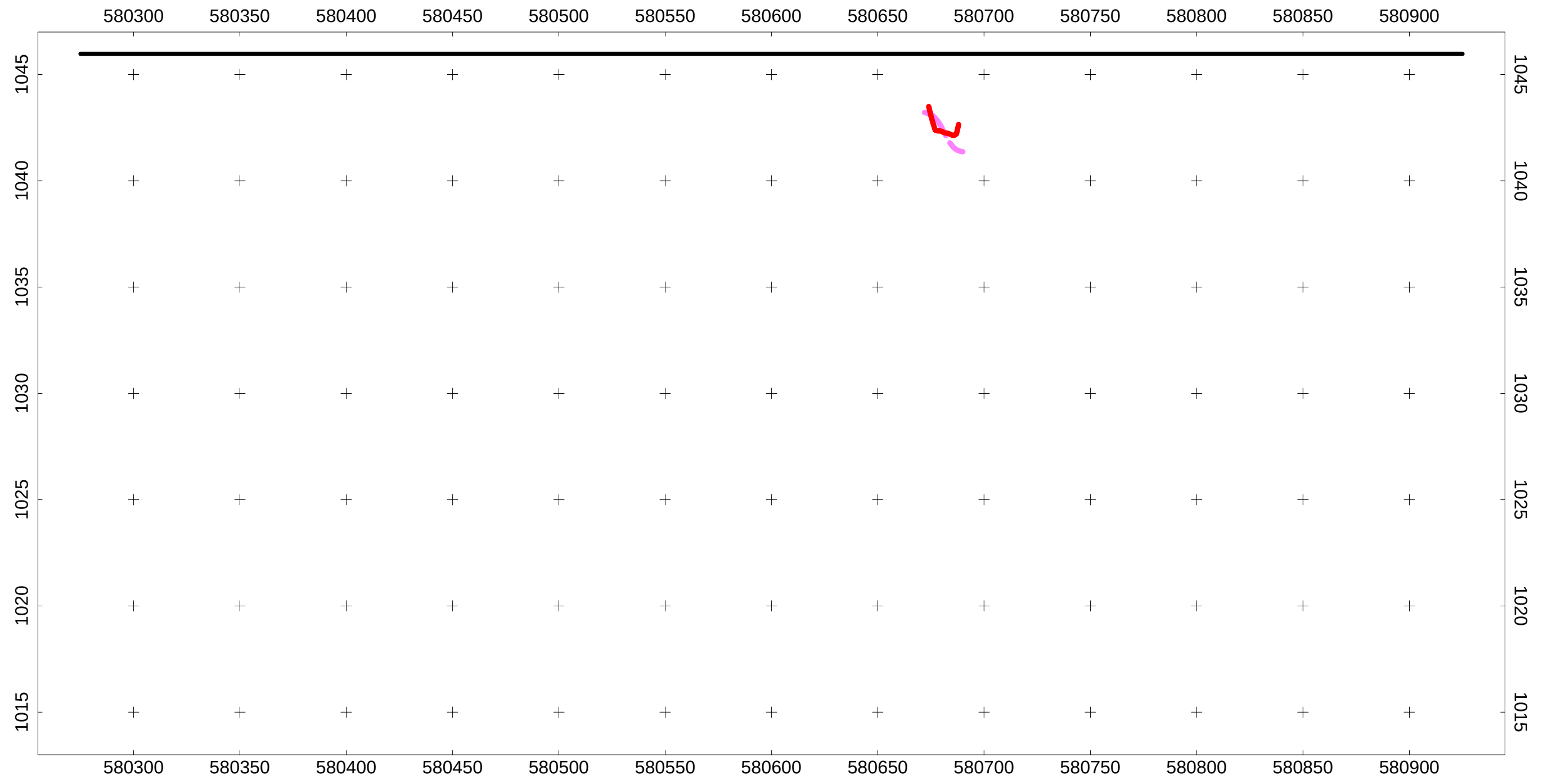
**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914350**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

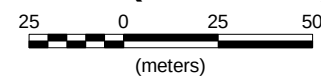
**AURORA GEOSCIENCES LTD.**



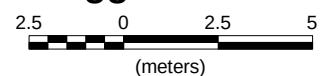
## LEGEND

- Water : —
- Mudline : —
- Feature 1 - Upper : —
- Feature 1 - Lower : —
- Feature 2 - Upper : —
- Feature 2 - Lower : —
- Feature 4 : —
- Feature 5 : —

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

**CH2M HILL LTD.**

**INTERMEDIATE DAM POND  
Bathymetric and Sub-Bottom Survey  
Cross section at UTMN 6914400**

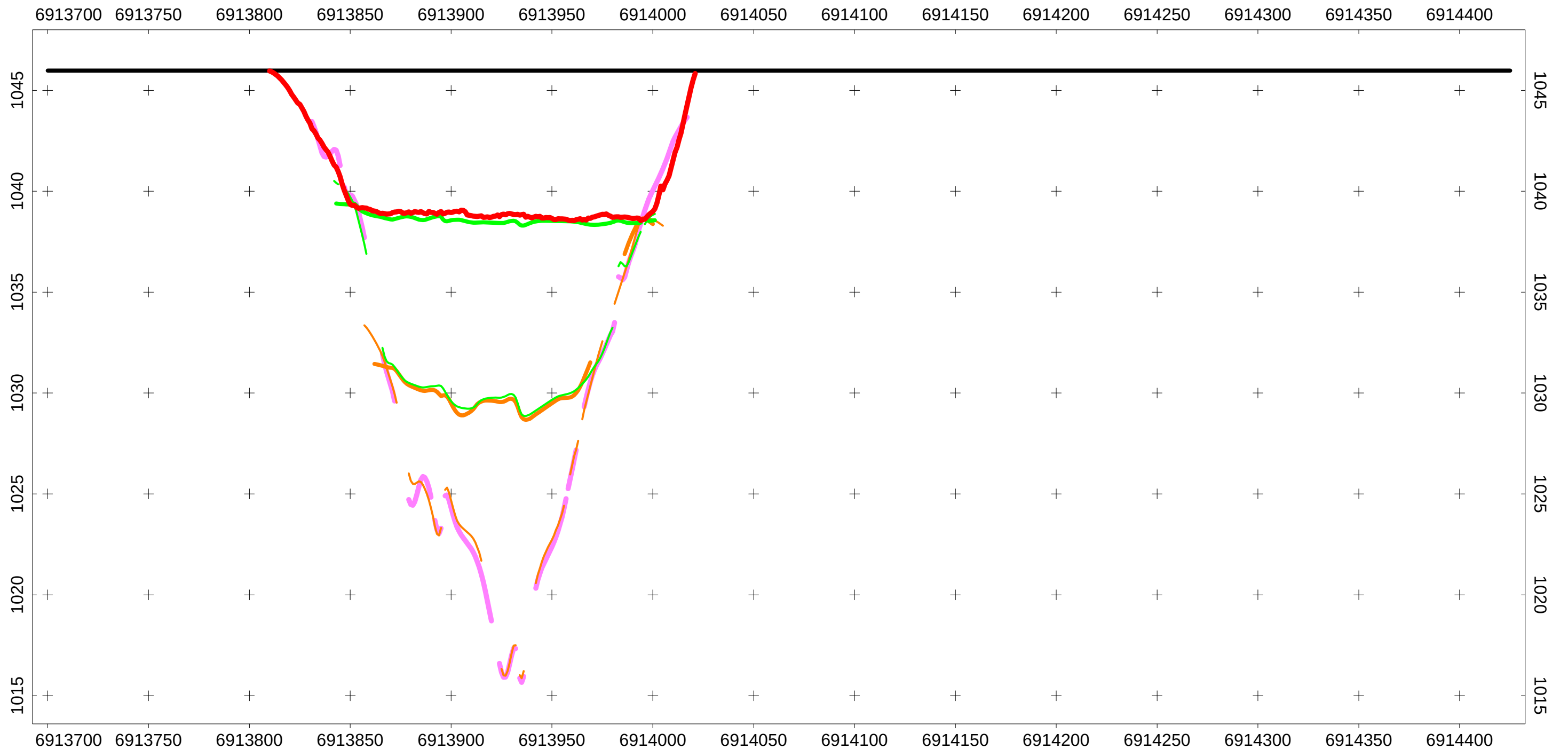
Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

**AURORA GEOSCIENCES LTD.**







## LEGEND

Water : 

Mudline : 

Feature 1 - Upper : 

Feature 1 - Lower : 

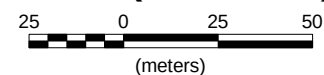
Feature 2 - Upper : 

Feature 2 - Lower : 

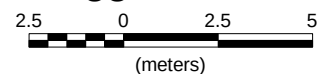
Feature 4 : 

Feature 5 : 

### Scale (horizontal)



**Scale (vertical)  
exaggeration X10**



**X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing**

**Y-AXIS - Orthometric elevation**

**CH2M HILL LTD.**

## INTERMEDIATE DAM POND

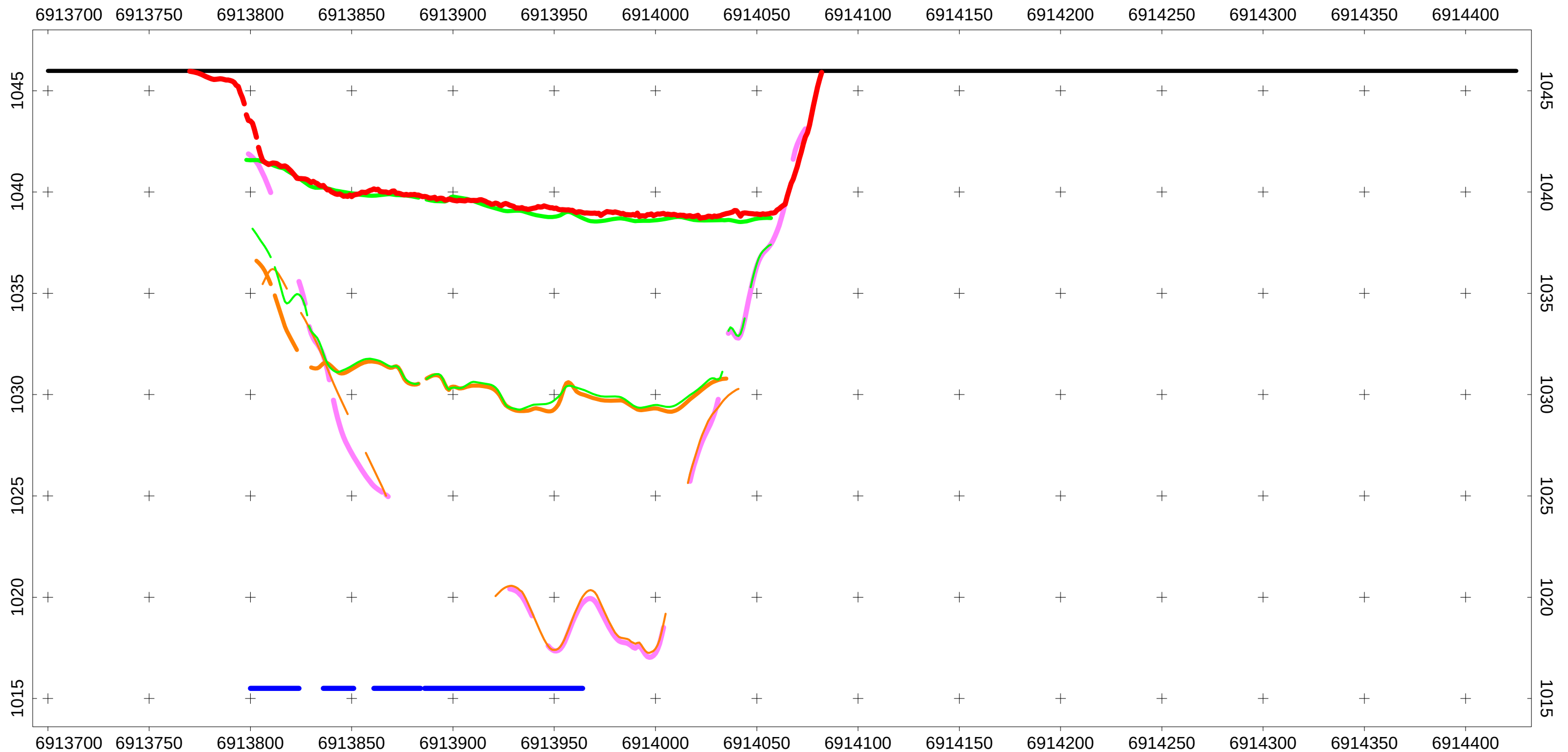
### Bathymetric and Sub-Bottom Survey

#### Cross section at UTME 580400

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.



## LEGEND

Water : 

Mudline : 

Feature 1 - Upper : 

Feature 1 - Lower : 

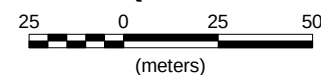
Feature 2 - Upper : 

Feature 2 - Lower : 

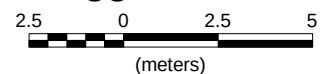
Feature 4 : 

Feature 5 : 

### Scale (horizontal)



**Scale (vertical)  
exaggeration X10**



**X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing**

**Y-AXIS - Orthometric elevation**

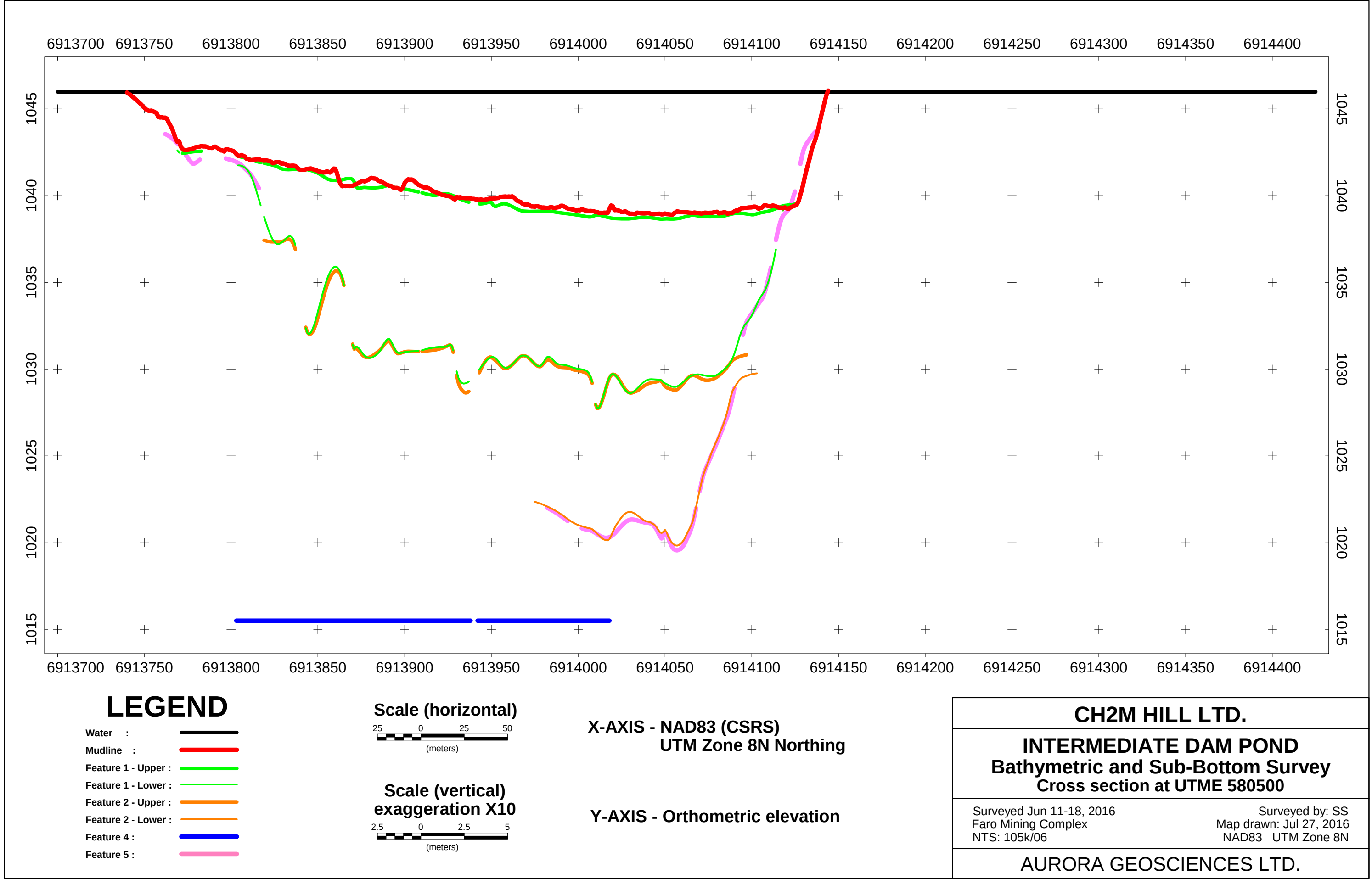
**CH2M HILL LTD.**

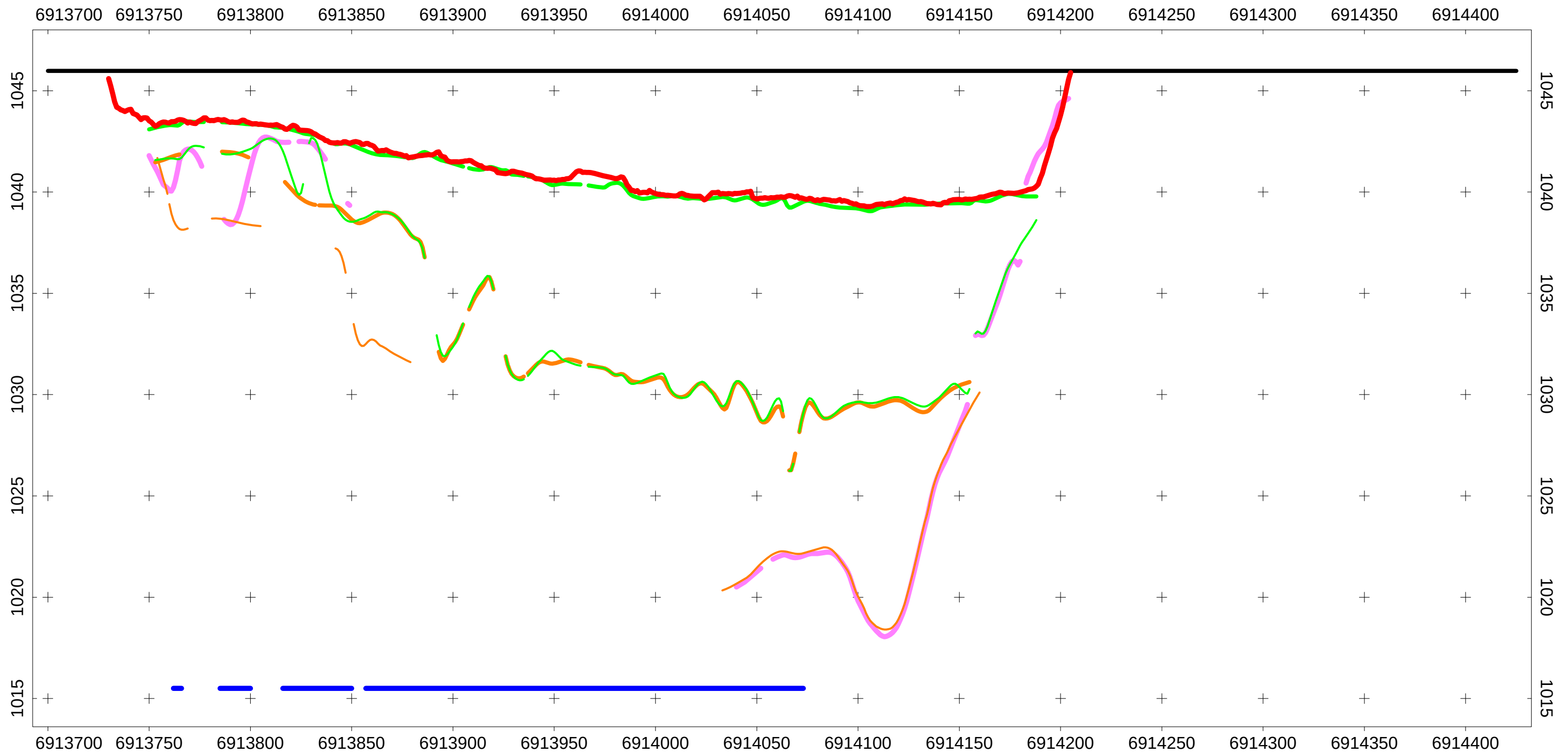
**INTERMEDIATE DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580450**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.





## LEGEND

Water : 

Mudline : 

Feature 1 - Upper : 

Feature 1 - Lower : 

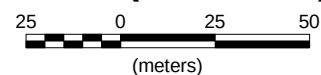
Feature 2 - Upper : 

Feature 2 - Lower : 

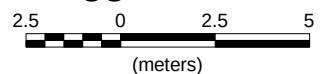
Feature 4 : 

Feature 5 : 

### Scale (horizontal)



**Scale (vertical)  
exaggeration X10**



**X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing**

**Y-AXIS - Orthometric elevation**

**CH2M HILL LTD.**

## INTERMEDIATE DAM POND

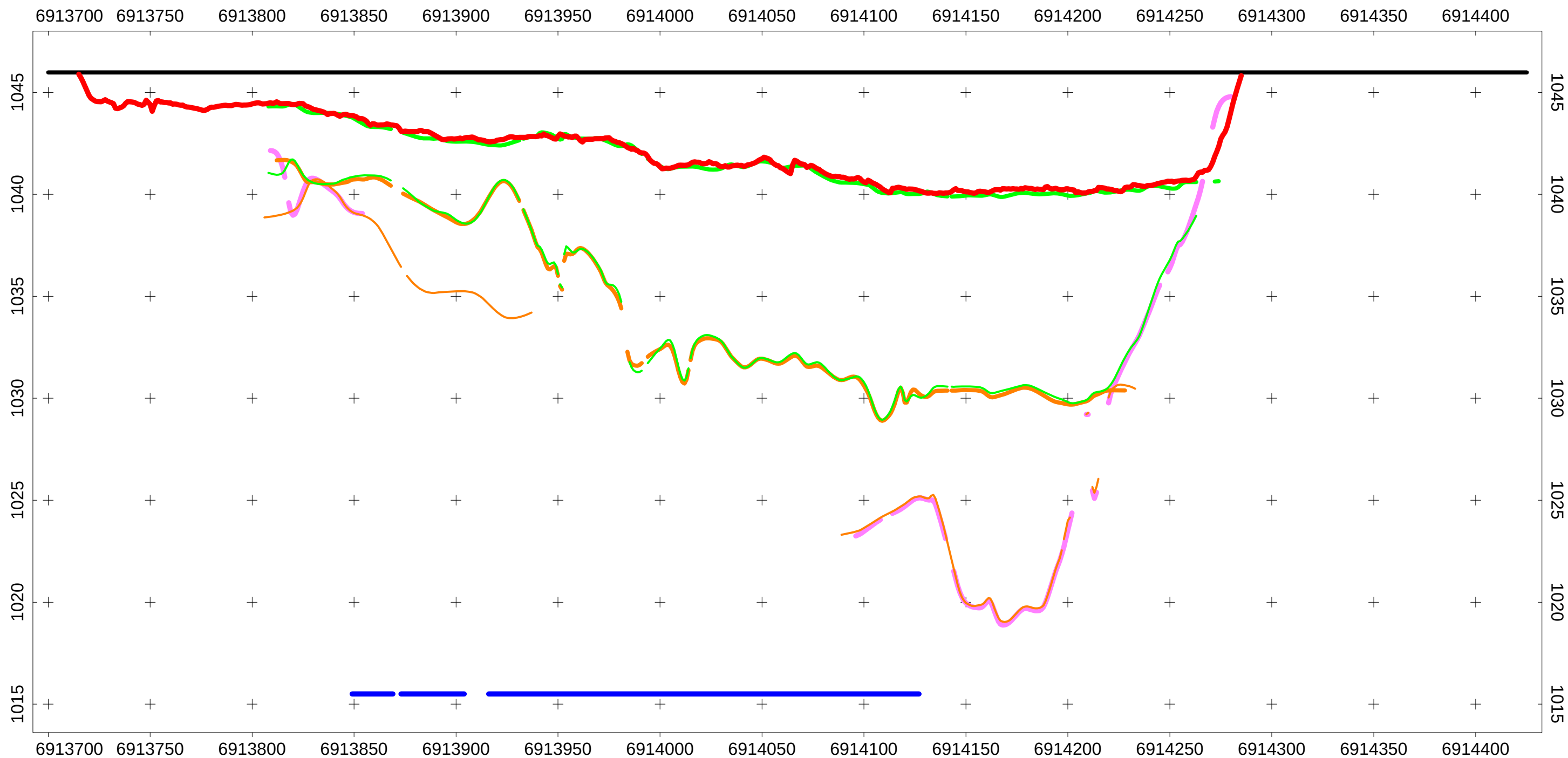
### Bathymetric and Sub-Bottom Survey

#### Cross section at UTME 580550

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.



## LEGEND

Water : 

Mudline : 

Feature 1 - Upper : 

Feature 1 - Lower : 

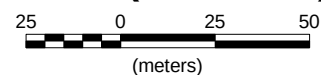
Feature 2 - Upper : 

Feature 2 - Lower : 

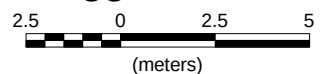
Feature 4 : 

Feature 5 : 

### Scale (horizontal)



**Scale (vertical)  
exaggeration X10**



**X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing**

**Y-AXIS - Orthometric elevation**

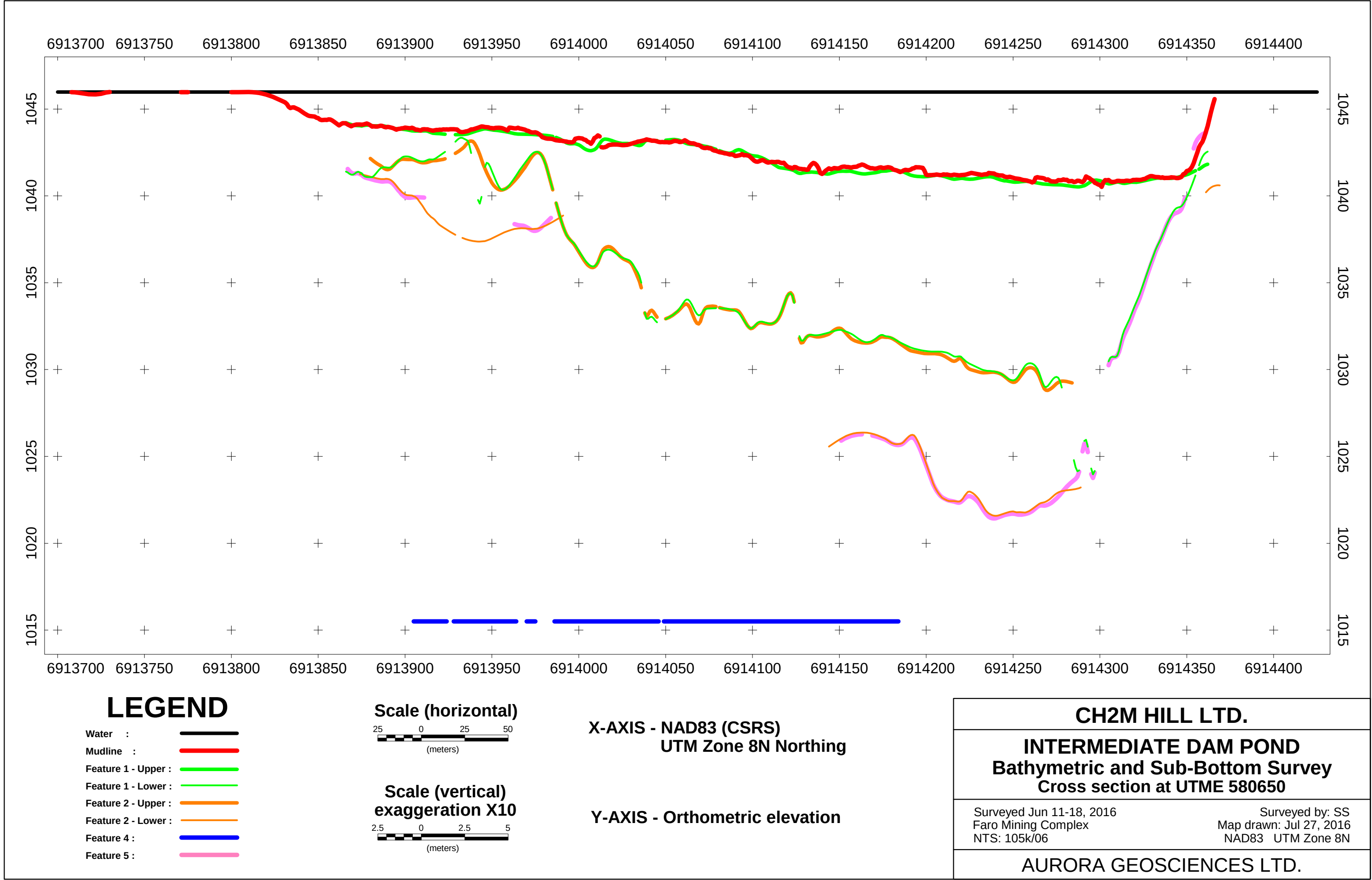
**CH2M HILL LTD.**

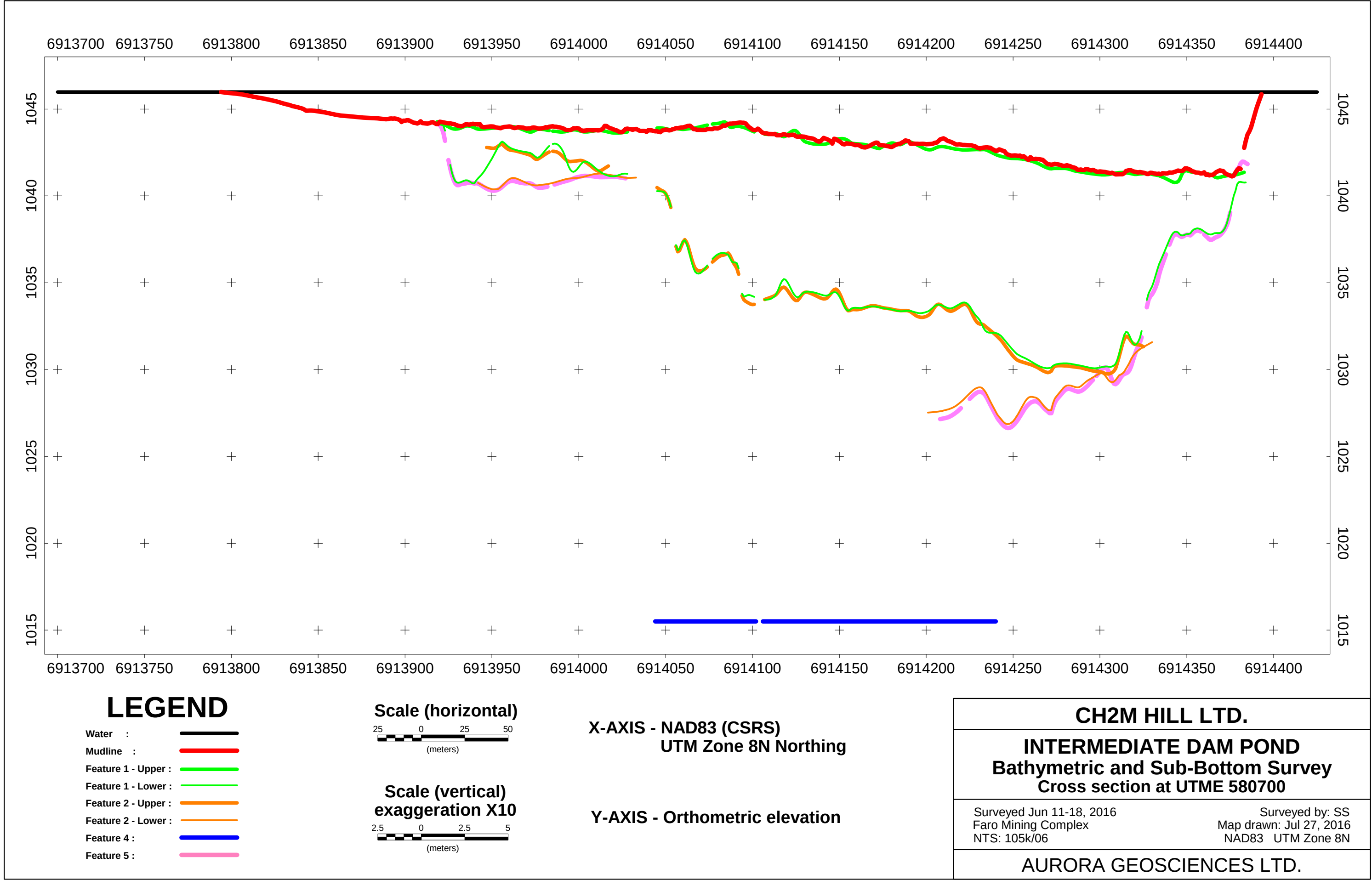
**INTERMEDIATE DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580600**

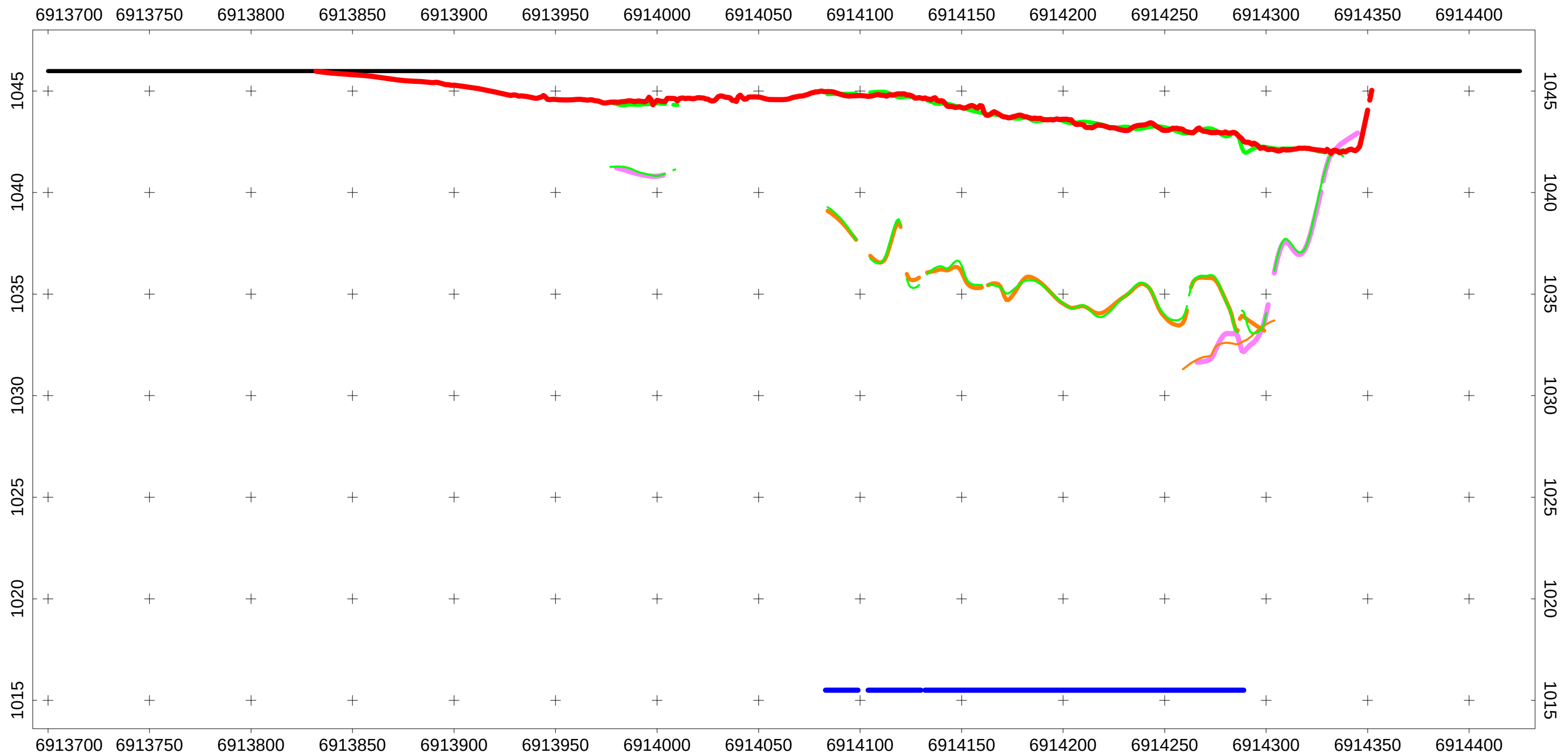
Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

AURORA GEOSCIENCES LTD.



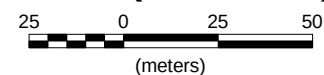




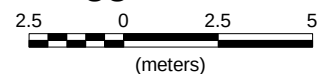
## LEGEND

Water :   
Mudline :   
Feature 1 - Upper :   
Feature 1 - Lower :   
Feature 2 - Upper :   
Feature 2 - Lower :   
Feature 4 :   
Feature 5 : 

### Scale (horizontal)



### Scale (vertical) exaggeration X10



X-AXIS - NAD83 (CSRS)  
UTM Zone 8N Northing

Y-AXIS - Orthometric elevation

**CH2M HILL LTD.**

**INTERMEDIATE DAM POND**  
**Bathymetric and Sub-Bottom Survey**  
**Cross section at UTME 580750**

Surveyed Jun 11-18, 2016  
Faro Mining Complex  
NTS: 105k/06

Surveyed by: SS  
Map drawn: Jul 27, 2016  
NAD83 UTM Zone 8N

**AURORA GEOSCIENCES LTD.**







**Appendix III**

**EdgeTech jsf format**

---

# ***EDGETECH SONAR DATA FILE FORMAT***

## **DESCRIPTION OF THE EDGETECH (.jsf) FILE FORMAT**

**Document No. 990-0000048-1000**

***Revision: 1.8 / October 2009***



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## TABLE OF CONTENTS

|                                                                |    |
|----------------------------------------------------------------|----|
| INTRODUCTION .....                                             | 3  |
| C/C++ Code Example for Reading a JSF File .....                | 4  |
| 16-Byte Message Header .....                                   | 4  |
| Message Type 80: Sonar Data Message (segydefs.h) .....         | 6  |
| Navigation data .....                                          | 8  |
| Pulse Information.....                                         | 9  |
| CPU Time .....                                                 | 9  |
| Weighting Factor .....                                         | 10 |
| Orientation Sensor Data.....                                   | 10 |
| User defined area from 180-239 .....                           | 11 |
| NMEA Navigation Data .....                                     | 11 |
| Other User Defined Data .....                                  | 11 |
| Sonar Trace Data .....                                         | 12 |
| Message Type 82: Side Scan Data Message (sidescandefs.h) ..... | 13 |
| Computer date / time data acquired .....                       | 14 |
| Auxiliary sensor information .....                             | 14 |
| Sonar Trace Data .....                                         | 14 |
| Message Type 2020: Pitch Roll Data.....                        | 15 |
| Message Type 2002: NMEA String.....                            | 16 |
| Message Type 2060: Pressure Sensor Reading.....                | 16 |
| Message Type 2080: Doppler Velocity Log Data (DVL).....        | 16 |
| Message Type 2090: Situation Message .....                     | 17 |
| Message Type 182: System Information Message.....              | 19 |

## **INTRODUCTION**

EdgeTech topsides by default record in JSF file format, which consists of a set of messages. Each message begins with a 16-byte header which indicates the type of data to follow and its size. Different types of data will have different message numbers (Message Type field). Sonar data is recorded on a per-channel basis. Therefore, for a single frequency side-scan system there will be two messages per ping – one for port (channel 0) and one for starboard (channel 1). Other types of sensors (such as pitch roll) will have their own message numbers as well, and will similarly have a single message per reading set. A typical file might have the following:

- Header1:    Sonar Data for Subsystem SSL and channel 0 (Port Side)
  - Sonar Data Header for Message 1 (Ping number 1, Port, Time Stamp)
  - Sonar Data for Message 1 (16-bit integers – one per sample)
- Header2:    Sonar Data for Subsystem SSL and channel 1 (Starboard Side)
  - Sonar Data Header for Message 2 (Ping number 1, Starboard, Time Stamp)
  - Sonar Data for Message 2 (16-bit integers – one per sample)
- Header3:    Pitch Roll reading
  - Serial Device Standard Header (Time Stamp)
  - Pitch Roll Data Structure
- Header4:    Sonar Data for Subsystem SB
  - Sonar Data Header for Message 4 (Ping number 1, Time Stamp)
  - Sonar Data for Message 4 (16-bit integer pairs – one pair per sample)

Since data is stored in a binary format, the byte ordering of 16-bit and 32-bit values is important. JSF uses little endian (Intel) format for binary data where the least significant bytes are stored first. This is the native format for Intel x86 computers such as the IBM PC and compatibles. If data is read on a big endian machine (such as most Sun Workstations), you will need to byte reverse the data so that the 2 bytes of a 16-bit value are flipped, and the 4 bytes of a 32-bit value are flipped (Bytes 0, 1, 2, 3 become Bytes 3, 2, 1, 0).

EdgeTech topsides often have an option to limit the size of created files, and will generate a sequence of files for a long data run. In this case, the concatenation of these files will yield a valid JSF file for a longer run time if desired.

This document describes the messages of common interest to those processing JSF files. It is not intended to be a complete description of all valid messages.

## C/C++ Code Example for Reading a JSF File

Here is a C code example for reading an entire JSF file.

```
void readFile(char *fileName)
{
    FILE *fid;
    int i;
    SonarMessageHeaderType hdr; /* Basic 16-byte message header */

    fid = fopen(fileName, "rb");
    if (fid == NULL) return;

    while(!feof(fid))
    {
        if (fread(&hdr, sizeof(hdr), 1, fid) != 1)
            break;
        if (hdr.startOfMessage != SONAR_MESSAGE_HEADER_START)
        {
            printf("Invalid file format\n");
            break;
        }
        for(i = 0; i < hdr.byteCount; i++)
        {
            if (getc(fid) == EOF)
            {
                printf("Invalid file format\n");
                break;
            }
        }
        printf("Message Type %d\n", hdr.sonarMessage);
    }
    fclose(fid);
}
```

Details of data structure of the types of messages in a JSF file are described below.

### **16-Byte Message Header**

A JSF file is a collection of messages, and every message in a JSF file begins with a sixteen byte long header. It identifies the type and size of the message, as well as the originating subsystem and channel.

| Byte Offsets | Description                                                                                                            | Size   |
|--------------|------------------------------------------------------------------------------------------------------------------------|--------|
| 0 – 1        | Marker for the Start of Header (always 0x1601)                                                                         | UINT16 |
| 2            | Version number of protocol used (e.g.10)                                                                               | UINT8  |
| 3            | Session Identifier                                                                                                     | UINT8  |
| 4 – 5        | Message Type (e.g. 80 = Sonar Trace Data)                                                                              | UINT16 |
| 6            | Command Type<br>2 = Normal data source                                                                                 | UINT8  |
| 7            | Subsystem Number<br>0 = Sub-bottom<br>20 = Single or Lower Frequency Side Scan<br>21 = Higher Frequency Side Scan      | UINT8  |
| 8            | Channel for a Multi-Channel Subsystem<br>For Side Scan Subsystems, 0 = Port, 1 = Starboard<br>For Serial Ports: Port # | UINT8  |
| 9            | Sequence Number                                                                                                        | UINT8  |
| 10 – 11      | Reserved                                                                                                               | UINT16 |
| 12 – 15      | Size of following Message in Bytes                                                                                     | UINT32 |

Every message header begins (bytes 0 - 1) with a 0x1601 start of a message header marker. This serves as a sanity check during file processing.

The Protocol level (byte 2) indicates which revision of this specification was used to write that message. Messages of differing protocol levels may be interspersed in the same file. Maintaining backward compatibility in the public interface is a priority. Protocol level changes involve additional messages or changes to the non-public portion of the interface.

The session identifier (byte 3) is used for internal routing and can be ignored.

The Message Type field (bytes 4 - 5) defines the type of data to follow. Some data formats of interest are detailed in the following sections. If the Message Type field contains an unwanted or unknown (i.e. not defined below) type, use the Size of the message (bytes 12 – 15) to skip over the data to the next Message Header.

The message protocol is used for command and control as well as data. The command type field (byte 6) while of interest during real time operation can normally be ignored when reading JSF files.

The subsystem number (byte 7) is used to determine the source of the data. Common subsystem assignments are as follows:

- Sub-bottom data - 0
- Single frequency sidescan data - 20

---

|                                                    |       |
|----------------------------------------------------|-------|
| Lower frequency data of a dual frequency sidescan  | - 20  |
| Higher frequency data of a dual frequency sidescan | - 21  |
| Raw serial data                                    | - 100 |
| Parsed serial data                                 | - 101 |

The channel (byte 8) is zero for single channel (most sub-bottom) systems. For most sidescan systems, it is zero for port and one for starboard. For serial port data the channel number is the logical port number, which often differs from the physical COM port in use. The sequence number (byte 9) and reserved fields (bytes 10 - 11) can normally be ignored when reading JSF files.

The byte count (bytes 12 – 15) is the number of bytes until the next start of message header. This is the amount of additional data to read if processing the current message, or the amount of data to skip over if the current message is not of interest.

### **Message Type 80: Sonar Data Message (jsfdefs.h)**

The Sonar Data Message consists of a single ping (receiver sounding period) of data for a single channel (such as Port Side Low Frequency Side-Scan). Standard sidescan sub-systems have two channels of data, port and starboard. Standard sub-bottom sub-systems have a single channel of data. Data files with higher channel counts exist. Which fields have data present depends on the system used and data acquisition procedures. This message may contain data from multiple non-acoustic sensors. Non-acoustic data contained in this message will often not be time interpolated. EdgeTech strongly recommends that if high positional or situational accuracy is required that the individual sensor messages be processed. Otherwise, this may be the only message that will need to be interpreted in a JSF file. Validity flags indicate which auxiliary fields are populated. By convention, if a value is not present the field is set to 0.

A Sonar Data Message consists of a 240-byte header, which is very similar to a traditional SEG Y header, and the actual acoustic sample data follows the header. This 240-byte header described below:

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                             | Size      |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Ping Time in seconds [since the start of time based on time() function] (1/1/1970) (added in protocol version 8) <sup>1</sup>                                                                                                                                                                                                                                           | INT32     |
| 4 – 7        | Starting Depth (window offset) in samples<br>- usually zero                                                                                                                                                                                                                                                                                                             | UINT32    |
| 8 – 11       | Ping Number (increments with each ping)                                                                                                                                                                                                                                                                                                                                 | UINT32    |
| 12 – 15      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 2 |
| 16 – 17      | MSBs – Most Significant Bits – High order bits to extend 16 bit unsigned short values to 20 bits. The 4 MSB bits become the most significant portion of the new 20 bit value.<br>Bits 0 - 3 – start frequency<br>Bits 4 - 7 – end frequency<br>Bits 8 – 11 – samples in this packet<br>Bits 12 – 15 – reserved<br>(added in protocol version 10)(see description below) | UINT16    |
| 18 – 27      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 5 |
| 28 – 29      | ID Code (always 1)<br>1 = Seismic Data                                                                                                                                                                                                                                                                                                                                  | INT16     |
| 30 – 31      | Validity Flag (See mapping below)                                                                                                                                                                                                                                                                                                                                       | UINT16    |
| 32 – 33      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | UINT16    |
| 34 – 35      | Data Format<br>0 = 1 short per sample - Envelope Data<br>1 = 2 shorts per sample - Analytic Signal Data, (Real, Imaginary)                                                                                                                                                                                                                                              | INT16     |
| 36 – 37      | Distance from Antenna to Tow point in Centimeters, Aft +<br>(Fish Aft = +)                                                                                                                                                                                                                                                                                              | INT16     |
| 38 – 39      | Distance from Antenna to Tow Point in Centimeters, Starboard<br>+ (Fish to Starboard = +)                                                                                                                                                                                                                                                                               | INT16     |
| 40 – 43      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                            | INT16 x 2 |

The Most Significant Bits fields are used to extend sixteen bit integers to twenty bits. These are added as needed when the range of possible values exceeds what can be stored in a sixteen bit integer. The simplest way to use these additional bits is to treat the value as a 32 bit integer, the existing value becomes the least significant 16 bits, the MSB field becomes the next most significant 4 bits with the most significant 12 bits set to zeros.

<sup>1</sup> NOTE: For protocol revisions 7 and before this field was always zero.

## Validity flags bitmap:

- Bit 0: Lat Lon or XY valid
- Bit 1: Course valid
- Bit 2: Speed valid
- Bit 3: Heading valid
- Bit 4: Pressure valid
- Bit 5: Pitch roll valid
- Bit 6: Altitude valid
- Bit 7: Reserved
- Bit 8: Water temperature valid
- Bit 9: Depth valid
- Bit 10: Annotation valid
- Bit 11: Cable counter valid
- Bit 12: KP valid
- Bit 13: Position interpolated

**Navigation Data**

This is most often the position at the last navigation fix. See the time NMEA Navigation Data fields for the time of the fix. On most systems, position is not time interpolated and should not be used for mosaicing or other processing requiring high accuracy positioning. Validity flags indicate whether these fields are valid and interpolated. The representation of the navigation data depends on the coordinate-units field. For Latitude / Longitude representations, a positive value designates east of the Greenwich Meridian or north of the equator.

| Byte Offsets | Description                                                                                                                        | Size       |
|--------------|------------------------------------------------------------------------------------------------------------------------------------|------------|
| 44 – 47      | Kilometer of pipe (see bytes 30-31)                                                                                                | FLOAT32    |
| 48 – 79      | Reserved – <b>Do not use</b>                                                                                                       | INT16 x 16 |
| 80 – 83      | X in millimeters or decimeters or<br>Longitude in Minutes of Arc / 10000<br>(see bytes 30-31 and 88-89)                            | INT32      |
| 84 – 87      | Y in millimeters or decimeters or<br>Latitude in 0.0001 Minutes of Arc<br>(see bytes 30-31 and 88-89)                              | INT32      |
| 88 – 89      | Coordinate Units<br>1 = X, Y in millimeters<br>2 = Longitude, Latitude in minutes of arc times $10^{-4}$<br>3 = X, Y in decimeters | INT16      |

## Pulse Information

This data describes the transmitted pulse characteristics, as well as sampling parameters.

| Byte Offsets | Description                                                                                                                               | Size       |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 90 – 113     | Annotation String (ASCII Data)                                                                                                            | UINT8 x 24 |
| 114 – 115    | Number of data samples in this packet<br>See bytes 16 – 17 for MSB information<br>Note: Very large sample sizes require multiple packets. | UINT16     |
| 116 – 119    | Sampling Interval in Nanoseconds                                                                                                          | UINT32     |
| 120 – 121    | Gain Factor of ADC                                                                                                                        | UINT16     |
| 122 – 123    | User Transmit Level Setting (0 – 100) percent                                                                                             | INT16      |
| 124 – 125    | Reserved – <b>Do not use</b>                                                                                                              | INT16      |
| 126 – 127    | Transmit pulse starting frequency in decahertz (daHz)<br>(units of 10Hz)<br>See bytes 17 – 18 for MSB information                         | UINT16     |
| 128 – 129    | Transmit pulse ending frequency in decahertz<br>(daHz)(units of 10Hz)<br>See bytes 16 – 17 for MSB information                            | UINT16     |
| 130 – 131    | Sweep Length in milliseconds                                                                                                              | UINT16     |
| 132 – 135    | Pressure in milliPSI (1 unit = 1/1000 PSI)<br>(see bytes 30-31)                                                                           | INT32      |
| 136 - 139    | Depth in millimeters (if not = 0) (see bytes 30-31)                                                                                       | INT32      |
| 140 – 141    | Sample Freq of the data in hertz, modulo 65536 NOTE *                                                                                     | UINT16     |
| 142 – 143    | Outgoing pulse identifier                                                                                                                 | UINT16     |
| 144 – 147    | Altitude in millimeters (If bottom tracking valid)<br>0 implies not filled (see bytes 30-31)                                              | INT32      |
| 148 - 155    | Reserved – <b>Do not use</b>                                                                                                              | INT32 x 2  |

NOTE\* : For all data types EXCEPT RAW (Data Format = 2) this is the Sampling Frequency of the data. For RAW data, this is one-half the Sample Frequency of the data ( $F_s/2$ ). All values are modulo 65536. Use this in conjunction with the Sample interval (Bytes 114-115) to calculate correct sample rate.

## CPU Time

The time that the Acoustic data was recorded. The time of the start of the ping of data represented by the following trace data is the Ping Time.

The Ping Time in seconds since 1/1/1970, (in the same time base as the device messages that follow), is contained in bytes 0-3. The millisecondsToday field (bytes 200-203), MODULO 1000, will yield the milliseconds in current second, compatible with the time stamp of the device messages. This time stamp is only valid for data recorded in Protocol Revision 8 and above.

The Ping Time can also be determined from the Year, Day, Hour, Minute and Seconds as per bytes 156 to 165. Thus provides 1 second level accuracy and resolution. For higher resolution (milliseconds) use the Year, and Day values of bytes 156 to 159, and then use the milliSecondsToday value of bytes 200-203 to complete the timestamp. System time is set to UTC, regardless of time zone. This time format is backwards compatible with all older Protocol Revisions.

These 2 time stamps are equivalent and identical.

| Byte Offsets | Description                                           | Size  |
|--------------|-------------------------------------------------------|-------|
| 156 – 157    | Year (e.g. 2009) (see Bytes 0-3) (Should not be used) | INT16 |
| 158 – 159    | Day (1 – 366) (Should not be used)                    | INT16 |
| 160 – 161    | Hour (see Bytes 200-203) (Should not be used)         | INT16 |
| 162 – 163    | Minute (Should not be used)                           | INT16 |
| 164 – 165    | Second (should not be used)                           | INT16 |
| 166 – 167    | Time Basis (always 3)                                 | INT16 |

## **Weighting Factor**

The trace data is transmitted as sixteen bit integers in block floating point format per message. This saves bandwidth and storage space while preserving dynamic range. The weighting factor MUST BE applied to each of the sixteen bit integer values to restore the original floating point value.

| Byte Offsets | Description                                               | Size  |
|--------------|-----------------------------------------------------------|-------|
| 168 – 169    | Weighting Factor N (Signed Value!)<br>Defined as $2^{-N}$ | INT16 |
| 170 – 171    | Number of pulses in the water                             | INT16 |

## **Orientation Sensor Data**

These fields contain useful information about the attitude of the sonar sensor. The Compass heading will be magnetic heading of the towfish. If a Gyro sensor is properly interfaced to the Discover Topside acquisition unit, with a valid NMEA HDT message, this field will contain the Gyro heading, relative to true north

| Byte Offsets | Description                                                              | Size   |
|--------------|--------------------------------------------------------------------------|--------|
| 172 – 173    | Compass Heading (0 to 360 ) in units of 1/100 degree (see bytes 30-31)   | UINT16 |
| 174 – 175    | Pitch: Scale by 180 / 32768 to get degrees, + = bow up (see bytes 30-31) | INT16  |
| 176 – 177    | Roll: Scale by 180 / 32768 to get degrees, + = port up (see bytes 30-31) | INT16  |
| 178 – 179    | Tow fish electronics Temperature, in unit of 1/10 <sup>th</sup> degree C | INT16  |

## Miscellaneous Data

| Byte Offsets | Description                                                   | Size   |
|--------------|---------------------------------------------------------------|--------|
| 180 – 181    | Reserved – <b>Do not use</b>                                  | INT16  |
| 182 – 183    | Trigger Source<br>0 = Internal<br>1 = External<br>2 = Coupled | INT16  |
| 184 – 185    | Mark Number<br>0 = No Mark                                    | UINT16 |

## NMEA Navigation Data

These fields contain the time of the last position fix. If the position data is interpolated this will be the same as the CPU and ping time.

| Byte Offsets | Description      | Size  |
|--------------|------------------|-------|
| 186 – 187    | Hour (0 – 23)    | INT16 |
| 188 – 189    | Minutes (0 – 59) | INT16 |
| 190 – 191    | Seconds (0 – 59) | INT16 |
| 192 – 193    | Course           | INT16 |
| 194 – 195    | Speed            | INT16 |
| 196 – 197    | Day (1 – 366)    | INT16 |
| 198 – 199    | Year             | INT16 |

## Other Miscellaneous Data

| Byte Offsets | Description                                                                                                                                        | Size     |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 200 – 203    | Milliseconds today (since midnight) (use in conjunction with Year / Day to get time of Ping)                                                       | UINT32   |
| 204 – 205    | Maximum Absolute Value of ADC samples in this packet                                                                                               | UINT16   |
| 206 – 207    | Reserved – Do not use                                                                                                                              | INT16    |
| 208 – 209    | Reserved – Do not use                                                                                                                              | INT16    |
| 210 – 215    | Sonar Software Version Number - ASCII                                                                                                              | INT8 x 6 |
| 216 – 219    | Initial Spherical Correction Factor<br>(Useful for multi-ping / deep application) * 100                                                            | INT32    |
| 220 – 221    | Packet Number<br>Each ping starts with packet 1                                                                                                    | UINT16   |
| 222 – 223    | 100 times the A/D Decimation Factor. Data is normally sampled at a high Rate. Digital filters are applied to precisely limit the signal bandwidth. | INT16    |
| 224 – 225    | Decimation Factor after the FFT                                                                                                                    | INT16    |
| 226 – 227    | Water Temperature in units of 1/10 degree C<br>(see bytes 30-31)                                                                                   | INT16    |
| 228 – 231    | Layback in meters                                                                                                                                  | FLOAT32  |
| 232 – 235    | Reserved – Do not use                                                                                                                              | INT32    |
| 236 – 237    | Cable Out in decimeters (see bytes 30-31)                                                                                                          | UINT16   |
| 238 – 239    | Reserved – Do not use                                                                                                                              | UINT16   |

## Sonar Trace Data

Sonar trace data follows the 240-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 114-115) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding Message Header byte count, (bytes 12 –15) less the header size of 240.

Each of the data sample values then needs to be scaled by the weighting factor thus:

ScaledDatasample = datasample \*  $2^{(-N)}$ . (NOTE Sign !)

Future expansions of this data format will use floating point values to represent samples, and will result in other valid values for Data Format (bytes 34-35). Data readers will be more robust if this data section is skipped over if the Data Type does not match the 4 values presented here.

## **Message Type 82: Side Scan Data Message (sidescandefs.h)**

Side-Scan Data Messages are no longer used and only described here for historical reasons. While configuring a sonar to generate these messages is still possible, new systems are not configured in that manner. If your sonar is storing Side-Scan Data Messages the configuration should be changed to store Sonar Data Messages instead. Side-Scan Data Messages are never stored by Discover, and are only encountered in data stored by sonar. This data is almost always compressed rendering it unusable without further processing. A Side-Scan Data Message is similar to a Sonar Data Message. It contains the exactly the same acoustic data. While the Side Scan Data Message was intended for Side Scan data, it can also be used for Sub-bottom data. The system configuration determines which type of data is actually stored. Each Side Scan Data Message has an 80 byte header, the content of which is defined below. As with Sonar Data Messages, unused fields should be set to 0.

| Byte Offsets | Description                                                                                                                                                                                                                          | Size   |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| 0 – 1        | Subsystem (0 .. n)                                                                                                                                                                                                                   | UINT16 |
| 2 – 3        | Channel Number (0 .. n)                                                                                                                                                                                                              | UINT16 |
| 4 – 7        | Ping number (increments with each ping period)                                                                                                                                                                                       | UINT32 |
| 8 – 9        | Packet number (1..n) Each ping starts with packet 1                                                                                                                                                                                  | UINT16 |
| 10 – 11      | TriggerSource (0 = internal, 1 = external)                                                                                                                                                                                           | UINT16 |
| 12 – 15      | Samples in this packet                                                                                                                                                                                                               | UINT32 |
| 16 – 19      | Sample interval in ns of stored data                                                                                                                                                                                                 | UINT32 |
| 20 – 23      | Starting Depth (window offset) in samples                                                                                                                                                                                            | UINT32 |
| 24 – 25      | Weighting Factor : Defined as $2^{-N}$ volts                                                                                                                                                                                         | INT16  |
| 26 – 27      | Gain factor of ADC                                                                                                                                                                                                                   | UINT16 |
| 28 – 29      | Maximum absolute value for ADC samples for this packet                                                                                                                                                                               | UINT16 |
| 30 – 31      | Range Setting (in decameters) (meters times 10)                                                                                                                                                                                      | UINT16 |
| 32 – 33      | Unique pulse identifier                                                                                                                                                                                                              | UINT16 |
| 34 – 35      | Mark Number (0 = no mark)                                                                                                                                                                                                            | UINT16 |
| 36 – 37      | Data format<br>0 = 1 short per sample - envelope data the total number of bytes of data to follow is 2 * samples<br>1 = 2 shorts per sample - stored as real(1), imag(1), the total number of bytes of data to follow is 4 * samples | UINT16 |
| 38           | Number of simultaneous pulses in the water                                                                                                                                                                                           | UINT8  |
| 39           | Reserved – <b>Do not use</b>                                                                                                                                                                                                         | UINT8  |

## Computer date / time data acquired

| Byte Offsets | Description           | Size   |
|--------------|-----------------------|--------|
| 40 – 43      | Milliseconds today    | UINT32 |
| 44 – 45      | Year                  | INT16  |
| 46 – 47      | Day of year (1 – 366) | UINT16 |
| 48 – 49      | Hour of day (0 – 23)  | UINT16 |
| 50 – 51      | Minute (0 – 59)       | UINT16 |
| 52 – 53      | Second (0 – 59)       | UINT16 |

## Auxiliary sensor information

| Byte Offsets | Description                                            | Size      |
|--------------|--------------------------------------------------------|-----------|
| 54 – 55      | Compass heading in minutes (0 – 360) x 60              | UINT16    |
| 56 – 57      | Pitch Scale by 180 / 32768 to get degrees, + = bow up  | INT16     |
| 58 – 59      | Roll Scale by 180 / 32768 to get degrees, + = port up  | INT16     |
| 60 – 61      | Heave (centimeters)                                    | INT16     |
| 62 – 63      | Yaw (minutes)                                          | INT16     |
| 64 – 67      | Pressure in units of 1/1000 PSI                        | UINT32    |
| 68 – 69      | Temperature in units of 1/10 of a degree Celsius       | INT16     |
| 70 – 71      | Water Temperature in units of 1/10 of a degree Celsius | INT16     |
| 72 – 75      | Altitude in millimeters (or -1 if no valid reading)    | INT32     |
| 76 – 79      | Reserved – <b>Do not use</b>                           | UINT8 x 4 |

## Sonar Trace Data

Sonar trace data follows the 80-byte header and consists of sixteen bit integer values. The number of integers to be read can be found by multiplying the number of samples in the trace (bytes 12-15) by the number of integers per sample for the data type used (1 or 2). Further doubling will yield the byte size of the data section. This should exactly match the preceding 16 byte Message Header byte count, (bytes 12 –15) less the header size of 80. Each of the data sample values then needs to be scaled by the weighting factor thus:

$\text{ScaledDataSample} = \text{datasample} * 2^{-(N)}$

## **Message Type 2020: Pitch Roll Data**

A pitch roll message consists of a single reading from a pitch roll sensor such as a Seatex MRU, TSS or Octans device. Not all devices provide all data for the defined structure. Use the validity flags to determine which fields are populated.

| Byte Offsets | Description                                                                                                                                                                                               | Size      |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Time in seconds (since the start of time based on time() function) (1/1/1970)                                                                                                                             | INT32     |
| 4 – 7        | Milliseconds in the current second                                                                                                                                                                        | INT32     |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                                                                                                              | UINT8 x 4 |
| 12 – 13      | Acceleration in x: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 14 – 15      | Acceleration in y: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 16 – 17      | Acceleration in z: Multiply by $(20 * 1.5) / (32768)$ to get Gs                                                                                                                                           | INT16     |
| 18 – 19      | Rate Gyro in x: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 20 – 21      | Rate Gyro in y: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 22 – 23      | Rate Gyro in y: Multiply by $(500 * 1.5) / (32768)$ to get Degrees/Sec                                                                                                                                    | INT16     |
| 24 – 25      | Pitch Multiply by $(180.0 / 32768.0)$ to get Degrees<br>Bow up is positive                                                                                                                                | INT16     |
| 26 – 27      | Roll: Multiply by $(180.0 / 32768.0)$ to get Degrees<br>Port up is positive                                                                                                                               | INT16     |
| 28 – 29      | Temperature in units of 1/10 of a degree Celsius                                                                                                                                                          | INT16     |
| 30 – 31      | Device specific info. This is device specific info provided for Diagnostic purposes                                                                                                                       | UINT16    |
| 32 – 33      | Estimated Heave in millimeters                                                                                                                                                                            | INT16     |
| 34 – 35      | Heading in units of 0.01 Degrees (0...360)                                                                                                                                                                | UINT16    |
| 36 – 39      | Data valid flags<br>Bit 0: ax<br>Bit 1: ay<br>Bit 2: az<br>Bit 3: rx<br>Bit 4: ry<br>Bit 5: rz<br>Bit 6: pitch<br>Bit 7: roll<br>Bit 8: heave<br>Bit 9: heading<br>Bit 10: temperature<br>Bit 11: devInfo | INT32     |
| 40 – 43      | Reserved – <b>Do not use</b>                                                                                                                                                                              | INT32     |

## **Message Type 2002: NMEA String**

A NMEA String consists of a time stamp followed by a NMEA string as read from a GPS, Gyro or other device. Each message is a single NMEA string excluding the <CR>/<LF>.

| Byte Offsets           | Description                               | Size                    |
|------------------------|-------------------------------------------|-------------------------|
| 0 – 3                  | Time in seconds since 1970                | INT32                   |
| 4 – 7                  | Milliseconds in the current second        | INT32                   |
| 8                      | Source, 1 = Sonar, 2 = Discover, 3 = ETSI | INT8                    |
| 9 – 11                 | Reserved – <b>Do not use</b>              | UINT8 x 3               |
| 12 – To Message Length | NMEA string data                          | INT8 x remaining length |

## **Message Type 2060: Pressure Sensor Reading**

If a pressure sensor is present in the system these messages will be in the data stream.

A single pressure sensor reading is provided, along with a time-stamp. While pressure sensors can be configured in different units, the default is PSI absolute.

| Byte Offsets | Description                                                                                                            | Size        |
|--------------|------------------------------------------------------------------------------------------------------------------------|-------------|
| 0 – 3        | Time in seconds (since the start of time based on time() function).                                                    | INT32       |
| 4 – 7        | Milliseconds in the current second.                                                                                    | INT32       |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                           | UNIT8 x 4   |
| 12 – 15      | Pressure in units of 1/1000th of a PSI                                                                                 | INT32       |
| 16 – 19      | Temperature in units of 1/1000th of degree Celsius.                                                                    | INT32       |
| 20 – 23      | Salinity in Parts Per Million                                                                                          | INT32       |
| 24 – 27      | Data valid flags:<br>Bit 0: pressure<br>Bit 1: temp<br>Bit 2: salt PPM<br>Bit 3: conductivity<br>Bit 4: sound velocity | INT32       |
| 28 – 31      | Conductivity in micro-Siemens per cm                                                                                   | INT32       |
| 32 – 35      | Velocity of Sound in mm per second                                                                                     | INT32       |
| 36 – 75      | Reserved – <b>Do not use</b>                                                                                           | INT 32 x 10 |

## **Message Type 2080: Doppler Velocity Log Data (DVL)**

This is data from a DVL (if fitted) and often includes velocity and altitude readings.

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Size      |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 0 – 3        | Time in seconds (since the start of time based on time() function).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT32     |
| 4 – 7        | Milliseconds in the current second.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT32     |
| 8 – 11       | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | UINT8 x 4 |
| 12 – 15      | Flags. Indicates which values are present.<br>Bit 0: X, Y Velocity present<br>Bit 1: 1 => Velocity in ship coordinates<br>0 => Earth coordinates<br>Bit 2: Z (Vertical Velocity) present<br>Bit 3: X, Y Water Velocity present<br>Bit 4: Z (Vertical Water Velocity) present<br>Bit 5: Distance to bottom present<br>Bit 6: Heading present<br>Bit 7: Pitch present<br>Bit 8: Roll present<br>Bit 9: Temperature present<br>Bit 10: Depth present<br>Bit 11: Salinity present<br>Bit 12: Sound velocity present<br>-----<br>Bit 31: Error detected | UINT32    |
| 16 – 31      | 4 Integers: Distance to bottom in cm for up to 4 beams.<br>A 0 value indicates an invalid or non-existing reading.                                                                                                                                                                                                                                                                                                                                                                                                                                 | INT32 x 4 |
| 32 – 33      | X Velocity with respect to the bottom in mm / second<br>Positive => Starboard or East.<br>-32768 indicates an invalid reading.                                                                                                                                                                                                                                                                                                                                                                                                                     | INT16     |
| 34 – 35      | Y Velocity: Positive => Forward or North (mm/second)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | INT16     |
| 36 – 37      | Z Vertical Velocity: Positive => Upward (mm/second)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT16     |
| 38 – 39      | X Velocity with respect to a water layer in mm / second<br>Positive => Starboard or East                                                                                                                                                                                                                                                                                                                                                                                                                                                           | INT16 x 3 |
| 40 - 41      | Y Velocity: Positive => Forward or North                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |           |
| 42 - 43      | Z Vertical Velocity: Positive => Upward                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
| 44 - 45      | Depth from depth sensor in decimeters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | UINT16    |
| 46 - 47      | Pitch -180 to +180 degree (units = 0.01 of a degree) + Bow up                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | INT16     |
| 48 - 49      | Roll -180 to +180 degrees (units = 0.01 of a degree) + Port up                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | INT16     |
| 50 - 51      | Heading: 0 to 360 degrees (in units of 0.01 of a degree)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | UINT16    |
| 52 - 53      | Salinity in 1 part per thousand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | UINT16    |
| 54 - 55      | Temperature in units of 1/100 of a degree Celsius                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | INT16     |
| 56 - 57      | Sound velocity in meters per second                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | INT16     |
| 58 - 71      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | INT16 x 7 |

## **Message Type 2090: Situation Message**

A situation message is a composite of several motion / position sensors. This message is not commonly used. The detailed data structure is shown below:

| Byte Offsets | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Size     |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 0 - 3        | Time in seconds (since the start of time based on time() function).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | INT32    |
| 4 - 7        | Milliseconds in the current second.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | INT32    |
| 8 - 11       | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | INT8 x 4 |
| 12 - 15      | <p>Validity Flags<br/>Validity Flags indicate which of the following fields are valid. If the corresponding bit is set the field is valid.</p> <p>Bit 0 : microsecondTimestamp<br/>           Bit 1 : latitude<br/>           Bit 2 : longitude<br/>           Bit 3 : depth<br/>           Bit 4 : heading<br/>           Bit 5 : pitch<br/>           Bit 6 : roll<br/>           Bit 7 : XRelativePosition<br/>           Bit 8 : YRelativePosition<br/>           Bit 9 : ZRelativePosition<br/>           Bit 10 : XVelocity<br/>           Bit 11 : YVelocity<br/>           Bit 12 : ZVelocity<br/>           Bit 13 : NorthVelocity<br/>           Bit 14 : EastVelocity<br/>           Bit 15 : downVelocity<br/>           Bit 16 : XAngularRate<br/>           Bit 17 : YAngularRate<br/>           Bit 18 : ZAngularRate<br/>           Bit 19 : XAcceleration<br/>           Bit 20 : YAcceleration<br/>           Bit 21 : ZAcceleration<br/>           Bit 22 : latitudeStandardDeviation<br/>           Bit 23 : longitudeStandardDeviation<br/>           Bit 24 : depthStandardDeviation<br/>           Bit 25 : headingStandardDeviation<br/>           Bit 26 : pitchStandardDeviation<br/>           Bit 27 : rollStandardDeviation</p> | UINT32   |
| 16 - 19      | Reserved – <b>Do not use</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | UINT x 4 |
| 20 - 27      | Microsecond timestamp, us since 12:00:00 am GMT, January 1, 1970                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | UINT64   |
| 28 - 35      | Double float: Latitude in degrees, north is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | FLOAT64  |
| 36 - 43      | Double float: Longitude in degrees, east is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | FLOAT64  |
| 44 - 51      | Double float: Depth in meters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | FLOAT64  |
| 52 - 59      | Double float: Heading in degrees                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | FLOAT64  |
| 60 - 67      | Double float: Pitch in degrees, bow up is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | FLOAT64  |
| 68 - 75      | Double float: Roll in degrees, port up is positive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | FLOAT64  |
| 76 - 83      | Double float: X, forward, relative position in meters, surge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | FLOAT64  |
| 84 - 91      | Double float: Y, starboard, relative position in meters, sway                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | FLOAT64  |

|           |                                                                           |             |
|-----------|---------------------------------------------------------------------------|-------------|
| 92 - 99   | Double float: Z, downward, relative position in meters, heave             | FLOAT64     |
| 100 - 107 | Double float: X, forward, velocity in meters per second                   | FLOAT64     |
| 108 - 115 | Double float: Y, starboard, velocity in meters per second                 | FLOAT64     |
| 116 - 123 | Double float: Z, downward, velocity in meters per second                  | FLOAT64     |
| 124 - 131 | Double float: North velocity in meters per second                         | FLOAT64     |
| 132 - 139 | Double float: East velocity in meters per second                          | FLOAT64     |
| 140 - 147 | Double float: Down velocity in meters per second                          | FLOAT64     |
| 148 - 155 | Double float: X angular rate in degrees per second, port up is positive   | FLOAT64     |
| 156 - 163 | Double float: Y angular rate in degrees per second, bow up is positive    | FLOAT64     |
| 164 - 171 | Double float: Z angular rate in degrees per second, starboard is positive | FLOAT64     |
| 172 - 179 | Double float: X, forward, acceleration in meters per second per second    | FLOAT64     |
| 180 - 187 | Double float: Y, starboard, acceleration in meters per second per second  | FLOAT64     |
| 188 - 195 | Double float: Z, downward, acceleration in meters per second per second   | FLOAT64     |
| 196 - 203 | Double float: Latitude standard deviation in meters                       | FLOAT64     |
| 204 - 211 | Double float: Longitude standard deviation in meters                      | FLOAT64     |
| 212 - 219 | Double float: Depth standard deviation in meters                          | FLOAT64     |
| 220 - 227 | Double float: Heading standard deviation in degrees                       | FLOAT64     |
| 228 - 235 | Double float: Pitch standard deviation in degrees                         | FLOAT64     |
| 236 - 243 | Double float: Roll standard deviation in degrees                          | FLOAT64     |
| 244 - 275 | Reserved – Do not use                                                     | UINT16 x 16 |

## **Message Type 182: System Information Message**

The system information message contains details of the system used to acquire data. This message is normally present at the beginning of a JSF file, and may be repeated if configuration parameters change.

| Byte Offsets | Description                                            | Size  |
|--------------|--------------------------------------------------------|-------|
| 0 - 3        | System Type                                            | INT32 |
| 4 - 7        | Reserved – Do not use                                  |       |
| 8 - 11       | Version Number of Sonar Software used to generate data | INT32 |
| 12 - 19      | Reserved – Do not use                                  |       |
| 20 - 23      | Serial Number of Tow Vehicle used to collect data      | INT32 |
| 24 - End     | Reserved – Do not use                                  |       |

The size of the System Information Message is subject to change as more detailed information is may be added in future versions of the software. The byte count in the

message header should be used to determine the total size of the structure and get to the next message in the file.

The System Type is the major type of system used to collect data. To date, the following system types are defined:

| System Type Number | Description                                                        |
|--------------------|--------------------------------------------------------------------|
| 1                  | 2xxx Series, Combined Sub-Bottom / Side Scan with SIB Electronics  |
| 2                  | 2xxx Series, Combined Sub-Bottom / Side Scan with FSIC Electronics |
| 4                  | 4300-MPX (Multi-Ping)                                              |
| 5                  | 3200-XS, Sub-Bottom Profiler with AIC Electronics                  |
| 6                  | 4400-SAS, 12-Channel Side Scan                                     |
| 7                  | 3200-XS, Sub Bottom Profiler with SIB Electronics                  |
| 11                 | 4200 Limited Multipulse Dual Frequency Side Scan                   |
| 14                 | 3100-P, Sub Bottom Profiler                                        |
| 16                 | 2xxx Series, Dual Side Scan with SIB Electronics                   |
| 17                 | 4200 Multipulse Dual Frequency Side Scan                           |
| 18                 | 4700 Dynamic Focus                                                 |
| 19                 | 4200 Dual Frequency Side Scan                                      |
| 20                 | 4200 Dual Frequency non Simultaneous Side Scan                     |
| 21                 | 2200-MP Combined Sub-Bottom / Dual Frequency Multipulse Side Scan  |
| 23                 | 4600 Bathymetric System                                            |
| 128                | 4100, 272 /560A Side Scan                                          |

# Attachment 3

## Stage Storage Curve Calculation

## Spreadsheets

[Attachment 3 is provided electronically.]

# Attachment 4

## GoldSim Water Management Tool

[Water management tool version of the GoldSim model incorporating new stage-storage curves is provided electronically as Attachment 4]