USING GEOGRAPHICAL INFORMATION SYSTEMS IN PLANNING NLLP DECOMMISSIONING AND ENVIRONMENTAL RESTORATION ACTIVITIES

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ABSTRACT

The Nuclear Legacy Liabilities Program (NLLP) manages Canada's nuclear legacy liabilities at Atomic Energy of Canada Limited (AECL) sites and is funded by the Government of Canada through Natural Resources Canada (NRCan). Through the first five years of the Program these two organizations have worked collaboratively to bring numerous projects to completion. In addition to the diversity of facilities and waste dealt with under the NLLP, the Program involves seven sites in three different provinces. The breadth of the Program encompasses over 20 different projects at AECL's Chalk River Laboratories (CRL) site alone, with new projects evolving as work continues.

Nuclear legacy liabilities are the result of over 60 years of nuclear research and development conducted by the National Research Council of Canada (1944 to 1952) and AECL (1952 to 2006) on behalf of the Government of Canada. The liabilities consist of outdated and unused research facilities and buildings, a wide variety of buried and stored radioactive waste, and affected lands.

Since 1952, AECL has safely and cost effectively managed Canada's nuclear research facilities and the waste generated by their operation. During this time AECL improved waste management technologies and developed expertise in best practices.

All projects undertaken by the NLLP contain a spatial, or geographically referenced, component that can be captured in a geographic information system (GIS). From the decommissioning of a single building within the plant itself (e.g. the building location itself or spaces within the building) to the process of locating a new facility within the CRL site (e.g. location within the CRL property in three dimensions and adjacency to other communities) all these projects contain spatially referenced information. This spatial information can be captured, organized and used by the GIS software to analyze and model any number of questions.

The paper will discuss projects that address a variety of GIS data sets, tools, and techniques and how the discipline of geomatics can and should be used as another tool in the decision making process. In most projects the process can be categorized into five major steps; ask, acquire, examine, analyze, and act. The presentation provides examples, and includes a discussion of the four steps in which the GIS process has been used in NLLP projects: ask, acquire, examine and analyze.

The projects to be discussed include:

- Analysis to Determine the Most Efficient Groupings for the Decommissioning of Buildings at CRL Subject to Environmental Assessments

- Study of the Chalk River Site to Determine its Suitability to host a Geologic Waste Management Facility for Low and Intermediate Level Waste
- Geophysical Surveys of the Ottawa Riverbed Adjacent to CRL

1. INTRODUCTION

What is a geographic information system (GIS)? A common definition used is "*a GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information*". Geographically referenced means that a feature has a location or spatial component attached to it. For example the location of your house described in real world coordinates such as degrees of latitude and longitude (i.e. where is it located on the earth?). The heart of a GIS is the database through which questions such as what a feature is, where it is, and how it relates to other features can be answered. This is why when an organization considers implementing a GIS, a rule of thumb often quoted is that eighty percent of the overall cost will be in the creation and maintenance of the required data sets. And the key that enables this database to be utilized in a GIS is the 'where is it' element of the data.

The challenge is to ensure that the existence of this data is communicated such that groups are able to leverage appropriate data and the GIS capability for their projects. CRL geographic data range from broad regional (e.g. bedrock geology) to specific local data sets (e.g. waste management containment features). Spatial data sets or geographically referenced data are often described as layers when discussing GIS applications. Some examples of layers are listed below:

- Hydrography – lakes, river, streams, wetlands
- Transportation networks – highways, roads, trails, railway
- Administrative boundaries – CRL boundary, site fence lines, municipality, lot, concession, township
- Contamination – plumes, groundwater levels, waste management area features
- Vegetation – forest inventory, plantations
- Site imagery – 2009 aerial photography (high resolution, colour), 2002 aerial photography (high resolution black and white), coarse resolution satellite imagery
- Geologic data – regional bedrock, CRL detail bedrock, overburden thickness

The following images (Figures 1 – 6) provide examples of these data sets. The same spatial location is represented but a variety of data types are displayed.

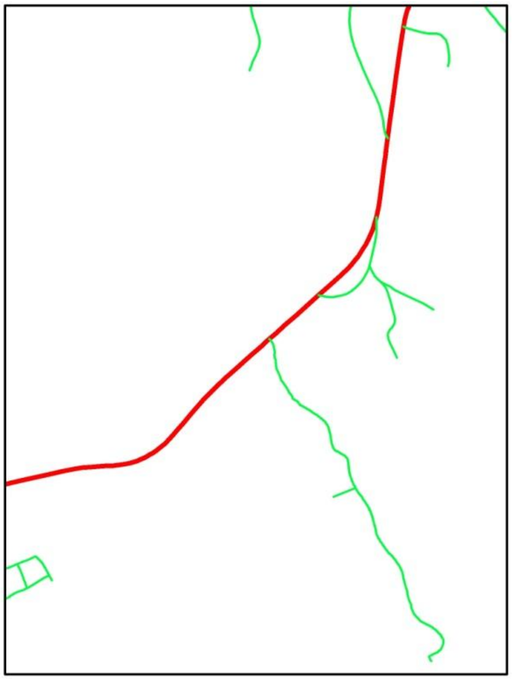

Figure 1. Roads.

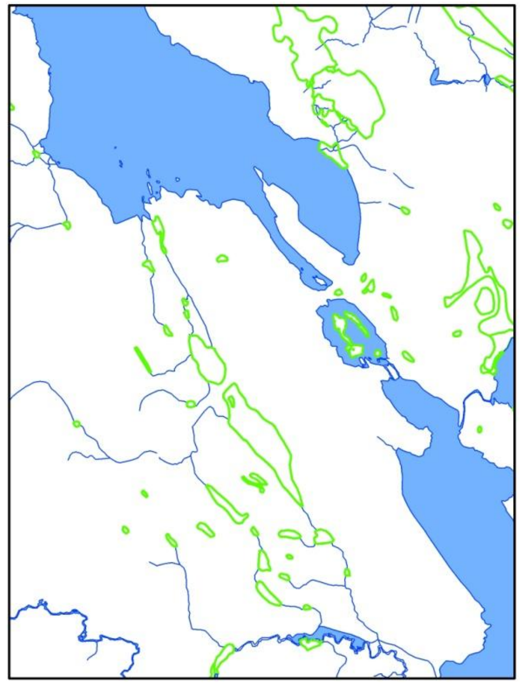

Figure 2. Hydrography.

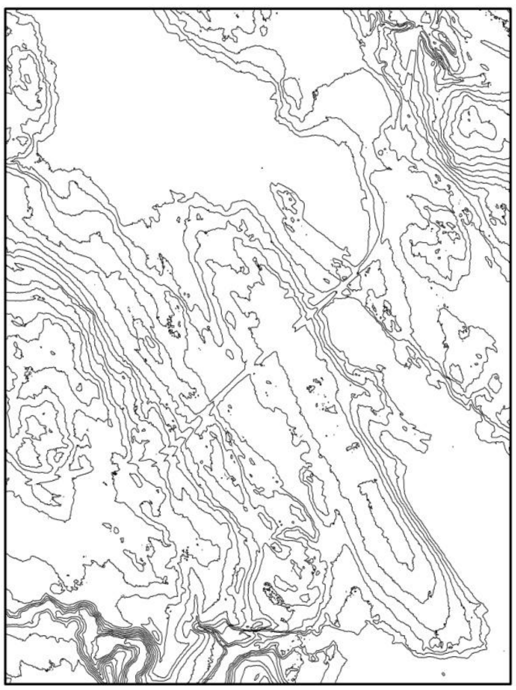

Figure 3. Elevation contours.

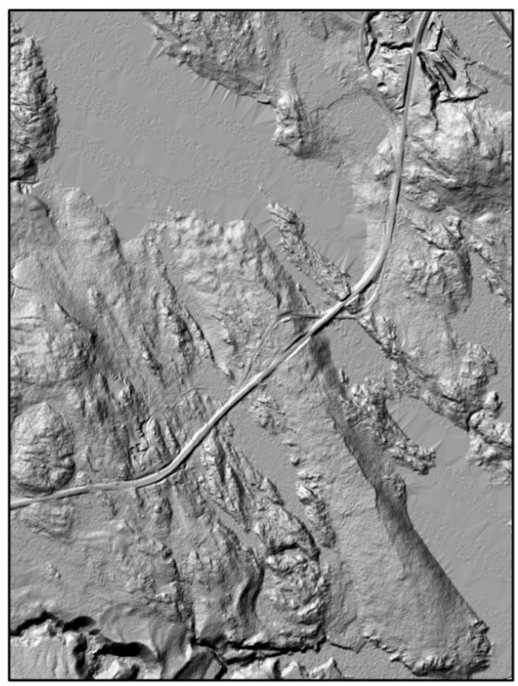

Figure 4. LiDAR.

Figure 5. Aerial photos.

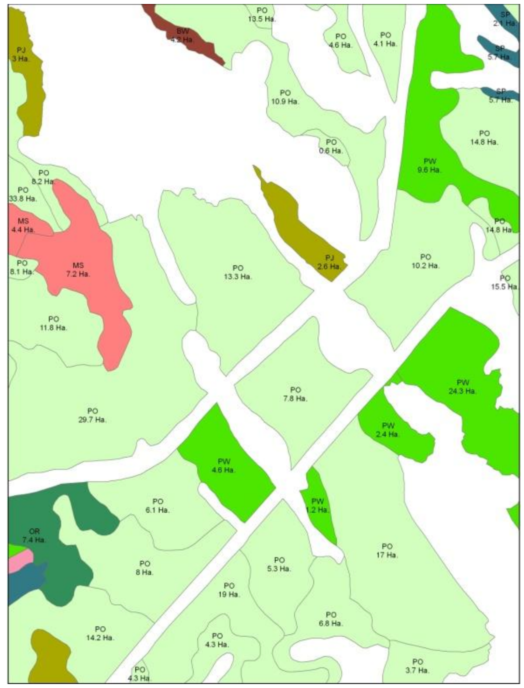

Figure 6. Forest resource inventory.

The typical process flow for GIS support in NLLP projects, and generally for most projects, is illustrated in Figure 7. The process involves six key steps which include; identify the issue, develop the criteria, determine the GIS process, run the analysis. The boxes show the major steps and the text boxes contain specific examples. The process is initiated with an issue and/or question(s) that result in a project. In this diagram we want to reduce the number of environmental assessments required for building decommissioning. The next step is the development of criteria. Once the issue and criteria are identified a process is developed, reviewed and revised if necessary, and finally the analysis is accepted and completed. The analysis, including all output products, is critically reviewed and either is accepted and implemented to support a decision and develop a solution or is refined and the analysis is completed again. The area where the GIS provide increasing support is shaded in grey.

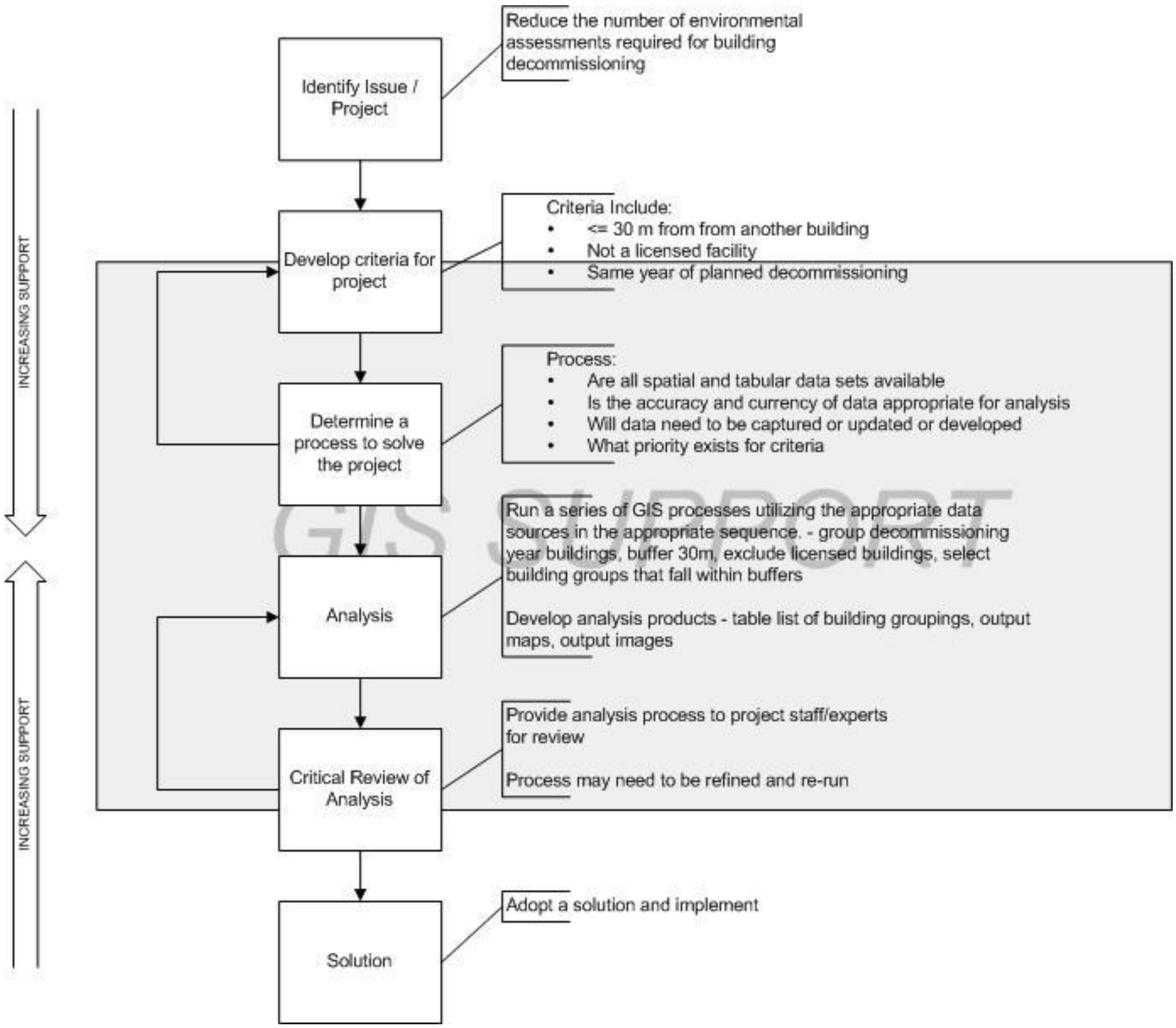

Figure 7. GIS support flow diagram.

The remainder of the document will discuss NLLP projects where the GIS was utilized.

2. APPLYING GIS TO PLANNING FOR NLLP

2.1 Analysis to Determine the Most Efficient Groupings for the Decommissioning of Buildings on the CRL Site Likely Subject to Environmental Assessments

The CRL was developed over sixty years ago and during that time many facilities have been constructed and some have been removed. Decommissioning generally involves the safe removal of hazards and the dismantling of a building or facility and the packaging or processing of contaminated material for further processing or disposal. As a crown corporation AECL is required to comply with the Canadian Environmental Assessment Act (CEAA). The Act and the regulations made under the Act define when an environmental assessment (EA) is required.

2.1.1 Ask - Can the number of EAs be reduced by grouping the buildings?

To answer this question, several factors need to be considered. These include the size of the building, the proximity of the building with respect to other buildings, the time when the buildings need to be removed, whether the buildings are listed on the site license, and so on. Several of these factors can be identified and illustrated graphically using the GIS tools, thus providing input into the answer to the question.

2.1.2 Acquire – What information do we have

The key data set required for this analysis is the buildings footprint. This layer exists for the site and is highly accurate and is updated annually. Other base layers were used to develop the final output maps (i.e. roads, water bodies) but were not required for the analysis. The other required pieces of information are attributes associated with the building. Decommissioning staff provided the most current decommissioning schedule from which the building number and year of planned decommissioning were extracted and applied to the GIS layer. CRL maintains a facilities information system (FIS) which contains information about the buildings on site, one of which is whether or not the facility is licensed. This database was queried and the building number and license information was extracted and applied to the GIS layer.

2.1.3 Examine – Plot the data

Figure 8 depicts the buildings on the CRL site, highlighting those that are scheduled to be removed over the next few years. The Decommissioning staff suggested that the buildings be arranged into the following classes according to current planning timelines. As shown in the figure, these timelines are:

- current (red);
- less than two years (orange);
- between two and five years (blue); and
- greater than five and less than fifteen years (green).

Figure 8. Map Depicting the Timelines for Building Decommissioning on the CRL site.

2.1.4 Analyze

The output products included an output summary map (Figure 8) and a listing of potential building groups for each decommissioning year class. As can be seen in the figure, many buildings that are adjacent to each other yet have very different decommissioning timelines. That is not to say that these timelines should be changed, but when planning for the environmental assessments likely required before they can be removed, these buildings could be grouped under a single assessment. Decommissioning staff are assessing their planning assumptions to verify the current plan and are looking for opportunities to group buildings for EA purposes.

2.1.5 Moving forward

As buildings are decommissioned and removed then the organization of buildings and adjacency of buildings to each other changes. As such the decommissioning schedules and groupings are also likely to change. It follows that this analysis should be performed annually to provide an accurate description of the potential EA groupings.

2.2 Study of the Chalk River Site to Determine its Suitability to host a Geologic Waste Management Facility for Low and Intermediate Level Waste

Studies are currently underway to determine whether the CRL site is suitable for a Geologic Waste Management Facility [1]. The use of GIS is an integral part of those studies

2.2.1 Ask – Is the CRL site a suitable location for a Geological Waste Management Facility?

If we consider the GIS support flow diagram (Figure 7) the first step is the issue, which in this case is; should a GWMF be built at CRL? It is obvious that this question cannot be answered solely on the basis of a GIS analysis. However, the GIS clearly provide support in the acquisition, development, and quality assurance of several required data sets. These data sets were then used to develop maps for inclusion into proposals and reports, importation into other specialized modeling software, and the development of 3-D models of geologic structures. Ultimately the products derived from these spatial data sets are just pieces of the puzzle that will be used to provide a recommendation for or against the development of a GWMF.

2.2.2 Acquire – What information do we have?

Much of the required data was initially created during 1994-1995 by a group called the 'Siting Task Force'. The mandate of that task force was to determine whether the CRL site was a suitable location for the waste soils from Port Hope. Under that mandate, their work included bedrock geological mapping and studies of the CRL property [2]. The output data sets from this work provided for much of the background data for the GWMF project. Unfortunately, even though these data sets were built in a GIS, some of the data could be found and recovered only as scanned images from the original summary maps. This meant that in order to use those data sets in the GIS they needed to be digitally recreated.

The GIS process used to recreate these spatial data sets was:

- If necessary, scan a hard copy map to generate a digital image
- Georeference or register the image to existing base layers
- On-screen digitize the features in question
- Data quality and assurance (Q/A) and apply attributes to the digitized features

Figure 9 is a screen shot of a registered image (bedrock geology) and GIS layers used in the register process. The map image comprises most of the background and the base data used to georeference the image is the water bodies and roads. The water body layer is shown in dark blue and green lines while the roads are black double lines. All other features shown (e.g. annotation, bedrock polygons) are part of the map image.

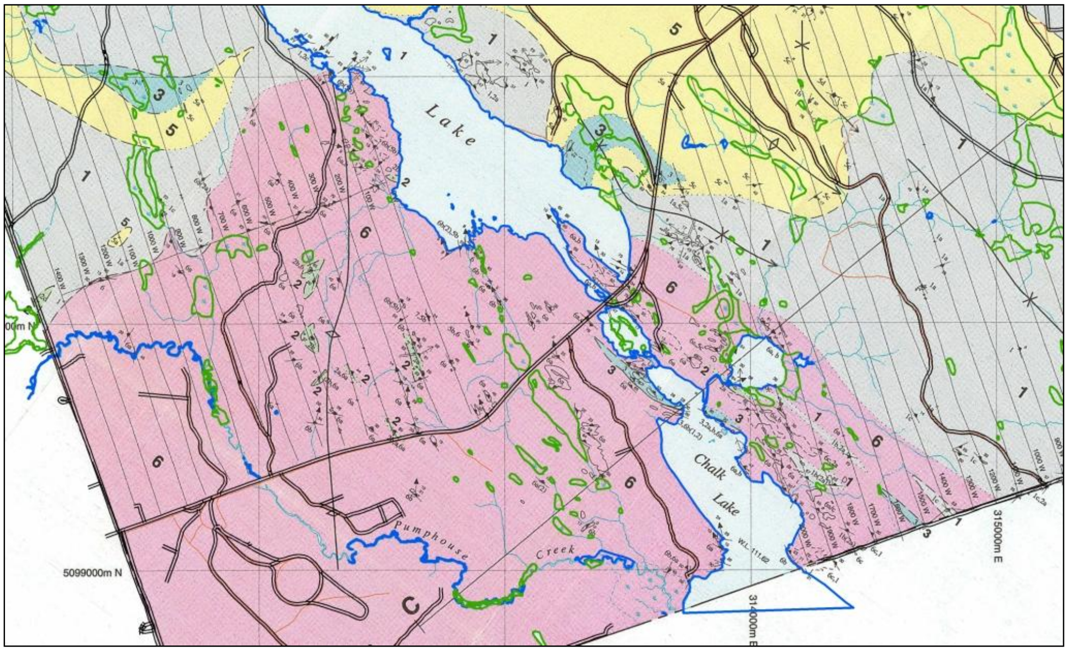

Figure 9. Registered local data image.

The registering process essentially involves creating links between the GIS layer and the image. A link is a unique feature like an intersection of roads, a peninsula, or point of land extending into a lake. This feature can be easily identified on both the image and the base feature. There are several potential links visible in Figure 9. The link is used to apply the geographic coordinates from the known base feature, such as the water body, to the unknown location on the image. A minimum of three links is required to georeference the image to the land base. However it is desirable to have many unique links with a good distribution throughout the image. This allows the software to 'fit' the image more accurately to the existing base layers.

Once the image is properly registered it becomes the source to on-screen digitize from. On-screen digitizing is a digital form of tracing. As the user traces the feature using their mouse the GIS is capturing the real world coordinates and linking them to form points, lines, and polygons. These points, lines, and polygons represent the spatial features which in this case describes the bedrock geology. For example the coloured spaces in Figure 9 represent major bedrock polygons for the site. The separation between the colours is where the digitized line would have been traced. This was the principal means of capturing the regional bedrock geology from Quebec and Ontario sources as well as the detailed layers (i.e. outcrops and foliation) from the local STF maps.

Other data sets from the STF efforts already existed in various digital formats but did require Q/A work to ensure spatial accuracy and content currency. Some of these data sets existed in MapInfo file and DXF file formats. Much of this work involved converting to a common GIS file format and importing into the GIS to compare feature location on original hard copy maps to the digital layers in the GIS project. Also, inquiries were made to verify that there were no updated equivalent data sets developed either by other groups within AECL or the various provincial/federal agencies.

2.2.3 Examine – Plot the data

Upon completing the assembly and correction of the required data sets they were then available for use in the creation of summary maps, use in analyses, and use in other specialized modeling software such as GeoSoft Target. Figure 10 and 11 are samples of output maps derived from several of the GIS developed data sets. Work will continue on the GWMF project and the developed data sets will continue to be used and maintained.

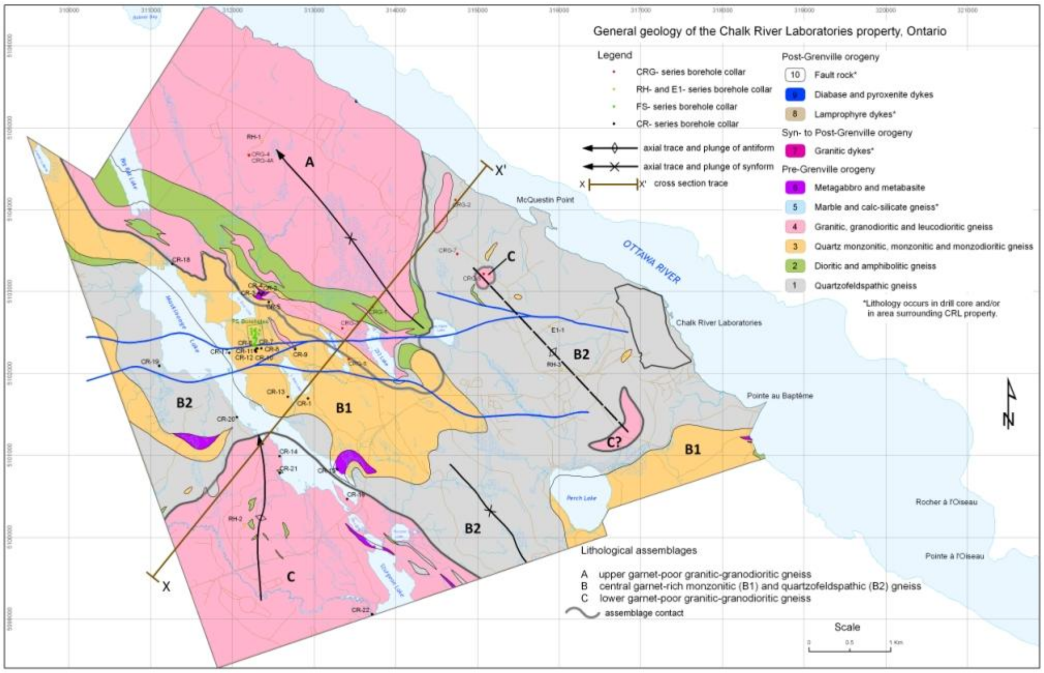

Figure 10. Summary map for GWMF project [3].

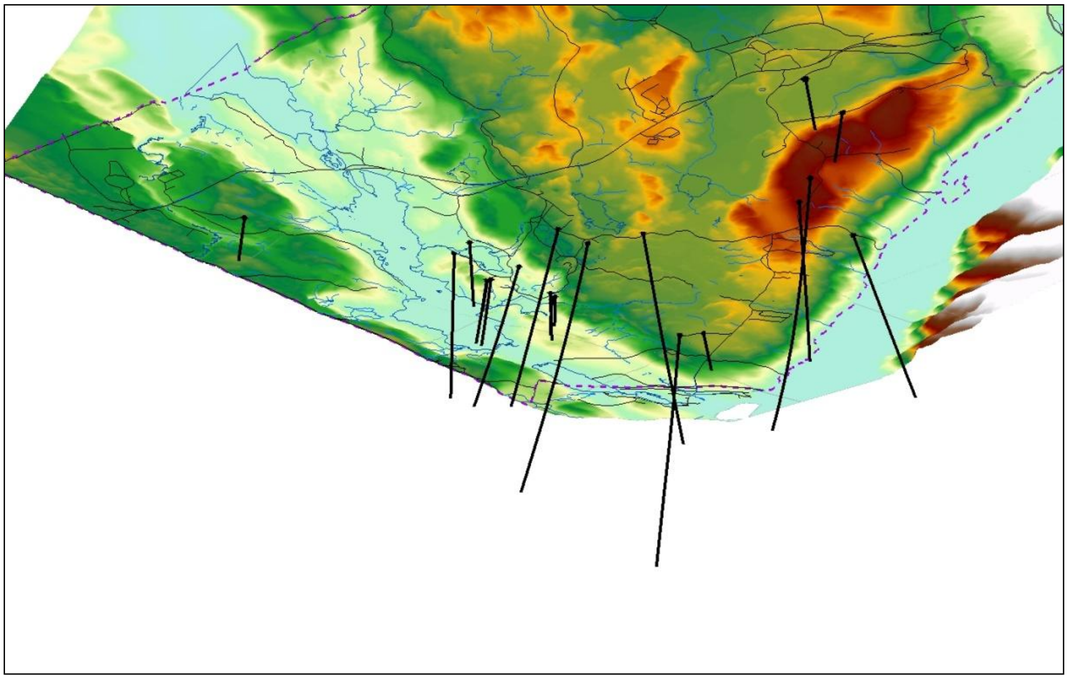

Figure 11. 3D view of CRL boreholes.

2.2.4 Analyze

At present, these GIS datasets are insufficient to answer the question as to whether the CRL site is a suitable location for a GWMF. However this information forms the basis on which to conduct the additional analyses required.

2.2.5 Moving Forward

The project is progressing with the classification of the subsurface major rock structures or lithology. These structures are determined through analysis of the extracted borehole cores. The resultant rock formations will be integrated with the other geologic layers and be used to develop an overall 3D model of the CRL subsurface geology.

2.3 Geophysical Surveys of the Ottawa Riverbed Adjacent to CRL

Studies are currently underway to determine how to best manage the low level radioactive contaminants embedded in the river sediments adjacent to the process outfall discharge pipe. These contaminants have been deposited over the fifty plus years of operation at CRL. A portion of these sediments were deposited as a result of the 1952 NRX reactor accident. A prime concern is with high river flows and the potential of dispersing the sediments and moving them further downstream. To gather more evidence on this issue a sediment transport model was commissioned [4].

2.3.1 Ask – Are the data sets currently available for the riverbed sufficient for the sediment transport model?

The sediment transport model was performed using existing bathymetry and water flow data for the Ottawa River adjacent to the site. The initial model run provided useful evidence of the sediment flow behavior and potential implications for the deposited contaminants. However more accurate riverbed morphology data was required to recalibrate the model and perform the sediment transport analysis again. With greater confidence in the model, it could then be used to base decisions on how best to deal with the contaminated sediments.

2.3.2 Acquire – What information do we have? What additional information do we need?

A geophysical and bathymetric survey of the Ottawa riverbed in the vicinity of the CRL property was completed during the autumn of 2009 [5]. The contract was commissioned to create new data (e.g. seismic) and replace current data (e.g. bathymetry) with a more accurate profile of the riverbed. The purpose of the surveys was to provide high resolution and accurate data of the topology and morphology of the Ottawa riverbed in proximity to the CRL site. Much of the captured data sets is spatially referenced and thus can be integrated with existing GIS layers.

GIS support for this project involved providing the contractors with relevant spatial data required for the surveys and ensuring the newly generated data sets were spatially referenced and aligned with the CRL base data. During the course of this project it became clear that having the geomatics staff involved early on was beneficial. This allowed for the proper data sets to be provided to the contractor and that expectations regarding spatial data (i.e. datum, projection, file format) were clear and ultimately met.

The data sets received from contractor (Canadian Seabed Research Ltd.) are georeferenced and primarily in a raw format. This means that much of the data arrived as point features in a simple text file format. This strategy is followed to easily allow for importing and converting into multiple software/file formats. However in order to use this data, principally the bathymetry, in a GIS some post-processing into derivative products was required. The steps taken in the GIS to generate the derived bathymetry products are:

- Convert bathymetry 'XYZ' text file into GIS depth point features
- Convert point features into riverbed surface
- Generate contours from the riverbed surface

Figure 12 provides an illustration of the sheer volume of data points captured during the multibeam sonar survey. This image displays only a small fraction of the total points acquired and yet the density and coverage of points is apparent.

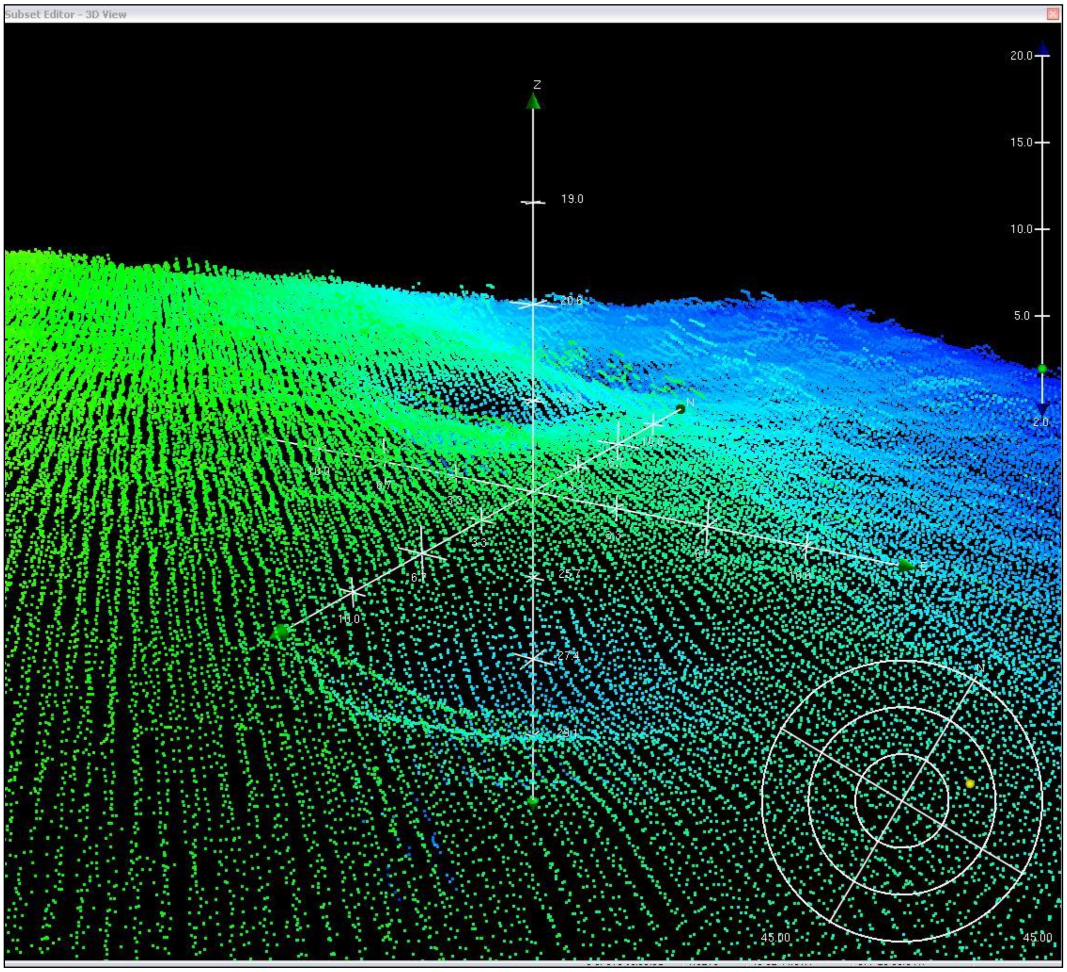

Figure 12. Raw bathymetry data of the Ottawa River.

2.3.3 Examine – Plot the data and review

A series of maps were generated to facilitate the review process of the bathymetry information. The high resolution bathymetry data will prove useful for AECL in planning river sampling surveys. Figure 13 is an example of one of these maps from a series of thirteen.

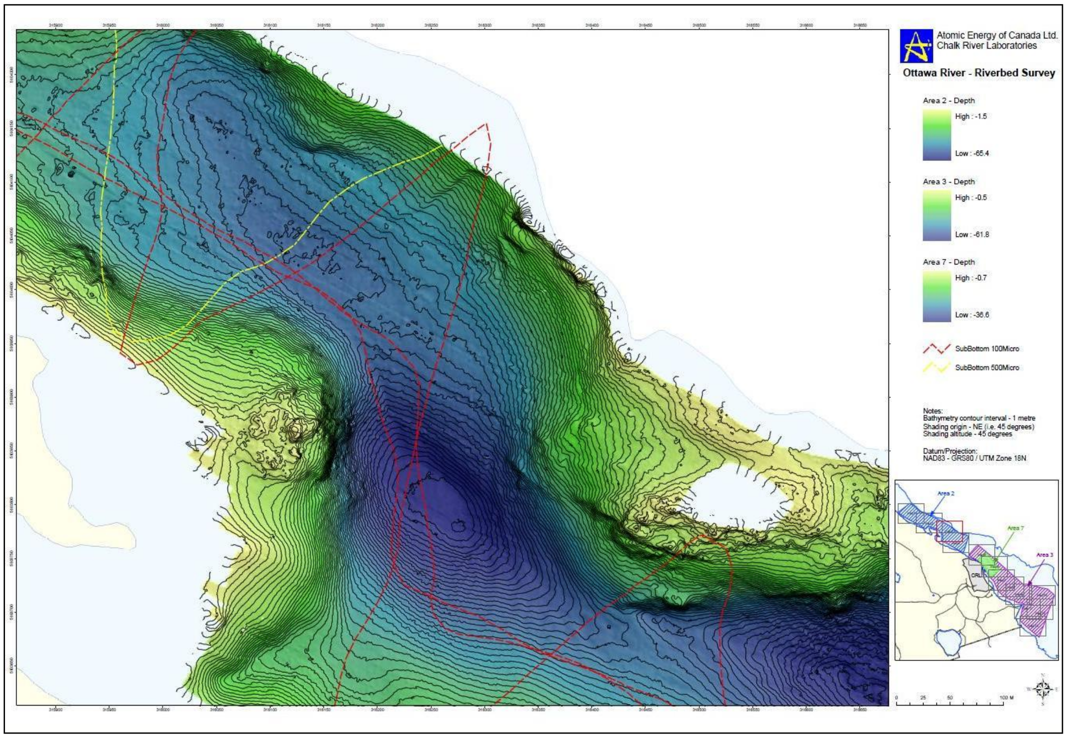

Figure 13. Bathymetric map series.

While reviewing some of the sidescan sonar images a dredging like pattern was noticed. There is some weak historical evidence that a cleanup operation may have occurred shortly after a contamination release into the river during the 1952 NRX reactor accident. The dredging pattern may indicate that an attempted cleanup of the NRX released contaminants had occurred. Figure 14 illustrates the area identified (within the green rectangle). A light and dark grey dredge like pattern parallel to the shoreline can be seen within the smaller interior green rectangle.

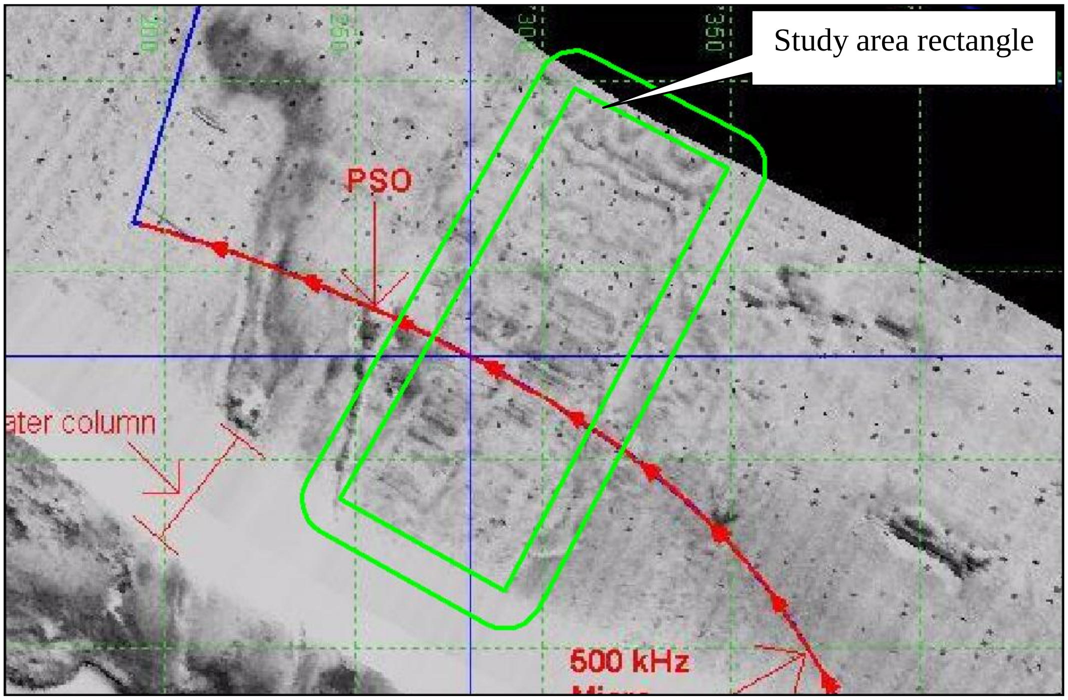

Figure 14. Sidescan sonar image of possible dredged area.

2.3.4 Analyze

As directed the newly captured bathymetry data was used to recalibrate the transport sediment model and the model was rerun [4]. The bathymetric maps series will be further analyzed by the Environmental Technologies Branch staff and other projects/studies may be impacted.

The visual evidence of dredging (Figure 14) presents a subsequent question. Does the detailed bathymetric data also provide evidence of dredging? This scenario shows how, as illustrated in Figure 7, upon critical review of the analysis new questions arise that require further analysis. Subsequently an analysis of a focused study area (the green rectangular area in Figure 14) was requested.

Fortunately the raw data exists in immense detail (sub-metre sampling) for the study area. The raw data sets were queried for the study area and bathymetric data points were extracted where an excess of one hundred and fifty thousand were selected. The queried data was then processed in the GIS to generate a highly detailed surface. From the surface ten centimetre contours were generated to see if further evidence of dredging appears. Figure 15 and 16 illustrates the results of the detailed surface and contour development. This analysis yielded no further evidence of dredging. As such it is believed that the pattern on the sidescan sonar image first thought to be evidence of dredging is 'noise' from the data capture process.

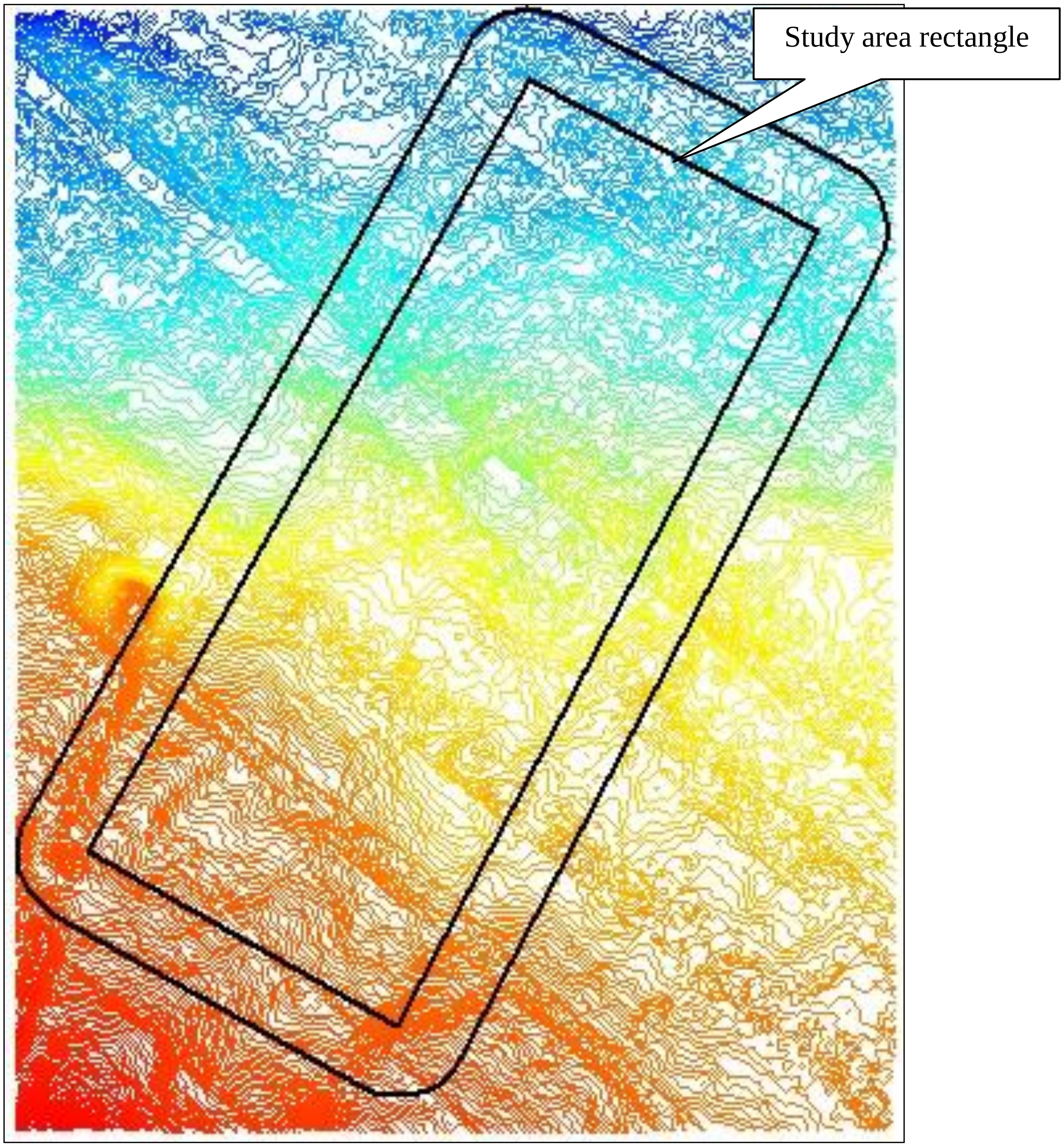

Figure 15. Ten centimeter contours of riverbed study area.

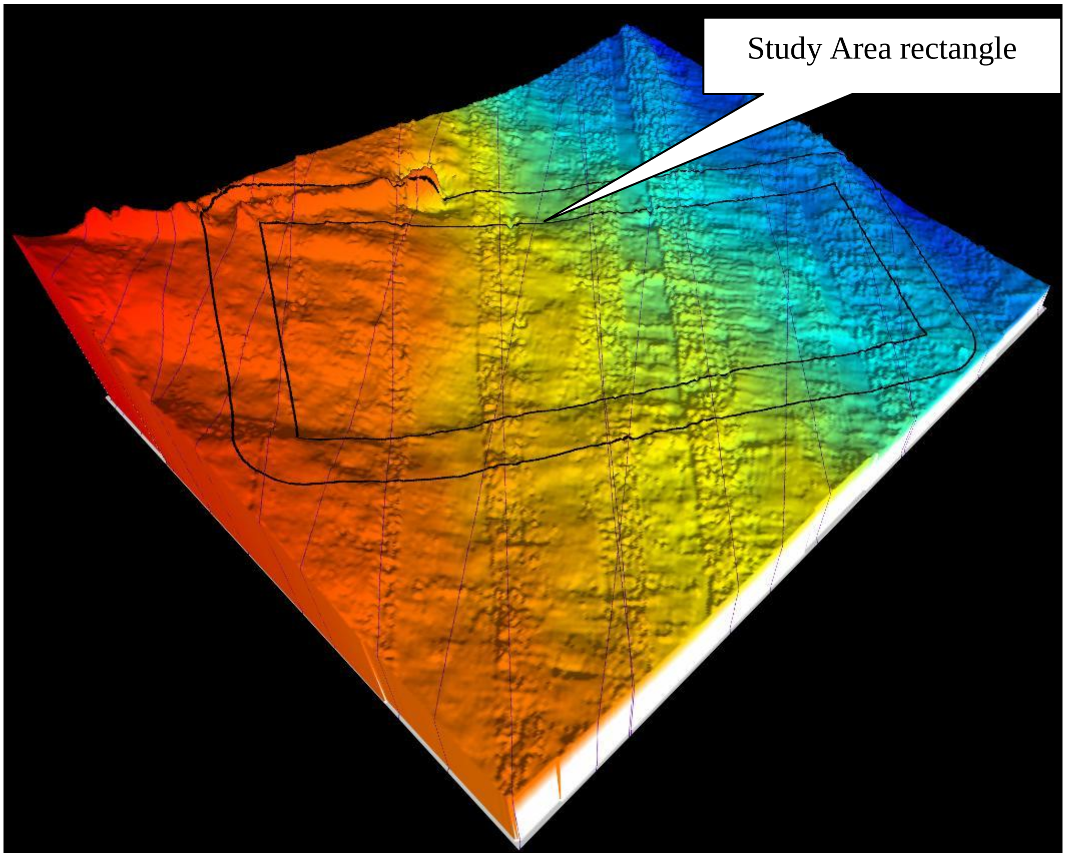

Figure 16. 3D view of the study area surface.

2.3.5 Moving Forward

The review of the bathymetric maps series is ongoing. It is expected that further GIS analysis of various riverbed projects will be required as more AECL staff utilize the new riverbed geophysical surveys. There has also been some suggestion of having Canadian Seabed Research come back and perform another detailed survey of the dredging study area to help verify if any dredging took place to remove the NRX released contaminants. If this occurs the GIS will be again utilized to process and provide review of the resulting data sets.

3. CONCLUSIONS

GIS allows us to view, question, interpret, understand, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, reports, and charts. The output information is based on spatial relationships amongst features.

The projects described in this paper demonstrate that much of what is possible with a GIS is dependent on the data available. The questions asked and answered with GIS need to be tempered by a thorough understanding of the nature of the data sets used. For example the riverbed survey contract resulted from the need for more detailed and accurate data for the transport sediment model. The model was originally run with available data. The results were reviewed and it was determined that a more accurate and robust data set should be acquired to re-run the model. With the new data in the existing model, the two results can be compared.

Decisions based on the model can then be better justified and defended because of the model recalibration. Often this occurs in GIS analysis where an initial investigation and analysis is performed using current data sets and after critically reviewing the results it is determined that more accurate and enhanced data sets are needed. Although an initial analysis may be sufficient, to have the confidence in the analysis and ultimately a solution, more accurate data is essential.

Reviewing the process steps of an analysis, such as the grouping buildings for EA purposes, further questions about the project assumptions and criteria are identified. In this particular analysis, one of the criteria was the existing decommissioning schedule which placed strict control on the analysis. Perhaps by removing this criteria level and using the 'what-if' power of a GIS, other building groupings would appear potentially providing a more efficient decommissioning schedule.

In supporting the GWMF project it became apparent that AECL has an enormous amount and variety of information about the CRL property and site. This data has been commissioned and captured by a multitude of groups within a large number of projects. Many of these data sets have a spatial element to them. One of the major challenges for the use of GIS in planning NLLP decommissioning and environmental restoration activities is finding, understanding, managing , maintaining and ultimately using these data sets.

4. REFERENCES

[1.] Mann, A., Baumgartner, P. 2008. Conceptual-Design Description of a Geologic Waste Management Facility Located at Chalk River Laboratories for AECL's Radioactive Wastes. AECL Report No. : 361101-10180-REPT-001.

[2.] RBEL (Raven Beck Environmental Ltd.). 1994b. Bedrock geological mapping and studies of the Chalk River Laboratories property, Deep River, Ontario. Volume 1 of 2. Siting Task Force Geo-Sci 10, Bib. No. 338A.

[3.] Thivierge, R.H., McCrank, G.F., Sikorsky, R.I., Janzen, M.S., Killey, R.W.D., Martino, J.B., Pucciarelli, D.M., King-Sharp, K.J., Siddiqui, J.A. 2010. Preliminary Geological Synthesis of the Chalk River Laboratories Property. AECL Report No. : 361101-10120-REPT-010.

[4.] SEI (Sea Engineering, Inc.). 2010. Updated Ottawa River Sediment Transport Evaluation. AECL Report No.: 175-00030-REPT-001.

[5.] CSRL (Canadian Seabed Research Ltd.). 2010. Geophysical Surveys of the Ottawa Riverbed. AECL Report No. : 175-121250-REPT-006.