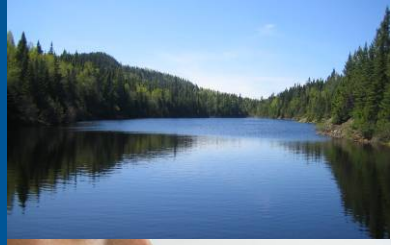




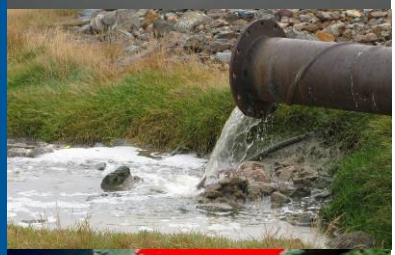


Application of Earth Observation Technology to Improve Water Resource Management in Newfoundland and Labrador

May 2010

Government of Newfoundland & Labrador
Department of Environment and Conservation
Water Resources Management Division
St. John's NL A1B 4J6 Canada

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Hydrologic Modelling Section
Water Resources Management Division
Department of Environment and Conservation

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Introduction

The Water Resources Management Division (WRMD) of the Department of Environment and Conservation is the lead agency for the management of the water resources of Newfoundland and Labrador. Water resource issues are often very complex and frequently require large amounts of diverse data. Effective management of water resources can be greatly aided by methods which allow for timely and accurate data collection. Collection of data by traditional means (e.g. field work) can be quite difficult at times, especially in remote areas, as well as costly and resource intensive. The use of Earth Observation (EO) technologies such as satellite based monitoring can be very useful as it can provide a cost-effective means of replacing or complimenting field data collection. Some of the main benefits of EO data are that it can provide coverage over large and remote areas with systematic, repetitive data captures (EURAC Research, 2010). EO data can also be integrated with field or remotely collected data (i.e. real-time) to produce effective up-to-date predictive and analytical products.

WRMD has used EO technologies for a number of years. The use of this technology has largely been led by the Hydrologic Modelling Section of the Division. Prior to 2003 several pilot studies were conducted to assess the utility of EO. These early studies began in the mid 1980's and focused on the use of Landsat satellite imagery to detect the changes of land cover in a single watershed (Department of Environment, 1994).

With continuous improvements made in the availability and usability of EO data, WRMD is able to incorporate more EO technology into its operations. Current applications of EO within the WRMD include:

(i) river ice monitoring,
(ii) land cover and land use mapping,
(iii) slope stability mapping,
(iv) flood risk mapping,
(v) snow extent mapping,
(vi) wetland mapping,
(vii) water quality monitoring, and
(viii) pollution source detection.

A brief description of each application is provided as follows. The final section describes future EO applications plans for the WRMD.

River Ice Monitoring

In February 2003, the Town of Badger experienced extensive flooding due to ice activity on the Exploits River. As a result of this event, the WRMD recognized the need for a more comprehensive means of monitoring ice conditions to improve upon flood forecasting and flood response practices. EO technology provided a means to resolve these concerns. Under the European Space Agency's PolarView program, the WRMD was able to work with a local company (C-CORE) to develop the Badger River Ice Service, which utilizes radar data to monitor ice conditions on the Exploits River in near-real time. This was a vast improvement over the traditional methods of relying on field observations provided by volunteers from limited vantage points along the river (Water Resources Management Division, 2010).

The Badger River Ice Service was the first operational implementation of EO by the WRMD. It was also the first ice monitoring service in the world based on satellite imagery. The Badger River Ice Service continues today, providing three ice cover products. These include a map of the progression of the ice front, an ice classification product showing open water vs. ice (shown in Figure 1), and a change detection product which depicts whether there is more or less ice present since the previous image. The program has now expanded to utilize new radar data types (i.e. RADARSAT-2) and remains an important component of the Badger flood monitoring program. The use of EO in river ice monitoring has improved the ability of the Department to observe the progression of the ice front along the Exploits River as well as the capacity to forecast possible flood conditions. The ice cover products allow staff to better understand the processes involved in the formation of ice and provide more accurate input to ice progression models that predict future conditions. Enhancement of the accuracy of the data and models used to issue flood watch advisories and warnings has increased the safety and security of residents of this region.

The success of the Badger River Ice Service has led to the expansion of this program on a provincial, national and international scale. The WRMD has implemented a similar river ice monitoring program on the Churchill River in Labrador. River ice monitoring systems, based on techniques developed in Newfoundland and Labrador, have been implemented in Alberta, and the Yukon, as well as in regions of Russia.

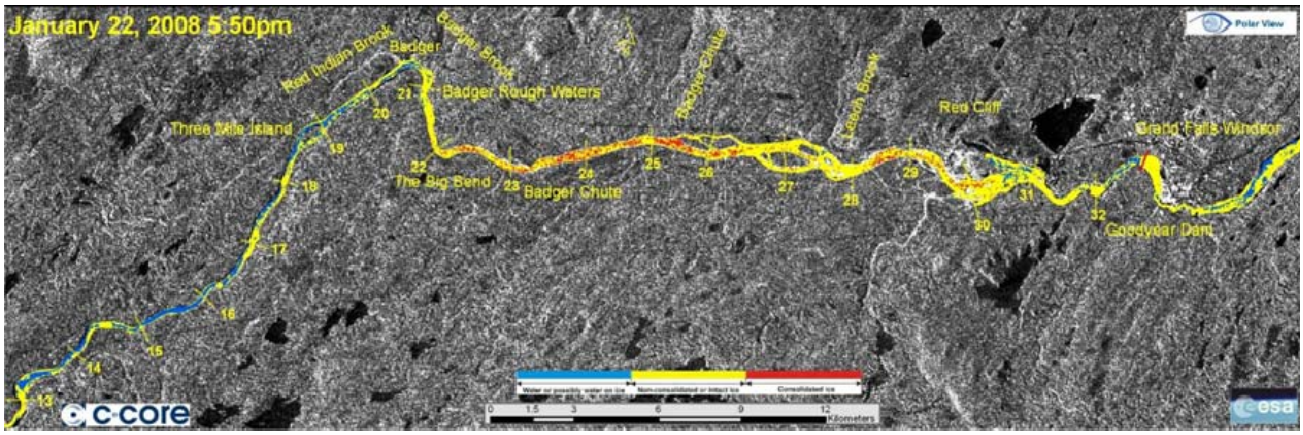
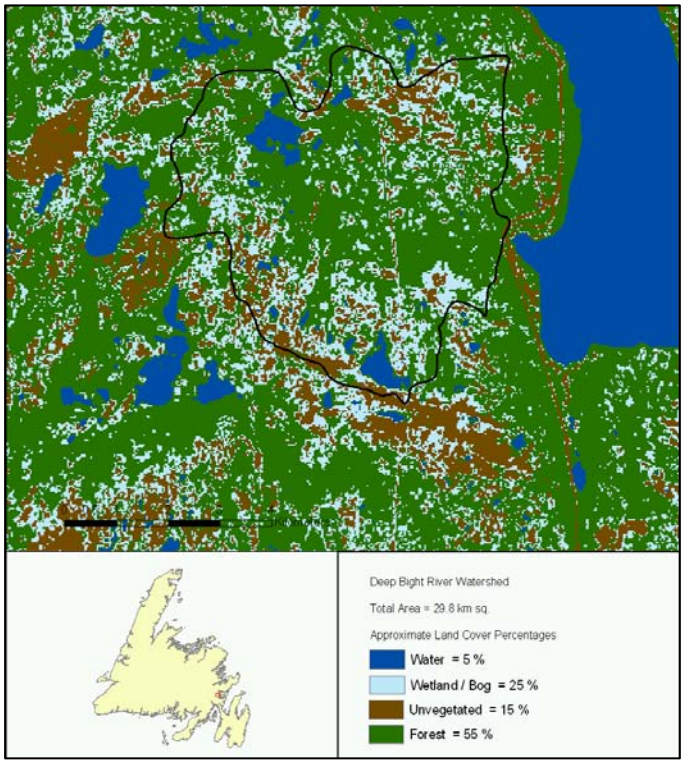


Figure 1. Badger River Ice Service – Ice Classification.

Land Cover & Land Use Mapping

The WRMD has also developed and tested methods of analyzing EO data for land cover and land use mapping of watersheds. Land cover is an important component in the formation of watershed management plans. For example, this data can be used to indicate areas that have high percentages of impervious surfaces (e.g. pavement, rocky areas) that are more prone to runoff during rainfall events. These areas may be more susceptible to flooding or contamination from potential pollution sources. The use of Change Detection studies – comparing the change in land cover in a watershed over time – can help asses the cumulative impact of land use development. This information is valuable to land planners and managers to assist in analyzing and visualizing the influence of various land cover types and land uses on water quality and quantity within a watershed (Figure 2a). One recent initiative of the WRMD is the use of land cover data provided by the Canadian Forest Service, as part of the Earth Observation for Sustainable Development (EOSD) project, to calculate land cover statistics for the Province's public water supply areas and for the Water Quality Monitoring Agreement watersheds (Figure 2b).

a.



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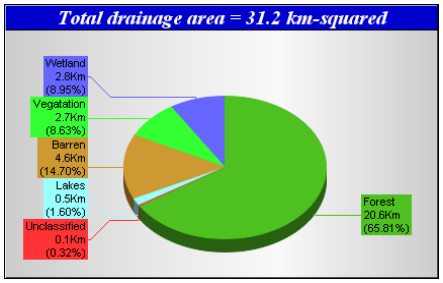

Figure 2. Land cover information derived from Landsat EO data for watershed management.

Digital Elevation Models and Slope Stability Mapping

Digital Elevation Models (DEMs) are often created using remote sensing techniques and are an important tool for water resource studies. The WRMD uses DEMs extensively in their Geographic Information System (GIS). Some of the tasks DEMs have facilitated include the development of automated tools for tracing the path of flow of water across the terrain and delineating watersheds and flood risk zones. DEMs are also used to assess slope stability and identify areas that may be prone to erosion from runoff or sensitive to development (Figure 3). For example, areas with high slopes may not be suitable for logging or other activities. This information has been used as an important component in the development of Watershed Management Plans for Public Water Supply Areas. Slope mapping has also been an important element of natural hazard mapping (e.g. landslides) in various areas of the Province.

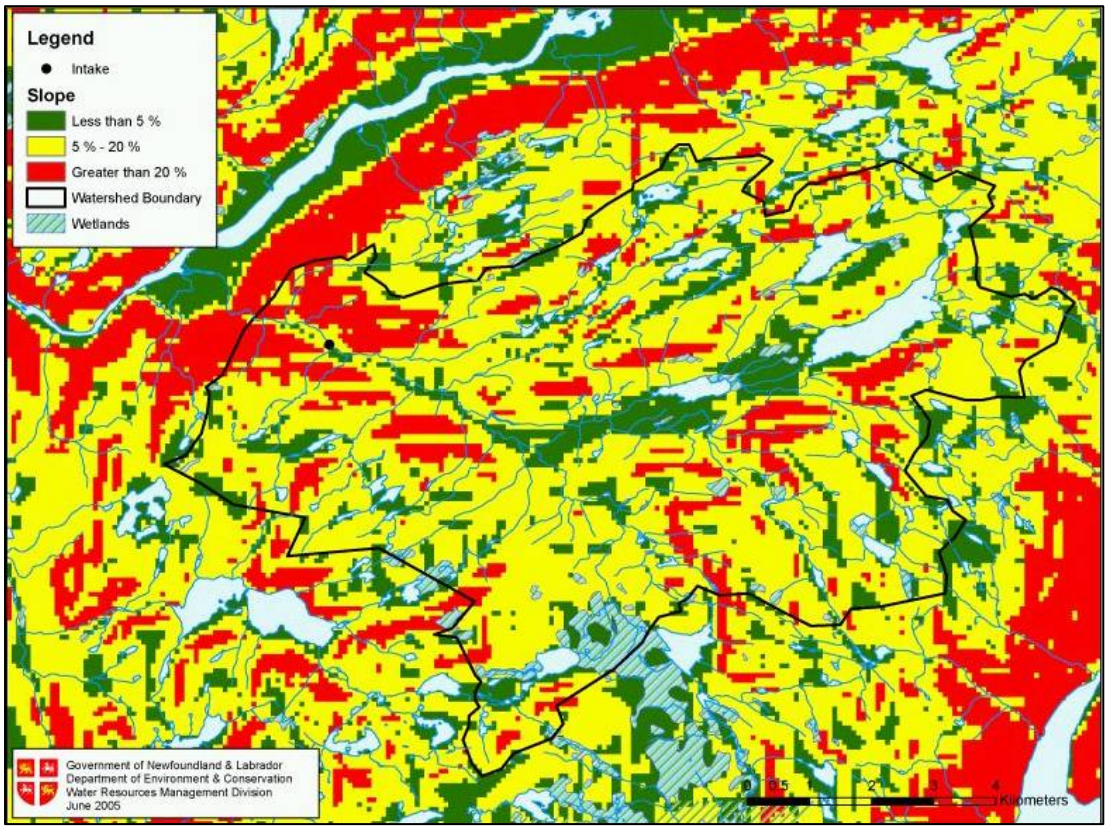

Figure 3. Slope analysis of the Steady Brook Public Water Supply Area.

Flood Risk Mapping

EO products have been very helpful in the area of flood forecasting and mapping. For example, in recent flood risk studies air photos and high resolution imagery have been used to map land cover for flood modelling and used as maps themselves to provide current views of land use in flood prone areas (Figure 4). The techniques used to produce these land cover maps are well documented for future replication with newer datasets. This will allow for accurate change detection analysis to assist in updating any hydrologic and hydraulic models.

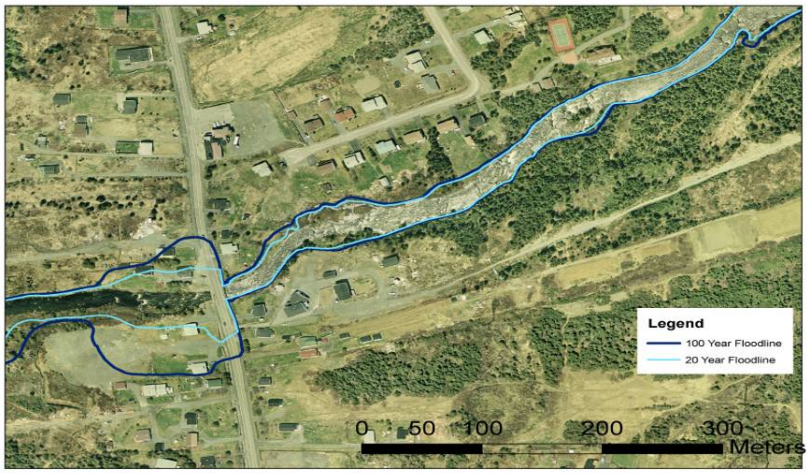

Figure 4. Air Photos used in delineating and displaying flood zones.

EO data was also used to assess the impact of land use on flood events and water quality. In response to the 2005 flood of Stephenville, WRMD used satellite imagery in conjunction with GIS data of clearcuts to assist in evaluating the effect of clearcut harvesting on flooding in the area (Figure 5). The analysis showed that due to the scattered nature of forestry activity in the watershed and the high amount of rainfall, forestry activity would not have had a significant impact on the flood.

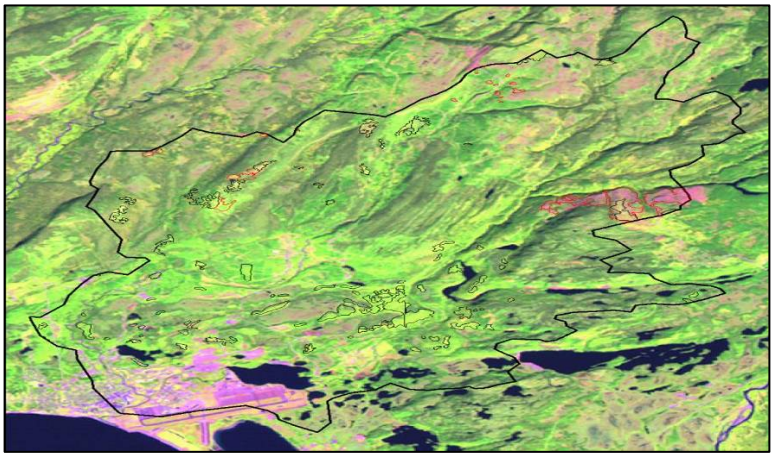

Figure 5. Landsat image showing extent of clearcutting in Blance Brook Watershed.

Snowcover Mapping

EO has been used for determining other conditions that influence water quantity. A recent initiative by the WRMD is using MODIS satellite imagery to assess the extent of snow cover in the Exploits River and Humber River Watersheds (Figure 6). These snow cover maps help predict the timing of spring runoff in these flood prone watersheds (Abbott et al., 2009). WRMD is also participating in the GlobSnow project, an initiative of the European Space Agency. The goal of the project is to use EO to measure snow extent and snow water equivalent throughout the Northern Hemisphere. These products will be valuable for flood forecasting and hydrological and meteorological studies, as well as for climate change research.

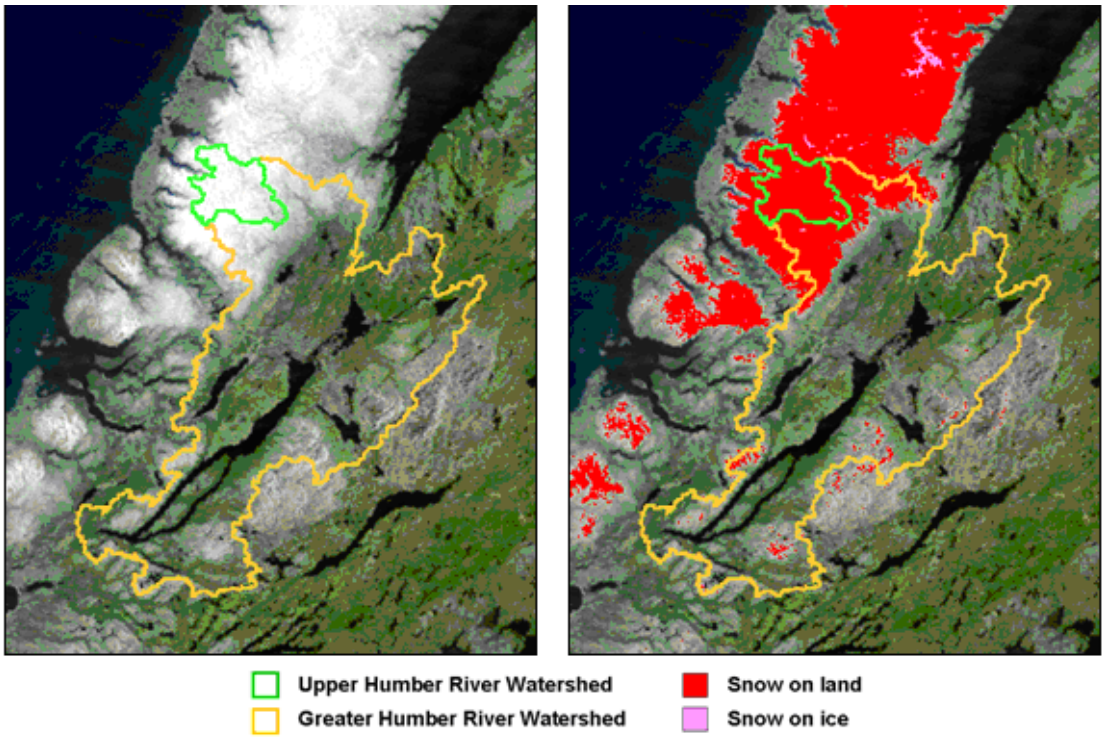

Figure 6. Snowcover mapping for the Humber River Watershed.

Wetland Mapping

Mapping of particular features of interest is another potential use of EO. WRMD has used high resolution satellite imagery in its efforts to develop methodologies and procedures to enable the Department to create a detailed wetlands inventory for regions under high development pressures (Figure 7). Newfoundland and Labrador is one of the few provinces without a dedicated wetlands inventory. Although these techniques are still in the development stage, if successful they will provide a number of benefits. Improved mapping of wetlands will allow WRMD to better protect wetlands which serve important ecological functions, such as providing wildlife habitat or attenuating flood waters. It will also aid in monitoring if the cumulative impact of development activities on small wetlands is significant in terms of total wetland area in these regions of interest.

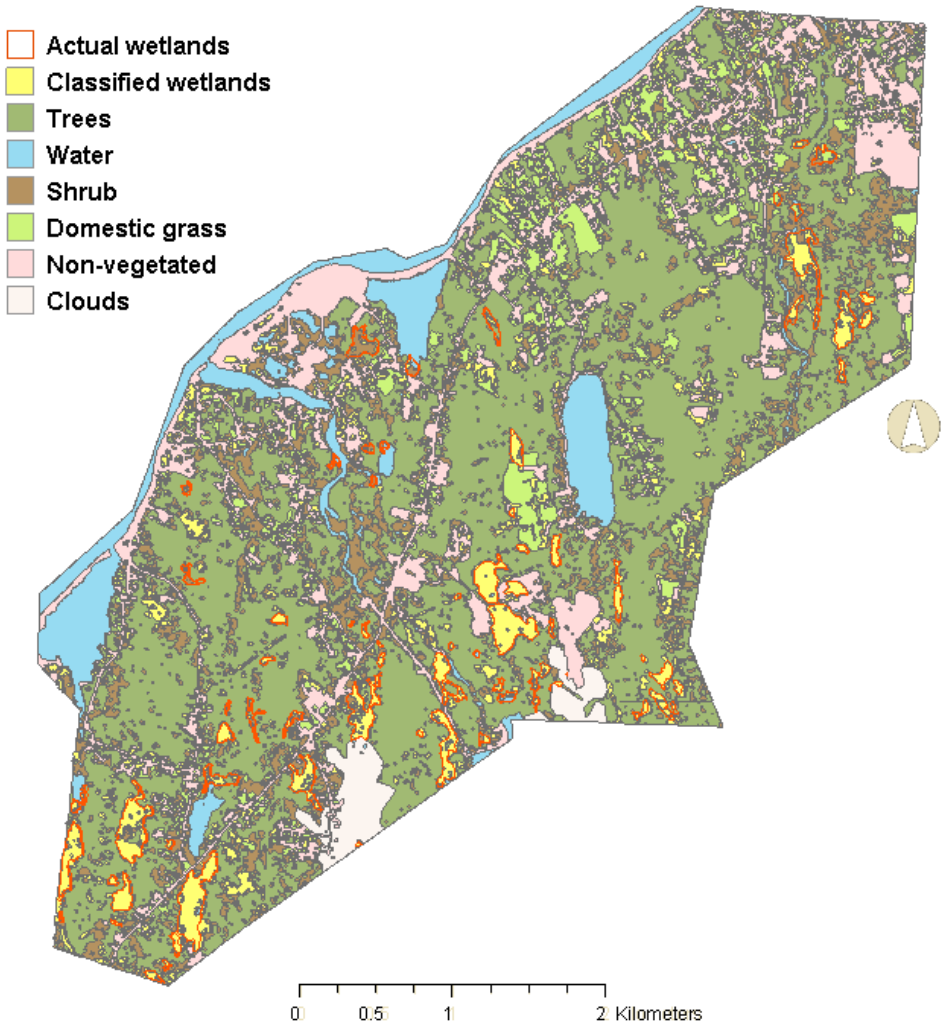

Figure 7. Mapping wetlands in Conception Bay South using Quickbird and RADARSAT-1 imagery.

Water Quality Monitoring

The power of EO analysis can be enhanced when used in conjunction with field observations or real-time data collection. Verifying and calibrating EO analysis techniques with in-situ data allows for the creation of more accurate and informative products. WRMD has developed a number of methodologies to produce such products. For example, WRMD participated in the European Space Agency's TIGER project to monitor water quality in several lakes in Egypt using MERIS and MODIS imagery and real-time water quality data sensors (Figure 8). The Division is testing this process on Wabush Lake and hopes to implement similar methodologies on selected water bodies in Newfoundland and Labrador. This would allow the Department to not only monitor changes to water quality at the locations of sensors, but to use the calibrated satellite images to infer conditions throughout the entire water body and region as a whole. This will be useful for large natural resource development projects that could potentially impact ponds and lakes.

Figure 8. TIGER Project – Calibrated water quality image of Lake Manzalah, Egypt.

Pollution Source Detection

EO can also be used to monitor pollution sources and points of discharge into water bodies. WRMD has worked on two pilot studies with the European Space Agency to determine the effectiveness of various types of satellite imagery in detecting point discharges from sewage and industrial outfalls (Figure 9) as well as monitoring sedimentation in water bodies caused by industrial activity (Figure 10).

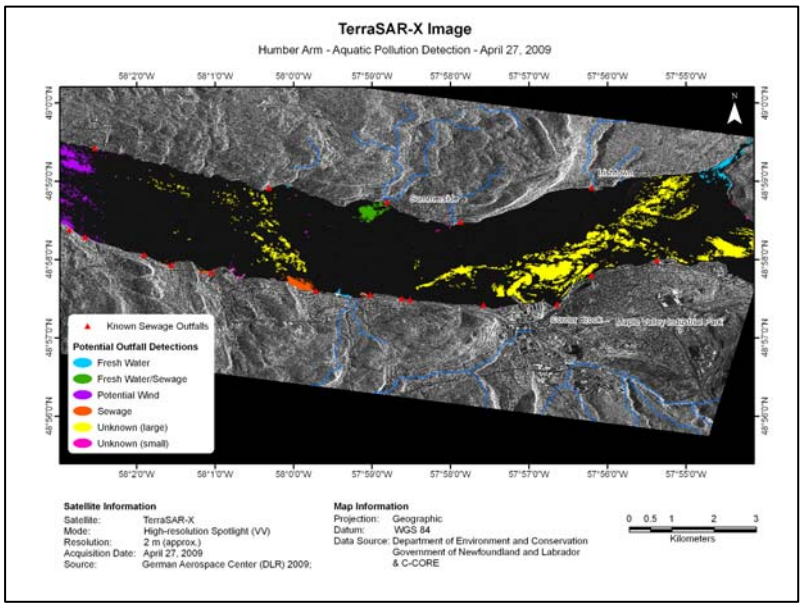

Figure 9.
Monitoring sewage and industry outfalls with TerraSAR-X imagery in the Humber Arm of the Bay of Islands.

Figure 10.
Detecting sedimentation loads resulting from mining activities near Wabush Lake.

Future EO Applications

WRMD is one of the few agencies in Canada to have adapted EO products and tools for the purposes of advancing water resources management. WRMD will continue to find new and innovative ways to utilize EO technologies to enhance the quality and efficiency of the programs and services it provides. For example, upcoming flood risk studies will use Light Detection and Ranging (LiDAR) technology to create highly accurate Digital Elevation Models for improved floodplain mapping.

Other potential implementations of EO include:

(i) expanding the snow cover monitoring program to include snow water equivalent measurements for both the Humber River and Exploits River Watersheds;
(ii) applying the skills and methods developed in monitoring water quality in Egypt to several lakes in the Province;
(iii) using imagery to detect the amount of impervious surfaces in watersheds, to assess runoff potential;
(iv) comparing landcover change over time with water quality trends;
(v) applying EO products and technology to monitor the impacts of climate change and assist in developing adaptation strategies;
(vi) investigating the potential for applying EO methodologies to assess groundwater conditions;
(vii) employ ice monitoring products to evaluate the safety of winter travel routes for northern communities; and
(viii) continuing to facilitate the integration of EO data and products with the WRMD's GIS database.

The WRMD will also continue to apply and enhance the products and methodologies outlined above, and seek out new areas and programs that can benefit from EO. The Division will keep abreast of new developments in EO technology with the intent of adopting those that will improve upon water resources management.

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