Geospatial Data Integration for Applications in Flood Prediction and Management in the Red River Basin.

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ABSTRACT - Following the 1997 flood, the Red River Basin Task Force recommended the development of an international geospatial database. This database will consist of remotely sensed and GIS data that will eventually be implemented in the Decision Support System, to improve forecasting and modelling of the Red River basin. This project demonstrates the cross border issues and challenges encountered in the process of merging roads and hydrography vectors from Canadian and US federal governments. The major differences in the datasets between countries are: classification systems, details of attributes, validation dates, and mapping scales. Discrepancies include: horizontal offsets, feature density variations, feature discontinuities, and attribute discontinuities at the border. Flood extent vectors were extracted from RADARSAT images to provide an overview of flood extent at specific time within the Red River basin.

The development of an international geospatial database for the Red River basin requirement require resolving cross border mapping issues, and Canadian copyright issues.

I. INTRODUCTION

In response to a devastating flood in 1997, Canadian and American agencies, in part through the efforts of the International Joint Commission, are working together to reduce the impact of future flooding in the Red River Basin. The Red River Basin Task Force (RRBTF) was formed by the International Joint Commission (IJC) and made 40 recommendations to the governments of Canada and the US to prepare for floods in the future. One of the recommendations was to develop a common Canada and US Red River Database, which could be implemented into a Decision Support System (DSS) to improve forecasting and modelling of the Red River basin. This database will consist of remotely sensed and geospatial data.

As part of a consortium of Canadian and US government and industry partners, the Canada Centre for Remote Sensing and the United States Geological Survey EROS Data Center, are currently integrating a number of Canadian and U.S. spatial datasets to create a seamless international geospatial database for the Red River. The objective is to work towards a comprehensive set of commonly needed data for a model basin crossing the border, and to build a consensus on the best way to use this framework in the context of watershed management. Geographic Information Systems (GIS) is being used as a tool to integrate the data that will serve as the first level geospatial database required for the development of a system to monitor and predict floods within the Red River watershed.

Federal hydrography and road network were selected as framework datasets to demonstrate the challenges and issues that arise in the creation of a seamless geospatial database for this large international watershed. Over the years, CCRS has collected a considerable amount of RADARSAT data for this area, in particular for the floods of 1996, 1997, and 2001. RADARSAT is Canada's first earth observation satellite C-Band SAR. The frequent coverage by RADARSAT combined with the all-weather acquisition capabilities makes it well suited for monitoring floods. RADARSAT also has the ability to acquire imagery in various beam modes and resolutions, which provides improved repeat coverage for flood monitoring. Flood vector extracted from these images will be used to create flood extent maps that will also be integrated in this geospatial database.

II. STUDY AREA

The Red River is an international watershed that originates in Lake Traverse, United States and flows north into Lake Winnipeg, Canada. The Red River basin covers 116,500 km^2, of which 103,600 km^2 are in South Dakota, North Dakota and Minnesota and the remaining 13,000 km^2 are in Manitoba (Fig.1). The central portion of the Red River basin, known locally as the "Red River valley", is very flat as it originated from

the glacial bed of Lake Agassiz. The River only drops 71 m over a distance of 870 km, while the slope varies from 250 mm/km in the headwaters to 40 mm/km at the International Boundary [1]. The River channel can roughly hold the mean annual flood peak, but during major flood events the river leaves its banks and flows north constrained by natural topography and infrastructure such as road and rail networks. In 1997, the Red River spread to a width of up to 40 km in Manitoba.

The Red River basin has a sub-humid to humid continental climate with moderately warm summers, cold winters, and rapid changes in daily weather patterns [2]. Monthly mean temperatures range from -15 to +20^{o} C. About three-quarters of the basin's precipitation (approximately 500 mm of annual) occurs from April through September, with almost two-thirds of that falling during the spring season [1]. The winter months are driest, with only about 10 to 15 mm of precipitation per month [1]. Terrain and climatic conditions contribute to the creation of an area highly sensitive to spring flooding.

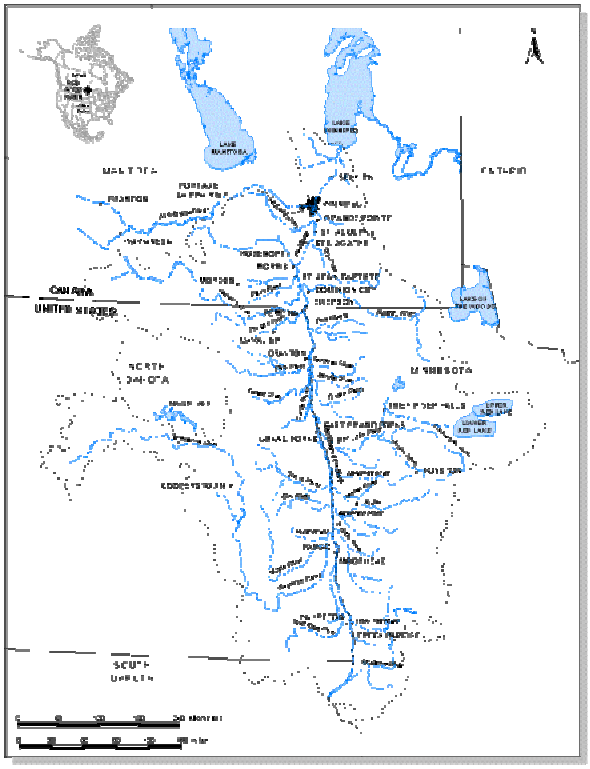

Figure 1 Location of the Red River Basin [2].

III. METHODOLOGY

The hydrography and the roads network from federal Canadian (1:50 000) and United States (1:100 000) databases were selected as framework datasets to investigate cross-border issues in the Red River basin. The Canadian hydrography data are from the National Topographic Database (NTDB) and the roads dataset are from the Updated Roads Network (URN). The United States hydrography data are from the National Hydrography Data (NHD) and the roads dataset are from the Bureau of Transportation Statistics (BTS). The international hydrography and road layers were created by reprojecting datasets to a common datum then by appending using ArcGIS software. The full set of Canadian and US feature attributes were retained.

The flood extent vectors were extracted from RADARSAT images in the Red River basin. Imagery collected during the flooding season of 1996, 1997, and 2001 were processed using CCRS in-house software, FnF Hi/Lo Class Extraction Module, developed by Robert Landry of CCRS. Radarsat images are ingested and transformed to radar brightness beta nought values, from which a thematic flooded and non-flooded image is created. The original radar image and thematic image were geocoded to a UTM projection, zone 14/NAD83 using the NTDB 1:50000 vector layers. Flooded and non-flooded area vectors were extracted from the geocoded thematic image. To provide a general flood extent overview, the minimum polygon size was set to 100 Hectares and smaller polygons were deleted. The flood extent vectors extracted from Radarsat images, of April 24th 2001(S3, Asc.) and May 4th 2001 (S6, Des.), were then compared to high-resolution images from the Multispectral Thermal Imager (MTI) of April 29th and 30th 2001. MTI is a U.S. government research and development satellite that has visible and near-infrared bands with a spatial resolution of 5 meters.

IV. RESULTS

The standards for this project were selected for ease of data sharing, ease of use, compatibility with common software tools, use of common and widely accepted standards, and their applicability over large trans-border areas such as the Red River Basin. The standards described below are those used for data distribution, and it is anticipated that the geospatial data user will need to transform the dataset to suit their needs. Even though the Canadian data policies are significantly different than the United States, and does not permit the distribution and sharing of dataset, it is anticipated that progress on this issue will be made soon. Projection standards for merged datasets are as follows: geographic, decimal degrees, NAD83 horizontal datum, and GRS80 spheroid. The Metadata Format adopted for this project is FGDC-STD-001-1998.

In the process of merging international roads and hydrography datasets numerous cross-border issues were identified and are grouped into two classes:
1) Attributes: Differences in classification systems and the disparity in the level of detail contained in the attributes made it impossible to correspond attributes without losing the rich information contained in individual datasets. The full set of Canadian and US attributes was retained with the exception of Canadian attributes related to feature metadata and some internal GIS attributes. Information pertaining to deleted attributes was incorporated in the metadata for ease of use.
2) Geographic Characteristics: Differences in mapping standards, validation dates, and mapping scales results in visual matching problems at the international boundary. These differences create problems such as horizontal offsets (Fig.2), feature density variations, and feature discontinuities (Fig.3). Resolving these issues requires the knowledge of local people and/or imagery with the support of GIS experts.

The flood extent vectors extracted from RADARSAT images provide a good overview of flood extents at specific times during the Red River flood. Flood extent vectors extracted from Radarsat images were overlaid on the high resolution MTI images. Results are comparable to the flood extent observed in the visible and near infrared channels, differences observed are probably the result of offsets in acquisition dates. A stage variation of 37cm or less, measured at the Morris hydrometric station, is observed between Radarsat and MTI acquisition dates.

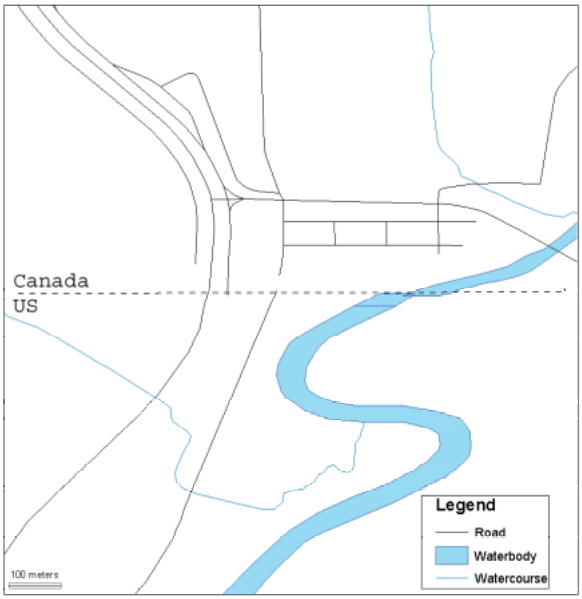

Figure 2 Horizontal offset of the Red River at the border.

Figure 3 Wetland discontinuity at the border.

V. CONCLUSIONS

This study demonstrates the cross border issues that arise when trying to create international datasets within the Red River basin. Resolving these issues would require the collaboration between international agencies, governments, and mapping/GIS experts.

Efforts should be concentrated on resolving the Canadian copyright issues that restricts GIS data and RADARSAT imagery from being shared amongst organisations. There is also a needed to simplify data access to better serve the communities within the Red River basin during flood events.

RADARSAT derived flood extent maps provide a good overview of flooding extents at specific points in time, and provide an excellent tool for flood monitoring.

REFERENCES

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[2] International Joint Commission 2000. Living with the Red. pp.75