MODELING SURFACE-FLOW CHARACTERISTICS IN GLACIATED LANDSCAPES

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1. INTRODUCTION

GIS hydrologic modeling techniques are used to better understand the surface-flow characteristics in the Prairie Pothole Region (PPR) of North America. This research uses an airborne Interferometric Synthetic Aperture Radar (IFSAR)-derived digital terrain model (DTM) as a base for developing a hydrologically-correct DEM and derivative products. The IFSAR DTM is assessed for accuracy and ability to resolve wetland features. A wetland mask is developed to selectively fill the DTM and from it products such as wetland catchments and drainage linkages are derived and interpreted. Study sites in the PPR are two surveyed and closely monitored wetland complexes, Crystal Springs and Orchid Meadows in Deuel County, South Dakota, USA..

The PPR, a 715,000 sq kilometer area, extends from Alberta, Saskatchewan, and Manitoba in Canada to Montana, North Dakota, South Dakota, Nebraska, Minnesota, and Iowa in the United States. Retreating glaciers left over 25 million depressional wetlands, which fill with snowmelt and rain in the spring. The size of prairies potholes (sloughs) range from a fraction of a hectare to several square kilometers. Most depressional wetlands are small with an estimated median of .16 ha, only slightly larger than the 0.09 ha pixel size of Landsat TM data. Pothole wetlands are shallow, with depths generally less than a 1 meter and vary in permanency. Potholes can function as groundwater recharge sites, flow-through systems, or groundwater discharge sites. Surface flow characteristics are poorly understood. Pothole wetlands are often viewed as isolated (closed) basins, though in wet years they overflow and form surface connections with one another. Drainage in these incidences becomes more organized, a start of an integrated surface drainage system, that would eventually eliminate wetland features as the landscape ages.

A hydrologic model is used to gain insight on the evolution of drainage systems in a glacial landscape. Modeling the surface-flow characteristics in the PPR require high resolution digital elevation models (DEMs). DEMs created using hypsography data extracted from U.S. standard 1:24,000 scale topographic maps have been shown to be inadequate for representing surfaces of low-lying, extremely flat areas and/or containing numerous ponds or wetlands. IFSAR-derived DTMs show potential for resolving subtle landscape features in low-lying landscapes.

2. IFSAR EVALUATION

IFSAR is an active imaging technique that has been developed for capturing digital elevation data. Relatively high resolution and low cost, IFSAR competes well with LiDAR in low relief, rural and non-forested landscapes. In this study, IFSAR z values for a 5-m DTM were compared with ground survey data. For the Crystal Springs site, elevations for 80,027 upland survey points deviated less than .13 m on the average with a range of -2.09 to 2.08 m and standard deviation of .33 m. For some 1342 survey points in collected in wetland depressions, the average value was -.24 m with a range of -1.01 to .86 m and a standard deviation of .27 m.

IFSAR resolved all but two of the 18 wetlands at Crystal Springs and all 10 of the wetlands in the Orchid Meadows complex. The two unresolved depressions were small, shallow wetlands situated on undulating ground. IFSAR data were further tested with construction of a hydrologically-correct DEM and DEM derivatives such as flow direction and flow accumulation matrices.

Processing DEMs for hydrologic modeling normally requires filling of depressions (sinks), features that inhibit surface flow. Majority of sinks are spurious artifacts of DEM creation. Yet some sinks represent real features such as depressional wetlands, and should not be filled. To maintain sinks, a threshold grid or mask that identifies real depressions is first generated. Creating a realistic mask grid requires a DEM that properly resolve topographic depressions, a methodology for sink selection, and data for validation.

3. HYDROLOGIC MODEL DERIVATIVES

Using a 5-m IFSAR DTM as input, ArcHydro Beta Version 1.3 Tools were utilized in terrain preprocessing and drainage connectivity characterization.

Methodology for sink selection was as follows:

- Prescreen sinks. Eliminate all sinks with less than 100 cells (2500 sq m)
- Evaluate depressions. Products include fully attributed vector datasets that show depressions and their drainage areas and contain information on depth and area.
- Determine which depressions are wetlands. Results serve as a mask during the fill operation. GPS data collected for Crystal Springs and Orchid Meadows and National Wetland Inventory data were used to valid the selection process.
- Selectively fill the DTM.

Terrain preprocessing tools in ArcHydro Beta Version 1.3 have several special options for DEMs that have sinks, for example, the flow direction with sinks tool. Beyond that normal procedures for preprocessing DEMs for hydrologic modeling were followed. Catchment polygon processing produced a dataset showing catchments for each of the depressions defined by the wetland mask. Drainage connectivity characterization produced a dataset showing the drainage to wetland depressions within catchments. Figure 1. show catchments and drainage connectivity for the Crystal Springs wetland complex. For wetland labeling, SP = semi-permanent, S = seasonal, and T = temporary.

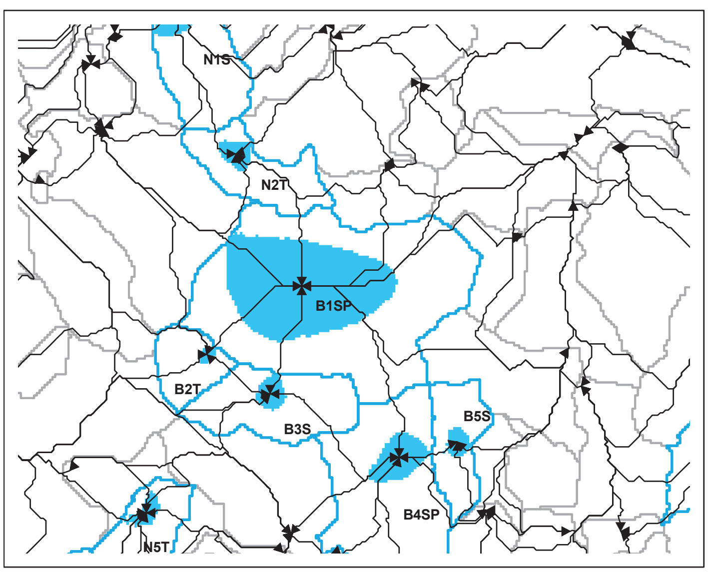

Figure 1. Crystal Springs wetlands and catchments with drainage connectivity.