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Effects of River Ice Jams on the Floodplain Storage Characteristics of the Mackenzie Delta

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1. Introduction

The Mackenzie Delta is approximately 200 km in length and 80 km wide, making it the second largest northern delta in the world (Emmerton, Lesack, and Vincent 2008). The Delta is comprised of a complex network of interconnected channels and lakes. During the spring breakup on the Mackenzie River, melt water from southern portions of the Mackenzie River Basin flows northward and can cause significant ice jams and flooding in the Delta (Lesack and Marsh 2010). When an ice jams forms, water backs up and can flow out of the main channels into lakes and across the floodplain.

Ice jams can have a significant effect on flow distributions within the Delta, and this in turn has important implications for heat and nutrient fluxes to the Beaufort Sea. A hydraulic model is being developed to quantify these effects; Nafziger et al. (2009) have identified a number of primary and secondary flow channels for inclusion in this Delta hydraulic model, based on available geometry data and flow magnitudes (Figure 1). To facilitate this hydraulic modeling effort, it is important to be able to quantify the floodplain storage capacity throughout the Delta, as this storage can have significant effects on wave peak attenuation and speed. Understanding the water storage characteristics in the Delta will therefore allow for a more accurate model of the timing, flow distribution, and volume of water conveyed to the Beaufort Sea.

This study has two objectives: 1) to understand conveyance and storage trends and variations down and across the Mackenzie Delta, and 2) to quantify these characteristics for use in modeling the effects of ice jams on flow distributions in the Mackenzie Delta.

2. Available Topography Data

Given its enormous size, it was not practical or economical to survey floodplain topography for the entire Delta. Therefore, topography data was obtained for three representative transects extending right across the Delta, using airborne LiDAR (Light Detection and Ranging) instrumentation (Hopkinson et al. 2011). These transects are shown in Figure 1 as the *Southern*, *Inuvik*, and *Northern Transects*. Additional data was surveyed in the outer Delta (labeled as the *Outer Delta Transect* in Figure 1). The LiDAR data was collected during the low flow period from August 11 to 16, 2008 so as to capture the maximum amount of exposed topography possible.

Channel and lake beds are not included in this topography data since LiDAR does not penetrate water. Instead, average (low) water levels were obtained (Hopkinson et al. 2011).

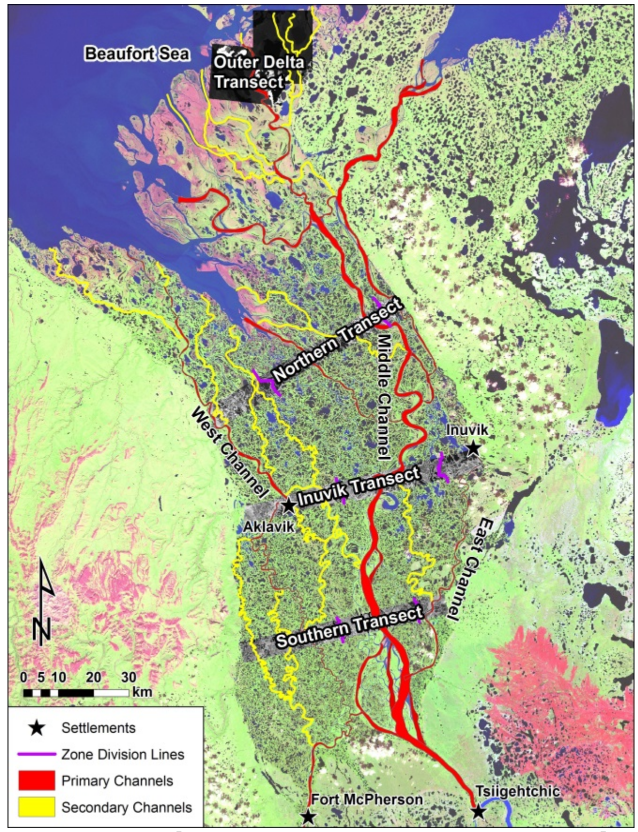

Figure 1. The LiDAR transects, primary, and secondary channels.

3. Methodology

Five (approximately equally spaced) cross-sections were drawn across each of the full transects, and four were drawn across the Outer Delta transect. Each of these cross-sections was examined meticulously, in conjunction with air photos and satellite imagery, to distinguish lakes, channels, and overbank (land) areas. Also, because the storage areas were expected to vary both across and down the Delta, each of the full transects was divided into West, Middle, and East zones. A MatLab code was written to automate the calculation of the storage areas above each feature (i.e. above ground or above the lake level, on the day of survey) for a full range of feasible water levels. The results for all cross-sections in each transect were then averaged to obtain representative characteristics for each transect. Figure 2 illustrates the results for the *Northern Transect*; results for all transects are on the poster. Active flow areas (above the low water level) in the primary and secondary channels were also obtained by this same method, and ratios between the active flow area (in channels) and total storage areas (in the floodplain) were computed to determine relative storage areas in each zone, as a function of water level.

4. Results

As Figure 2 shows, there is significant variance in storage capacity across the Delta, as a result of the zones being of significantly different sizes. For example, the East Zone is the smallest in all three transects and thus has the least storage capacity, the West Zone is the largest in the Southern and Inuvik Transects thus having the largest storage area, and the Middle Zone is the largest and has the largest storage area in the Northern Transect. It was found that the storage capacity is relatively evenly split between the lakes and overbank (land) areas for all zones, except in the Outer Delta, where overbanks dominate. This shows that both lakes and land surface areas are important parts of the water storage in most of the Mackenzie Delta. It was also found that, in general, storage area increases down the Middle Zone, both because of the increase in physical size of the Middle Zone in the downstream direction, and the decrease in the ground and lake elevations from the upper to the lower Delta.

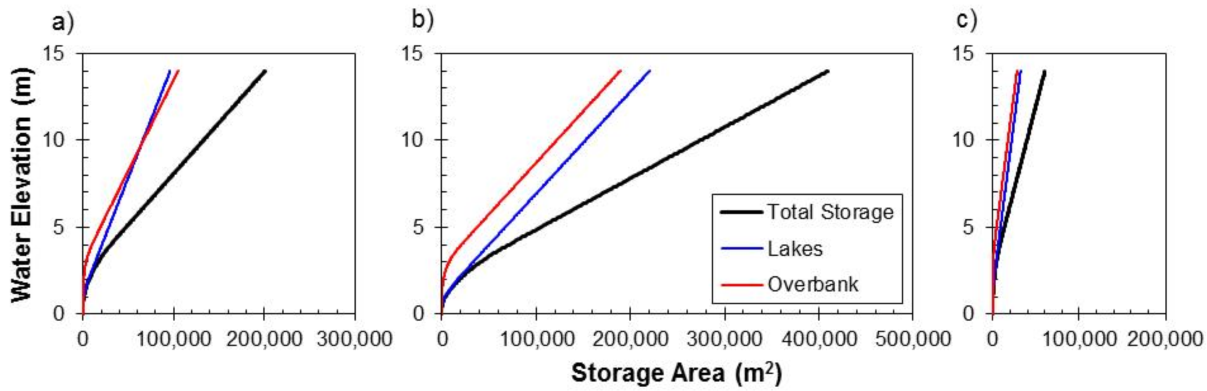

Figure 2. Storage area characteristics in the Northern Transect for the a) West, b) Middle, and c) East Zones.

5. Summary and Future Plans

Representative topographical data in the Mackenzie Delta, obtained using airborne LiDAR, was analyzed to determine available floodplain storage areas in lakes and overbank (land) areas as well as active flow areas in major Delta channels. It was found that, except in the outer delta, lake and overbank areas provide comparable storage areas. It was also found that, for the Middle Zone, storage area tends to increase down the Delta, primarily as a result of lowering topography. This study represents the first quantitative assessment of the floodplain storage capacity of the Mackenzie Delta and will provide key input data for the hydraulic model being used to model ice jam events in the Mackenzie Delta. The modeled channels in each zone will be assigned storage areas based on the relative storage area relationships determined for that particular zone, and the actual active flow area in the channel. This will enable a more realistic assessment of the wave attenuation effects associated with floodplain storage.

6. Cited References

Emmerton, Craig A., Lance F. W. Lesack, and Warwick F. Vincent. 2008. "Mackenzie River Nutrient Delivery to the Arctic Ocean and Effects of the Mackenzie Delta During Open Water Conditions." *Global Biogeochemical Cycles* 22 (1): 15 pp.

Hopkinson, C., N. Crasto, P. Marsh, D. Forbes, and L. Lesack. 2011. "Investigating the Spatial Distribution of Water Levels in the Mackenzie Delta Using Airborne LiDAR." *Hydrological Processes* 25 (19): 2995-3011.

Lesack, Lance F. W., and Philip Marsh. 2010. "River-to-lake Connectivities, Water Renewal, and Aquatic Habitat Diversity in the Mackenzie River Delta." *Water Resources Research* 46 (12): 16 pp.

Nafziger, Jennifer, Faye Hicks, Robyn Andrishak, Philip Marsh, and Lance Lesack. 2009. "Hydraulic Model of River Flow and Storage Effects in the Mackenzie Delta, Canada." In *17th International Northern Researsh Basins Symposium and Workshop,* 10 pp.