Valued Component – Water Quantity (Update November 2004)

STATE OF KNOWLEDGE – WHAT IS HAPPENING?

A very brief overview of the state of knowledge with respect to water quantity in the NWT is presented below. This overview is preliminary and not intended to be exhaustive.

❖ **What are the baseline conditions with respect to water quantity?**

- In the Northwest Territories baseline water quantity conditions depend mainly on the physiographic characteristics of the region but they are also influenced by latitude. There are three main physiographic regions and two large lakes, Great Bear Lake and Great Slave Lake, in the Northwest Territories, which result in a complex hydrologic picture.

  Northern Cordillera. High-energy alpine streams characterize this region. Lakes and wetlands are not common in the cordillera region. Spring freshet, the snowmelt period, generally results in peak stream flows. However, summer rainstorm events can also produce peak flows, especially if the storms trigger a rapid melt of late lying snow packs. The steep slopes and the lack of lake or wetland storage results in a rapid streamflow recession following the spring freshet and after summer rainstorms. Low flows occur in late winter. In smaller and more northerly basins, winter low flows can drop to zero. The difference between summer high flows and winter low flows can be several orders of magnitude.

  Interior Plains. Numerous lakes and wetland areas characterize this region. Lakes and wetlands provide a significant water storage component, which affects the streamflow regime. During the spring freshet period, the total winter precipitation (snow storage) is released in a few weeks, making the spring floods the most significant hydrological event. Summer rainfall events are attenuated by lake and wetland storage, although hydrographs vary considerably depending on the size, shape and drainage patterns of the basin. Streamflows recede throughout winter, but a baseflow is generally maintained by the lake and groundwater storage. The lowest streamflows occur just prior to spring break-up.

  Precambrian Shield. This region is characterized by numerous small and large lakes, which are often connected by short turbulent streams. Spring freshet is the most significant hydrological event, but it is somewhat subdued by the attenuation of flows by the many lakes. Runoff from summer rainfall events is also attenuated by lake storage. Lake storage tends to maintain baseflow over winter. Low flows occur just prior to spring breakup.

  Great Bear and Great Slave Lakes have an enormous capacity to attenuate the flow variability of their tributaries, which results in relatively stable outflows throughout the year.

- There is a network of 75 hydrometric stations currently measuring water levels and streamflows in the Northwest Territories. Of these stations, 22 are operated seasonally. Sixteen stations are operated to provide a flow forecast on the Mackenzie River. There are historic data for another 50 sites from stations that were closed between 1991 and 2000. Baseline water quantity conditions can be expressed graphically and with descriptive statistics. For example, the mean annual discharge of the Mackenzie River into the Arctic Ocean is approximately 9100 m^3/s. Flood frequency analysis can be

KEY MONITORING INDICATORS

Water Levels
Stream Flows
Ice Phenology
Sediment Load

done for sites with long term records, i.e. greater than 30 years, to provide estimates of flood return periods.

❖ **What are the trends observed in the hydrological regime in the NWT?**

- Water levels and streamflows are continually changing in response to hydro-climatic inputs and outputs (precipitation-evaporation, inflows-outflows, groundwater discharge-recharge). There is a large natural variability between inter-annual and inter-seasonal flows.

- The timing and magnitude of streamflow peaks on the Slave River has been significantly altered by the Bennett Dam on the Peace Rivers in northeastern British Columbia. During the initial filling of the Williston Reservoir from 1968 to 1971, there was a decrease in Great Slave Lake water levels and a corresponding decrease in the flow of the Mackenzie River. Current operations of the Bennett Dam have an effect that, although small, can be identified on the Mackenzie River and in the Mackenzie and Slave Delta channels.

- There are some identified trends in the hydrological regime in the Northwest Territories, including some cyclic trends between 1965 and 1998 in mean and maximum flows (Spence, 2002), linear trends over shorter time frames (Whitfield and Cannon, 2000), increasing winter flows and earlier spring freshets in the Liard basin (Burn, 2004). There are also the changes in the Slave River flow regime due to the operation of the Bennett Dam.

❖ **Can the natural variability be determined?**

- Natural variability in water levels and stream flows are recorded at the existing water monitoring network stations. Long-term data, of 30 years or more, are required for statistical analysis of natural variability. There are a limited number of monitoring stations in the NWT that have long-term records.

❖ **Are there changes in the timing of freeze-up and break-up and can these be good indicators of climate change?**

- Changes in the timing of freeze-up and break-up (ice phenology) are not readily available in a single database. However, there may be information collected by community residents, in records from Hudson Bay Company trading posts, and through water quantity monitoring by the Water Survey of Canada. There is evidence that the timing of break up is changing (Burn, 2004; Marsh, 2002), but there is less definitive information on freeze up.

❖ **Have river-based travel patterns and routes changed as a result of levels and flows?**

- It is unknown whether river-based travel patterns and routes have changed as a result of water levels and flows. There is a natural variation in the timing of freeze-up and break-up from year to year. This affects the length of the barge traffic season on the Liard and Mackenzie Rivers, and the duration of ice-bridge and ice-road travel. The transportation season is monitored by the GNWT Department of Transportation. Records of the transportation seasons could be used to determine trends of freeze-up and break-up. Caution must be used when interpreting the data because improved technology and increased effort may affect the duration of the ice bridges and ice roads.

CURRENT MONITORING

Ongoing monitoring programs with respect to water quantity in the NWT are found below.

► Northwest Territories water quantity monitoring program includes75 stations operated by the Water Survey of Canada, with funding from Environment Canada, Indian and Northern Affairs Canada, Northwest Territories Power Corporation, and

the Canadian Coast Guard. Monitoring began in 1938 but most stations were established in the 1960s and 1970s.

Subsets include:

- Northwest Territories reference hydrometric basin network (since 1965) (water flow rates, water quantity, ice phenology)
- Mackenzie Delta water level, flow and hydrometric data monitoring (includes a modeling component)

► Northwest Territories evaporation/ water balance studies were initiated in 1992 for mine site water management. Study sites are located at the Salmita/Tundra mine in the upper Lockhart River basin, the Colomac mine site in the Snare River basin, and Pocket Lake on the Giant mine site near Yellowknife (Indian and Northern Affairs Canada).

► The Global Energy and Water Cycle Experiment (GEWEX) seeks to understand and model the high latitude water and energy cycles that play roles in the global climate system, and improve the ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change. Canada is carrying out an investigation of the water and energy cycles of the Mackenzie River, under a program called the Mackenzie GEWEX Study (MAGS). A series of large-scale hydrological and related land-atmosphere studies are being conducted in the Mackenzie Basin to help understand the role of high latitude hydrological and meteorological processes in the global climate system. MAGS is one of 7 regional experiments in different regions of the world. For further details see http://www.msc-smc.ec.gc.ca/GEWEX.

► Water balance studies at Lower Carp Lake and in the Snare River basin as part of the Mackenzie GEWEX study were established in 1997. Additional GEWEX studies have been initiated for hydrological research in the Baker Creek watershed (Yellowknife area) (Environment Canada), and for ice jam studies at Hay River Indian Affairs and Northern Development, University of Alberta). MAGS researchers studied lake evaporation from Great Slave Lake from 1997 – 2003 and from 2000 – 2003 on smaller lakes in the Yellowknife area. Investigations studying evaporation from Great Bear Lake began in 2004.

► Forest fire effects on water quality and microclimate at Tibbitt Lake were started in 1998 (Indian and Northern Affairs Canada).

► The Coppermine Cumulative Effects Monitoring Program is an enhanced program of water quality and water quantity monitoring. Hydrological studies include a snowmelt-runoff study started in 2001 at Daring Lake (Indian and Northern Affairs Canada) and a small basin hydrologic study that began in 1999 (Wilfrid Laurier University).

► A dendrochronological sampling and analysis project was initiated in 1999. This project correlates standardized tree ring widths with streamflow and precipitation records. Hydrological records have been extended to the late 1600s with these proxy data methods. Sampling has been done in several locations, including the Yellowknife area, along the Mackenzie Highway, in the South Nahanni Watershed, the East Arm (Great Slave Lake) watershed, the Mackenzie River Delta and the Great Bear Lake watershed. (Indian and Northern Affairs Canada, Environment Canada, and University of Regina).

► Northern Rivers Ecosystem Initiative (NREI) is a follow up to the Northern River Basins Study (NRBS).

The Ministers agreed with the direction of the NRBS recommendations and committed to focus their efforts in the areas of pollution prevention, science-based ecological management, resolving contaminant and nutrient issues, endocrine disruption, long-range transport of atmospheric pollutants and continuing environmental research in northern rivers. The NREI will work with industry, Aboriginal peoples, academia, communities and others to address the recommendations from the NRBS. The main partners are Environment Canada, the Government of the Northwest

Territories and the Government of Alberta. Other key partners are Indian and Northern Affairs Canada, Health Canada and Alberta Health.

GAPS AND RECOMMENDATIONS FOR MONITORING

A list of monitoring gaps and recommendations for future monitoring under the NWT Cumulative Impact Monitoring Program is found below.

Gaps

- Water quantity monitoring of east bank tributaries of the Mackenzie River, along the proposed Mackenzie Valley gas pipeline route.
- Water quantity monitoring for baseline data in areas with no development.
- Small basin hydrology in the Liard basin related to oil and gas development.
- Small basin hydrology in the Lockhart and Coppermine basins (subarctic shield and southern arctic) related to diamond mine developments.
- Annual record at hydrometric stations in the Mackenzie Mountains.
- Long-term water quantity monitoring data.
- Sediment sampling for loading calculations.

Recommendations

- An enhanced and coordinated program for water monitoring, including flow/level stations, sediment data and weather data collection, will improve baseline databases for environmental assessments. This can be accomplished by:
- Re-opening some gauging stations closed between 1991 and 2000 and returning selected seasonal stations to annual operations.
- Identifying a typical large-scale basin within which water quantity monitoring and research could be focused. Activities could be nested in different sized basins in order to develop tools to determine natural variability and improve predictive ability at a range of scales.
- Installing additional stream gauging stations on the east bank tributaries of the Mackenzie River along the proposed pipeline route.
- Doing detailed data analyses to separate natural versus artificial changes in the Slave and Mackenzie Rivers resulting from operations of the Bennett Dam in BC.
- Continuing dendrochronology reconstructions of climate and streamflow data to extend records back into the late 1600s.
- Documenting traditional knowledge of changes in river-based travel patterns and routes, and freeze-up and break-up dates (ice phenology) from community representatives, Dene Elders, staff of barge transportation companies, and members of the Canadian Coast Guard.

REFERENCES

Relevant monitoring reports, past monitoring programs, research documents, and scientific publications are found below. This list is a small sample of what is available.

Bastedo, J. (2000). ***Lords of the rings****. Up Here magazine, 16(8): 60-62.*

This article describes a streamflow and climate reconstruction project based on dendrochronology. The project provided proxy streamflow records for several Northwest Territories rivers dating back to the late-1600s.

Bicknell, D. and B. Reid (2001). ***Summary of hydrometeorological and water quality data collection in the Coppermine River Drainage Basin and the Central Arctic Region.*** *Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NT*

Burn, D.H. (2004). ***Trends in hydrological variables for two watersheds in the Mackenzie River Basin****. Paper presented at the Canadian Water Resources Association annual meeting, Montreal, June 2004.*

Coulombe-Pontbriand, M., B. Reid and F. Jackson (1998). ***Overview of the hydrology and water quality of the Coppermine River****. Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NT*

Environment Canada (2001). ***HYDAT 99-2.00 surface water and sediment data.*** *Water Survey of Canada, Meteorological Survey of Canada.*

The following parameters were monitored: mean daily, monthly and annual discharge in rivers, annual extremes of discharge, maximum instantaneous discharge, and total annual discharge. Real-time and archive data area also available on the internet at http://www.msc.ec.gc.ca/wsc/products/main_e.cfm?cname=products_e.cfm

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MacDonald, D.D., T.F. Johnsen and D. Milburn (1999). ***Development of an approach to cumulative effects monitoring in the Coppermine River Basin, NWT.*** *Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NT.*

Marsh, P. et al. (2002) ***Water and energy fluxes in the lower Mackenzie Valley, 1994/95****. Atmosphere Ocean 40: 245-256*

Northern River Basins Study *(1991-1997).*
Northern River Basins Study (NRBS) was a five-year, $12 million study, which was completed in 1996. It examined the cumulative effects of development on the Peace, Athabasca and Slave River basins and presented a number of recommendations. Numerous reports were published and are referenced in the Arctic Science and Technology Information System (ASTIS). The Northern Rivers Ecosystem Initiative (NREI) began in 1998 to apply recommendations from the NRBS (see current monitoring).

Oswald, C. J., Rouse, W. R. (2004) ***Thermal Characteristics and Energy Balance of Various-Size Canadian Shield Lakes in the Mackenzie River Basin.*** *Journal of Hydrometeorology: Vol. 5:. 129–144*

Reid, R. (1995) ***Flow gauging of selected small streams in the Mackenzie River Valley*** *(1992-1994)****.*** *Indian and Northern Affairs Canada, Yellowknife, NWT.*

Reid, R. (2001) ***Evaporation Studies at Mine Sites in the Northwest Territories and Nunavut, Canada, 1993 to 2000,*** *Proceedings of CWRA BC Branch Conference,*

Reid, R and D. Faria (2004 Draft) ***Evaporation Studies in Small NWT Watersheds*** *Indian and Northern Affairs Canada, Yellowknife, NWT. Submitted to IAHS Redbook on Northern Hydrology*

Rouse, W. R.,et al. 2003 ***Interannual and Seasonal Variability of the Surface Energy Balance and Temperature of Central Great Slave Lake****. Journal of Hydrometeorology: Vol. 4: 720–730.*

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Strong, G.S. (ed.) (2000). ***Proceeding of the 5th scientific workshop for the Mackenzie Global Energy and Water Experiment (GEWEX) Study [MAGS].*** *Edmonton, AB, 184 pp.*

Strong, G.S. (ed.) (2001). ***Phase 1 Final reports and proceedings of the 6th scientific workshop for the Mackenzie Global Energy and Water Experiment (GEWEX) Study [MAGS].*** *Saskatoon, SK, 432 pp.*

Whitfield, P. and A. Cannon (2000). ***Recent variations in climate and hydrology in Canada.*** *Canadian Water Resources Association, Spring 2000 Journal. pp. 19-65.*