over the year is approximately 2 m<sup>3</sup>/s, but outside of

suggest inter-annual variations in snow accumulation

High maximum values for mean monthly flows in late

summer, due to storm events, can contribute large

volumes of water to the system, but the closeness o

4.0E+08

2006 2001 1996 1991 1981 1981 1976

Kiskatinaw River Total Annual Discharge, Water Survey of Canada

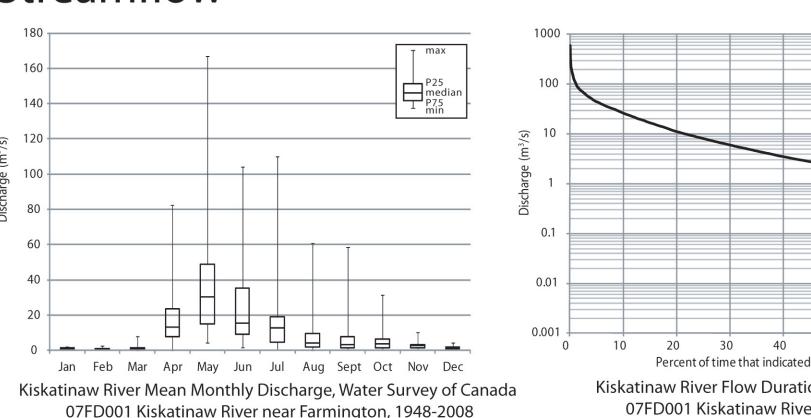
07FD001 Kiskatinaw River near Farmington, 1966-2008

and subsequent melt significantly impact total vol-

umes of water flowing through the river system.

May and June this may dwindle to a trickle. Very

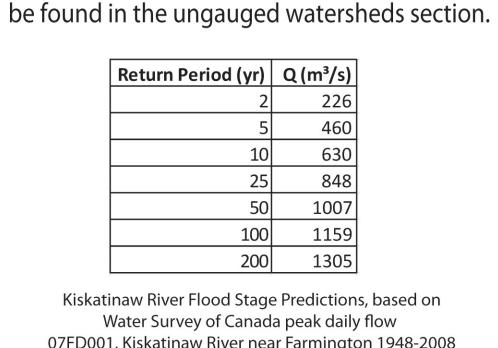
#### Streamflow



Hydrometric stations operated by the Water Survey In the Kiskatinaw River watershed, small probability of Canada were analyzed to identify several key parameters of flow characteristics in the study area

total annual flow volumes inter-annual variability seasonal flow volumes drought flows

These analyses provide information useful to under-P25, median and P75 values to zero indicate baseflow standing flow conditions in the associated water- contributed by reservoirs in the watershed (lakes, sheds such as intra-annual timing of peak flows, peri- wetlands, groundwater) cannot sustain flow condiods of low flow and magnitude of flood and drought tions through extended periods of drought. This is flow events. Regression analyses were performed on further supported by the rapid decline in discharge total annual flows, drought flows and peak flows to above the 95th exceedance probability percentile on relate flow characteristics to watershed size, and can the flow duration curve.



7FD001, Kiskatinaw River near Farmington 1948-2008

lood predictions assuming log-Pearson Type III Distribution

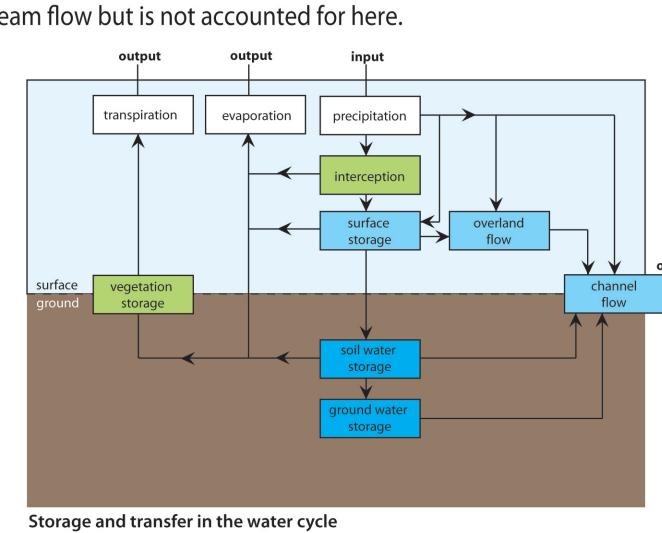
## Water Balance

Creating a water balance for the hydrologic cycle weighs input to the system against outputs. Precipitation (rain and snowfall) are the only input to the system. Variations occur depending on when, where and at what rate precipitation occurs but for this purpose all of the water that enters the watershed leaves on an average annual basis. The three dominant processes that transport water out of the watershed are evaporation, transpiration and channel flow. Water that passes through ground water stores may take several years to exit the system. This complicates coupling water balances on a year to year basis. The relationship between ground water and surface water processes requires more in depth investigation, and in this application only considers ground water in communication with streams. Glacial meltwater may contribute to historical stream flow but is not accounted for here.

imateBC and ClimateWNA (see Future Climate section) are models which were used to produce mean annual precipitation maps for the watersheds. These maps were summed to calculate total volume of water input. Gauged streamflow records provide one output calcula tions, leaving evaporation, transpiration and loss to groundwater (ET/GW) unknown. The Consultative Group for International Agricultural Research estimate actual evapotranspiration to be in the range of 40 - 50 cm per year.

Precipitation is based on PRISM data for period 1961-1990.

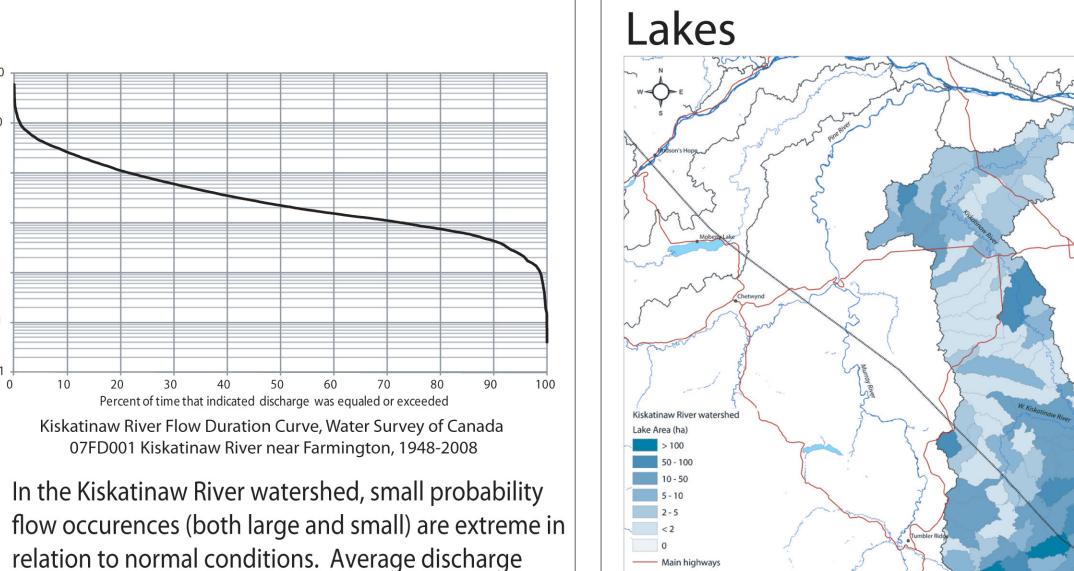
Runoff is based on WSC data: 07fd001 - 1966-2008.



Characteristics of the water balances calculated for the Kiskatinaw and Pouce Coupe River watersheds are different from the other watersheds within the Montney Water Project study area. Runoff, when considered in relation to both watershed size (cm/yr) and to precipitation (% runoff), is lower than that found in the Pine, Moberly, or Halfway River watersheds. This suggests that most of the Pouce Coupe and Kiskatinaw River watersheds are within a prairie or northeast plains type hydrologic zone, along with the Beatton and Alces River systems on the north side of the Peace River.

Precipitation in these watersheds mostly occurs during the summer, and may only be slightly in excess of the evapotranspiration rates for the region. Two stations in the Pine River watershed, 07fb005 and 07fb009, are very close to the headwaters of the West Kiskatinaw River and may provide insight into hydrologic conditions in this part of the Kiskatinaw River watershed. Water balances for these two stations are available in the report accompanying the poster series.

Watershed Station Area (km²) Precip (cm/yr) Runoff (cm/yr) ET/GW (cm/yr) % runoff Precip 2010-2039 (cm/yr) Average annual water balance for gauged watershed in the Kiskatinaw River watershed



small minimum monthly discharges for May and June

the Montney Water Project area are available in the database for this project. Area (ha) Volume (m³) Mean Depth (m) Maximum Depth (m) 1449 lakes in total 1281 < 1 ha

There are close to 1500 lakes in the Kiskatinaw River

watershed. Over 100 of these are larger than 2 ha.

Most of these larger lakes are in the southern, for-

ested portion of the watershed, with Scott (58 ha)

and Norrie (30 ha) Lakes being notable exceptions,

located on the Sunset Creek tributary in the north-

Over 1000 very small (<1/3 ha) waterbodies are

distributed throughout the watershed, many of

which are in the northern portion which is heavily

farmed. Some of these ponds may be man-made

drainage networks, most of which likely flow for a

Bathymetric maps are available for 7 lakes within

the Kiskatinaw River watershed (Rat, Cutbank, One

Island, Boot, Blackhawk, Bearhole and Trout Lakes).

These bathymetric maps have been collected by

the BC Ministry of Environment and provide infor-

mation on maximum and average depths, perim-

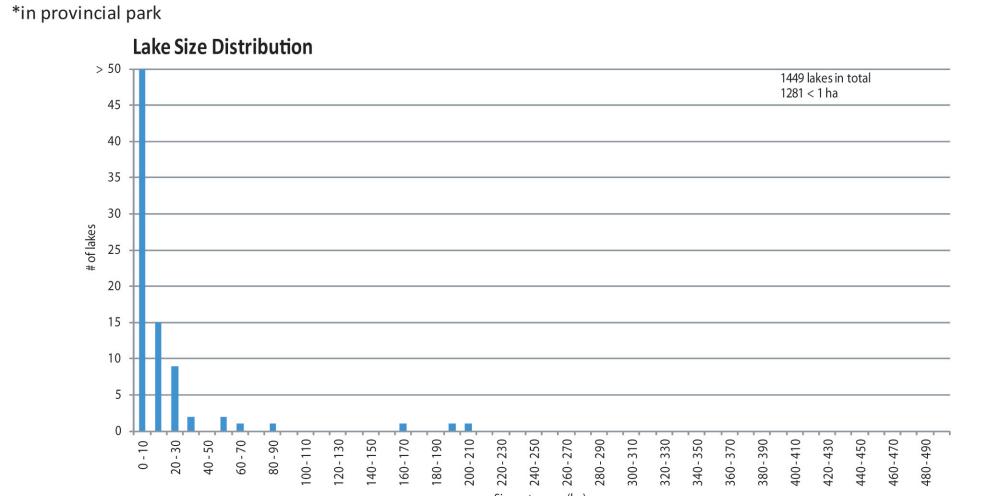
eter, area and volume. All bathymetric maps for

ocated on major drainages. This leaves many watersheds without gauged

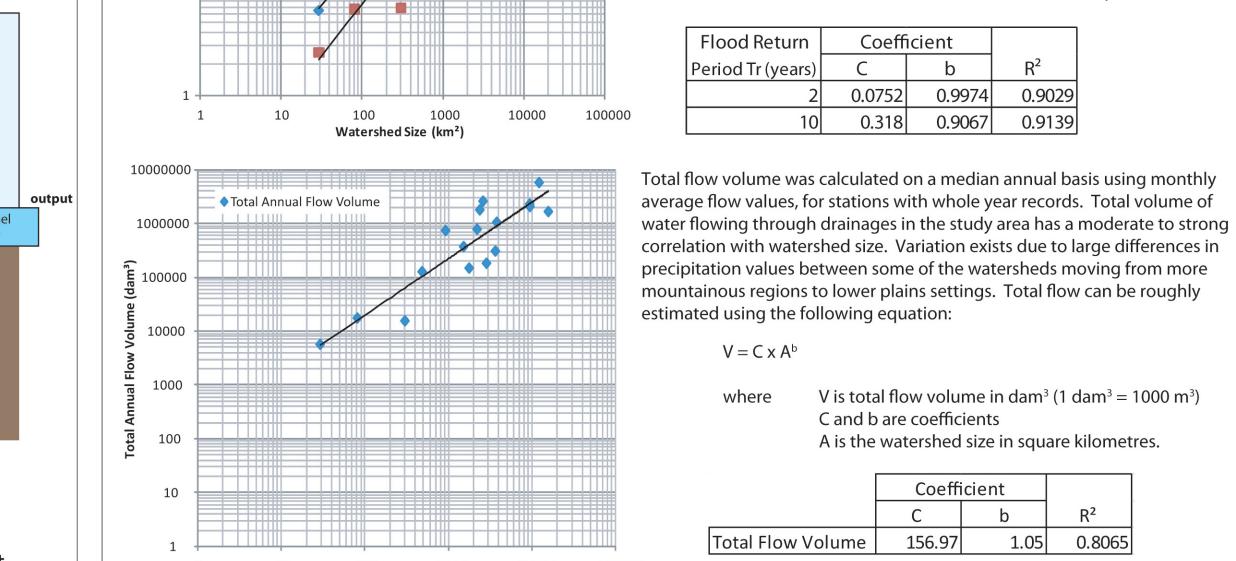
but many are connected by extensive dendritic

west part of the watershed.

small portion of the year.



cients for estimating the same parameters in ungauged watersheds, using upstream drainage area. frequency analysis using a log-Pearson Type III distribution was onducted to determine the peak daily discharge for 17 stations in the study area. Regression analysis suggests that both the 2 and 10 year peak daily discharges are strongly correlated to watershed size. These values can thus be roughly estimated using the equation: Tr is the return period C and b are coefficients A is the watershed size in square kilometres.



 $V = C \times A^b$ where V is total flow volume in dam<sup>3</sup> (1 dam<sup>3</sup> = 1000 m<sup>3</sup>) C and b are coefficients A is the watershed size in square kilometres C b R<sup>2</sup> Total Flow Volume 156.97 1.05 0.8065 1 10 100 1000 10000 100000 Watershed Size (km²) Low flow characteristics at monitoring stations were determined using the 7 day low flow period with 10 year recurrence interval, which is commonly used as a general indicator of drought conditions. These values

the following equation:

were calculated for 11 stations and compared with other published values for these stations where available. No relationship was found (R<sup>2</sup>=0.2) when correlating 7Q10 values with watershed size for all of the stations. Moderate to strong correlation was found when all stations other than those in the Kiskatinaw and Pouce Coupe River watersheds were considered\*. This correlation used only larger watersheds as inputs as smaller drainages are seasonaly intermittent. Drought discharge can be estimated in larger (>500 km<sup>2</sup>) watersheds in the foothills region by

where 7Q10 is the seven day low flow (m<sup>3</sup>/s) with a return period of 10 years

Methodology after British Columbia Streamflow Inventory, BC Ministry of Environment, 1998

#### Baseline Thematic Mapping, GeoBC Freshwater Atlas, GeoBC

Kiskatinaw River watershed surficial materia

# 07FC003 WSC Hydrometric Station BC Snow Survey Station OGC Oil / Gas Field Montney Trend **Road Network**

#### Surficial Materials and Land Use

The Kiskatinaw River watershed is mostly glacial till with approximately 25% ine grained glaciolacustrine sediments. The map to the left is coarse scale, national mapping at 1:5,000,000 scale. As part of the Montney Water Project more detailed mapping is being compiled into digital format. N.T.S. Map Sheets 94A and 93P will be available at 1:250,000 and 94A/SE and 93P/NE will be available at 1:50,000. Surficial material type is an important component for hydrological modelling and can provide other operational benefits such as construction aggregate resource identification.

The B.C. Ministry of Forests Vegetation Resources Inventory provides detailed stand level mapping including tree species, age and height estimates. Coverage of the Montney Water Project area is not complete. GeoBC provides Baseline Thematic Mapping, which reflects current conditions as of the date of imagery of the product (1992) which is out of date for time sensitive or transitional areas (e.g. burned, logged, etc). A third data set useful in characterizing vegetation characteristics is the Biogeoclimatic Ecosystem Classification (BEC) Program which classifies the province into zones based on forest type, moisture and temperature.

The southern portion of the Kiskatinaw River watershed is mostly coniferous forest and wetland, and grades into broadleaf forest and agricultural lands moving northwards. Forested areas in the northern portion of the watershed are mostly restricted to along drainages, with agricultural being the dominant land use.

Surficial Materials of Canada, GSC Map 1880A Vegetation Resources Inventory, BC Ministry of Forests and Range

#### Kiskatinaw River Watershed Overview

The Kiskatinaw River originates in B.C.'s Rocky Mountain foothills at Bearhole Lake and flows into the Peace River just west of the B.C. – Alberta border (Figure 1). The river drains an area roughly 4,000 km2 in size. Almost one-quarter of the watershed is covered by crop or rangeland with the majority of the remaining lands being forested. Its major tributaries include Hourglass, Jackpine, Sundown and Burial creeks which flow into the West Kiskatinaw River; Sunderman, Borden and Ministik creeks which flow into the East Kiskatinaw River; and Oetata, Brassey, Tremblay, Norrie and Coal creeks which flow into the mainstem.

A distinguishing feature of the Kiskatinaw watershed is that it contains no major urban centers. The watershed boasts a healthy ranching and farming area with a significant amount of forestry and natural gas exploration and development activity. Coal resources are concentrated in the headwaters of the West Kiskatinaw, while natural gas exploration and development activity is scattered throughout the watershed. The City of Dawson Creek and the Town of Pouce Coupe, just outside the watershed to the east, utilize the Kiskatinaw River for their water supply. Recreation and tourism are popular activities in the watershed.



**Left:** Kiskatinaw River in early fal

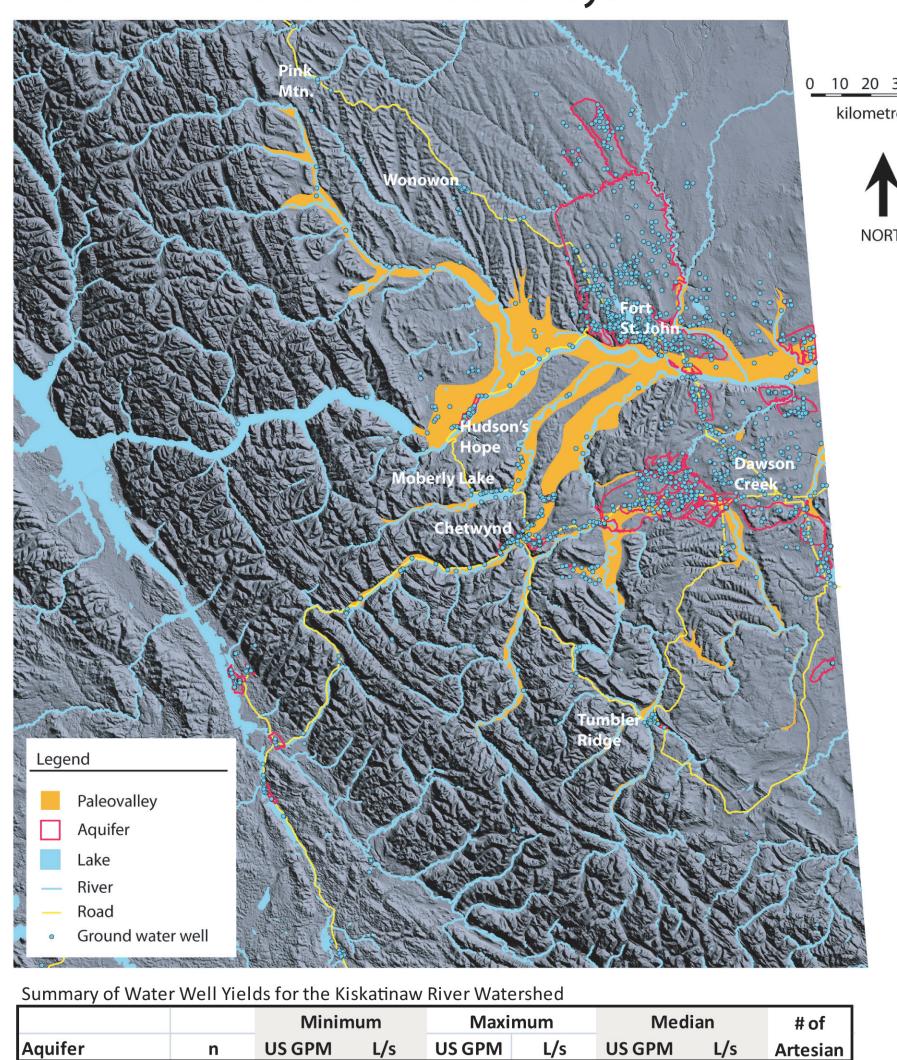
## Peace Region

The Peace River originates in the mountains of British Columbia and forms the southwestern branch of the Mackenzie River System. From its headstreams in the Rocky Mountains the Peace River flows northeast into Alberta and eventually empties into the Slave River, which enters the Arctic Ocean through the Mackenzie basin. The Peace River's total course from the head of the Finlay is 1,923 km, and it covers a total area of 302,500 km<sup>2</sup>. The B.C. portion of the Peace River basin covers an area of 41,600 km<sup>2</sup>.

The largest tributaries of the Peace River basin in B.C. are the Pine, Halfway, Beatton, Moberly, and Kiskatinaw Rivers. The Peace River is influenced by BC Hydro's WAC Bennett and Peace Canyon Dams in the upper reaches of its drainage. These hydro-electric dams produce 31% of British Columbia's hydro-electric power.

The basin includes the major communities of Fort St. John, Dawson Creek, Chetwynd Mackenzie, Tumbler Ridge, and Hudson's Hope. Much of the basin is forested with significant natural gas exploration and production in the Montney shale gas play, a northwest to southeast trending geologic zone underlying the river basin from Pink Mountain to the BC border at Dawson Creek. Agricultural production occurs near the communities of Fort St. John and Dawson Creek. Natural gas, mining, agriculture, forestry, and tourism are the basis of the local and regional economies with mining and natural gas development being the biggest employers in the region.

## **Ground Water and Paleovalleys**



Undifferentiated 17 1.0 0.06 20.0 1.26 10.0 0.63 0

Unconsolidated 44 0.5 0.03 75.0 4.73 6.2 0.39 1

40 0.5 0.03 50.0 3.15 7.0 0.44 2

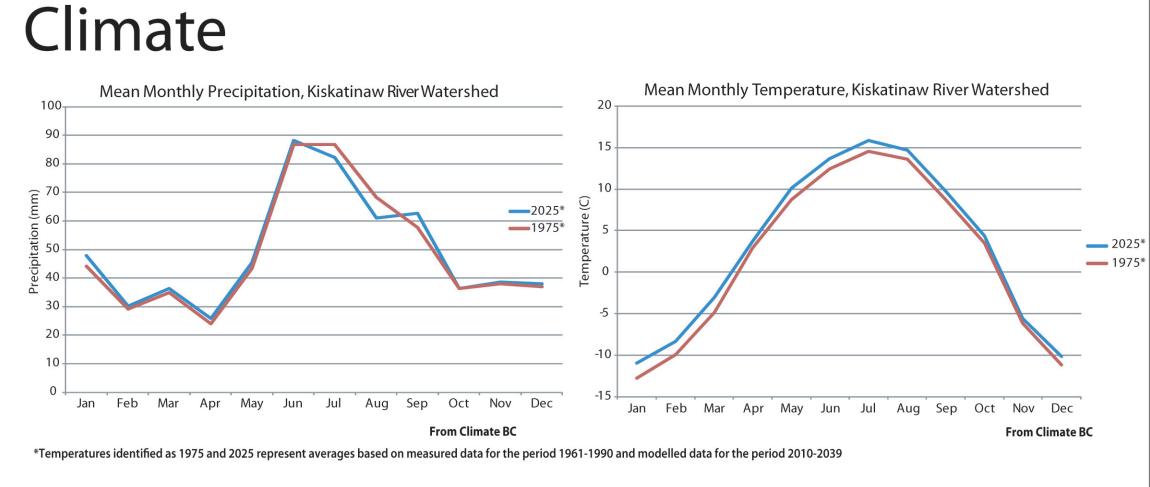
The majority of the Peace Region is covered by glacial and interglacial sediments deposited during repeated glaciations in the Quaternary Period. These sediments 0 10 20 30 40 vary significantly in thickness. In some locations, bedkilometres rock is covered by a thin veneer of sediment or is exposed at surface. In others places, such as in pre-glacial buried paleovalleys, these sediments can be over 100 m thick. In many cases modern rivers occupy pre-glacial iver valleys and the thick unconsolidated valley-fill sediments may host aquifers with significant volume of water. Areas with thick Quaternary sediments are targets for further aquifer evaluation.

> The BC Ministry of Environment maintains a database of water wells drilled in the province and delineates ground water aquifers based on this database and other geologic and hydrogeological information.

As part of the Montney Water Project, geologic analysis is being performed by the B.C. Ministry of Energy to more accurately map the thicknesses of Quaternary sediments that may have potential for hosting water. The B.C. Ministry of Environment is collecting additional water well information, which is being used to update the online water well database and refine mapping of aguifers in unconsolidated sediments and bedrock.

This map illustrates the geographic distribution of water wells, currently mapped and classified aquifers and areas that likely have thick Quaternary sediment which will be evaluated for their aquifer potential.

Ground water Aquifers, B.C. Ministry of Environment aleovalleys, B.C. Ministry of Energy unpublished Ground water wells, B.C. Ministry of Environment



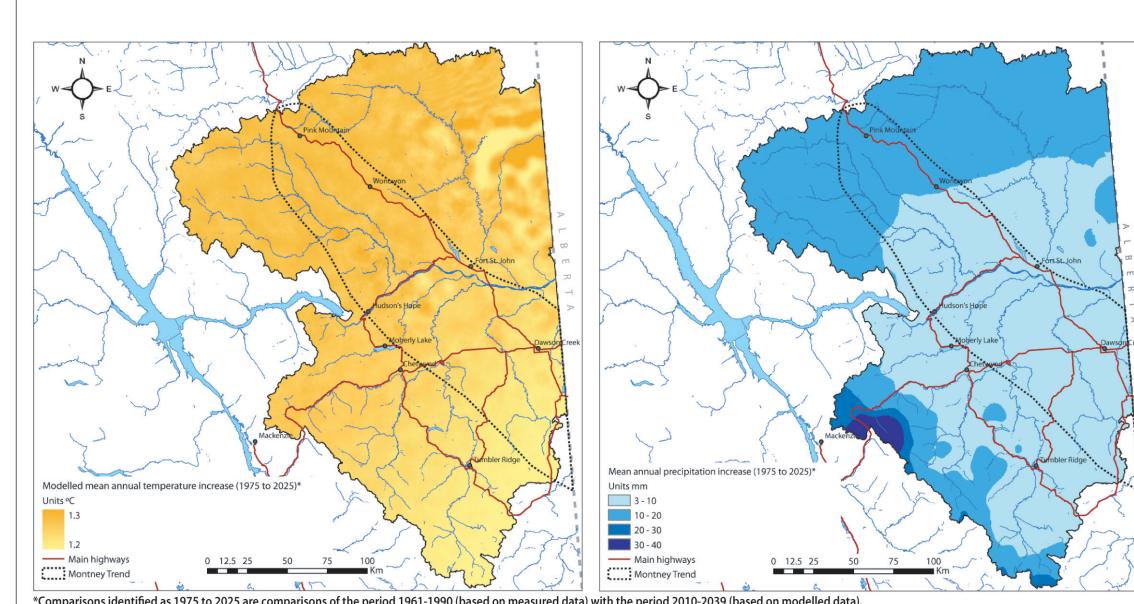
In the Kiskatinaw River watershed, maximum precipitation occurs during the summer. Precipitation decreases moving north-eastward from the headwaters of the West Kiskatinaw River at the southern end of

At Pine Pass, an automated snow pillow collects information on snow accumulations. Peak accumulation regularly occurs in April. Snow water equivalent (swe) is a standardized method of communicating the water volume in snow pack considering depth and density.

There are 14 other snow monitoring locations within or very near the Montney Water Project area, the majority of which are high in the mountains in the headwaters of the watersheds. Stations 4A20 and 4A31 at Monkman and Bullmoose Creeks are the nearest to the watershed. These are 50km west or southwest into the mountains and likely not good indicators of conditions in the Kiskatinaw watershed.

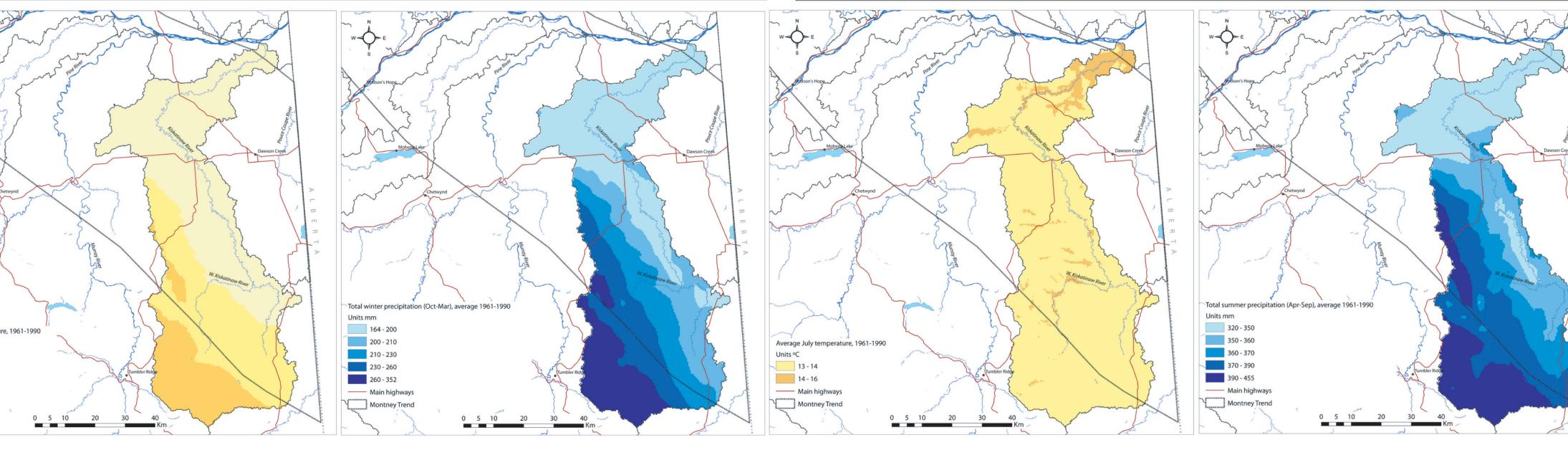
Environment Canada, and the BC Ministries of Transportation and Forests operate weather stations throughout the Peace region. Climate data from these stations is available in the database for the project

## Future Climate Model (2025)



collaboration with the BC Ministry of Forests, in order to provide high resolution climate data for resource management in Western Canada. Recent updates have expanded the scope of the project to Western North America in ClimateWNA. These products are based on PRISM Climate Data developed by Oregon State University, with improved elevation related variations, additional modelled parameters, and the introduction of forward looking climate predictions based on a variety of global circulation models. T period of normals (1961-1990) has been compared with predicted values for the period 2010-2039 using the CGCM2-A2x global circulation model. Mean annual temperatures as well as mean annual precipitation is expected to increase across the Peace region. Temperature is expected to increase in a relative way, consistent across the region, while the magnitude of precipitation will vary.

ClimateBC is a modelling program developed by researchers at the University of British Columbia in



Seasonal Climate, 1961-1990 averages: January Mean Temperature All data from ClimateBC

Diagram of Hydrolo

discussion, and references.

#### Winter (Oct-Mar) precipitation

**July Mean Temperature** 

#### Montney Water Project Overview:

drilling, which will increase the demand for water and deep sites for the disposal of fluids. Provincial, First Nations and local governments, industry, communities, and environmental groups all want to ensure that water sources are carefully managed during natural gas development. These stakeholders require detailed, scientifically-based and unbiased information about existing water resources to make appropriate policies, regulations and permit decisions as well as to support public discussion on issues related to water use.

In response to this need, Geoscience BC met with industry and government in early 2010 and began a collaboration to undertake water studies in the Montney area. The Project is designed to create a comprehensive database of surface water, ground water and deep saline aquifers in the Montney area.

Phase I of the study focuses on collecting, analyzing and interpreting available water information in the Montney region. quired, a second phase of the study will focus research on addressing remaining data gaps. Three components of the project are as follows:

Surface Water: Collection and presentation of data on surface water system (lakes, streams and wetlands) and processes that control availability of water (timing and amount). Analysis of these components provides insight into important aspects of the regional water cycle, including seasonal flow conditions, climate, vegetation and land use

Unconsolidated and shallow bedrock: Unconsolidated and shallow bedrock aguifers host a significant source of water in the Peace Region. These aguifers are best developed in areas with thick Quaternary age sediments often associated with buried paleovalleys. This component of the MWP has focused on compiling a database of available surface and subsurface data that elucidates the thickness of the unconsolidated drift and the bedrock topography. These data will be used to model and map major drift thickness trends and bedrock topography which represent high potential target areas for water in unconsolidated aquifers.

Deep bedrock: Define and characterize candidate aquifers (water sources) and potential deep disposal zones, providing a general description and indicating the homogeneity of each aquifer. The work focuses in zones deeper than domestic water wells and in zones typically explored by the oil and gas sector, greater than 250 m below surface. Compilation of existing hydro-stratigraphic data and development of groundwater flow models for select areas will assist in the identification of regional aquifers with suitable reservoir characteristics, fluid content, and capacity to be viable source/disposal candidates.

#### **Montney Water Project Partners:**

440 - 890 W. Pender St.





















Geoscience BC is an industry-led, industry-focused not-for-profit society. Its mandate includes the collection, interpretation and marketing of geoscience data and expertise to promote investment in resource exploration and development in British Columbia. Geoscience BC is funded through grants from the Provincial Government and works in partnership with industry, academia, government, First Nations and communities to attract mineral and oil & gas investment to

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- Foundry Spatial Ltd.



## For the surface water component of the Montney Water Project, several parts of the water cycle have been assessed and described. Themes include flow charac-

teristics in gauged watersheds, lake size distributions, climate and projected future climate, groundwater, vegetation and surficial geology characteristics water balances and discussion of estimating conditions in ungauged watersheds. Posters have been created highlighting key aspects of these themes, in each of the major watersheds in the region. Supporting information is available in a report accompanying the poster series, and includes additional analyses, more thorough