Issues about Hydropower Generation

Type of Hydro-Power

Reservoir Storage Systems
Pump Storage Systems
Run of the River Hydro

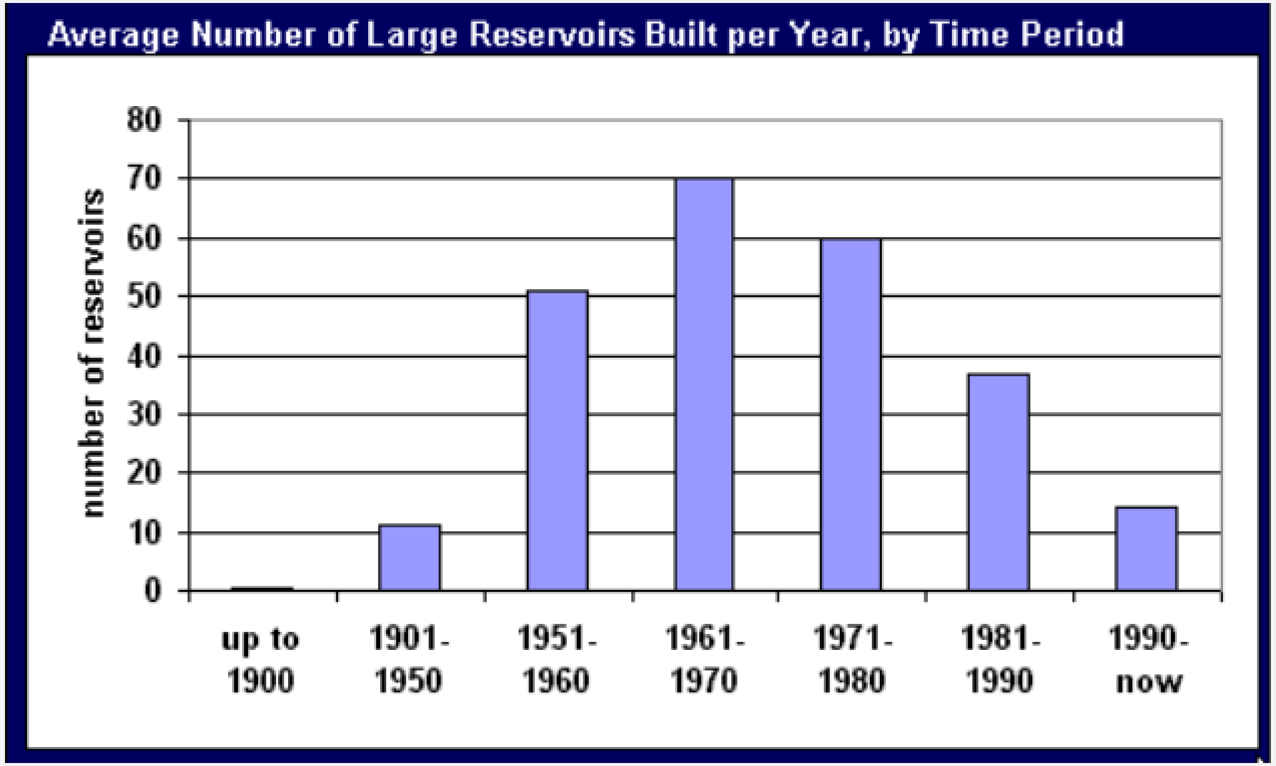
Key for Low Carbon Economy

Hydro = 6 gr CO_2 /kWh
Coal = 1024 gr CO_2 /kWh
Solar = 45 gr CO_2 /kWh
Wind = 16 gr CO_2 /kWh

Most of the Hydro-Systems are in Mountains

Some are Glacial Fed
Some are dominated by Snow or Rain
Or a Combination of all Types

Hydropower Development



Number of Large Dams: > 40000 (>150m tall, > 15m3/sec discharge)
Number of Small Dams: > 80000 (All kinds os storage)
500000 km2 of Land Inundated, Storing 6000km3 of Water

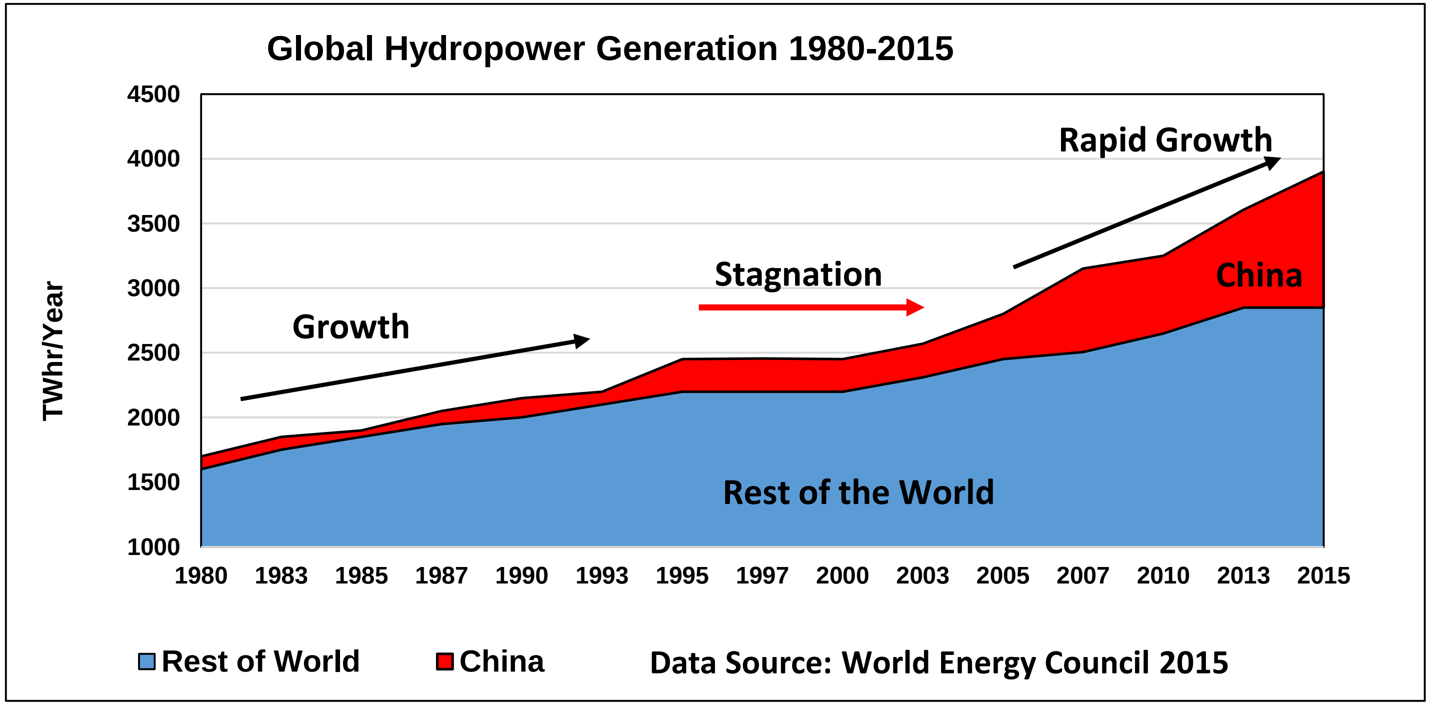
Current trends: Re-emergence of need to build reservoirs because: Increased water shortages, increased demand for green energy and increased climatic variability

Hydro-Power = 16% or World Electricity Capacity

71% or Global Renewable Energy (Flexible Capacity)

Increases in Installed Capacity Between 1905-2015 = 39%

Projected Hydropower Demand = 1-4% / Year
By 2020 Winter Electricity Demand Will Decrease
Summer Demand is Expected to Increase by 9-11% (Air-Conditioning)



By 2040-2060: Expect a 60% Decrease in Capacity of Glacier Fed Reservoirs

Estimated No. of Air-Conditioning Units in the World
2018 = 1.6 Billion Units (Current Electricity Use 20%)
2050 = 5.6 Billion Units (Estimated Use in 2015 > 50%

Data Source: International Energy Agency (IEA) 2018

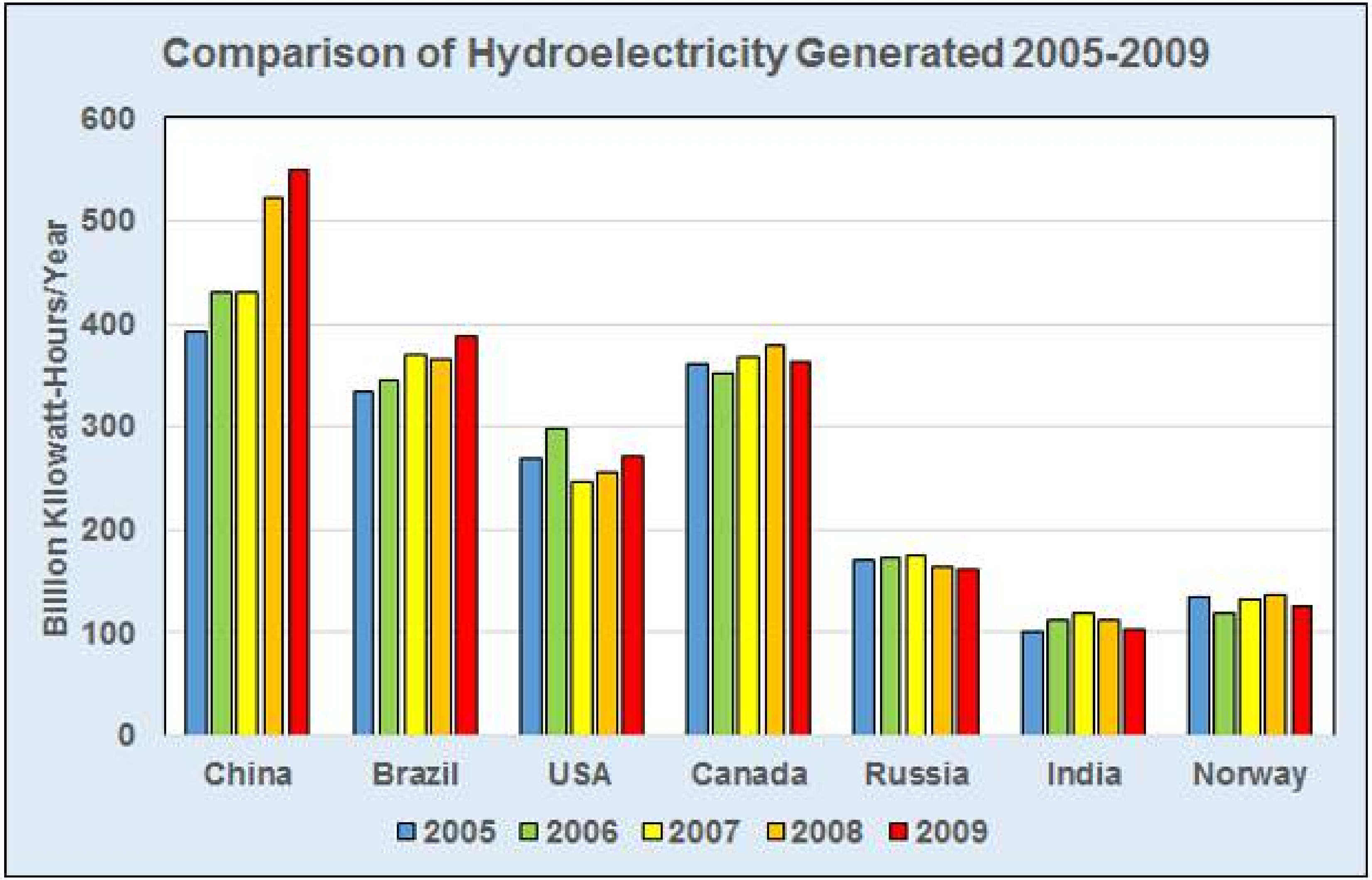
Examples of Record Temperatures

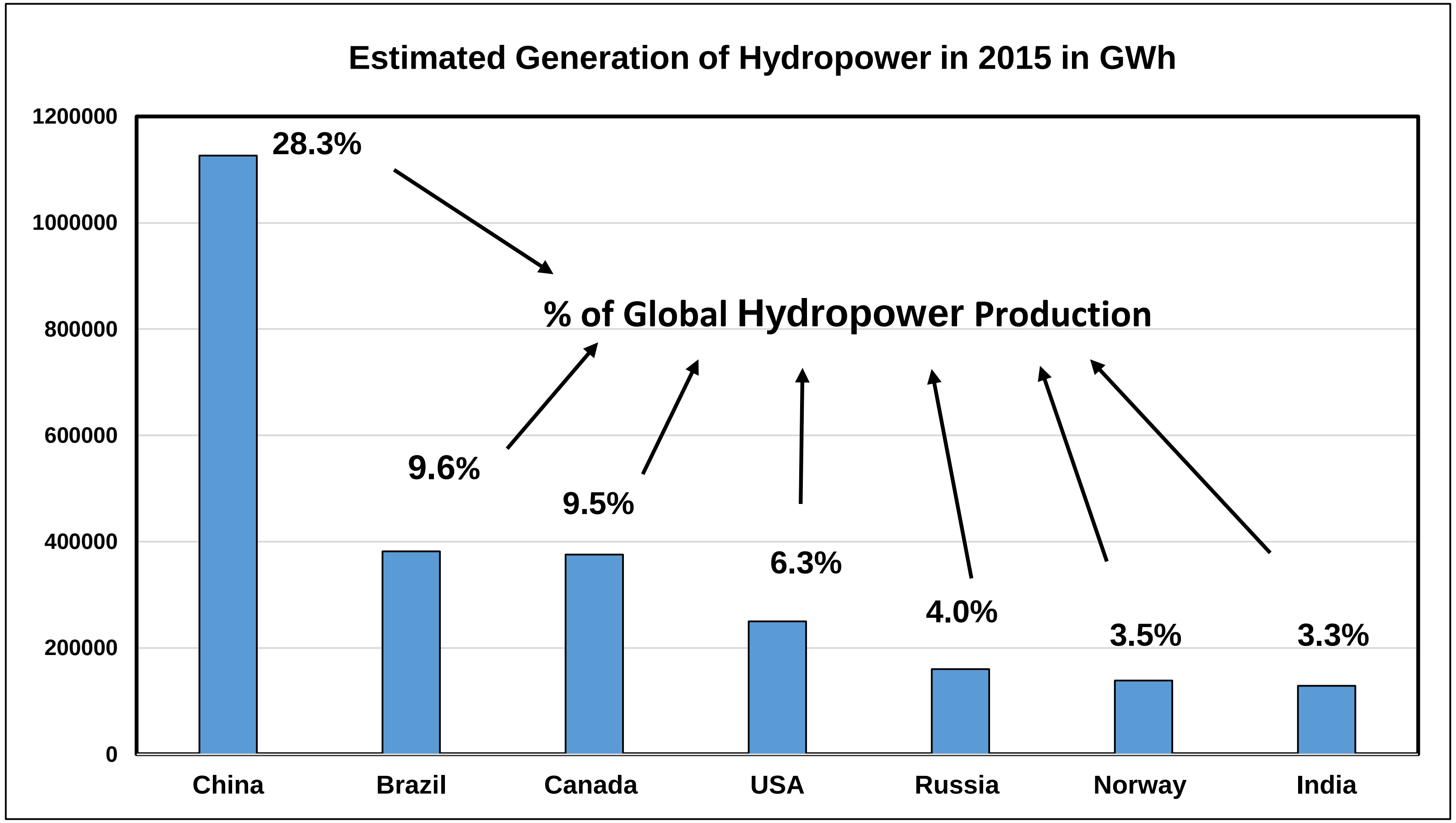
		Temp.	Population
2016	Phalodi, India	51°C	0.4 Million
	Basra, Iraq	53.9	2.2 Million
	Kuwait	54.0	4.0 Million
2017	Ahvas, Iran	53.7	1.1 Million
	Turpan, China	50.5	0.6 Million
	Oman	50.8	4.4 Million
2018	Nawabshah Pakistan	50.0	1.1 Million
	Sydney, Australia	47.0	5.0 Million
	Rajasthan, India	46.0	70 Million

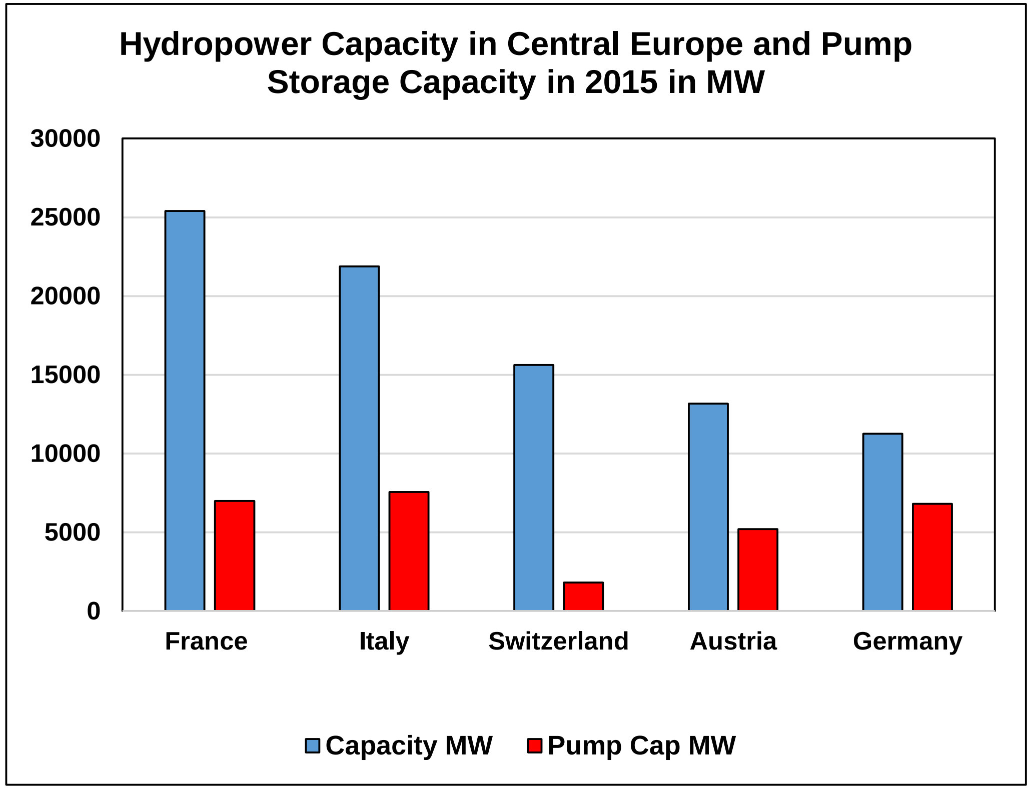
Blood Temperature = 36-37 ^{0}C
Sauna Temperatures = 40 + Degrees

Air Conditioning is Critical Above 45°C

Changes in Hydropower Electricity Generated 2005-2009

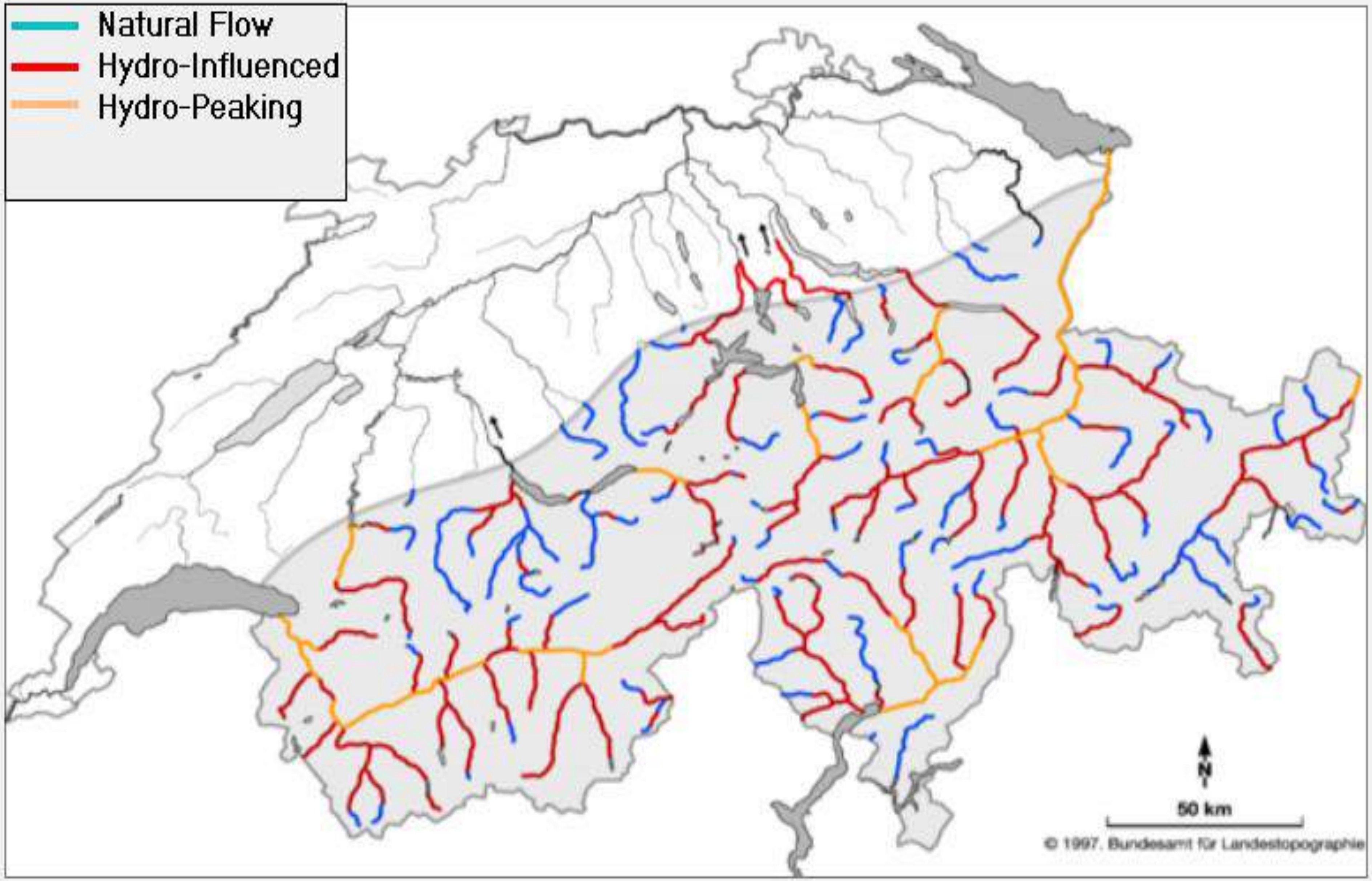



Estimated Generation of Hydropower in 2015 in GWh
1200000
1000000
800000
600000
400000
200000
0
28.3%
% of Global Hydropower Production
9.6%
9.5%
6.3%
4.0%
3.5%
3.3%
China
Brazil
Canada
USA
Russia
Norway
India


Hydropower Capacity in Central Europe and Pump Storage Capacity in 2015 in MW
30000
25000
20000
15000
10000
5000
0
France
Italy
Switzerland
Austria
Germany
Capacity MW
Pump Cap MW

What does this traffic sign indicate ???

Discharge Regime in Swiss Rivers



4th Largest River in North America
900 m Vertical Gradient
Average Discharge = 7500 m3/sec

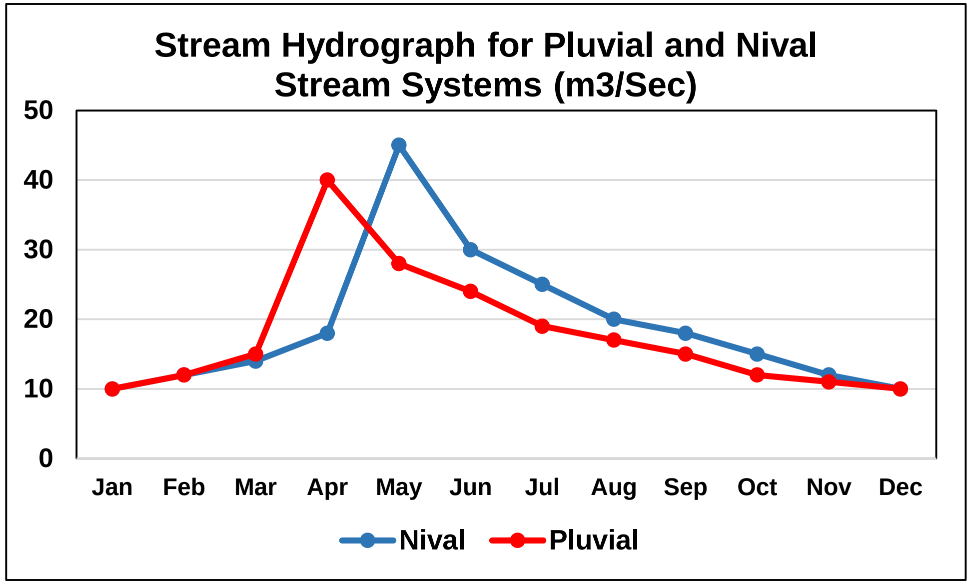
Has 450 Dams for Hydropower Generation

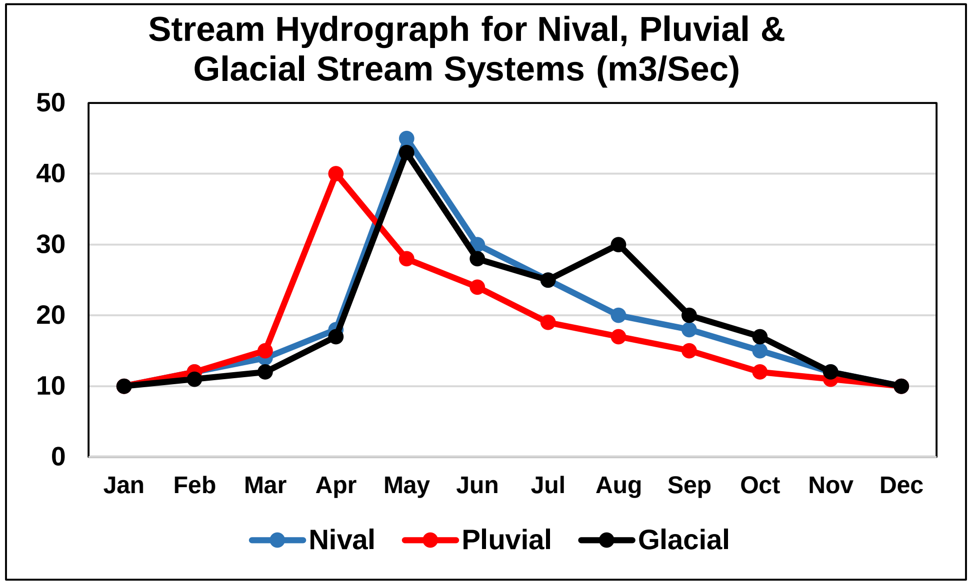
Canadian Portion 15% of River Basin
Provides 40% of Annual Discharge

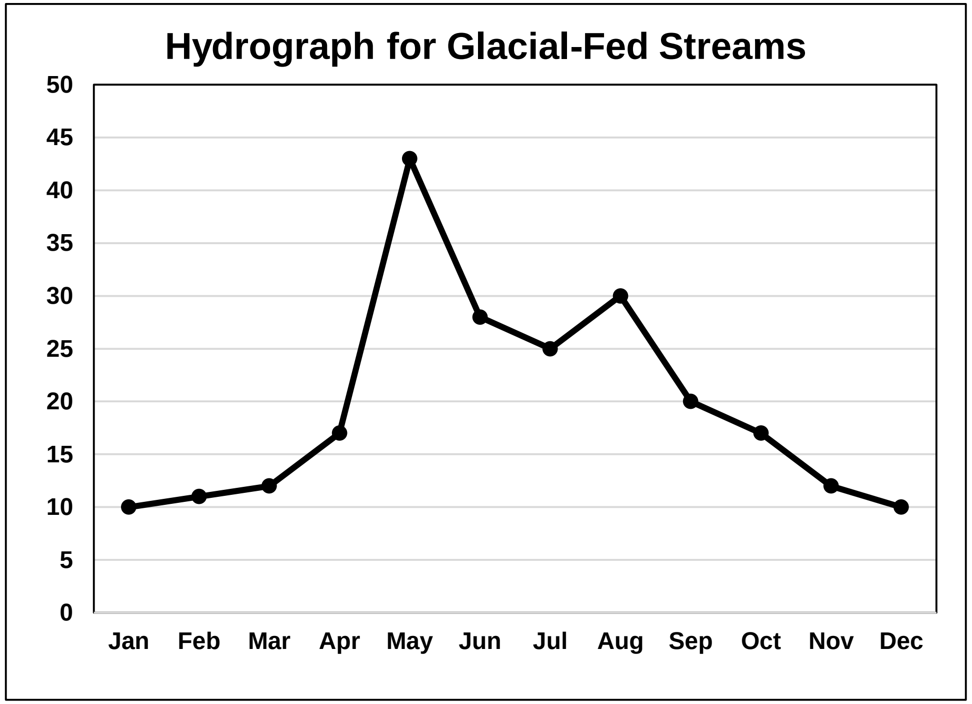
% of Large Free Flowing Rivers Remaining in the World

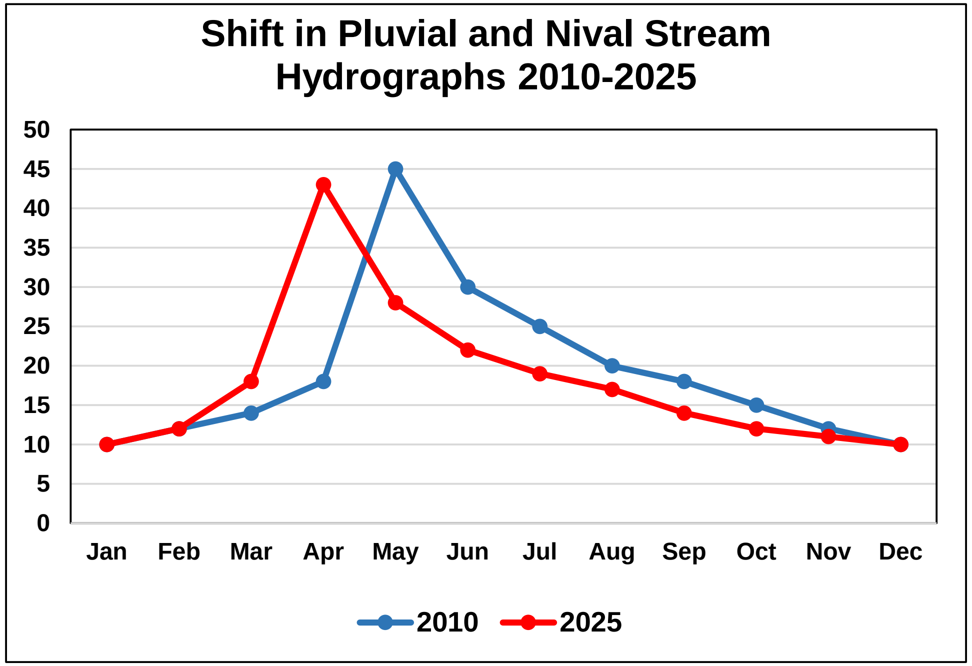
Asia	37%
South America	54%
North America	18%
Africa	35%
Europe	28%
S-Pacific	43%

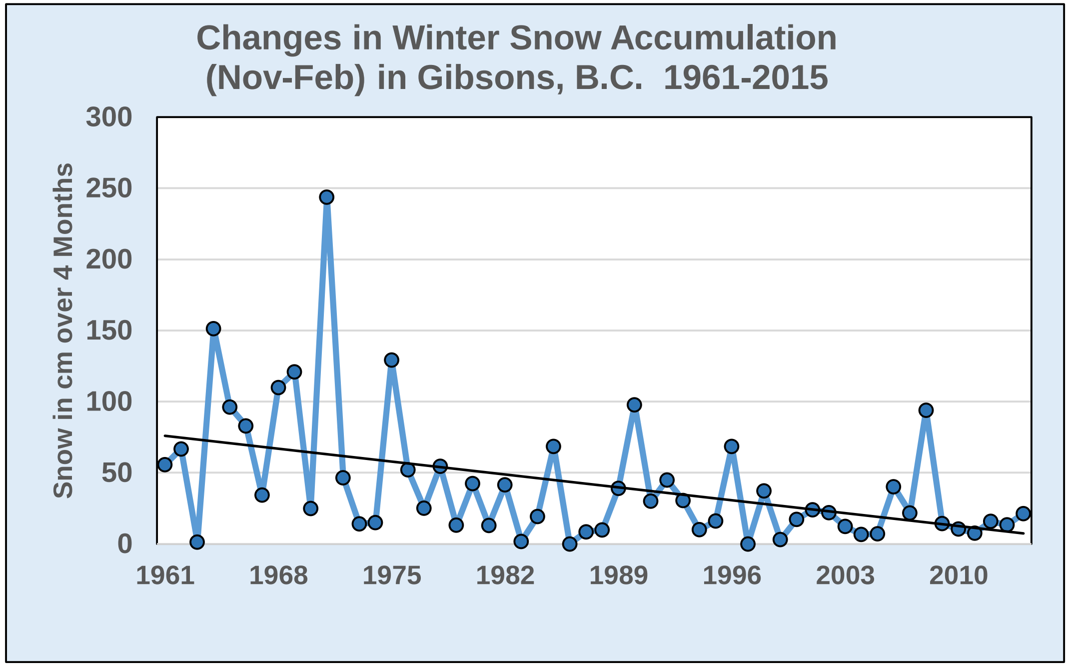
Data Source: WWF 2017

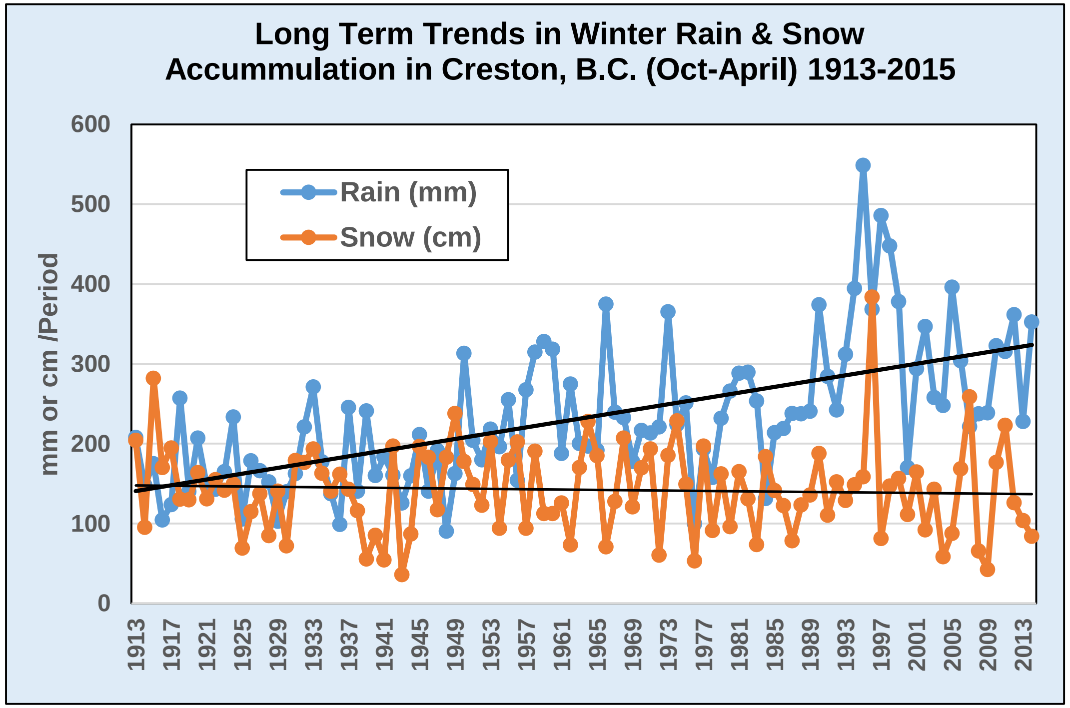

Stream Hydrograph for Pluvial and Nival Stream Systems (m3/Sec)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Nival
Pluvial


Stream Hydrograph for Nival, Pluvial & Glacial Stream Systems (m3/Sec)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Nival
Pluvial
Glacial

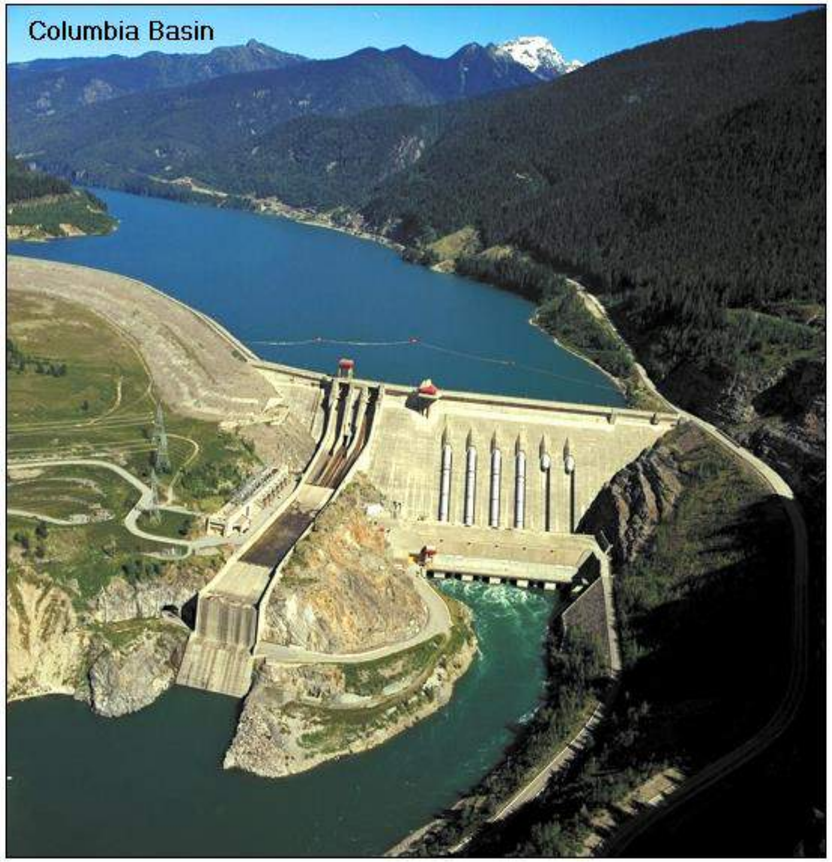

Hydrograph for Glacial-Fed Streams
50
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

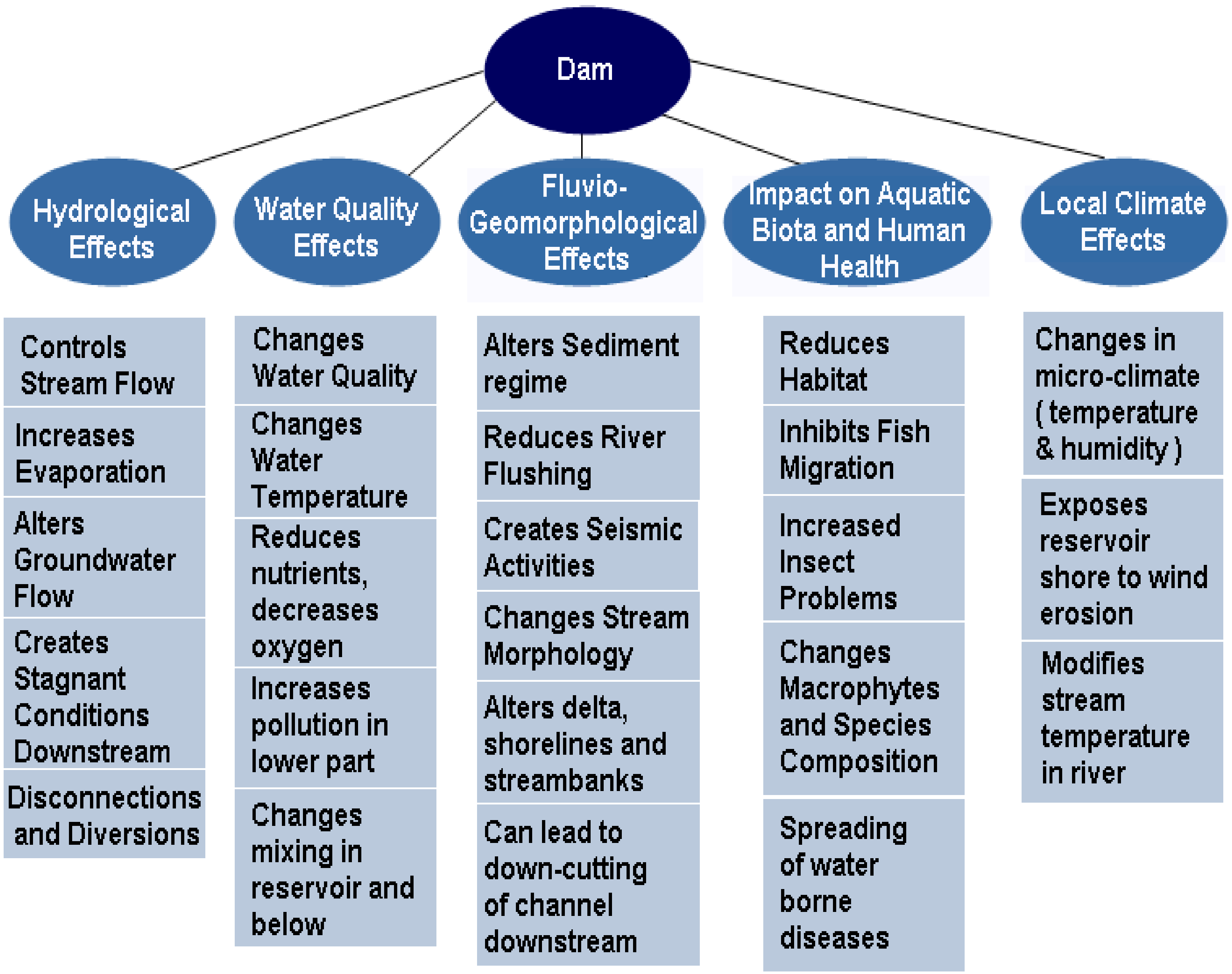

Shift in Pluvial and Nival Stream Hydrographs 2010-2025
0
5
10
15
20
25
30
35
40
45
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010
2025


Changes in Winter Snow Accumulation (Nov-Feb) in Gibsons, B.C. 1961-2015
Snow in cm over 4 Months
0
50
100
150
200
250
300
1961
1968
1975
1982
1989
1996
2003
2010


Long Term Trends in Winter Rain & Snow Accummulation in Creston, B.C. (Oct-April) 1913-2015
mm or cm /Period
0
100
200
300
400
500
600
Rain (mm)
Snow (cm)
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013

Impact of Hydropower





Dam
Hydrological Effects
Water Quality Effects
Fluvio-Geomorphological Effects
Impact on Aquatic Biota and Human Health
Local Climate Effects
Controls Stream Flow
Increases Evaporation
Alters Groundwater Flow
Creates Stagnant Conditions Downstream
Disconnections and Diversions
Changes Water Quality
Changes Water Temperature
Reduces nutrients, decreases oxygen
Increases pollution in lower part
Changes mixing in reservoir and below
Alters Sediment regime
Reduces River Flushing
Creates Seismic Activities
Changes Stream Morphology
Alters delta, shorelines and streambanks
Can lead to down-cutting of channel downstream
Reduces Habitat
Inhibits Fish Migration
Increased Insect Problems
Changes Macrophytes and Species Composition
Spreading of water borne diseases
Changes in micro-climate (temperature & humidity)
Exposes reservoir shore to wind erosion
Modifies stream temperature in river

Kulekhani Hydropower Project, Nepal

Height	150m
Reservoir storage	85 million m^3
Reservoir length	approx. 8000m
Power production	92 MW
Completed	1982
Watershed Area	125 km2

Estimated Sediment Production:

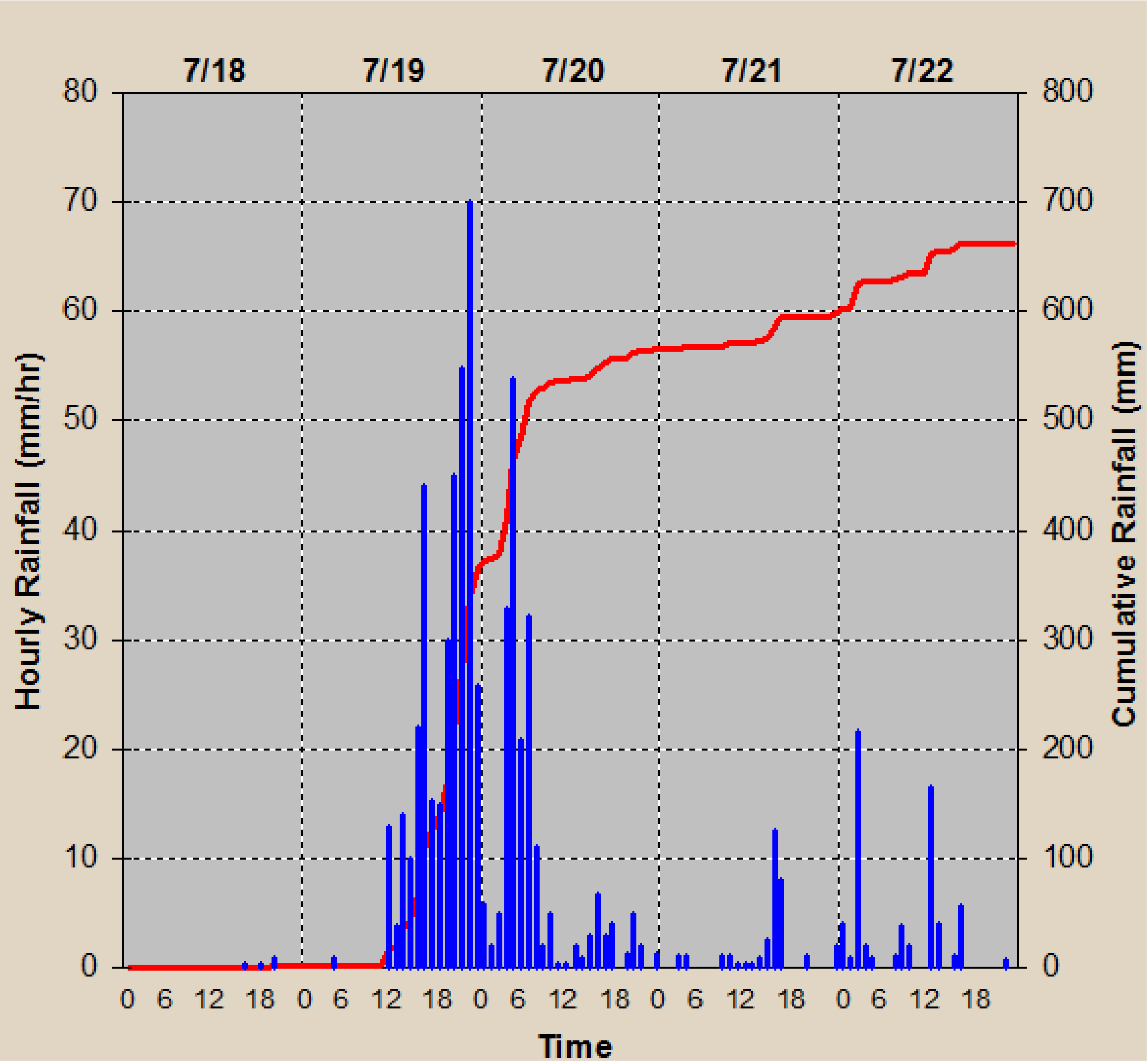
a) At Construction Time 1982 : 11.2 t / ha / Year
b) Averages Rate 1982-1992 : 20- 45 t / ha/ Year
(based on reservoir sonar surveys,
Galay et al. 1995.)

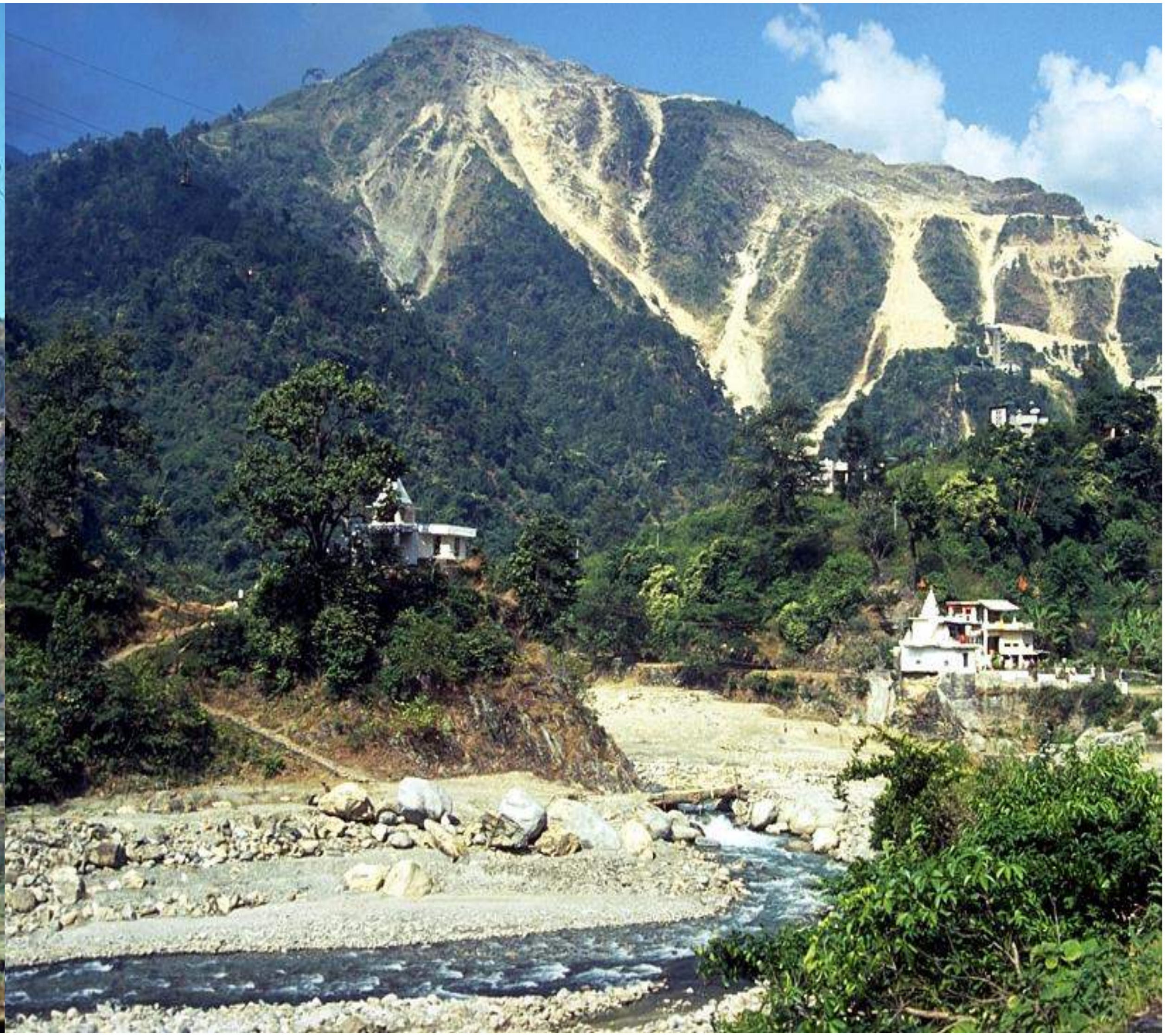
Hydropower reservoir and dam

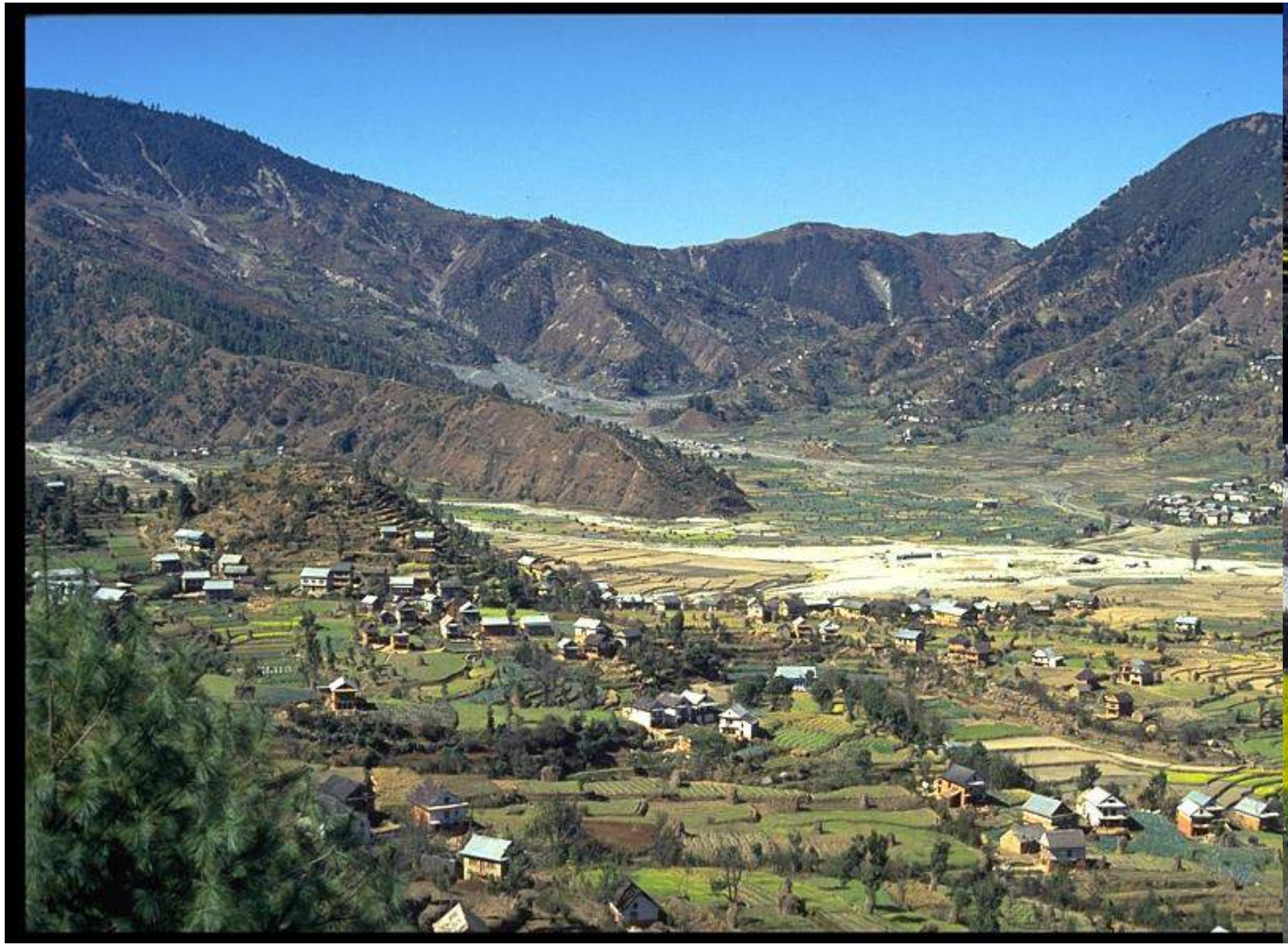
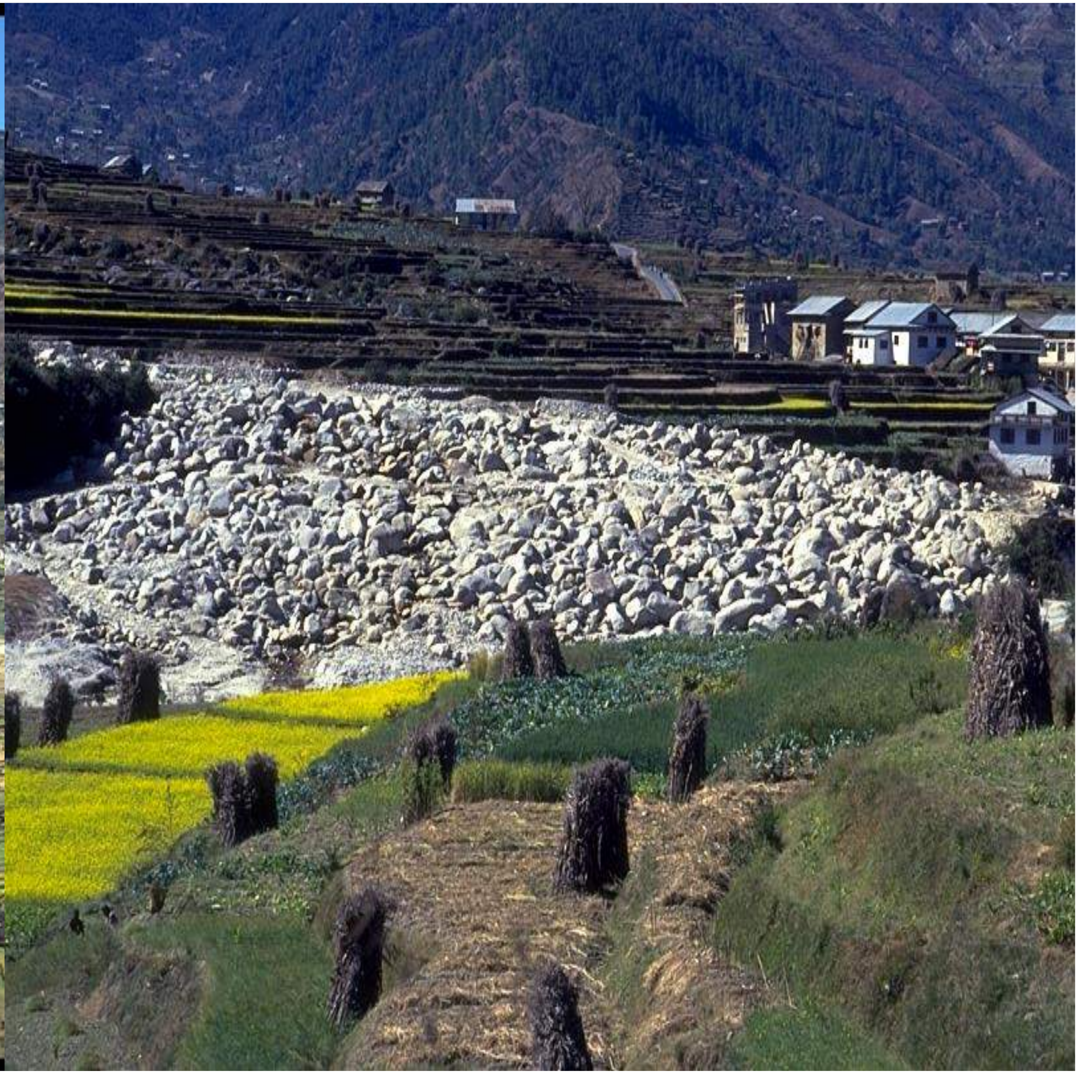
1993 Rainstorm Event

Total Rainfall in 24 hours : 540 mm

Max Rainfall / hour: 70 mm



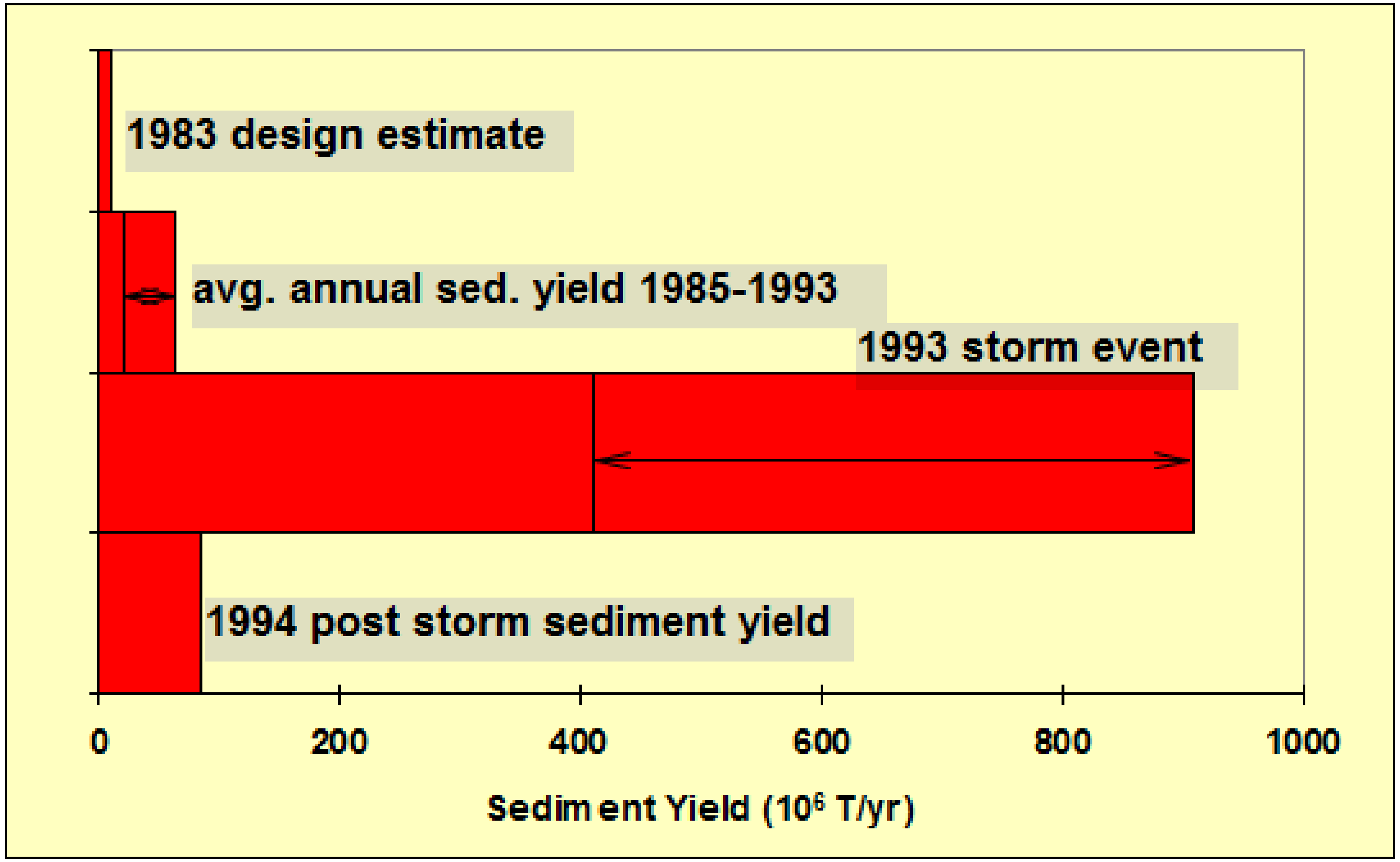



Sediment Accummulation History

Sediments accumulate in the reservoir were measured regularly with sonar profiling

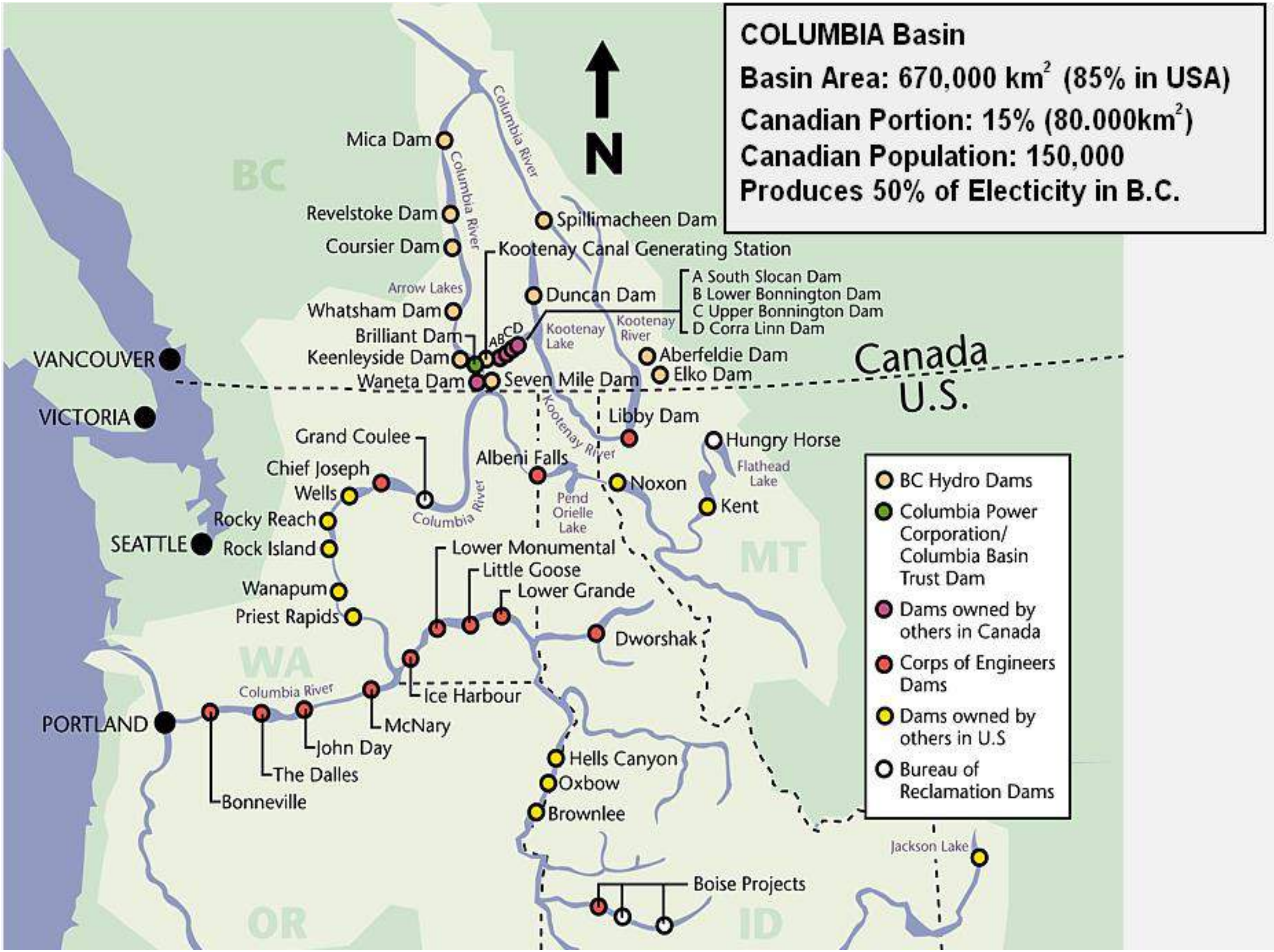
1993 storm characteristics:

- 540 mm total rainfall in 24 hrs
- up to 70 mm/hr rainfall intensity
- more than 1000 landslides
- up to 47 slides/km^2 in some areas
- return frequency of storm <100 years, maybe < 50 years



Life-Time Reduction of Resevoir = 20-25 Years

Columbia Basin Case Study Canada/USA

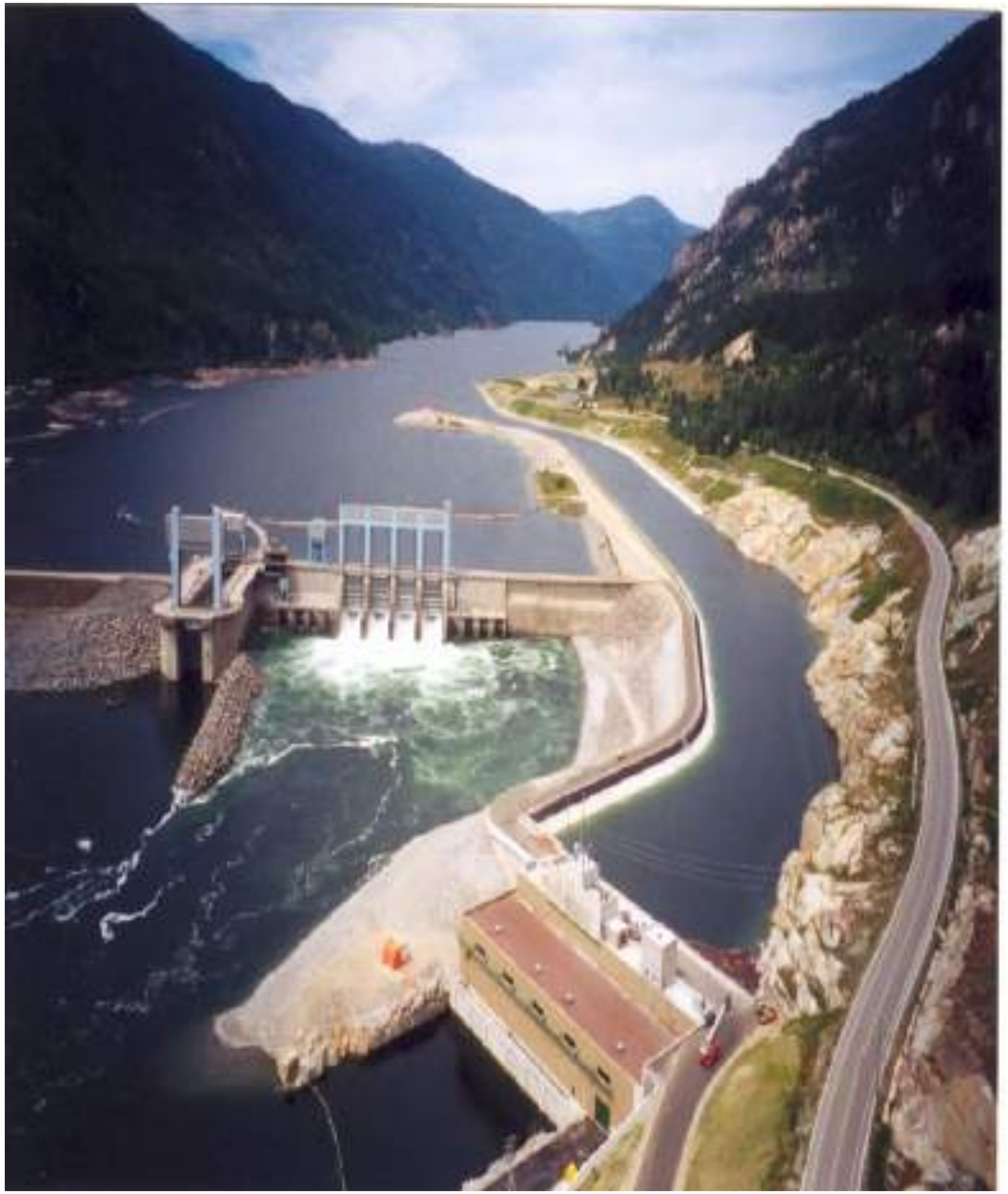


400 + Reservoirs Within the Basin

Treaty Dams
3 in Canada

Mica
Duncan
Keenleyside

Total Major Reservoir In Canada: 15



Total Size: 660000 km2

Canadian Portion 80000 Km2 (15% of Basin)
Produces 45% of annual Streamflow
Highest Vertical Gradient in NA

Canadian Portion:
Population: 150000 People (4% of B.C.)
20 Communities (200-20000 People)

Economic Activities:
Forestry, Mining (Coal) Mineral Processing
Hydro Power (50% of Electricity for B.C.)
Recreation (Winter & Summer)
Minor Agriculture

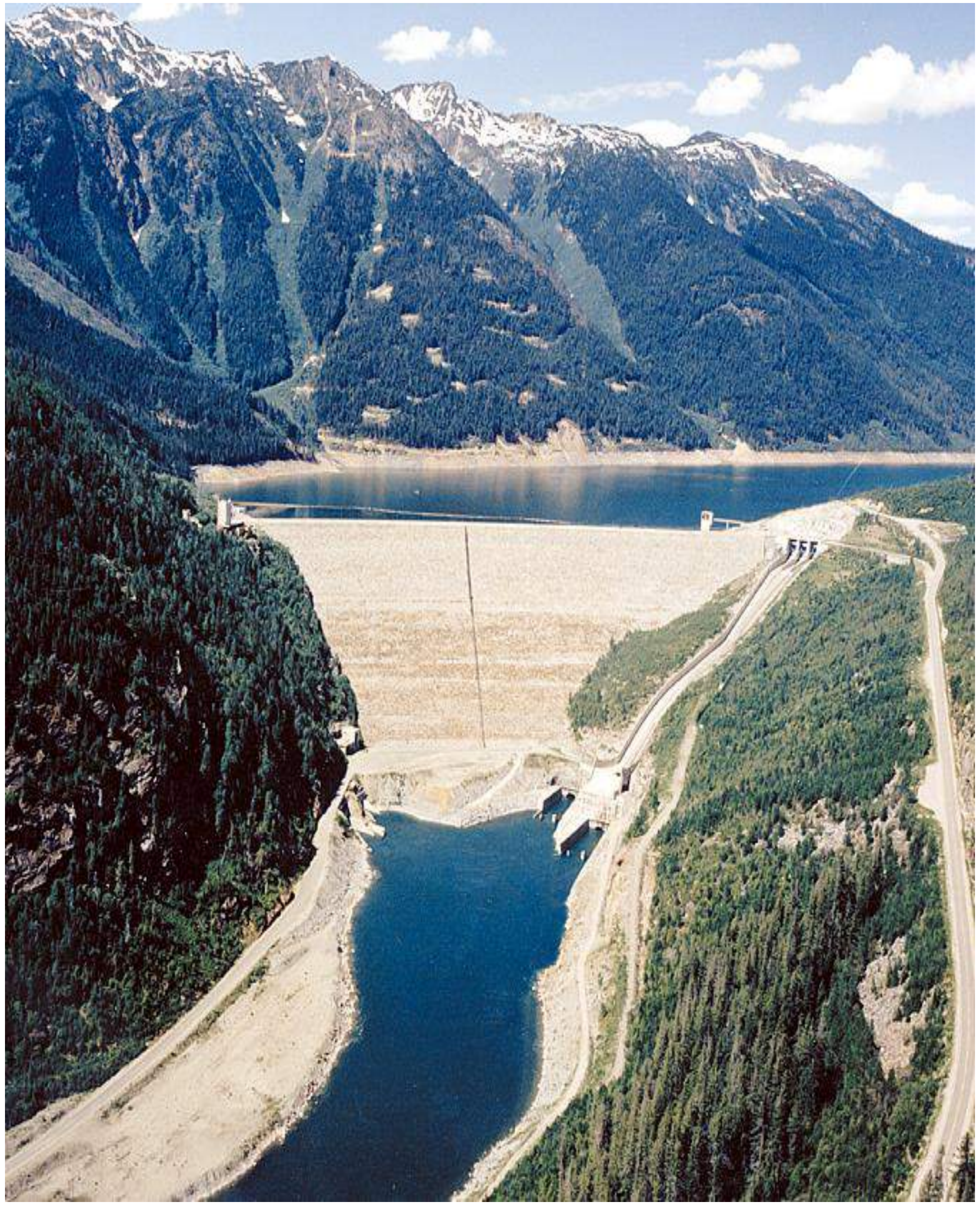
Columbia River Treaty 1964-2024 (60 Years)

Unique Treaty Between USA & Canada
WHY: Flood Protection & Hydropower Production

US Agreed to Compensate Canada to share 50% of the additional Hydropower generated From the stored Water in Canada

Compensation: $ 200-300 Million/Year

2014-2024: Treaty Renegotiating Period
New Issues to be to considered in Negotiations
Climate Change, Ecosystem Services
Fish & Aquatic Resources, First Nation Demands
Alternative Water Uses (Agriculture etc.)



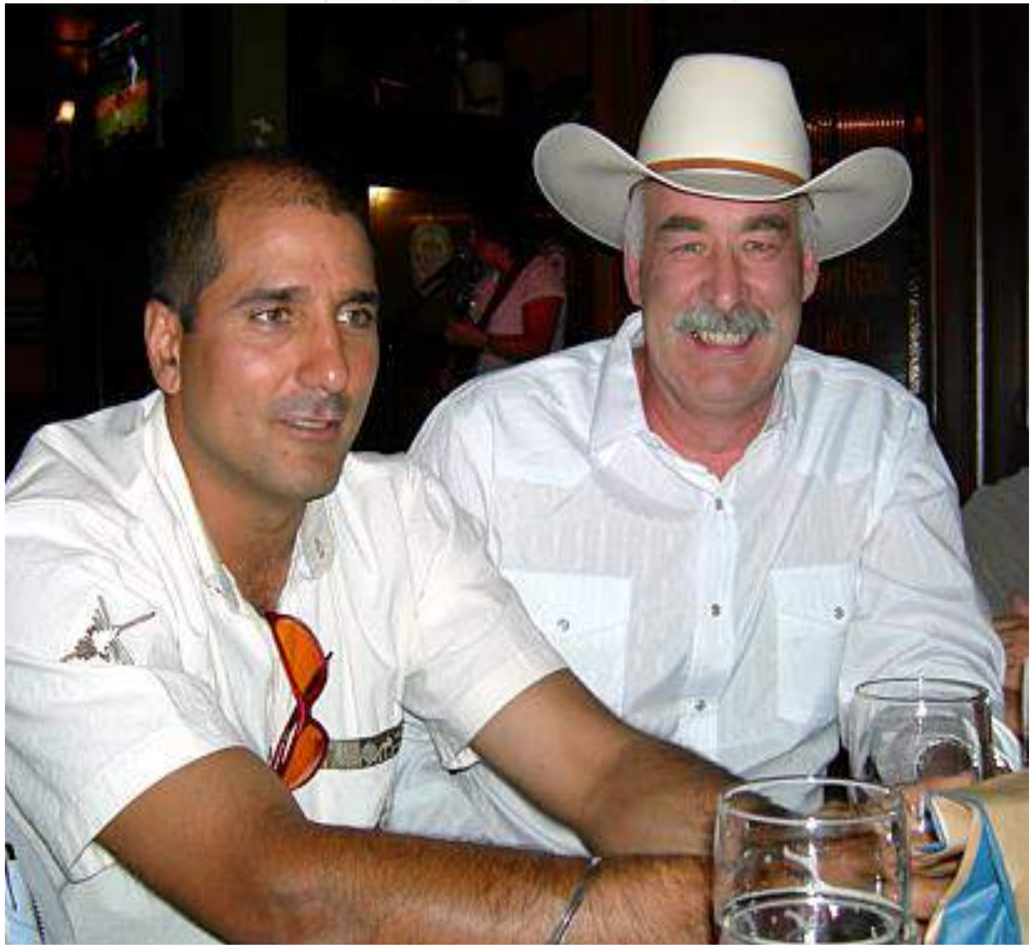
Columbia Basin trust

COLUMBIA BASIN TRUST

a legacy for the people

Created in 1995
Compensation for Hydro Impacts
$ 330 Million, Invested in Hydro-Power
Investment Interests to be used for:
Delivering social, economic & environmental
Benefits to the people in the Basin

Mandate:
Support Efforts by the People in the Basin
To create a Legacy to achieve greater
Self-sufficiency for Present & Future
Generations



Lack of Data

Little Information on Glaciers

Lack of Groundwater Mapping & Monitoring

Water Quality & Flow (Little long term data)

Water Use (Domestic & Agriculture) Poor

No Metering & Poor Water Accounting

Community Monitoring

Water quality

Aquatic Biota (Cabin)

Stream Flow Measurements

Geospatial Analysis of Watersheds

Tools

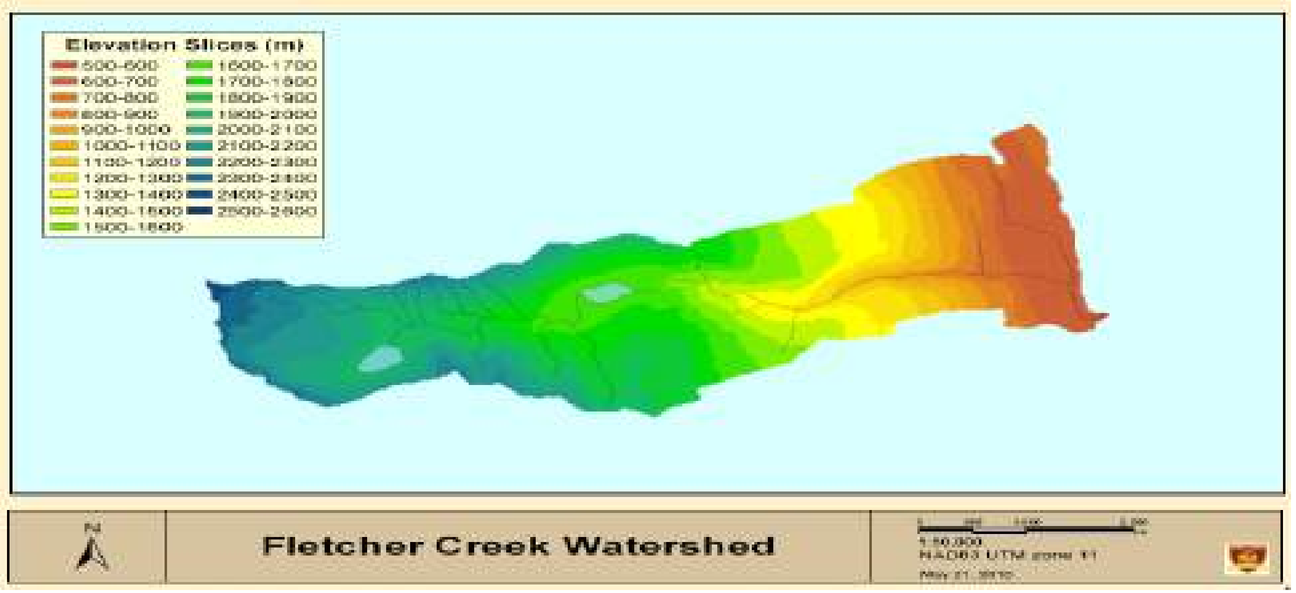
OTT Orpheus Mini Water Level Logger

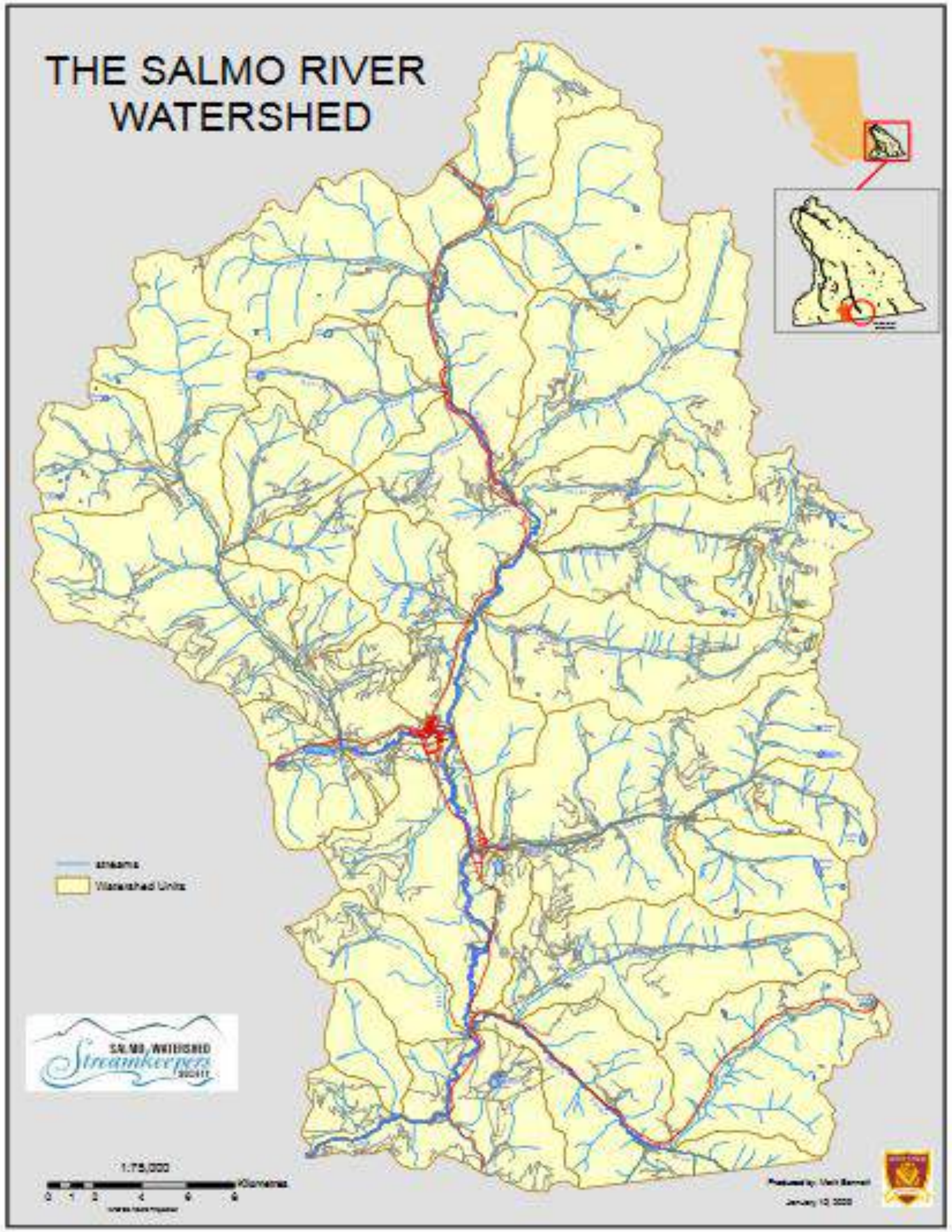

12 Community Watershed Groups

Monitoring Water Quality
(pH, Cond., Nitrate Phosphate, DO, Turbidity. etc)

Monitoring Invertebrates (Cabin Method)
New: Flow Measurements With Cellphone

Selkirk College: Geospatial Mapping Program





Claims by Dam Proponents	Evidence
Environment & Social Impact will be Mitigated	Problems with Involuntary Settlements Fish Passage, Poor Operation to Maintain Environmental Services
Large Scale Projects are considered more Economically Efficient	Small Scale Projects are less Distructive
Lots of Untapped Potential Sites	Most Suitable Sites are Already Used
High Urban Demand & They Can Pay	Rural Benefits are Small
Reliable Long Term Revenue Source	High Risk, Short Live-Time of Reservoirs Due to Sediment Issues and Extreme Climatic Events & Earthquakes