Issues about Hydropower Generation

Type of Hydro-Power

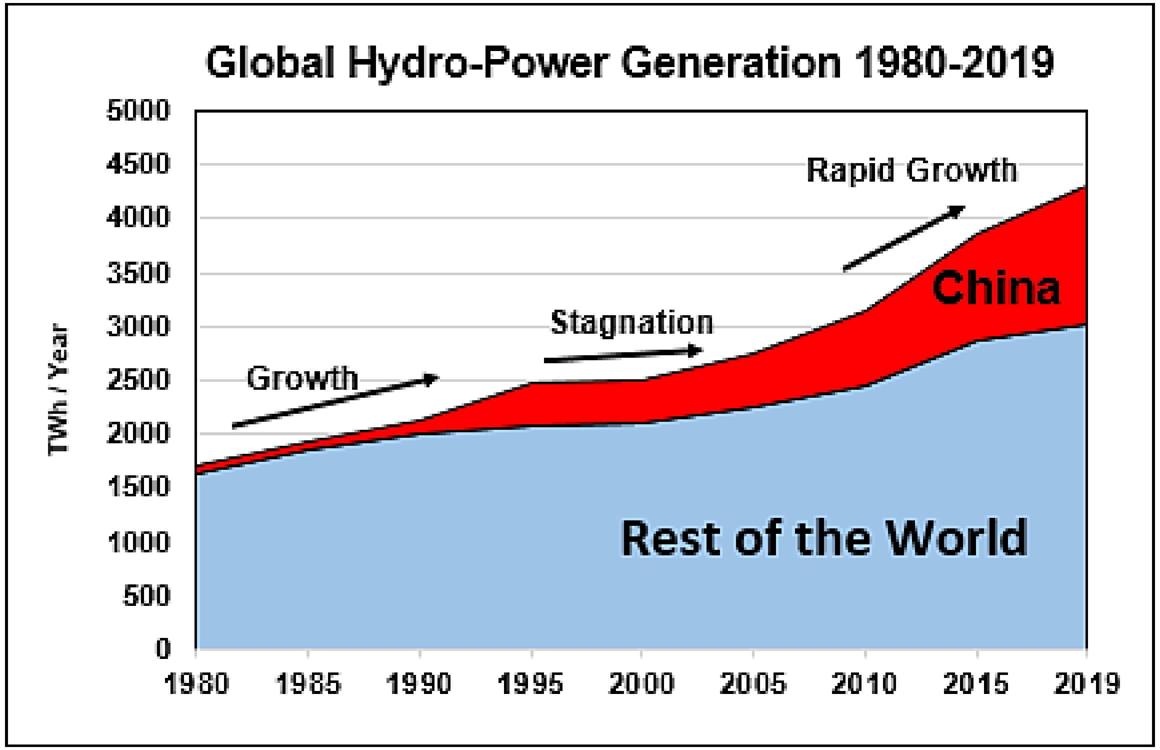
Reservoir Storage Systems
Pump Storage Systems
Run of the River Hydro

Key for Low Carbon Economy

Hydro	= 19 gr	CO_2 /kWh
Coal	= 820 gr	CO_2 /kWh
Gas	= 490 gr	CO_2 /kWh
Biomass	= 230 gr	CO_2 /kWh
Solar	= 48 gr	CO_2 /kWh
Wind	= 11 gr	CO_2 /kWh

Most of the Hydro-Systems are in Mountains
Some are Glacial Fed or a
combination of Snow or Rain

Changes of Hydro-Power Generation



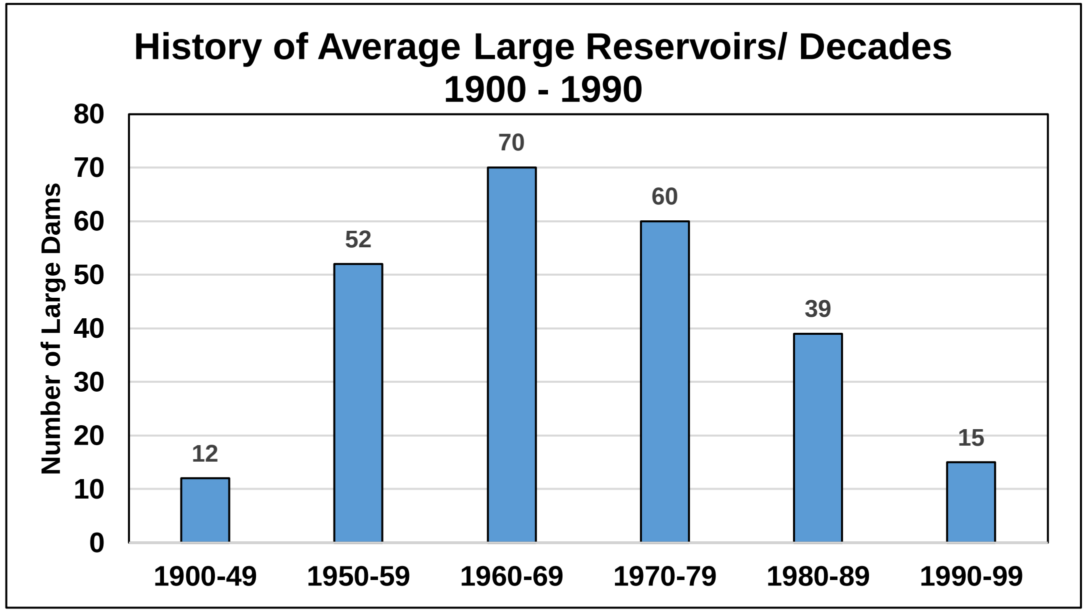
Hydro-Power = 17%
of World Electricity Capacity

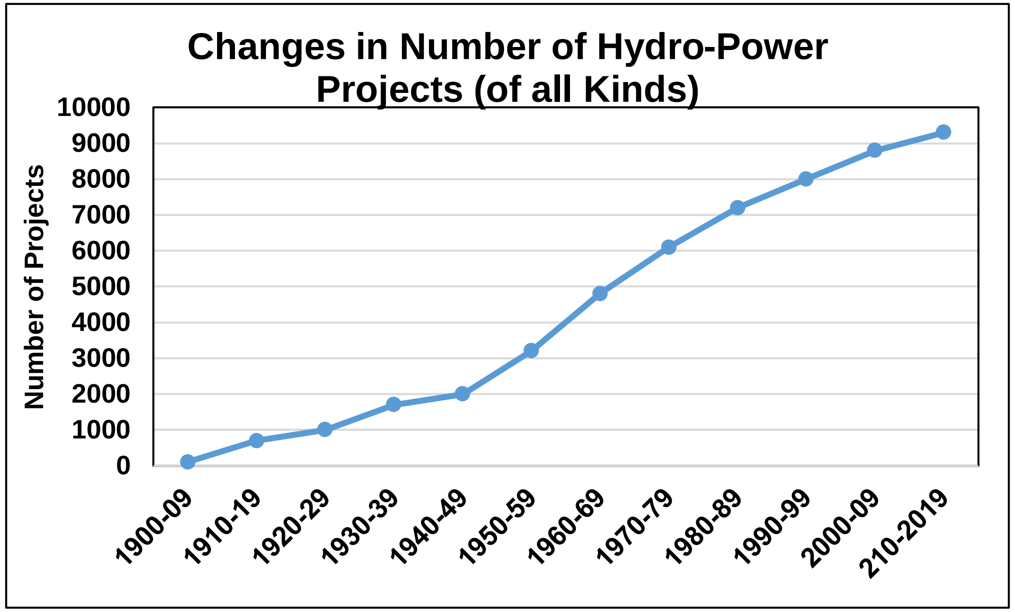
71% or Global Renewable
Energy (Flexible Capacity)

Projected Hydropower Demand is
Expected to Increase 1-4% / Year

By 2020 +

- Winter Electricity Demand is Decreasing
- Summer Electricity Demand is Increasing by 9-11% (Air-Conditioning)





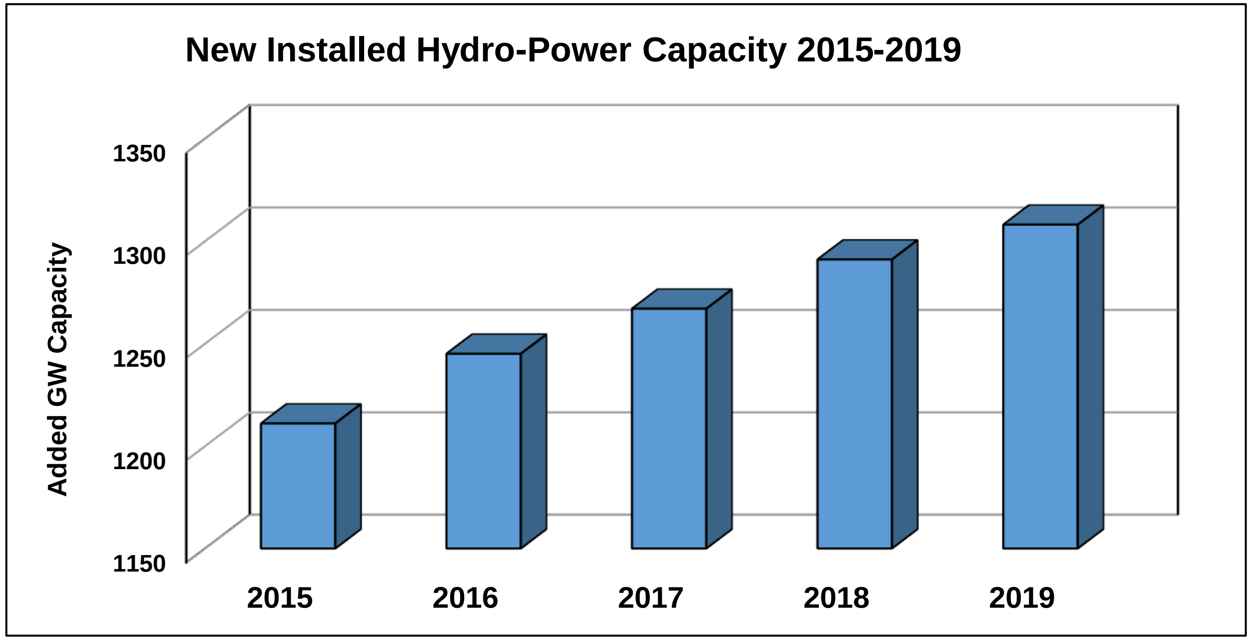
By 1990 there were:

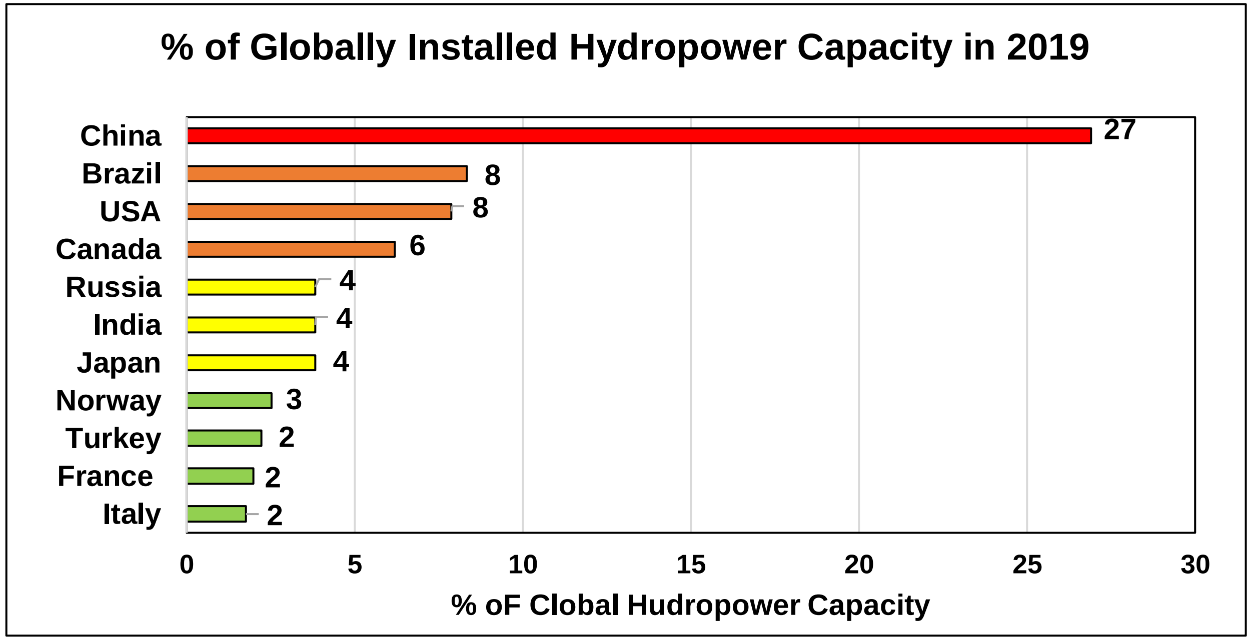
- **40000 Large Dams**
- **(> 150 m Tall, > 15m3/Sec Discharge**
- **500000 km2 of Land Inundated**
- **6000 km3 of Water Stored**

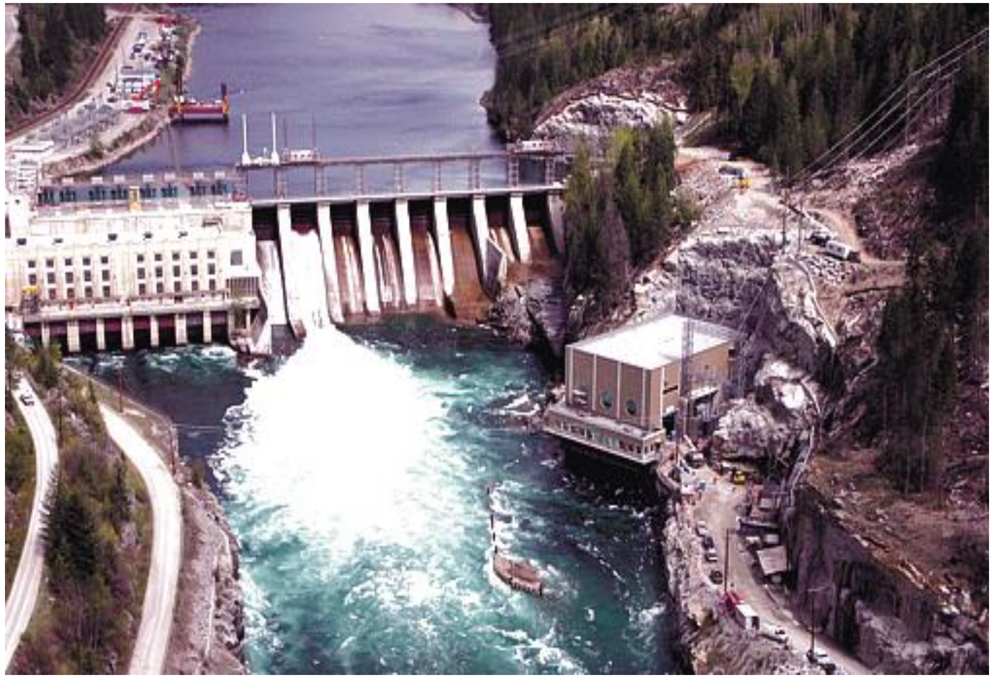
Since 1990 there is a Renewed Interest in Building Dams & Reservoirs Because:

- **Water Shortages by Cities**
- **Need for Green Electricity Production**
- **Concern about Global Warming and GHG**

Hydro-Power = The Battery for Electricity IHA 2020



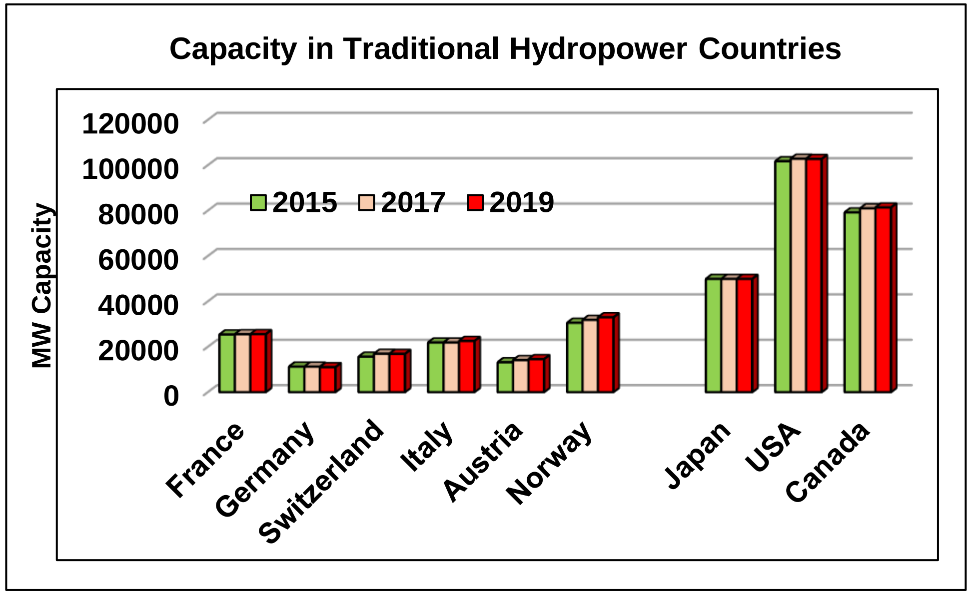




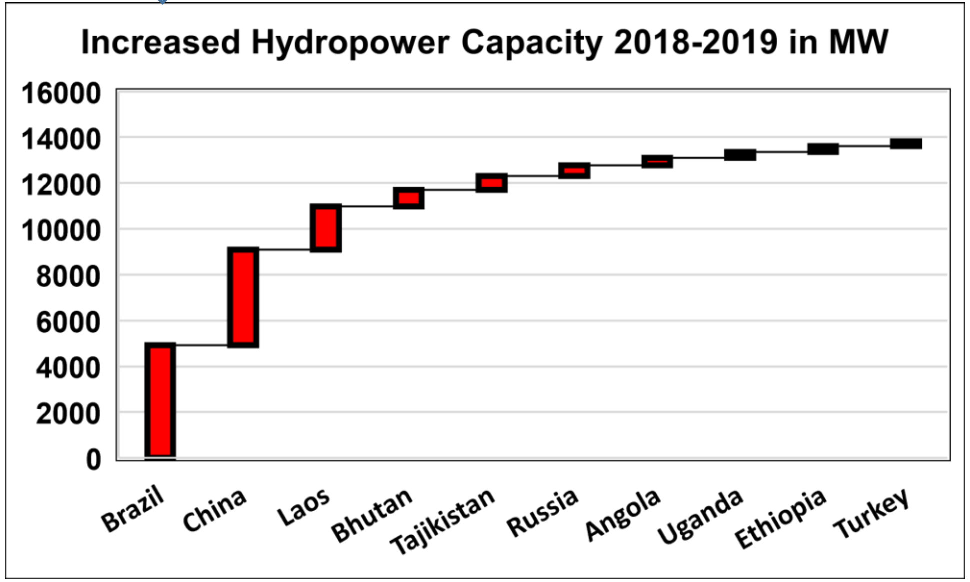
Data Source: Intern. Hydro-Power Association IHA 2020

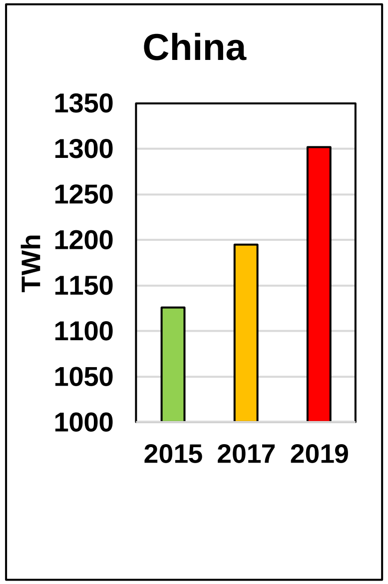
Shifting from Traditional Hydropower Countries to Emerging Countries

Traditional Countries

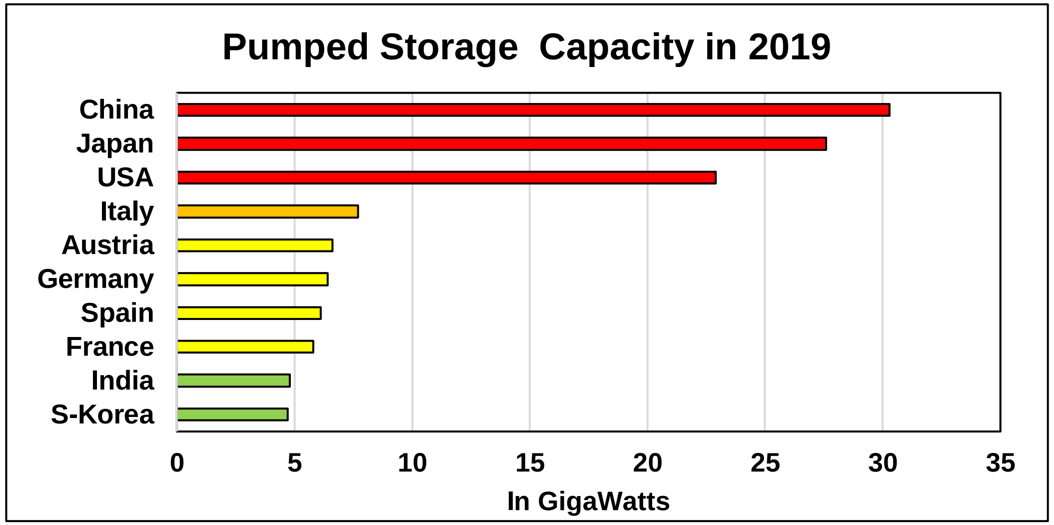


Emerging Countries

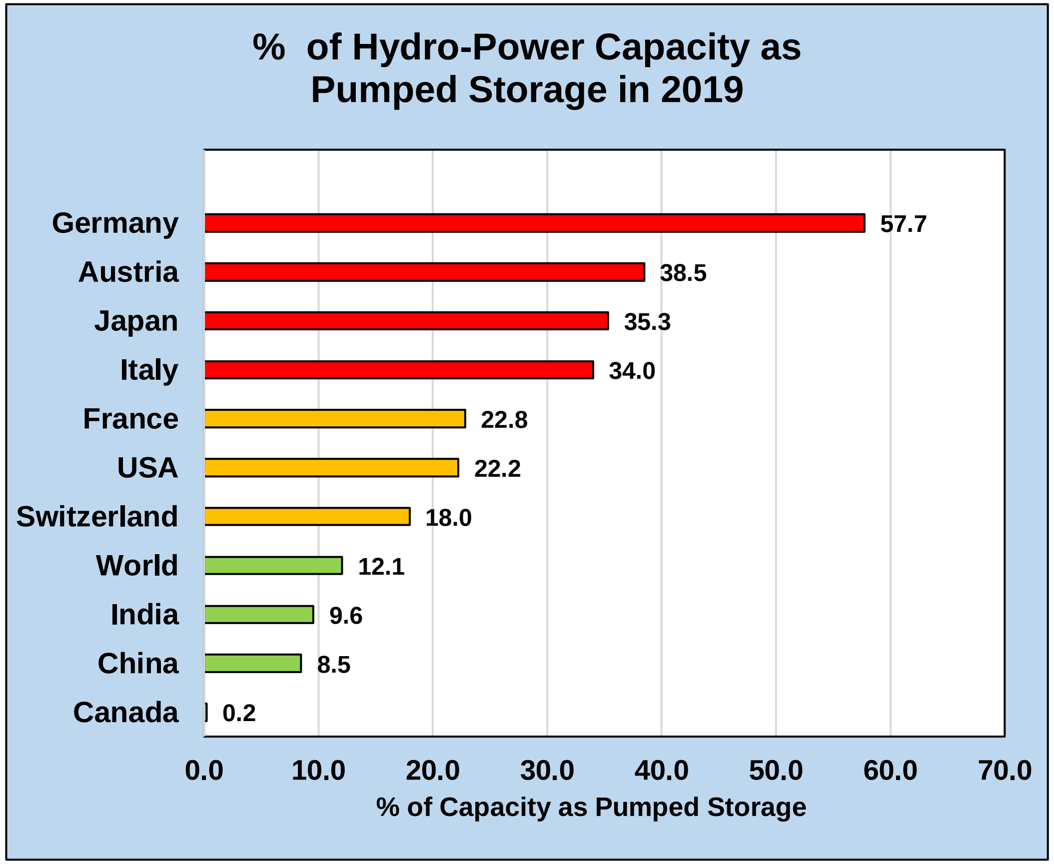


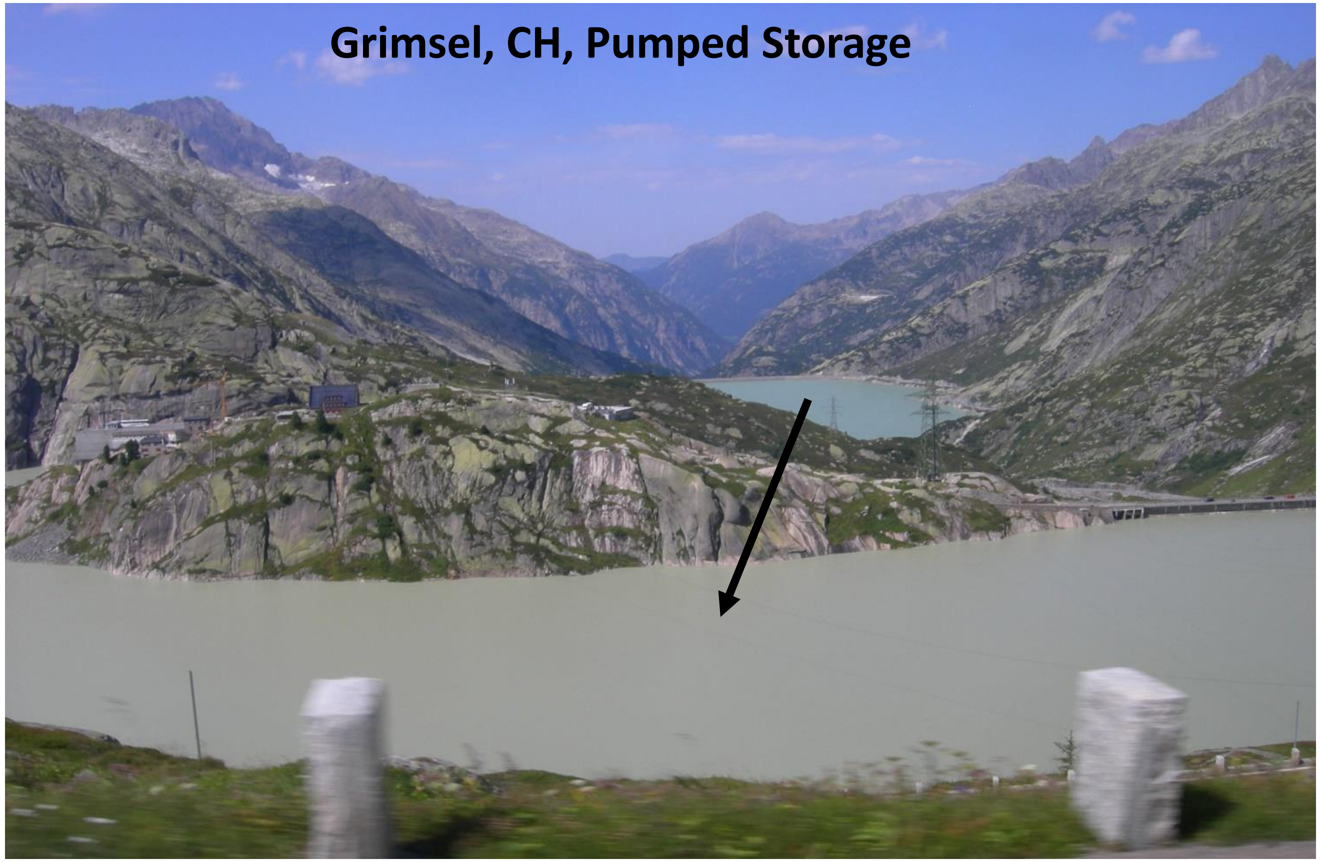


Hydropower Generated by Pumped Storage



Highest Pumped Storage Capacity:
China, Japan, USA
34-58% of the Hydropower Generated by Germany, Austria, Japan & Italy is from Pumped Storage





Advantages

- Only Operate at Peak Electricity Demand (7-9 am, 11-13;00 and 16-18:00 hrs.
- Produces Electricity when Prices are High (is highly Profitable)
- Use Other Sources of Electricity Between 1-4 am when Demand & Prices are Low to Pump Water from Low to High Reservoir

Disadvantages

- Reduces Streamflow below Reservoir
- Affects the Hydrology & Eco-Services in River Downstreams
- Inundates Land for 2 Reservoirs
- Hard on Equipment Operation since it always Works at peak Capacity

Increased Concerns About Hydropower Development on International Rivers

Key Issues in Asia

Mekong
China 11 Operational, 7 Planned
Thailand & Laos: 8 Planned
Cambodia: 1 Operational 2 Proposed

Salween
China: 2 Operational 14 Agreed, 12 Planned
Myanmar: 3 Planned
Thailand 2 Planned

Brahmaputra:
China: 4 Operational, Several Planned

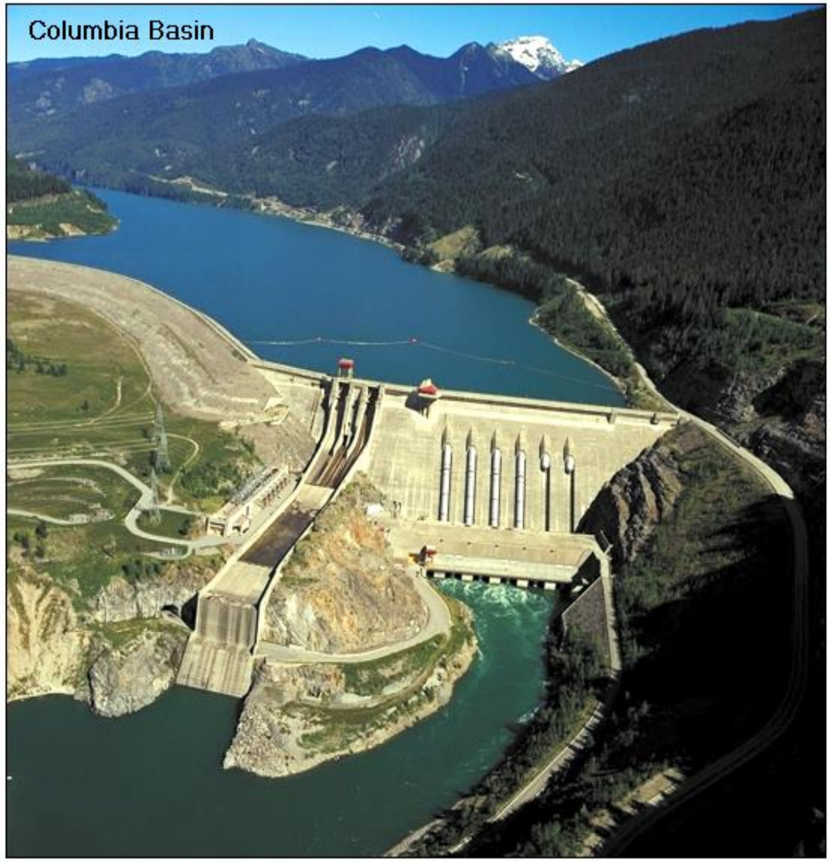
Key Issues in Africa

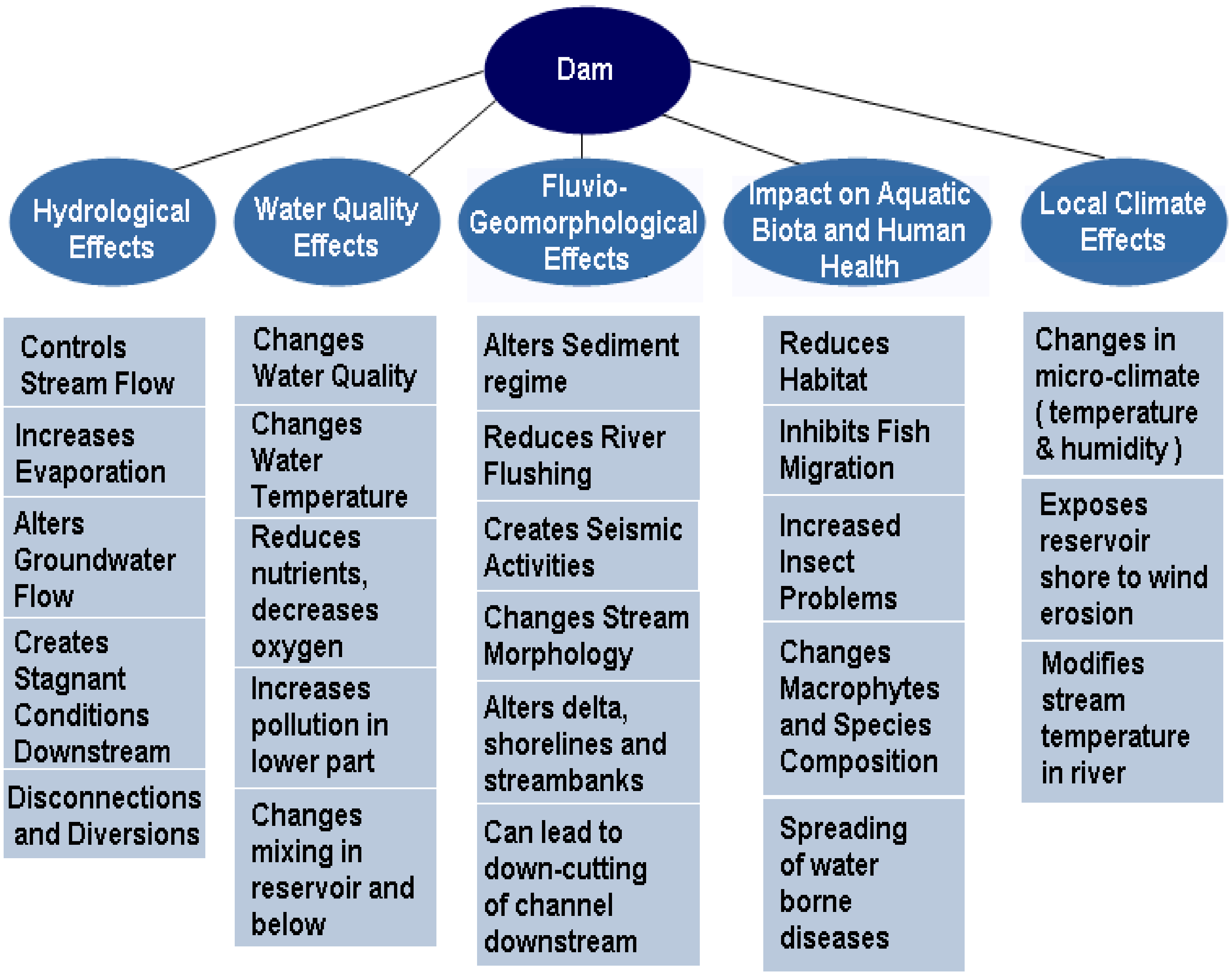
Nile
Ethiopia: Renaissance Dam
Sudan: 2 Operational
Egypt: Aswan Dam

Rest of Africa
22 In Various countries with Chinese, & Saudi Arabian Investments

Sub Saharan Africa:
980 Large Dams with
589 in South Africa

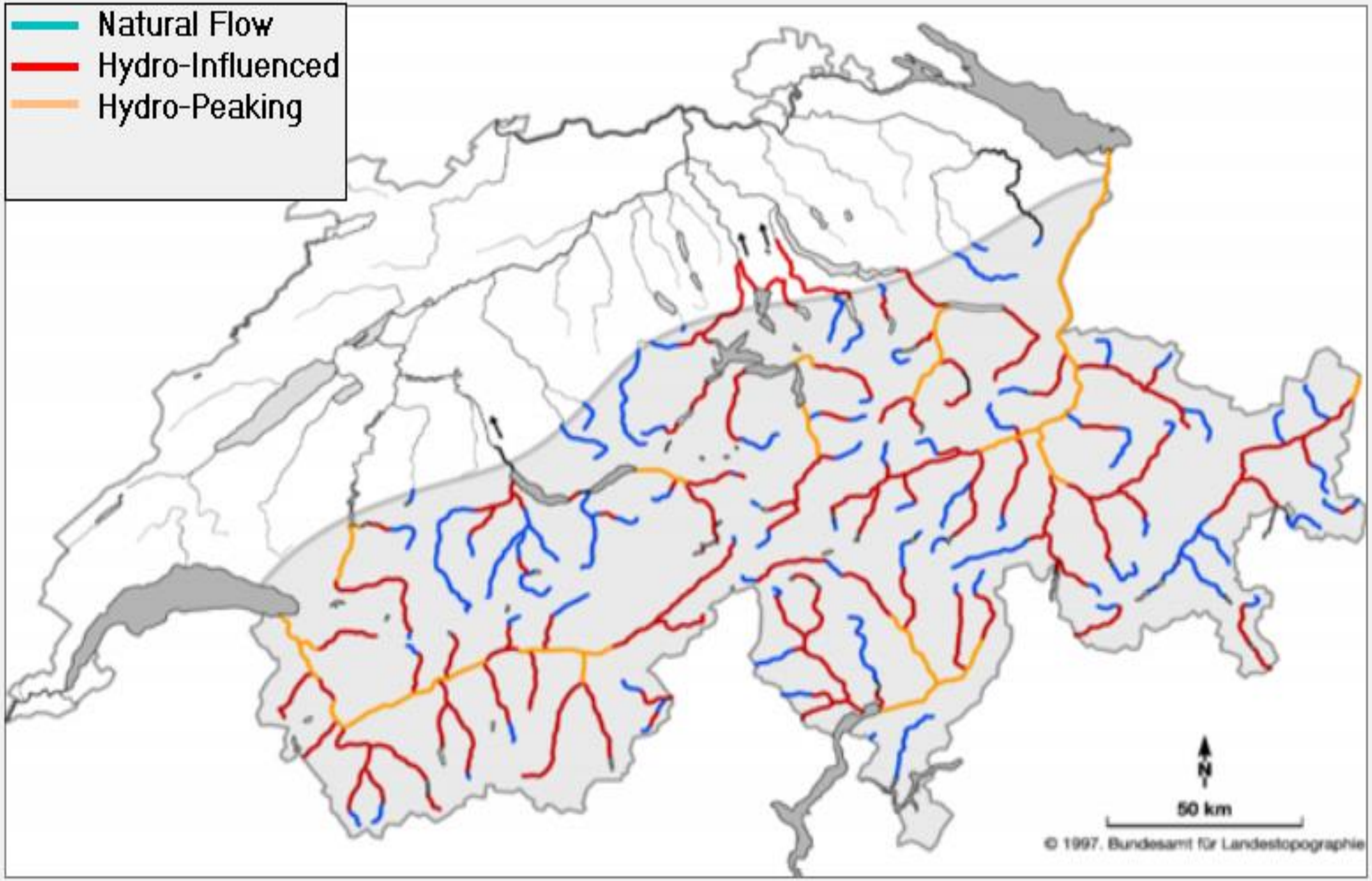
Impact of Hydropower

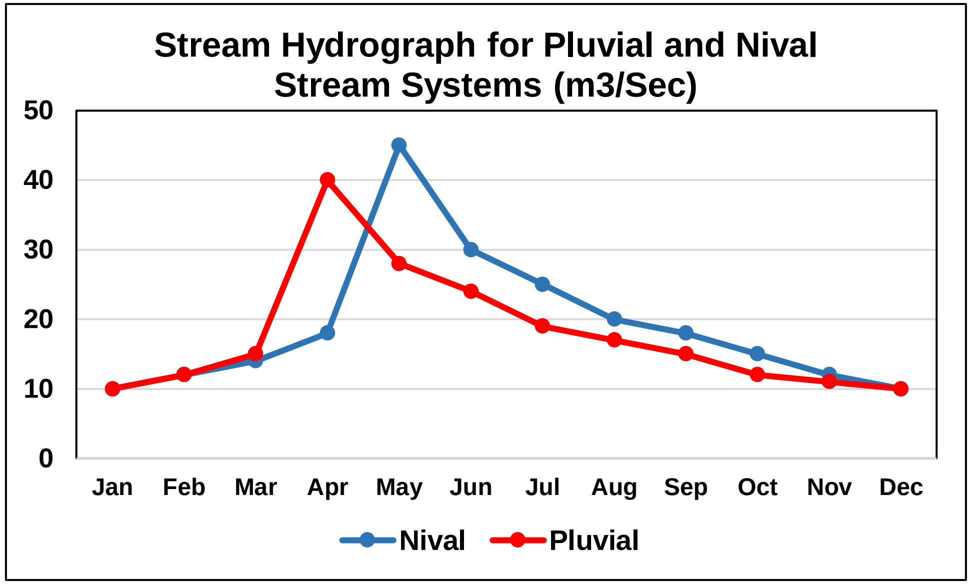


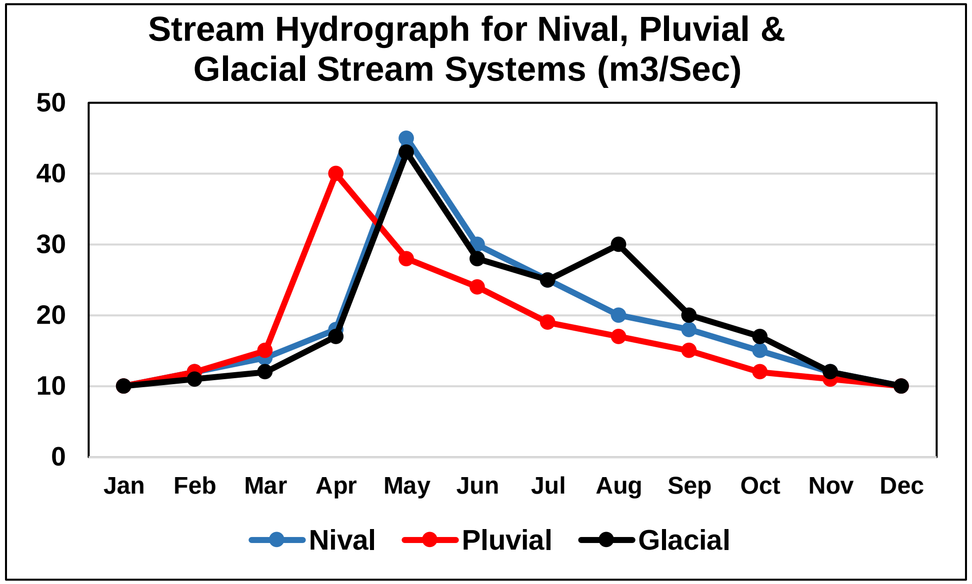

Dam
Hydrological Effects
Water Quality Effects
Fluvio-Geomorphological Effects
Impact on Aquatic Biota and Human Health
Local Climate Effects
Controls Stream Flow
Increases Evaporation
Alters Groundwater Flow
Creates Stagnant Conditions Downstream
Disconnections and Diversions
Changes Water Quality
Changes 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

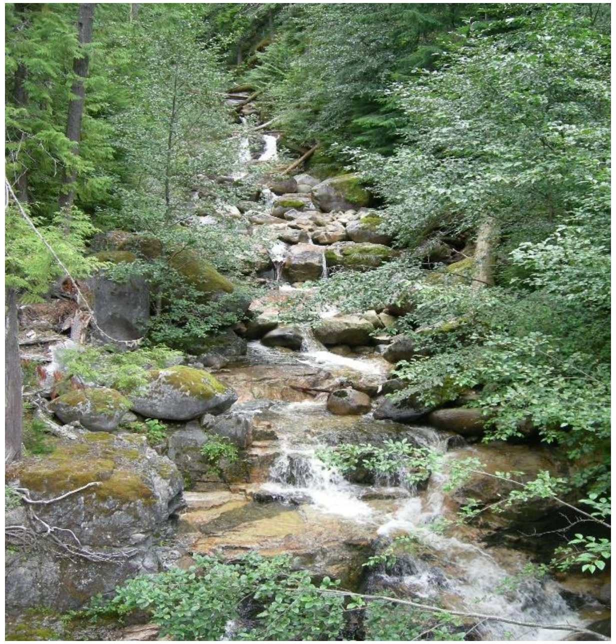
What does this traffic sign indicate ???

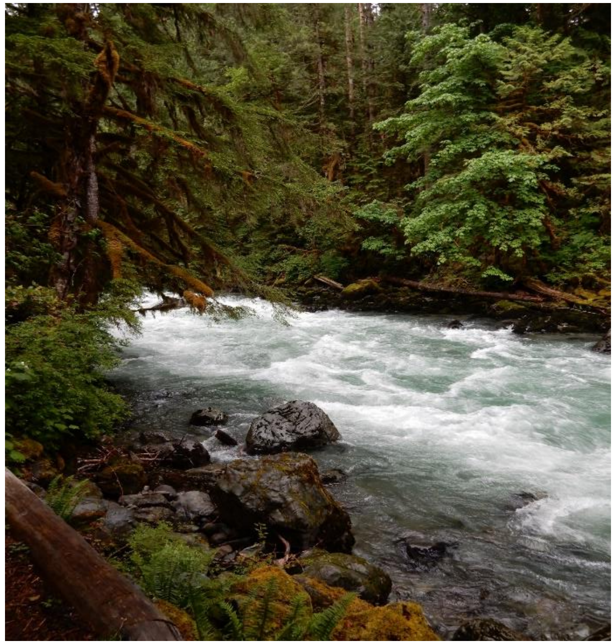
Discharge Regime in Swiss Rivers

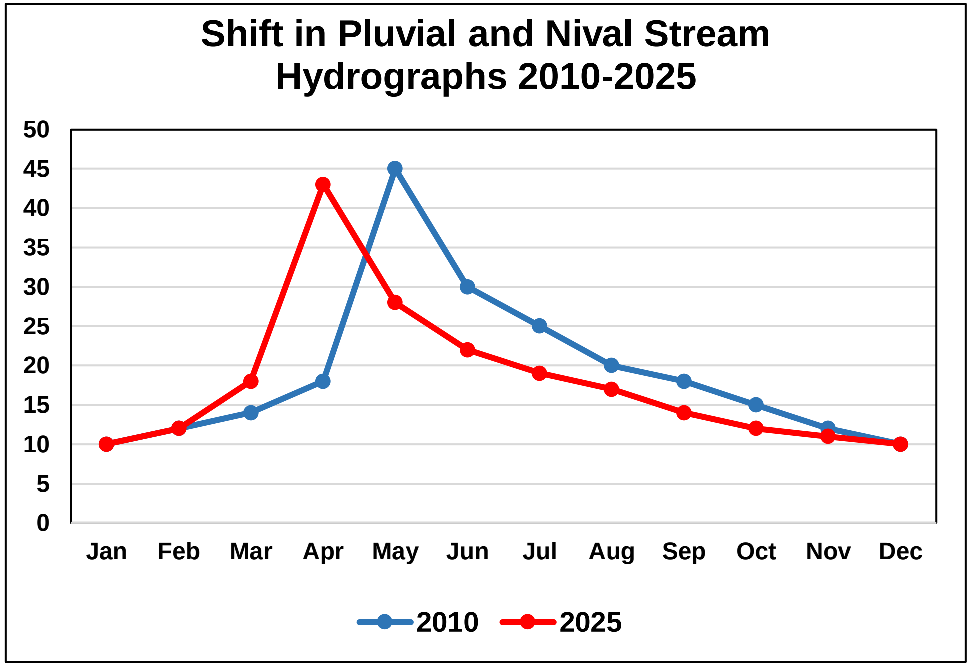



Stream Hydrograph for Pluvial and Nival Stream Systems (m3/Sec)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Nival
Pluvial

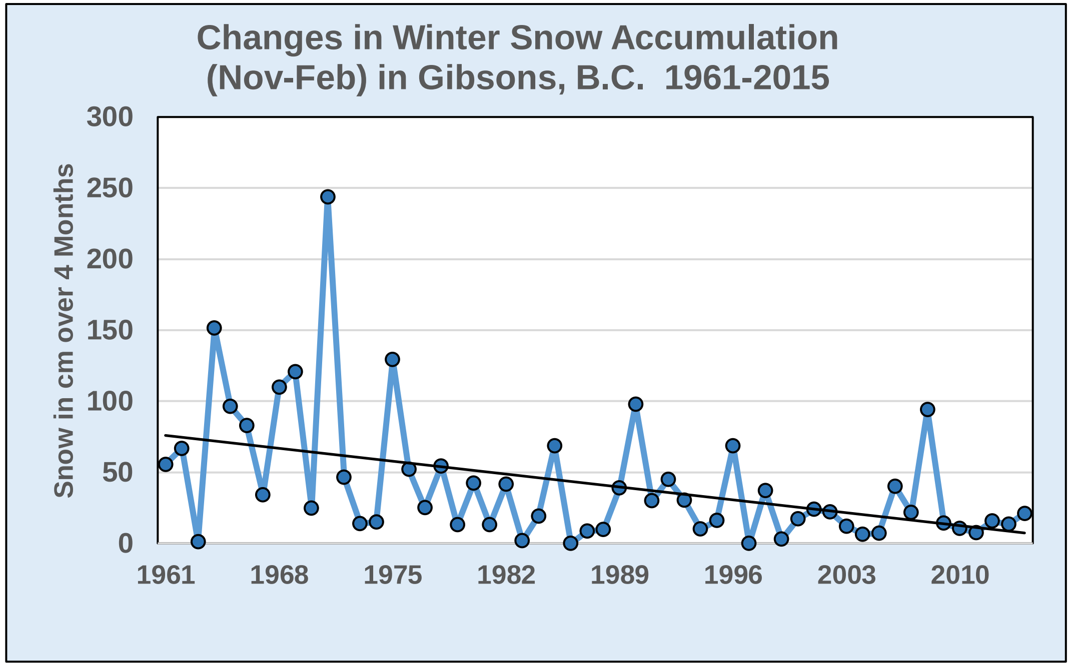

Stream Hydrograph for Nival, Pluvial & Glacial Stream Systems (m3/Sec)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Nival
Pluvial
Glacial



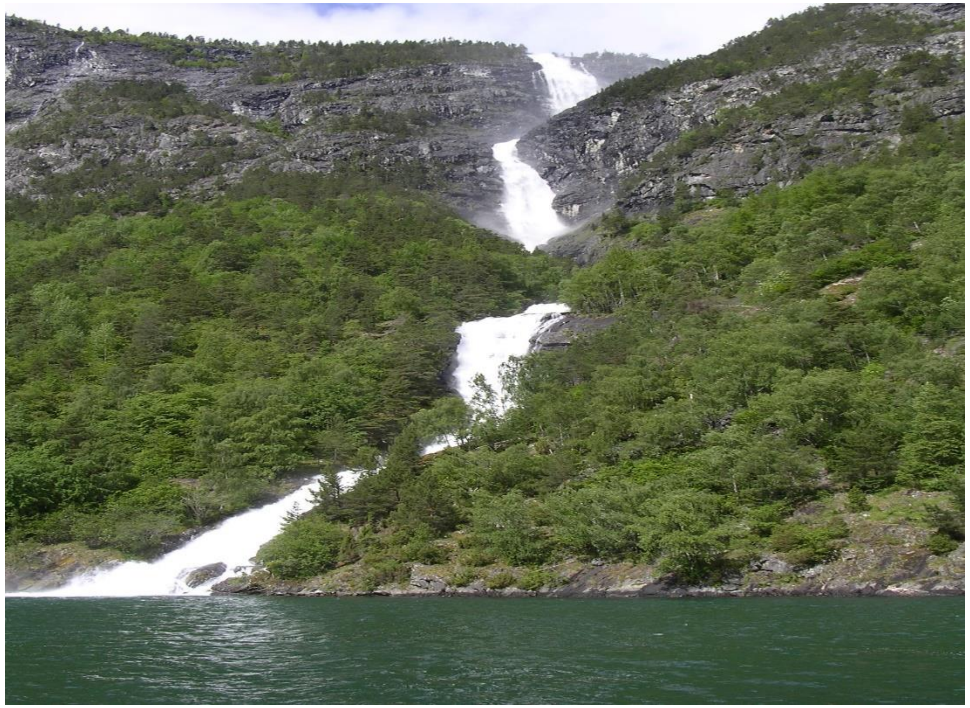


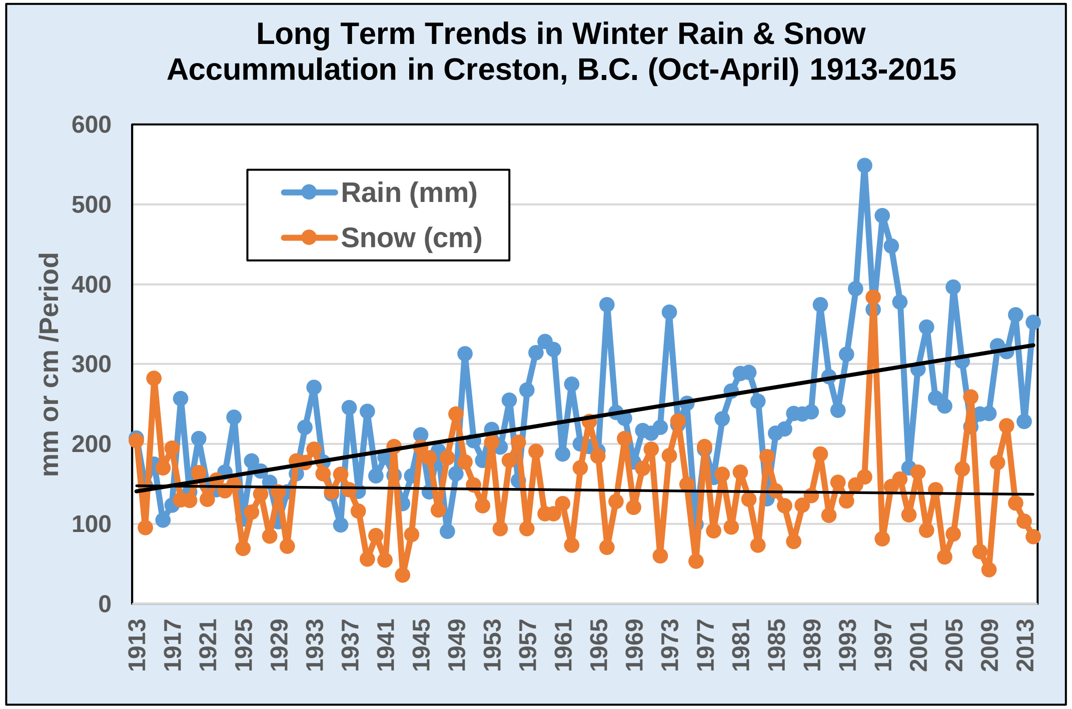


Shift in Pluvial and Nival Stream Hydrographs 2010-2025
50
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010
2025



Changes in Winter Snow Accumulation (Nov-Feb) in Gibsons, B.C. 1961-2015
Snow in cm over 4 Months
300
250
200
150
100
50
0
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
600
500
400
300
200
100
0
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

% 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

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:

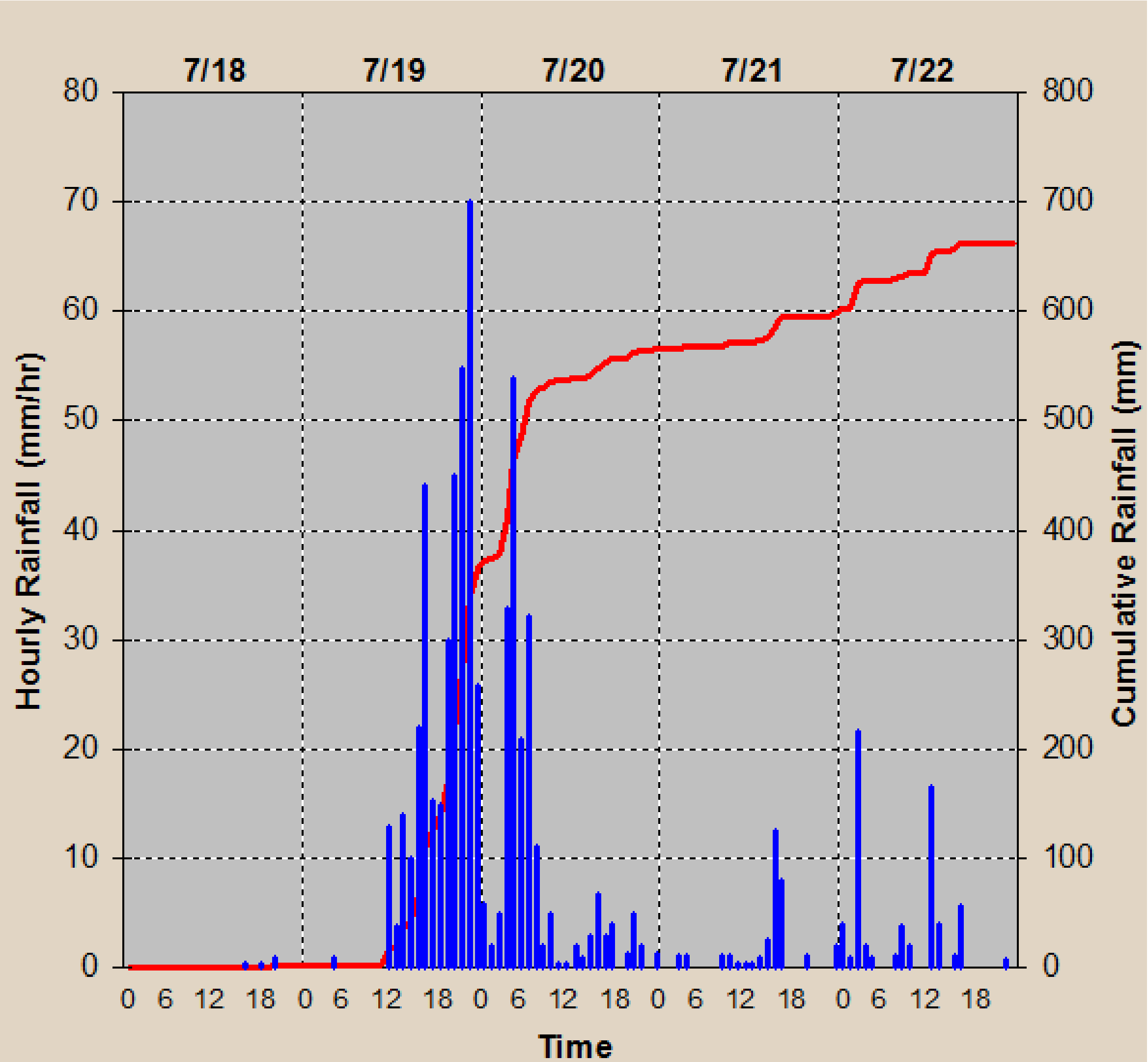
a) At Construction Time 1982 : 11.2 t / ha / Year
b) Averages Rate 1982-1992 : 20- 45 t / ha/ Year
(based on reservoir sonar surveys,
Galay et al. 1995.)


Hydropower reservoir and dam

1993 Rainstorm Event

Total Rainfall in 24 hours : 540 mm

Max Rainfall / hour: 70 mm

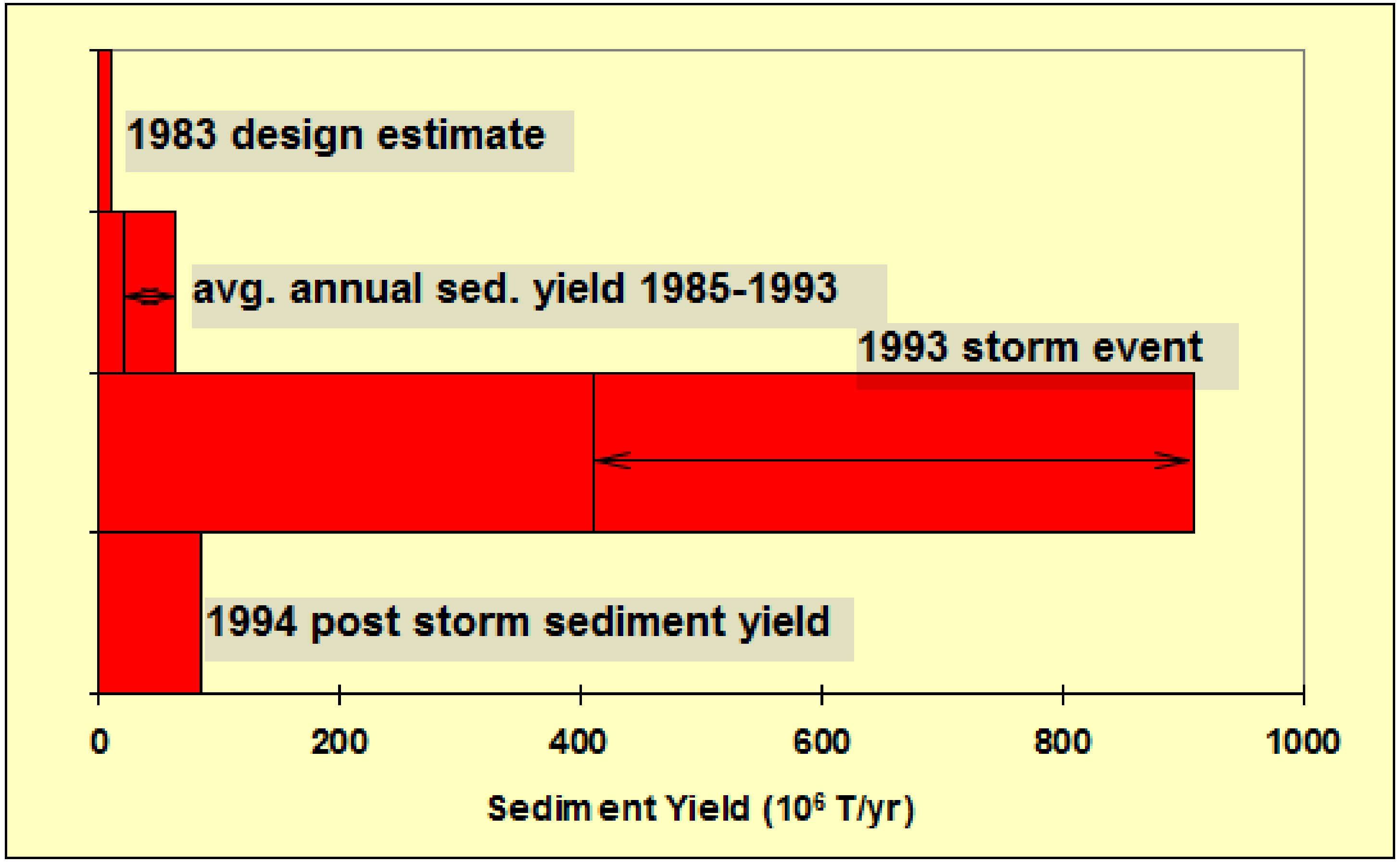


Sediment Accummulation History

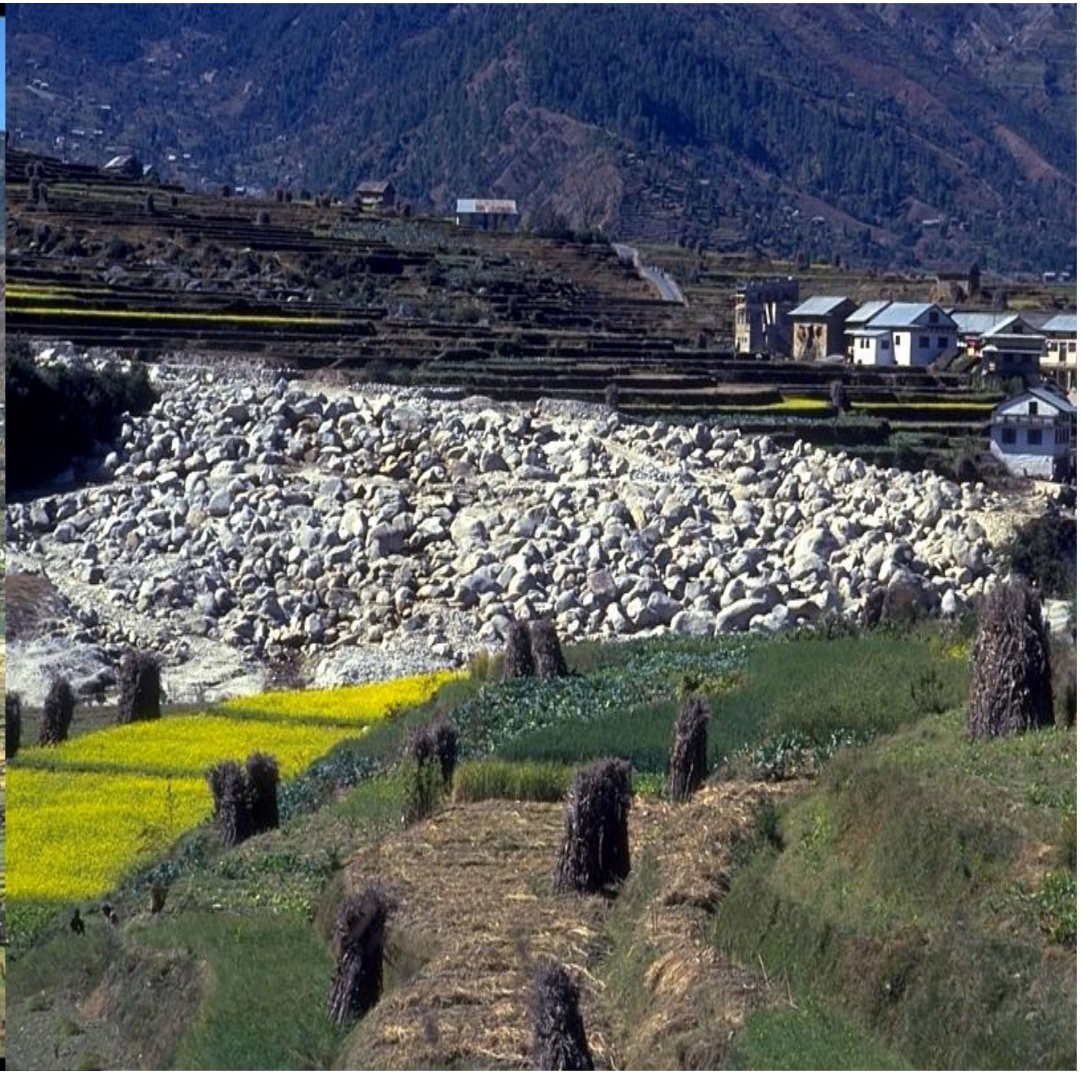
Sediments accumulate in the reservoir were measured regularly with sonar profiling

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 Reservoir = 20-25 Years

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

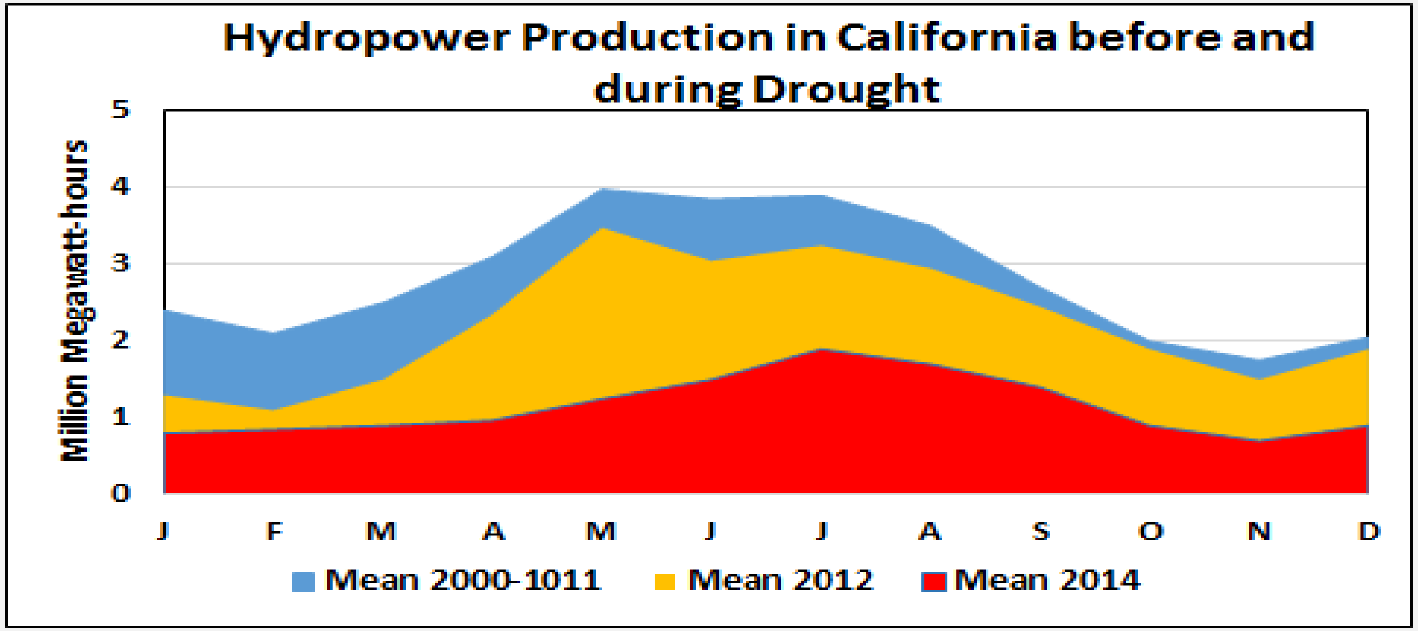
Examples of Record Temperatures

		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

Drought Impact on Electricity Production



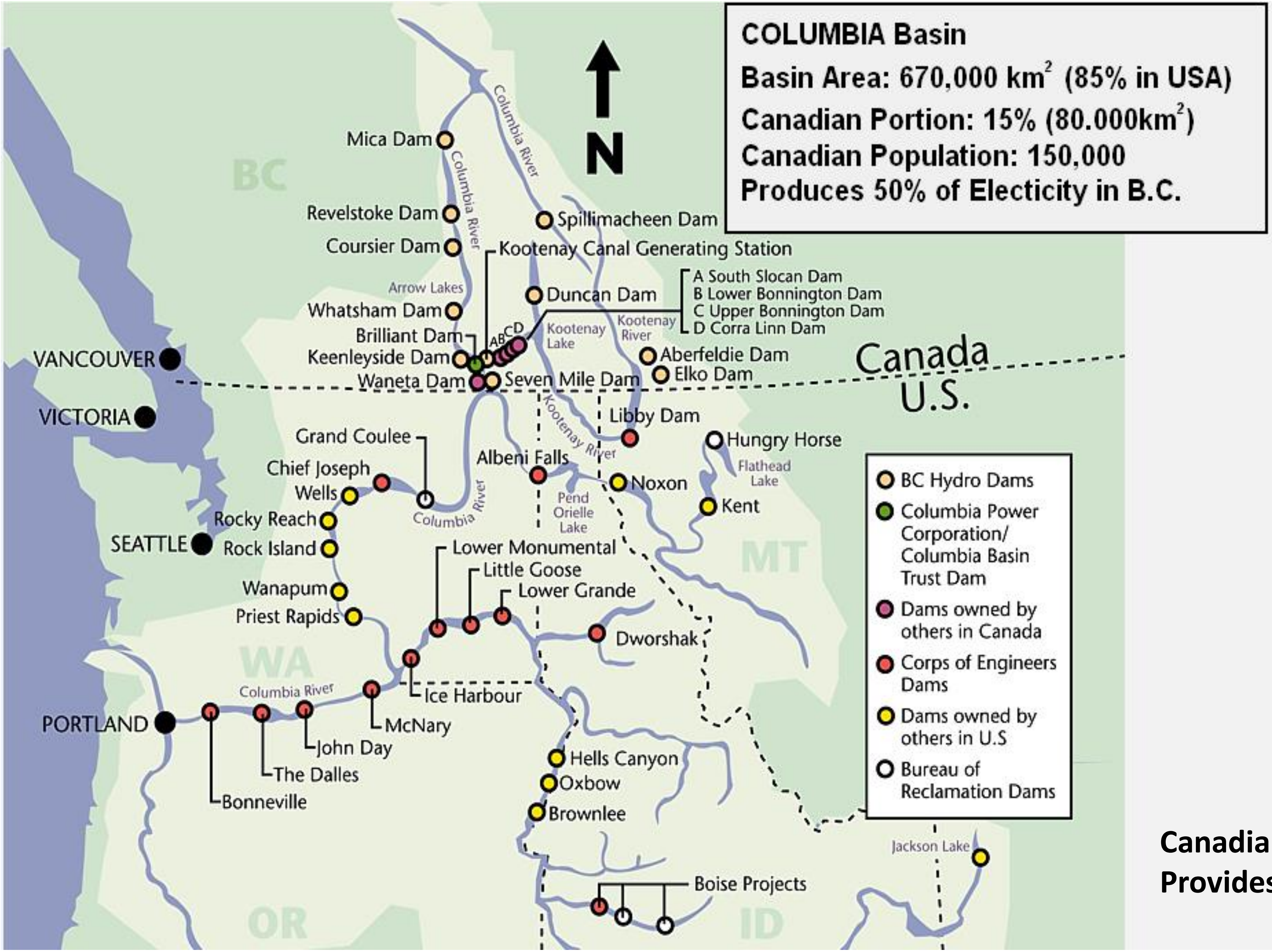
Hydropower

2000-2011: 18% of Electricity
2014: 12% of Electricity
2015: 7% Of Electricity

Replaced with Natural Gas
Cost: $ 2 Billion between 2013-2015
Power Plant CO_2 Emission Increased by 10%

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

Columbia Basin Case Study Canada/USA



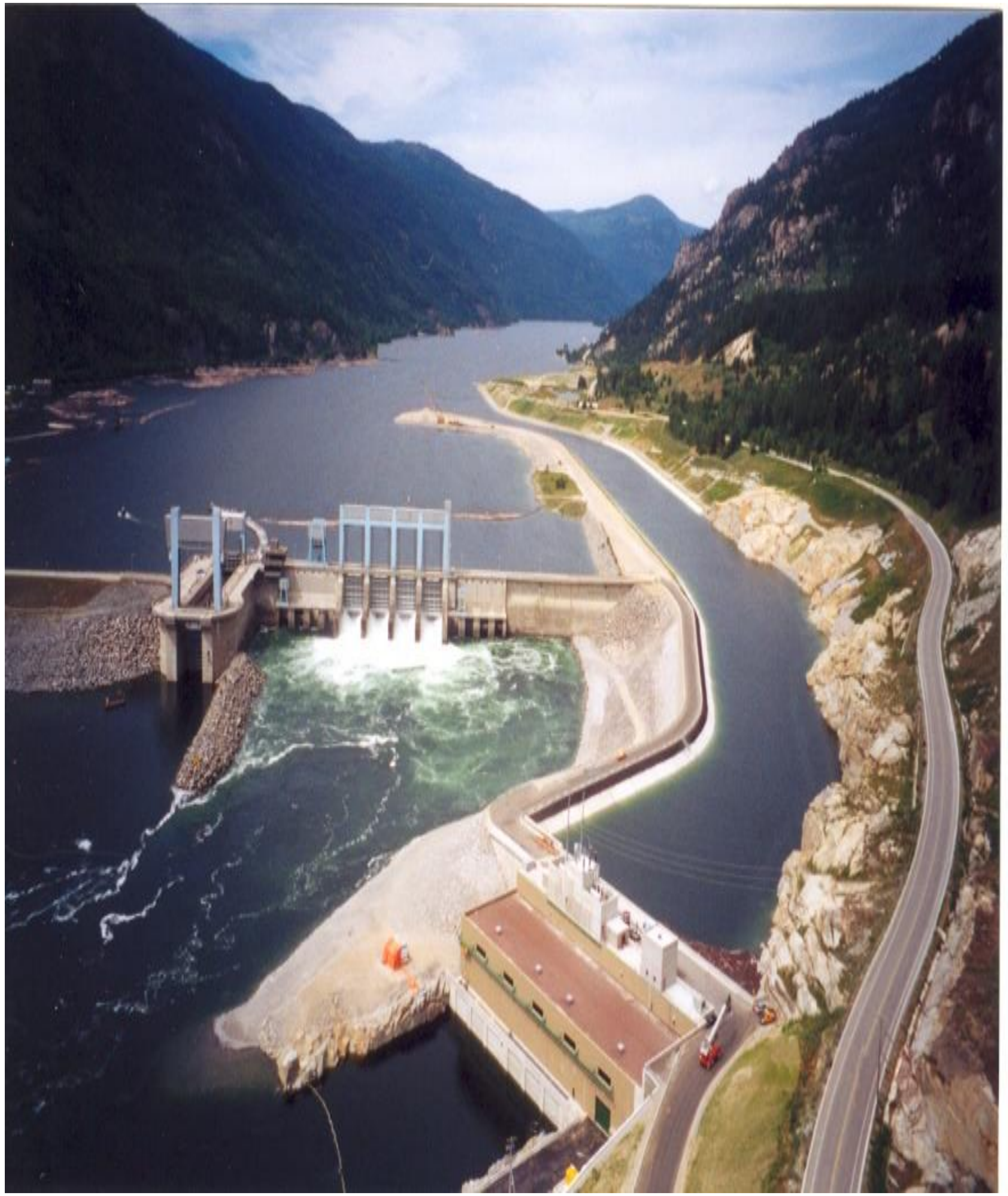
400 + Reservoirs
Within the Basin

Treaty Dams
3 in Canada

Mica
Duncan
Keenleyside

Total Major
Reservoir
In Canada: 15

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



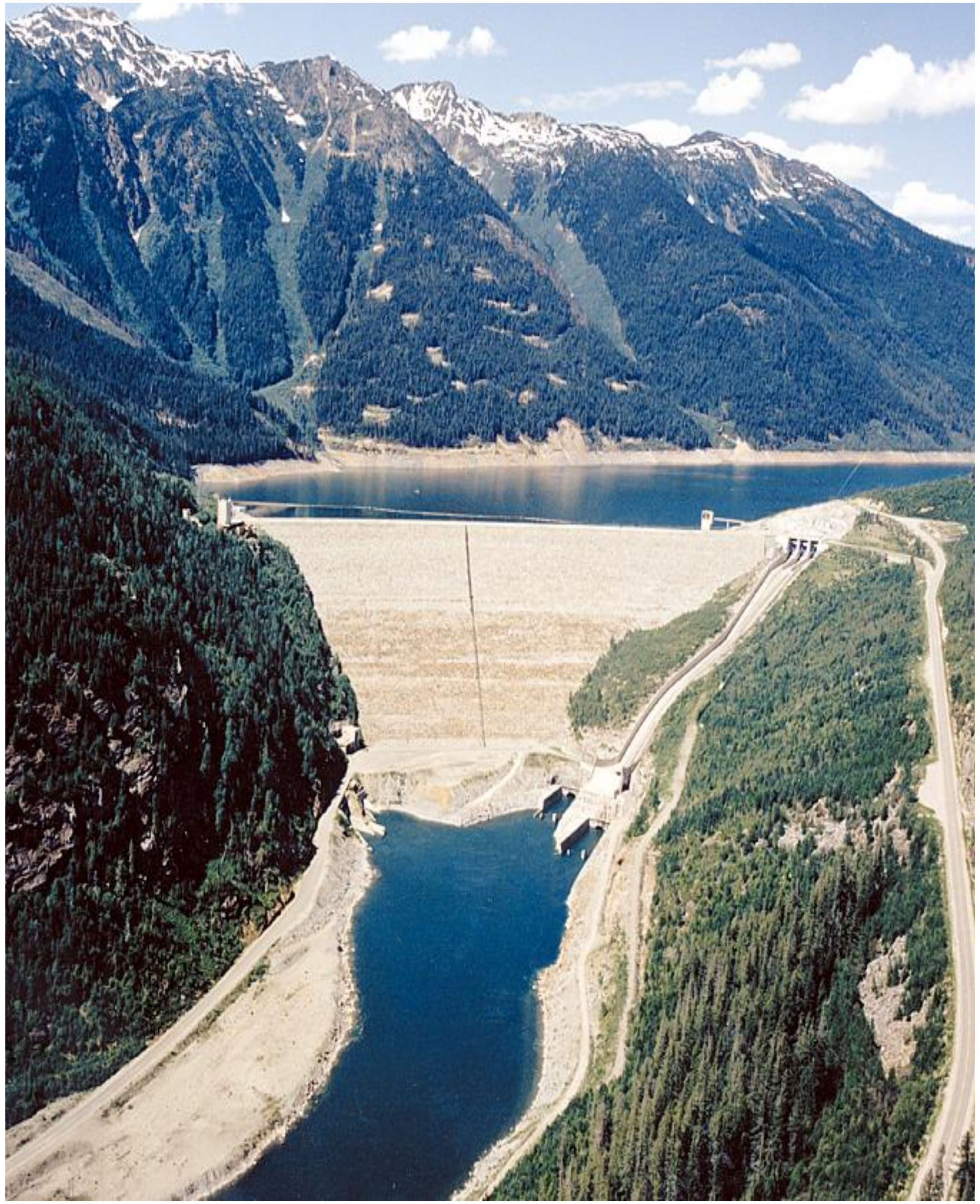
Columbia River Treaty 1964-2024 (60 Years)

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.)

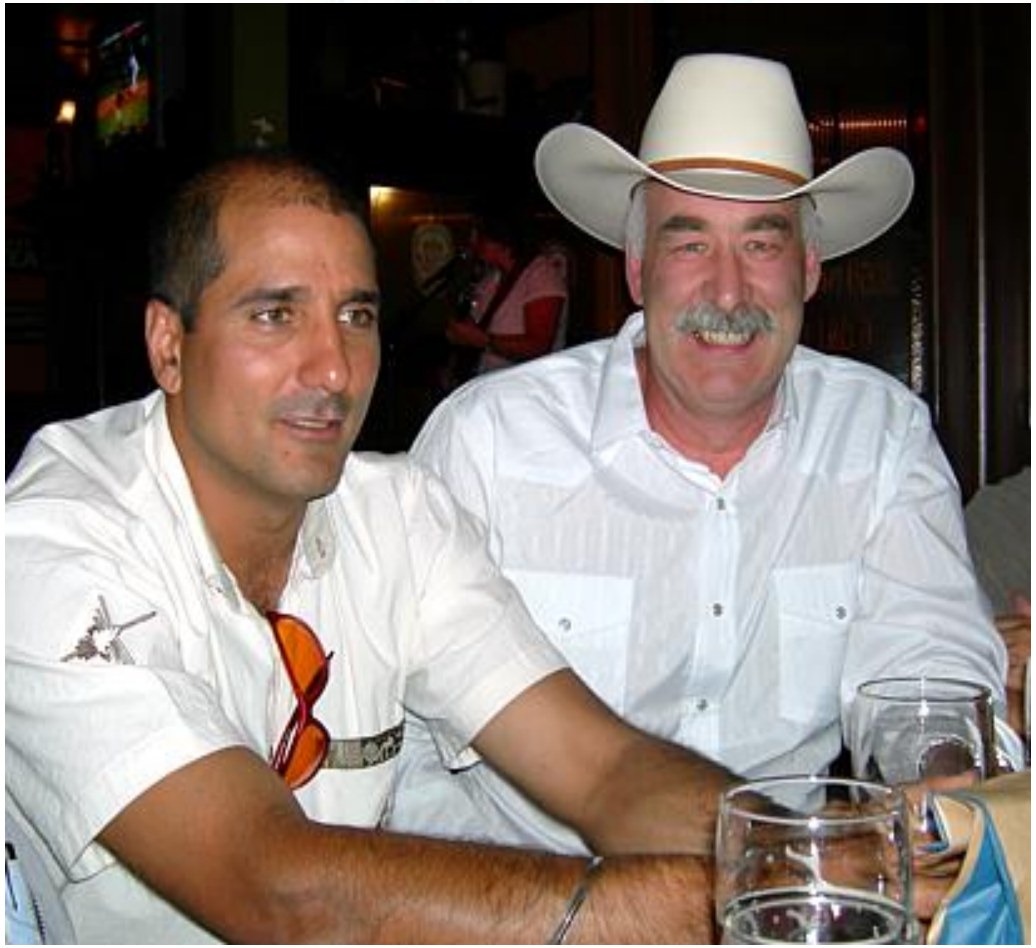


Columbia Basin trust

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

AP-7000 – Long-term

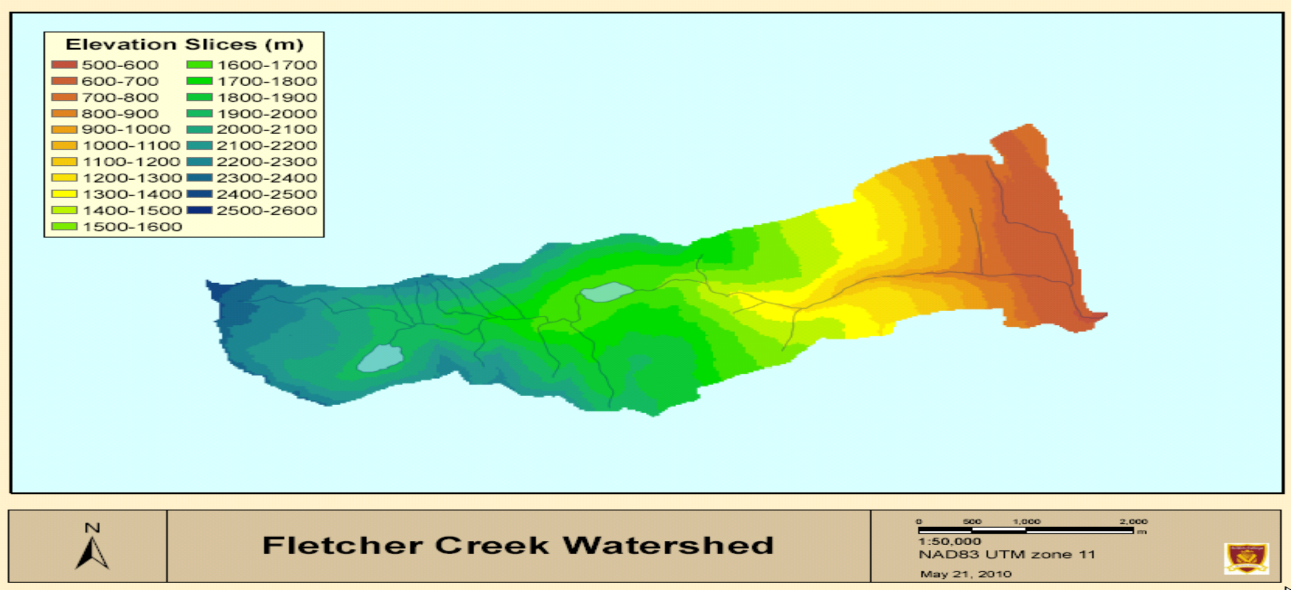
OTT Orpheus Mini Water Level Logger

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



Change Focus

From Hydropower to the Himalayan-Andean Watershed Project

The Himalayan-Andes Watershed Project

Hans Schreier, University Of British Columbia, Vancouver, Canada

Compare 8 Watersheds in 2 Mountain Regions

Objectives and Aims

Develop & Use:

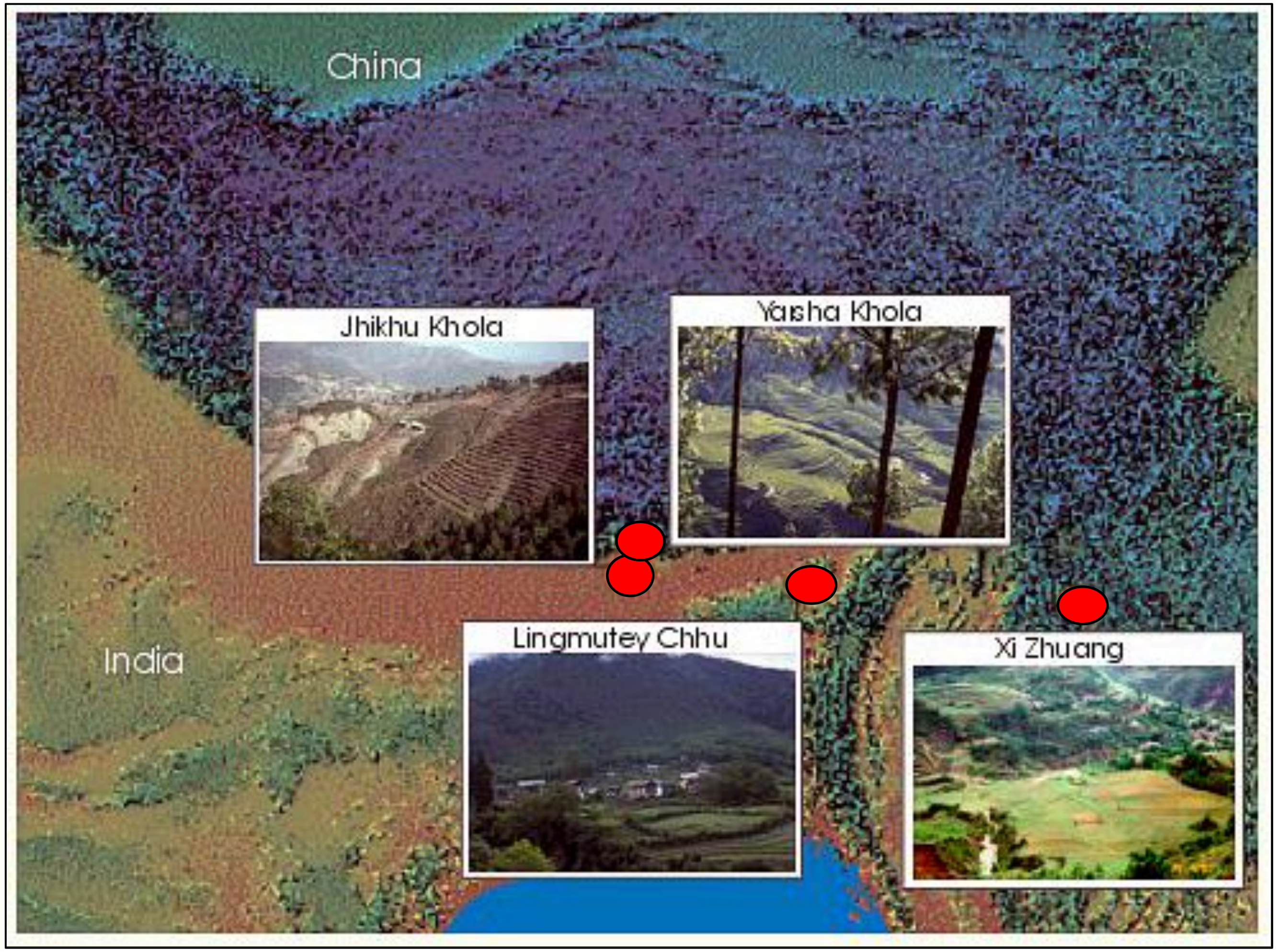
- **Common Framework**
- **Comparable Indicators**
- **Similar Methodologies**
- **Multi-Media Tools**
- **Integrated Approach**

Identify & Compare:

- **Prioritize Key Issues**
- **Common Problems**
- **Unique Issues**
- **Highlight Successes**
- **Identify Transferable Option**

The Andean Watersheds

The Himalayan Watersheds



Introduction to project

Himalayan Region

Nepal 1 Nepal 2 Bhutan China

Himalayan comparison

Andean Region

Peru 1 Peru 2 Ecuador Bolivia

Andean comparison

Himalayan-Andean Watershed Comparison

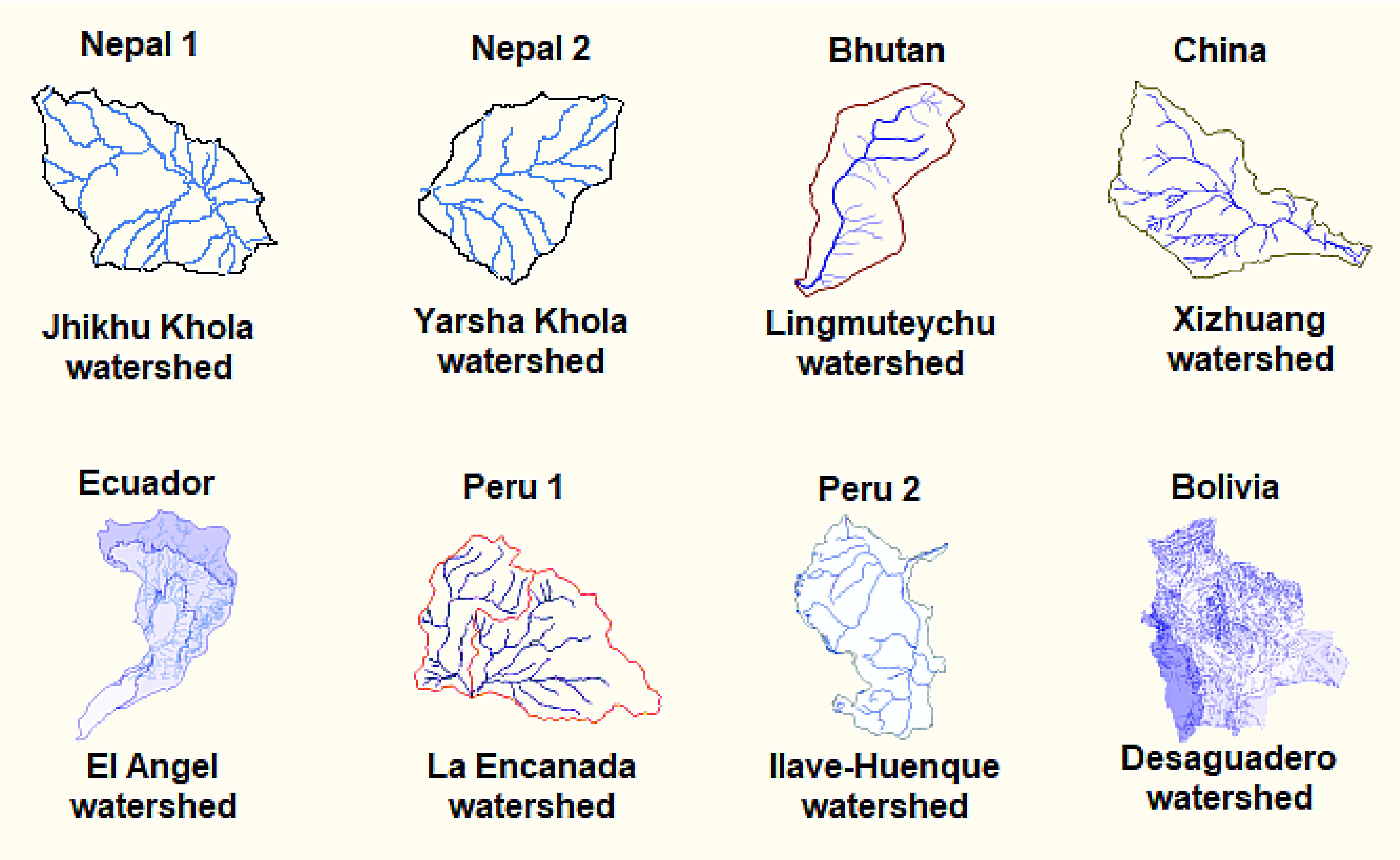
Indicators

Common & Unique Issues & Constraints

Options & Opportunities

Success stories

Lessons learned


Nepal 1
Jhikhu Khola watershed
Nepal 2
Yarsha Khola watershed
Bhutan
Lingmuteychu watershed
China
Xizhuang watershed
Ecuador
El Angel watershed
Peru 1
La Encanada watershed
Peru 2
Ilave-Huenque watershed
Bolivia
Desaguadero watershed

Jhikhu Kola Watershed, Nepal

Yarsha Kola Watershed Nepal

Xizhuang Watershed, China

Lingmuteychu Watershed, Bhutan

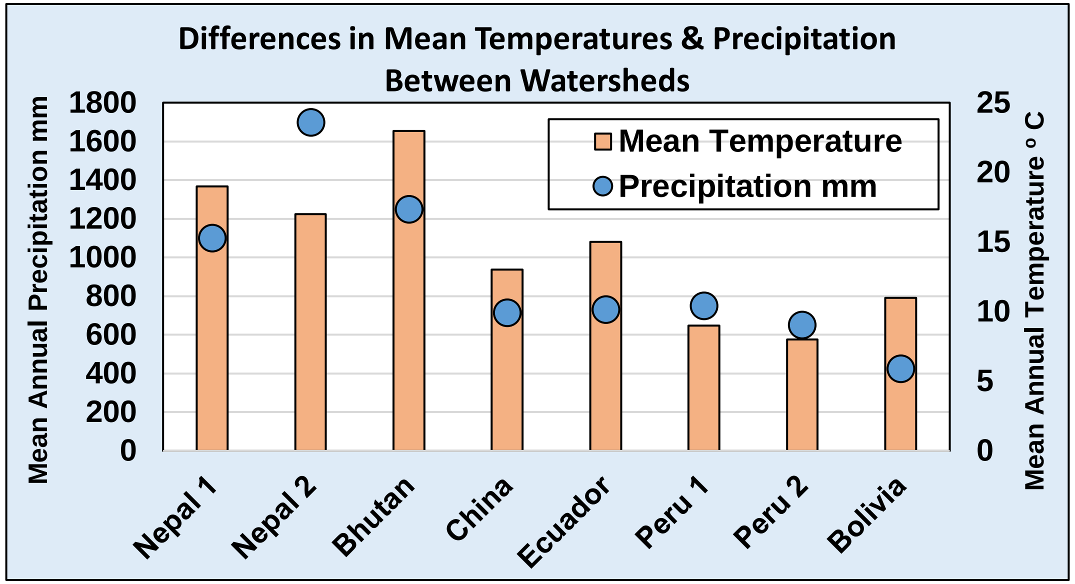
Desaguadero Watershed, Bolivia

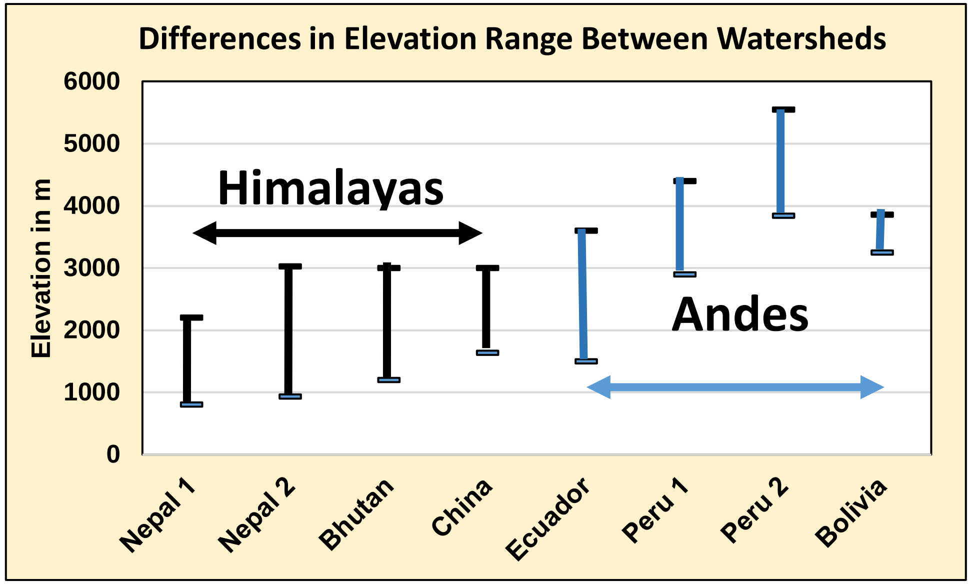
El Angel Watershed, Ecuador

El Ilave Huenque Watershed, Peru

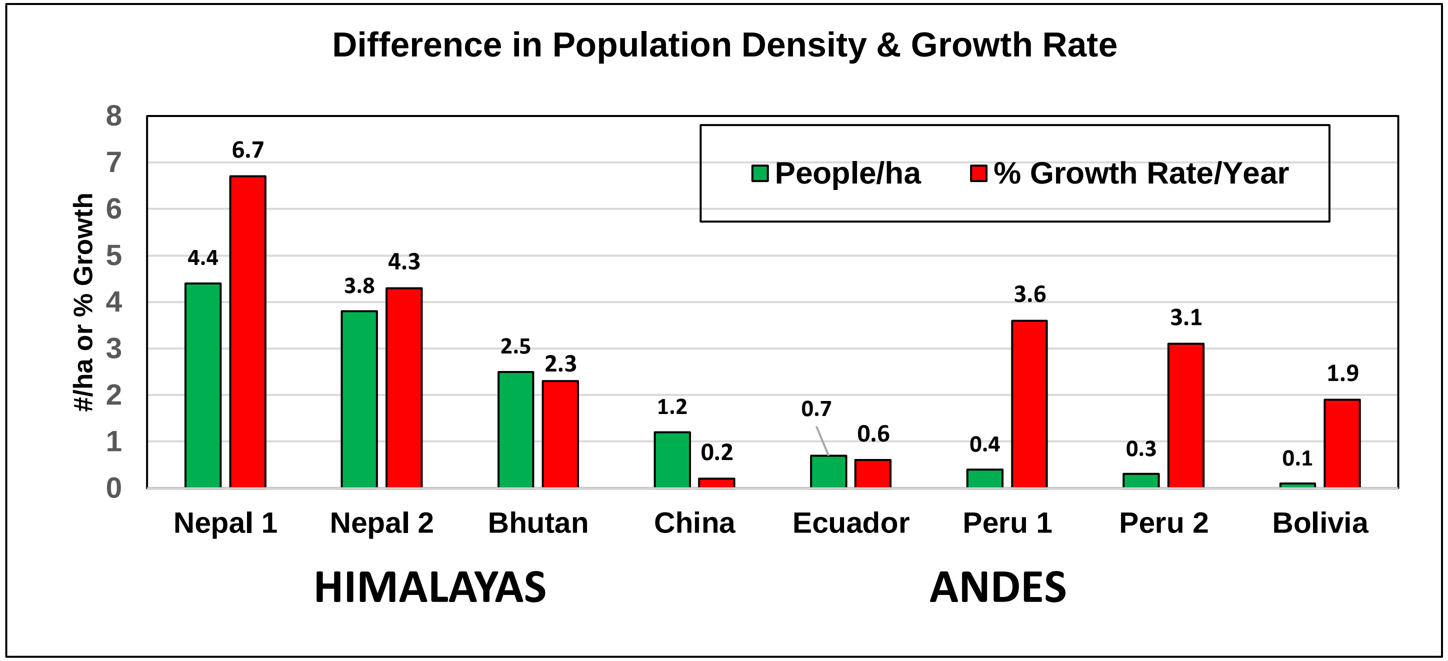
El Encanada Watershed, Peru

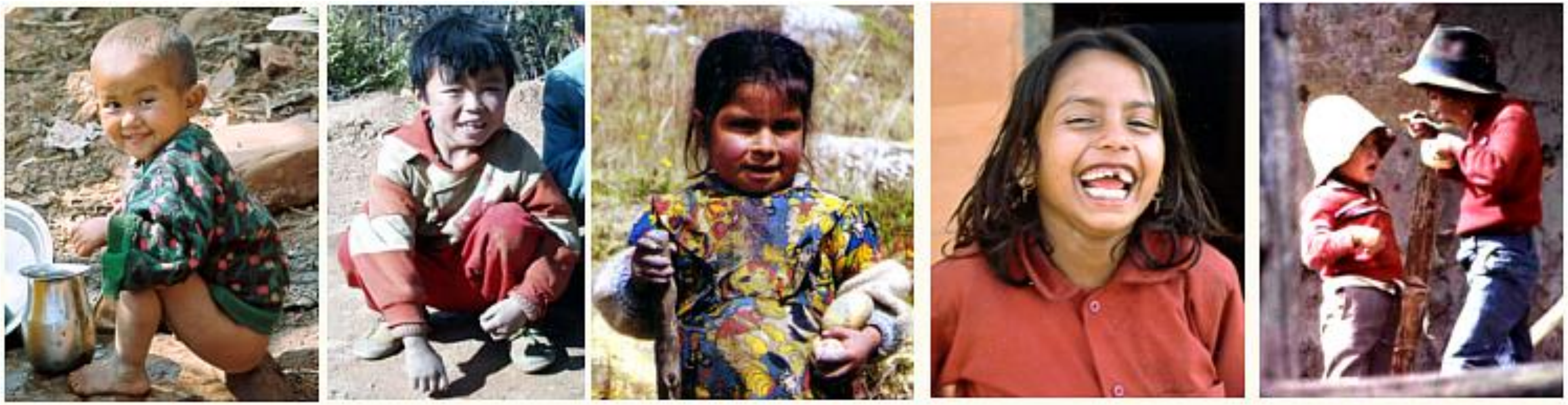
Climate and Elevation Differences





Population Density & Population Growth Rate





Comparison of the Key Issues in the 8 Watersheds

Issues	Nepal Jhikhu	Nepal Yasha	Bhutan Lingmuteychu	China Xizhuang	Peru La Enanada	Peru Ilave	Ecuador El Angel	Bolivia Desaquadero
Insufficient Food	3	2	1			1		4
Water Shortages	1	3	2	1	1		1	3
Soil Fertility Fertilizer Access	4	5	3	6	2	2		
Erosion, Degradation Rehabilitation	6		5		3	3	4	5
Insufficient Animal Feed	2	6	6	5	7	4		1
Market Access	7	1	4	4	5	6		6
Women Workload	5	8	7					
Education Extension		7		3	6		5	
Health-Pesticide				2			2	
Adverse Climate		4			4			2
Land Tenure						5	3	
Migration						7		7

	The Andean Watersheds	The Himalayan Watersheds
Dominant Crop	Potatoes	Rice
Crop Biodiversity	Very High	Low (Hybrid)
Water Requirement	Low (255 m^3/Ton)	High (901 m^3/Ton)
Cropping Intensity	Low (1-Year)	High (2-3-Year)

Climate Warming: **Crop Diversification**

Higher Temperature, Less Frost, Longer Growing Season

More Efficient Irrigation, Water Harvesting

But More Variability

Constraints

Inherent biophysical conditions

Hazardous terrain
High hydrological variability
Steep slopes
Distinct dry season
Harsh climatic regime
Restricted growing season due to high elevation range
Difficult access due to geology, topography, and remoteness

Human Resource Issues

High population growth
High mobility
Gender Inequities
Market Access Problems
Lack of Opportunities to Improve Skills
Poor Governance and Support
High Workload & Few Options
Gender Equity & Cultural Taboos

Resources Management Issues

High variability in water availability and distribution
Limited fodder production
Forest resources under pressure
Range of crop production is limited
Low overall productivity
Biodiversity is declining
Difficulties to maintain soil quality

Common Concerns & Differences

Common General Issues	Himalayas	Andes
Low Bio-Productivity	Yes	Yes
Poor Infrastructure	Yes	Yes
Many Hazards	Yes	Yes
High Popul. Growth	Yes	Yes
Subsistance Agric.	Yes	Yes
Differences		
Geology	Sediment.	Volcanic
Climate	Monsoon	Arid
Direction of Mts.	E-W	N-S
Extremes	Wettest	Driest

Drinking Water Concerns & Differences

Common Drinking Water Issues	Himalayas	Andes
Insufficient Quantity	Yes	Yes
Poor Quality	Yes	Yes
Poor Regulation	Yes	Yes
Health Concerns	Yes	Yes
Many Water Conflicts	Many	Many
Differences		
High Workload	Women	Share
Running Water	No	Most
Ownership	Private	Common
Water Sources	Surface	Ground W

Irrigation Management Issues

Irrigation Water Manangement Issues	Himalayas	Andes
Inefficient (flood Irr.)	Yes	Yes
Conveyance losses	Yes	Yes
High Water Shortages	Yes	Yes
Up-Low Land Conflicts	Yes	Yes
Difficult Resolutions	Yes	Yes

Differences		
Irrigation Intensity	High	Low
Irrigation System	Traditional	Modern
Water Demand	Rice	Potatoes
Women Involvement	Low	High

Soil Management Issues

Soil Manangement Issues	Himalayas	Andes
Soil Acidity	Yes	Yes
Low Phosphorus	Yes	Yes
Low Soil Org. Carbon	Yes	Yes
Moderate Erosion	Yes	Yes
Low Micro-Nutrient	Yes	Yes

Differences		
Manure Use	High	Moderate
Stocking Density	Low	High
Depleted Base Cations	Yes	Adequate
Soil Type (Weathered)	Old (red)	Young

Livestock Management Issues

Livestock Manangement Issues	Himalayas	Andes
Low Productivity	Yes	Yes
Feed Shortages	Yes	Yes
High Workload Women	Yes	Yes
Limited Milk Production	Yes	Yes
Security, Low Profit	Yes	Yes
Differences		
Animal Mix	Low	High
Stocking Density	Low	High
Cash Control	Male	Women
Meat Consumption	Low	High

Food Management Issues

Food Security & Management Issues	Himalayas	Andes
Few Cash Crops	Yes	Yes
Variable Fertilizer Use	Yes	Yes
High Pesticides Use	Yes	Yes
Potatoes/Wheat/Maize	Yes	Yes
Low Crop Yields	Yes	Yes
Differences		
Cropping Intensity	High	Low
Unique Crops	Rice	Quinoa
Crop Bio-Diversity	Low	High
Amount Irrigated	High	Low

Grassland Concerns & Differences

Common Grassland Issues	Himalayas	Andes
Overgrazing	Yes	Yes
Low Productivity	Yes	Yes
Low Biodiversity	Yes	Yes
Seasonal Shortage	Yes	Yes
Low Nutritional Value	Yes	Yes
Differences		
Amount Available	Insuffient	Abundant
Mix if Animals	Limitied	Diverse
Free Grazing	Limitied	Open
Collection & Storage	Limitied	Some

Forestry Concerns & Differences

Common Forestry Issues	Himalayas	Andes
Little Firewood	Yes	Yes
Low Productivity	Yes	Yes
Declining Biodiversity	Yes	Yes
Seasonal Shortage	Yes	Yes
Community Managed	Yes	Yes
Differences		
Litter Collection	High.	Low
Fodder from Forest	High	Low
Dominant Species	Pine	Others
Amount of Forest	M-High	Low

Common Issues	Best Options
Livestock Production	Improve Fodder Supplies
Improved Dairy Production	Milk & Cheese Production (Cash)
Improved Irrigation	Sprinkler & Drip Irrigation
Water Harvesting	Low Cost storage Systems
Improved Drinking Water	Source Control & Protection
Water Equality	Water Reallocation, Rights
Health & Pesticide Use	IPM, Education, Extension
Value Added Crops & Markets	Processing, Handicraft, Quinoa
Improved Soil Management	Nutrient Analysis, Fertilizers INM
Soil Organic Matter Enrichment	Cover Crops, Carbon Sequestration
Forest Enhancement	Multi-Purpose Trees, N-Fixers
Population Pressure	Out-Migration, Family Planning

Use of Analytical Methods

- Health evaluation of pesticide impacts
- Water budgets & balances
- Manure / Nutrient management budget
- Soil fertility evaluation using nutrient budgets
- Gender and workload assessment
- Community based management
- Constraints and opportunities in millk production

Improving livelihoods

- Drinking water harvesting
- Trickle irrigation for offseason vegetables
- Improving pasture
- Community forests
- Fodder management
- Fodder tree rehabilitation
- Addressing water equity
- Production in rustic greenhouses (Peru)
- Production in rustic greenhouses (Bolivia)
- Community forest on degraded land

Conservation & rehabilitation

- Rehabilitation of degraded lands
- Soil conservation methods
- Erosion control in Aynokas
- Trashlines for preventing soil erosion
- Fruit trees and forests
- Reclamation of saline soils with kauchi
- Controlling erosion and producing biomass

What Did We Learn?

	Himalayas	Andes
Farmers	More Adaptive	More Traditional
Knowledge	High Yield Focus	Crop Biodiversity
Water Resources	Dry Season Scarcity, Up-Lowland Conflicts	
	Irrigation Focus	Limited Irrigation
Livestock	Limited Diversity	Divers Animals
Grazing	Restricted,Limited	Widespread
Climate Risk	Problematic in Both, Floods & Droughts