

Urbanization in Mountains

Expanding Cities

Population (Millions)	2018	2050	Elevation
La Paz, Bolivia	0.9	1.2	3700 m
Quito, Ecuador	1.8	2.8	3000 m
Bogota, Colombia	10.7	14.1	2640 m
Kathmandu, Nepal	1.4	3.0	1500 m

Expanding Mountain Tourism

Annual Visitors	2018	Elevation
Mt. Everest, Summit	800	8848 m
Everest Base Camp	35000	5364 m
Mont Blanc France	20000	4792 m
Alpine Regions	120 Millions	

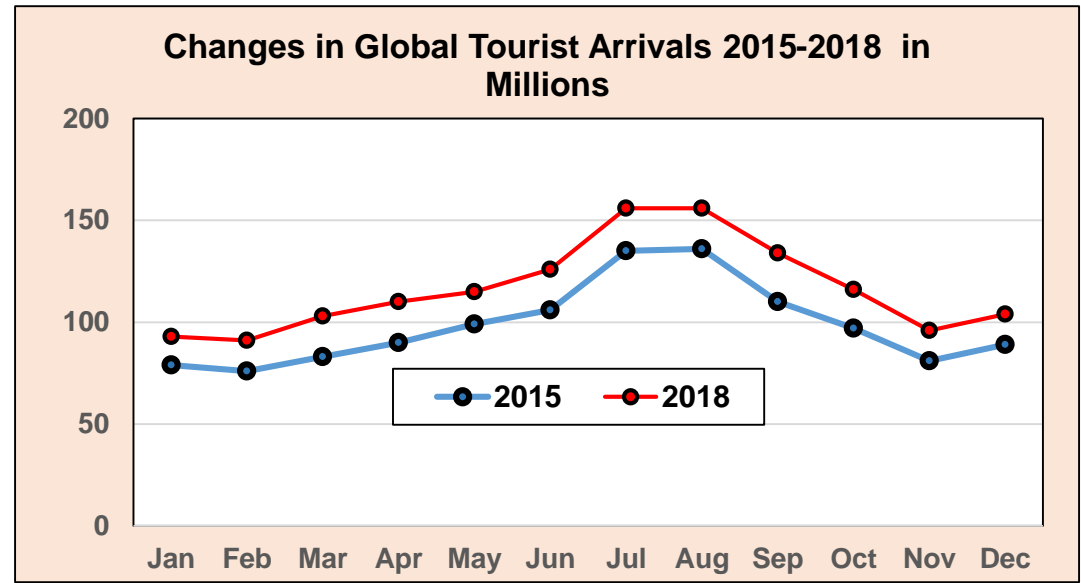


Global Tourism



2018 = 1.3 Billion Arrivals
(17% of Global Population)
Projected 2020 = 1.4 Billion
Projected 2030 = 1.8 Billion

Direct Expenditures = \$ 2.3 Trillion
10% of Global GDP



Data Source World Tourism Org. (UNWTO)

Mountain Tourism

15-20% of Global Tourism in Mountains

Global Mountain Tourism

**Employs 50 Million People
5700 Mountain Resorts
400 Million Skier Days
59000 km Skiable Slopes
23000 Skilifts & Gondolas**

Mt. Tourism in European Alps

**Employs 5 Million People
1500 Mountain Resorts
200 Million Skier Days
27000 km Skiable Slopes
9000 Skilifts & Gondolas**



Water & Recreation

Water Use for Golf Courses
Water Use for Snow Making
Reservoirs Water Table Problem

Impacts of Mountain Tourism on Water Resources

Tourist Activities

Impacts on Water Resources

Skiing

High Water Demand for Snow Making & Use of Chemicals, Litter, Sanitation Issues

Hiking

Water Pollution: Litter, Fecal Matter, Pathogens, Nutrients

Golfing

High Water Use, Excess Nutrients, Pesticides, Eutrophication

Mountain Biking

Dust, Sediments, Turbidity, Fecal Issues

Swimming

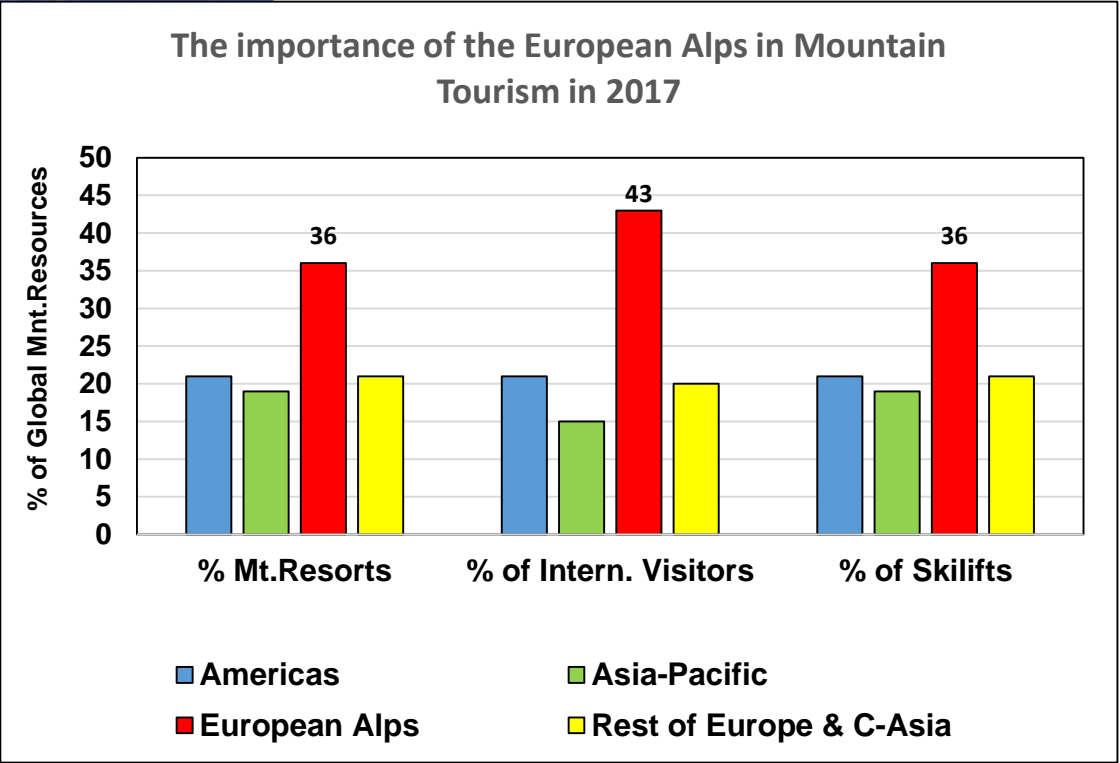
Nutrients, Pathogens, Chlorine





Chamonix, France

The Importance of the European Alps in Mountain Tourism



Mountain Landscape Changes by Tourism



Urbanizing Mountains



Snow Farming

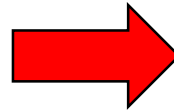


Economic Issues for Mountain Resorts

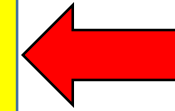
Requirements : 100-120 Days of Secure Skiing (Open at Christmas)
Viable Summer Tourism (Diversity of Activities)
Access, Scenery, Culture

Summer Activities

Hiking & Mt.Climbing
Mt. Biking, Swimming
Paragliding
Sightseeing, Golf



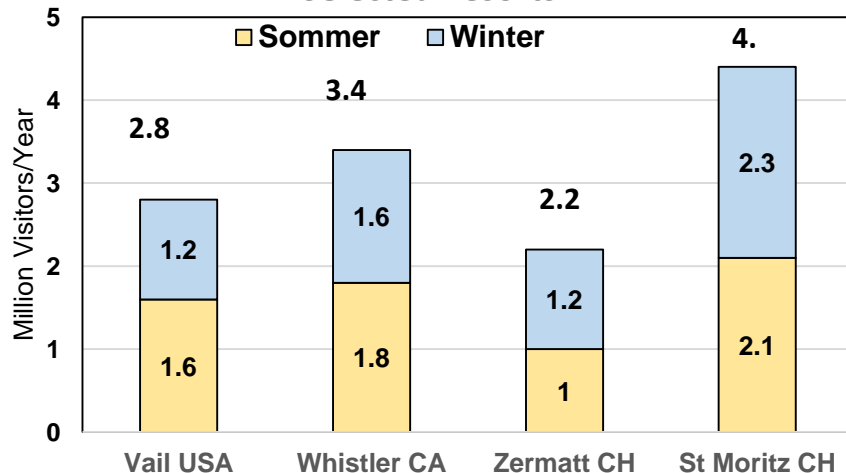
Conferences, Concerts, Festivals
Spas, Wellness, Health
Shopping, Culture, Entertainment



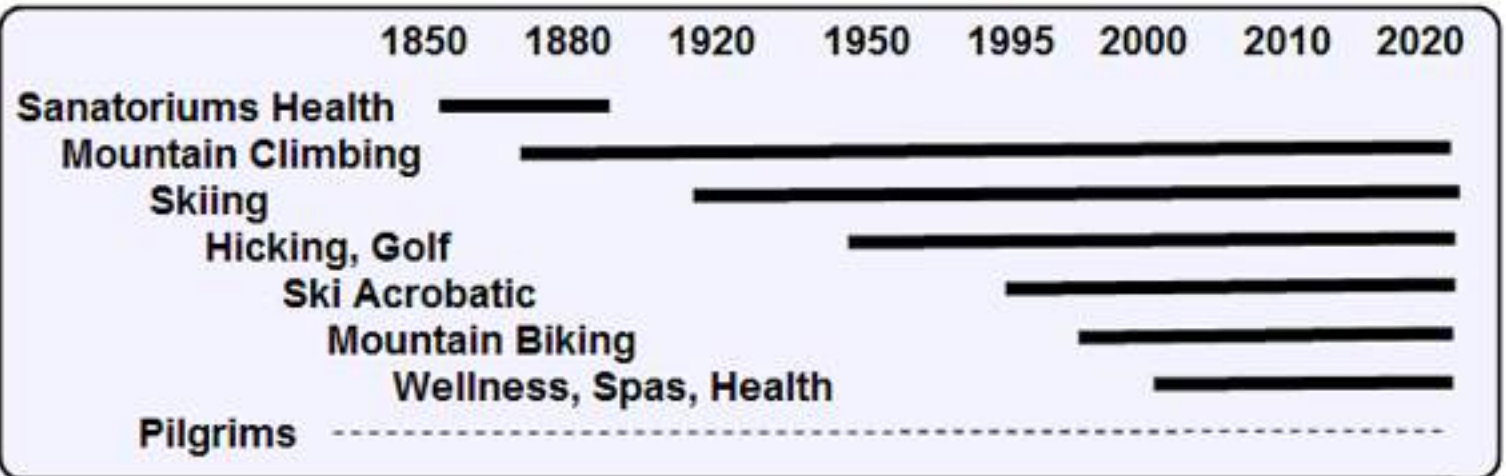
Winter Activities

Skiing (Various Types)
Snowboarding
Ice Skating
Sledding

Number of Summer & Winter Visitors/Year in Selected Resorts



History of Alpine Tourism



Protection for too much Snow



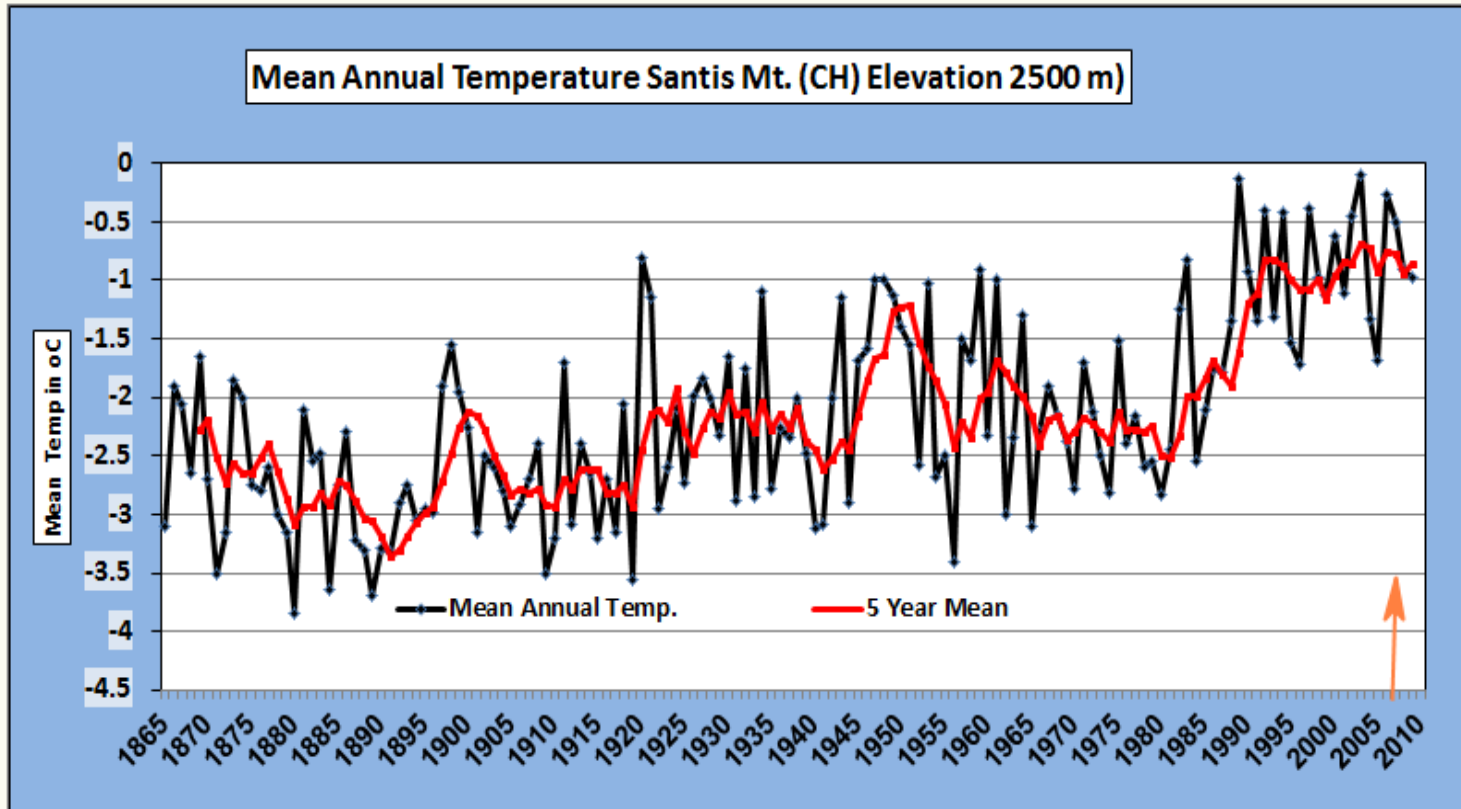
Protection for too little Snow



Mean Annual Temperature Increases at High Elevations

There are very few high elevation climate station with long term records

There is now enough information available to show that high mountains areas are warming up faster than many lowland stations.

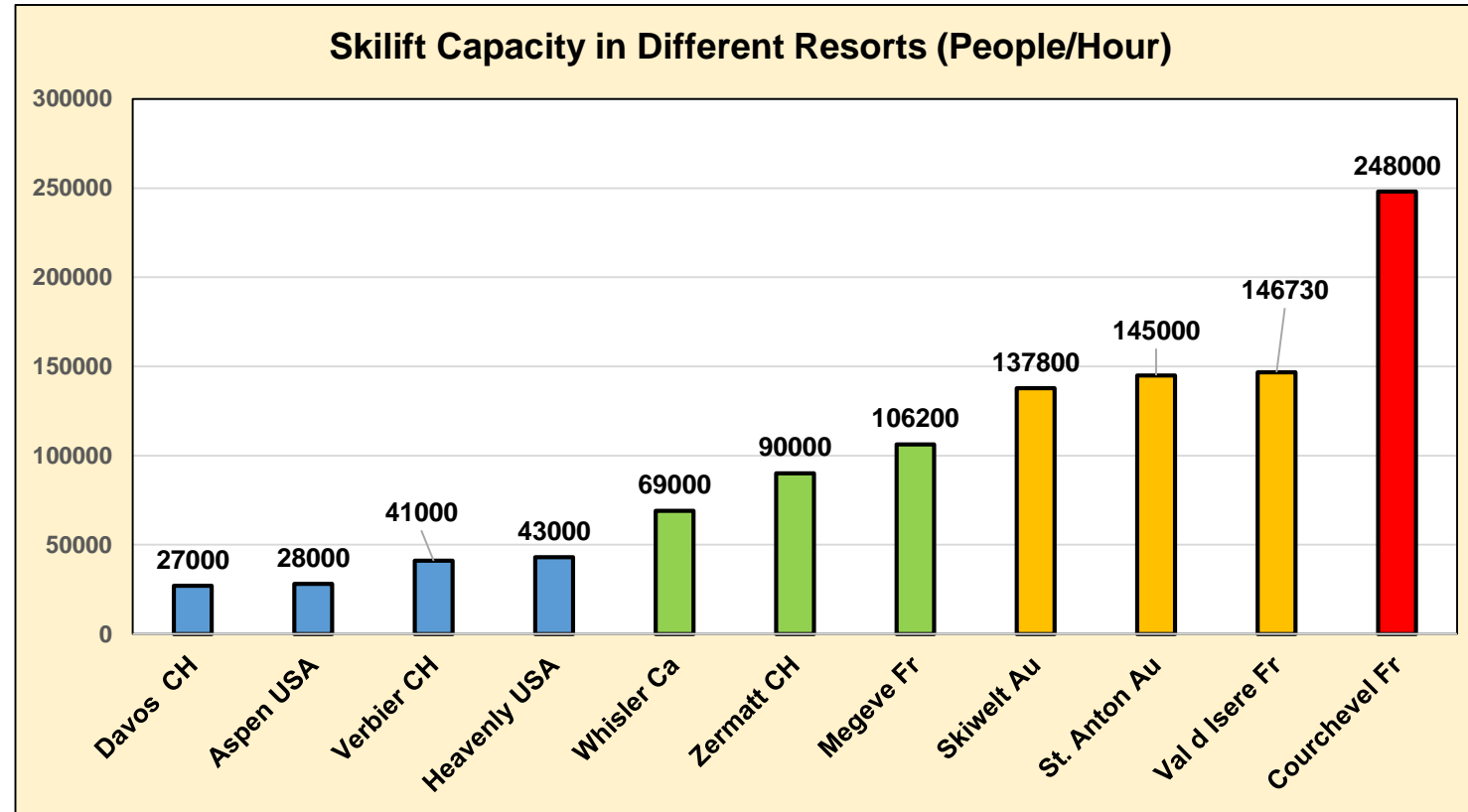


The Rate of Temperature Increases in the High Mountains Appears to be more Rapid than at Lower Elevation in the Northern Hemisphere

Data Source: Swiss Federal Department of Meteorology 2011

Mountain Infrastructure for Tourism, in Grindelwald, Switzerland

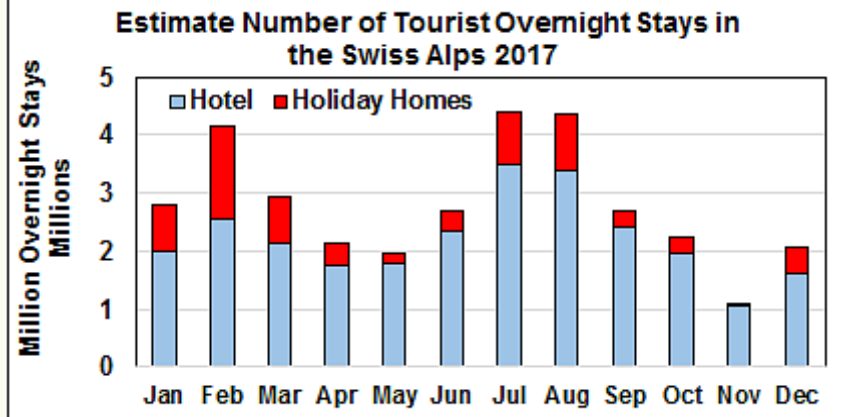




Tourism in Switzerland

Number of Ski Resorts : 150
Trails > 2800 m Elevation : 3400km
Mountains > 3000 m " : 208
Number of Lakes : 1500

Total Population : 8.5 Million
Tourist Arrivals : 21 Million (2018)
Tourist Employment : 175000
Total Overnight Stay: 38.8 Millions
(Swiss: 51%, Foreign: 49%)
Hotels: 4400, Hotel Beds: 250000



Total Number of Ski Resorts: 150
20% have 100-650 km of Ski Runs

Resorts	V-Elevation	No. Lifts	No.Runs	Length
Davos	1724 m	55	85	300 km
Verbier	2000 m	88	88	450 km
St Moritz	1373 m	24	89	163 km
Grindelwald	1900 m	66	50	213 km
Zermatt	2279 m	54	147	360 km

Number of Skier Days: 22 million

Trail Network

Hicking	12000 km
Cycling	12000 km
Mt. Biking	8000 km

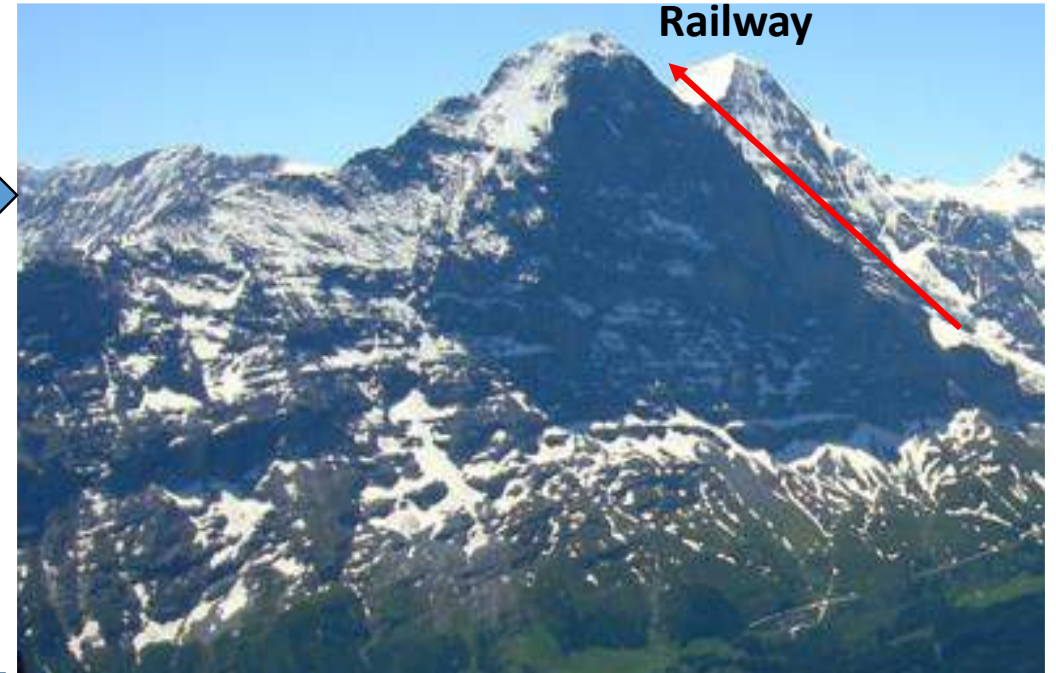
Total Trail Network: 65500 km
Paved Trail Network: 16298 km

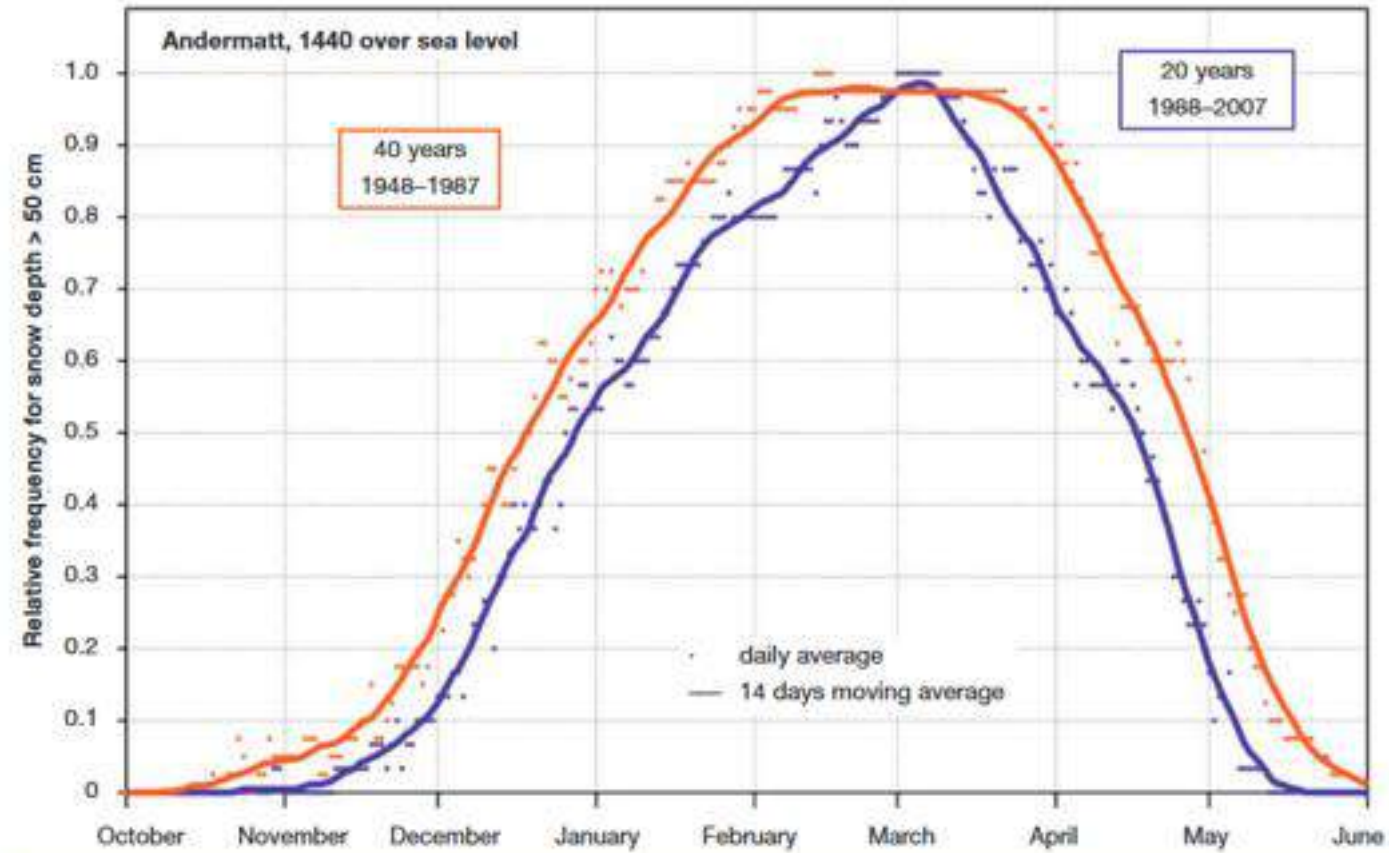
Distance Across Canada: 6000 km
Distance Across Russia : 9000 km



**2018 Number of Rail Passenger
To the Top of the Alps
Jungfrauoch – Aletsch Glacier
3350 m Elevation**

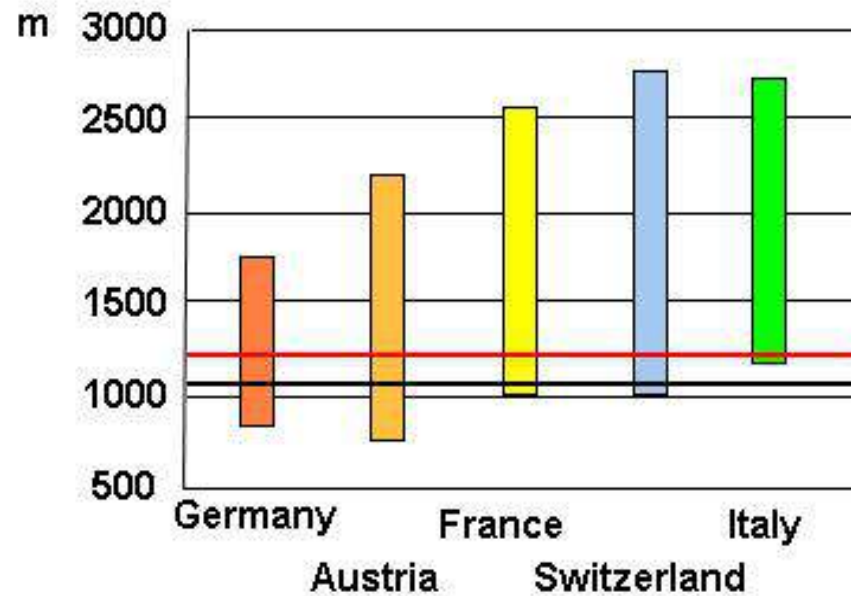
1.04 Million in 2017





Source: WSL-Institut für Schnee- und Lawinenforschung SLF.

Elevation Range of Ski Resorts in the European Alps



**Vulnerability to Temperature
Requires to go Higher & North Facing**

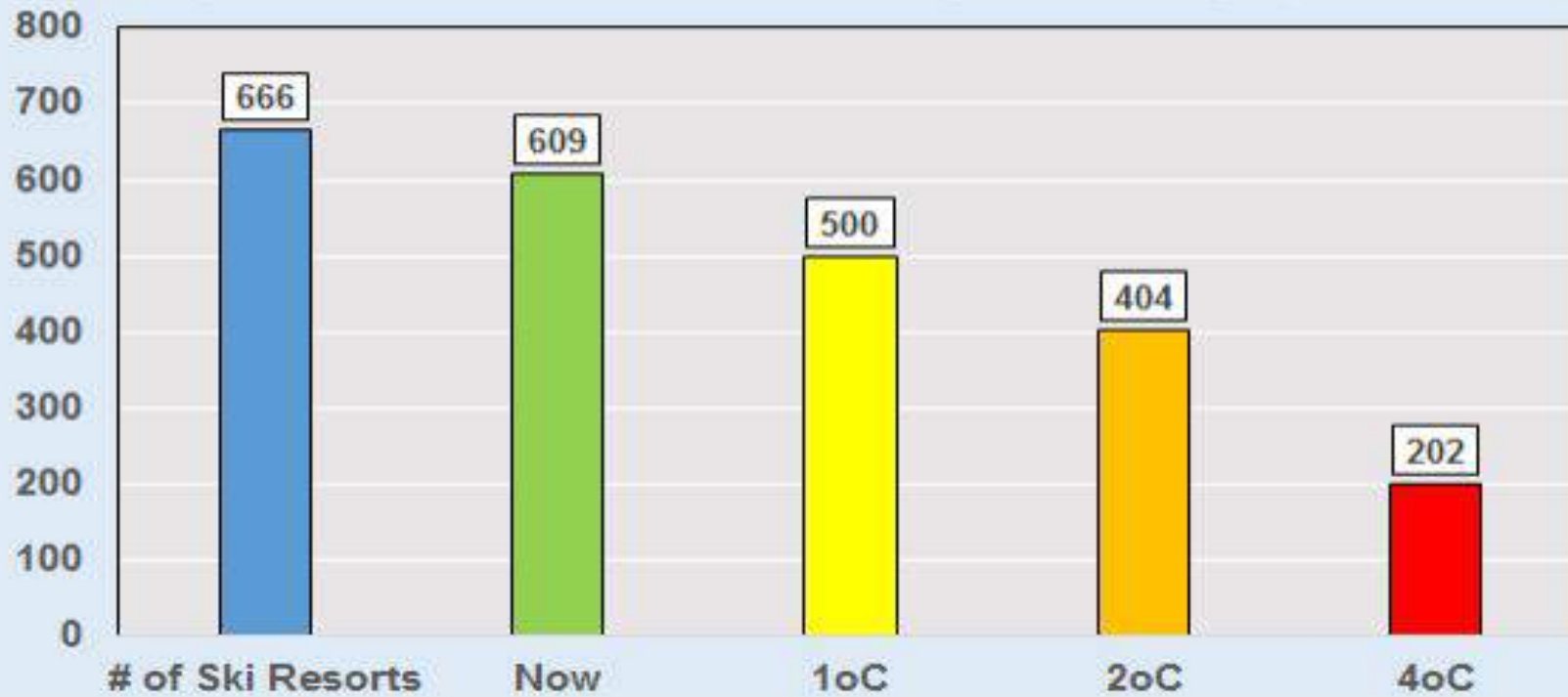
Current Reliable Snow Line = 1050 m
1°C Temperature Increase = 1200 m S
2°C Temperature Increase = 1350 m

Current Reliable Snow Line = 1200 m
1°C Temperature Increase = 1350 m N
2°C Temperature Increase = 1600 m

For every 1°C increase it is estimated
that the permanent Snow Level will
move up in elevation by about by 150 m



Decline in Snow Reliable Ski Resorts in the European Alps with increases in Global Temperatures by 1, 2 & 4°C





Schneesicher? Aber sicher!

Neue Beschneiungsanlage ab Winter 07/08
auf allen Pisten.



Rosswald
Die Sonnenterrasse

Rosswald Bahnen - www.rosswald-bahnen.ch / info@rosswald.ch



Snow Making

```
graph TD; A[Snow Making] --> B[Water Requirements]; A --> C[Energy Requirements]; B --> D["2000-4000 m³ / ha (30cm)  
~ 0.5 m³ / 1m³ of Snow"]; D --> E["Snow Making Guns  
Cost: $ 6000-30000.-  
Water Use/Gun : ~ 11m³/hr  
Operating time : ~ 120 hrs  
Air Temp. < - 4°C & Humidity  
10-40% Loss (Subl. Evapo.)  
Equal to Irrigates Agric.  
3000 - 4000 m³/ha of Corn"]; C --> F["1050-1350 kWh / ha (30cm)  
3.5-4.5 kWh / 1m³ Snow"]; F --> G["Wide Range of kWh  
Depending on Type of Gun,  
Air Temp. and Humidity  
1 - 14 kWh / 1m³ of Snow  
13-40% of Energy Use in  
Resorts (highly Variable)"];
```

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Resorts (highly Variable)



Major Ski Resort in the USA

117 Major Ski Resort > 1220 m Elev.

70% Make Snow

Area of Snow Making : 1 -1370 ha

**15 Largest Resorts: 243-1370 ha Snow Making
Use 22 Million m³ of Water**

= Domestic Water Use By 110000 People

Use 2.9-16.3 Million kWh of Electricity

**= Energy Consumption: 290-1630 Households
Equivalent to 13-40% of Resorts Energy Use**

Major Ski Resort in Europe

115 Major Swiss Ski Resorts (35% Make Snow)

254 Major Resorts Austria (70% Make Snow)

349 Major Resorts Italy (~ 80% Make Snow)

325 Major Resorts France (60% Make Snow)



Constructed Water Storage for Snow- Making in the Italian Alps



Snow Fences



Snow Making



Snow Farming

Make Snow in Winter
Preserve it over Summer
Cover it with Sawdust or Plastic
Provide Snow Base for Christmas



Additives for Snow Making:

Ammonium nitrate,

KCl improves quality, hardens snow

CO₂ or liquid N, Ag (LC50),

Keolinite (enhances crystal formation)

Bacteria *Pseudomonas syringae*

(protein that catalyses ice formation)

Water Sources In Switzerland:

For snow making:

34% Rivers, 30% drinking water,

21% Springs, 15% Lakes

Snow Preservation over Summer

Courchevel France

20000 m³ of Snow

Covered with Insulating Plastic

Davos, Switzerland

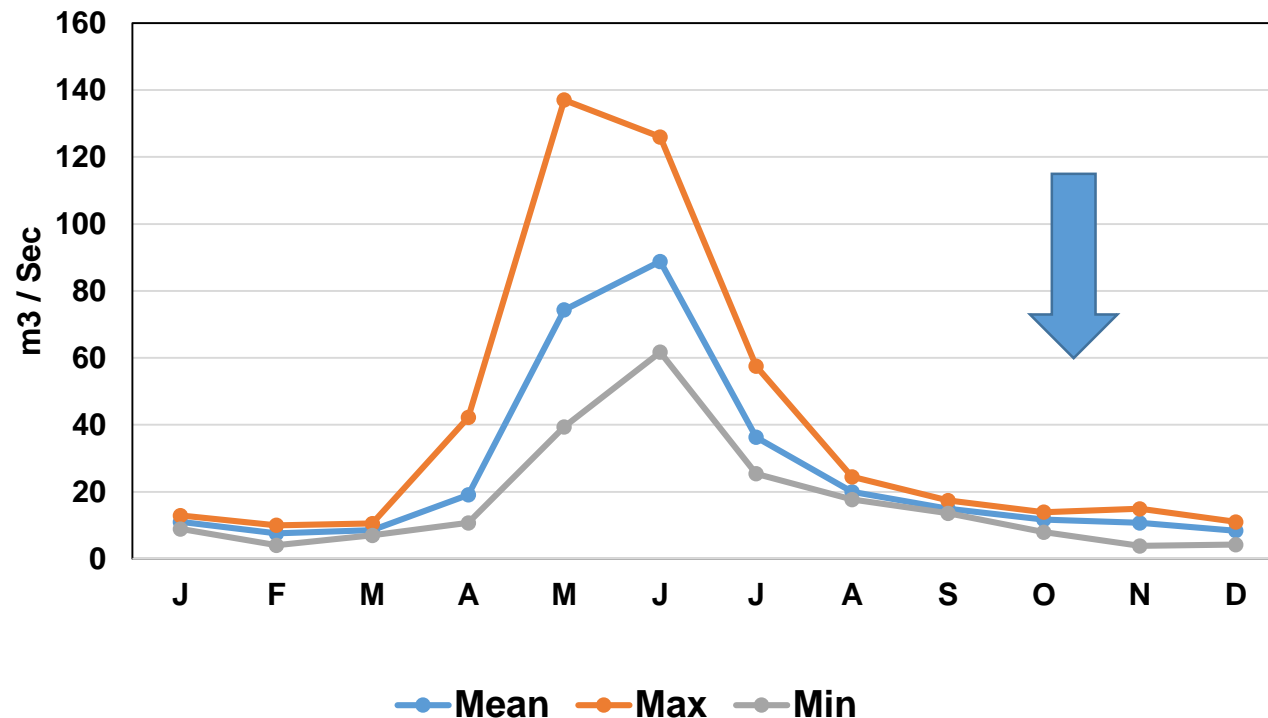
20000 m³ of Snow

Covered with 40 cm Sawdust



Problems when Using River Water for Snow Making

**Discharge at Elk Creek near Fernie
Mean Monthly Discharge 1925-2006**

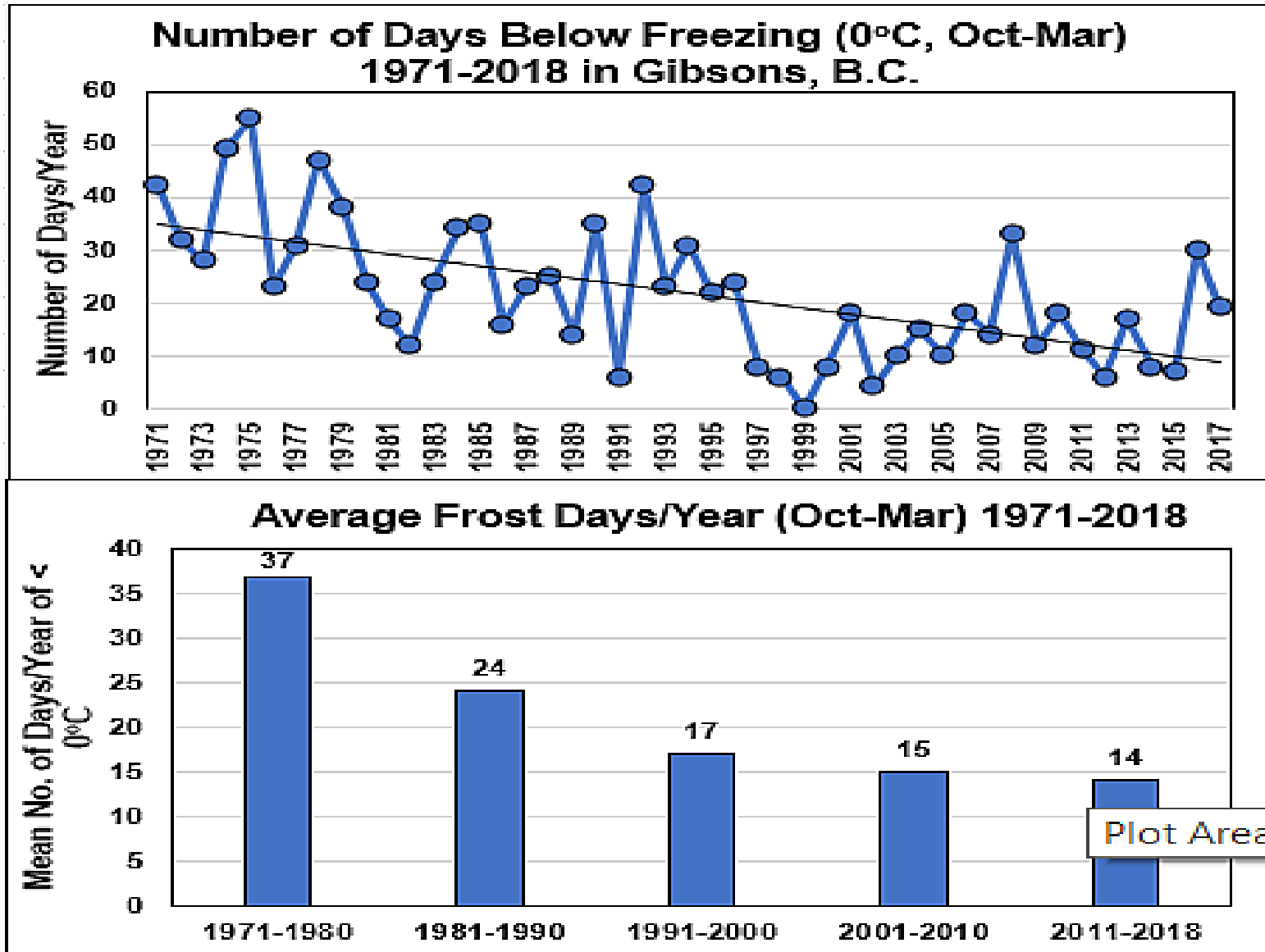


**Water Requirement
Timing for Snow Making**

**October- November
When Stream Discharges
are very Low**

**Impacts on
Environmental Services**

Winter Temperature Fluctuation Affecting Snow Security



Snow Farming Impacts on Water Resources

Impacts

Reasons

Water Demand

**Snow Making & Storage
Hydropower**

Pollution (NPS)

**Adatives to Snow Making
Soil Erosion -Turbidity**

Green House Gases

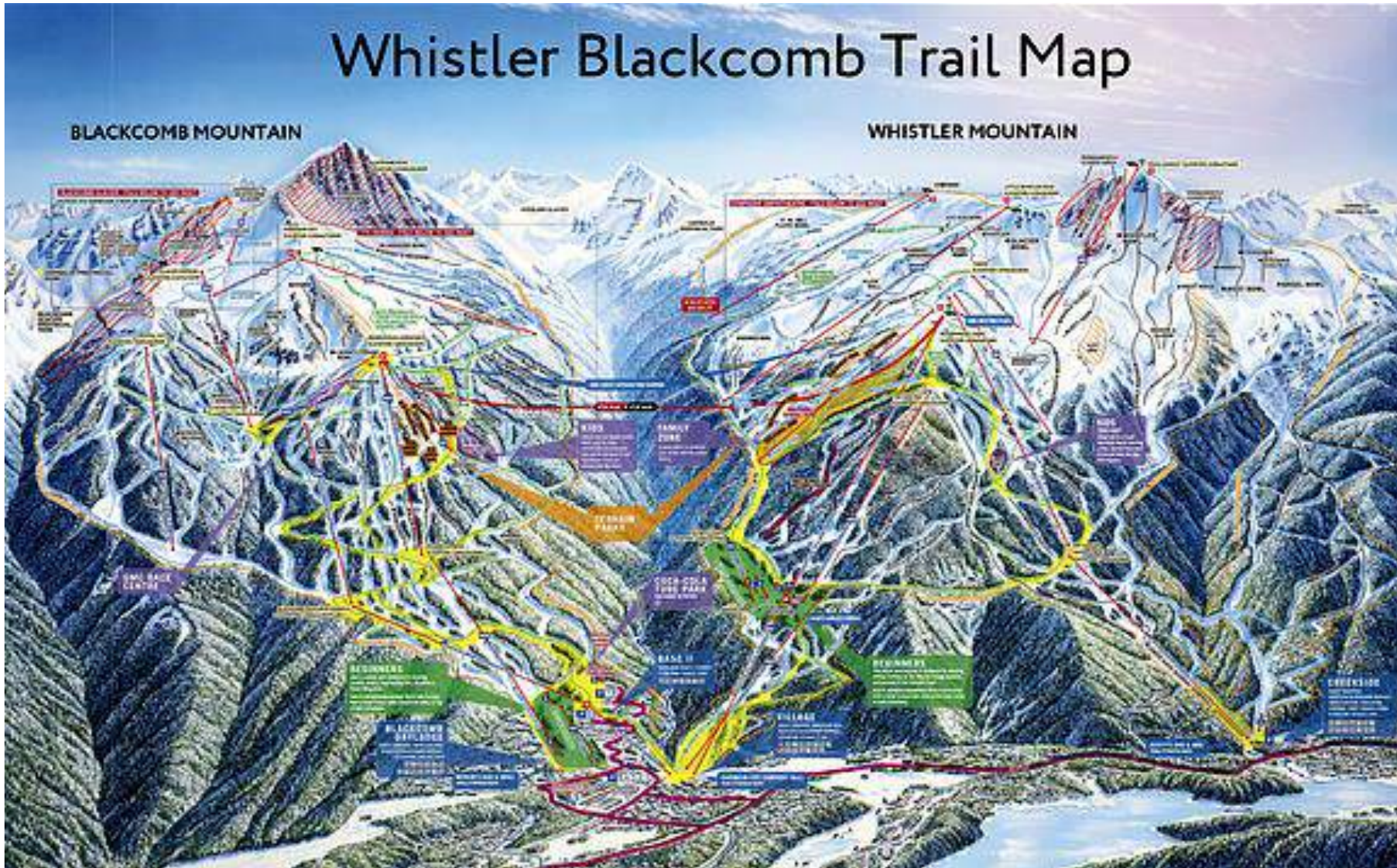
**Increased Energy Use
For Snow Making & Pumping**

Hydrological Cycle

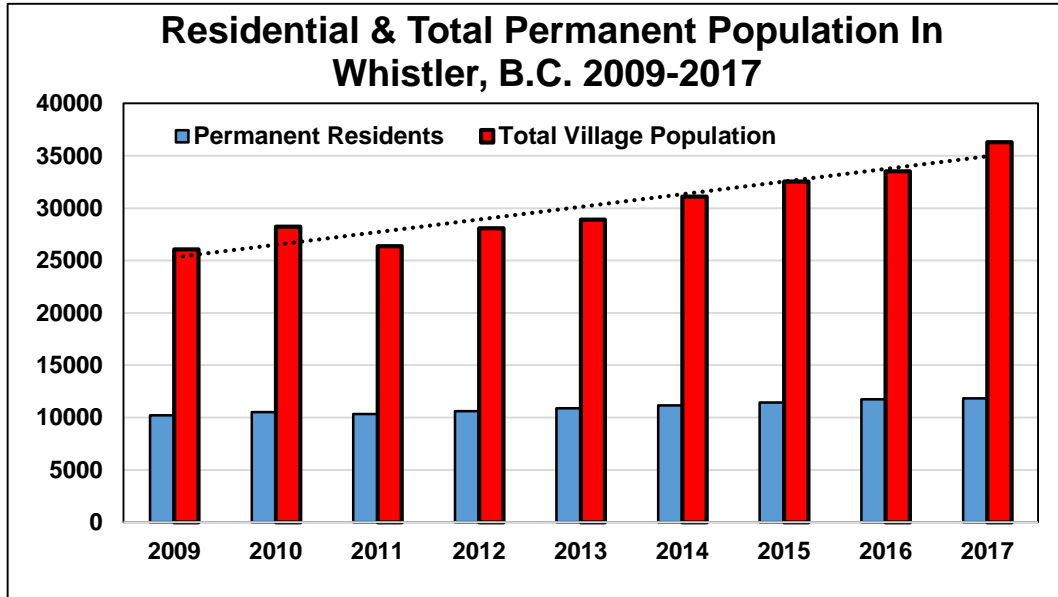
**River Water Extraction
during Low Flow Period
Impacts Environmental Services**



Case Study: Whistler Resorts, B.C. Canada







**In 2018
35000
Residents**



**3.5 Million
Visitors**

**Ratio
1:100**

Whistler at a Glance:

**150 Hotels (30000 Beds/Days)
Other Accommodations 10000 Beds
200 Restaurants & Bars
200 Shops**

**37 Ski Lifts & Gondolas
Lift Capacity 70000 People/ Hour**

**200 Ski Runs (50 km)
1600 m Vertical Drop
36 Snow Making Guns**

**4 Golf Courses (23500 Golf Rounds)
250 km of Mt. Biking Trails**

**Winter Visitors 45%
Summer Visitors 55%**

Green Initiatives are Essential to Attract Tourists in Many Mountain Resorts

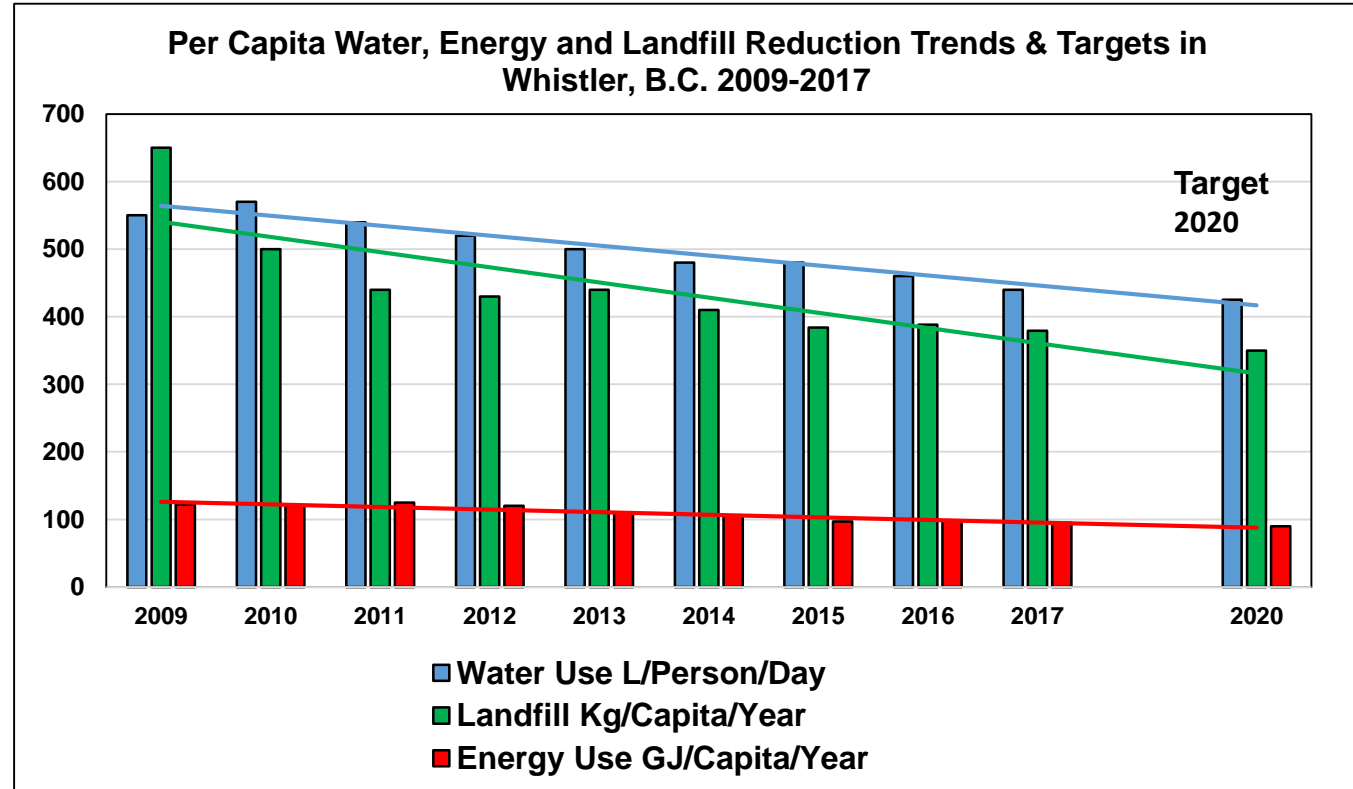
Whistler in Canada Hosted the 2010 Winter Olympics

Before the Olympics Whistler Set Environmental Targets to be Reached 2020 :

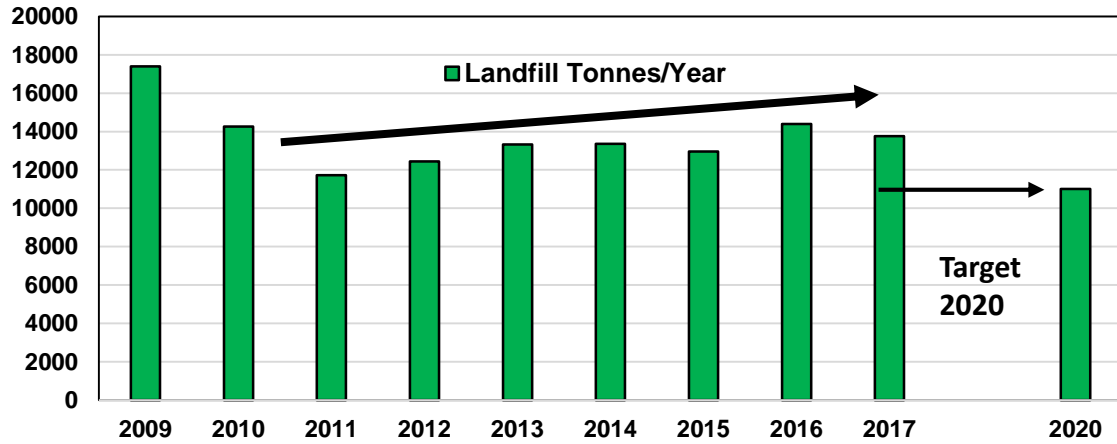
Reduction in Water & Energy Consumption

Reduction in Landfill Deposition

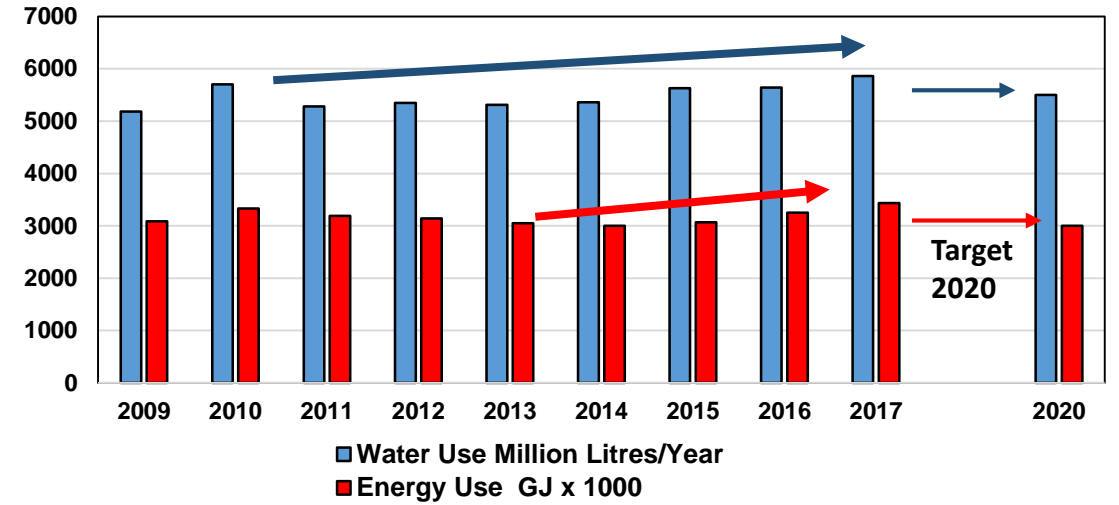
Reductions in Total CO₂ (equ.) Emissions



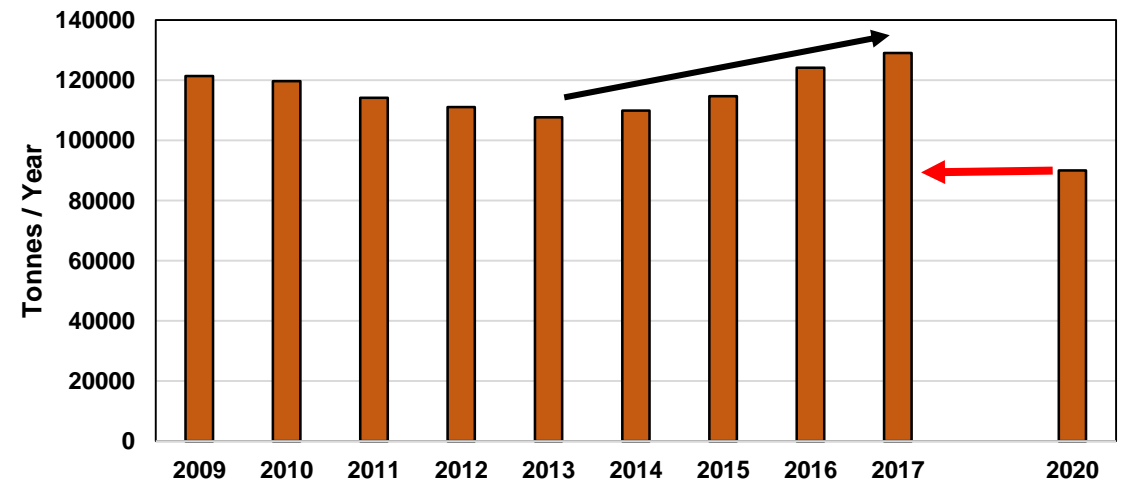
Total Landfill Production Trends vs. Target in Whistler, B.C.



Total Water & Energy Use and Targets in Whistler, B.C.



Total CO2 equ. Emissions in Whistler, B.C.



Glacier in the Headwaters of Whistler



New Experiment in Whistler

**4 Snow Guns to make
Snow on Glacier in Winter**

**Trying to Compensate for
Glacial Melt in the Summer**

Question: Economic Viability

Summer Tourism in Mountains

Mountain Biking in the Columbia Basin, B.C.

Mountain Resorts	Number of Biking Trails	Length of Biking Trails
Kimberley/Cranbrook	148	253 km
Fernie	241	151 km
Golden	122	167 km
Revelstoke	111	123 km
Nelson	164	133 km
Rossland	141	145 km

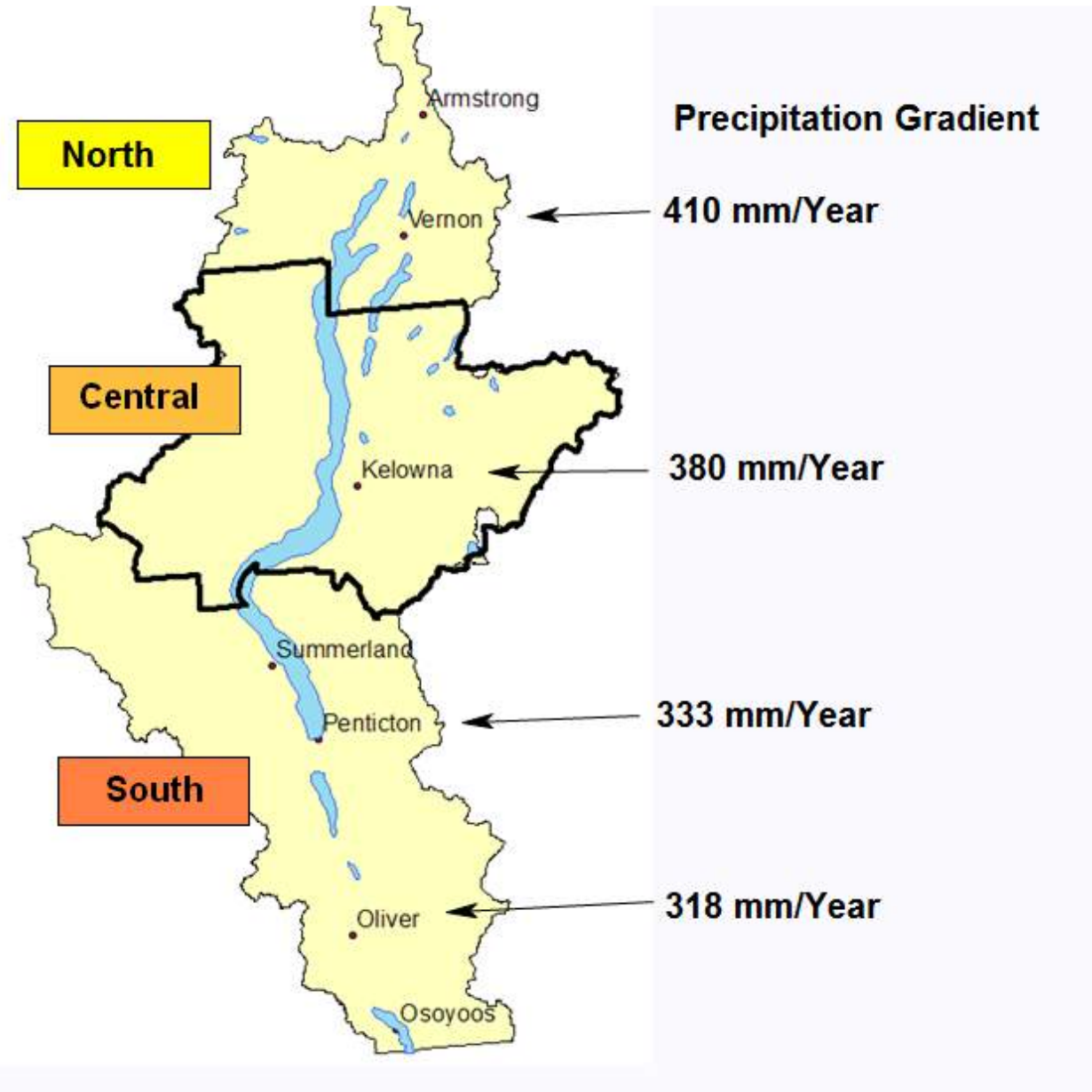


Photo: Luc Anderson

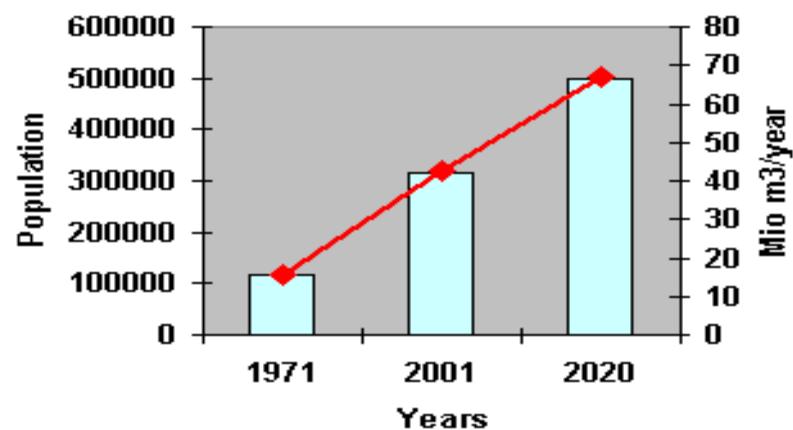


The Okanagan Watershed Project

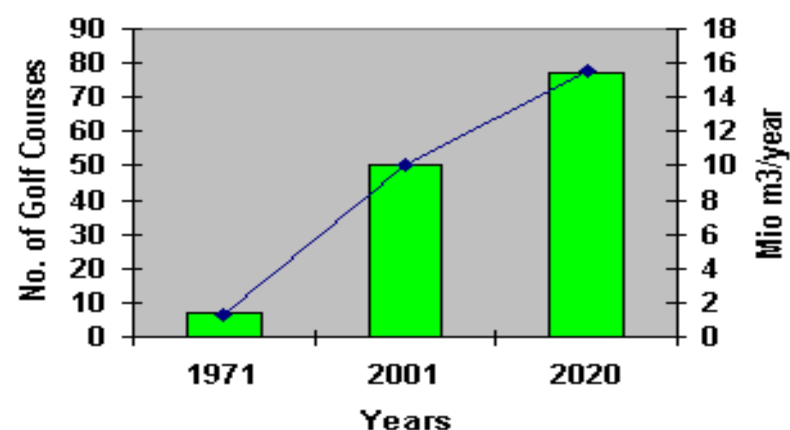
The Driest
Watershed in
Canada



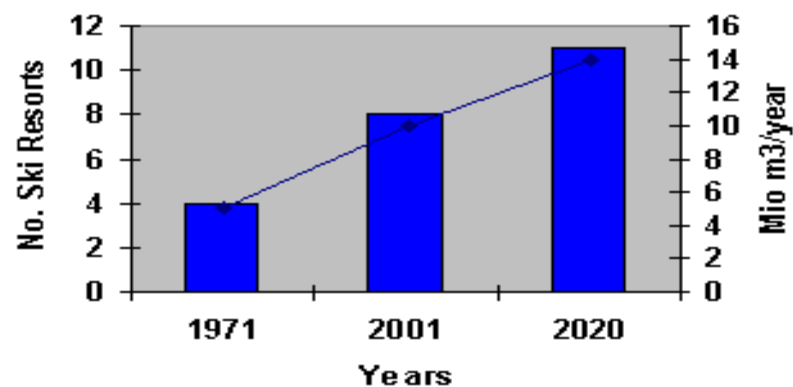
Population and Domestic Water Use



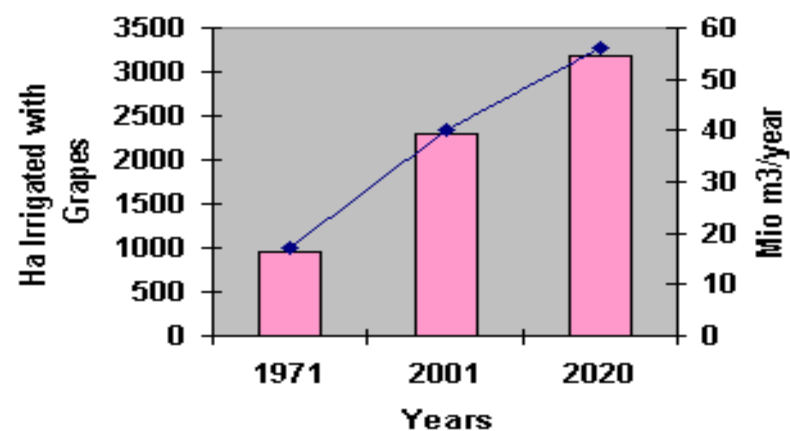
Golf Courses & Water Use



Water Lost by Snow Making (Sublimation)



Water Use for Wine Production



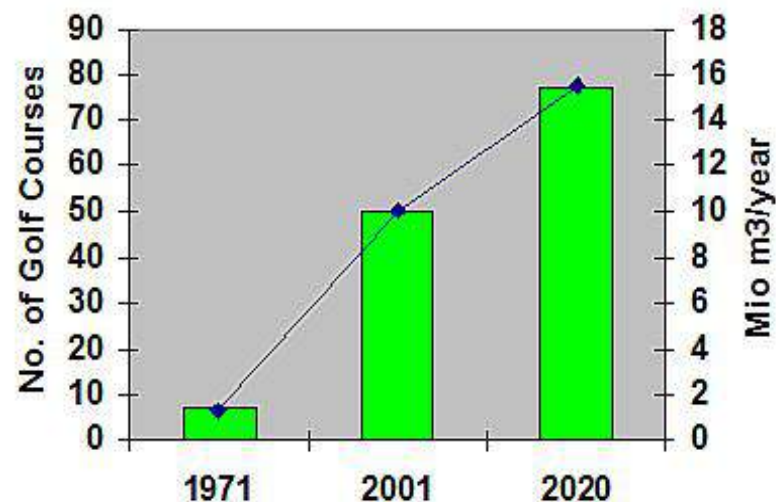
MAJOR CHANGES IN LAND USE ACTIVITIES 1971-2010 in OKANAGAN BASIN

Growth Indicators	1971	2010	% Increase
Population	115'000	350'000	175%
Golf Courses	7	50	600 %
Ski Resorts	4	8	100 %
Water Storage Systems	81	147	81%

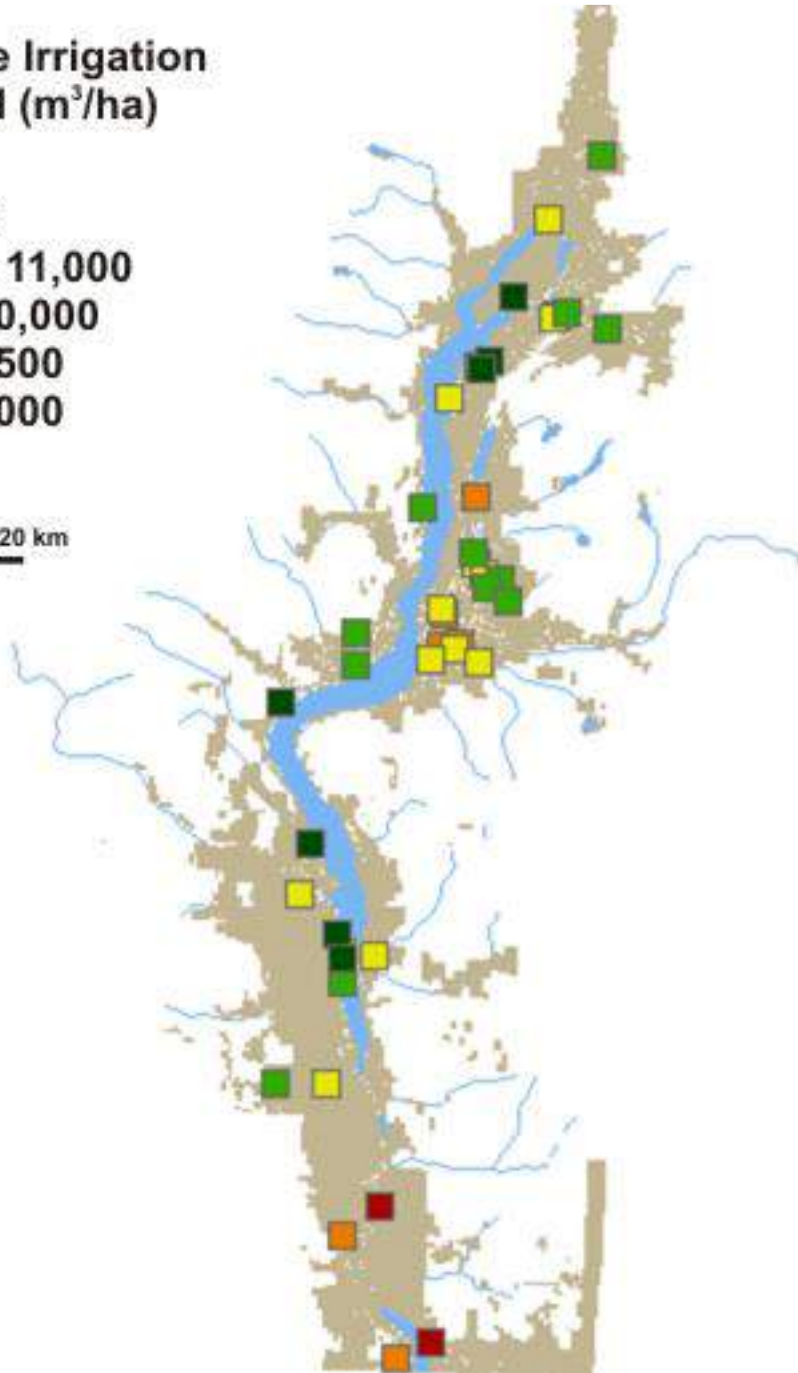
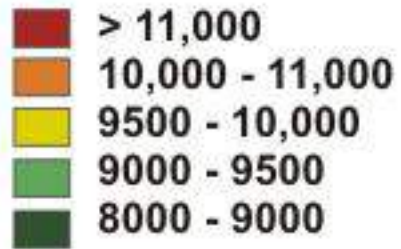
Average Golf Course Water Consumption in the Okanagan: 9000 m³/ha



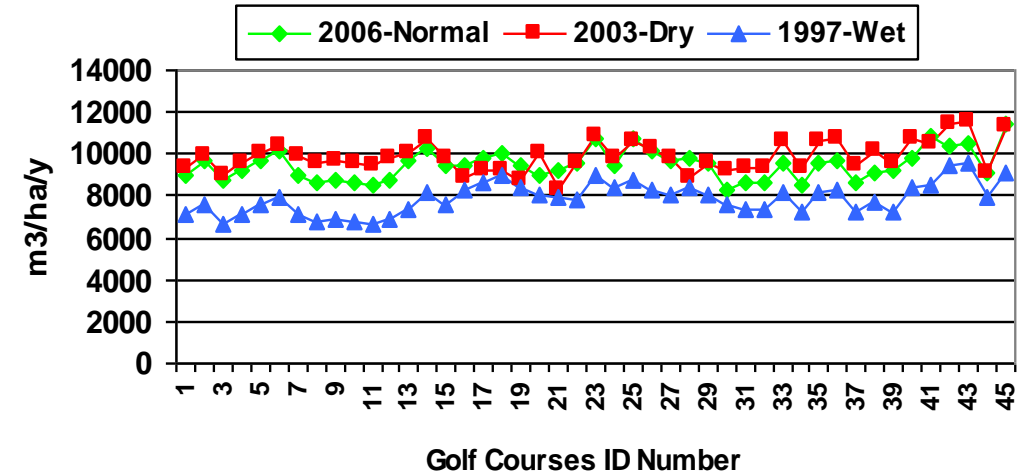
Golf Courses & Water Use



2006 Golf Course Irrigation Water Demand (m³/ha)



Wet v. Dry vs. Normal Year Irrigation Water Demand for Golf Courses (m³/ha/y)



Average Golf Course Water Use In the Okanagan Watershed

9700 m³/ha (20-40% over irrigated)-
Difference: Wet & Dry Years: 29%-38%

Average Water Use for Crops: 6100 m³/ha

Glacier National Park, Montana

Created 1910

Size 400 km²

Lakes 763

GLACIERS IN 1910 = 125

GLACIERS IN 2010 = 25

Total Visitors since 1910

100 Million in 2015

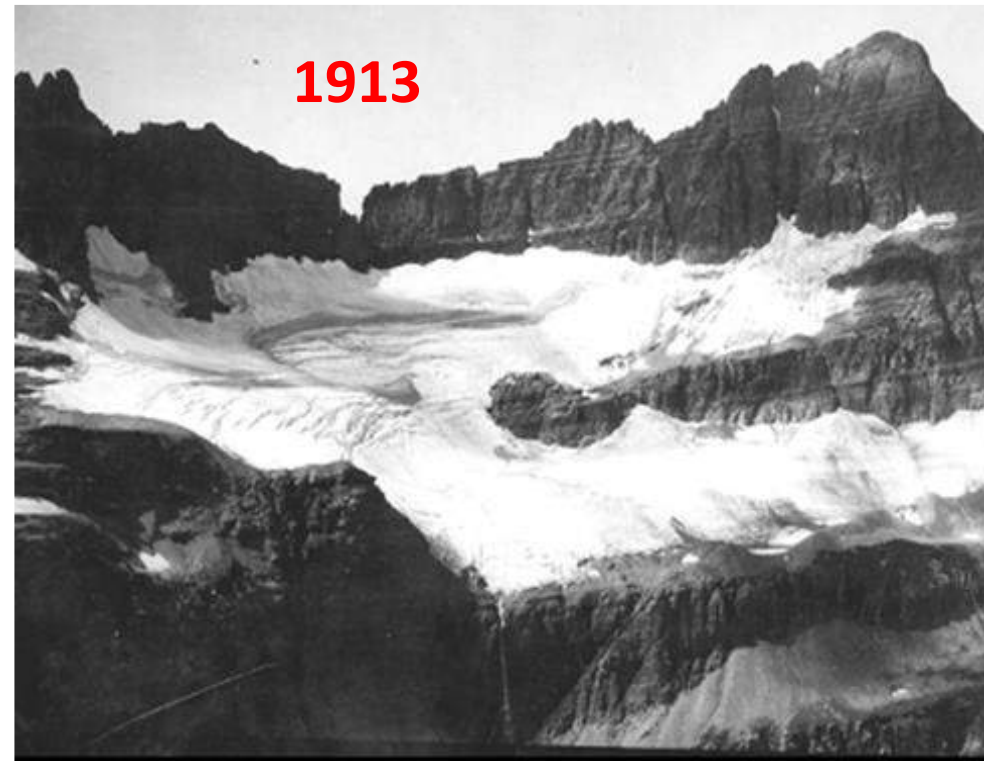
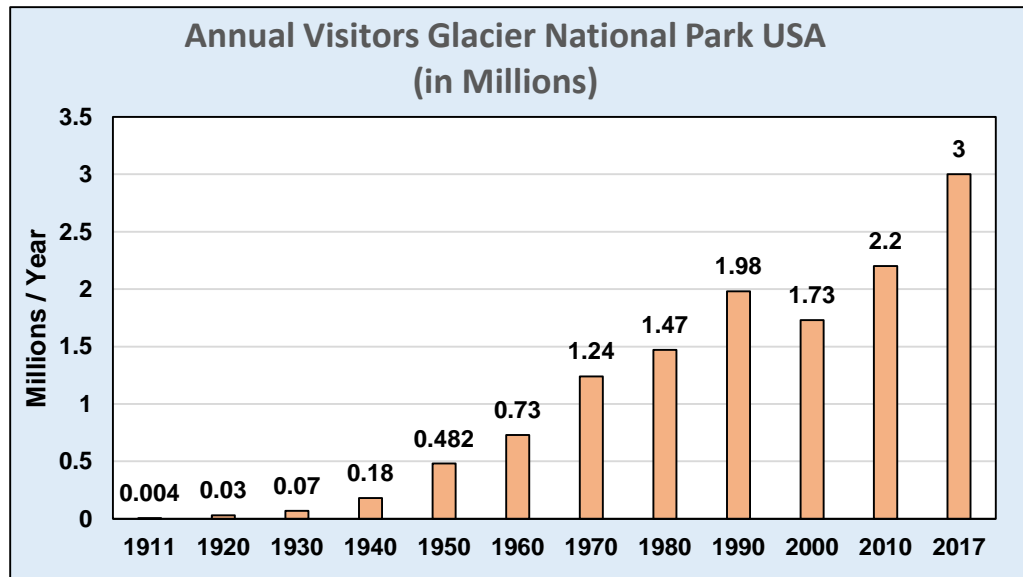


Photo
W. Alden
USGS



Photo B.
Reardon
USGS

Dan Fagre
USGS/USFS
2006 With
Permission

- **Visit Glacier National Park Before the Glaciers Melt Away!**

travelingteichs.com

Glacier National Park, located in Montana, is one of those parks in the US that you should definitely visit, and you should visit VERY SOON! Due to climate change these glaciers are rapidly melting and will most likely completely disappear by 2030.

They will need to change the Name of the Park !





Mount Blanc

**Highest Peak
in the Alps**

Elevation 4810 m



**Around 30000 people attempt the Peak/Year
Average 400/day
Around 60% get sick & fail to reach the peak
Around 100 rescues/year by Helicopter
500 kg/Week of Trash removed by Helicopter**

**1-16 death/year
More Dangerous Climb due to Climate
Warming Glacial Melt & Permafrost**

**In 2018 Set Limits of 214/Day
because of Overcrowding**

Ski Resorts	Skiable Area (ha)	Number of Runs	Lift Capacity People/hr
Kimberly/Cranbrook	729	68	6500
Fernie	1012	142	14290
Golden, Kiking	1133	120	8500
Revelstoke	1262	69	6000
Nelson, Pouder Mt.	958	81	4500
Rossland, Red Mt.	1699	110	7500
Invermere Panorama	1152	125	8500

