

INTRODUCTION

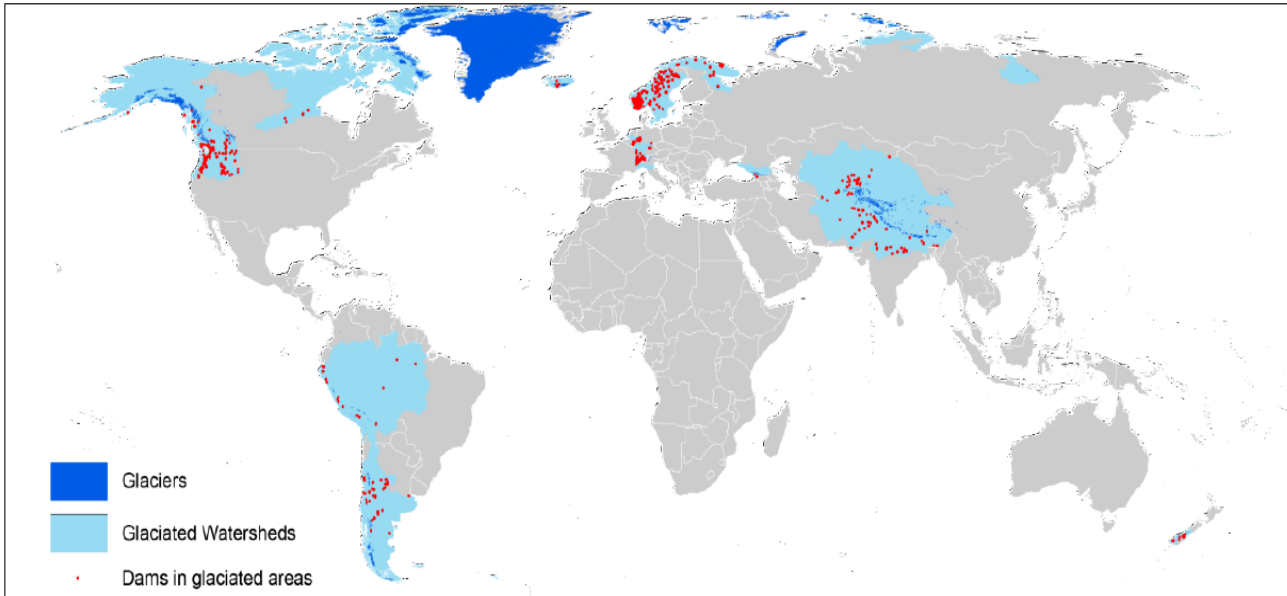


Figure 15: Glaciated watersheds of the world. This map uses components of the USGS HYDRO1k Pfafstetter watershed delineation system to represent the drainages of the world that contain glaciers. Dams located within those glaciated drainages are also shown. Data: GRand Dam Database 2011, USGS HYDRO1k 2011.

Figure 1 - Glaciated areas (Blackshear et al., 2011)

As we all learned this semester, approximately 70 percent of the earth's surface is covered in water (Thorsteinson, 2012). From this total, oceans take up to 98%. The remaining percentage of water left, 1,6 %, is locked up in snow, ice and glaciers. 1,6 % may not seem much, but considering humanity's dependence on water for survival, let's just say that it's well worth looking into, especially that glaciers are found in every continent in the world (NSIDC, 2012). Many of these glaciers feed off river systems that are used by many communities. Some parts of the world harness its power and generate hydroelectricity out of it. Others use it directly as a potable water source for irrigation and drinking. Whatever its use, water is primordial for humanity. This research focuses on how humanity uses the stored water locked up in glaciers as a utility resource. Firstly, we will discuss storage capacity, runoff modelling and sediment transport. This general discussion aims to inform on how we can theoretically analyse glacier and determine its water output capacity and issues. We will then discuss the different impacts on society, environment and economy. Different worldwide examples will be given to support our findings.

Glaciers, like mentioned earlier, hold a large part of the world's fresh water. This storage and the release of its content are important. Storage is defined in a glacier on many levels. As precipitations occur, glaciers tend to delay runoff by preventing direct runoff. At the same time glaciers are

themselves a source of storage as they are composed of frozen water that will thaw depending on different climatological factors. Therefore a single time-scale that takes into account storage for a glacier is unthinkable. Water can be stored in many ways as it has two main storage phases, solid and liquid. Hence, it can be stored in crevasses, snow, firn, basal sediments and even subglacial drainage networks. This diversity of storage means leads us to define three major time-scales. Each defined storage time-scale influences water output differently: long-, intermediate- and short-term represent respectively each time-scale that will be discussed (Jansson, Hock and Schneider, 2002).

LONG-TERM STORAGE

As the name states, long-term storage is defined on a time-scale that spans from years to millenniums (Jansson, Hock and Schneider, 2002). The important measuring factor is the glacier mass balance. As we have seen in class, mass balance is the sum of the glacier accumulation and ablation (Thorsteinsson, 2012). It defines if the glacier growing or shrinking. These calculations enable us to monitor the quantity of stored water in the glacier.

$$b = c - a$$

Where c = accumulation, a = ablation and b = balance.

Effects

Long-term storage is mainly affected by climate. During glacier growth, less water is generated, and the opposite happens during glacier shrinkage (Jansson, Hock and Schneider, 2002). One thing is certain, even at small levels of glaciation, there is an impact on catchment hydrology. In larger catchments, mainly dominated by rain-water runoff, glacier runoff tends to compensate for low precipitation, mainly in summer, when the climate becomes drier. For example, in a well studied basin, a 2% yearly contribution was calculated. This contribution grew to 13% in a lower flow year and for the driest months, it accounted for 54% (Jansson, Hock and Schneider, 2002). This tampon effect is important because it enables the river systems to be continually fed even in drier periods. Because of the climate changes and the disappearance of glaciers, this regulatory effect would be a great loss. Figure XX shows just how negative glacier net balance would impact runoff.

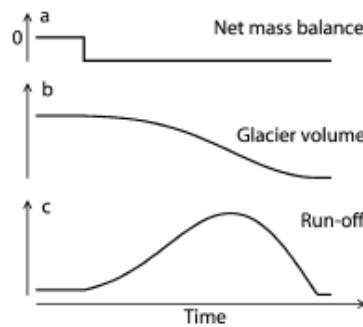


Figure 2 – Long-term effect of negative mass balance on glacier

(Jansson, Hock and Schneider, 2002)

INTERMEDIATE-TERM STORAGE

Seasonal variability drives this mid level time-scale storage. Summer is the main season where water is released and winter, on the opposite, is when most precipitations are stored. Hence, most glacier runoffs are concentrated in the warmest months. Even if most of the glacier discharge occurs during summer, many studies note that there is still some present in the winter (Jansson, Hock and Schneider, 2002). Other means of storage generate this discharge. In fact, winter release come mainly from firn storage and basal water systems.

Firn storage

The firn layer is made up of two distinct parts: the unsaturated layer and the saturated one. Firn storage happens when melt water and rain water percolate through the firn surface to reach the unsaturated firn layer. Because the firn layer is sitting right on the impervious ice layer an aquifer forms itself. As for the saturated firn, only 40% of the pore space can be used to store water. The remaining 60% is occupied by isolated air-filled pores (Fountain, 1989). Depending on the location, firn storage can account from 12% (Tangborn et al, 1975) to 44% (Schneider, 2000) of the total water storage of a glacier. Another process of water storage happens through capillarity of the firn layer. The water, stuck in the unsaturated layer re-freezes as the cold temperature reaches the layer (Jansson, Hock and Schneider, 2002). This internal accumulation is important, not only for intermediate storage but also long-term storage as it influences the whole glacier mass balance. The firn storage greatly impacts the runoff delay not just the way it was described but also because percolating water may hit parallel ice lenses diverting the water from reaching the basal water drainage system.

Subglacial storage

Channels and cavity beneath the glacier can also store a large quantity of water. The surface of some glacier may even rise at the start of the melt season because of the uplift cause by water pressures developing underneath the glacier (Jansson, Hock and Schneider, 2002). This subglacial storage area is mainly caused by the ground formation and quality. The firn storage is one of the main sources of water for this area.

Effects

Firn storage and subglacial storage are two very important form of intermediate storage. Its major impact is on runoff delay (Jansson, Hock and Schneider, 2002). This delay varying from weeks to months create a gap in response in the glacier fed water systems. This means that the water retaining structures need to be properly design and take this into account. This is very important as water retaining structures are design to withstand a certain level of risk. If we do not correlate properly maximum glacier discharge and maximum precipitation discharge we might over-design our structure or in a worst case, under-design it.

SHORT-TERM STORAGE

Diurnal variations are a well known phenomenon (Lang, 1967). Since radiation occurs during day time, the melt water gradually increases during this period to slowly decrease at night. Because the discharge increases, it is noted that preferential channels are formed creating a lower delay as time goes on. These flow paths are reconstructed and modified via the climate.

Effects

The effects of short-term storage aren't much significant to the water retention structures but they may lead the way to greater problems. The diurnal flow paths may create a preferential discharge channel that leads to singular storage release which can be catastrophic.

Singular storage release

Singular event which release large amounts of water and sediments can cause great problems to the use of glacier fed water systems for utilities. Long-term storage build-ups as glacial lakes can be releases in a short-term time scale. These high impact effects happen rarely. Therefore water retention structures aren't designed to withstand such a high flow. Outburst floods or jökulhlaup are either caused by meteorological reasons or, as in Iceland, high geothermal heat fluxes. Other than outburst floods, glacial surges are also a high impact phenomenon. During a surge, a glacier can advance distances as high as kilometers (Jansson, Hock and Schneider, 2002). This immense

mass of water and ice move at increased velocities and therefore affect either directly the structures or modify the underlying landscape hence changing the hydrological system.

These different time scaled storage system affect mostly the catchment hydrology of a glaciarized basin. This notion is important because this is the way we design structures that will, after their construction, create possibilities for human use of glacier runoff. So then, how are runoff predicted?

RUNOFF MODELING

The melt water from glaciers joins waters from other sources, such as groundwater and non-glaciated watersheds, and is harnessed by downstream dam schemes for use in hydroelectric power; irrigation and drinking. These multi-source systems have a supply profile that is altered by the storage effect of the glaciers. There are different models that can enable engineers to design effective dams to maintain and harness in the best way possible the many different water systems. Glaciers are a complex system. We illustrated this case by detailing the different levels of storage that are confined in a glacier itself. It is important to note that the model we will be showing is explicitly for glaciers. In order to create a complete hydrological model, we need to take into consideration rain fall and many other hydrological processes occurring in the catchment. For the sake of simplicity and since this a glaciology class, we will only address the glacier runoff modeling theory.

Since glaciers are made up of different components that obey to different dynamics, we need to account for the specific effects of each component. Therefore the main model used is a multi-reservoir hydraulic system (Quick and Pipes, 1977; Tangborn, 1984). Snow, ice and firn are separated in distinct reservoirs that are either coupled in parallel or in series depending on the situation of the glacier catchment. They are separated in order to simplify their different dynamics towards rain and melt water. By separating them we can easily generalize for the whole area and therefore create homogenous characteristics for each reservoir. Even if this system is relatively simple, it is shown to correlate extremely well to measured data as shown in figure XX. Figure XX shows a diagram that explains the dynamic of a three reservoir system. The values for K vary depending on the nature of the reservoir. They need to be quantified for each glacier as the nature of each element is subject to change. The values range from 16 hours for ice up to 350 hours for firn.

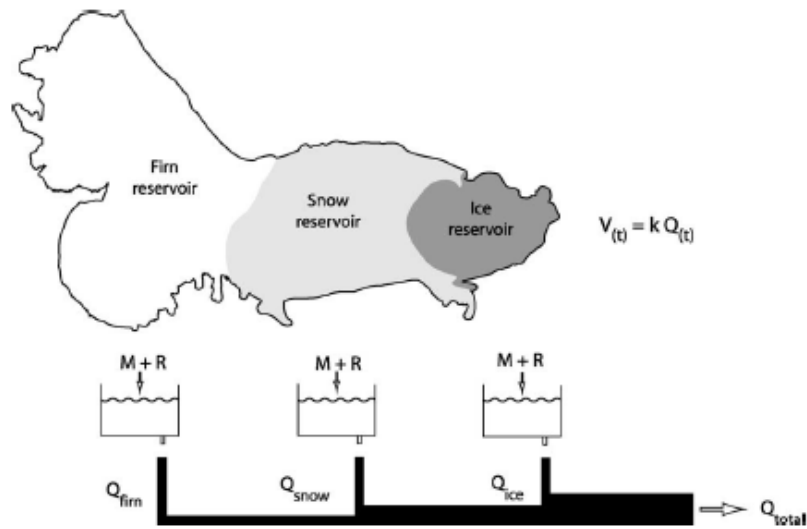


Fig. 7. Concept of three parallel linear reservoirs as applied to Storglaciären (Hock and Noetzi, 1997). The area of the firm reservoir is kept constant, while the areas of the snow and ice reservoir vary inversely, the latter expanding at the expense of the former, as the snow line moves upglacier during the melt season. The reservoirs are supplied by melt, M , and rain water, R . Outflow, Q , is proportional to reservoir volumes, V .

Figure 3 – Three reservoir parallel diagram (Jansson, Hock and Schneider, 2002)

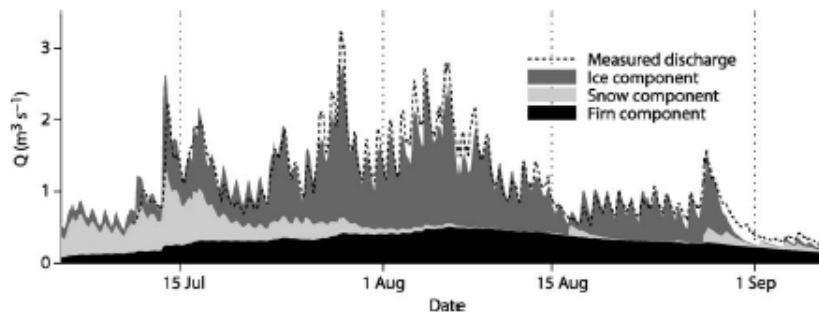


Fig. 6. Simulated and measured hourly discharge at Storglaciären 1994 assuming storage coefficients $k_{\text{firm}} = 350 \text{ h}$, $k_{\text{snow}} = 30 \text{ h}$, $k_{\text{ice}} = 16 \text{ h}$. The shaded areas mark the contributions of the firm, snow and ice reservoirs to total discharge. The snow reservoir contribution decreases as the snow line moves upglacier. Melt is computed from a distributed energy balance model (Hock, 1998).

Figure 4 – Computed data vs measured data (Jansson, Hock and Schneider, 2002)

By having a system to model runoff, engineers can now apply these calculations in order to create a structure that will be able to retain the water. These structures are made in order to create a more stable flow for hydropower production. They can also create a storage reservoir used for irrigation all year long. This way, man uses the glaciers by controlling the water discharge and harnessing its potential as a utility.

SEDIMENT TRANSPORT

The underlying ground of a glacier is subject to enormous pressures from the glacier's own weight. This way, glaciers can carve out majestic valleys, fjords, cirques, arêtes and horns (NSIDC, 2012). The eroded materials are transported via the glacier bed and retreating glaciers often leave behind moraines made out of till, a nutrient-rich mix of gravel, sand, small rocks and mud (NSIDC, 2012). These sediments sometimes left behind. Most of the times though of lot of these sediments are carried out by the water discharge (NSIDC, 2012). This sediment rich water creates many problems for the water retaining structures. The sediments fill out the water reservoir therefore limiting water storage capacity and hydropower potential. Sometimes sediment transport occurs inside the hydropower turbines damaging the turbines and reducing hydropower production. It is clear that for many reasons sediment transport need to be monitored in order to prevent problems for utilities.

ECONOMIC IMPACTS

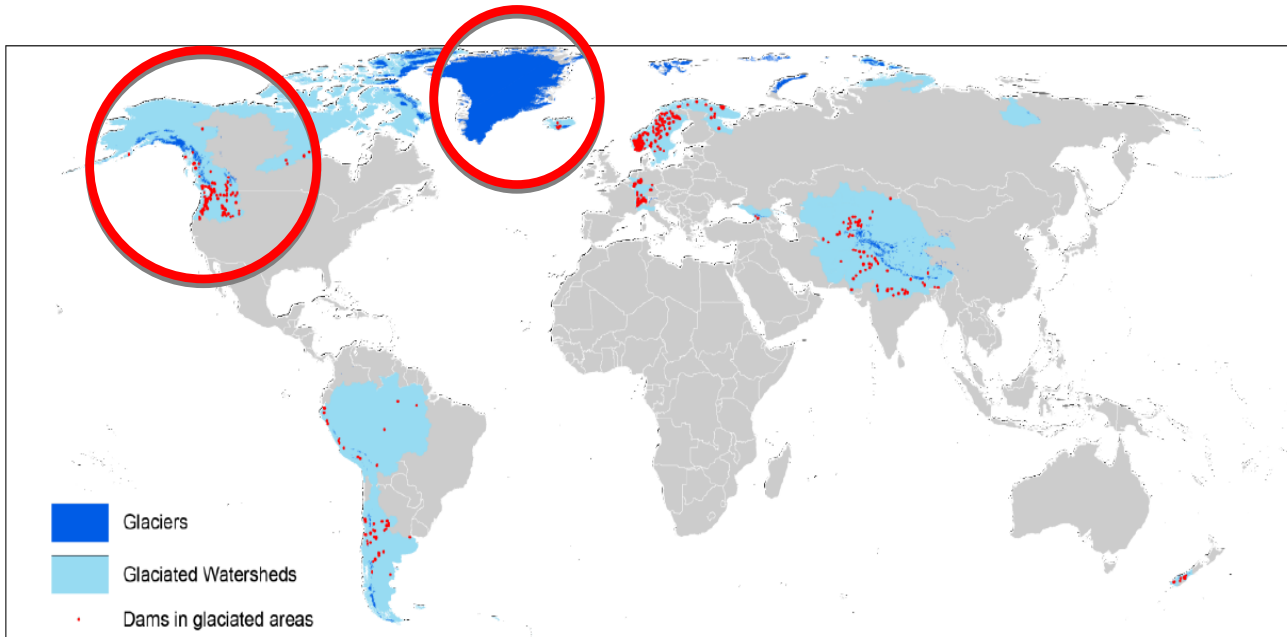


Figure 15: Glaciated watersheds of the world. This map uses components of the USGS HYDR01k Pfafstetter watershed delineation system to represent the drainages of the world that contain glaciers. Dams located within those glaciated drainages are also shown. Data: GRanD Dam Database 2011, USGS HYDR01k 2011.

Figure 5 - Glaciated areas (Blackshear et al., 2011)

NORTH AMERICA

The glaciated areas of N. America, which would include permafrost etc., are restricted to the Pacific NW coast, from Washington state to Alaska and to the arctic areas of NE Canada (fig 1). On continental N. America glaciers are further restricted to the mountain chains of the Cascades and Rockies which follow the Pacific coast all the way to Alaska. The glaciers are usually alpine glaciers which, in the more northern latitudes, can join to form larger ice streams.

Looking at a representative small example we can see the interplay and effect of the glacially derived water on the systems. Looking at a larger and more complex system we then see how these processes operate on a regional scale.

The Simple System – the Eklutna Lake and Basin

The Eklutna basin and storage lake supplies the city of Anchorage in Alaska with drinking water and electricity. The study by Larquier (2010) gives us a clear indication of the importance of glaciers in the water supply system which includes non-glaciated watersheds. It also introduces the concept of

“de-glaciation discharge dividend” – or the supplemental runoff available from the ice loss of a glacier due to negative mass balance.

KEY POINTS:-

- The system is two sub-basins, one more glaciated than the other.
- The glaciated basin is 60% of the area of the less glaciated basin
- The glaciated basin produces up to 2 X the runoff as the non-glaciated
- The glaciers are in negative balance but the loss is variable.
- Ice loss (negative balance) added ~ 24% to the West basin runoff in 2009 and 3% in 2010
- The glaciated basin is a more efficient water supplier to the lake storage in terms of volume supplied per km².

The Complex System – the Columbia Basin

Many studies have been carried out on the hydrology of the Columbia river system. Here we use a small number of those (Power (1986); Gleick (2000); Littell et al. (2009)) to show that the enhancement effects of glacial runoff demonstrated by the Eklutna study can be seen in larger and more complex river systems. Alongside this is the fact that watershed systems with glacial storage can cross national borders and therefore require international cooperation. In this example the Columbia river treaty has been signed. More information on this can be found at <http://www.cbt.org/crt/>. The studies also show the value in dollar terms of the negative mass balance, or “de-glaciation discharge dividend” introduced above, in the Columbia system, and how this dividend is relatively short term.

KEY POINTS:-

- A small percentage glaciated area can have a large proportional impact on runoff volumes.
- In large systems the additional runoff supplied by ice loss through negative mass balance has a significant financial value.
- Cross border treaties are required to manage a resource which can be spread over hundreds of thousands of km².
- Arrangements and schemes designed and built before the realization of climate change, and its effect on glacial runoff, may need to be re-worked and conflict can result.
- The additional runoff from negative mass balance ice loss is a short-term phenomena.

ICELAND

Iceland's glaciers consist of a number of small ice sheets with associated outlet glaciers feeding into inland river systems or glacial outwash plains. The inland river systems have been exploited for hydroelectric schemes on an increasingly large scale.

The Iceland case study uses the data from the largest power company, Landsvirkjun, to show how glacially supplied hydropower has not only supplied the local population with electricity but has also enabled the creation of a major heavy industry. Iceland's more modern utilization of the glacially fed rivers is geared primarily to long-term contract supply to global aluminum manufacturers.

KEY POINTS:-

- Small number of high power generation schemes
- High proportion of the energy generated goes to heavy industry
- Glacier volumes are forecast to half in less than 100 years and some may disappear completely by 2150.
- Glacier runoff flows will peak around 2050 and start to fall by the later part of the century.
- There is a forecast of a possible 16% increase in energy from runoff by 2050 due to negative mass balance melting
- There is no forecast plan beyond 2050.

(Landsvirkjun, 2012b)

(Landsvirkjun, 2012a)

(Linnet, 2011)

GREENLAND

While Greenland has the largest accessible ice resource in the northern hemisphere, it has been largely unused. The Greenland ice sheet supplies a large number of outlet glaciers that feed into fjords, the sea and huge inland glacial lakes e.g. lake Tasersiaq – see fig 2.

Currently 4 or 5 small hydroelectric schemes exist to supply the needs of the local populations. However, following from the Iceland experience, there are developments in progress to utilize these glacial water supplies for further heavy industry development, specifically aluminum smelting.

The data shown is from the Greenland Development Inc website (Greenland Development Inc., 2012).

Further information is available about this proposed development from the website of ERM (consulting engineers employed to carry out the environmental impact assessment) <http://www.erm.com/alcoagreenland>.

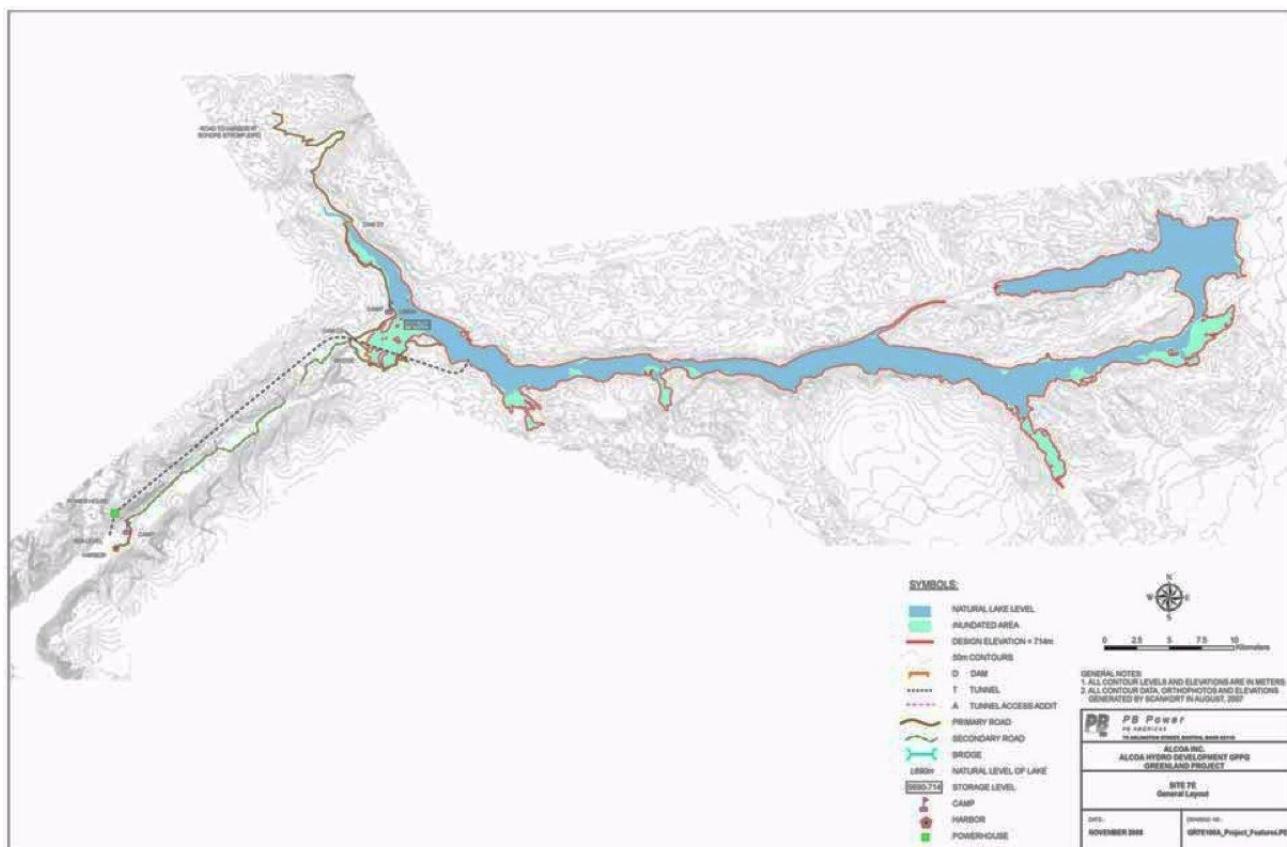


Figure 6 - Lake Tasersiaq (Ott, 2009)

SOCIAL IMPACTS

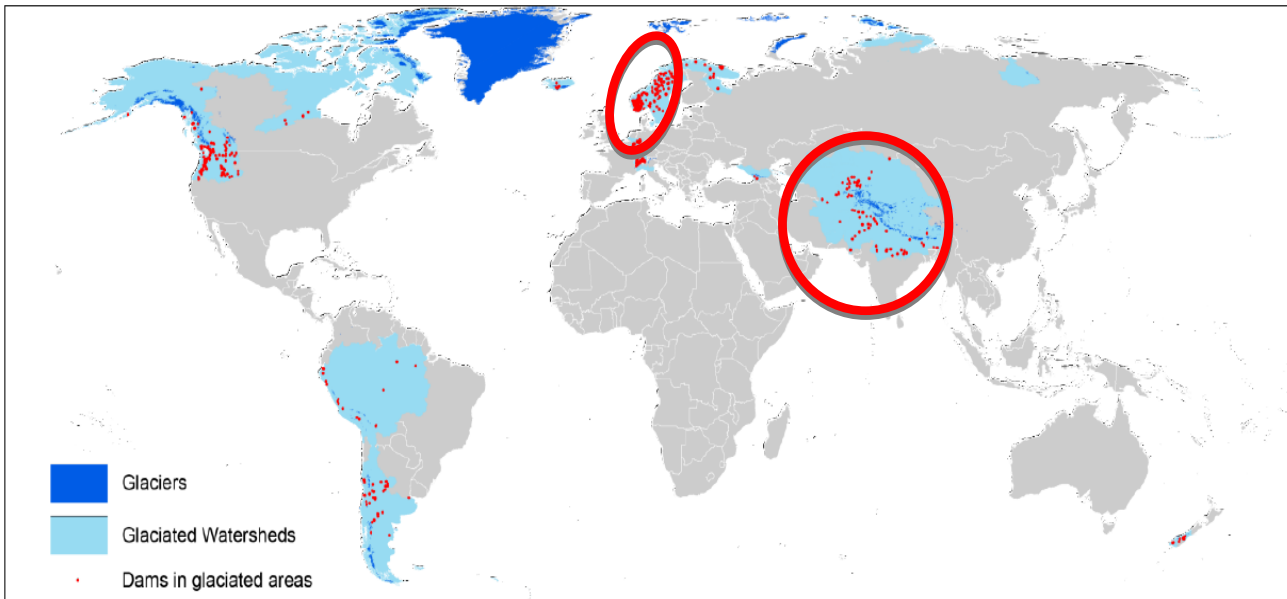


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Figure 7: Glaciated areas (Blackshear et al., 2011)

NORWAY

Norway is one of the leading countries, with 99% of total energy production, when it comes to using glacier runoff. Norway has 1,627 glaciers that total 2,595 square kilometers (1993) in area. These are mostly ice caps, outlet, cirque, and valley glaciers. Glacier utilization has been the key factor to produce scientific data on Norwegian glaciers. Their big interest is the sediment rich runoff water which wears out hydropower equipment quickly. By studying the amount of sediment that the river carries before building the power station wear out the problems can be minimized by various means. To control the flow of sediments power companies have used river regulation, sand traps, sedimentation chambers, and settling basins. (Statkraft 2012; Østrem and Haakensen 1993; Bogen 1989)

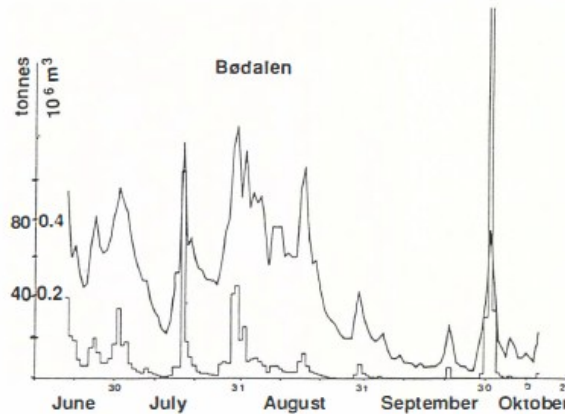


Figure 8: Water discharge (curve) and suspended-sediment transport (column) in melt-water river from Bodalsbreen.(Bogen 1989)

The location of sediments can be analyzed from satellite images and monitoring the glacier originated rivers by taking several water samples. Studies of Bogen (1989) show that the highest sediment transport takes place during flash flood events which can be seen from figure 3. Sediment distribution is also dependent on available sediment at the glacier bed. The turbine wear depends on the amount, grain size and mineralogy of the sediments. For example sand has bigger abrading affect that silt, and quartz causes heavier wear than softer minerals. (Østrem and Haakensen, 1993; Bogen 1989)

When the sediment is trapped the systems mentioned above the river environment is heavily altered. Glacier related sediments carry nutrients, metals, bacteria and pesticides, and also affect the light conditions such that photosynthesis in the river system is affected. Coarse sediments form substrate for living organisms in river beds and therefore changing the distribution of sediment can damage the ecological conditions in river basins and ethe coastline. (Østrem and Haakensen, 1993; Bogen 1989)

ASIA

Glaciers in south and east Asia, in Himalayas and Tibetan Plateau, provide drinking water for more than 1 billion people. Glacial melt provides most of the water that brings life to one quarter of people living in China. Asian agriculture depends on glacier runoff and also the nutrients carried in it. China is famous for its ambitious hydropower projects, but in India, hydropower utilization is just taking place. Study by Yao et al. (2003) shows that increased runoff by warming climate has increased

river flows in NW China, which can have considerable benefits for hydropower and agriculture for some time. (Barnett et al 2005; Cuffey and Paterson 2010; Singh et al. 2004)

Development in Himalayas and India

The slopes in Himalaya are steep and valleys narrow which gathers the runoff water into individual streams and makes the water utilization fairly easy. Rural areas can be supplied with electricity from local mini and micro hydroelectric power stations. However the Himalayan glaciers have tendency to build up moraine dams around glacial lakes and these form a serious threat of glacial lake outburst flood, (GLOF). These floods can cause serious damage to hydropower plants. (Bennett and Glasser 2009; Kulkarni et al. 2002)

At the moment about 50% of the water in Indian rivers is glacier runoff. It can be predicted that in 30-100 years glacier runoff will increase and after that decrease or end completely due to warming of climate. It is also possible that warming climate will trigger more floods due to precipitation and, therefore, it is important to prepare for those with dam construction. Dams work as water storages and help to prevent hazards triggered from flooding. (IPCC 2012, World Bank)

Water politics

In Middle Asia, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Kazakhstan draw their water from the Amu Darya and Syr Darya Rivers, which originate at Tien-Shan and Pamir-Alay mountains. When rivers span through several countries, conflicts arise on which country has the right to harness the power or clean drinking water from a river. Over usage of the water in these rivers has led into drying of Aral Sea. With the increasing runoff due to warming climate, demand for international agreements arises. With the right power investments and procedures the welfare of whole regime can be improved. (Luterbacher et al. 2007)

CLIMATE CHANGE IMPACTS

As we all know climate changes are real and present everywhere. It is almost impossible to talk about glacier without approaching this aspect. But it is still impossible to predict climate change tendencies. We are sure it is present and we cannot ignore it. With the help of the regions as examples, we will see how human's use of glacier is linked to climate changes.



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Figure 9: Glaciated areas (Blackshear et al., 2011)

SWITZERLAND

Switzerland is the central spot in Europe for glaciers. Most glaciers in central Europe are in Switzerland. They are all alpine glaciers and they are situated in the Alps mountain range. The Switzerland's mountain glaciers have a fundamental role to play in Europe. Since it is the biggest location of glacier in central Europe, it is the most important source of water. The relief of the Alps feeds off most of the rivers in Europe. In Switzerland most of the human's use of glacier is represented by alpine hydropower plants. Mass balance from glacier in Alps region is negative over the last 40 years. (EEA report, 2005)

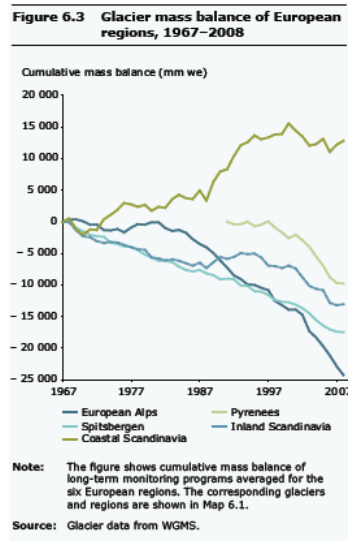


Figure 10: Glacier mass balance of European regions (1967-2008), EEA report 2005

How climate changes affect human's use of glacier?

Mean temperature in Switzerland have increased by 0.5 Celsius degrees each of the last three decade (Walter Havenstein, 2005). This change in temperatures results in warmer and dryer summer, but also in warmer winter. General scientific consensus is that no matter the climate change there is no guarantee there will be an important impact on Switzerland's alpine glacier, since alpine regions may not be affected by winter less precipitations. Contrariwise, warmer summer will initiate faster melting. At one point, there will be nothing left to melt (Walter Havenstein, 2005). It is the whole hydrological cycle that will be modified. Hydrological cycles are known to regulate climate (Nordstrom, Gupta and Chase, 2005).



Figure 11: Mauvoisin reservoir and glacier de Gietro

Since 90% of the inflow occurs during the summer season and the energy demands appears mostly in the winter, hydrological storage basins are necessary. As the inflow seems to be increasing, authorities have decided built a 250m high dam in the Alps to create the Mauvoisin 204 hm³ reservoir. The increasing amount of glacier melting creates numerous problems in Switzerland's Alps. More reservoirs will need to be built in order to prevent floods and keep the water for energy used. This is how increased melting due to climate change influences the way humans use glaciers. (Terrier & all, 2011)

But how does man's use of glaciers influence the glacier (climate changes)?

Most of the impact produced by human is from hydropower plants. When it is time to discuss about hydropower plants, there is two way of thinking. Some are in favor of hydropower plants, but that's not always the case.

In Switzerland, it has been calculated that total energy consumption in 2002 was about 853 000 TJ. In Switzerland, hydropower plants play a major role in energy production. The total fossil fuel energy consumption for the construction of hydropower plants has been estimated as 50 000 TJ. This represents 6 % of the total energy consumptions of Switzerland. They claim that most part of hydropower plants have a lifetime of 40 to 80 years. Hydropower plants are estimated to produce at least 150 times the total energy consumed by their construction. In comparison, windmills are estimated to create only 30 times more energy than it was consumed for their construction. That means a lot more windmills for the same amount of energy. This comparison demonstrates that hydropower plant, using water coming from glaciers mitigate climate changes. (Walter Havenstein, 2005)

In another point of view, hydropower plants destroy ecosystems. Water ecologists would like to see the downstream flow to be reduced. This is a direct contrast with the efficient use of hydropower plants. To mitigate influence on climate changes, hydropower plants need to be operated at their full

capacity. The power of runoff affects the ecosystem. Fish and plants are killed by the runoff water power. Landscape and river shape are also affected. (Walter Havenstein, 2005) (EEA report, 2005)

ANDES

The major part of glacial area in South America is in the Andes. The Andes extend from Venezuela on to the north of Chile and in the southern part of Argentina. The Andes is the longest continental mountain range in the world. This geographic condition created possible areas for alpine glaciers. Due to their unique location those glaciers have an important role in the lives of South American citizen.

How climate changes affect human's use of glacier?

It's now known, Andes alpine glaciers are retreating very fast. 80% of the glaciers of the Andes are expecting to be disappearing in 10 to 20 years. Glaciers provide, in most regions, more than 75% of the drinkable water. (Walter Vergara, 2007)

In Bolivia, 90 % of the water demand is used for the irrigation. Less and less water is available. Chacaltaya glacier's origin dates back to 18 000 years ago, but since 1960, 99% of its mass has already melted. Chacaltaya is expecting to vanish in the course of this year (2012). (Miriam Lara Jeschke, 2009)

Ecuador's glacier Cotacachi already disappeared. The impacts have already been observed. They lost their biodiversity. Agriculture is now almost inexistent and most of the inhabitants of the region have moved away. (Walter Vergara, 2007)

The survival of Andes region's inhabitants depend on glaciers. The water supply from glaciers is fundamental. The agriculture, the potable water and the energy are all depending on the melting of glaciers. There is a huge need for immediate adaptation. World Bank claim the Andes region will be one of the most affected by climate changes. (Walter Vergara, 2005)

But how does man's use of glacier influence the glacier (climate changes)?

Everywhere in the Andes the lack of water resources has been felt. For some regions, adaptation meant starting to use fertilizer and pesticides for local agriculture. This has been observed in Peru where water from glaciers has completely disappeared.

Other idea to reduce human melt water use is to produce more energy by fossil fueled thermal power stations. The use of fossil fuel produces a bigger portion of green gas effect than hydroelectricity. (Walter Vergara, 2009)

Another solution is to build more dams in order to prevent melt water from being lost where melting is too high. The process is tricky and difficult since the Andes region is highly affected by earthquakes. This means bigger structures and a shorter lifetime. Furthermore, concrete itself is known to produce 5% of green gas effect but this number is now known to be diminishing. Scientists found that concrete reabsorbs around 40% of the CO₂ that was emitted to create it. So the CO₂'s footprint is not too bad for concrete. (Liv Haselback, 2009)

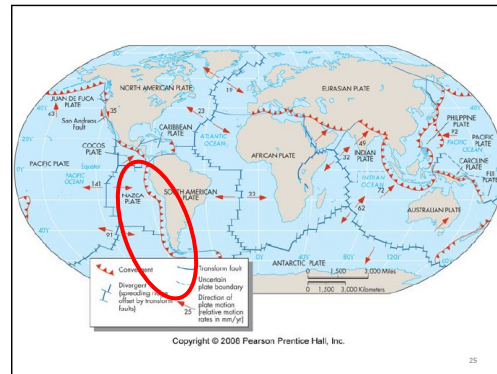


Figure 12: Earthquake region and continental fault

In a more environmental solution, in Peru the authorities started planting Quenual trees. Its major advantage: it captures large volume of rainfall and replenishes ground water systems. This will help use less water for irrigation and agriculture. This solution affects positively the climate changes. (Heather Summerville, 2011)



Figure 13: Plants of Quenual in Peru, (<http://global-warning.org/main/peru/>)

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