Industrialization of Rivers: A Water System Approach to Hydropower Development

Eva Jakobsson

"Not only the operatives make Sunday a day of rest, but the river too [...]
All nature begins to work with new impetuosity on Monday."

—H D Thoreau[1]

Introduction

In a letter dated 1906, one of the Swedish hydropower pioneers outlined his plan to build the country's largest hydropower plant in River Gullspång.[2] A key element in the grand plan was to use Lake Skagern as a reservoir. In his letter, he described the design of the project. His plan was to turn Lake Skagern into"a water container"[3] where the "Sunday water"[4] was to be accumulated. Water flowing in to the "water container"during the day of rest was to be stored for further use in hydropower production during working days. By naming Lake Skagern"a water container", he conceptually distanced himself from designating it a lake, and by the new term he made an abstraction of the lake and described it as a body of measurement. By using the concept"Sunday water,"he also gave a new meaning to the water discharge.

This glimpse from the pioneer days in hydropower development focuses on the extensive alterations of rivers all over the world (Dynesius & Nilsson, 1994). By introducing the concept of Industrializing Rivers this development, from the free flowing to the harnessed water system, will be analyzed. Secondly, the hydropower-producing river as a Large Technological

Eva Jakobsson holds a Ph.D. in history from Gothenburg University, Sweden. Her thesis, *Industrialization of Rivers. Studies in Swedish hydropower development, 1900-1918* (in Swedish), was published in 1996. She has been affiliated to the Department of the History of Science and Technology, Royal Institute of Technology, Stockholm. At present she is a senior research scientist at RF- Rogaland Research in Stavanger, Norway. She also serves as the Regional Representative of the Nordic countries in the European Society for Environmental History. Her main interests are water history, water policy and water law. She may be contacted at <eva.jakobsson@rf.no>.

Knowledge, Technology, & Policy, Winter 2002, Vol. 14, No. 4, p. 41-56.

System will be discussed. Finally, using the Swedish hydropower development as an example, the social institutions needed to control water in the Large Technological System will be emphasized.[5]

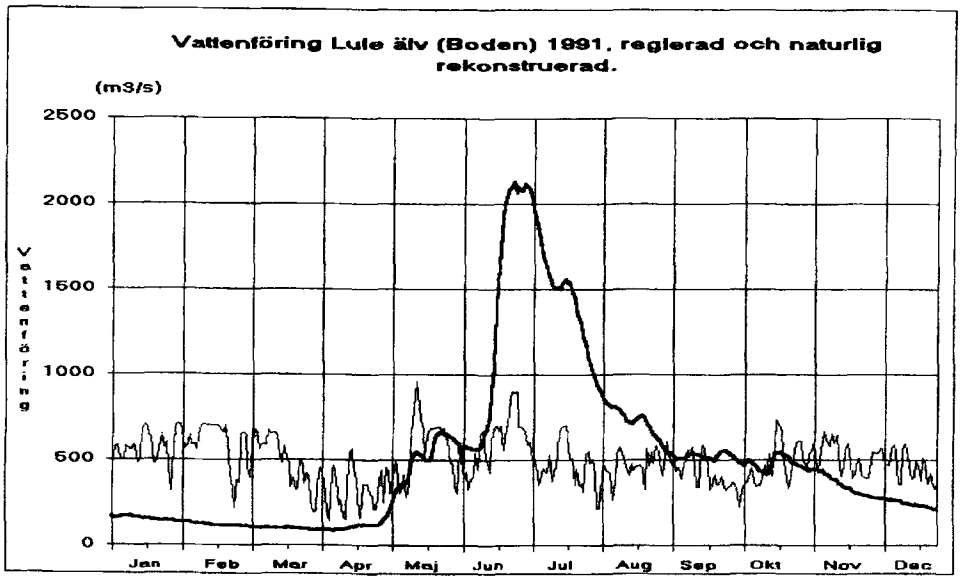
Industrialized Rivers—a concept

Rivers untouched by man are probably not to be found any more. However, some rivers have not yet been cut up by dams and reservoirs. As those rivers still keep their natural flow, they can be categorized as free flowing rivers even if they have been altered by activities as for example timber floating, channeling and water mills.[6]

To contrast the free flowing with the harnessed river, the following illustration showing the most harnessed river in Sweden, the Lule River, producing a quarter of the hydropower electricity, will be used. The graph is illustrating real and natural (calculated) run-off in 1991. Its natural run-off is at its lowest in spring and when the snows begin to melt in the mountains it raises from 100 to 2000 m^3/sec. This would have happened if the river were not regulated. Today the water discharge had to be radically altered to function as a hydropower producer—to let the flowing water out of the reservoirs and through the turbines when there is a demand for electricity. Today 15 hydropower plants are working in the river and the spring flood (e.g. summer flood) is stored in regulating reservoirs (storage capacity 9475 million m^3).

Figure 1

Real (*thin line*) and calculated natural (*broad line*) runoff (m^3/sec) in River Lule at its mouth 1991



Source: Adell, 1992

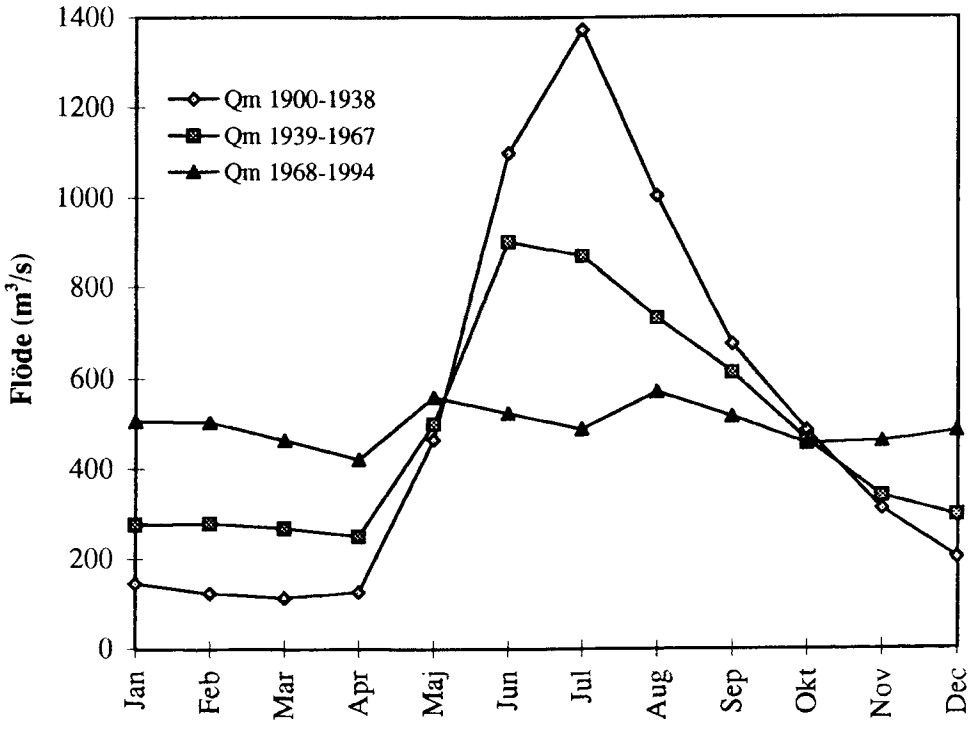
The radical alteration of the runoff in River Lule has changed gradually since the first power plants were built in the river at the beginning of the 20th century. The second graph presents the change in runoff during the 20th century, when the regulation became more and more radical.

In a water system perspective there is no difference between the build up of a hydropower system or constructing a drainage system in a wetland or lowering a lake or maintaining timber floating in a water system or to uphold a net of ditches between fields in an agrarian landscape, or perhaps, most apparent, an irrigation system (Pisani, 1992 and 2000). These are all built up water infrastructures stretching out and binding together the water flow through the landscape to an ever-increasing extent. These infrastructures have an integrated duality. They are both a part of the hydrological cycle at the same time as man controls them. These kinds of controlled natures have been named "second nature" (Worster, 1990 and Cronon, 1991).

When an investor establishes an electricity system based on hydropower, he secures himself a part of the hydrological cycle for future utilization and

Figure 2

Monthly runoff (m^3/sec) in River Lule at its mouth 1900–1994



Source: Brandt and Ehlert, 1996

harnesses a combination of the rivers water volume and height of fall. A natural resource is transformed to conform to the demand for electric power and the natural rhythm of the river is broken. The flow of water takes on an "industrial pace"—to use Theodore Steinberg's words (Steinberg, 1991, pp. 8 and 76). By introducing the concept *Industrialization of Rivers* I am encapsulating the idea of water flow being rendered more efficient and of it's transformation for production of electricity.[1] Homogeneity, maximization, rationality, management and large scale are associated with this industrialization concept. One could argue that the regulated water system has undergone a metamorphosis: it has been recreated and given a new role. The industrializing concept captures the process of making the water flow of the river into a commodity (Steinberg, 1995 and Nye, 1999, pp.107-113). Through the industrialization of the water system, the power companies can even make themselves masters of time: as has been shown, the water system loses its annual rhythm.

In the following picture a watershed turned into a hydropower system is portrayed, where the effect of hydropower plants (built and planned) and reservoir volume (in work and planned) is defined. The *industrialized* River Indal and its tributaries have been turned into a production system. Its spatial description is changed from length of the river to the height of fall and volume at each power plant.

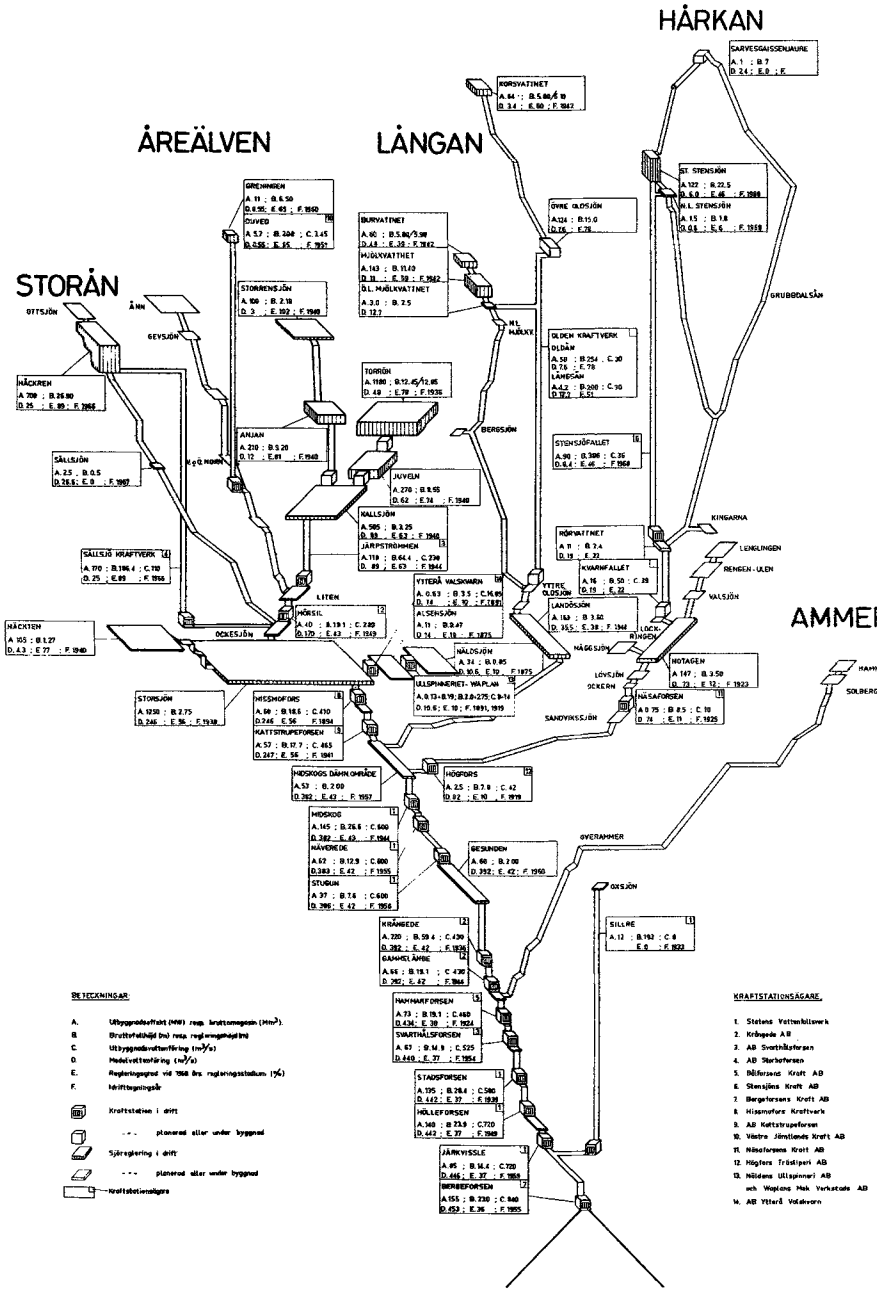
Industrialized rivers as Large Technological Systems

As illustrated above these industrialized rivers are in control of man and functions as a Large Technological System. They can also be interpreted as socio-technological systems as defined by Thomas P. Hughes. It is a technological system impregnated with ideology and integrating actors and institutions:

> Among the components in technological systems are physical artifacts, such as the turbogenerators, transformers, and transmission lines in electric light and power systems. Technological systems also include organizations, such as manufacturing firms, utility companies, and investment banks, and they incorporate components usually labeled scientific, such as books, articles, and university teaching and research programs. Legislative artifacts, such as regulatory laws, can also be part of technological systems.[1]

Of course, one could, at first sight, claim that hydraulic engineering, the dam and the water regulation techniques make these alterations and radical changes of discharge. The power company decides, based on the electricity demand, the amount of water and at what time water is to be let through the turbines or sluice gates. The result is rivers operating on 'factory time' and a web consisting of transmission and distribution lines, industrialized lakes and rivers, stretching across the country. However, these alterations can not have taken place without interacting with society. As pointed out by Hughes, these socio-technological systems are dependent

Figure 3


HÅRKAN
ÅREÄLVEN
LÅNGAN
STORÅN
AMMERÅN
SARVESSAISSENJAURE
KORSVATTNET
ST. STENSJÖN
N.L. STENSJÖN
ÖVRE OLDSJÖN
GRUBBDALSÅN
BURVATTNET
HJULKVATTNET
GRENINGEN
OUVED
STORRENSJÖN
OTTSJÖN
ÅNN
GEVSJÖN
OLDEN KRAFTVERK
OLDÅN
LÅNGSÅN
TORRÖN
HÄCKREN
ANJAN
BERGSJÖN
STENSJÖFALLET
SÄLLSJÖN
JUVELN
KALLSJÖN
JÄRPSTRÖMMEN
KINGARNA
RÖRVATTNET
LENGLINGEN
KVARNFALLET
RENGEN-ULEN
SÄLLSJÖ KRAFTVERK
YTTERÅ VALSKVARN
YTTRE OLDSJÖN
VALSJÖN
LITEN
LANDÖSJÖN
LOCK-RINGEN
HÄCKTEN
ÖCKESJÖN
MÖRSIL
ALSERSJÖN
NÄLDSJÖN
HÄGGSJÖN
HOTAGEN
HAMMERDALSSJÖN
SOLBERGSVATTNET
ULSPINNERIET-WAPLAN
LÖVSJÖN
ÖCKERN
STORSJÖN
MISSMOFORS
KATTSTRUPEFORSEN
NÄSAFORSEN
SANDVIKSSJÖN
HÖGFORS
MIDSKOGS DÄMN OMRÅDE
MIDSKOG
HÄVERDE
STUDUN
GESUNDEN
ÖVERTÄMMER
OXSJÖN
KRÅNGEDE
SILLRE
NAMMARFORSEN
SVARTHÅLSFORSEN
STADSFORSEN
HÖLLEFORSEN
JÄRKVISSLE
BERGEFORSEN
BETECKNINGAR
A. Utbyggnadseffekt (MW) resp. bruttomagasin (Mm³).
B. Bruttofallhöjd (m) resp. regleringsmöjlighet
C. Utbyggnadsvattenföring (m³/s)
D. Medelvattenföring (m³/s)
E. Regleringsgrad vid 1968 års regleringsstadium (%)
F. Idrifttagningsår
Kraftstation i drift
planerad eller under byggnad
Sjöreglering i drift
planerad eller under byggnad
Kraftstationsägare
KRAFTSTATIONSÄGARE
1. Statens Vattenfallsverk
2. Krångede AB
3. AB Svartnäsforsen
4. AB Storbyforsen
5. Bålforsens Kraft AB
6. Stensjöns Kraft AB
7. Bergeforsens Kraft AB
8. Hissmofors Kraftverk
9. AB Kattstrupeforsen
10. Västra Jämtlands Kraft AB
11. Näsaforsens Kraft AB
12. Högfors Trästiperi AB
13. Nälidens Ullspinneri AB
och Wapkens Mek Verkstads AB
14. AB Ytterå Valskvarn

on the social context; their design is shaped in an historical context and is in some meaning mirroring the distribution of power in society.

One of the concepts used by Thomas P. Hughes to describe the development of the socio-technological system is the concept *reverse salient*. The phrase is military terminology and is the name of the part of an advancing front that has lagged behind. In analogy with this picture, a reverse salient arises in an expanding technical system, when some part of the system does not follow the development at the same pace as the other parts of the system. Finally, the reverse salient holds back the progress of the entire system. A reverse salient can be of a technical, economic as well as political nature. Studying such obstacles with the aid of this concept does not result exclusively in knowledge about the technical system, but even provides knowledge about the society in which the technical system is established.

One aspect of building a hydropower system is that the power company also has to take into consideration institutions set up by society for regulating the use of water. In the following, the role of institutional hindrances related to the use of flowing water will be discussed by analyzing the early development of the Swedish hydropower system.

A reverse salient in the Swedish hydropower system

There are many indications that Swedish hydropower production throughout its pioneering years was an insecure and uneven energy form. In particular during periods of low water, power plants had production problems. The irregular discharge in the Swedish rivers, created by the Swedish climatic rhythm conditions, and not adapted to the electricity demand, hindered a rationally planned hydropower system. This could have created a reverse salient in the Swedish hydropower system. However, this barrier could be cleared away, as the hydraulic engineering skills and economic means were present. Instead, a subjective or a cultural-political reverse salient can be identified. At the end of the 19th century, a dawning hydropower industry met a water law reflecting the interests of an agrarian society in a country with abundant water. The old Swedish water law tradition prevented the building of dams across the rivers. The expansion of the new technical system thus met with an obstacle. According to Swedish water legislation during the first years of the last century, provisions given for building hydropower plants in the rivers gave no right to regulate the flow of water. Authorizations to build dams in the rivers stated a general prohibition against any "alteration of the hitherto existing water level situation taking place."

The early hydropower system in Sweden was a lumbering and incomplete technical system, imprisoned in a "non-rational" nature. When electricity deliverance could not be guaranteed, it met an obstacle in asking consumers change to a new energy source. One of the conditions for using electricity is that the producer is capable of guaranteeing deliverance—both for the day and for the future. The contracts could only secure electricity equivalent to the power accessible at low water levels. Dissatisfaction

of the situation spread among the engineers. They had the know-how to efficiently harness the river and they assisted in building hydropower plants possessing capacity far over what they could be used for. The Director General of the State Power Board complained that "water was allowed to flow identically on Sunday as on a weekday."

To understand this hindrance—or reverse salient—we have to discuss the Swedish example in the context of the institutional framework—the legislation that regulated the water infrastructures.

Placing the Swedish example in a water conflict and law perspective

Water politics are based on some specific characteristics in flowing water. Water infrastructures consist of a melting together of the non-human and the human. As the systems get more complex several demands on the water have to coexist in the systems. These infrastructures are linked to the water circulation. They depend on and compete with each other. Alterations in the water circulation is spread both upstream and downstream, and the changes affect both man and ecosystems. This happens regardless of the historical context. The structure and scale of the alterations are, however, dependent on the historical situation and the level of technology. This often leads to various kinds of up and downstream conflicts. Such a conflict can for example arise between two mill owners or between two states sharing a river basin.

In the Scandinavian countries—a region with abundant water—we can identify another water related conflict, connected to the purpose that water is used for. It is the conflict between those who want to dam water—pro-dammers—and those who want to protect their land from flooding—anti-dammers (Myllyntaus, 1991, pp. 161-162). In Swedish history, anti-dammers were represented by agrarian actors carrying out drainage of fields and wetlands, lowering lakes and fishing. Log driving, by its use of the spring flood to float the timber out of the forests and down to the sawmills on the coast, was an anti-dammers' interest, who shared the agrarian interest of keeping the watercourse open. Furthermore, I suggest that a modern anti-dammering interest is expressed by environmentalists who want to stop the harnessing of rivers. Mill and sawmill owners, other waterpower users and hydropower developers, on the other hand, represent pro-dammers. Their interest is in controlling the flowing water and storing the water to use it when the demand for power increases.

Water-related conflicts, which developed simultaneously to the build-up of water related infrastructures, have for hundreds of years been governed by normative systems establishing opportunities and limits for private or public control over the water system. From time immemorial water alterations have been regulated by special water laws. The laws have either hindered alteration, frozen water development or given priority to alterations in watercourses. Water laws are made up of deeply rooted beliefs such as, for example, if water is private or public property. These water-related conflicts and systems of norms also reflect social relations, rather than, for example, climatic or geographical conditions (Pisani, 1996, p. 2).

To place the Swedish water legislation in a water law context some relevant concepts describing different ways of dividing flowing water have to be introduced.[2] The concepts relevant to the Swedish example are *riparianism*, and its two differing principle concerning what ways alterations in the watercourses can be carried out: *natural flow rule* and the principle of *reasonable use*.

Riparianism does not see a difference between land and water. The principle postulates that only the riparian who owns the shore of a lake or a watercourse has the right to use the water contiguous to his shore. All riparians, regardless of the length of, for example, the riverbank, have the same kind of right to the water contiguous to their shore. The riparians do not have to harness their water.[3] Riparianism has been an unquestioned principle in Sweden. In medieval law it was stated that "he who owns the land owns the water." At the beginning of the 20th century riparianism was formulated by statuary provisions as: "Each person is entitled ... to have control over the water which is on his ground."

Originally riparianism guaranteed the riparian the water in its natural flow—natural flow rule (Lauer, 1970, Teclaff, 1967, pp. 89-88 and Wisdom, 1975). The legal maxim was, "Water flows, and ought to flow, as it has customarily flowed" (Lauer, 1970, p.1, note1). Riparianism and the natural flow have deep roots in Swedish history. In the oldest preserved book written in Swedish, the older law of Västergötland, which dates from the middle of the thirteenth century, it is stated: "If a man wants to build a mill, he may not build it so that another man's ground is damaged, nor his field or meadow, nor public roads, nor the neighbor's sidewalk and not a mill built, nor a fishery." The legal text can be interpreted as a prohibition against alteration in watercourses not caused by nature.

The natural flow rule is often replaced with a second variant of riparianism; the principle of reasonable use. It originates from the beginning of the 19th century when, during a period when the harnessing of rivers was intensified, it became a tool for managing conflicts between riparians. The principle of reasonable use made it possible to alter the flow of water, even if it affected other riparians. Thereby it implies that land and water were no longer chained to each other. The principle was obviously essential for increasing the energy taken from the watercourses. The criteria for reasonable use have changed depending on the historical context. Variables such as benefit for society or the user has often been used as definition of reasonable use. This means that changes in the definition of reasonable use can lead to abrupt changes in watercourses.

As already indicated, the Swedish landscape is characterized by abundant water. Historically one of the main concerns for the Swedish farming population was that the rainwater remained in the fields and moistened the seeds. Consequently the soil became hard to cultivate as it suffered from "water sickness." In spring it took a long time for the frost in the ground to break up the wet soil. (It was only in the late 20th century when intensified agriculture was introduced that irrigation became an interest for the Swedish farmer). However, the abundant water in rivers and lakes has also

been of interest to those using water- and hydropower. The conflict arose between the advocates of two variants of riparianism: the natural flow rule—which did not allow change in the water flow and which was defended by agrarian interests, and the principle of reasonable use—which allowed interference in the water flow and which was defended by those wanting to exploit the watercourses. At the risk of over-simplifying, one can sum up that anti-dammers are advocates for the natural flow rule while pro-dammers represent the principle of reasonable use.

After presenting these social institutions related to the build up of water infrastructures, and as the development of the technical system is dependent of a social context, we also have to place the dawning Swedish hydropower industry in its historical context.

Controlling Water in 19th Century Sweden

At the beginning of the 19th century, agrarian production increased considerably. Reclamation, large drainage projects supported by the State, contributed to this. Drainage of fields and wetlands as well as the lowering of lakes were instruments in the struggle to reclaim and gain arable land. It is estimated that a little more than 600 lakes have been drained and 2.5 % of all the lakes (a total of 2 500 lakes) have been lowered in Sweden.[4] Underdrainage was also introduced in the middle of the 19th century. With the more efficient and spatially widespread system of ditches, the rainfall was more and more rapidly washed through the landscape and into the watercourses. Intensified forestry also caused alterations in the water balance. Clear-cutting made the snow melt faster and it removed roots that had previously bound the water in the ground. Symptoms of imbalance in the landscape appeared when the shores of the outlets were flooded. Therefore, it became more and more important to keep the watercourses open for the direct outlet of water from the cultivated land. The natural flow rule became increasingly—perhaps more than ever—important for the anti-dammers.

In Sweden a legal institution guaranteed the natural flow rule. Its name was "King's Vein" (*kungsådran*). During at least 500 years this special institution had stipulated that a third of the water continually had to flow freely in the larger watercourses and rivers. In watercourses where by definition there was a King's Vein, it was forbidden to build dams. Historically, the function of King's Vein was to protect migrating fish, guard against flooding and preserve navigable passages, e.g. protecting the interests of an agrarian society.[5]

In the late 19th century a parliament, where agrarian interests were heavily over represented, instituted a new water law. The old King's Vein institution was retained. However, in the new water law of 1880, it was given a new definition. At first sight this could seem trivial. From a water system perspective, it was significant. The former definition had established that one third of the *quantity* of water constituted King's Vein. In the new water law, King's Vein henceforth consisted of a third of the *width* of the water-

course. The revision of the definition on one side strengthened the agrarian interests, who wanted to keep the watercourses open for an effective outflow of abundant water in the fields. On the other side it was a setback for the owners of waterworks.

The old King's Vein definition guaranteed two thirds of the water quantity to owners of waterworks regardless of the flow of water and the shape of the watercourse. If instead one third of the width of the watercourse was to be kept open, naturally more than one third of the quantity of water current would flow through it. The outcome was a greater current through the watercourses and abundant water discharged faster from the fields. Thus far, it can be concluded that the natural flow rule held a strong position in the history of Sweden's waters.

Under pressure from pro-industrial members of Parliament the Parliament passed an ordinance in 1899 allowing the building over of the King's Vein with government permission. Dams were built in the large rivers. Control of the watercourses had passed over to the dam-owners.

Did this mean that the technical system was completed? Could the power in the rivers be fully exploited? In an analysis of the practice of the 1899 King's Vein decision, I have shown that the principle of the natural flow rule still held firm. The government terms stated, carefully not violating the 1880 water law ordinance, that dams could be built but the water flow could not be altered. Engineers had to reconstruct the river's natural flow and let the water flow through dams and turbines imitating the river's natural current. As a result, the indisputably largest power plant at Trollhättan, had to produce power from a water flow varying between 300 and 800 cubic meters per second. To uphold the natural water level so-called dam tables were worked out for the dam owner to follow. It is debatable that these tables could reconstruct a natural run-off. At this time, knowledge of discharge in the watercourses was diffuse. Manipulating the system was most likely possible. Using formulas from scientific literature to determine run-off in Swedish rivers did not automatically provide first-class results. As alleged by a opponent of a calculation made by a professor: "Every watercourse has its own character, and it is not granted, that River Klar, will force upon itself, a formula, set up for the Mississippi."[6] In this situation, the hydropower industry could only guarantee delivery of electricity equivalent to the minimum river discharge.

A decision in 1915, however, which allowed regulation of the previously mentioned Lake Skagern, changed this practice. The result of the 1899 King's Vein decision was at first sight a setback for the hydropower industry. However, it favored them in the long run. Their expansion was virtually unstoppable because of the major investments in dams, power stations and distribution lines to industries, which in turn had changed their energy sources.

So, who were the actors that forged the legislation to adjust it to the new technology? The advocates could be found in what was called *The Swedish System*, a mixture between one State and several private power companies. This organizational structure arose during the period of West-

ern European history known as organized capitalism. In organized capitalism, industrially rooted actors were given greater freedom of action. The Swedish System was ideologically charged. It was an industry-friendly and large-scale model, which was created at a time when democratic principles had not yet been introduced into Sweden. When the actors set themselves up as system builders, they were crossing a boundary. The group of about ten actors, consisting of engineers who owned hydropower companies, leaders in the State hydropower production, consultant engineers in the water development area, and water rights lawyers. Organized capitalism gave the Hydropower Developers more room to maneuver in the public sector. They were active over a wide area and were involved on many fronts. Their goal was to make Swedish hydropower always available and not dependent upon non-regulated and fluctuating rivers.

Making the Swedish hydropower system complete

The prospects were promising. The political climate became more and friendly towards the growing industry. The technical problems had been solved. Investments were being made in the new, large power stations. It was thus absolutely essential for the hydropower industry, both public and private, to change the legislation, partly so that they could fully exploit the major investments, and partly for the sake of future expansion. The motivation was thus not only the need for more power, but also the need to demonstrate the reliability of the new system. The system developers in Sweden had to show that the energy system could grow and satisfy the power demand.

The hydropower developers were supported by the engineers of the modernizing Sweden in their frustration over a King's Vein that allegedly had a "paralyzing effect on industry which would flourish at Sweden's magnificent waterfalls.". They considered that the water "uselessly run away through the holy King's Vein!"

Industry-friendly members of Parliament went on the offensive. For those wanting to industrialize the Swedish rivers, it was vital that water legislation incorporate the principle concerning reasonable use. Owing to more intensive exploitation of natural resources by both farmers and industry, the divide between the advocates for the two different principles of water allocation widened towards the end of the nineteenth century. It became a political affair and a legal power struggle.

On the other side, who were the opponents to the industrialization of the water system? It was the log-drivers and farmers in the early twentieth century who became the opponents to the big hydropower companies. Their interests where contradictory and this raised the political and legislative question concerning which interests controlling the flow of water were to be given priority. At this stage, as mentioned, the natural flow rule was becoming increasingly important to the agrarian interests because of their ever more intensive land use. Owing to more intensive exploitation of natural resources by both farmers and industry, the cleavage between the advo-

cates for the two different principles of water allocation widened towards the end of the nineteenth century. Opposition also arose because the riparians felt their rights of ownership to the land threatened if the water were raised above the shores during the vegetation period. This threatened the core of the small farmer's identity—his ownership of land. Furthermore it turned upside down the long traditions in the early 20th century of rules for interplay between riparians in water systems. In practice the legal protection the riparians had trusted in faltered under the pressure from the hydropower interests. It also disrupted their understanding of nature. The new regulation technique, which was to interplay with the demand for electricity from industries and towns far from the local community, would alter the rivers as they had known them.

A political campaign waged during the first two decades of the twentieth century to introduce Swedish legislation based on reasonable use. The Hydropower Developers had a decisive advantage in this struggle. They were strategically placed in Parliament, and they participated in the commissions which drew up suggestions for a new water law, and they gained from the general political context in Sweden by the beginning of the 20th century.

Parliamentarianism was on the way in Sweden. In 1907 the right to vote for Parliament was extended to all adult men. The relative strengths in Parliament consequently shifted. Certainly, the number of speakers for agrarian interests diminished. It was a matter of urgency, nonetheless. New political winds, principally represented by the Social Democrats, could however end the positive movement for the Hydropower Developers. The Left forces were not opponents to development of rivers, but they were supporters of stronger State control of hydropower development. Profits from the expansion of power should benefit all the members of society.

The Hydropower developers aim was to "work for the rapid and rational utilization of hydropower for the benefit of industry and the country." Their first goal was to establish "a practical water law", by awakening an interest in "macro-economically justified regulation of water level in lakes." Another method of achieving their aim was to interpret decisions on water distribution in a new way. Such decisions were no longer to be regarded as political questions, even if their own actions can clearly be seen an efficient political maneuvering. Consequently, the traditional definition of the natural flow rule was claimed to be out-of-date. Instead, the principle of reasonable use was given an ideological image associated with modernity and rationality. The Hydropower Developers directed their campaign for a new water legislation towards de-politicizing the limits for enterprise by precluding direct political influence. The decisive instrument was the move to establish special water courts, which would decide about water-related civil engineering projects. Water politics were also influenced by non-domestic events. With the First World War, a difficult power supply situation arose in Sweden. It became increasingly clear that the country needed to focus on domestic sources of energy. The agrarian interests finally gave way under this pressure.

In 1918, the new Water Act was passed, and brought with it the riparianism principle of reasonable use into Swedish law. If the benefit could be shown to be three times greater than the damage caused to fields and meadows and twice the damage to other property, water-related civil engineering projects and regulation of the water flow were allowed by the newly established water courts. If these conditions could *not* be fulfilled, but the enterprise was of considerable benefit to business or community, water-related civil engineering projects could be permitted by the government. The most important de-politicizing instrument was the move to establish special water courts that would decide about water-related civil engineering projects. The new water courts would not be peopled only by lawyers; technicians would also be decision-makers.

This provided the terminus in the first conflict over Swedish hydropower development. Substantial regulation of water had become possible. An expanding technical system was now in balance. The campaign for new water legislation, and the introduction of the principle of reasonable use, was a success. Now it was the closing off of water, and not keeping it open, which was given priority. A reverse salient in the technical system was a thing of the past. It can be claimed that the 1918 Water Act became an element of the socio-technical system. The power over the Swedish rivers had tipped over to those who wanted to industrialize the flowing water.

Epilogue

Not until the 1950s can we trace some ecological criticism, at this time still essentially esthetic, concerning the impressive harnessing of Swedish rivers. These critics were an elite of environmentalists, scientists and tourists who wanted to preserve parts of the water circulation in its natural state, especially in the north of Sweden. After 1970 environmental groups—The River Savers, with a distinct ecological platform—protested against hydropower development. These River Savers are said to form the foundation of the environmental movement in Sweden (Jamison et. al., 1990). The environmentalists became a new group protecting the principle of natural flow, at least for some of the Swedish rivers. After nearly one hundred years of one-dimensional use of the Swedish rivers, voices for open rivers were raised, this time in the name of protecting nature itself. Like the hydropower developers at the beginning of the century, they had to start with a political campaign. Their first victory was "The Peace in Sarek" (1963) when the hydropower industry promised for the first time *not* to exploit some rivers. In 1993 the four most important unharnessed rivers—the Torne, Kalix, Pite and Vindeln—were declared "National Rivers" by Parliament and were to be free flowing in the future. This must be regarded as a great victory for the modern anti-dammers. However, we have to keep in mind that up until today 70 percent of the power in the Swedish rivers already has been industrialized (Löfgren, 1997).

This shows that the concept of free-flow must not be interpreted as "natural," that is to say never touched by man. During the late 20th century new

environmental politics have led to new stipulations on dam operation in many places. For example at the Glen Canyon Dam it is no longer power demands that predominate the way water is let into Grand Canyon (Aton and McPherson 2000, p. 168). However, the water current could at any moment be altered again.

Summary

Man wanting to fetter the water circulation has at all times been a part of human civilization. It has affected both areas with abundant water and arid regions. During the 20th century hydropower development has played an important role in transforming rivers from free flowing to water systems controlled by man. These transitions can be discussed in technological as well as in a social perspective. However, the concept socio-technological system opens for an integrated analysis of these altered rivers.

The radical harnessed river is in this article described as an industrialized river—a river with its run-off rationalized and made into a production system generating electricity. This idea in its simplest form was explained by one of the Swedish hydropower pioneers as storing "Sunday water." The electricity system can furthermore be described as a seamless web—to use Thomas Hughes' metaphor. In this article the industrialized river is integrated in this seamless web, which also consists of distribution and transmission lines, hydropower plants, dams, institutions, organizations and actors.

Attention has been called to the social aspects of developing this socio-technical water system. To analyze the integration of social institutions regulating water infrastructure I have discussed this aspect of the early development of hydropower in Sweden. It has been especially emphasized that these institutions can be of hindrance or support to the build up of a water system, in this case a hydropower system.

Because of the abundant water in the Swedish landscape, many water-associated activities had to coexist. The waters of rivers and watercourses were linked to other alterations in the landscape, for example drainage of land used for agricultural purposes. In agrarian Sweden, there was a multi-purpose aim of keeping the rivers flowing naturally, as opposed to damming them. A legal institute, with roots in mediaeval law, King's Vein, secured river passage for migrating fish, minimized flooding, protected navigation and became the "high way" of log-driving. The King's Vein represented the legal principle of natural flow. This was the legal principle, and a social reverse salient, that the Swedish hydropower pioneers came in conflict with. They had to defeat it to make the hydropower system a functioning technical system.

During the 20th century, the social benefit of a one-dimensional use—power-generation—of the rivers became more valuable. After a very effective campaign by the hydropower pioneers and under the pressure on the country during First World War, it was made possible to introduce the principle of reasonable use in a new water law 1918. With the support of this new water law the power companies from now on could regulate rivers

and make lakes into reservoirs. The long era of Swedish hydropower development had begun. Thus the Swedish example illustrates that the actors can recreate social conditions in order to serve their technical ends. The extent to which the actors achieve their goal depends on the society in which the technical system is created.

Both free-flowing as well as industrialized rivers call for political control. In that respect the relations of power in the society are reflected in the way the water circulation is dominated (Worster, 1985 and 1986). Consequently the Large Technological System bears the stamp of the society in which it originates.

Notes

1. Henry David Thoreau quoted from Donahue 1989, p. 54.
2. Letter from Gustaf Grevilli to William Olsson, 18 March 1906, *William Olsson Archive* F 3: 22, in Museum of Science and Technology, Stockholm.
3. Swedish: "vattenbehållare".
4. Swedish: "söndagsdygnsvattnet".
5. The article is an expanded version of some results and discussions presented in my thesis from 1996 "The Industrialization of Rivers. Studies on the development of Swedish hydro-power, 1900-1918" ["Industrialisering av älvar. Studier kring svensk vattenkraftutbyggnad 1900-1918"]. For references, see my thesis (Jakobsson, 1996).
6. It is worth observing that, today, when talking about a non-harnessed river, we add the prefix free flowing or call them wild stream, to emphasize their natural state. See for example Waters, 2000.
7. This is not an established concept for hydropower development in Sweden. The expression is taken out of an expert examination during a trial 1910 on building a hydropower plant and a dam: "The industrialization of River Gullspång, i. e. the alteration of the water flow for the advantage of a rational utilization of the hydro power have already been started ... so as its river regime is rather irregular and dependent on human interventions, especially at lower water levels" (Record book, 1 November 1910, § 116, A 1a: 34, *Ölme, Wisnums och Wäse District Court*, in Kristinehamn District Court).
8. Hughes, 1987, p. 51.
9. For discussions and examples of other systems of water legislation, see Teclaff 1972, Dunbar 1983, Wisdom 1975 and Glick 1970.
10. Riparianism has its origins in countries with private landownership. In states with a strong central regime, navigable floods are often exempted from this principle (Teclaff 1985, p. 6-7).
11. "Sänkta och torrlagda sjöar", SMHI Hydrologi, nr 62, 1995.
12. Despite the name there are no signs of possession of King's Vein by the kingdom. The first element—King's, is interpreted as the King being entitled to keep King's Vein open. At the end of the 17th century the King guaranteed "an open way in all rivers and rapids all over the country". This could indicate that the principle of natural flow was not followed.
13. Report, 6 September 1906 by Sven Lübeck for Vattenbyggnadsbyrån, *Dejefors Kraft och Fabriks AB* F 2D: 1, in *Värmland Archives*.

References

Adell, B. (1992). Lule älv. Hydrologi och kraftverk. In *Norrbottens Natur*.

Aton, J. M. & McPherson, R. S. (2000). *River Flowing from the Sunrise. An Environmental History of the Lower San Juan*. Logan, Utah: Utah State University Press.

Blomqvist, E. (1970). *Indalsälven - en kraftkälla*. Östersund: Wisénska bokh..

Brandt, M. & Ehlert, K. (1996). Avrinningen från Sverige till omgivande hav. In *SMHI Hydrologi*, nr 65.
Cronon, W. (1991). *Nature's Metropolis: Chicago and the Great West.* NewYork: W. W. Norton.
Donahue, B. (1989). Dammed at Both Ends and Cursed in the Middle: "The Flowage" at the Concord River Meadows, 1798-1862. *Environmental Review*, 13.
Dunbar, R. (1983). *Forging New Rights in Western Waters.* Lincoln: Univ. of Nebraska Press.
Dynesius, M. & Nilsson, C. (1994). Fragmentation and Flow Regulation of River Systems in the Northern Third of the World. *Science,* vol 266, 4 November.
Glick, T. F. (1970). *Irrigation and Society in Medieval Valencia.* Cambridge, Mass.
Hughes, T. P. (1987). The Evolution of Large Technological Systems. In *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology.* Cambridge, Mass: MIT Press.
Jakobsson, E. (1996). *Industrialisering av älvar. Studier kring svensk vattenkraftutbyggnad 1900-1918.* Göteborg: Göteborgs universitet.
Jamison, A. & Eyerman, R. & Cramer, J. & Læssøe, J. (1990). *The Making of the New Environmental Consciousness. A Comparative Study of the Environmental Movements in Sweden, Denmark and the Netherlands.* Edinburgh: Edinburgh Univ. Press.
Lauer, T. E. (1970). Reflections on riparianism. *Missouri Law Review* vol 35.
Löfgren, L. (1997). Moratorium in Sweden. An account of the dams debate. In *Dams as Aid. Routledge Studies in Development and Society 3.* London: Routledge.
Myllyntaus, T. (1991). *Electrifying Finland. The Transfer of a New Technology into a Late Industrial Economy.* London: Macmillan.
Nye, D. E. (1999). Remaking a "Natural Menace": Engineering the Colorado River. In *Technologies of Landscape. From Reaping to Recycling.* Amherst: University of Massachusetts Press.
Pisani, D. J. (1992). *To Reclaim a Divided West. Water, Law and Public Policy, 1848-1902.* Albuquerque: University of New Mexico Press.
Pisani, D. J. (1996). *Water, Land and Law in the West. The Limits of Public Policy, 1850-1920.* Lawrence: Univ. Press of Kansas.
Pisani, D. J. (2000). Beyond the Hundredth Meridian. Nationalizing the History of Water in the United States. *Environmental History,* 5 (4).
SMHI Hydrologi (1995), nr 62. *Sänkta och torrlagda sjöar.*
Steinberg, T. (1991). *Nature Incorporated. Industrialization and the Waters of New England.* Cambridge: Cambridge Univ. Press.
Steinberg, T. (1995). *Slide Mountain, or, The Folly of Owing Nature.* Berkeley: Univ. of California Press.
Teclaff, L. A. (1967). *The River Basin in History and Law.* The Hague: Martinus Nijhoff.
Teclaff, L. A. (1972). What You Always Wanted to Know About Riparian Rights, But Were Afraid to Ask. *Natural Resources Journal,* January.
Teclaff, L. A. (1985). *Water Law in Historical Perspective.* Buffalo. NewYork: William S. Hein.
Waters, T. F. (2000). *Wildstream. A Natural History of the Free-flowing River.* St. Paul Minnesota: Riparian Press.
Wisdom, A.S. (1975). *The Law of Rivers and Watercourses.* London: Shaw and Sons.
Worster, D. (1985). *Rivers of Empire. Water, Aridity, and the Growth of the American West.* NewYork: Pantheon Books.
Worster, D. (1986). The Hoover Dam: A Study in Domination. In *The Social and Environmental Effects of Large Dams, Volume 2: Case Studies.* Camelford: Wadebridge Ecological Centre.
Worster, D. (1990). Transformation of the Earth: Toward an Agroecological Perspective in History. *The Journal of American History,* 4.