Lahden ammattikorkeakoulu
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The removal of a culture-historical dam for improved resilience of urban nature

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Urban sustainability
Master´s Thesis
Autumn 2017
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VALTONEN, TIIA:

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Master's Thesis

104 pages, 9 pages of appendices

Autumn 2017

ABSTRACT

Tikkurila dam is in the River Keravanjoki in the centre of Vantaa and it has lost its original function of providing water power for linseed oil production. The dam is an important part of the historical factory surroundings of Vernissa, but it is in poor condition and in need of refurbishing. The dam is an obstruction for migratory fish species that try to climb upstream to spawn and the waterfront is heavily focused by recreational pressure. All these factors combined have set the dam removal decision-making process in motion. The project has been carried out by Ramboll Finland Oy for the city of Vantaa since 2014 and the plan implementation and dam removal is expected to take place in 2019.

This thesis introduces the project process and the case area of Tikkurila dam. It also aspires to evaluate the physical, biological and cultural changes in the case area resulting from the dam removal and river restoration and to form a monitoring programme to survey the main outcomes. One objective is to review how the benefits and losses in ecological quality compare with those in cultural quality. A literature review has been conducted on free-flowing rivers, the effects of dams on river integrity and ecosystem, dam removal and river restoration processes and possible dam removal outcomes. The evaluation of changes has been performed by using the ecosystem services approach as a framework. The study indicates that the ecological benefits obtained by performing the dam removal and river restoration are greater than the losses in some cultural services (i.e. culture-historical surroundings). The dam removal will affect many services in the area, but most importantly will restore the integrity of the natural river ecosystem. The effects should be monitored through key indicators of the most essential services. The study was cohesive with the literature review and it suggests that dam removal projects should be carried out as a multi-disciplinary and co-operative process.

Key words: Dam removal, river restoration, monitoring program, urban ecology, ecosystem services, free-flowing waters

Lahden ammattikorkeakoulu
Kestävä kaupunkiympäristö

VALTONEN, TIIA:

Kulttuurihistoriallisen padon purkaminen kaupunkiluonnon elinvoimaisuuden parantamiseksi

Case Tikkurilan pato

Opinnäytetyö (YAMK) 104 sivua, 9 liitesivua

Syksy 2017

TIIVISTELMÄ

Tikkurilan pato sijaitsee Keravanjoessa, Vantaan Tikkurilassa. Se on menettänyt alkuperäisen tarkoituksensa tuottaa vesivoimaa vernissaöljyn tuotantoon, mutta on edelleen tärkeä osa Vernissan teollisuushistoriaa. Pato vuotaa ja on laajan kunnostuksen tarpeessa. Pato ja huonosti toimiva kalaporras muodostavat kulkuesteen vaeltaville meritaimenille, jotka yrittävät päästä ylävirtaan kutemaan ja jokirantaan kohdistuu suuria virkistyksellisiä paineita. Nämä tekijät yhdessä vaikuttivat päätökseen aloittaa selvitys padon poiston mahdollisuuksista. Projektin on tehnyt Ramboll Finland Oy Vantaan kaupungille. Esiselvitys käynnistettiin vuonna 2014 ja suunnitelman toteutus ja padon poisto tulee todennäköisesti tapahtumaan kesällä 2019.

Tämä opinnäytetyö kuvailee projektin eri vaiheet ja Tikkurilan padon alueen ominaisuudet. Opinnäytetyössä pyritään arvioimaan padon poiston ja jokikunnostuksen aiheuttamat fyysiset ja kulttuuriset muutokset alueella ja muodostamaan seurantaohjelma, joka keskittyy tärkeimmiksi havaittuihin muutoksiin. Yksi tavoite on myös arvioida muutoksesta aiheutuvien ekologisten ja kulttuuristen ominaisuuksien hyötyjä ja haittoja keskenään. Kirjallisuustutkimus on tehty vapaista virtavesistä, patojen vaikutuksista jokien eheyteen ja ekosysteemiin, patojen poiston ja jokikunnostuksen prosesseista ja mahdollisista patojen poiston lopputuloksista. Muutosten arviointiin on käytetty ekosysteemipalvelu-näkökulmaa, koska se mahdollistaa kulttuuristen ja ekologisten vaikutusten vertailun rinnakkain. Tutkimuksen mukaan padon poiston ja jokikunnostuksen ekologiset hyödyt ovat suuremmat, kuin padon poiston kulttuuriset haitat. Padon poistolla on vaikutuksia moniin ekosysteemipalveluihin alueella, mutta tärkeimpänä on joen eheyden ja luonnollisen ekosysteemin palautuminen. Vaikutuksien seurantaa tulisi tehdä pääasiassa avainindikaattorien kautta, jotka muodostuvat projektin tavoitteista. Tutkimuksen tulokset ovat yhteneväiset kirjallisuustutkimuksen kanssa ja sen mukaan padon poisto-projektit tulisi toteuttaa monialaisina ja yhteistyöpainotteisina prosesseina.

Asiasanat: padon poisto, jokikunnostus, seurantaohjelma, kaupunkiekologia, ekosysteemipalvelut, vapaat virtavedet

CONTENTS

1 INTRODUCTION

This thesis records the process of a project that started as a pre-survey for the rehabilitation of the Tikkurila dam and developed into the realization plan of the rapid Tikkurilankoski. The project has been carried out by Ramboll Finland Oy for the City of Vantaa, starting in 2014 and continuing at least until the year 2019, when the dam removal presumably takes place. The author of this thesis has been involved in the project from the start as a project coordinator and landscape designer.

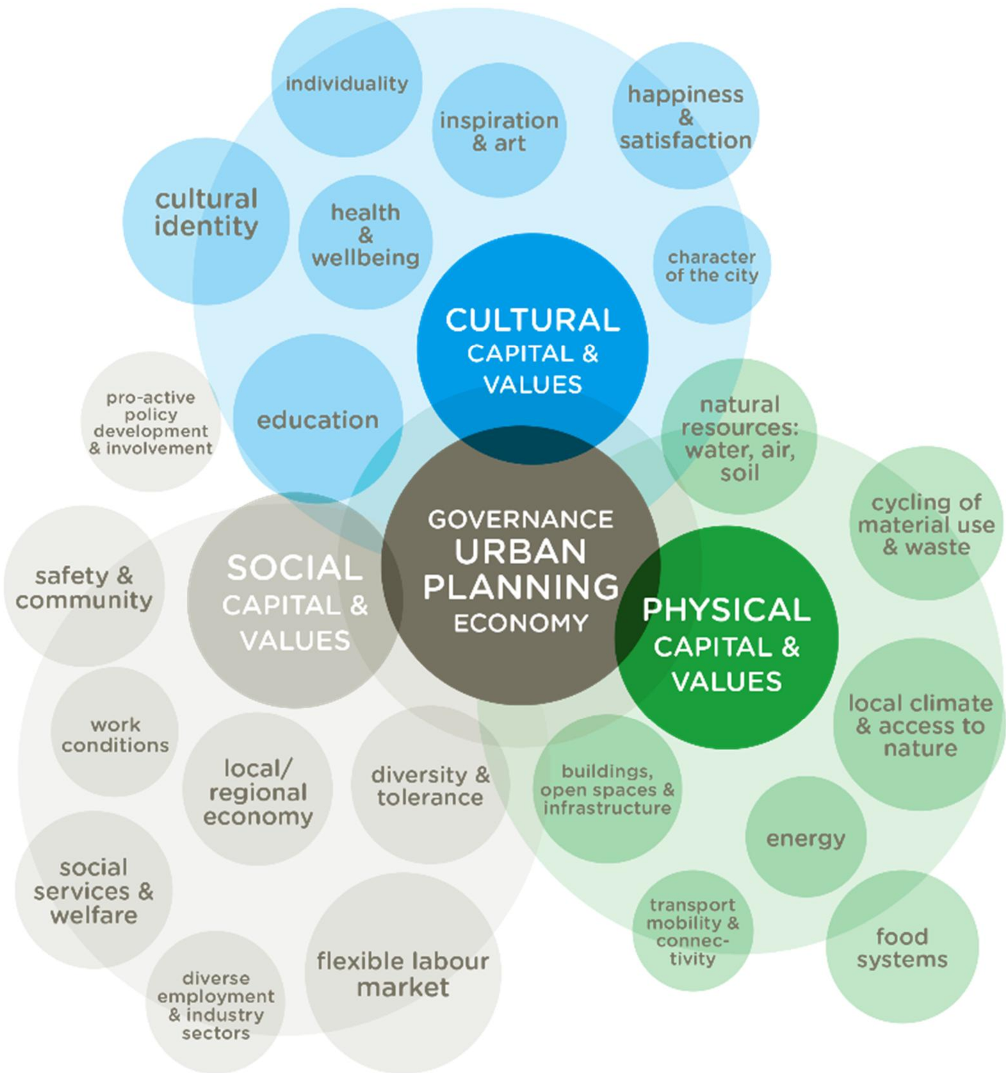


Figure 1. The main parameters of a liveable city (Liveable cities 2015, 19).

Urbanization is one of the megatrends of our time. Now, half of the world population lives in cities and this causes many urban challenges, such as social issues, pollution and scarcity of water. People move into cities seeking a better life and this drives the demand for liveability. The definition of liveability is unique in every city, but the approach of liveable city development is holistic, multi-dimensional and sustainable. It involves cultural, social and physical capital and values, and allows people and society to develop prosperously. (Liveable cities 2015, 2-19.)

Case Tikkurila is a good example of liveable city development because it has a holistic approach and it strives for a more resilient urban environment not only for people, but also fish and other organisms of nature. The demand for the project arose from the fact that the dam needed refurbishment and there was great technical and political ambition for studying the possibilities of removing the dam.

From the very start of the process it was apparent that there were three principal factors affecting on the dam removal question: fish, cultural history and recreation, and that there was a contradiction between removing the dam for improved fish passage and preserving the dam as part of the cultural historical integrity. The process has engaged an extensive network of experts, stakeholders, decision-makers and residents, ensuring that the ambitions and opinions have been heard and the result is accepted by a majority.

In the pre-survey phase, multiple alternatives were examined to map out the viable solutions, their effects and crude costs. The alternative, which suggested total or partial removal of the dam and a long river restoration area, was chosen by the technical board on 18 August 2015 to continue with in general planning. A landscape architecture competition was arranged starting in August and ending in November 2015. The winning design was called “Keidas” and it was designed by Loci Maisema-arkkitehdit Oy.

The general planning phase included conducting numerous surveys, compiling the application for a water permit, modelling the channel hydraulics and designing the dam removal, fish ladder reuse, the channel structure and the river banks on the upstream side of the current dam. The technical board of Vantaa accepted the general plan and dam removal on the 8th of November 2016. At present, the detailed planning phase is underway and likely to finish in early 2018. The water permit is expected to be granted in the spring 2018 and dam removal and river restoration to take place in the summer 2019.

The main objectives of this thesis have been to record the process and goals of the Tikkurila dam project, evaluate changes in the physical, biological and cultural environment when the plan is implemented by using the ecosystem services approach as a framework and to form a monitoring programme for getting valuable information on the ecosystem rehabilitation after the dam removal. This thesis includes a short literature review on the effects that segmenting rivers have on social, culture and physical capital, how dam removal processes could be conducted to achieve a result where all stakeholders have been heard and how dam removals are expected to change the river ecosystem.

Dam removal is a topical issue in Finland. Even though dam removals and restorations for fish have been performed for decades, the case of Tikkurila dam represents a new generation of projects where cultural environment is modified to support urban sustainability and resilience. Fervent discussions are undertaken on numerous dams in the largest cities in Finland, such as the dam of the rapid Vanhankaupunginkoski and the dam of the rapid Tammerkoski.

2 BRIEF REVIEW ON DAMMING AND UNDAMMING RIVERS

Rivers are lifelines that constitute an immense part of all ecological processes on earth. They provide an immeasurable amount of services to all life on earth. The view on rivers has through the ages been anthropocentric, leading to regard them as a commodity. From an early stage in human history, societies have been established near rivers, since they have provided food, water and security. The extent of exploitation has left our rivers polluted, segmented and degraded. Even though the consensus has been shifting towards restoring the state of our rivers and water systems, the growing population and increased urbanization has led to a demand for more food, electricity, irrigation and other services provided by rivers. There has been a lot of debate globally on preserving our few free-flowing rivers and removing dams to restore the integrity of rivers. Dam removals have been carried out extensively globally and it is becoming more and more common, as the benefits are revealed.

2.1 Free-flowing rivers and the threats dams impose on them

A free-flowing river is a river that flows undisturbed from the source to its mouth, into the sea, a lake or another river. The ecosystems of a river and its landscape are formed of five main components that each contribute to the integrity of a free-flowing river. The components are physical habitat, flow regime, energy and food base, biological interactions and water quality. (WWF 2006, 2.)

Free-flowing rivers have been recognized through the ages as one of the most vital ecosystems to sustain human life. Therefore, undisturbed rivers are increasingly rare and most have been extensively modified with weirs, dams and drainage channels. These measures have mostly been carried out to harness the provisioning services i.e. the products obtained from river ecosystems, such as water, food and energy. However, in recent years, recognition of equally important, regulating and cultural services has been growing. (WWF 2006, 2-4.)

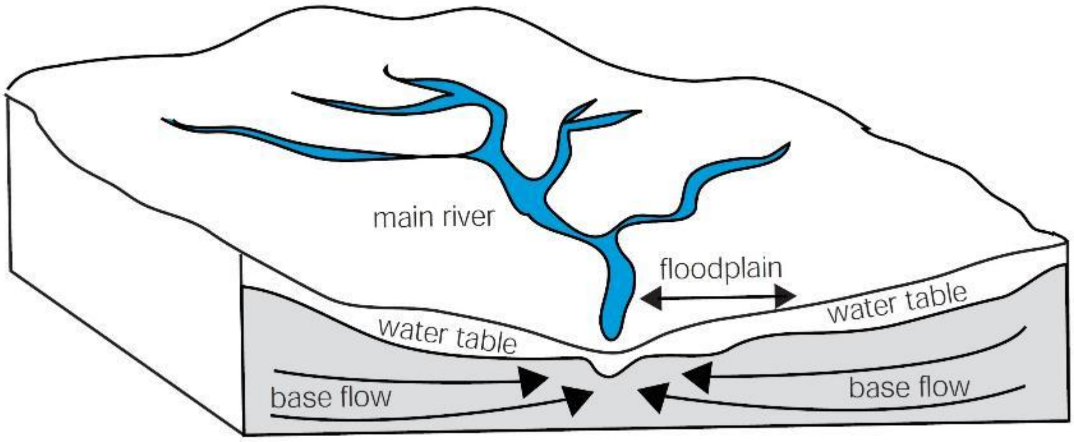


Figure 2. The interactions of a free-flowing river (WWF 2006, 2).

Dams impair many of the ecological functions provided by different flow levels (see figure 3). It has been estimated that freshwater biodiversity is degrading more rapidly than any other ecosystem. (WWF 2006, 10-11.)

The modification of rivers will lead to several declining regulating services. It can increase evaporation loss, age runoff resulting in poor water quality (water will be 2-4 times older when it reaches the mouth), interrupt the flow of carbon, change nutrient balance and alter oxygen and thermal conditions. Rivers carry a lot of sediment to estuaries. By damming a river, the sediment will be deposited in the dam pool, leading to multiple problems when the sediment gets free, releasing also the nutrients and pollutants collected in the sediment. (WWF 2006, 6.)

The size of the dam must be considered when analysing the effects it has on the river. Whereas large dams create large reservoirs, have sediment deposits and store inflows, small run-of-river dams have very few effects on the flow of water downstream, preserving the flow levels and seasonality on the river reach. (The Heinz Center 2002, 24-25.) However, the removal of small dams might have extensive effects on river ecology by enabling fish passage and restoring ecosystems on long river reaches (The Heinz Center 2002, 50).

Damming and fragmenting rivers will most probably have a negative effect on fish production on both sides of the dam. The most radical impact will be targeted at migratory fish species. (WWF 2006, 5). Free-flowing rivers help ecosystems adapt to climate change by allowing warm-water fish to expand in the north and the south (WWF 2006, 7).

Low (base) flows	**Normal level:** • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in the floodplain and soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (those living in saturated sediments) **Drought level:** • Enable recruitment of certain floodplain plants • Purge invasive introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel, including pools and riffles • Determine size of stream bed substrates (sand, gravel, and cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels and prevent siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., in insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish and waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels and oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

Figure 3. Ecological functions provided by different flow levels (WWF 2006, 10).

> *"Dams and other infrastructure fragment 60 per cent of the large river systems in the world (MEA, 2005)." (WWF 2006, 11.)*

Dams affect freshwater ecosystems by:

- Dividing the river and cutting off connections
- Disconnecting rivers from their floodplains and wetlands
- Reducing water speed in river
- Obstructing migratory fish movement
- Flooding habitats of low water levels, such as rapids and riverbanks
- Preventing natural sediment movement to deltas etc.
- Affecting natural nutrient cycle
- Reducing flood pulses, therefore influencing the downstream riparian and wetland ecosystems
- Often reducing water quality and the waste processing capacity
- Altering temperature
- Releasing water at artificial times and volumes
- Impairing oxygen levels
- Changing chemical composition
- Hosting non-native and invasive species

(WWF 2006, 12.)

The upkeep of a dam is usually expensive, and their useful life expectancy is quite short. Dam safety is often an issue because a dam failure can lead to unexpected floods and even to the loss of lives. Recreation near dams (fishing, canoeing) might also result in accidents. (The Heinz Center 2002, 41-45.)

Dams also contribute to global warming. It is estimated that the reservoirs they establish produce as much global greenhouse gas emissions (mainly methane) as global aviation. (International Rivers 2017.)

Damming rivers was most popular in the 20th century. The decline in the number of large free-flowing rivers started in the beginning of the 1900s and by the 1980s fewer than 50 % of the largest rivers were undammed.

For the last three decades building of new dams has been moderate, but there is a rising need to harvest water for energy and supply along with mitigating climate change effects on urban structures, posing a threat to the surviving free-flowing river ecosystems. (WWF 2006, 15.)

Dams in the US have been built mostly to harness water and produce power and electricity. Other reasons have been to create reservoirs for recreational purposes, have water storage for fire extinguishing and farming, improve flood control, ensure sufficient water supply for urban, domestic and industrial use, trap water for irrigation, build waste disposal ponds and ensure navigation on the inland rivers with adequate water depth. (The Heinz Center 2002, 32-40.)

In recent decades, the impacts dams impose on ecology and hydrology have become more widely recognized. Fish and fauna passages have been constructed for many years, especially in northern Europe. The problem with the technical solutions is that they only work for a few species and will not benefit the other aspects of a free-flowing river. A new trend, especially in northern Europe and the US is to conduct a full restoration and removal of the barrier. In energy production, the interest has been shifting towards wind and solar energy instead of hydropower. However, the use of hydropower is still increasing globally, and the main focus is in China and Asia (see figure 4). (Adamsen, 2015.)

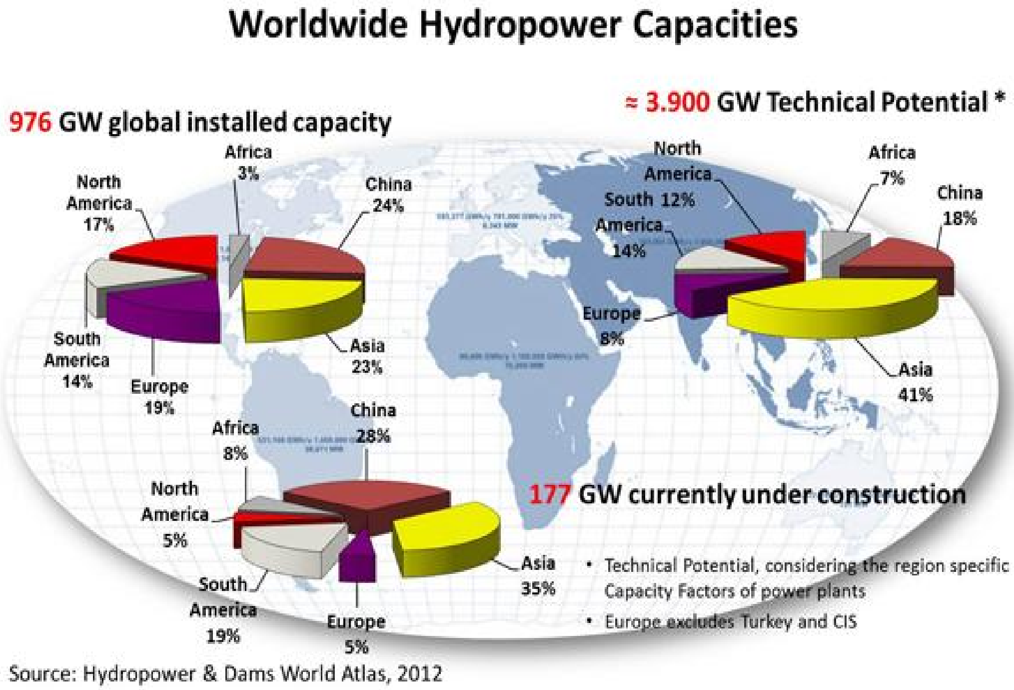


Figure 4. Worldwide hydropower capacities (Adamsen, 2015).

2.2 Dam removal and decision making

Dam removal is a complex process and the decision should be made with careful consideration of the benefits, detriments and effects it will cause. The removal process is site-specific and in most cases, there are competing values and perceptions to consider. A dam removal project will be acceptable to managers, decision makers and the public, when it considers administrative, political, social and environmental issues and takes economic values into account. (The Heinz Center 2002, 79, 96). A general method for making decisions about dam removal proposed by The Heinz Center is represented in figure 5.

To perform step 1, a diversified stakeholder group needs to be assembled. In the first step, the group is to evaluate the original purpose and need for the dam in present situation. Another question to address is the additional concerns that have arisen since the dam has been built (e.g. safety issues), which might challenge the outright need for the dam. (The Heinz Center 2002, 80-83).

After the issue of leaving the dam in place or removing it has been settled on in step 1, a transparent review should be carried out to identify stakeholder controversies and concerns. The project group needs to involve experts from many different fields and institutions, and the review should include views from different owners in the area (dam owner, land owners etc.), local government and federal regulatory agencies, non-governmental organizations and groups and the individual citizens. An extensive involvement of stakeholders will be the best way to compromise and reach a credible decision about dam removal, and it might even create new innovations and reveal concerns to be addressed in an early stage. In most cases, the project group needs to address at least the issues that are presented in figure 5. (The Heinz Center 2002, 84).

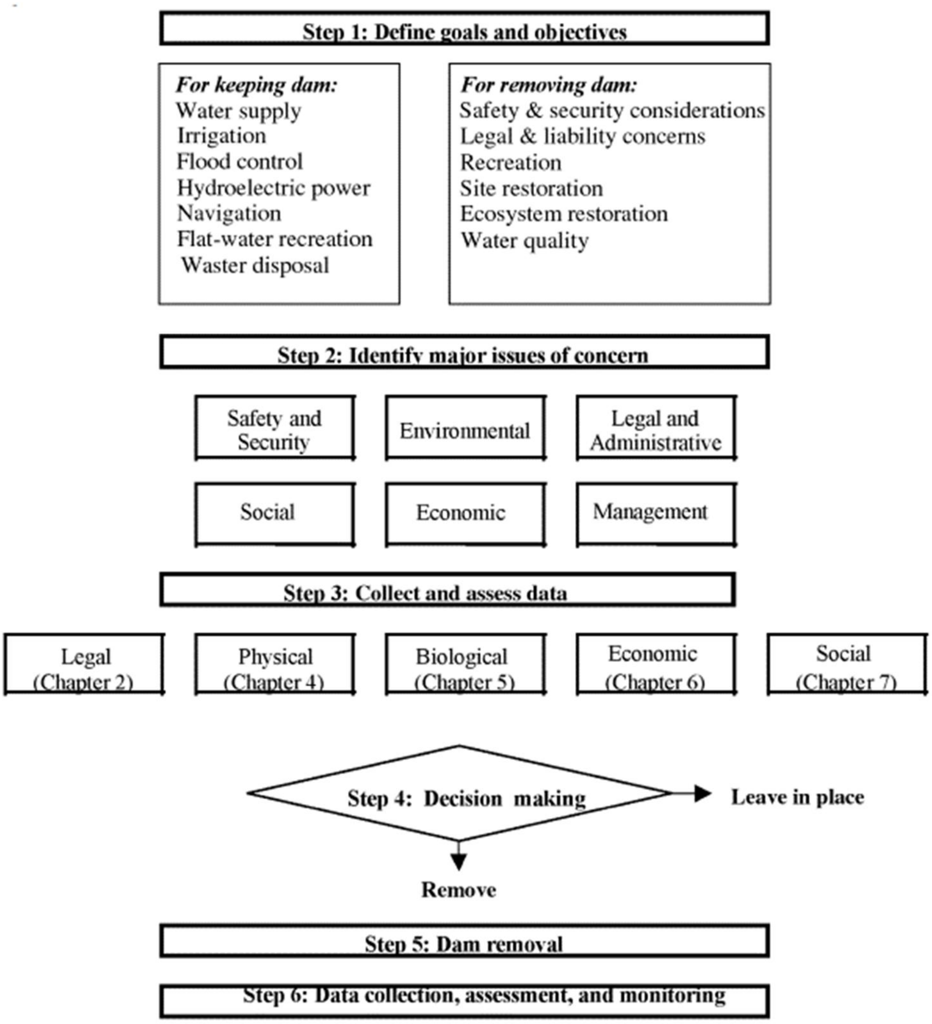


Figure 5. Dam removal decision process. (The Heinz Center 2002, 80.)

Step 3 consists of data collection and assessment. The Heinz Center suggests it to be performed with the help of a list of indicators that will be quantified and measured, and the outcomes predicted. Other similar rivers, both with and without a dam can be perceived as points of reference. (Dam removal, 88-89)

Once enough data has been collected, the assessments conducted, stakeholders and the public heard, and legal issues tackled, decision making takes place. The process will most likely focus on scaling the concerns of safety, economics, ecological drivers and benefits, societal views, legal issues, public interest and support and interests from local to international level. (The Heinz Center 2002, 89-94.)

Step 5 is the actual dam removal, which should be designed carefully taking all aspects (engineering, environmental, social, economic) into consideration. After removal, it is essential that sufficient monitoring takes place (step 6). Monitoring will give information on how the objectives of removal project are met. It will also give data on how the ecosystem adapts and recovers, which can be used as reference in other dam removal projects. (The Heinz Center 2002, 94-95.)

2.3 River restoration

Restoration or rehabilitation of rivers is a common goal of a dam removal project. Restoration can either be a passive or an active process, or both. (The Heinz Center 2002, 140-145.)

> *Passive restoration uses the natural river processes following their own timetable. Active restoration involves direct actions and management to assist in the restoration effort. (The Heinz Center 2002, 145.)*

The rate of a passive restoration might be slower than that of an active one, and it may not reach all goals that have been set for the project, as the active restoration success is dependent on the expertise of the restoration group and luck. Often the best approach is to use both, active and passive methods. (The Heinz Center 2002, 148-149.)

There are numerous factors that affect restoration success rates.

Physical habitat. The size of the dam, reservoir, and its location in the watershed effect on the revival capacity of the river reach.
Restoration of terrestrial and riparian vegetation. The integrity of the riparian corridor and effectiveness of riparian and watershed vegetation support the physical and biological components of the aquatic ecosystem.
Size of disturbed area and upstream sources of drift. Great distances to colonizing macroinvertebrates and fish decrease the possibilities of a successful restoration.
Continued disturbances. Disturbances (i.e. land use changes upstream causing flow control) slow and limit the restoration rate.
Frequency of previous disturbances. Aquatic community that has experienced disturbances may have the ability to revive more effectively than a community that has seen few to no disturbances.
Presence and proximity of refugiums. The smaller the distance to recolonization organisms is, the better are the possibilities for a successful restoration.
Flushing capacity and persistence of disturbance. If the sediments behind the dam are not flushed from the system quickly, the system takes more time to recover.
Watershed characteristics and land use. If the watershed includes i.e. agriculture, logging or mining activities, it is prone to experience sediment and flow disturbances.
Timing of disturbance and life cycles of the biota. The life stage and the species distribution of the colonizing population might affect the sequence and succession of the restoration.
Nutrient input and recycling. Low nutrient input and turnover in the system indicate low resilience, which might lead to poor restoration success.

Location of disturbance in stream course and stream order. If the dam removal occurs lower in the river system, there is a larger pool of recolonization organisms available.
Water quality. Water quality has high effects on restoration success rate.
Upstream watershed. High integrity upstream can indicate better possibilities of successful restoration.
Temperature. Thermal regimes define a large part of the aquatic assemblage after the disturbance.
Sediment. Increased turbidity and sediment levels after dam removal can affect heavily on downstream ecosystem and delay the recovery.
Heavy metal mobilization. Mining waste and heavy metals can be trapped in sediments and impact on water quality after dam removal.
Dissolved gas. Water released during a dam removal might increase the levels of total dissolved gases downstream.
Organic matter transport. Sunken trees, aquatic plants etc. can be mobilized and build up organic matter and carbon supply downstream.
(The Heinz Center 2002, 149-156.)

Measures for biological diversity, abundance, and ecosystem processes are considered key indicators when assessing restoration success on the field. (Palmer et al. 2014, 256.)

Palmer et al. (2014) have listed three dominant perspectives on river restoration methods.

Restoration as channel design

The science and practice of channel design has been used in a majority of river restoration projects. It considers flow as a master variable in riverine ecosystems and focuses on forming the channel, possibly by using boulders, wood and armoured banks to slow water and prevent erosion. The method suggests that when the channel is equipped to handle flow and sediment fluxes, ecological processes will be restored. The method has been widely critiqued and there are numerous examples of project failure due to primary focus being on channel form or physical structures instead of ecological processes. Often water quality is the factor that affects most on successful restoration, and in many channel design projects it is overlooked. (Palmer et al. 2014, 249-251.) In many projects where channel design was used to improve stability as the primary method, success has been moderate. Even though the projects have shown progress in habitat, channel form, substrate or local velocity, few of them have succeeded in restoring biodiversity. (Palmer et al. 2014, 259.)

Restoration of ecological function

Restoration of ecological functions is an emerging approach to river restoration and it goes beyond hydrogeomorphic processes and includes also restoring ecological processes. The method considers restoration of structural ecosystem features (e.g. riparian vegetation) and ecological processes (i.e. nutrient cycle). This approach has become more popular partly due to increasing interest towards ecosystem services. (Palmer et al. 2014, 251-252.) In the research Palmer et al. (2014) performed the highest success rates were in the projects that involved riparian zone restoration which includes either planting native vegetation or removing non-native vegetation. (Palmer et al. 2014, 262.)

Restoration beyond the channel and beyond the disciplinary silos

This method suggests that the stressors (e.g. uncontrolled stormwater runoff) affecting the stream are outside of the channel in the watershed and once they have been removed, the stream will recover on its own. Dam removal projects are a good example of functional restoration that targets problems at their source. There have been many successful projects involving watershed-scale restoration. (Palmer et al. 2014, 252-253.)

2.3.1 The effects of dam removal

The ecosystem is impossible to restore to the pre-dam condition, but a primary goal of restoration should be the recovery of the system to an approximation of its undisturbed condition. (Dam removal, science and decision making, 141)

The removal of a dam will not completely restore the past conditions of the river, but it provides a more natural aquatic environment in place of the dam, and most importantly it enables the processes of a free-flowing watercourse that works as an integrated system. River ecosystem functionality is sometimes difficult to predict, because of the complex riverine systems and the interrelated changes in them. (The Heinz Center 2002, 6-8.)

The outcome of a dam removal depends on the size of the dam. Run-of-river dams might have very little effects on the physical and biological state of the river, as large dams significantly alter the entire river downstream. (The Heinz Center 2002, 98, 102.)

According to a study performed by Bednarek, the most important ecological measures for assessing the effects of dam removal are flow, shift from reservoir to free-flowing river, water quality, sediment release and transport and connectivity. (American Rivers 2002, 1.)

The natural flow regime of a river supports a large diversity of species, both aquatic and terrestrial. The flow regime in a free-flowing river changes in magnitude, regularity and seasonality. Dams affect a river's flow fluctuations by storing water in the reservoirs. This can alter the aquatic community by limiting diversity to a few species that can survive the changed flow conditions of the river. Research shows that by removing a dam and restoring the natural flow regime in a river, biodiversity and the density of native species are increased. The removal of dams might also enhance the reproduction rates of migratory species, since they often depend on high flows to get to their upstream breeding grounds. (American Rivers 2002, 2-3.)

Dams create reservoirs, which provide habitats for species that survive in a lake-like warm-water environment and accordingly the composition of the aquatic community is likely to change. According to research, restoring the natural riverine conditions allows the revival of native cold-water aquatic species and terrestrial species, whereas the species that have survived in the reservoir will most likely decline. (American Rivers 2002, 3-4.)

Reservoirs have warmer, slower and deeper water, which often causes poor oxygen conditions in the bottom layer of water. The low-oxygen water might be released as tail waters, affecting river conditions downstream. The warm reservoir can create a thermal block for migratory fish, considering that they are acclimated to colder waters. The removal of a dam naturally restores the oxygen and temperature conditions of the river. Drawing down a reservoir needs to be executed slowly and controllably to minimize the short-time effects of releasing warm, low oxygen waters downstream. (American Rivers 2002, 4-5.)

Sediment transport is one of the most vital processes of a river, because it supports riparian and riverine habitats and species. Different flows carry a wide variety of sediment sizes ranging from small, nutrient-rich sediments to boulders, accordingly enhancing species diversity and aquatic health. Often a dam blocks the movement of sediment, causing erosion in the river channel and stream banks downstream. Changes in sediment transport might result in inhospitable habitats. Removing the dam restores the sediment conditions to a pre-dam state. Native species will most likely benefit from returned natural habitats and breeding grounds, and increase in numbers. The sediment release might cause short-term increase in turbidity and poor water quality, and it needs to be addressed especially if the sediments are contaminated. In most cases the effects are temporary and timing the sediment release helps mitigate the effects. (American Rivers 2002, 6-8.)

A dam segments a river and accordingly connectivity both up- and downstream for migratory fish species and other aquatic species. Dams isolate populations and habitats by changing the riverine conditions physically and thermally, subsequently reducing reproduction. Removal of a dam secures the appropriate timing for breeding, decreases mortality of fish swimming up- and downstream and supports safe passage for fish of all sizes. It has been recognized that also non-migratory fish and other wildlife benefit from dam removal. The integrity of the entire river needs to be acknowledged - if one dam is removed but several are still in place on the same river reach, fish migration is yet disrupted. (American Rivers 2002, 9-10.)

Other physical changes resulting from dam removal include channel forming. Most dams cause channel shrinkage and reduced geomorphic complexity, because of the lack of peak flows. Often implementation of a dam reduces the total available space in a channel. The shrinkage of a channel is likely to be reversed when a dam is removed. (The Heinz Center 2002, 118-119, 123.)

Social and cultural issues are as important to consider as the physical and biological qualities of a dam removal process. Often social and cultural aspects relate to aesthetics, recreation and cultural and historical preservation and they are vital to involve in decisions, since society pays the costs of dam removal both in monetary terms and lifestyle changes. The natural environment has been valued in diverse ways throughout human history. For a prolonged period, rivers were thought of as a commodity and damming them was a natural and necessary way to harness water for power. Only in the early twentieth century was it realized how important the conservation of resources really is. Today there is a desire for aesthetically pleasing environments along streams and restoring riparian corridors for natural species, but a set of values for social and cultural aspects that apply to every site, is hard to define. Therefore, dam removal depends largely on the public perception of the project. (The Heinz Center 2002, 175-180.)

Study has shown that often the public appreciates restoring biological conditions in a river, and consider it to be important. Kananen found in her research, that different user groups (fishermen, residents on the riverfront, kayakers) were favourable towards river restoration and the project had improved their cultural services and the scenery was considered to be more beautiful and natural. It had also positive effects on the sound scenery. (Kananen 2014, 83). Polizzi et al. noticed that most respondents (85 %) were willing to visit a restored river area more often because of improved recreation facilities and fish breeding conditions. (Polizzi et al. 2015, 8-9.)

2.4 Experiences from Denmark

The author participated in organizing an excursion to Denmark to learn about dam removal and river restoration projects. The experiences from the trip are introduced in this chapter.

Denmark has a long tradition in weir removal and stream restoration, which contributes to Denmark being one of the best places to fish for sea trout in Europe. Still there are approximately 3500 weirs in numerous sizes disconnecting Danish rivers and streams. All the weirs have been planned to be removed by the year 2021. (Seatrout Fyn 2017.)

Hydropower was one of the reasons that Atlantic salmon disappeared from Danish rivers. The Atlantic salmon's life cycle is dependent on migratory routes between the sea and the upper reaches of the river where its spawning grounds are. (Adamsen, 2015.)

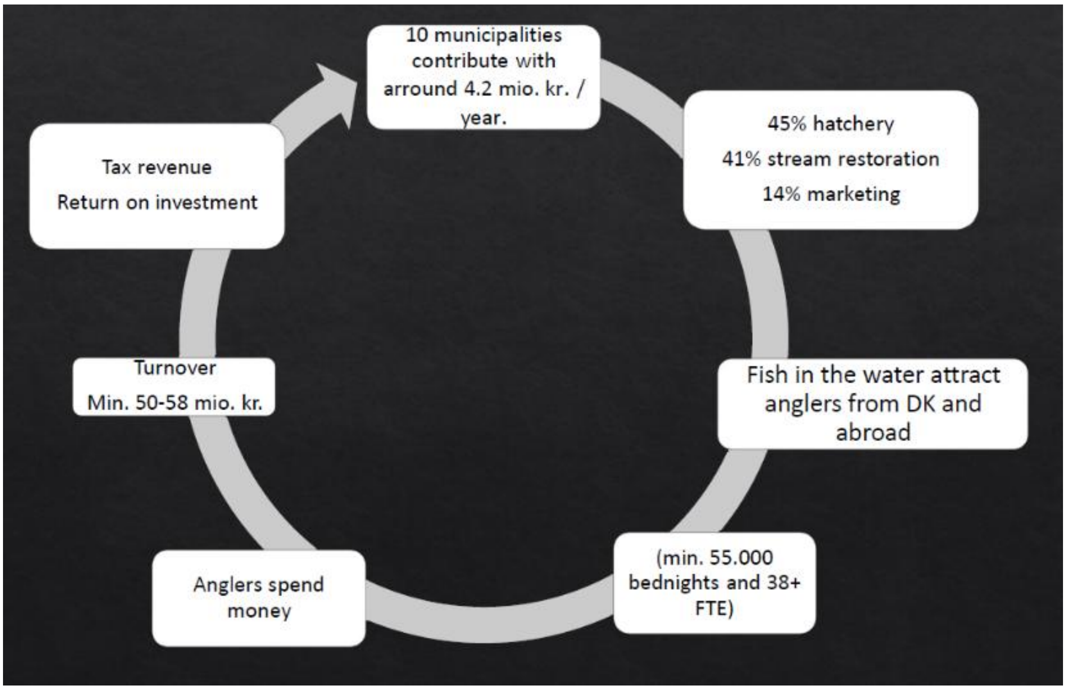


Figure 6. The economic cycle of the Seatrout Fyn-project (Kjeldsen 2017).

In the island of Fyn, the project Sea Trout Fyn directs weir removal and stream restoration. The project was founded in 1990 with a mission to restore flowing waters to a natural state, to enhance fish stock vitality and increase the income gained from tourism. The project budget is distributed as follows: 45 % for sea trout breeding, 41 % for river and stream restoration, and 14 % towards tourism and marketing. The ten municipalities of Fyn fund the project yearly to the sum of 4.2 million Danish crowns and in 2013 the profit gained was approximately 50-58 million crowns, making it a self-sustaining cycle (see figure 6). The profit flows mainly from fishing tourism. (Kjeldsen 2017.)

Many weir restoration projects include a culture historical reference, since weirs are often located next to old mills. Some of the mills are in private possession, therefore involving the owner in the projects as a stakeholder. Most weir removals and river restorations result from the need to enhance fish passage, mainly for sea trout and salmon. With fish being the focus, other circumstances (e.g. cultural history) might be set aside. The stakeholders and the project group agree on the goals of the restoration and the museum is rarely consulted, unless there are archaeological findings or references in the area. The project group is often quite small, and it rarely involves landscape designers.

In many cases the still pond or the mill cascade has been preserved as an aspect of culture historical reference. In some cases, it impairs fish passage downstream since fish swim towards the mill pond instead of the free passage, because they follow the largest flow.

The river restorations and weir removals are often executed with a combination of a passive and active approach, implying that only the weir is removed, and compulsory erosion control and geotechnical measures are performed to avoid any threats to the built environment around the rivers, but otherwise the river will be left to restore its ecosystems through the natural ecological cycle over time.

2.5 Dam removal and river restoration in Finland

The revival of migratory fish populations is one of the key projects of the Government Programme in Finland. (Finnish government, 2017.)

There is a long history of river restoration in Finland and the restorations have been usually successful in improving river channel diversity and enhancing salmonid populations. In a survey performed for fishermen and residents on restorations of the Rivers Simojoki, Kiiminkijoki and Kostonjoki indicated that the perceived changes in river landscape and fish catch influenced how successful the restorations were considered to be (see figure 7). (Marttila 2017, 2-8.)

Ekosysteemipalvelu	Kiiminkijoki		Kostonjoki		Simojoki	
	Kalastajat	Asukkaat	Kalastajat	Asukkaat	Kalastajat	Asukkaat
Maisema-arvot	+	++	++	++	--	--
Jokiuoman monimuotoisuus	-		++		-	
Kalastusmahdollisuudet	0		-		+	
Veneily		+		--		-
Kalasaaliit	+	0	++	++	-	-
Jään muodostuminen		-		+		+

Figure 7. A summary on the questionnaire results for success in restoration of the Rivers Simo-, Kiiminki- and Kostonjoki (Marttila 2017, 8).

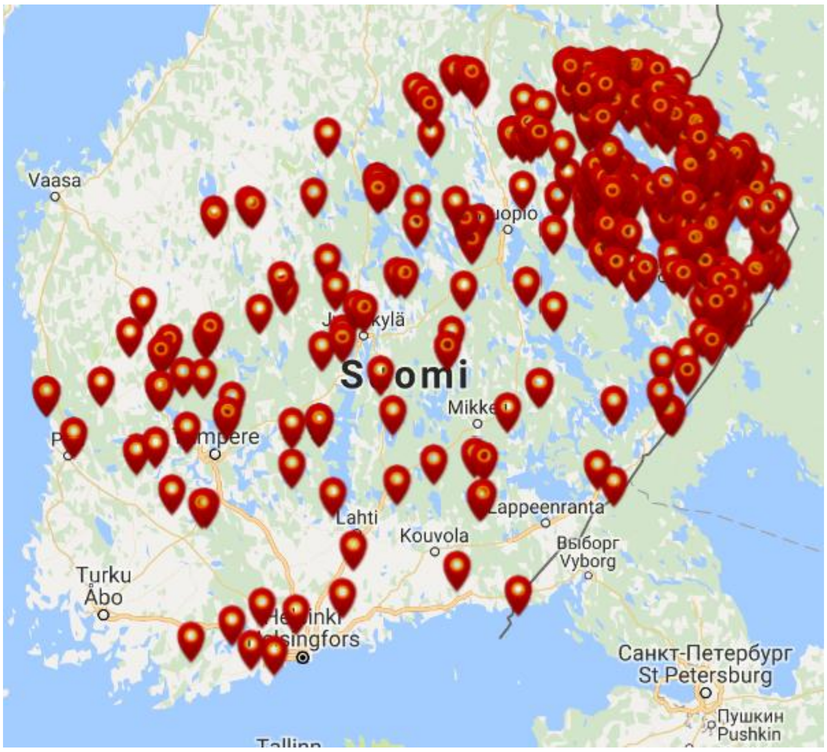


Figure 8. Dam removals in Finland, most of them have taken place in eastern Finland in the 1980s and 1990s. (The European dam removal map 2017.)

Dam removal is a topic that has been getting an increasing amount of attention in recent years. Finnish rivers have been exploited for water power, industry and agriculture and it has resulted in rapid degradation of migratory fish populations. The extensive river restorations and fishing regulation carried out in the past years will not benefit fish if they are not able to climb to their natural spawning grounds. (Erkkilä WWF 2017, 2.) Several dam removals have already been executed in Finland, especially in eastern Finland during the 1980s and 1990s (see figure 8), but there are still many obstructions on which action needs to be taken.

At the moment there are at least two ongoing programmes that are investigating dam removal opportunities. One is called exPato and its goals are to gain a general view on the amount, location, usefulness and obstruction effects of dams in Finland, to search for new methods of mapping migration obstructions and develop solution models on cases where the dam has become purposeless. (SYKE 2017.)

The other programme is called Patokato, which is funded by the European Maritime and Fisheries Fund operational programme for Finland 2014-2020 and the Southwest Finland Centre for Economic Development, Transport and the Environment. The objective is to raise awareness on fish migration and migration obstructions, initiate the removal of redundant obstructions in pilot cases, offer guidance with work that is aiming towards removing migration obstacles and activate and commit local stakeholders to the removal work. (Erkkilä WWF 2017, 3-12.)

3 ECOSYSTEM SERVICES

3.1 Ecosystem services

The concept of ecosystem services (the acronym that will be used in this thesis is ESS) means the material and immaterial services provided by nature to humans, society and the rest of nature. In the approach of ecosystem services, nature is not seen as a limitation, but as a focal part of the well-being of a human and society. The focus is on the opportunities provided by nature rather than on the avoidance of environmental hazards. (Känkänen et al. 2017, 8.)

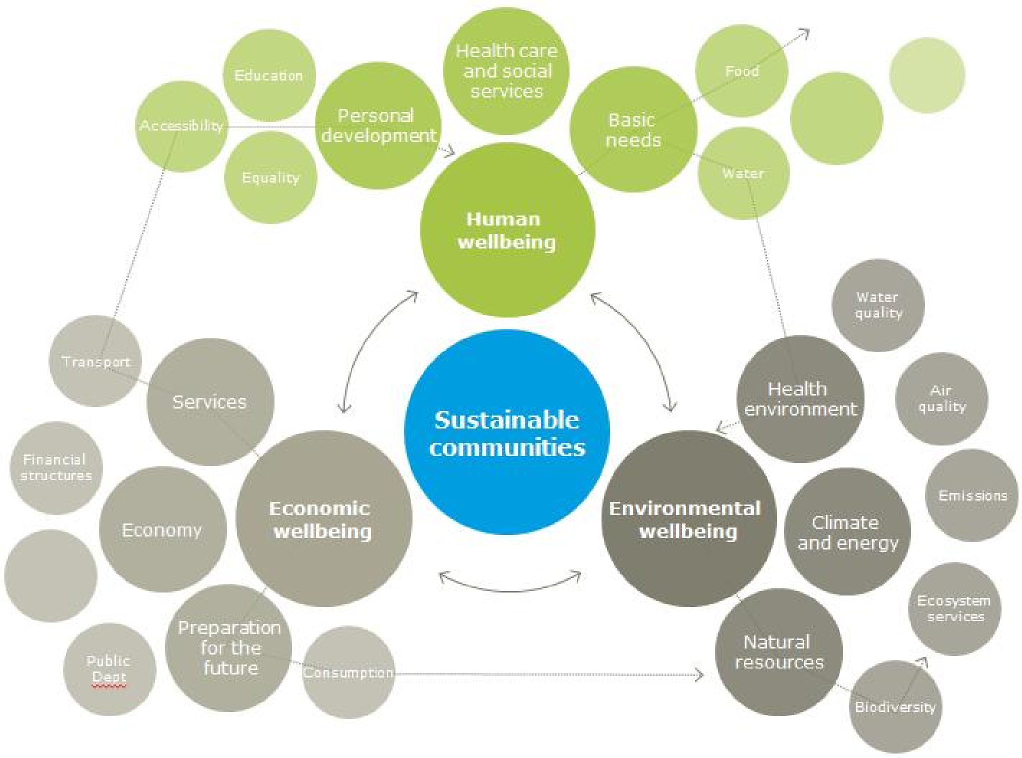


Figure 9. The typology and interactions between different components in sustainable communities. (Mustajärvi et al. 2017, 3.)

The concept of ESS has been in use since the 1970s, but it was brought into wider publicity through the UN Millennium Ecosystem Assessment (MEA) in 2005. The assessment demonstrated that many of the world's ecosystems are in danger and the ESS they provide have been weakened and even vanished. The reason for this is the extermination of entire ecosystems, the overuse of natural resources, discharge to ground, water and air, the spreading of alien species and climate change. Humans have been changing nature's ecosystems over the past decades faster than ever before. Human well-being has increased with the changes, but at the same time the quality of many ecosystem services has been decreasing. From the aspect of sustainable decision-making, humans can impair the operation of ecosystems through their actions, but also care for and add to ecosystem services. (Känkänen et al. 2017, 8.)

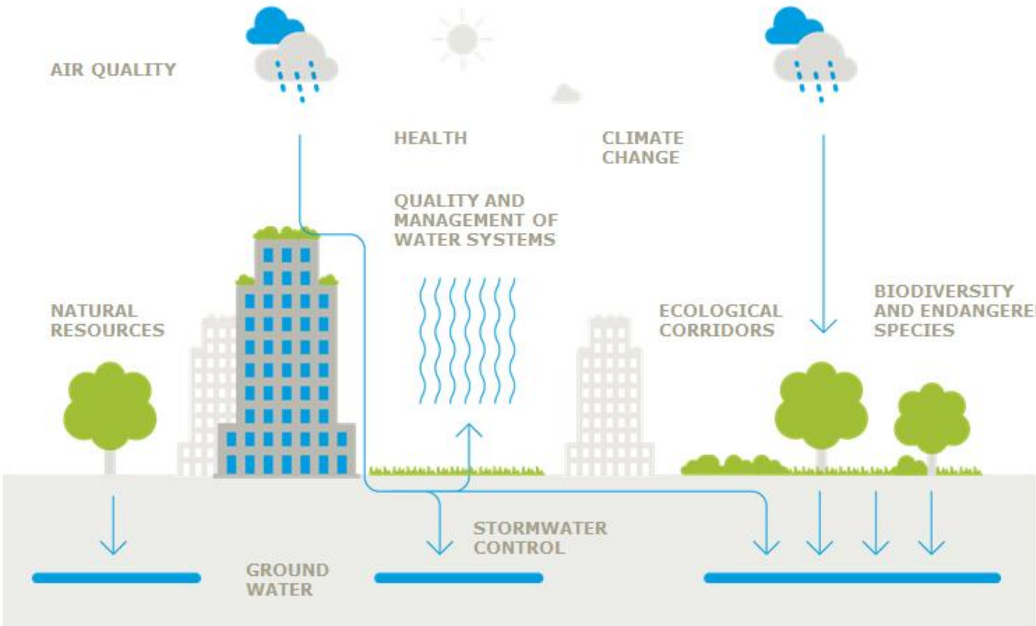


Figure 10. Functionality and interactions – ecosystem. (Mustajärvi et al. 2017, 5.)

3.1.1 Material and immaterial benefits

Many different practices have been classified as Ecosystem services. This thesis mostly applies water related ecosystem services that have been classified in the Cook-book for water ecosystem service assessment and valuation. The services have been separated into three groups according to CICES:

– Provisioning services
– Regulating services
– Cultural services

The MA (The Millennium Ecosystem Assessment) separates ecosystem services into four groups: provisioning, regulating, cultural and supporting, but CICES treats supporting services as part of the underlying processes of other services and aims to identify the “final products” of ecosystems. (Centre for Environmental Management 2010, 3).

With ESS it is vital to understand the integrity of the system (holistic approach) and the relationships between the services (e.g. causal connections). Ecosystem services form a network, where every service is a vital part of the functional ecosystem. (Känkänen et al. 2017, 9.)

Provisioning services are gained from nature, ready to be utilized for promoting human well-being and economy. The commodities that provisioning services provide include e.g. nutrition, clean drinking water, biomass, fuel and building material. (Centre for Environmental Management 2010, 10).

Regulating services include the ecological processes that provide for living organisms which support and regulate environment for humans. The processes can be local, regional or global in scale. Local services include for example preventing environmental hazards, cleaning air and pollination. Formation of groundwater is a regional service, whereas coal-binding and climate-regulation are global services. (Centre for Environmental Management 2010, 14).

Cultural services are formed from immaterial services produced by nature for humans, such as recreational, scientific and educational possibilities, experience of silence and aesthetical landscapes, which might include significant cultural historical characteristics. (Centre for Environmental Management 2010, 14).

The ecosystem services approach completes the concept of biodiversity, which was an important theme in the 1990s. Biodiversity is a basis for all ecosystems and it ensures ecosystem recovery from changes and distractions, i.e. ecosystem resilience. The requirements for ESS production are different ecosystem functions, which are based on ecosystems biophysical structure and biodiversity. To secure production of ecosystem services, one has to understand the different external factors that affect ecosystem functions and ecosystem service production, i.e. the pressure affecting the ecosystem, the societal ambitions causing change, the state of a resource or environment, chosen procedures and the effects of the changes that are caused by human activity. (Känkänen et al. 2017, 10.)

When mapping ecosystem services it is noticed that multiple benefits can be obtained from the same area. This “benefit-approach” helps to visualize how much value biodiversity and ecosystem services can give to societal and human well-being. This approach also highlights the values of nature’s distinct parts, such as river or forest. The approach suggest that the same area can produce many different benefits without some being threatened by others, e.g. wood production and berry-picking can be performed in the same area. Recreation and wood production can be carried out in the same area, if forestry strategy involves recreational demands and goals. As a concept ecosystem service is anthropocentric: the goods gained from ecosystem services are recognized primarily through human and societal needs. However healthy and functional ecosystems and the services they provide benefit all living organisms. (Känkänen et al. 2017, 10-11.)

In CICES ESS are seen as commodities, which are produced by different ecosystems. The commodities are divided into indirect (or intermediate stage) and final (end product) ecosystem services. One service enables the production of another service and vice versa: the deterioration of one service affects the existence of another service. For example, wood that is harvested from a forest is a final ecosystem service, that benefits society.

Wood production, however, requires multiple biophysical processes and provisioning services, such as land formation, photosynthesis, nutrient and water cycle. These services represent the indirect services in the service chain. The division to two stage-services is especially important in monetary valuation of ESS to avoid double valuations. (Känkänen et al. 2017, 11.)

3.1.2 Benefit valuation

Nature and ecosystem services have a great socio-economic significance. ESS are the driving force of world economy and irreplaceable contributors to the well-being of people and society. Nature supports the economy, e.g. agriculture and forestry, fishing, travelling and medicine production that are all based on biodiversity and ESS. Many societal sectors, such as health and security, are dependent on nature. For example, the pharmaceutical industry utilizes numerous substances originating from plants. (Känkänen et al. 2017, 12.)

The recreational use of nature can have significant effects on regional and national economy. Valuation surveys have compared the costs for maintaining benefits and services on a recreational area and indicated that for example economic support for maintaining national parks might be a cost-effective investment on a regional level. Based on a Nordic estimate, the economic support targeted for maintenance and recreational opportunities in national parks in Finland, has been estimated to provide a profit of 10 euros for every 1 euro regional investment. (Känkänen et al. 2017, 12.)

The valuation of ESS benefits helps to demonstrate their importance to well-being. Valuation can also be used to research the effects different societal solutions have on human well-being and for estimating the value of environmental impacts of different plans, programmes and projects. (Känkänen et al. 2017, 12.)

For now, a direct or an indirect monetary practical value has been specified for only a few ESS. The monetary valuation of ESS has been resisted, since many of the services provided by nature have no practical monetary value, but instead ecological, social and ethical grounds to protect the services are significant. According to sustainable development principles, the valuation of ESS should regard all three aspects: ecological, economic and social. In addition to economic criteria, we should gain knowledge of non-economic criteria, such as nature's ecological, aesthetical, cultural and spiritual values. Nature values are usually site-specific and many ecological functions and the services they provide will take time to start flowing. When analysing nature values, one should consider the long time frame and be able to determine the current value of benefits or losses that realize in the future. (Känkänen et al. 13-14.)

Every ecosystem service has its users, which leads to stakeholders valuing ESS and gained benefits differently (e.g. a landowner versus a recreational user). The value of ESS is always dependent on the background, appreciation, living conditions and standards of the person who is doing the valuation. The personal values of those making decisions and strategic choices have an influence on the state of ecosystems and the production of ecosystem services. (Känkänen et al. 2017, 14.)

3.2 Water-related ecosystem services

Rivers provide a large variety of ecosystem services (see figure 11) that produce benefits for the society. The most important products (provisioning services) that rivers provide are food and fresh water, which are guaranteed through regulating and supporting services such as water purification, nutrient cycling and sediment deposition. Rivers also provide many cultural services varying from recreational benefits to local identity.

Provisioning Services *Products obtained from ecosystems*	**Regulating Services** *Benefits obtained from regulation of ecosystem processes*	**Cultural Services** *Nonmaterial benefits obtained from ecosystems*
• Food • Fresh water • Energy • Fibre • Biochemicals • Genetic resources	• Food • Fresh water • Energy • Fibre • Biochemicals • Genetic resources	• Spiritual & religious • Recreation & ecotourism • Aesthetic • Educational • Sense of place • Cultural heritage
Supporting Services Services necessary for the production of all other ecosystem services • Soil formation • Nutrient cycling • Primary Production • Habitat / biodiversity		

Figure 11. Ecosystem services provided by rivers. (WWF 2006, 4.)

This thesis applies mainly the ESS suggested by Cook-Book for water ecosystem service assessment and valuation (see Figure 12), which was performed as a part of the research project MARS (Managing Aquatic ecosystems and water Resources under multiple Stress) that has been funded by the Seventh Research Framework Programme of the European Commission. The services were classified based on CICES v4.3 and linked to the Millennium Ecosystem Assessment (MA, 2005a) and the Economics of Ecosystems and Biodiversity (TEEB, 2010). (Grizzetti et al. 2015, 17.)

The MARS research also presents a list of indicators for water ecosystem services that have been selected based on a literature review and considered as relevant or irrelevant by several experts through a questionnaire. (Grizzetti et al. 2015, 87.) The most relevant indicators on the MARS list have been selected to present the changes in ecosystem services in the Tikkurila dam case presented in this thesis.

	Ecosystem services terminology proposed in MARS	Examples	Ecosystem services from CICES	Ecosystem services from TEEB
Provisioning	Fisheries and aquaculture	e.g. fish catch	Food - Biomass	Food
	Water for drinking	e.g. provision of water for domestic uses	Drinking water	Fresh water
	Raw (biotic) materials	e.g. algae as fertilisers, vegetal compounds for cosmetics	Materials - Biomass	Raw materials, Medicinal resources
	Water for non-drinking purposes	e.g. provision of water for industrial or agricultural uses	Non-drinking water	Fresh water
	Raw materials for energy	e.g. wood from riparian zones	Energy - Biomass	Raw materials
Regulation & Maintenance	Water purification	e.g. excess nitrogen removal by microorganisms	Mediation of pollution in water	Waste-water treatment
	Air quality regulation	e.g. deposition of oxides of nitrogen on vegetal leaves	Mediation of pollution in air	Local climate and air quality
	Erosion prevention	e.g. vegetation controlling soil erosion on river banks	Mediation of mass flows and erosion	Erosion prevention and maintenance of soil fertility, Moderation of extreme events
	Flood protection	e.g. vegetation or floodplains trapping and slowing down the water flow, coastal habitats protecting from inundation	Flood protection	Moderation of extreme events
	Maintaining populations and habitats	e.g. key habitats use as reproductive grounds, nursery, shelter... for a variety of species	Maintaining populations and habitats	Habitats for species, Maintenance of genetic diversity
	Pest and disease control	e.g. diseases and parasites are better controlled in the wild (by natural predation on weakened individuals)	Pest and disease control	Biological control
	Soil formation and composition	e.g. rich soil formation in floodplains or in wetlands borders	Soil formation and composition	Erosion prevention and maintenance of soil fertility
	Carbon sequestration	e.g. carbon accumulation in vegetation or sediments	Global climate regulation	Carbon sequestration and storage
	Local climate regulation	e.g. maintenance of humidity and precipitation patterns by wetlands or lakes, shading effect	Micro and regional climate regulation	Local climate and air quality
Cultural	Recreation	e.g. swimming, recreational fishing, sightseeing, boating	Experiential interactions with nature	Recreation and mental and physical health, Tourism
	Intellectual and aesthetic appreciation	e.g. subject matter for research, artistic representations of nature	Intellectual and aesthetic interactions with nature	Aesthetic appreciation and inspiration for culture, art and design
	Spiritual and symbolic appreciation	e.g. existence of emblematic species like *Lutra lutra* or sacred places	Spiritual and symbolic interactions with nature	Spiritual experience and sense of place

Figure 12. The list of ecosystem services relevant for water systems. (Grizzetti et al. 2015, 83.)

The research project MARS tested a hypothesis that states that multiple stressors or pressures influence the status of an aquatic ecosystem, which might cause a change in ecosystem services and in their economic value (see Figure 13). (Grizzetti et al. 2015, 21.) In other words, ecosystem services have a certain capacity, flow and value (e.g. **service**: water for drinking, **natural capacity**: surface water availability, **service flow**: water consumption for drinking), on which the pressures have an effect through altering the status of the ecosystem. (Grizzetti et al. 2015, 88

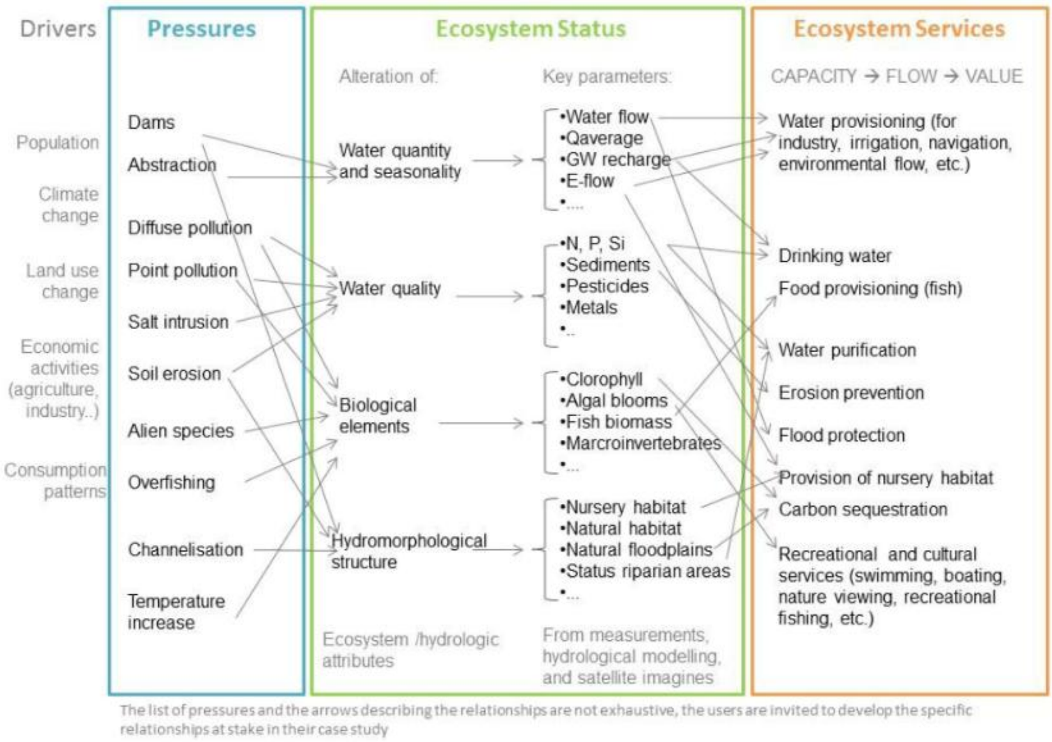


Figure 13. A framework for water-related ESS assessment according to the Cook-book. (Grizzetti et al. 2015, 85.)

This thesis studies the dam removal and river restoration as a pressure on the present ecosystem and aspires to evaluate the changes in the ecosystem service flow or benefit.

4 THE TIKKURILA DAM

4.1 Location and history

The Tikkurila dam has been built in the main channel of the river Keravanjoki on the south side of Tikkurila centre.

The natural rapids of Tikkurilankoski have been a natural obstruction for sailing upstream and therefore the lower reach of Tikkurilankoski became a centre for trade. The rapids also provided a perfect place for a watermill much needed by the inhabitants in the area. Land surveyor Nils Westermark and the owner of Dynnas farm, applied for a license in 1756 for a mill on the north bank, though there have been mills even before that. Westermark constructed the mill on the north side (rapids were divided in two by a small island) of Tikkurilankoski. In approximately 1829 trader Georg Magnus Brofeldt, who owned the Dynnas farm, built the dam preceding the current dam. (Björkman et al. 1986, 1-2.)

In the year 1861 the owner of Dynnas lieutenant colonel Anders Lorentz Munsterhjelm applied for a license to build an oil pressing factory, right next to the old flourmill. An inspection was made, and there it was stated that the mill and its dam would stay in its place, though the new factory would probably use all the water. In addition, they stated that there were no fish trying to climb upriver in the River Keravanjoki and it was not used for log driving. (Björkman et al. 1986, 2.)

The railway between Helsinki and Hämeenlinna was opened in the year 1862. In 1867 the factory also started producing linseed oil. (Vernissa 2017.)

MAINOSPIIRROS VUODELTA 1886

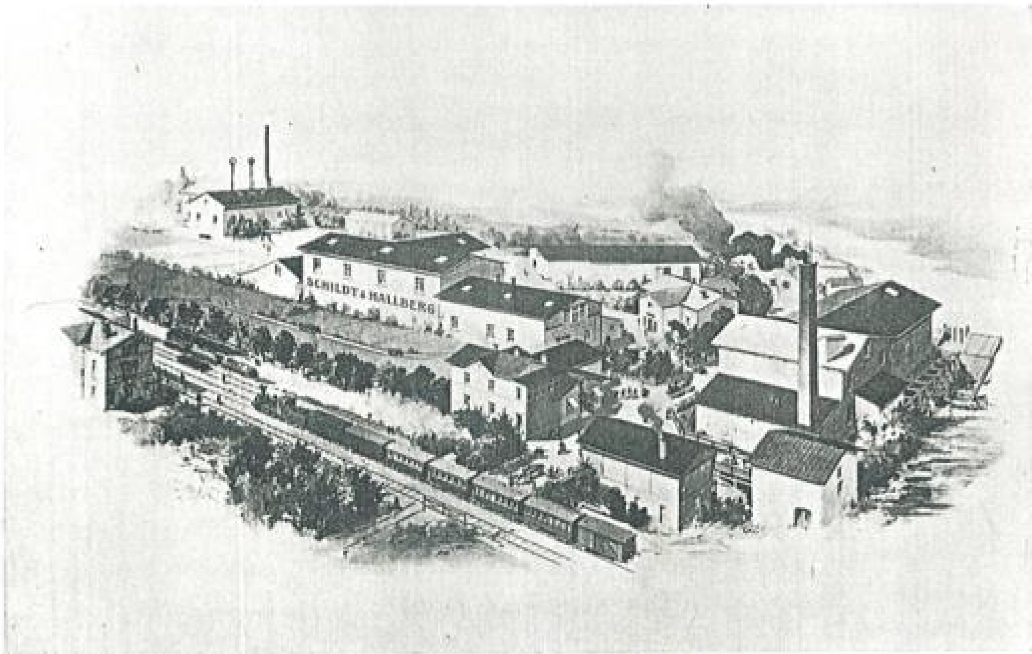


Figure 14. The factory of Schildt & Hallberg in Tikkurila in the year 1886. The oil pressing plant is on the river bank on the right. (Vuojolainen 2015, 13.)

The factory changed owners in 1885 (Oy Schildt&Hallberg), who then built a new factory in 1886-1887, which was partly destroyed in a fire in 1912. In reconstruction, they decided to build a new dam, since the old one needed fixing, and they did not want to start using the domain’s electrical grid. The plans for the dam were made by Ab Axel Jusélius Vattenbyggnadsbyrån in 16.6.1912 and they were based on the existing systems and constructions. (Björkman et al. 1986, 3.)

In the early 1900s business was growing rapidly and the factory was expanded on multiple occasions. The current brick buildings were built in 1912 and the high brewing part was designed by architect J. Fabritius and built in 1937. The personnel rooms that stand on columns on the riverside were built in the 1950s. (Vernissa 2017.)

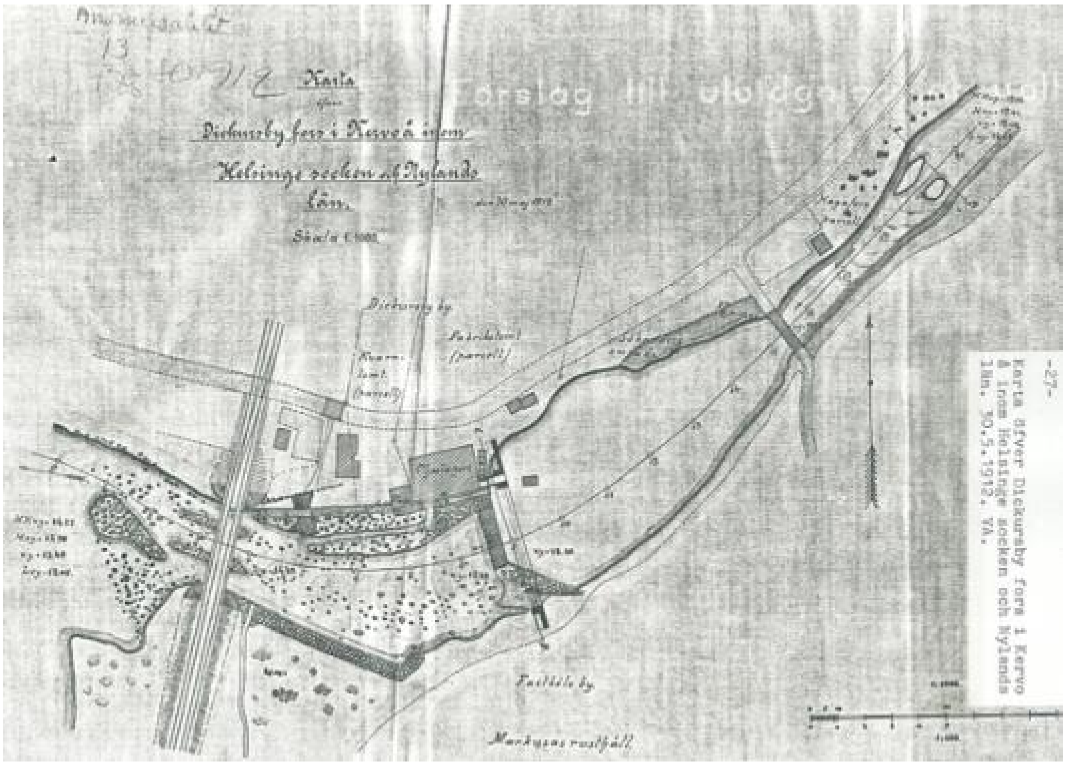


Figure 15. The linseed oil factory on a map from 1912. (Vuojolainen 2015, 9.)

The dam height varies between 2-3 meters and the sides are over four meters high. The ridge of the dam is at the level +15.30 (N2000), and the sides are at +17.10. There is a hatch on the ridge of the dam and on the bottom, and they both are situated a little to the north from the centre. The dam has a concrete heart and it is upholstered with large natural granite stones varying in shape and dimension. The intake to the factory is on the northern side. The dam structure has been anchored to the bedrock securely.

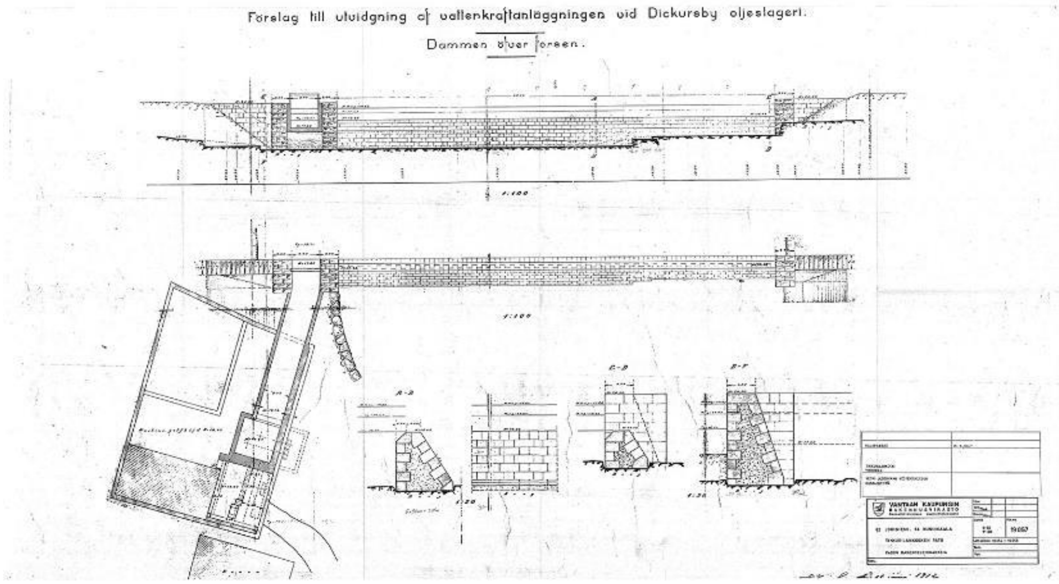
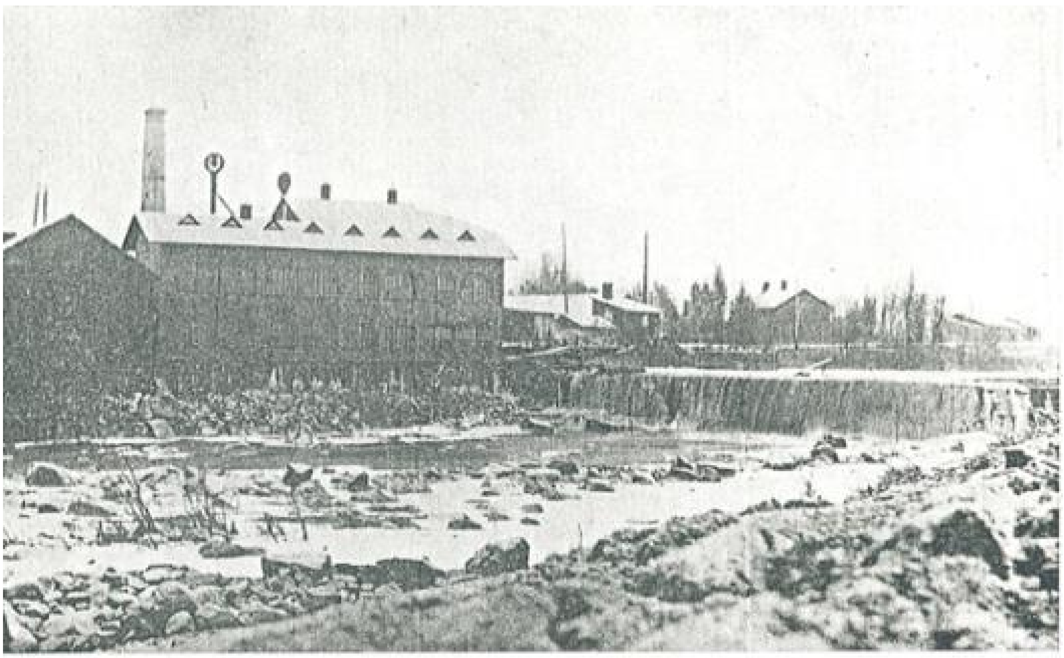


Figure 16. The original drawings for the dam from the year 1912. On the left is shown the intake opening, where water was harvested for factory use. (Vantaan kaupunki 2015.)



ÖLJYNPURISTAMO, RAKENNETTU 1886—87. VASEMMALLA VANHA MYLLY

Photo 1. The picture shows the linseed oil factory, on the left the old mill and on the right the old dam. (Vuojolainen 2015, 11.)

Photo 2. Picture from 1930. (Vuojolainen 2015, 15.)

The factory functions ended in 1960. In 1979 the factory with all its domains transferred to the city of Vantaa and it slowly started to decline. In May 1985 youngsters from Vantaa took over the building and demanded it to be used for cultural purposes, which finally lead to the cultural centre Vernissa launching in 1990. Everything valuable in the building has been taken into use or restored and the most vital new structures have been made with old materials. (Vernissa 2017.)

Photo 3. The young people of Vantaa took over Vernissa in 1985, demanding it to be used for cultural purposes. Vantaan kaupunginmuseo, 2015.)

The dam was under restoration in 1994, when the fish ladder was also built. Before the fish ladder, there was no way for fish to get upstream, since the dam is 2 to 3 meters high. When the restoration work began, the bottom hatch of the dam was opened, allowing the water to flow out of the dam basin in a controlled way, therefore also enabling the sediments to stay in place. Restauration was performed in mid-summer, when flow levels were lowest. It was noticed that the natural rapids bed was in rather appropriate shape and not a lot of sediments had collected on the banks. There were many large rocks, some gravel and visible bedrock on the river bed.

Photo 4. Water flows through the bottom hatch. (Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä 1994.)

Photo 5. The natural rapids bed exposed upstream of the dam. (Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä 1994.)

4.2 Condition at present

The dam's original function ceased with the factory ending its operations, but it is still an important part of the early 20th century industrial surroundings.

After the restauration in 1994 there have not been any significant repair works on the dam. Today it is working and mainly intact, but it leaks from several points and several upholstery stones have fallen off. Some of the seaming has been disintegrated and with the base concrete exposed, it has also been disintegrated. The dam needs at least some restauration work.

Photo 6. The dam in summer 2016.

Photo 7. The fish ladder in summer 2016.

The concrete structure of the fish ladder is in a decent shape, but the structure is easily clogged and therefore expensive to maintain. The ladder opening is far from the dam where most fish head, since the largest stream is coming from there. Some of the fish are not able to navigate to the ladder opening, so they try to jump over the dam causing them to die from crashing onto the dam or the rocks. Others spawn right under the dam, leaving the fry in danger of drying up, when the flow level is low in the summer months and most of the water is conducted through the fish ladder to keep it functional in dry seasons. The fish ladder is also a dangerous structure since its opening is wide open.

4.3 The River Vantaanjoki

The River Vantaanjoki is the main watercourse of the watershed. The river is 101 km long and it descends 111 metres. The source of the Vantaanjoki is in Hausjärvi and its most important tributaries are the River Keravanjoki, River Tuusulanjoki, River Luhtaanmäenjoki, River Palojoki and River Kytäjoki. (Vahtera et al. 2014, 9.)

The watershed area is 1680 m² and it covers 14 municipalities (Helsinki, Vantaa, Tuusula, Nurmijärvi, Hyvinkää, Riihimäki, Hausjärvi, Loppi, Mäntsälä, Vihti, Järvenpää, Kerava, Sipoo and Espoo). Lakes cover 2.25 % of the watershed area, forests 51 %, agriculture 30 % and 20 % is covered by housing, industrial and commercial building and traffic areas. The most common soil types range from clay and silts (39 % of the area) to till-derived soils (25 %). The watershed area is flood sensitive, since there are only a few lakes. (Vahtera et al. 2014, 9-11.)

River flow levels and therefore water quality, vary greatly. The amount of nitrogen transported to The Gulf of Finland by the River Vantaanjoki has been on average 13000 tons in the 2000s (10 % of the total nitrogen load that is transported to The Gulf of Finland), approximately 10 % of the 1300 tons is caused by wastewater loads from five municipal treatment centres that drain to the River Vantaanjoki. Phosphorous is transported to the River Vantaanjoki on average 69 tons, which is close to 11 percent of the total load in the Gulf of Finland and the amount that comes from waste water is under 5%. The most intense loads happen usually after heavy rainfalls in spring and autumn. (Vahtera et al. 2014, 15.)

In the 2015 water quality surveillance, the headwaters of the River Vantaanjoki had on average a phosphorous concentration of 30 µg/l and a nitrogen level of 1300 µg/l. The water was brown from humus and it contained a lot of oxygen. The hygienic quality of the Vantaanjoki varied from good to poor. (Vahtera et al. 2016, 16).

Surface water ecological state evaluation contains five different classes, excellent, good, satisfactory, passable and poor. The valuation in river waters is based on quality indicator values such as periphyton, zoobenthos, fish, physiochemical factors (water quality) and hydro morphological factors. (Karonen et al. 2015, 89). The ecological status of the River Vantaanjoki has mainly been classified as satisfactory.

4.3.1 The River Keravanjoki

The River Keravanjoki is the longest tributary (65 km in total) of the River Vantaanjoki. The River Keravanjoki starts from the lake Ridasjärvi in Hyvinkää and connects to the River Vantaanjoki 6 km before the sea. The upper stream flows through forested lands and it accelerates to a stream on steeper areas. The lower stream meanders through farmed lands. (Virkisty Keravanjoella 2012-2014.) The river bed has been for the most part in the same place for the past centuries.

The river offers a variety of recreational possibilities i.e. kayaking, fishing, bird watching, cultural sightseeing etc. It also functions as a vital ecological corridor for multiple species and enhances biodiversity in especially Vantaa, but also Helsinki.

The River Keravanjoki divides into two water formations, an upper part and a lower part. The ecological status of the upper part of the River Keravanjoki is good and the lower part satisfactory. All point loads ended since the construction of a sewage system in the summer 2016 at the Kaukasten treatment centre in Hyvinkää. (Vahtera et al. 2016, 53.)

The average flow in the River Keravanjoki in 2015 at the measuring point in Hanala was 2.8 m^3/s in 2015. In the summertime the water level in the River Keravanjoki usually decreases significantly. Additional water is being conducted by KUVES (Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä) from Päijänne water tunnel in summertime to increase recreational possibilities and to keep a sufficient level of water in the channel. (Vahtera et al. 2016, 53.) In 2015 the conduction of additional water started on the 8th of June and ended on the 31st of August. The flow was 0.54 m^3/s on average and the total amount was 3.9 million m^3. In June before the additional water the flow was 800 l/s, whereas with the added water, it stayed at a minimum of 1 m^3/s. (Vahtera et al. 2016, 55.)

On the headwaters of the River Keravanjoki the total phosphorous amount in winter was 30-50 µg/l and the total nitrogen 1100 µg/l. In the summer phosphorous decreased by 15 µg/l and nitrogen by 600 µg/l. The phosphorous levels nearly doubled in the stretch between the upper and the lower part of the River Keravanjoki, but stayed at good status as a whole for the entire year. In the dam pools water warms up in summertime by approximately 2 degrees compared to rapids. In the summer the hygienic levels were within the requirements for swimmable water. (Vahtera et al. 2016, 59-60.)

The water quality and oxygen level of the upper part of the River Keravanjoki were good. The diatoms specimen taken from the rapid Seppälänkoski showed diverse species that indicates eutrophicated conditions. (Vahtera et al. 2016, 54.) The chlorophyll concentrations measured from the River Keravanjoki, indicating spreading of algae, originated partly from the algae formed in the lake Ridasjärvi (eutrophicated lake in eastern Hyvinkää, on the headwaters of the River Keravanjoki). The a-chlorophyll concentrations were low in the River Keravanjoki. (Vahtera et al. 2016, 63.)

In the year 2015 2000 sea trouts were planted in two different places in the River Keravanjoki. In 2015 electrofishing the following species of fish were found from the river: stone loach, miller's thumb, burbot, bleak, roach, trout (both planted and wild) and gudgeon. The rapid Seppälänkoski had low fish density, but trout was found from all test sites. Miller's thumb and trout appearance usually indicates good water quality, and they were both found from the rapid Tikkurilankoski. The biomass caught from the rapid Tikkurilankoski test site was in total approximately 1800 g/100 m^2. The amount of trout fry originating from natural spawning was exceptionally high in the River Vantaanjoki and it has been increasing rapidly. However, the density of older fry has been low throughout the years. In the River Keravanjoki the trout density has been much lower. (Haikonen 2016, 6-14.)

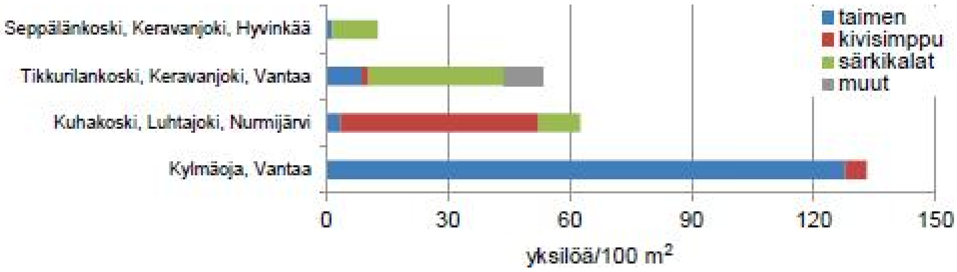


Figure 17. Results of electrofishing in the River Vantaanjoki tributaries in 2015. (Haikonen 2016, 9.)

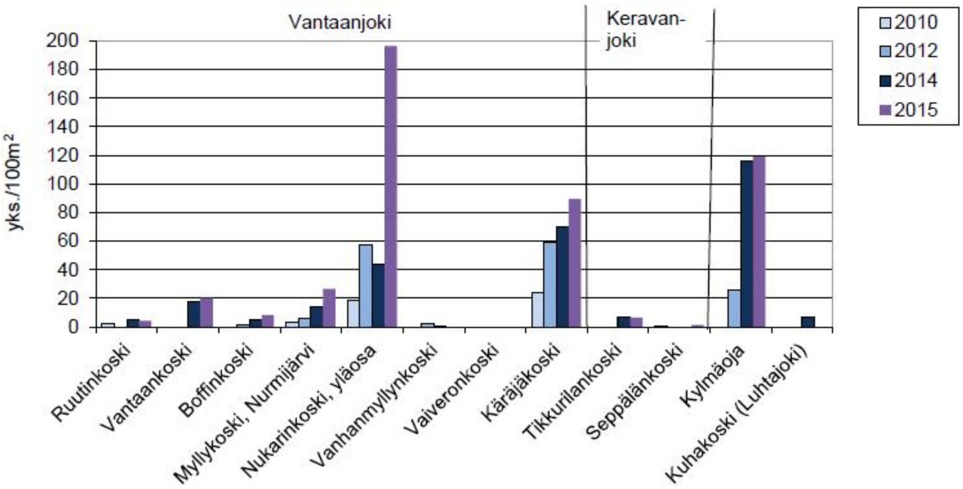


Figure 18. Trout fry 0+ density in the River Vantaanjoki in years 2010-2015. (Haikonen 2016, 12.)

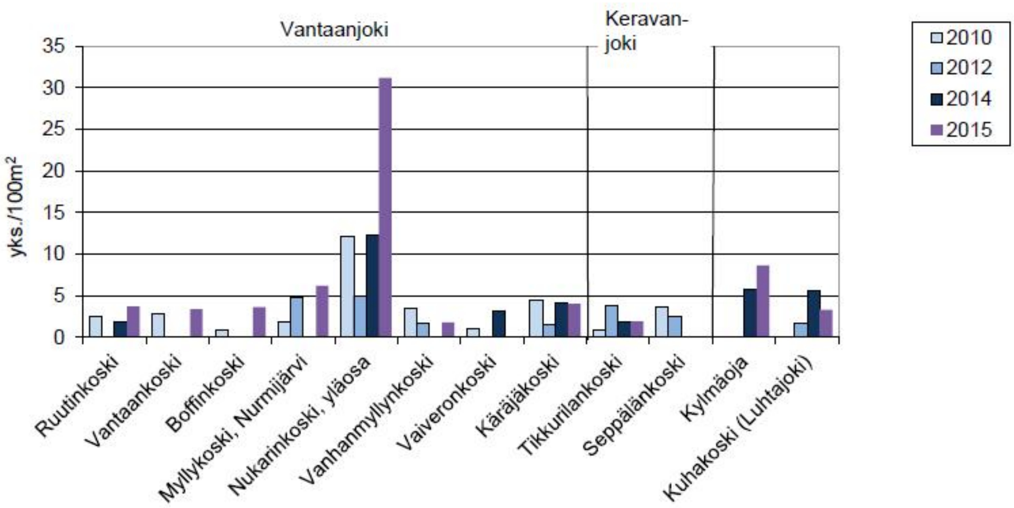


Figure 19. Density of 1-year old trout and older in the River Vantaanjoki in years 2010-2015. (Haikonen 2016, 13.)

5 PLANNING PROCESS

5.1 The need for a project

There were multiple reasons to why the situation needed to be resolved. The city of Vantaa decided to carry out a pre-survey project in 2014. The most important strains that led to decision making were:

- Condition. The dam is deteriorating and in need of restoration, even though it is mostly a surface injury, since the base concrete is in appropriate shape.
- Fish. The technical fish ladder is not working properly because the opening is located far from the dam. A radio transmitter research study was performed, and it was found that fish were not getting up through the fish ladder and there were many fish spawning in the rapids under the dam. There has been an increase of trout in the rapid Tikkurilankoski in the latter years, but their spawning in the Tikkurilankoski area is weak. The city of Vantaa has itself committed to improving conditions for migratory fish.
- Recreation. The component master plan suggests that the centre of Tikkurila would have 250 000 m2 of new floor space and 5000-6000 new inhabitants by the year 2030 and 200 000 m2 more floor space by the year 2050. This creates a lot of pressure on developing recreational areas near the city centre to accommodate an increasing amount of people.

Hanna Keskinen, the head of park planning from the city of Vantaa commented on the decision to start the project:

> *“Refurbishment of the dam was inevitable due to the repair requirements that were presented at dam safety inspections. There was a strong ambition for studying if the dam could be removed, both within the technical directors and politicians. Still, removal of the dam was decided on only after the pre-survey had been done and approved by the technical board.” (Keskinen 2017, free translation from Finnish.)*

The city of Vantaa had a theme year 2015 for brooks and the year 2016 for rivers and brooks. The main goals were to raise awareness, engage residents and organizations in care-taking and restoration activities, develop diversity in flowing water landscapes and to improve the resilience and recreational use of flowing waters (brooks and rivers). (Keskinen 2016, 3-14).

The need came also through many strategic programmes, which were represented in the background introduction to a landscape architecture competition:

- The green area programme for the city of Vantaa 2011-2020. The programme suggests that green areas will be sustainably built, maintained and used, representative of their surroundings, biodiverse and they are planned to accommodate climate change. The services of green areas will be reachable for everyone and diverse. It includes a proposition that rivers, waterbodies and attractive sites are the assets of green areas and that the ecological state of waterbodies is good. The programme illustrates the rapid Tikkurilankoski as an attraction target.
- The architecture programme for the city of Vantaa 2015. The programme incorporated goals for sustainable way of building, creating a good environment and emphasising nature as an integral part of the city.
- The City of Vantaa Public Utility Services Centre set goals for developing urban environment with ecological and sustainable choices and to mitigate climate change.

(Keskinen 2015, 2-11.)

Photo 8. A photo of the dammed water pool taken from Kuninkaalantie bridge.

Photo 9. A photo of the current rapid area taken from the top of the dam, on the right is Vernissa.

Photo 10. An aerial photograph taken from southwest. In the centre is the dam and next to it on the left side is Vernissa.

5.2 Pre-survey

The pre-survey was launched in January 2015. The goal was to figure out practical solutions for the dam and functional fish passage, assess their impacts and make an estimate on the price of construction works. There was an ambition of integrating ecological, recreational and culture-historical factors into the solutions to enable fish to swim upstream and to build a functional riverfront that still maintains a visible reminder of the dam as a part of the early 1900 factory surroundings.

The customer was the Green Area Department in The City of Vantaa Public Utility Services Centre. The contact person and the chairman of the steering group was landscape architect Hanna Keskinen and the dam expert was Ari Asikainen.

The steering group for the pre-survey formed of advocates from different departments and Service Centres from the city of Vantaa, including experts of geotechnics, bridge engineering, water supply, sports (fishing), land use, environment and from Vantaa City Museum. The steering group also had a spokesperson from KUVES (Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä).

5.2.1 Stakeholder goals

Cultural history

In the past years the city museum has given many statements that the dam should be preserved. Vernissa is a listed building and the dam is a vital part of its history and the factory surroundings. The dam was never listed as a conservable structure, but it still is a notable construction. The dam has high landscape and cityscape values. Inside Vernissa there is a mill ruin that is listed as a relic.

Land use

The waterfront is under a lot of pressure to develop towards better serving the increasing number of people in need of recreational facilities in downtown Tikkurila. Most of the pressure is set for the west side of the railway bridge, including the possible expansion of Hotel Vantaa on the northern river bank. The land use department had sketched some ideas also for the east side of the railway bridge and they included a wood-decked quay in front of Vernissa and some seating beside the small pond on the south side. A new bridge must be built on the east side of the railway bridge to accommodate a fast-access bicycle lane.

The long-term goal is to develop the connection between the pedestrianized city centre and the riverfront into a seamless, achievable and functional public space which focuses on pedestrians and bicyclists. The riverfront would be a pleasant place for encounters and recreation and could be arranged to host events.

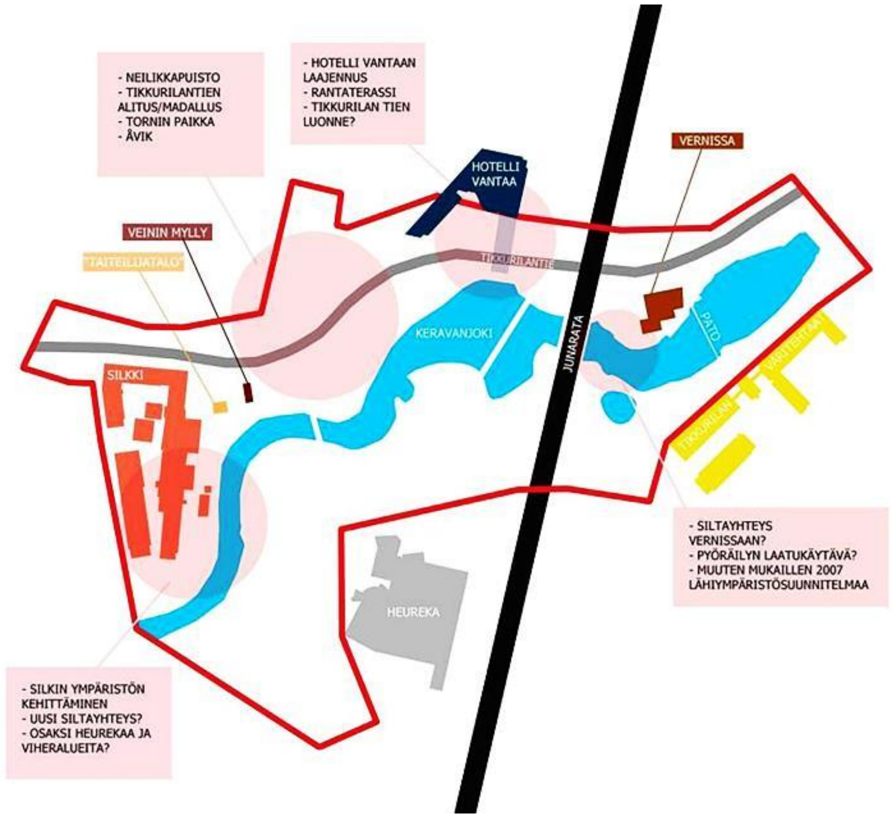


Figure 20. The main goals of developing the riverfront of the River Keravanjoki in Tikkurila. (Muukka 2015.)

Fish

The fish ladder is not technically working properly and that together with the high dam, forms an obstacle for fish climbing upstream. There has been a considerable increase of fish in the River Keravanjoki, and the river would be an optimal habitat for trout, without the climb obstructions. The goal is to develop the river into one of the best trout rivers in southern Finland. At present, fishing is not that popular in Keravanjoki, but Tikkurila has the potential of becoming a significant fishing destination, due to its central location and connections to Helsinki region and even further Finland.

Water resources and flooding

In summer 2004 water flooded the railway underpass of the street Tikkurilantie because of the dam. The River Keravanjoki also rose in the storm water drainage network and flooded in some of the private parking places of the street Vernissakatu. After 2004 valves have been installed to drains to prevent flooding. The worst flood of the River Keravanjoki happened in 1966.

Additional water to the River Keravanjoki is conducted from the Päijänne-tunnel approximately 3-4 million m^3 per year.

The area is flood-sensitive, and it has been attempted to manage storm water inside the city structure. There are few possibilities to manage storm water on the riverfront.

The river banks are formed of loose lands here and there, and when the water level decreases it should be taken into consideration so that the banks will not collapse into the river. The natural variation of water level is quite extensive, so the situation will probably not change greatly.

Environmental values

The River Keravanjoki has a lot of environmental values as it is the most important green area in Tikkurila. A lot of valuable trees grow on the riverbanks and they are the living environment of many notable beetle, butterfly and bird species. The trees however can be thinned a little without compromising their nature value.

The butterfly species include varied species of owlet-moths, and the birds include e.g. lesser spotted woodpecker, sedge warbler, thrush nightingale, chiffchaff and common sandpiper. Extensive lighting on the river banks might cause harm to the ecological value, if it interferes with the green corridors that light-sensitive bats use.

The river is also a vital ecological corridor in the city centre. However, the ecological connection on the planning area is marked as poor. The reed grass that grows in the dam pool is an invasive alien species, and hence has no environmental value.

Vernissa and Heureka

Vernissa is nowadays a centre for many different companies; Tikkurila Theatre and Circus School, Vantaa jazz association, Vantaa dance academy, Vantaa music academy, puppet theatre Sampo and many more.

The stakeholders of Vernissa wish for it to be an achievable, liveable, tempting and diverse culture space and hope that also the surroundings attract people to visit Vernissa.

Heureka is a science center on the west side of the railway bridge. The director board hopes that the park areas have diverse nature that the children can explore.

5.2.2 Public opinion

When the pre-survey phase started, a bulletin of the goals and the planning process was released, and it received 37 comments from inhabitants, active fishermen, companies, protectors of flowing waters etc. Most of the feedback was encouraging the removal of the dam, on grounds of a more ecologically sound and fish-friendly future and better recreation possibilities. Some of them stated that the restoration of the rapid Tikkurilankoski to a more natural state would promote the river ecosystems gradual recovery.

Some of the comments also praised Vantaa for showing an example to others on how old dams should be managed to improve the conditions of migrant fish species and restore the natural state of rivers. They also mentioned that Vantaa could be following the good example of removing dams that is a trend in other countries as well. Removing the dam would also bring a lot of positive publicity to the city and enhance the city image as a sustainable and a biodiverse city.

Many fishermen stressed that the rapid Tikkurilankoski could develop into a very popular and profitable fishing place. One comment mentioned the fish ladder construction works in the 1990s and how there were natural rapids with bedrocks, that could be repaired with small effort to provide a habitat for a lot of trout. A few mentioned that there are many potential brooks for trout spawning upstream of Tikkurila dam, and if the dam was opened, the brooks would possibly be as lively as for example the restored brook Longinoja in Helsinki. According to one comment, removal of the dam would enable a free passage through the centre for canoeists and kayakers.

A few of the comments suggested that if the dam needs to be preserved for historical values, then it could be partially dismantled from the centre. They also commented that the refurbishment of the dam and leaving it in place would eventually be more expensive than natural rapids, since the dam would need refurbishment every few years.

There have also been opinions that are not favourable towards dam removal and the technical issues have raised some concerns. One person stated that the dam should not be removed because it is a part of the great industrial and town culture of Tikkurila.

Two resident sessions on the rehabilitation of the rapid Tikkurilankoski have been organized during the project. Some concerns have been raised, but most of them relate to solving geotechnical issues with structures close to the river bank.

Vantaan Sanomat newspaper performed an enquiry in April 2015 relating to an article on their website, where they asked, whether the dam should be opened or not (see figure 21). The answers were highly inclined towards the dam opening (96 %, 953 votes), whereas not opening the dam got only 38 votes. (Vantaan sanomat 2015.)

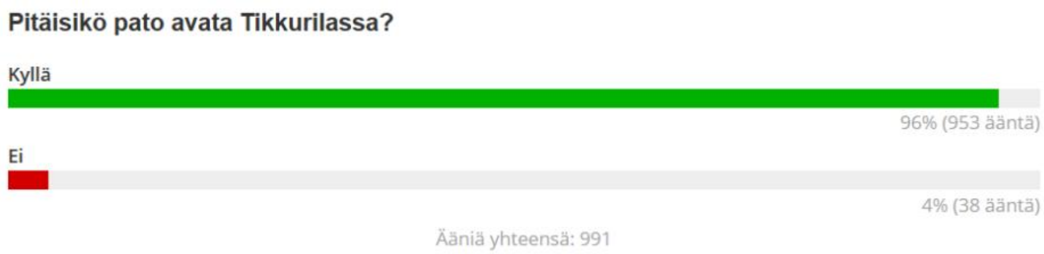


Figure 21. Enquiry on opening the dam in 2015 in the newspaper Vantaan Sanomat. (Vantaan sanomat 2015.)

Another inquiry was carried out in April 2017 (see figure 22), when a resident's opinion writing was published in the newspaper Vantaan Sanomat. Again, the opinions strongly agreed on the dam removal (91 % for not preserving the dam and 9 % on preserving it). (Vantaan sanomat 2017.)

Figure 22. Enquiry on preserving the dam in 2017 in the newspaper Vantaan sanomat (Vantaan sanomat 2017.)

5.2.3 Identified challenges

During the pre-survey it became evident that three aspects with special importance needed to be considered and accommodated in the area. They were: passage for fish, cultural history and recreation.

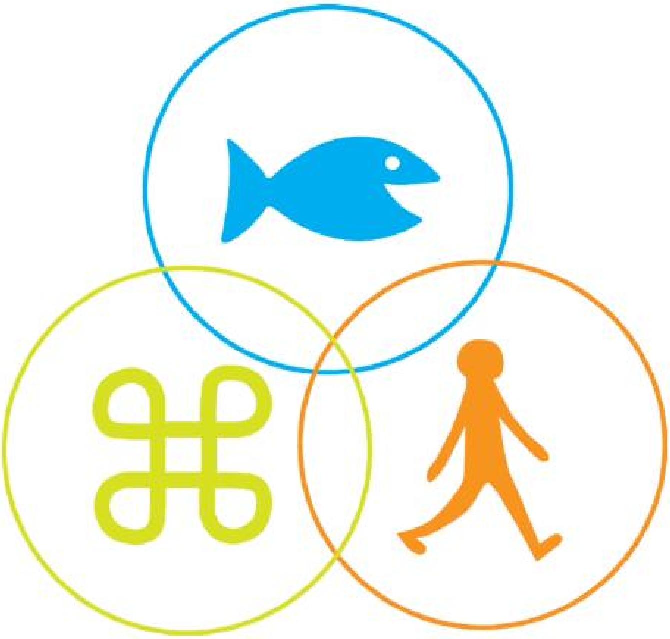


Figure 23. The three aspects: recreation, fish and cultural history.

While cultural history often increases recreational values and they both can exist without downsizing the other, the culture historical attractions in the area at present are not easily achievable and recreation is focusing on other parts of the riverfront. As the population of Tikkurila increases, more pressure is set on the riverfront, which drives towards expanding and improving the recreation possibilities both on the riverfront and in the water.

5.2.4 The options and impact assessments

To integrate the goals of the steering group, four alternative suggestions on the solution were made and their impacts assessed on a general level.

The alternatives were:

0+ Refurbishment of the fish ladder

1 Partial removal of the dam

2 Complete/nearly complete removal of the riverbed section of the dam

3 Complete/nearly complete removal of the riverbed section of the dam and long natural rapids

Alternative 0+

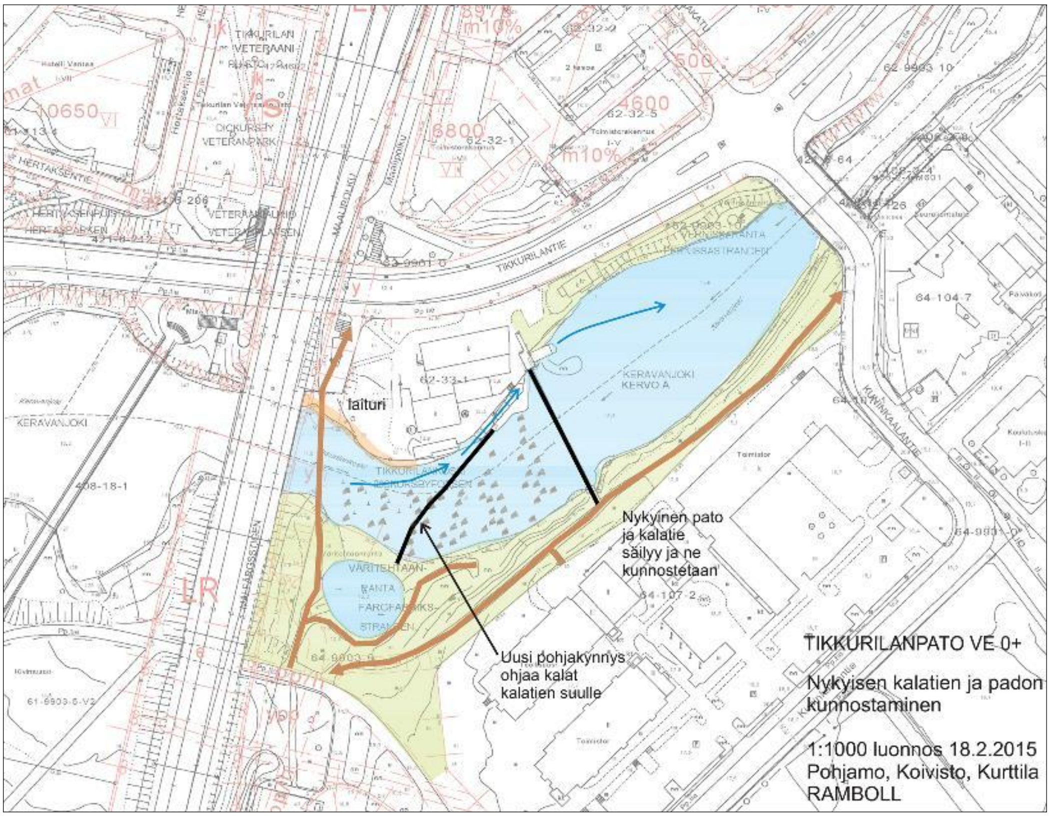


Figure 24. Alternative 0+. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

In Alternative 0+ the current structures would stay in place, but they would be refurbished as required. A new groundsill would be constructed to calm the current and to guide the fish to the fish ladder opening during underflow. The sill would be on the level, so that water flows over broadly and therefore does not attract fish to jump over it. The dominant flow would come from the fish ladder at underflow situation.

Alternative 1

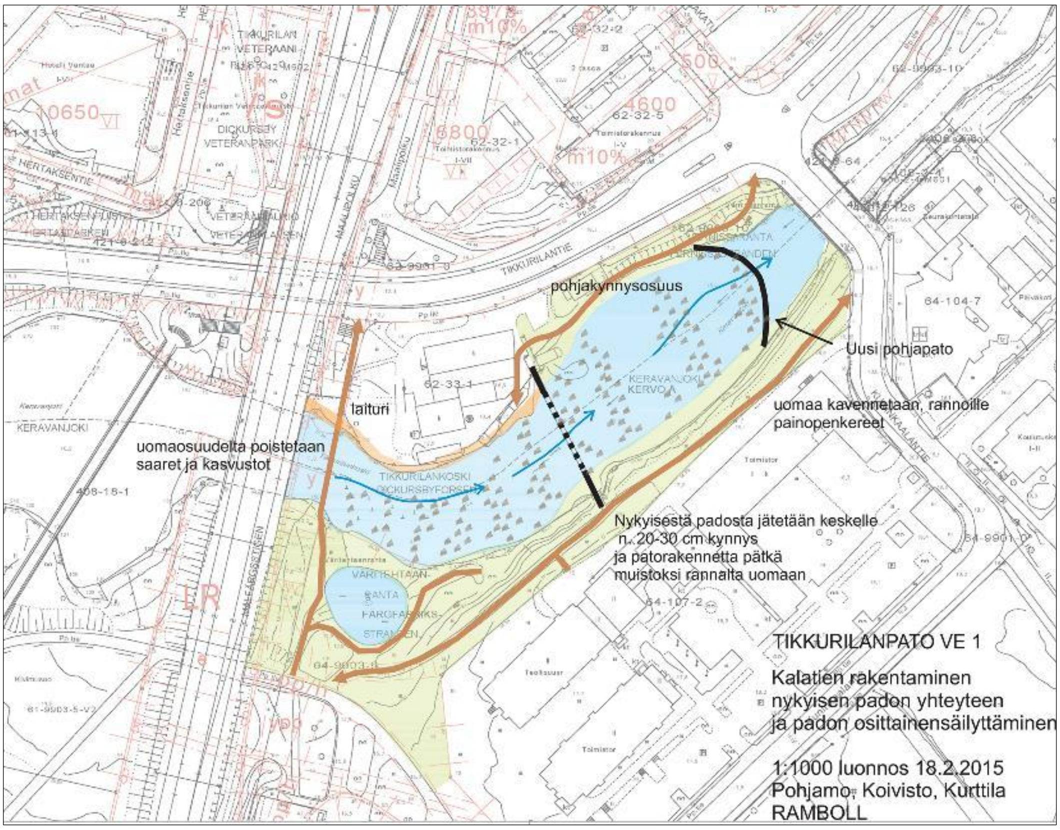


Figure 25. Alternative 1. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

Only the necessary sections of the dam would be dismantled, and a natural fish passage would be constructed in connection to the dam in Alternative 1. The fish ladder would be completely removed, and the centre part of the dam would be dismantled to the height of 0,2 meters, from which a natural fish passage would be built upstream. Fry nursery areas would be built to the sides and the river banks would be supported to handle the descending water level and control erosion.

Alternative 2

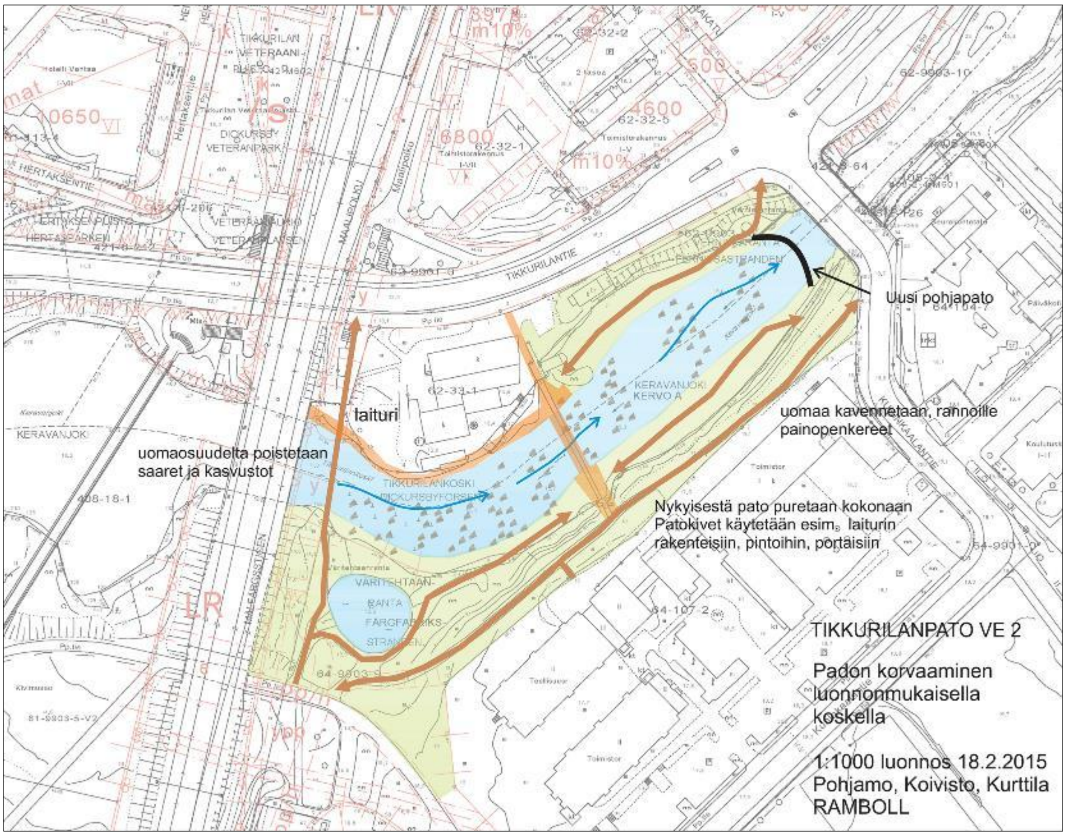


Figure 26. Alternative 2. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

In Alternative 2 the dam and the fish ladder would be completely removed, and natural rapids would be constructed. A new wooden bridge would represent the old dam in its place. The riverbed would be narrowed to match the channel upstream, to achieve deeper water during underflow. Spawning beds and fish nursery areas would be built in the rapids, and the banks would be supported by berms to control erosion and collapsing.

Alternative 3

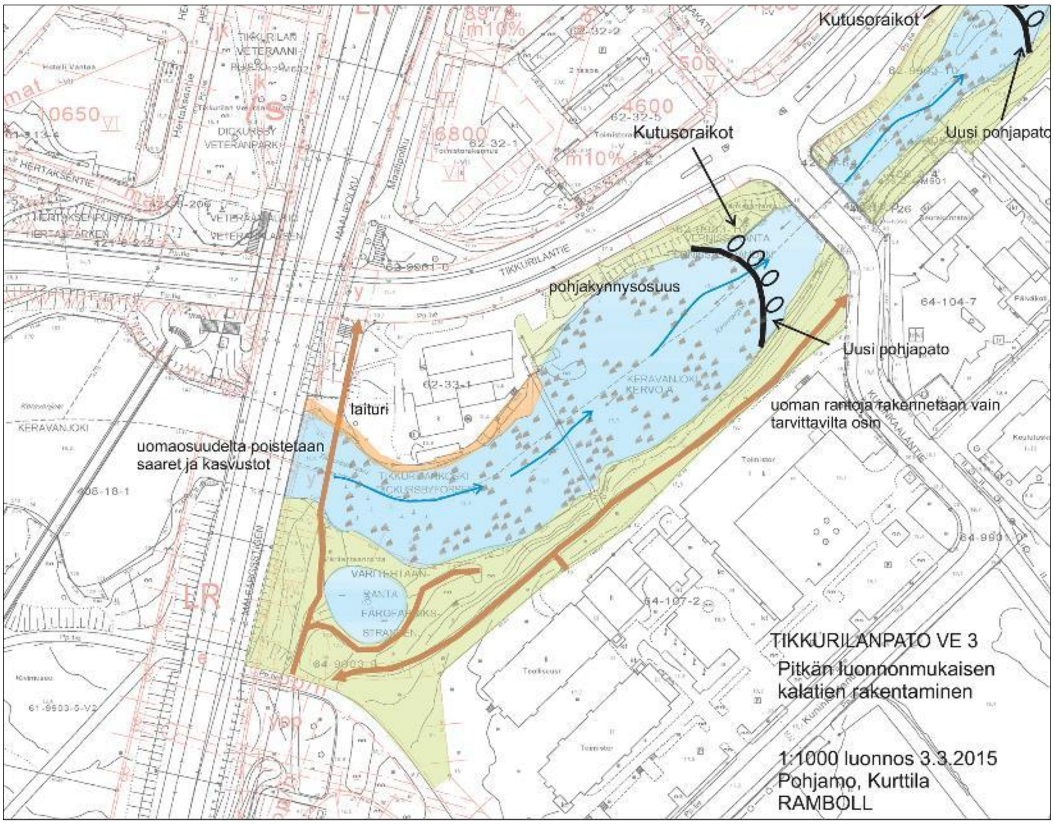


Figure 27. Alternative 3. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

The dam and the fish ladder would be removed completely, and long natural rapids would be built in Alternative 3. The banks and vegetation would mostly stay the same and water flow speed would stay small, since water spreads over a wider area. The challenge would be summertime drying, which would be taken into consideration by building an underflow channel. Spawning beds, fish nursery areas and protective rocks would be built to achieve a maximum fish reproduction and habitat area.

The alternatives were assessed on their effects to the following factors:

- Fish
- Fry production
- Other benthos
- Fishery

- Waterscape
- Culture historical value
- Construction costs
- Maintenance costs
- Water flow

	VE0+	VE1	VE2	VE3
Kalasto	0/+	+	+	++
Poikastuotanto	0	+	+	++
Muut pohjaeliöstö	0	+	+	++
Kalastus	0	+	+	+
Vesistömaisemakuva	0	?	?	?
Rantojen virkistyskäyttö ja maisemakuva	0	+	+	0/+
Kulttuurihistoriallinen arvo	0	-	--	-
Rakentamisen kustannukset	0	--	-	--
Ylläpidon kustannukset	-	-	0	0
Vaikutukset virtaamiin:	Virtaamat pysyvät nykytilan mukaisina	Padon yläpuolisella osuudella Aliveden aikana ja keskiveden aikana vaikutukset virtaamaan rajoittuvat nykyisen padon ja Kuninkaalantien sillan alla olevan koskenniskan väliselle osuudelle Yliveden aikainen vaikutus virtaamaan ulottuu Hanabölen koskelle, vaikutukset vähäisiä Hanabölen kosken läheisyydessä	Vaikutukset virtaamiin merkittäviä muokattavalla uoman osuudella - > virtausnopeudet kasvavat koskiosuudella. Suurimmat vaikutukset ali- ja keskivirtaamalla muokattavalle osuudelle. Yliveden aikana vaikutukset ulottuvat Hanabölen koskelle asti	Vaikutukset virtaamiin merkittäviä muokattavalla uoman osuudella - > virtausnopeudet kasvavat koskiosuudella. Suurimmat vaikutukset ali- ja keskivirtaamalla muokattavalle osuudelle. Yliveden aikana vaikutukset ulottuvat Hanabölen koskelle asti. Leveämmän uoman vuoksi alivedenvirtaama leviää laajemmalle -> vähäinen vesipinta. Ylivirtaamalla rauhallisempi virtaama kuin VE2:ssa

Figure 28. The impact assessment on the alternatives. Green indicates a positive change, red negative and yellow is neutral. The changes have been described in the chapters below. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

Alternative 0+ effects on water flow would be restricted between the dam and the new groundsill. The effects would manifest mainly on low and medium flow. It would preserve the placid pool above the dam and would not affect fishing opportunities.

Positive effects:

- Slight changes for fish, since they might find the ladder opening easier on low and medium flow
- Preservation of the culture historical value
- Minor changes in waterscape
- Affordable construction costs

Negative effects:

- Fry production would stay small
- The potential of working as a habitat for endangered migrant fish would not be utilized.
- Fish ladder and the dam would require maintenance; the life cycle of the structures might be short.
- The groundsill would not direct the fish during high flows, when the migrant sea trout is climbing upstream to spawn.

Alternative 1 would influence low and medium flow levels between the dam and the bridge of the street Kuninkaalantie. Minor high flow effects would continue to the rapid Hanabölenkoski. It would also change the dam pool into flowing rapids.

Positive effects:

- Improved landscape and recreation possibilities on the banks
- Better fry production area and passage for fish
- The river bed would be under water even at underflow.
- Partly preserved dam structures

Negative effects:

- Some decrease in culture historical value
- The fry production potential of the old rapids would not be fully exploited
- Construction costs would be quite extensive

Alternative 2 would have a significant impact on water speed, since the river bed would be considerably narrower. The water level at underflow and medium flow would be higher and the effects on high flow would reach the rapid Hanabölenkoski.

Positive effects:

- Unrestrained passage for fish and expanded fry production area
- Narrower stream enables wider park areas and therefore also more opportunities for recreation

Negative effects are mostly the same as in Alternative 1.

Compared to Alternative 2, **Alternative 3** would help keep the water flow speed smaller, since water would level out. Effects during high flow would be minimal, because the highest groundsill would be constructed in a place that is close to as wide as the dam.

Positive effects:

- Original culture historical rapid of Tikkurilankoski would be mainly restored in place
- The best option for fish; fry production area would be maximized, and the passage would be unrestrained for fish and all benthos.

Negative effects:

- Slightly more expensive than the other alternatives
- Decreased culture historical value of the dam

Alternatives 2 and 3 were more neutral on upkeep costs than alternatives 0+ and 1, because the upkeep of a natural rapid area would most likely be more affordable than the upkeep of concrete constructions.

After a discussion with the steering group, it was decided to continue with Alternative 3 and make some further examination on partial or total removal of the dam and the extent of river banks and groundsills.

5.2.5 The final pre-survey plan

The final pre-survey plan is presented in figure 29.

The dam would be preserved and refurbished on both sides for a length of 5-15 meters. The centre part would be dismantled to enable unrestrained passage for fish and benthos and the old groundsills would be refurbished if needed.

The banks would be supported by landfills, which allow more space for recreation. A new path and recreation area would be constructed on the north bank and the waterside slope shaped varying and planted as a meadow.

The connecting path from Vernissa to the west side of the railway was proposed to be created as a wooden deck structure.

Figure 29. The final pre-survey plan. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

A new scenic platform could be erected on top of the preserved northern dam part and the fish ladder developed as a terrace for the café/restaurant.

The riverbed would be improved with new groundsills, which will keep a sufficient water level and habitats for fish fry.

A phasing for the implementation of the pre-survey plan was suggested, with different extent of construction. The alternative MIN requires the least construction, whereas alternative MAX requires the most construction.

Alternative MIN would include the required landfills, dam removal and river restoration measures and some small-scale vegetation and the costs would be roughly 340 000 €.

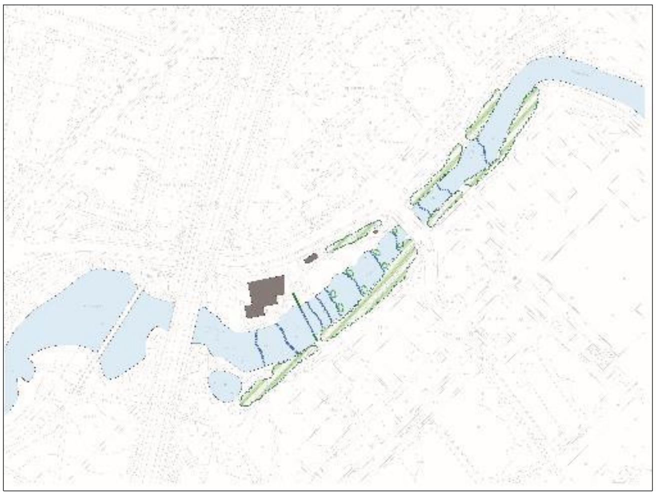


Figure 30. Alternative MIN of the phasing study. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

Alternative MID would incorporate the same dam removal, river restoration and vegetation measures as alternative MIN, but also more extensive landfills and a path on the north bank. Construction costs were estimated to be roughly 470 000 €.

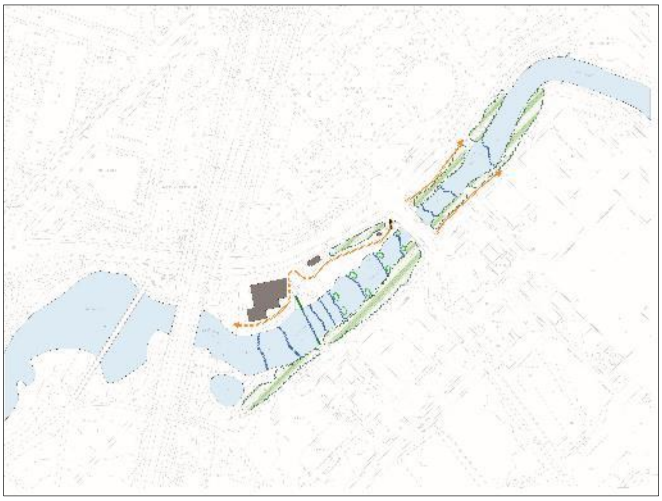


Figure 31. Alternative MID of the phasing study. (Tikkurilan padon kunnostussuunnittelun esiselvitys 2015.)

Alternative MAX is the same as the final pre-survey plan and the costs would be roughly 790 000 €.

The costs for the refurbishment and upkeep of the current dam were calculated to being 475 000-525 000 € in a timespan of twenty years.

5.3 The landscape architecture competition

In 2015 the city of Vantaa decided to start a landscape architecture competition on designing the riverfront of the River Keravanjoki in Tikkurila. One of the goals of the liveability programme for the city of Vantaa is the development of Tikkurila waterfront. There are a lot of important buildings in the surroundings, such as Heureka and the Silk Factory. The competition was kicked off to increase appreciation of the area and to get comparable suggestions for future area development and design (Keskinen 2017.)

A questionnaire on the riverfront was performed and it showed some contradicting results in the dam area. In the heat maps the dam area has been marked as good (see figure 32) and as not good (see figure 33). However, the rapid area was marked as good more often than not good, and it also attracted more comments than the dammed water pool.

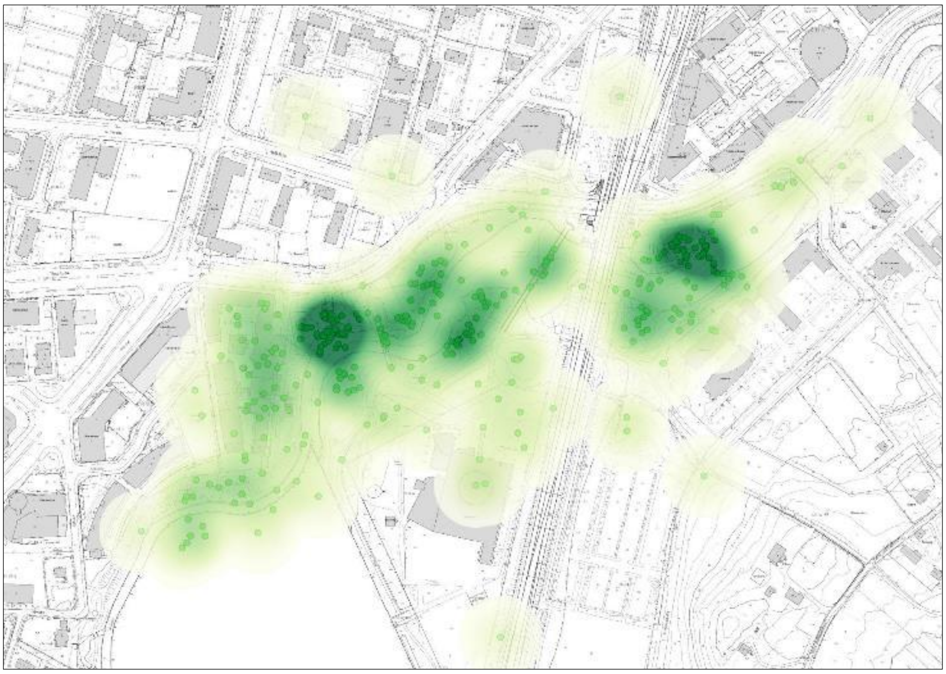


Figure 32. Good places marked on the map in connection with the questionnaire. (Resident questionnaire results on the riverfront development 2015.)

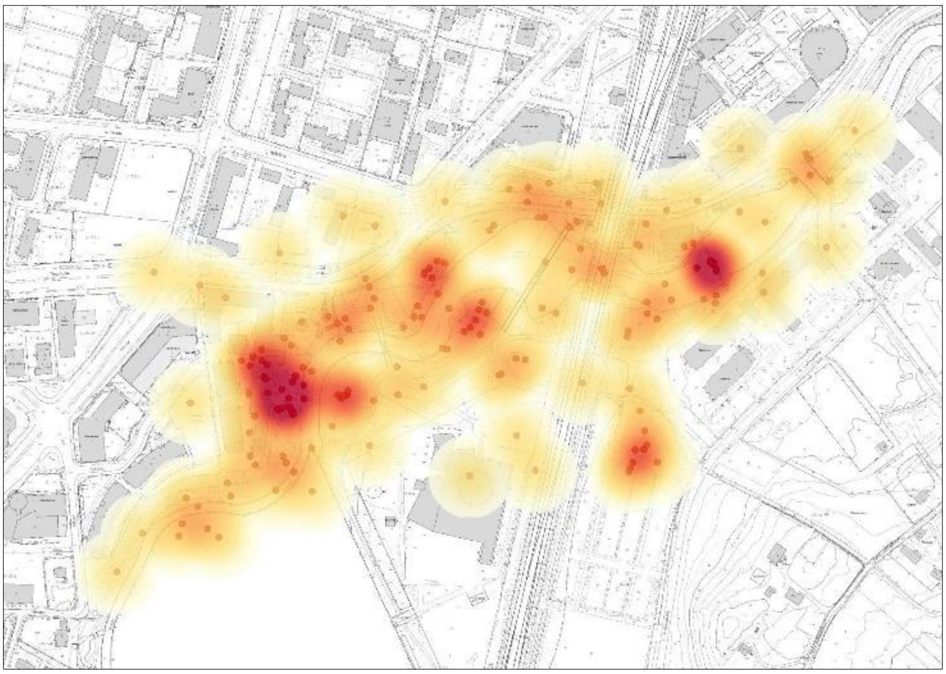


Figure 33. Not good-places marked on the map relating to the questionnaire. (Resident questionnaire results on the riverfront development 2015.)

The open answers highlighted the riverfront as an important recreational area and hoped that it would be developed as a multi-functional, yet pleasant and green “living room” for the residents. Also, some wishes were expressed towards preserving the diverse nature and on removing or preserving the dam.

The competition winner was Loci Maisema-arkkitehdit Oy and their proposal was called “Keidas”.

Figure 34. “Keidas” by Loci Maisema-arkkitehdit Oy. (Loci Maisema-arkkitehdit Oy 2015.)

5.4 The general plan

The general plan was finalized in March 2017 and the water permit for dam removal was applied in spring 2017.

In the general plan the interests focused on providing maximum space for trout reproducing and habitats. The river section had been a rapid before it was dammed, and it could be seen on the photographs taken in 1994 that the river bed included bedrock and rocks in varied sizes and the rapid-bed shape. Some opinions were supporting a more natural approach to the dam removal and river restoration process. They suggested that after the dam was removed, the rapids would take shape naturally and provide the habitats that were provided in the original state. Fish could climb up as they had climbed before the river was dammed. Other positions suggested that the stream velocity was too high for fish to climb up and the rapid would need groundsills to calm velocity and distribute water for the total width of the river bed. The groundsills would also help create more habitats, since they provide diverse water depths.

Photo 11. A picture taken from Vernissa towards Kuninkaalantie bridge in 1994 when the technical fish ladder was under construction. The bed rock and numerous stones are visible in the channel. (Keski-Uudenmaan vesiensuojelun liikelaitoskuntayhtymä 1994.)

5.4.1 Surveys

Numerous surveys were performed during the general planning phase. These included mapping the underwater in-channel structure, an analysis on contaminated soils in the area, site investigation, a survey on the structural condition of the old kiln smokestack, an ocular survey on the structural condition of the dam and fish ladder, a survey on the dismantling material of the dam and a survey on thick shelled river mussel habitats on the river reach.

The analysis of contaminated soils in the area revealed that the soil on the north shore was highly contaminated. The most problematic soils were in the immediate environment of the old kiln smokestack and it was also found that the total estimated amount of contaminated soils in the design area would be up to 1200 m³. The contaminated soil need to be either excavated or covered with new, pure soils.

The survey on the structural condition of the old kiln smokestack suggested that the damages in the kiln do not pose a threat of collapsing, but that they would advance in the structure making the refurbishment more expensive. It was suggested that the damages be repaired.

The densest thick shelled river mussel population was found from the backwater in front of Heureka (estimated population size 2900 specimens), but habitats were also above the dam pool (125 specimens), in the dam pool (800 specimens) and in the rapid area (46 specimens). The thick shelled river mussels in the dam pool should be moved to a suitable habitat, further away from the construction site.

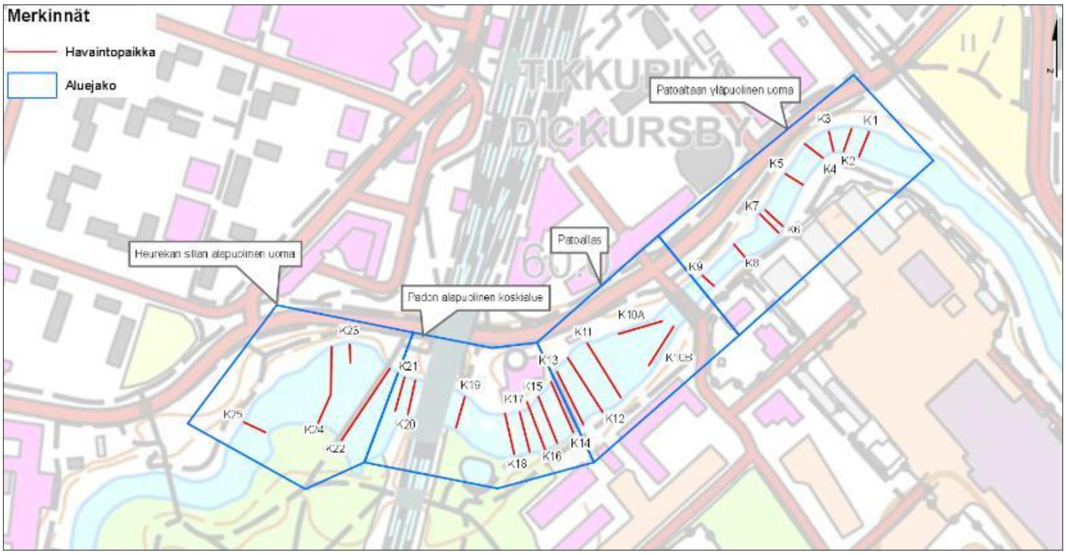


Figure 35. Observation lines from the thick shelled river mussel survey. Estimated population size in the dam pool was 800 specimens. (Sopanen 2015.)

An extensive modelling was performed to study the effects dam removal and the design would have on water levels. The modelled water flow situations were:

- Medium low flow 0,3 m³/s
- Median flow 2,0 m³/s
- Medium flow 3,3 m³/s
- Medium high flow 28,81 m³/s
- High flow 71,85 m³/s

The results showed, that the dam removal would influence water flow circumstances mainly in the area between the dam and the neck of the rapid, which is located some 80 meters upstream from the street Kuninkaalantie bridge. During low flow, water level would drop approximately 30 cm on the rapid neck and during medium flow about 8 cm.

Figure 36. Results from the modelling, water depth during medium flow at present state (up left), after dam removal (up right) and after the technical

construction measures (down left). (Tikkurilankosken yleissuunnitelma 2016, rev. 2017.)

5.4.2 The design

The general plan is presented in appendix 1.

The general plan suggested four new natural groundsills, one on the rapid neck and one just below the street Kuninkaalantie bridge to upkeep the medium water level upstream as close to present state as possible and two between the bridge and the current dam. The lower groundsills serve to create better habitats for fish with sufficient water levels and velocities and to improve fish climbing conditions. The groundsills were defined to be half-permeable and constructed with natural river restoration techniques (only natural materials, no concrete).

The modelling was used to map out optimal water depths and velocities for fish of different ages. Based on the mapping, places for spawning gravel and fry habitats and their construction measures were specified.

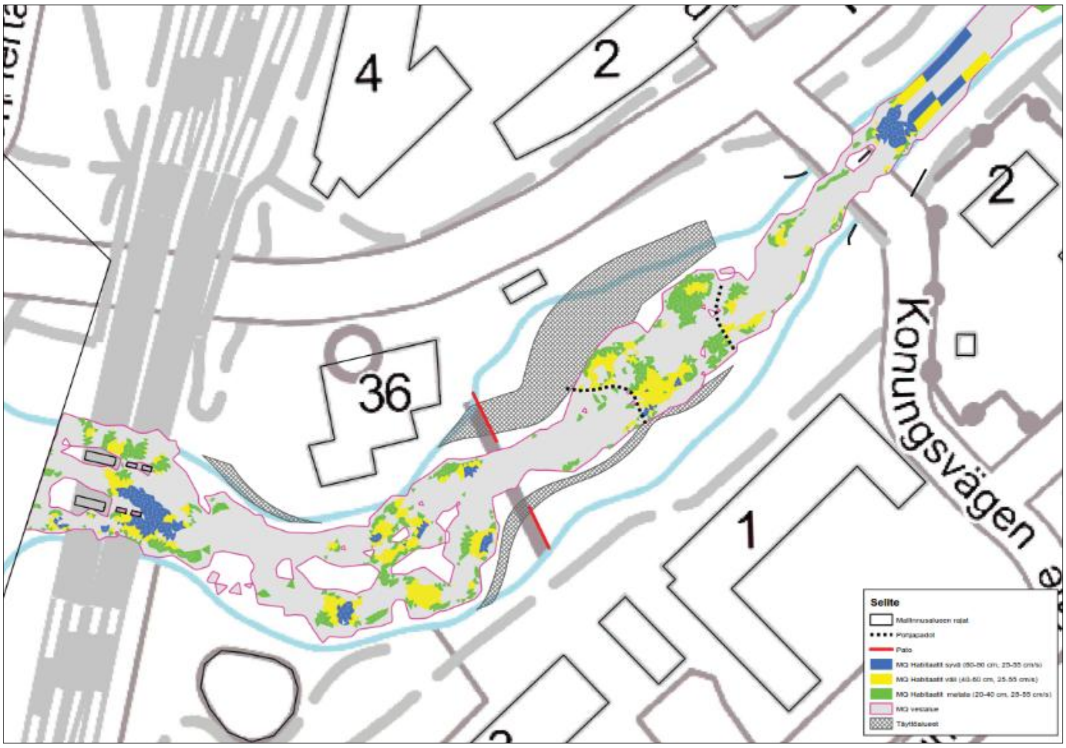


Figure 37. A theme map for trout habitats during medium flow. Blue areas have a water depth of 60-90 cm, yellow areas 40-60 cm, green areas 20-40 cm, and all the areas have a flow speed of 25-55 cm/s. Various water depths provide habitats for different age groups of trout. (Tikkurilankosken yleissuunnitelma 2016, rev. 2017)

The dam removal and the refurbishment of the preserved parts were designed. The fish ladder was suggested to be refitted as a terrace and general plans were drawn.

The basis for the design on the riverfront was on the MAX-alternative of the pre-survey phase and the landscape architecture competition winner “Keidas”, which suggested the riverfront in the dam pool area to be developed with roughly the same principles as the pre-survey plan.

Figure 38. An extraction from the general design. (Tikkurilankosken yleissuunnitelma 2016, rev. 2017)

In the general plan, the north shore was proposed to be filled moderately to improve the stability and functionality. The kiln smokestack environment would have to be excavated completely and filled in again, because of the contaminated soils. A new pathway and entrances to the shoreline would be constructed with room for recreation, picnic etc. Connections to the water were designed to be executed with old upholstery stones from the dam, as would be the case with all the stairs in the area. The current vegetation in the river bank should be preserved and new vegetation should be natural waterfront species. Some new plantings can be made to create more shadow on the recreation area.

The south shore filling would be very minimal in order of preserving the present vegetation. A fishing path would be implemented on the shoreline, but otherwise the look would be very natural rapid-like with grass and rocks.

An ascending platform for kayakers and canoers was designed on the river bend before the rapids.

The estimated construction costs were 750 500 € including construction materials and work, and contract tasks. The whole budget will be 1 022 800 € including construction materials and work, contract and client tasks.

5.5 Detailed planning

Now, detailed planning of the rapid Tikkurilankoski is in the making. The design area has been specified to apply the filling and excavation work in the dam pool area, the south shore fishing path and the channel design in the total river reach. Other riverfront landscape design will be continued relating to the larger totality of Tikkurila riverfront landscape design which is performed by Loci Maisema-arkkitehdit Oy.

The design work will include the dam removal design, geotechnical and municipal engineering on the banks, river restoration design and erosion control and vegetation design in the sub-water channel area. It will also contain measures for excavating/covering contaminated soils and rough instructions on how to arrange the construction site.

Detailed planning is expected to be finished in spring 2018.

5.6 Project culture

The project has been a fitting example of peaceful collaboration of different experts from various fields. The opinions of each expert have been valued and taken into consideration and the important decisions have been made together in the project meetings. The technical board has always made the final decision on further development with the help of extensive surveys and plans made during the project.

The planning process has been conducted with the help of “round table discussions”, where the consultants of different expertise gather in the same table and discuss the matter at hand, trying to find the best solution that will benefit project goals and the customer.

Hanna Keskinen, the project manager from the City of Vantaa commented on the project culture:

> *“Flat organization hierarchy and the flexibility of it have simplified the process of following trough novel initiatives. The broadmindedness and confidence of the management*

is also a vital factor. Open conversation, where everybody has a chance to voice their opinions, is most important in these kinds of projects. The task of the chairperson is to make sure that everyone is heard. Each expert is equal in the project group. The collaboration with the Vantaa City Museum is easy, because they have a better view on local matters, than the National Board of Antiquities that handled all the statements earlier." (Keskinen 2017, free translation from Finnish.)

6 RESEARCH OBJECTIVES AND METHODS

The main research question is:

How will the physical, biological and cultural environment change in the area that is affected by dam removal and river restoration?

Other research questions are:

Will the cultural losses be extensive compared to the ecological benefits of dam removal?

After plan implementation, how should the area be monitored to get valuable and essential data for future projects?

The use of ecosystem services approach as a framework for assessment is anthropocentric, but it was considered an appropriate tool for parallel evaluation of the environmental and cultural values of the area.

This thesis uses the ecosystem services perspective for the following reasons:

- It is an effective communication tool for multidisciplinary work, stakeholder cooperation and community outreach
- It focuses on the human scale and well-being
- It is holistic by default
- It offers methodology for valuation of urban nature and culture

The background for the ecosystem service assessment has been gathered through many various sources of information. First, the planning process has involved assessing changes in the physical, biological and cultural environment by multiple experts and the steering group throughout the project. Secondly, a literature review has been made in this thesis to recognize the most common effects of dam removal and river restoration on river ecosystem. In addition, the assessment has been reviewed by multiple professional experts working at Ramboll Finland Oy, including fish, hydrology, ecology and landscape experts, most of who have participated in the project.

The changes to the ecosystem services, assessment of the present state and the expectation for future state in the area are not necessarily based on exact biophysical measurements but more on literature values, case studies and the estimations made by specialists. Some exact information has been available of the present state, such as electro-fishing results from the rapid under the dam.

The ecosystem service assessment includes mapping the ecosystem services in the area, evaluating their current status, assessing the impacts dam removal and river restoration have on them and finally determining the impact scale and time-frame. The justification for evaluation has been specified with literature and expert interview references, but in addition all the thesis writer's knowledge gained throughout the process has been considered when performing the assessment.

This thesis also includes a monitoring programme that has been conducted by determining the most considerable changes in ecosystem services, forming key indicators for measurements, proposing a survey method on the future and present state, suggesting an interval for surveying and a publication. The ecosystem services to be monitored have been selected with the information gained in the project through the steering group and conducted surveys and the ecosystem service evaluation.

Suggestions for monitoring have been comprised based on literature review (such as Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO), The River Restoration Centre 2011 and Ecological Restoration of Streams and Rivers: Shifting strategies and shifting goals, Palmer et al., 2014), case studies, discussions with the steering group and professional experts working at Ramboll Finland Oy. At this stage, the monitoring programme works as a preliminary suggestion that should be discussed with the steering group and stakeholders and revised based on the conclusions and aspirations. It would be appropriate to focus on monitoring some key services that were set as the indicators for reaching project goals.

7 ECOSYSTEM SERVICE ASSESSMENT IN CASE TIKKURILA

7.1 Ecosystem services and indicators in the planning area

The ecosystem services in the area are presented in appendix 2.

The ecosystems and their indicators proposed by Cook-Book for water ecosystem service assessment and valuation (Grizzetti et al. 2015) were the basis for the assessment. Some of them were considered irrelevant in the area and discarded. Some indicators were added, because the Cook-book list did not cover every service found in the area.

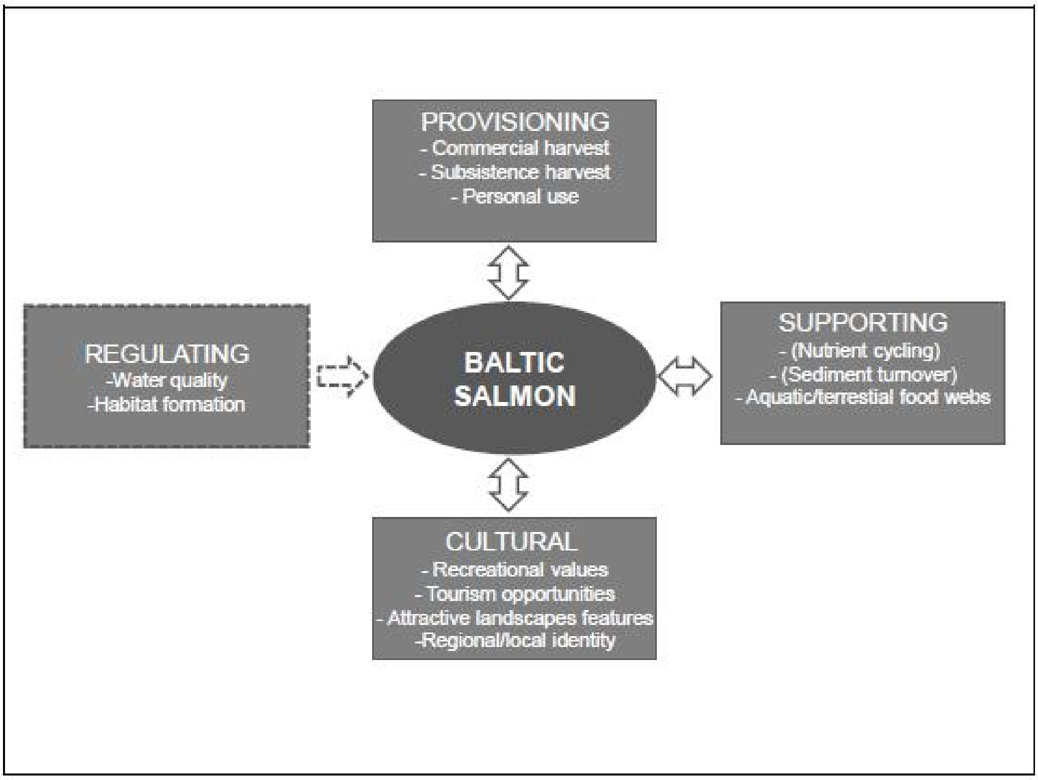


Figure 39. An example of the ecosystem service network of the Baltic salmon. (Kulmala et al. 2012, 2).

It was important to consider the synergies of ecosystem services, implying that many ecosystem services would be affected, if for example the sea trout population would grow (see figure 39). Also, an improvement in one service (e.g. reproduction areas) will most likely result to improvement of other services (e.g. fish abundance, fish production, number of fishing licenses) as a ramification. The trade-offs had to also be incorporated in the assessment, implying that improvement in some services might decrease the benefits of other services (e.g. the shift from still water to flowing water creates habitats for trout but removes habitats for thick shelled river mussels).

7.2 The structure of the assessment

The table of ecosystem services assessment is presented in appendix 3.

The present state was estimated based on information gained in the process and from realized studies and it varies from very poor to good. A present state has not been defined for all services due to lack of information or the difficulty of determining a certain value.

The dam removal and river restoration were considered to be stressors that will change the current situation and ecosystem balance. In the table, the state of each indicator has been valued to be either unchanged (0), improved slightly (+) or greatly (++) or deteriorated slightly (-).

The dam removal and river restoration serve as two separate issues that have their own effects and benefits, implying that if the dam removal impairs the flow of one service, river restoration might return the flow closer to its original state.

Dam removal works include water level descension, sediment disposal from the reservoir and filling and excavation on the shoreline.

River restoration work includes in-channel structure restoration for fish, new groundsills, implementation of green infrastructure, recreational functionalities such as walkways, benches etc., and paths and places for fishermen.

The expected time frame for the service flow has been determined as estimation. Some of the indicators might be affected immediately during construction works (e.g. surface water availability) and some gradually after the removal and restoration works (e.g. number of fishing licenses). In addition, the consequences of construction works have been considered. Some services might deteriorate right after the dam removal and restoration works (e.g. water quality will suffer from the sediment release in a short-term) but balance out in a few months after the work has been finished.

The scale of the effect has been evaluated and it ranges from small to large. It is highly dependent on the restoration success and other measures that will be made in the future. Most small-scale effects concern only the immediate dam reservoir area and its banks. The possible large-scale effects might improve the situation of the entire stretch of the River Keravanjoki and even the River Vantaanjoki (e.g. migratory fish populations might increase in the entire river, especially if other dams would be removed as well). The dam in the present state or its removal has minimal effects on technical issues downstream of the dam, i.e. hydrology, geotechnical qualities.

8 MONITORING PROGRAMME

The monitoring programme is presented in appendix 4.

8.1 Chosen indicators and suggestions for monitoring

Ecosystem services linked to fisheries and recreational fishing are suggested to be monitored, since improving habitat and reproduction conditions for fish and increasing fishing opportunities are one of the most important goals in the project. The fishery indicators to be surveyed would be fish production, status of fish population, fish nursery and reproductive areas and fish abundance. Most of these could be conducted relating to the Joint survey of the River Vantaanjoki - fisheries and benthos, which is performed every two years by Kala- ja Vesitutkimus Oy. Recreational fishing, including the indicators for the number of fishermen and number of fishing licenses/reserves could also be incorporated with the Joint survey of the River Vantaanjoki - fisheries and benthos. A separate set of questions on the rapid Tikkurilankoski river restoration and dam removal should be included in the survey to get information on the fishermen's views on project success. Questions on consumerism during fishing trips could also be incorporated, to receive data on how extensive the turnout from fishing tourism is.

Many other ecosystem services affect conditions for fish and riparian species and therefore would be useful to be monitored. In addition, they give valuable information on the river ecosystem rehabilitation. These include nutrient concentration, biodiversity value, indicators on surface water quality, area occupied by plants within river front and erosion control on banks. Some (nutrients, water quality) can be connected with the Joint survey on water quality in the River Vantaanjoki, if a new observation site was added on the rehabilitated area.

The other important goals have been to improve recreational conditions and preserve cultural historical value. The effects are hard to measure in any other way, then by user opinions. Therefore, it would be good to conduct a questionnaire on recreation, cultural history and the overall success of the dam removal and river restoration for residents and other users. The questionnaire should include questions on recreational opportunities, quality of the culture-historical environment, the changes in the landscape and soundscape and in local identity. Kayaking and white-water rafting can be connected with the questionnaire or be performed separately.

Some elements to be monitored have been decided on because of discussions with governmental agencies, the steering group and other experts. These include groundwater for drinking, alien species (mostly reed grass at this point) and habitats for thick shelled river mussel (nature directive species).

Additional needs for monitoring include channel form and in-channel structure and discharge. Discharge is critical to measure and it should be measured continuously before dam removal, during construction and after implementation. Channel form should be observed one and three years after the restoration and compare it to the situation right after construction, because it will provide valuable information on the river processes.

It would also be good to measure water level on the upstream side of the top of the rapid and downstream side of the current dam to compare the modelling results with reality. Water levels on situations after dam removal and after river restoration should be measured to get enough information.

An appropriate timespan for monitoring is hard to define. Often in river restoration projects three years is considered as a sufficient time for monitoring, but the complex river ecosystem might take more time to recover. Also fishing tourism will likely increase gradually and a longer time-period will be needed to survey the effects. This thesis suggests that the monitoring of fish abundance, production and population status, water quality, number of fishermen and fishing licenses and biodiversity should be continued for an unqualified period, especially if it can be incorporated to the River Vantaanjoki joint survey. Other indicators should be monitored at minimum for three years and some other suggestions have been given in the appendix 2. Questionnaires on recreation, landscape and cultural-history could be performed one, three and five years after the restoration.

The effects on water quality, fish production, status and abundance on the entire reach of the River Keravanjoki should be studied in order of getting an image on how comprehensive the outcomes of a dam removal are in reality.

8.2 Suggestions for monitoring and documenting during implementation

Monitoring and documentation during implementation of the dam removal and river restoration is extremely important. During the process, the project group has had access to old photographs from 1994, when the construction of the fish ladder was underway. These pictures have proved to be essential, because they have indicated the channel formation underwater better than soundings performed in the general planning phase and given more information on the dam structure. They also provide valuable information on how to organize the work site during construction.

When the water level is lowered, the intact dam should be documented thoroughly in the records of the City Museum.

During construction, numerous photographs should be taken on different work stages and work site arrangements. A good method of photographing would be fixed point photography, where photos will be taken from the same place before, during and after construction. Aerial photographs should also be taken, at minimum on the finished construction works, but maybe also during construction.

A time-lapse-camera installed to document the entire construction works would provide useful information of the process and valuable visual material for advertising the project.

It is inevitable that some issues will manifest themselves only during construction and the designs will not be applicable as they are. Some solutions need to be worked out on-site and therefore the implementation of the plan should be superintended by a qualified and experienced expert. The channel form needs to be modified, if it becomes obvious that during low flows there is not enough water, or if the water flow speed is too fast during high flows, for fish and benthos to pass through the rapid

Accurate documentation on, for example the origin of rocks used in the restoration, the amount of gravel deposited in the channel, the costs etc. would be important.

The continuous monitoring during construction works should include at least downstream water quality (preferably in the backwaters in front of Heureka, because of the thick shelled river mussel population), water flow and level and groundwater elevation.

9 RESULTS

The main research question in this thesis was:

How will the physical, biological and cultural environment change in the area that is affected by dam removal and river restoration?

Other research questions were:

Will the cultural losses be extensive compared to the ecological benefits of dam removal?

After plan implementation, how should the area be monitored to review if the project goals have been reached and to get valuable and essential data for future projects?

According to the literature review, free-flowing rivers provide numerous ecosystem services, which have resulted in extensive damming of rivers for food, water and energy. This is one of the reasons for the rapidly decreasing biodiversity of freshwater ecosystems. Dam upkeep is expensive, and often they pose a threat on general safety. Building of new dams has been slowing down for the last three decades, but there is a growing need of water resources and energy supply in the world posing a threat to free-flowing rivers all over the world.

The literature review gives an indication that even though dam removal will not restore the pre-dam conditions completely, it will restore the ecosystem closer to its original nature. When the integrity of the river system is returned, the original processes will take over and in time, recover most of the important characteristics of free-flowing water. The review also shows that dam removal decisions are usually interdisciplinary and need to be performed through multiple phases and extensive studies. One of the important phases is monitoring after dam removal, which gives information on how the goals of the project were met and how the ecosystem recovers from the stress of removing the dam.

The ecosystem service assessment shows that dam removal will have effects on some provisioning services, but mostly on regulating and cultural services. It is expected that the provisioning services of fish production, status of fish population and number of fishermen will grow due to dam removal.

From regulating services, a significant increase is presumed to be seen in biodiversity value, fish nursery areas and stream connectivity. Also surface water quality, fish reproductive areas, the situation with alien species and flood plain areas are predicted to improve. It is presumed that negative effects will arise in habitats for thick shelled river mussels and sediment retention.

Cultural changes will be mostly positive, at least on visitors in the area, recreational activities, fish abundance, safety and public and scientific interest. Some of the cultural services cannot be evaluated as being improved or impaired, since the value is difficult to determine and contradictory. Good examples are the landscape and soundscape values of a still pool compared to those of a rapid. Even though the still pool represents the cultural history of the past 300 or more years, the rapid represents a much older cultural history. The matter of how representative rapids created by humans can be of natural state rapids can be debated on, but the restored rapid might still capture the characteristics of a natural environment quite convincible if it is carried out carefully. The landscape value and soundscape of a still pool/flowing rapid has also another viewpoint: some might think that the still pool is a more attractive element in the scenery and soundscape than a flowing rapid, but again, a certain value is impossible to determine because every viewer has their own preferences.

The quality of the cultural-historical environment of Vernissa, which is a classified site, should be considered as a whole. The functions that have led to damming the river have been seized and there are new functional needs and values for the area and the buildings. In some cases, being able to make use of culture-historical structures has been the qualification for preserving them (like in the case of the dry dock in Suomenlinna). The Tikkurila dam is a locally important memorial of the factory surroundings and a structure that enables factory functions but at present state, it has no function. The dam has and will be carefully documented and a large part of it will be preserved, along with the visual illusion of continuity. Time will show what effects the dam removal will have on local identity together with the developing waterfront of Tikkurila.

According to the ecosystem service assessment, the ecological benefits of dam removal and river restoration seem greater than the losses in some cultural services. The greatest improvements are expected to be in the **river integrity** including biodiversity value and stream connectivity, **fishing opportunities** including number of fishermen, **fish population** including status, abundance and living conditions, and in **public and scientific interest**.

The ecosystem service assessment and literature review gave great insight into how the area should be monitored after plan implementation. The time-span for revival of river ecosystems is extensive and therefore the monitoring period should be continued for years. Regulating service indicators can be monitored mostly quantitatively (i.e. sampling, electro-fishing, charting), cultural services qualitatively (questionnaires) and provisioning services in both quantitative and qualitative ways. Monitoring can be done more lightly or more extensively, and the matter should be discussed in the next phase with the steering group.

10 CONCLUSIONS

The study results were quite cohesive with the literature review. Many cases referred to in the guidebooks and references, were situated in the United States and the dams were greater in size. Removal of small, run-of-river dams have more moderate effects on river ecology as can be expected in the case of Tikkurila dam. However, according to the literature, restoring the integrity of a river will benefit the ecosystem greatly in most dam removal cases. The Tikkurila dam decision-making process has been quite similar as the step-by-step guide suggested by The Heinz Center which is described in the literature study, and it has advanced in an efficient manner and has been accepted by the majority of public. This implies that dam removal processes in general should be transparent, engage all stakeholders, consider benefits, losses and effects extensively and agree on practical goals that can be monitored.

Ecosystem services as a framework for evaluating the effects served adequately because it took all the essential elements in the area into consideration. It allowed the cultural elements to be evaluated in the same context as the physical and biological elements. As previously stated, the valuation of ecosystem services is challenging especially in quantitative ways, so this thesis adhered to mainly specifying a probable change as positive or negative. The study results were mostly un-surprising and consistent with the discussions and presumptions that have been made throughout the process, but still presented some considerations to be discussed in the next phases. The study indicates that the ecological and cultural benefits obtained from dam removal will outdo the losses suffered mainly in culture-historical integrity. It also suggests that monitoring is a vital component of the dam removal process and it should be addressed properly with the steering group, who decide on future actions. The results of the study cannot be applied directly to other dam removal projects, because they are always site-specific, and the characteristics are different. However, the study gives some implication on how and which of the river ecosystem services might be affected due to dam removal. It also suggests, that obtained metric information from this project can be used as a reference in other cases, if the monitoring programme is conducted.

This thesis also explains the process and goals of the Tikkurila dam case extensively and demonstrate the present state of the distinctive features in the area.

Some challenges have been met during the thesis process. The changes in ecosystem services were supposed to be evaluated with biophysical quantification, but it was challenging due to the limited amount of monitoring information available from suitable reference projects. Since the thesis writer herself has been collecting part of the data during the process of the project, there is a concern that the reliability of the results has been compromised. There is also a slight risk of confirmation bias, because of the presumptions made during the process.

It is hard to predict how the ecosystem starts to function. The changes can occur in short term or in long term. The dam removal itself will not necessarily increase fish production in excessive amounts since there are still other dams in the river segment, but it is a step forward in developing the River Keravanjoki, and even the River Vantaanjoki towards more natural unsegmented river that provides suitable conditions for fish to spawn and habit. Developing the River Keravanjoki as a superior habitat for trout requires persevering restoration activities, more dam removals and measures on the watershed scale, to improve water quality. Objectives for trout population in the river might also demand trout plantings.

The Tikkurila dam project has been the first of its kind and therefore it should be monitored carefully to get valuable information to make use of in other dam removal processes. The success and careful documentation of this project can be a good reference for decision-makers on other dam removals, which are expected to increase in numbers in the future. Plans for the Tikkurila dam removal have already incited mainly positive publicity and Vantaa has been referred to as a forerunner and an example for other cities in improving conditions for migrating fish and condition of flowing waters. The well-being of, especially, urban nature will most likely be a developing concern due to urbanization, densifying city structure and climate change and therefore it is important to find new ways of valuating different elements compared to each other and methods for the project processes of improving urban nature resilience.

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APPENDICES

APPENDIX 1

57245-1A 57245-1B 57245-1C 57245-1D

PIIRUSTUSMERKINNÄT

- Nykyinen rakennus
- Jk+pp-tie
- Murskepolku
- Uusi kiveys
- Kivituhka
- Uusi kiviverhous
- Nykyinen kiveys
- Kalaportaiden päälle rakennettava terassi
- Arvioitu nykyinen avokallio
- Täyttöalue
- Vesialue
- Tulvavyöhyke täyttö karkealla soralla #0–150mm luonnonmukainen kasvillisuus
- Rantaniitty
- Nykyinen kasvillisuus
- Padon säilyvät rakenteet
- Säilytettävä puu tai pensas
- Istutettava puu
- Kutusoraikko, raekoko 20–60mm
- Nykyinen kivikko
- Pohjakynnys, katso piirustus nro. 57245-10
- kiviramppi puretun padon kohdalla kivien halkaisija 100–400mm ylä-ja alavirran puolella suuret kivet, halkaisija 700–1000mm
- Uudet luonnonkivet halkaisija rantakivikossa 200–800mm halkaisija uomassa 400–1500mm
- Poikaskivikko, koko 60–520mm
- Portaat puretuista patokivistä
- Astinkivet puretuista patokivistä
- Uusi kaide
- Nykyinen kaide
- Nykyinen muuri
- Suunnittelualueen raja
- +14.0 Rannan uusi korkeuskäyrä
- Muinaismuistolain nojalla rauhoitettu muinaisjäännös
- Paikallisesti arvokas kulttuurihistoriallisesti merkittävä kohde
- Säilyvä polttouunin piippu
- NU Nupukiviraita, 2 tai 3 kiveä
- Louhinnan aluevaraus
- Nykyinen pohjakartan mukainen rantaviiva

Vedenkorkeus eri virtaamilla:

- 0,3m3s (MNQ)
- 3,3m3s (MQ)
- 28,81m3s (MHQ)
- 71,85m3s (HQ250)

A	Lisätty kaksi kynnystä ja leikkaukset, louhinnan aluevaraus, muokattu vesikäyriä ja täyttöjä, leikkausten paalunumerot muuttuneet, lisätty tulvasuojelun korkotaso Vernissan pihalla	Hyv. 1.3.2017	Ramboll /Tiia Valtonen

VANTAAN KAUPUNKI
KUNTATEKNIIKAN KESKUS

Hyv.
Tark.
Suunn.

61 TIKKURILA

TIKKURILANKOSKI, VÄRITEHTAANRANTA, VERNISSA JA VERNISSARANTA

ASEMAPIIRUSTUS

Mittakaava 1:500
Koord.järj. ETRS-GK25
Korkeusjärj. N2000
Liitt. piir.nro

44 PUISTOSUUNNITELMA Hyv. Hyv.

Piir.nro **57245-1**

GEOTEK-NIIKKA Tark.

RAMBOLL 3.10.2016 Tark. Ulla Loukkaanhuhta
3.10.2016 Suunn. Tiia Valtonen

HSY:n vesihuolto
PL 300
00066 HSY
p.(09) 15611

Nro
Hyv.
Tark.
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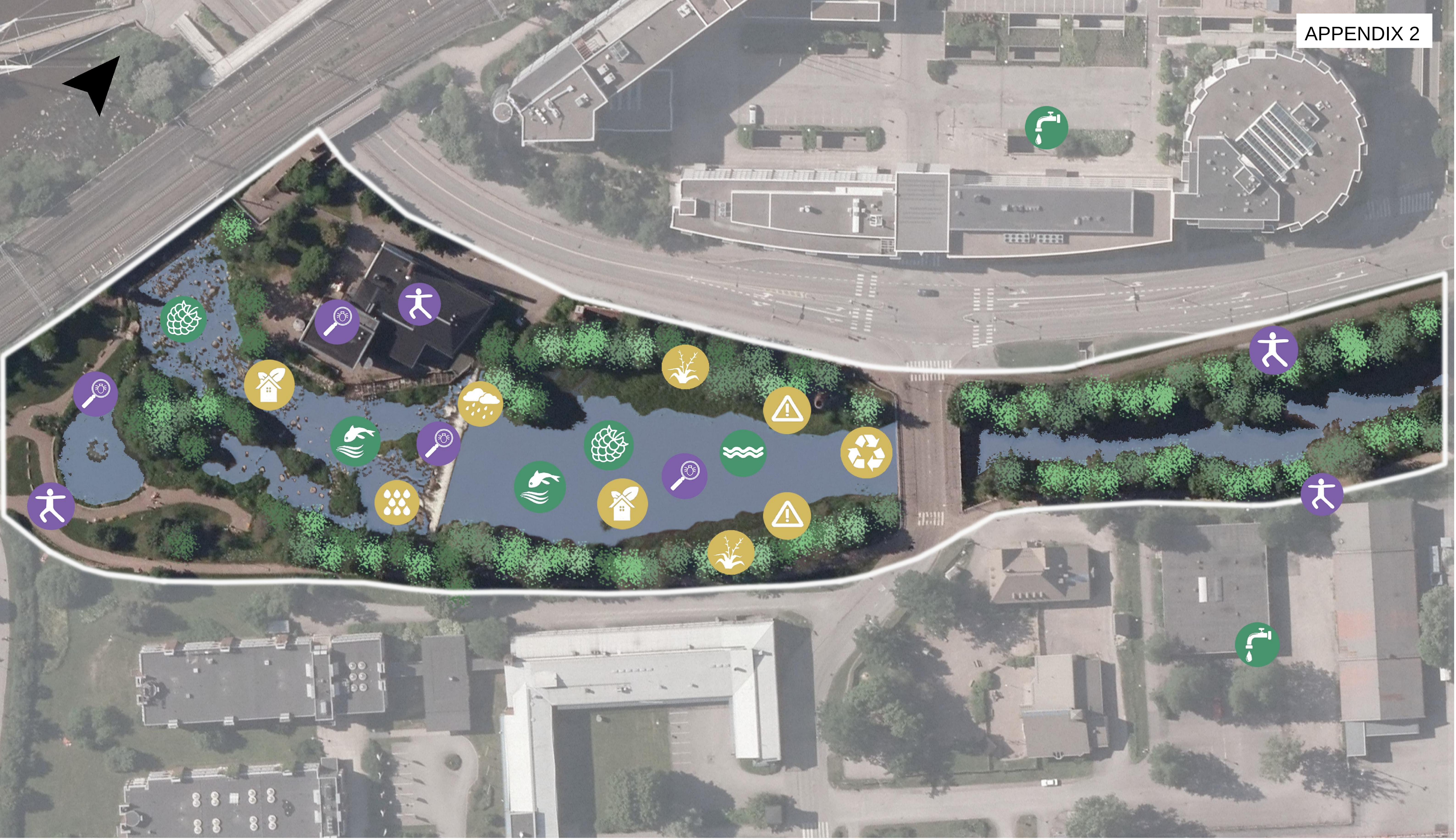
APPENDIX 2



PROVISIONING SERVICES

Food (fish production/catch)
Fisheries and aquaculture
Groundwater for drinking
Surface water availability

REGULATING SERVICES

Carbon sequestration
Nutrient cycle
Water purification
Pest control
Maintaining populations and habitats
Erosion prevention

REGULATING SERVICES

Recreation
Intellectual and aesthetic appreciation

APPENDIX 3 ECOSYSTEM SERVICE ASSESSMENT

	Ecosystem service	Indicator	Rationale	Present situation	Dam removal (including water level descension)	River restoration	Effect time frame	Effect scale	Source
PROVISIONING SERVICES	Fisheries and aquaculture	Fish production/catch (recreational fishing)	Fish passage upstream will be enabled and the study area will provide more spawning and nursery areas. At present situation, fishing is prohibited in the area. In the (distant) future it will most likely be allowed. Trout population has been growing in Vantaanjoki and it can be assumed, that removal of the dam will improve the possibilities of population growth.	Poor	+	+	Gradual/ Long-term	Medium to large	Aulaskari, Virtavesikunnostukset Uudellamaalla, 2012. Koivurinta, Vantaanjoen ja Keravanjoen vaelluskalakantojen nykytila ja tarvittavat jatkotoimenpiteet, 2016. Haikonen, Vantaanjoen yhteistarkkailu - Kalasto, kalojen vierasainepitoisuudet ja koeravustukset vuonna 2016, 2017. Haikonen, Vantaanjoen yhteistarkkailu – Kalasto ja pohjaeläimet vuonna 2014, 2015.
		Number of fishermen	Number of fishermen is likely to multiply in accordance to the number of trout and other valuable fish species in the river, when fishing will be allowed in the study area. The interest shown during the project indicates, that fishermen are very interested on the possibilities of improved recreational fishing opportunities.	Poor	+	++	Gradual/ Long-term	Large	Marttila, Virtavesikunnostusten vaikutukset jokiluonnon ja ekosysteemipalvelujen näkökulmasta, 2017. Kananen, Koskikunnostusten vaikutukset ekosysteemipalveluihin kalastajien, melojien ja ranta-asukkaiden näkökulmasta Kiiminki-, Koston ja Simojoella, 2014. Olkio, K. & Eloranta, A., Virtavesikunnostusten sosioekonomisista vaikutuksista Keski-Suomessa, 2007. Haikonen, Vantaanjoen yhteistarkkailu – Kalasto ja pohjaeläimet vuonna 2014, 2015. Residents and fishermen's Comments and feedback and results from inquiries.
		Status of fish population (species composition, age structure, biomass kg/ha)	Increase in valuable species, the amount of fish and variety of fish species lead to improved status of population.	Medium	+	+	Gradual/ Long-term	Medium	Haikonen, Vantaanjoen yhteistarkkailu - Kalasto, kalojen vierasainepitoisuudet ja koeravustukset vuonna 2016, 2017. Haikonen, Vantaanjoen yhteistarkkailu – Kalasto ja pohjaeläimet vuonna 2014, 2015.
	Water for non-drinking purposes	Surface water availability	Water level will descend considerably in the study area, but river restoration helps retain water level at a minimum level for river organisms. Surface water availability for fire extinguishing might be reduced.	Good	-	+	Immediate /short-term	Small	Modelling and expert evaluation done by Ramboll project team in 2017.
	Water for drinking	Groundwater for drinking	The changes of removing the dam on ground water level will be minimal		0	0	Immediate /long-term	Small	Pöyry Finland Oy, The results of groundwater flow modelling, 2016.

	Ecosystem service	Indicator	Rationale	Present situation	Dam removal (including water level descension)	River restoration	Effect time frame	Effect scale	Source
Regulating services	Carbon sequestration	Flood plain areas	New flood plains will be created, as water level fluctuates more after dam removal. Possible methane production of the dam reservoir will cease.	Medium	+	+	Immediate / Short- to long-term	Very Small	International Rivers, Environmental Impacts of Dams, 2017.
	Pest control	Alien species	Reed grass (Glyceria maxima) is an evasive species found on the banks of the dam pool. It will be removed during construction. As the nature of waterway shifts to flowing water and new banks will be constructed with coarse-grained material, the habitat will no longer be optimal for reed grass. The removal of the dam ensures natural riverine conditions that provide also for natural species. On the other hand, dam removal might increase the possibility of invasive species of the Baltic Sea spreading upstream.	Medium	+	+	Immediate /Gradual /Long-term	Small	Vieraslajit.fi, Isosorsimo, 2017. Ramboll expert assessments 2017 (Aino-Kaisa Nuotio, Landscape architect and Otso Lintinen, Fishery specialist).
	Nutrient cycle	Nutrient concentration	Nutrients gather to the sediments in the dam pool, which will change after the dam removal, since most sediments will flow through the rapid.	Medium	+	0	Immediate /Short-term	Small	The Heinz center, Dam removal - Science and decision making, 2002. Ramboll expert assessment 2017 (Johanna Jalonen, Doctor Of Science, Technology).
	Maintaining populations and habitats	Biodiversity value	The descended water level will enable diverse habitats, as the riverbed and the banks are more varied. The riparian corridor will be more versatile and functional, since the dam is removed and there will be more space on dry land.	Medium	++	+	Gradual/ Long-term	Medium	Marttila, Virtavesikunnostusten vaikutukset jokiluonnon ja ekosysteemipalvelujen näkökulmasta, 2017. American Rivers, The ecology of dam removal – A summary of benefits and impacts, 2002. Ramboll expert assessment 2017 (Kaisa Mustajärvi, Ph.D. Ecology)
		Fish nursery areas	In addition to the nursery areas that are situated in the current rapid area, new nursery areas will be constructed in both the old rapid area and the new restoration area.	Medium	+	++	Immediate /Long-term	Medium	Ramboll designs 2017.
		Fish reproductive areas	In addition to the reproductive areas that have been built in the 1990s, new reproduction areas will be provided above the new groundsills.	Medium	0	++	Immediate /Long-term	Medium	Ramboll designs 2017.
		Habitats for Thick shelled river mussel	A population of Thick shelled river mussels (Unio crassus) live on the edges of the dam pool, under the rapid area and above the neck of the rapid. Rapids are not a suitable environment for thick shelled river mussels, so they will be migrated to a more suitable habitat. The present habitat in the dam pool will be lost.	Medium	-	-	Immediate / Long-term	Small	Sopanen, Vuollejokisimpukkaselvitys – Tikkurilan padon yleissuunnittelu, 2016
		Stream connectivity	Re-establishing the physical integrity of the river is likely to improve the natural riverine habitats and well-being of riverine populations. The future situation will also improve the riparian corridor connectivity.	Very poor	++	+	Immediate /Long-term	Large	American Rivers, The ecology of dam removal – A summary of benefits and impacts, 2002.
	Water purification	Indicators on surface water quality (i.e. phosphorous, suspended solids, microbiological data for bathing waters, nitrate conc, phosphate conc, oxygen conditions, temperature, pH)	Sediments, that contain some contaminants are released and therefore water quality downstream might decline for some time. The realization of the plan might also cause some muddiness downstream. The surface water quality will improve in the dam pool area after dam removal, since temperature and pH conditions will be more natural. Oxygen conditions will be better because of improved water turnover and the rocks that increase turbulence in the stream. Downstream water quality will return back to pre dam removal conditions after some time. Possible effects on a larger scale for water quality in Keravanjoki.	Poor	+	+	Immediate /Gradual /Short- to long-term	Small	American Rivers, The ecology of dam removal – A summary of benefits and impacts, 2002. Ramboll expert assessment 2017 (Johanna Jalonen, Doctor Of Science, Technology).
		Area occupied by plants within river front	The reed grass on the shoreline will be removed during construction, but the vegetated banks will stay close to their current condition. After the river restoration, the study area will include more vegetated surface then at present state.	Medium	0	+	Immediate /Long-term	Small	Ramboll designs 2017.
	Erosion prevention	Sediment retention	There has been no proof of a significant amount of sediments on the upstream side of the dam according to study (photographs, soundings, experiences). Water level descension is advised to be executed slowly through the bottom hatch, in which case most of the sediment will stay in place. The sediments will be covered with new, clean soil or dug out. However the dam sediment retaining capacity will be lost.	Medium	-	0	Immediate /Long-term	Small	Ramboll designs 2017. Soil & sediment samples by Golder Associates Oy, 2016.
		Erosion control on banks	At present, water pressure and vegetation retains the slopes. After the restoration, new geotechnical banks, vegetation and rocks will control erosion on banks.	Good	-	+	Immediate /Gradual /Short- to long-term	Small	Ramboll designs 2017.

	Ecosystem service	Indicator	Rationale	Present situation	Dam removal (including water level descension)	River restoration	Effect time frame	Effect scale	Source
Cultural services	Recreation	Number of recreational visitors	The recreational value of the study area will increase, as descending water level releases room for recreational infrastructure. The waterfront will be developed extensively in the next years and the population of Tikkurila is expected to rise, leading to more recreational visitors on the waterfront.	Medium	+	+	Gradual/ Long-term	Medium	Marttila et al., Social success of in-stream habitat improvement: from fisheries enhancement to the delivery of multiple ecosystem services, 2016. Kananen, Koskikunnostusten vaikutukset ekosysteemipalveluihin kalastajien, melojien ja ranta-asukkaiden näkökulmasta Kiiminki-, Koston ja Simojoella, 2014. Olkio, K. & Eloranta, A., Virtavesikunnostusten sosioekonomisista vaikutuksista Keski-Suomessa, 2007. Vermaat et al., Assessing the societal benefits of river restoration using the ecosystem services approach, 2015. Polizzi et al., Is ecosystem restoration worth the effort? The rehabilitation of a Finnish river affects recreational ecosystem serviced, 2015. Marttila, Virtavesikunnostusten vaikutukset jokiluonnon ja ekosysteemipalvelujen näkökulmasta, 2017. Muukka, Tikkurilan keskustan kaavarunko ja maisema, 2015. Haikonen, Vantaanjoen yhteistarkkailu – Kalasto ja pohjaeläimet vuonna 2014, 2015. Residents, fishermen's, kayakers and white water rafters comments, feedback and results from inquiries.
		Number of visitors to attractions	The development of the waterfront as a more liveable and pleasant environment will most likely increase the amount of visitors to attractions, such as Vernissa and Heureka.	Medium	+	+	Gradual/ Long-term	Small	
		Number of bird watchers	Keravanjoki is an important green corridor for many species of birds. The improved biodiversity of the area might increase the variety of birds leading to increasing amount of bird watchers.	Medium	0	+	Gradual/ Long-term	Small	
		Number of people canoeing/kayaking	A place for getting up from the water will possibly be offered above the rapid area and kayaks can be carried to the lower part of the rapids. The dam removal will benefit people canoeing/kayaking, since it enables the whole Keravanjoki to be a more suitable river for kayaking and canoeing. On higher flows, it will probably be possible to kayak through the rapids.	Medium	+	0	Gradual/ Long-term	Small	
		Number of white water rafters	The new rapid area will provide a great environment for white water rafters during optimal flow situations.	Poor	++	+	Gradual/ Long-term	Small	
		Number of fishing licences and fishing reserves	As trout and other valuable fish species populations start to rise, there will most likely be more people interested to fish along the river. Fishing paths and places will be placed alongside the river.	Very poor	+	++	Gradual/ Long-term	Large	
		Fish abundance	Fish abundance is likely to increase as the dam is removed and river restoration and returning to natural flow conditions creates more diverse habitats.	Medium	+	++	Gradual/ Long-term	Small	Marttila, Virtavesikunnostusten vaikutukset jokiluonnon ja ekosysteemipalvelujen näkökulmasta, 2017. Aulaskari, Virtavesikunnostukset Uudellamaalla, 2012.
		Safety	The structure of the fish ladder and the poor condition of the dam causes a safety hazard in the future, unless extensive refurbishment would be made. The dam is also a constricting element on high flows, and removing it will decrease risk of flooding in the immediate environment on high flow events.	Poor	+	0	Immediate /Long-term	Small	Vantaan kaupunki, Vantaan kaupungin suorittama määräaikaistarkastus Tikkurilan padolla, muistio, 2016.
	Intellectual and aesthetic appreciation	Public and scientific interest (e.g. number of scientific projects, articles, studies, media attention)	The dam removal and reviving the river ecosystem has raised a lot of public interest, and it will most likely continue for many years, at least in some groups, such as fishermen. Removal process and restoration success might raise scientific interest and lead to monitoring the site. The present state is at medium, because of gained media attention on the possibility of removal.	Medium	++	+	Immediate /Gradual /Short-to long-term	Medium	Newspaper articles, news in internet, Facebook-group discussions, numerous studies that highlight the need for more monitoring information.
		Classified sites	Although the dam itself is not a classified site, the removal will change the integrity of Vernissa, which is a classified site. The city museum has estimated the design solution as satisfactory with a notion that the factory building, fire station, kiln chimney and dam together will preserve the remarkable culture-historical value despite the changes in the area.				Immediate /Long-term	Small	Vantaan kaupunginmuseo, Lausunto Tikkurilankosken yleissuunnitelmaan, 2016.
		Quality of culture-historical attractions	The dam removal will change quality and integrity of the culture-historical environment of Vernissa, but as the dam sides and the illusion of continuity will be preserved, some value will be maintained. The dam removal and restoring the rapids will create a new culture-historical layer to the area.				Immediate /Long-term	Small	Vantaan kaupunginmuseo, Lausunto Tikkurilankosken yleissuunnitelmaan, 2016. Ramboll expert assessments 2017 (Aino-Kaisa Nuotio, Landscape architect).
		Landscape value of still pool vs. rapid	The transformation of still water pool into a rapid is a great change in the immediate landscape. The rapid represents the natural historical situation that has been before the dam, and the dam pool the industrial cultural history that has been for about 300 years.				Immediate /Gradual /Long-term	Medium	Thesis writer's assessment. Ramboll expert assessments 2017 (Aino-Kaisa Nuotio, Landscape architect).
		Soundscape	The sound of water falling from the dam compared to the sound of a rapid is very different. People tend to have different preferences on soundscapes, so a positive or negative value is hard to predict.				Immediate /Long-term	Medium	Thesis writer's assessment.
		Regional/local identity	The dam removal will most likely improve local identity, since it has been encouraged by the society. On the other hand the dam has been a landmark and an important part in the integrity of the culture-historical environment.				Immediate /Gradual /Long-term	Medium	Newspaper articles, news in internet, Facebook-group discussions. Residents, fishermen's etc. comments, feedback and results from inquiries.

APPENDIX 4 MONITORING PROGRAMME

	Ecosystem service	Indicator	Examples for Indicator metrics	Survey method	Survey method of the present state	Interval of survey	Survey publication	Notes
PROVISIONING SERVICES	Fisheries and aquaculture	Fish production/ catch (recreational fishing)	Fish density, species composition	Electro-fishing	Electro-fishing should be done in late summer 2018 (august-september)/Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu). Electro-fishing in the dam pool should also be done before the dam is removed.	Every year/every two years	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Current survey site is under the dam, another site should be added after restoration on the upstream side of the current dam. If the survey is conducted separately, there should be at least two surveying sites in the rapid area, one upstream of the current dam and one downstream.
		Number of fishermen	Number of fishermen, number of fishing licenses, fish catch, days of fishing in the area, opinions on the dam removal and restoration	Questionnaire on recreational fishing	Questionnaire on recreational fishing /Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu). It should be done in the year 2018.	One year after restoration and from then every 2-3 years.	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	A questionnaire on recreational fishing has been conducted in connection with the Vantaanjoki joint survey every two years, and it should be continued with the same questions. Tikkurilankoski dam removal and river restoration effects on fish populations and fishing could be included as a separate part on the questionnaire. If the questionnaire is carried out separately, it should have more detailed questions on the respondents background and experiences and opinions on the dam removal and river restoration. Example questionnaire: Kananen, Koskikunnostusten vaikutukset ekosysteemipalveluihin kalastajien, melojien ja ranta-asukkaiden näkökulmasta Kiiminki-, Koston- ja Simojoella, 2014.
		Status of fish population	Species composition, age structure, biomass kg/ha	Electro-fishing	Electro-fishing should be done in late summer 2018 (august-sebtember)/Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu). Electro-fishing in the dam pool should also be done before the dam is removed.	Every year/every two years	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Current observation site is under the dam, another site should be added after restoration on the upstream side of the current dam. If the survey is conducted separately, there should be at least two surveying sites in the rapid area, one upstream of the current dam and one downstream.
	Water for drinking	Groundwater for drinking	Groundwater elevation	Groundwater observation pipes	Groundwater elevation level before the dam removal should be recorded from all the observation pipes that can be affected.	Continuous	Separate survey on the dam removal and river restoration	At least one new groundwater observation pipe is needed (Pöyry Finland Oy, 2016).

	Ecosystem service	Indicator	Examples for Indicator metrics	Survey method	Survey method of the present state	Interval of Survey	Survey publication/ form of survey	Notes
REGULATING SERVICES	Pest control	Alien species	Plant density, species composition	Vegetation charting, electrofishing, visual observation etc.	Reed grass areas should be charted once. Otherwise, available information is sufficient.	Once a year	Separate survey on the dam removal and river restoration	The reed grass areas need to be charted, dug out completely, and taken to a landfill site. The river reach should be inventoried visually once a year for four years after the restoration, to make sure that reed grass does not grow on the shoreline. If it does, then it should be monitored and removed if necessary. Other alien species should be revealed in connection with other surveys i.e. electrofishing and vegetation charting.
	Nutrient cycle	Nutrient concentration	turbidity (FTU), phosphorus (µg/L), solute PO4-P (µg/L), nitrogen (µg/L)	Sampling / continuous water quality monitoring	nutrient concentration of sediments and water in the dam pool should be sampled once before the dam is removed.	Once a month/sediment samples if needed once a year	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	water quality measurements will supposedly give enough information on the nutrient concentration in the water (i.e. phosphorous, nitrogen, but also turbidity might correlate with nutrients). Sediment samples can be taken above the groundsills to see if nutrients gather there.
	Maintaining populations and habitats	Biodiversity value	Diversity index, species composition, % sensitive macroinvertibrate species, presence or absence of native/non-native species, habitat quality, indicator species i.e. certain dragonfly species	Charting on certain survey areas or survey lines in terrain / nature survey	Charting on certain survey areas or survey lines in terrain / nature survey, should be done once before the dam is removed.	Once a year, during summertime	Separate survey on the dam removal and river restoration	The survey should involve both riverine and riparian environments, including macrophytes.
		Fish nursery areas	Fish density, species composition, age structure	Electro-fishing, expert observation	Electro-fishing, expert observation. The current nursery areas on the downstream side of the dam should be surveyed in early fall.	Once a year in late August- or September, during medium flow or lower.	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Fish nursery areas are likely difficult to observe, but electro-fishing will give enough information on how much smolts habitat the area. The nursery areas (rocky areas) can be observed by an expert to see if there are enough hiding places, and whether the water depth and velocity is sufficient.
		Fish reproductive areas	Silt deposit (%), location and amount of breeding grounds, amount of used breeding grounds, spawning success	expert observation, sampling	The reproductive areas downstream of the dam should be monitored once in the fall after spawning, and once in the spring before the dam removal takes place.	Once a year in late fall, several visits should take place.	Separate survey on the dam removal and river restoration	utilization rate of the breeding grounds should be observed by an expert during several visits. Used breeding grounds are usually sediment free, because they've been riffled and they stand out when water is clear enough. Fish spawning should be observed in late fall. The silt deposit in breeding gravel should be monitored by sampling one year after restoration and again three years after.
		Habitats for Thick shelled river mussel	turbidity (FTU), mussel density, population size	Sub aqua-charting on certain survey lines, turbidity sampling or continuous monitoring	Available information is sufficient.	Turbidity once a month/ continuously, An extensive survey one year after and three years after the restoration.	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Turbidity should be observed during construction in the backwater area in front of Heureka, where mussel population is vast. Success on relocation of the mussel population living in the dam pool should be monitored one year and three years after the relocation.
	Water purification	Indicators on surface water quality	temperature, oxygen (mg/L and saturation), pH, conductivity (mS/m), colour GF/C (Pt mg/L), CODMn (mg/L), phosphorus (µg/L), solute PO4-P (µg/L), nitrogen (µg/L), NO2+NO3-N (µg/L), NH4-N (µg/L), E-coli (units/100 ml), E.faecalis. (units/100 ml), a-klorof. (µg/L), sediment GF/C (mg/L), turbidity (FTU)	Sampling / continuous water quality monitoring	Sampling/continuous monitoring should begin as soon as possible to get enough information on the present situation. Water samples should be taken from the dam pool.	Once a month/ continuous	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Vantaanjoki joint survey has observation sites some kilometres up- and downstream. A new observation site should be established in the area of Tikkurilankoski to survey the changes in the immediate area near the dam. Continuous water quality monitoring would be ideal, but sampling once a month is also sufficient. Continuous monitoring should include measurements least on temperature, water flow, water elevation and turbidity, but also oxygen concentration and conductivity could be measured. The dam removal effects (or if there are any) on water quality should be studied on the whole reach of Keravanjoki as a part of the survey.
		Area occupied by plants within river front	Plant density and diversity, nitrogen fixers, habitat diversity, shade, biomass	Vegetation charting	Vegetation charting once before the dam removal.	Twice a year	Separate survey on the dam removal and river restoration	One charting in early summer which can be quite general, observing mainly abundance and spring-time bloomers. Another, more particular charting should be done in mid- /end-summer (in the middle of July). General observations on abundance and bloomers can be done 4-5 times a year.
	Erosion prevention	Erosion control on banks	Bank erosion rate	Visual observation, Modelling by Terrestrial or air-borne laser scanner/ortho scanner	Available information is sufficient.	One year and three years after restoration.	Separate survey on the dam removal and river restoration	

	Ecosystem service	Indicator	Examples for Indicator metrics	Survey method	Survey method of the present state	Interval of Survey	Survey publication/ form of survey	Notes
CULTURAL SERVICES	Recreation	Number of recreational visitors	Number of recreational visitors, opinions on the dam removal and river restoration, opinions on the quality of recreational possibilities on the site	Questionnaire on recreational possibilities on the shoreline	Available information gained from different sources is sufficient.	One, three and five years after the removal and restoration and shoreline construction	Separate survey on the dam removal and river restoration	Questionnaire should include e.g.: basic information of the respondent, opinions on the attractiveness, functionality and accessibility of the constructed shoreline and river reach, number of visits in the area per month, recreational activities that the respondent has taken part of, opinions on the importance of river restorations in general. Example questionnaire: Kananen, Koskikunnostusten vaikutukset ekosysteemipalveluihin kalastajien, melojien ja ranta-asukkaiden näkökulmasta Kiiminki-, Koston- ja Simojoella, 2014.
		Number of people canoeing/kayaking and/or white water rafting	Number of people canoeing/kayaking and white water rafting, opinions on quality of the environment for canoeing/kayaking and/or white water rafting	Questionnaire on kayaking & white water rafting possibilities in Keravanjoki	Questionnaire on kayaking and white water rafting possibilities in Keravanjoki for people that belong to kayaking and/or white water rafting organizations	One, three and five years after the removal and restoration and shoreline construction	Separate survey on the dam removal and river restoration	Questionnaire should include e.g.: basic information of the respondent, opinions on the attractiveness, functionality and accessibility of the constructed shoreline and river reach, number of visits in the area per year, opinions on if the kayakers/canoeists/white water rafters have been taken into consideration in the river restoration and shoreline construction, if the river reach has transformed more diverse/difficult for kayaking/canoeing/white water rafting and if river restorations are important in general. Example questionnaire: Kananen, Koskikunnostusten vaikutukset ekosysteemipalveluihin kalastajien, melojien ja ranta-asukkaiden näkökulmasta Kiiminki-, Koston- ja Simojoella, 2014.
		Number of fishing licences and fishing reserves	number of fishing licenses, fish catch	Questionnaire on recreational fishing	Questionnaire on recreational fishing in the year 2018/Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)	One year after restoration and from then every 2-3 years.	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	A questionnaire on recreational fishing has been conducted in connection with the Vantaanjoki joint survey every two years, and it should be continued with the same questions.
		Fish abundance	Fish density, species composition, biomass kg/ha	Electro-fishing	Electro-fishing should be done in late summer 2018 (august-sebtember)/Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu). Electro-fishing in the dam pool should also be made before the dam is removed.	Every year	Vantaanjoki Joint survey (Vantaanjoen yhteistarkkailu)/ Separate survey on the dam removal and river restoration	Current survey site is under the dam, another site should be added after restoration on the upstream side of the current dam. If the survey is conducted separately, there should be at least two surveying sites in the rapid area, one upstream of the current dam and one downstream.
	Intellectual and aesthetic appreciation	Quality of culture-historical attractions	opinions on the different elements of the site and effects of dam removal and river restoration.	Questionnaire on recreational possibilities on the shoreline	Available information gained from different sources is sufficient.	One, three and five years after the removal and restoration and shoreline construction	Separate survey on the dam removal and river restoration	All could be combined with the questionnaire on recreational visitors. Additional questions could include: opinions on the quality of the integrity of Vernissa, visual success of dam removal and river restoration, dam pool absence, soundscape transformation, effects on local identity.
		Landscape value of still pool vs. rapid						
		Soundscape						
		Regional/local identity						

		Indicator	Examples for Indicator metrics	Survey method	Survey method of the present state	Interval of Survey	Survey publication/ form of survey	Notes
ADDITIONAL NEEDS FOR MONITORING		Channel form and in-channel structure	spatial heterogeneity, streambed particle size distribution, amount of organic matter (leaf litter, woody debris etc.), channel width	Charting on survey lines/expert observation	Available information gained from different sources is sufficient.	One year and three years after restoration.	Separate survey on the dam removal and river restoration	At minimum, the in-channel structure and amount of organic matter should be observed a few times after the restoration.
		Discharge	water level (m), water discharge (m^3/s)	continuous monitoring	Available information gained from different sources is sufficient.	Continuous	Separate survey on the dam removal and river restoration	There are water flow and water level gauges owned by different organizations in Keravanjoki, that give reference on the situation in Tikkurilankoski. However the optimal situation would be to install a new gauge in Tikkurilankoski.