Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

THE SIGNIFICANCE OF NATURAL WATERS IN SALPAUSSELKÄ GEOPARK PROJECT

LAHTI UNIVERSITY OF APPLIED SCIENCES
Faculty of Technology
Urban sustainability
Master's Thesis
Spring 2019
Katariina Rikkonen

Abstract

Author	Type of publication	Published
Rikkonen, Katariina	Master's thesis	Spring 2019
	Number of pages	Pages of appendices
	84	

Title of publication

The significance of natural waters in Salpausselkä geopark project

Name of Degree

Master of Engineering

Abstract

One of the main purposes of this thesis was to study the natural waters of the Salpausselkä area in Päijät-Häme and describe the problems and factors affecting water quality. Salpausselkä geopark is applying for UNESCO's Global Geopark status, and the one main theme of the geopark could be natural watercourses. The aim of this thesis was to collect information on the significant natural water bodies in Päijät- Häme. From global perspective, water quality and water safety in Finland are very good. In Finland, water quality is monitored by the Centre for Economic Development, Transport and the Environment, together with the Finnish Environment Institute. The main focus is on monitoring the status of watercourses. One of the important measures for monitoring water status is sampling. Water samples show the chemical properties of water, which are also discussed in this work. Päijät-Häme region has plenty of valuable surface and groundwater areas, which have improved in recent years. Examples of these are the good quality of Lake Päijänne and the satisfactory quality of Lake Vesijärvi. The water quality of Lake Päijänne is already under pressure due to its importance in the distribution of drinking water. While the purpose of geopark is not to act as a protective programme, it is essential to understand the importance of natural waters and their global impact. When water resources are decreasing in the world, it is becoming increasingly important to maintain their well-being and international cooperation to improve the global water situation.

Keywords

Natural waters, geopark, groundwater

Tiivistelmä

Kirjoittaja	Julkaisun laji	Valmistumisaika
Rikkonen, Katariina	Opinnäytetyö, YAMK	Kevät 2019
	Sivujen lukumäärä	Liitesivuja
	84	

Työn nimi

Luonnonvesien merkitys Salpausselkä geopark- hankkeessa

Julkaisun nimi

Insinööri, YAMK

Tiivistelmä

Tämän opinnäytetyön pääasiallisena tarkoituksena oli tutkia Päijät-Hämeessä sijaitsevan Salpausselkä geoparkin alueen veden laatua ja kuvata veden laatuun vaikuttavia ongelmia ja tekijöitä. Salpausselkä hakee UNESCO:n Geopark-statusta, ja geoparkin pääteema voisi olla luonnonvesistöt alueella.
Tämän opinnäytetyön tavoitteena oli kerätä tietoa Päijät- Hämeen merkittävistä luonnon vesistöistä. Maailmanlaajuisesta näkökulmasta veden laatu ja veden turvallisuus Suomessa ovat erittäin hyvät. Suomessa vesienlaatua valvoo Elinkeino-, liikenne ja ympäristökeskus yhdessä Suomen ympäristökeskuksen kanssa. Valvonnan pääpaino on vesistöjen tilan seurannassa. Yksi tärkeistä vesistöjen tilan seurantaan liittyvistä toimenpiteistä on näytteenotto. Vesinäytteistä selviää veden kemiallisia ominaisuuksia, joita tässäkin työssä käsitellään. Päijät-Hämeessä on runsaasti arvokkaita pinta- ja pohjavesialueita, joiden tila on viime vuosina parantunut. Näistä esimerkkeinä laadultaan hyvä Päijänne ja laadultaan tyydyttävä Vesijärvi. Päijänteen vedenlaadulle luo painetta jo sen tärkeys juomaveden jakelussa. Vaikka geoparkin tarkoitus ei ole toimia suojelullisena ohjelmana, on olennaista ymmärtää luonnonvesien tärkeys, ja niiden maailmanlaajuinen vaikutus. Vesivarojen ehtyessä maailmassa, on yhä tärkeämpää ylläpitää hyvinvoivia vesistöjä, ja tehdä kansainvälistä yhteistyötä tilanteen parantamiseksi.

Asiasanat

Luonnonvedet, geopark, pohjavesi

CONTENTS

TERMINOLOGY

Aquifer. Groundwater impregnated rock and soil, which is highly conductive and permeable to water (Krämer 2009, 50).

Clean water. Generally, drinkable water is tasteless, soft and transparent. Conductivity is good and the amount of sediments is low. (Koivula 2016, 16.)

Climate change. From an environmental point of view, changing the general nature of weather conditions in the long run (Tieteen termipankki 2014).

Diffuse/non-point pollution. Caused by widespread sources, such as acid rain, pesticides, urban run-off (European Environment Agency 2015a).

Dystrophic lake. Contain high amounts of humic substances and organic acids, which causes the brown colour of the water, and low pH (Oravainen 1999).

Ecotourism. Moving in the natural environment under conditions of sustainable development. Primarily ecotourism refers to mobility in nature, such as tourism in forests and nature reserves. However, it increasingly refers to the overall environmental performance of the journey. In this case, it is not enough to act in an environmentally friendly way in the actual object, but the whole journey must respect the natural values. (Juhahalmu 2019.)

European geop*ark network (EGN).* Includes over 70 geopark areas in Europe, one of which Rokua Global Geopark in Finland. The main goal of the network is to help its members create sustainable regional development through geotourism that exploits the geological heritage of the regions. (European Geoparks 2019.)

Eutrophication. Excessive water enrichment with nutrients, often due to human activity, increases nitrogen and phosphorus concentrations (European Environment Agency 2015b).

Global geoparks network (GGN). A legally established non-profit organisation with annual membership fees and membership of the UNESCO Global Geoparks (Global Geoparks Network 2019).

Glacial lake. They were created in the ice age, when heavy glacier formed depressions and melted. Vesijärvi is a glacial lake, and so are most of the lakes in Finland. (Xiaojun & Shiyin & Co. 2018.)

Groundwater. Rain and melt water that have filtered through bedrock and soil and stored in the ground. (Groundwater Foundation 2019.)

Groundwater classification. The utility of water supply and the need for protection determine the classification of a groundwater area (Finland's environmental administration 2018).

International Hydrological Programme (IHP). Programme devoted to water research, water resources management, education and building capacity (UNESCO 2017).

Lake. A large body of water that is completely surrounded by land. The water of the lake comes from springs and rivers, land runoff, precipitation and melt water of snow and ice. (Lane 2019.)

Limnology. The science of lakes physics, chemistry, geology and biology. Often the study of other inland waters and coastal waters is also considered to be related to limnology. (Tieteen termipankki 2019.)

*Microplastic. S*mall pieces of plastic that are less than 5 millimeters in size. They can be divided into two groups according to their origin; primary and secondary microplastics. (European parliament 2018.)

Point source pollution. Pollutants from a particular source, such as wastewater treatment plant emissions (European Environment Agency 2015c).

Poison. A substance to which exposure affects the vital functions of the organism or kills the organism. In principle, any chemical substance can be a poison, in large quantities. Ecotoxicology is a study concentrated on environmentally harmful substances. (Koulu, Mervaala & Tuomisto 2012, 115.)

Protection of waters. Measures for the preservation of surface water and groundwater and for ensuring a sufficient amount of clean water for humans and natural ecosystems (Finland's environmental administration 2015).

Spring. A place where water flows under natural conditions from rock or soil to ground or surface water (Kuusisto 2014, 5).

Transgression. Shifting of the shoreline to the inland, which may be caused by rising sea levels or the land sinking. Transgression causes the deposition of deeper water sediments on lower water deposits. (Tieteen termipankki 2018.)

UNESCO. United Nations Educational, Scientific and Cultural Organization, whose mission is to promote peace and cooperation through sustainable development, education, science and culture (UNESCO 2019).

Water body. Surface or groundwater that is clearly distinctive and big enough, such as a lake, river or a pond. The groundwater body is a certain amount of water beneath the surface. (Alo 2018.)

1 INTRODUCTION

Lakes are an essential part of Finland’s landscape, about ten percent of the land is covered in lakes. Salpausselkä geopark is part of Päijät-Häme province. There are 11 municipalities and over 900 lakes in Päijät-Häme. For thousands of years, people have already settled on the lake shores of Päijät-Häme. Watercourses have provided a way of transportation in older times and there has been early settlement on the lake shores since pre-historical period. There are about 6,000 classified groundwater areas in Finland, mostly in eskers and terminal moraines, formed by the melting ice, at the end of the last Ice Age from 12,000 to 11,000 years ago. (Keskitalo 2017, 110).

This thesis is connected with Salpausselkä geopark project, coordinated by Lahti University of Applied Sciences. The main theme of the Salpausselkä geopark project is connected with water, which is recognised in different formats in Päijät-Häme region; large groundwater reservoirs, surface waters, lakes, rivers and springs. Salpausselkä geopark contains six municipalities; Cities of Lahti and Heinola, Asikkala, Hollola, Padasjoki and Sysmä.

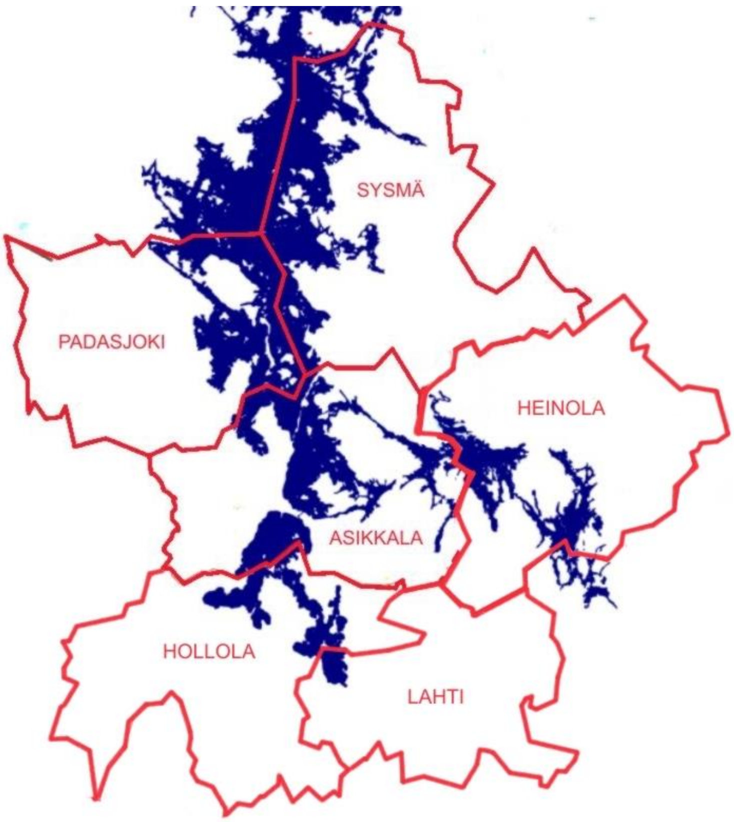


FIGURE 1. The municipalities of Salpausselkä geopark project.

Eventhough, geoparks are not protected areas, most of geopark's attractions, enjoy the protection of the law, either in geology, in the living nature based on it, or in relation to the cultural heritage. The aim is at the protection of environmental resources and sustainable development at the local level. (Lauhanvuori-Hämeenkangas Geopark 2019.)

Big part of Päijät- Häme region and Salpausselkä geopark area, is Lake Päijänne, which is second largest inner lake in Finland, just after Lake Saimaa. This thesis deals mostly with the Southern part of Lake Päijänne, which is included to the geopark because of the Southern Päijänne National Park.

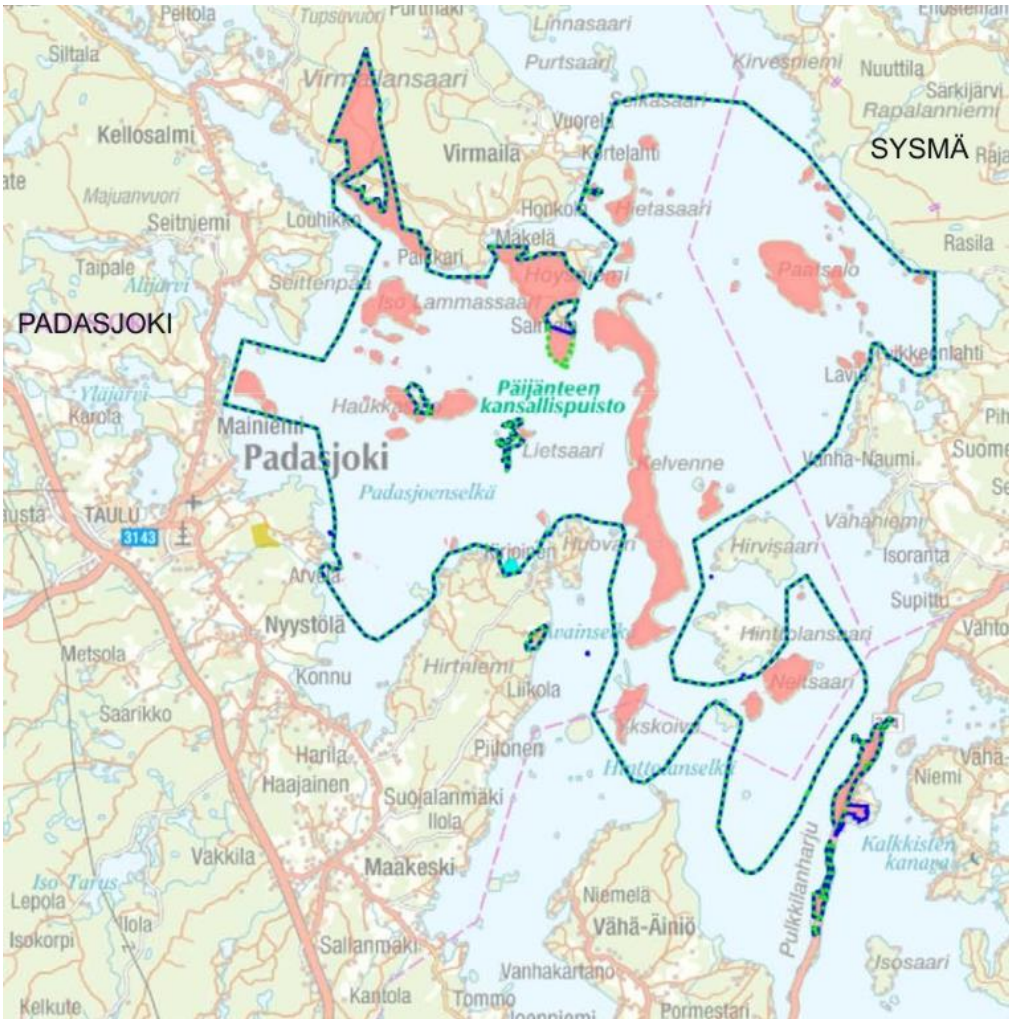


FIGURE 2. Southern Päijänne National Park (Metsähallitus 2017).

Lake Päijänne’s surface area is 1080 square kilometres, and average depth is 14,21 metres. It is significant from the point of view of housing, recreational use, natural water intake, tourism as well as business activities and research. Over 300,000 people live in the catchment area of Päijänne, and there is a wide- ranging industry and strong forest and agricultural activities. (Järvi & Meriwiki 2017.)

Päijänne is a multiform lake, with Salpausselkä eskers, rocks, islets, sandy beaches and wilderness. There are hundreds of smaller lakes in the Päijänne area, sandy coves and marshes of the Southern Päijänne National Park. Lake Päijänne contains 1886 islands. It is known as a unique and diverse natural environment and a significant cultural and historical habitat. (Uusitalo, Kellomäki & Vääriskoski-Kaukanen 2008, 15.) Groundwater in Finland is generally is of good quality and cleaner than surface water. Both Lake Päijänne and Lake Vesijärvi are examples of sensitivity and beauty of natural surface waters.

According to a 2017 survey, about 14,000 people visits the Southern Päijänne National Park annually, and the numbers is predicted to rise. The most famous sites in the park are Kelvenne, one of the largest graylings in Finland, and Pulkkilanharju, which has formed from the grayling line. (Kyrönviita & Tuomaala 2017, 48.)

Salpausselkä formations are important for the wellbeing of the local habitats, and industry, as they provide the region good quality natural groundwater. The largest of these recharge areas are situated in the first Salpausselkä. (Salpausselkä geopark 2018.)

This thesis also aims to study the essential factors and sources which can cause pollution and damage to natural waters. Today's challenge in Finland is micro plastics, pesticide residues and drugs that eventually end up in the human body through drinking water. Water resources have been considered as a basic and self-evident resource in Finland. Finland is generally regarded as a model for sustainable use of clean water technologies and water resources.

An active water cycle is an essential part of the Earth's system. As a result of nutrient growth, eutrophication of aquatic ecosystems is a global problem. Climate change affects nutrient cycles and hydrological processes in ecosystems as well as the balance between systems and water quality. (Nasa Science 2019.)

This thesis concentrates on the diversity of natural waters in the aspiring Salpausselkä geopark area and the possible threats to the quality of the natural waters. The thesis also introduces valuable water courses in Salpausselkä geopark area and identifies the future challenges for maintaining the high quality of the natural waters.

2 BACKGROUND OF THE RESEARCH PROJECT

This thesis is carried out for Salpausselkä geopark project, coordinated by Lahti University of Applied Sciences. The aim of the project is to apply for UNESCO status as an international geopark for Salpausselkä. The aim of this thesis is to study the area of Salpausselkä, the possible future geopark. The main theme is the status of natural waters in Päijät-Häme region.

The aim of the thesis is to find out what are the natural waters of Päijät-Häme region and what makes these Finnish lakes so significant nationally and globally, as well as how water safety, security and protection are linked to Global Geoparks. One of main themes to be included in the Salpausselkä geopark application, is the groundwaters and surfacewaters of the area. The thesis topic concentrates mainly on both of those and on how to measure the water quality. Most of the waters in Salpausselkä area have been found to be of qood quality. This thesis aims to answer the question, by what means can water be found to be of good quality. The research included familiarization of multiple online and printed sources, legislations, and publications of environmental authorities and specialists.

During the making of this thesis, attending some of the meetings, and discussing with the people involved in the development process, was part of the work. Also visiting some of the natural geosites of the Salpausselkä area and the events organised by the Salpausselkä geopark. Communication via e-mail and discussions were included to the process with Salpausselkä geopark project partners of how they see the future of the geopark and especially the groundwater situation, and what factors should be taken into account. The sustainable use of groundwater was one issue of importance raised in the debate.

In this work, written references, books and surveys, and numerous web references consititute the main research material.

3 GEOPARKS

3.1 Salpausselkä geopark project

The Salpausselkä geopark project began in 2017, aiming to promote sustainable, geological tourism and related economic activities. The project will develop the Salpausselkä geopark area in Päijät-Häme region, with the aim to be able to apply for UNESCO Global Geopark status. There are six municipalities involved in Salpausselkä geopark project. They are the city of Lahti and Heinola, Asikkala, Padasjoki, Sysmä and Hollola. Together with local entrepreneurs, European Agricultural Fund for Rural Development, Geological Survey of Finland, Metsähallitus and Lahti University of Applied Sciences they form a joint and active organisation. (Salpausselkä geopark project 2018.) The role of the local entrepreneurs in the project is the networking and co-designing services for a potential future geopark early on. European Agricultural Fund for Rural Development’s goal is sustainable growth, livelihood development and quality of life in rural areas (Centre for Economic Development, Transport and the Environment 2017).

Geological Survey of Finland provides expertise in geological resources and sustainable use. They also create map data and research material. As part of the project, the Geological Survey of Finland began to inventory geologically significant sites such as kettle holes and springs from the area around Salpausselkä during the summer of 2017. (Geological Survey of Finland 2019.) Metsähallitus manages Finland's nature reserves, and is responsible for protecting habitats, species and heritage sites. (Metsähallitus 2018.) Lahti University of Applied Sciences is involved in funding the project and organizing the meetings, as well as maintaining information and project web-, and event pages. Several students from different faculties at Lahti University of Applied Sciences have also had the opportunity to participate in project implementation and planning. (Lahti University of Applied Sciences 2018.)

In addition, the project has organized public events, produced content for destination guides, marketing materials, and networked in the international and domestic geopark community. An important part of the project has been the workshops, which have been gathering companies active in the field. Entrepreneurs have had the opportunity to meet over municipal boundaries and find new partners. Municipalities have nominated their own network of contact persons to operate and promote cooperation within the geopark. The project has already involved more than 30 programmes, accommodation and restaurant services, as well as companies that produce land and food products.

3.2 UNESCO Global Geoparks Network

At present, there are 147 UNESCO Global Geoparks in 41 countries, and 73 of these Geoparks are in Europe (UNESCO 2017).

A geopark is a single unified area with significant geological heritage. Geoparks operate under the supervision of UNESCO, which monitors what qualities geoparks should have. Such qualities are; well- defined boundaries, organized administrative, planned financial system, and geologically or internationally important geosites. Also, the geopark area should be regionally large enough to achieve real economic development. Geoparks also often have educational, archaeological, ecological, historical and cultural value. Educationally, the geopark area raises awareness and understanding of societal issues, such as the sustainable use of global resources, mitigation of climate change and reducing the risks associated with natural disasters.

The economic development of the region and its overall image and awareness is important. Geotourism or ecotourism is an important part of the development of the area. A geopark is not a protected area or a conservation programme, but it can include, for example, national parks and protected areas. Normal economic activity under national law is possible in geoparks. However, the goal of geopark is to protect and preserve the geological value and related objects for which it has been established. The goal is also that people living in and travelling to the geopark, appreciate the regional heritage values and actively take part in revitalizing its culture and nature. If a geopark chooses to sell products, as long as they are not minerals or fossils from the area, it is acceptable. For example, revenue can be used to protect or develop an area. (Nenonen 2015, 131.)

The Geopark network was set up in 1991, when representatives of more than 30 countries signed a declaration in France that emphasized the international character of the geological heritage. The idea continued in 1997, when geologists Guy Martini and Nickolas Zouros designed an initiative for a pan-European Geopark network. At that time, the preservation of the geological heritage was compared with the protection of cultural and natural heritage. The idea was to convey information to citizens in an understandable way. The European Geopark Network (EGN) was officially launched at a meeting in Greece in 2000, attended by four European regional experts to consider the development of large geocaches from the perspective of employment, geological heritage and sustainable development. (Nenonen 2015, 128.)

Global Geopark Network (GGN) was founded in 2004 in Paris. The purpose of UNESCO's land sites is to protect the Earths unique cultural and natural heritage. More than 700 destinations, most of the World Heritage Sites, represent sites of cultural heritage value. Less than two hundred items have been selected on the basis of natural science. It is important to know that a geopark is also a brand, and UNESCO is constantly monitoring the geopark networks. Geopark membership is sought from a network whose members decide to approve a new area annually as a geopark. The application process takes approximately two years. The development of the geopark area is a continuous and long- term effort. The Geopark Network evaluates the operation of each geopark every four years. Failure to do so may result in loss of geopark status. In this way, the network ensures the quality of geoparks and the quality of the geopark brand. (Saimaa Geopark 2019.)

3.2.1 UNESCO Global Geoparks in Finland

So far, Rokua Geopark is the only area in Finland that has received a UNESCO-approved status. In addition, Rokua is the world's northernmost Geopark destination. Rokua came to the approved Geopark network in 2010, and it belongs to European Geopark- network.

Every UNESCO Global Geopark has its own theme. Rokua Geopark's theme is ice age. The legacy of the ice age is associated with the specific rock development history of the Rokua Geopark area. In many ways, geology has also influenced the development of the living environment of the area and the spread of the settlement. The geological birth story of the Rokua Geopark area has shaped the soil and climate of the area to suit local food production. (Rokua Geopark 2019).

Rokua and Salpausselkä would be complementary but different types of Geoparks. They exist in different parts of Finland and represent different features of Finnish nature. The influence of Ice Age has formulated the geology of the landscape significantly in these areas.

Saimaa geopark registered association has applied for geopark membership in the autumn of 2017. The aspiring Lake Saimaa geopark covers an area of over 6,000 square kilometres, of which the water area is about 4,000 square kilometres. There are 65 geosites in the area, as well as nature and cultural sites. Also, Lauhavuori geopark in the western part of Finland has submitted their application in 2018, with the central theme of mires. (Remes & Nurmilaukas 2018, 81.) As a newcomer, the area of Lake Lappajärvi has also joined the Finnish group of aspiring geoparks (Lauhanvuori-Hämeenkangas Geopark 2019).

3.3 The significant natural sites of Salpausselkä geopark area

Southern Finland is divided into two terminal moraines; the first and the second Salpausselkä, which are about 17 to 18 kilometres apart from each other. The first Salpausselkä is a set of several terminal morainess that have grown together. The variation in the intensity of the glacier flow can be seen in the roughness of the rock material. The precipitates are visible in the cuts of formation, for example at soil deposition points. Similar terminal moraines can be found in the formation of Central Sweden, inner Finland; Kalevala and Rukajärvi. Salpausselkä formations are internationally best known geological features in Finland. (Palmu 2018.)

In the ridge- and terminal moraine formation areas, the landscape is often very variable due to the high- altitude fluctuations caused by adjacent ridges and depressions. The experts of the Geological Survey of Finland have estimated that Salpausselkä one and two are at their most representative in the area of Päijät-Häme, and they are accompanied by internationally valuable longitudinal ridges.

(The municipality of Padasjoki 2019.) In Finland, the deepest kettle holes are up to 40- 50 meters deep (Palmu 2018).

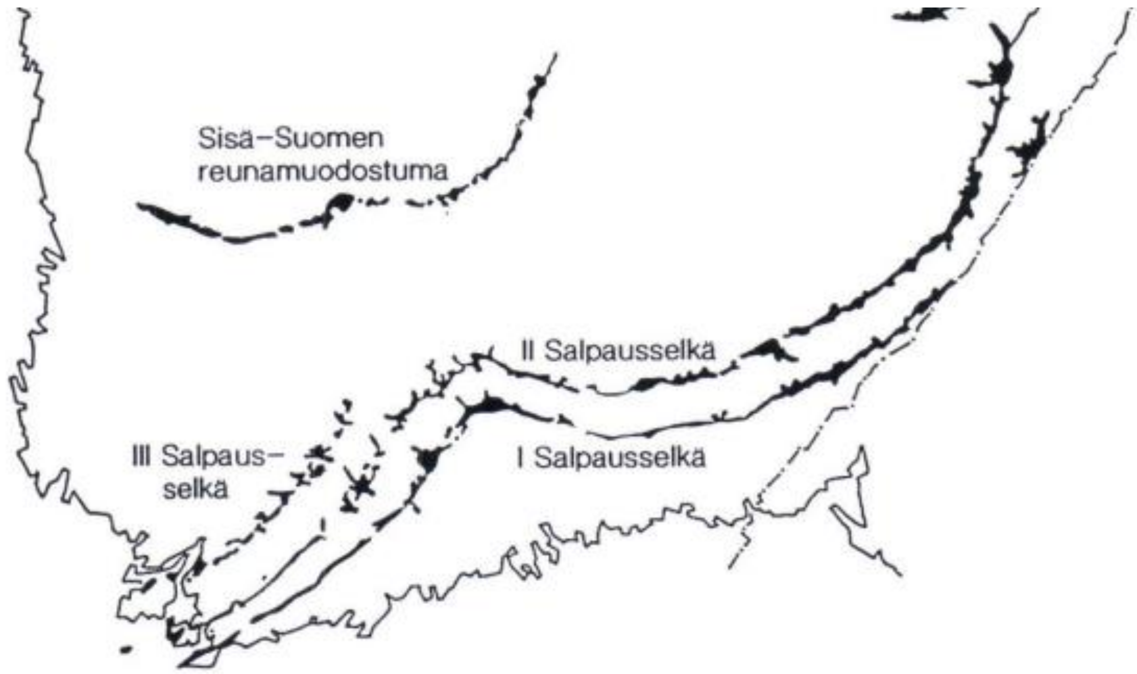


FIGURE 3. The three Salpausselkä formations in Southern Finland (Saarnisto, M., Rainio H. & Kutvonen, H. 1994, 20).

3.3.1 The city of Lahti

Salpausselkä is a visible element in the city of Lahti and the edge formation is a popular outdoor area, mostly covered with forest. On the slopes of Salpausselkä there are some boulders that are remnants of the coastline of the ancient Baltic Sea. The highest point in Lahti, is also situated there; 174 meters above the sea level and 93 meters above Lake Vesijärvi water surface. (Lahden seudun luonto 2019a.)

Lake Vesijärvi in Lahti is in recreational use both in summer and winter. The lake's recreational value has been improved. Lake Vesijärvi is a glacial lake formed in an ice block depression about 10,700 years ago. Vesijärvi is located in the city of Lahti, Hollola and Asikkala areas between the first and second Salpausselkä. (The Lake Vesijärvi Foundation 2019.)

The Linnaistensuo Nature Reserve is part of the national marshland protection programme. Linnaistensuo was accpented as a Natura 2000 protected area in 1998 to represent the raise bog nature of Southern Finland. Currently Linnuoensuo has an area of 200 hectares. There is also 22 hecaters endangered mire type located in the area. (Lahden seudun luonto 2019b.)

3.3.2 The city of Heinola

The natural environment of Heinola consists of different types of forests and groves. There are many protected areas and organisms around Heinola. There are a number of national conservation programmes in the Heinola area and 17 locations of the NATURA 2000 network. There is almost 100 private nature conservation areas and a few dozen of natural monuments. In the ridge area of Heinola, is an urban park with nemoral pine forest. Lake Venejärvi is a small wilderness lake, invasion by aquatic plants will turn it to a swamp over time. Lake Venejärvi and adjacent Rautjärvi are classified as provincially valuable small waters on the basis of their natural state and wilderness. (The city of Heinola 2019.)

3.3.3 Asikkala

A total of 48 solid relics have been found in Asikkala, of which up to six are underwater wrecks. Asikkala's ridges offer a versatile environment for recreational use. Asikkala ridge areas are also important groundwater areas. In addition, the ridges are raw material resources derived from mineral species, gravel and sand. Asikkala has valuable edge forms like Hyrtiälänkangas, Urajärvi, Vesivehmaankangas, Mikkolankangas, Hympylänmäki and Aurinkovuori. (Lahden seudun luonto 2019c.)

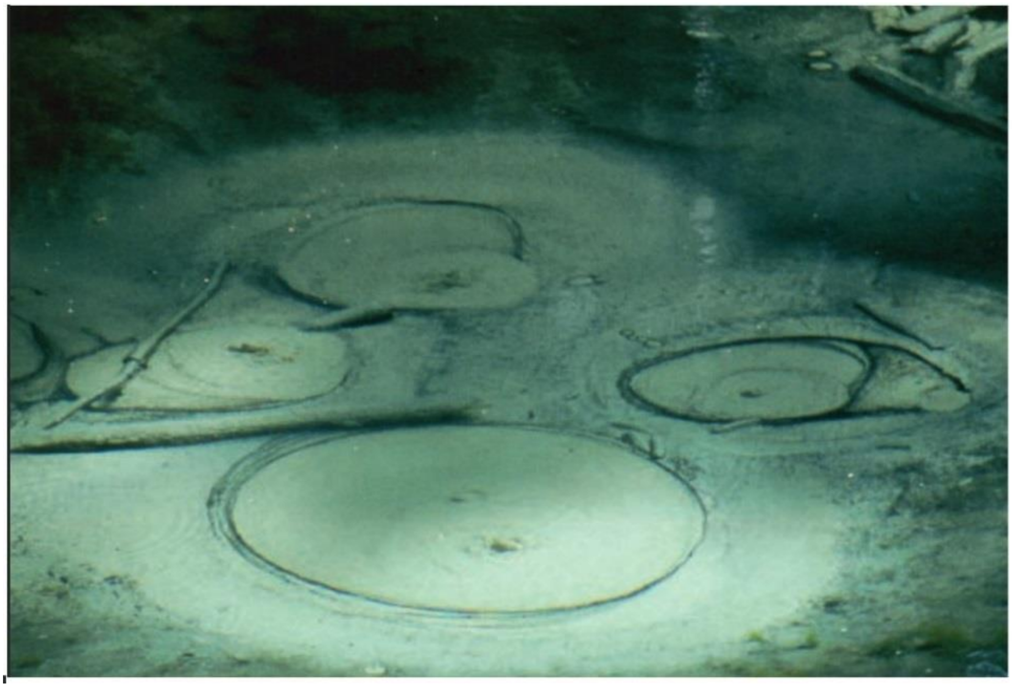
There are several nationally valuable marshlands in Asikkala, some of them are rich fens, which are part of the national protection programme and belong to the Natura 2000 network. The goal of the municipality of Asikkala is to protect the diversity of nature by preserving the area's most important marshlands. (The municipality of Asikkala 2019.)

3.3.4 Sysmä

There are plenty of small ponds, lakes and springs in Sysmä.

Springs can arise in places where the groundwater surface and the Earth surface are cut. Groundwater usually erupts on the flat sides of ridges as springs. There are a number of springs in the Salpausselkä area that were extensively studied already in the 1950s, when Finland's springs were counted, overall 22,000 springs were found in Finland, and 636 were found in the Päijät- Häme area. (Kuusisto 2014, 6.)

Most of Finland's clearest waters are in the Salpausselkä area, are in fact due to the influence of springs. The fauna of the springs is rich and versatile. Most of the benthic fauna consists of larvae of various insects, beetles, crustaceans and worms. Some of them are predators that eat smaller aquatic animals. The bottom dwelling animals are an important part of the aquatic ecosystem. Many springs have dried out, or damaged. Many of the small springs have been completely destroyed. In particular, springs have been affected by agricultural and forestry measures and their introduction into the economy. They have also lost their natural state through fish farming and gravel extraction, as well as the construction of roads and power lines. (Pohjois- Karjalan ympäristökeskus 2019.)



PICTURE 1. Underwater springs (Kuusisto 2014, 5).

3.3.5 Hollola

Pirunpesä is a gorge, only a few meters wide and its height ranges from 5 to 20 meters (Palmu 2018). The 34 acres wide area is quarrying and rocky, and the terrain is variable, with different kinds of plants, rocks and kettleholes (Lahden seudun luonto 2019).

One of the largest groundwater reservoirs in southern Finland is hidden under Salpausselkä, and Kiikunlähde in Hollola is one of its landing points. It is known for its turquoise, clear water, and is one of Finland's largest natural springs. It does not freeze in the winter, because the water flows from the bottom all year round. In the eye of the source, the water temperature is about five degrees Celsius. (Lahden Seudun luonto 2019a.)

There are as many as 2,000 kettle holes of different sizes and shapes in Hollola's Hälvälä area. A kettle hole is a depression formed in the gravel and moraine layer, created by the burial of large ice blocks carried by the melting currents of the Ice Age, where they slowly melted. Their size ranges from a few metres to tens or even hundreds of metres in diameter and can have a depth of several dozen of metres. There are some large boat shaped kettle holes with smaller ones inside at the bottom. The bottom of a kettle hole may be a swamp or a pond and sometimes a rock. (Nikkari 2018.)

FIGURE 4. Geological illustration of Kettle hole formations (Palmu 2018, 4.)

3.3.6 Padasjoki

A total of 26 Stone Age residences are known from Padasjoki, and significant archaelogical finds, such as fish bones, pieces of clay pottery and cheramics have been made from Padasjoki. It seems that some of the pieces of pottery have been in the water, and scientists have speculated that there has been some 5800 years ago of transgression of ancient Päijänne. Occasional flooding in the Lake Päijänne is likely to have led to the leaching of habitats into the water in some places (Kouki 2014).

3.3.7 Southern Päijänne National Park

Southern Päijänne National park, has an area of 14 square kilometres, including fifty islands. Kelvenne grayling and the associated ridge sections, continue partly under-water in the north to Tupasaari and to the south to the island of Ykskoivu. Kelvenne was formed from the gravel piled and sorted by the latest glacial ice flows, slowly retreating to the northwest, with deep kettle hole cavities. (Metsähallitus 2019.) The route through Pulkkilanharju was voted the most beautiful scenic route in Finland in 2014. Pulkkilanharju can be described as a narrow ridge formation, with clear lake scenery on both sides of the route. (Juotavan Hyvä Etelä- Päijänne ry 2017, 19.)

PICTURE 2. Aerial picture of Päijänne National park (Metsähallitus 2019).

FIGURE 5. Kelvenne camping and hiking map (Juotavan Hyvä Etelä- Päijänne ry 2017, 6).

4 SURFACE WATERS

There are 832 lakes in Salpausselkä geopark area. Most of them in the city of Heinola. (Järvi & Meriwiki

FIGURE 6. The map of surface waters of Salpausselkä geopark area.

4.1 The global importance of lakes

Only 3% of all the water on Earth is freshwater. Most of it is stored in glaciers, ice caps and groundwater. About 90,000 cubic meters of fresh water in the world is stored in five million lakes (Caldecott 2009, 112.)

0.3% of that freshwater is stored in lakes as surface water. Lakes are significant part of Earth’s natural biogeochemical and ecological processes. Water in the Earth system is influencing all aspects of life. Earth’s system consists of four dynamic, interacting subsystems; the geosphere, hydrosphere, atmosphere and biosphere. The active water cycle is one part of Earth’s system. At some points of the cycle, water is stored in natural reservoirs, such as a lake. Water molecules can stay in a lake for hundred years or more. And in groundwater from a month to ten thousand years. (Science Learning Hub 2009.)

The components and processes of water circulation are disturbed by human activities such as agriculture, irrigation, industrial processes, sea transport and waste water treatment.

Geoparks can play an important educational role, creating an image of the water cycle in an interesting and understandable way. Main objective of the cooperation between geoparks is the protection of geological heritage and the sustainable development of the areas in Europe. Sustainable development of the lakes in Päijät-Häme. A large amount of research and development has been conducted in Päijät-Häme, the City of Lahti has been very active, and one of the main objectives of sustainable development is the flood prevention and management.

According to dissertation by Jouni Heiskanen, at the University of Helsinki, lakes have a greater role in climate change than previously is thought. Organic matter is transported from rainwater to lakes. This gives the Finnish lakes the typical brown color that affects the entire lake, both in thermal deposition and in the duration of the ice cover. The biota of the lake breaks down organic matter, producing carbon dioxide when oxygen is available, and eventually the greenhouse gases are released into the atmosphere. Because of these, lakes affect both climate change and react to it, for example due to changes in rainfall. (Ilmasto-opas 2019.)

4.1.1 The ecological classification of surface waters

Finnish Environment Institute has defined the ecological classification of surface waters in Finland. 85% of the lakes in Finland are excellent or good in ecological status. The national objective is at least good status for all the surface and groundwaters. The surface waters are classified according to its ecological and chemical status as excellent, good, satisfactory, inadequate or bad, taking into account the inherent characteristics of the water area. (Finnish Environment Institute 2017a.)

Biological quality factors are primarily the basis for this classification. The state of the planktons, diatoms, aquatic plants, benthic animals and fish of the water body is compared with the conditions in which human activity has not caused observed effect on the biota. Water quality factors, such as total nutrients, pH, visibility depth and hydromorphological factors are also taken into account. In addition, surface water can be evaluated for chemical status, whereby concentrations of hazardous and noxious substances in the waters are compared with statutory environmental quality standards. These types of harmful substances include mercury, cadmium, lead, organohalogen compounds and organic tin compounds. (Finnish Environment Institute 2016.)

To achieve good water status, must water management plans and operational programmes be planned regionally. Water management in Finland, is planned in river basin districts. There is seven water management districts inland. (Finnish Environment institute 2018c.) Water management measures include oxidation, nutritional network restoration, management fishing, planting predatory fishes, mowing of aquatic plants, dredging, chemical treatment. (Lake Vesijärvi Foundation 2019.)

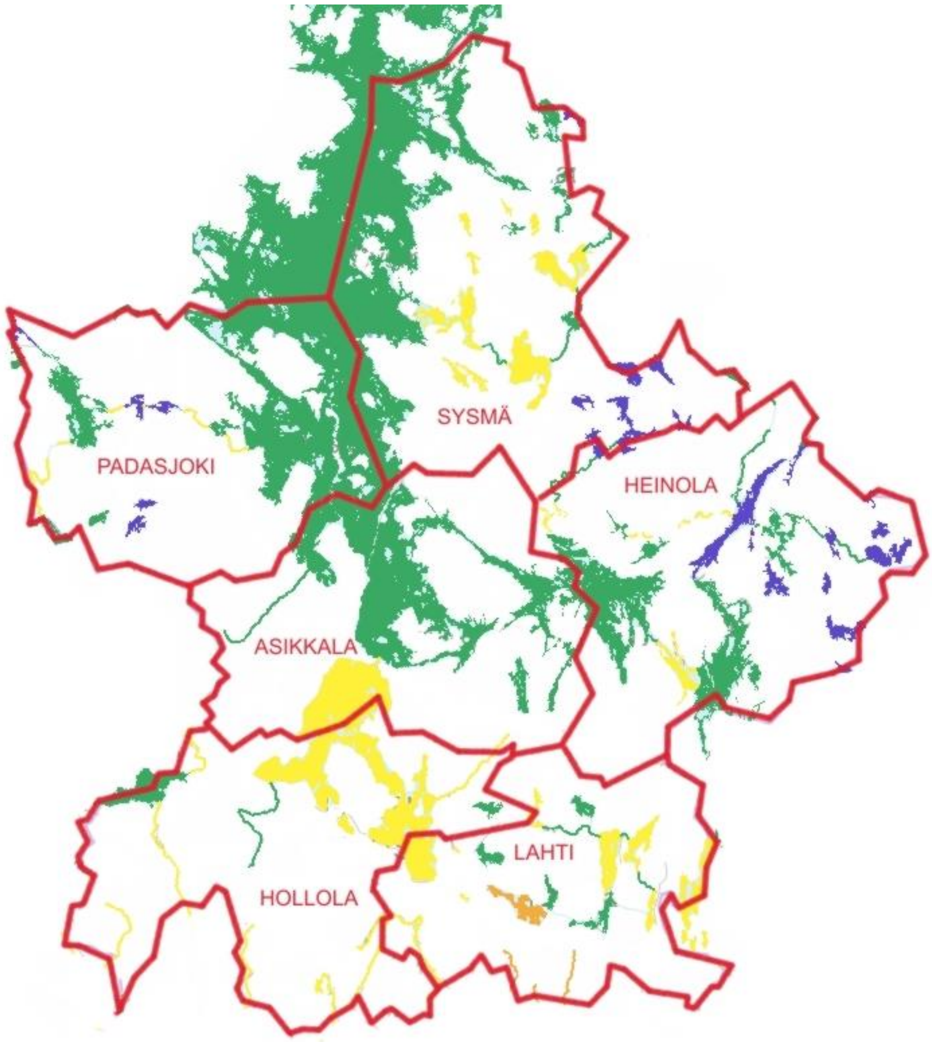


FIGURE 7. The state of the surface waters in Salpausselkä geopark area, blue colour meaning excellent, green good and yellow satisfactory.

4.2 A short history of Lake Päijänne

Finnish lakes are a product of the Ice Age, as is Lake Päijänne. Salpausselkä formations were created by the continental ice sheet and the meltwaters at the end of the last ice age about 11 600 to 12 300 years ago. This period was called the Younger Dryas, when the climate started suddenly to get colder during the deglaciation stage of the continental ice sheet. (Salpausselkä geopark project 2018.) It was prehistoric climate change, but that time it was not caused by humans. Some of the Päijänne National parks's small islands are formed by the waterstreams of melting ice 11 000 years ago. Some of the islands consist of ancient bedrock that is even 1900 million years old. (Oijala 2016, 8.)

The prehistoric time of Finland began when the first inhabitants came to Finland after the last ice age in about 8850 BC. Fishing was a vital part of survival. For centuries mankind has lived on the shores of lake Päijänne, in harmony with nature. Lake has offered drinking water and fresh fish. Over time, more and more permanent residences were established around lake Päijänne. (Oijala 2016, 8.)

The peaceful life lasted until the 19th century, after that the development has been extremely fast. The earliest industrial companies in the Lahti region were established in the late 19th century. Multiple businesses were set up in a short time. Many local companies had a strong family tradition to keep the head of the company inside the family, some of which are still continuing their tradition. The Vääksy Canal and the Riihimäki- Pietari railway made Päijät- Häme area hub for traffic. When access was available and an important raw material, wood could be efficiently transported, the area was favorable to industry. Saws and roll mills were the first to form the basis of the Finnish export industry. (Hakala 2017, 9- 10.)

At the time when the steamboat Suomi started operating in 1906, a large fleet of ships was already sailing in Päijänne. In addition to a few sailboats from Jyväskylä merchants, there were a number of beakers and barges sailing on the lake. They brought sawn timber to the southern shore of Päijänne, where it was further transported to the sea coast. There were plenty of forests in Päijänne's coast and Central Finland, of which sawmills made planks and boards for sale. The birch resources in the area also favored plywood production. The best markets were abroad. The sawmill's raw material was inexpensive, but the transportation of the products was difficult due to long distances. (Muranen 2007, 101.)

PICTURE 3. S/S Suomi in 1906 (Keski- Suomen museon kuva- arkisto 2019).

4.2.1 The significance of Lake Päijänne

Päijänne’s surface water type is large low humidity lake. Its management area is Kymijoki-Gulf of Finland water treatment area. Its ecological status and surface water condition was graded good in 2016 by Finnish Environment Institute. (Vesikartta 2019.)

Päijänne is considered as one of the cleanest large lakes in Finland. Helsinki metropolitan area takes its drinking water from Päijänne via a 120- kilometre underground tunnel. (Hakala 2017, 21.)

When the wastewater treatment plants came into operation and after the influence of large point sources, such as factories was controlled by trearment plants, the water quality in Päijänne also started to improve. The fresh waters of Lake Päijänne is home to a rich and functional and ecosystem.

4.2.2 The biodiversity of the Lake Päijänne freshwater environment

Biodiversity is generally considered as a measure of the health of ecosystems.

The aquatic ecosystem is very sensitive. It consists of the physical interactions and symbiotic relationships between the ecological balance of the life of water animals and plants. The natural state of the groundwater environment is the host of various microorganisms. Groundwater microbes are partly native to the upper soil layers through which the water has filtered. There are various microbial groups such as fungi, bacteria, viruses and protozoa. The number of microbes varies depending on the conditions. In addition to nutrients the amount of microbes is influenced by water temperature, acidity and mineral composition. (Mälkki 1999, 119.)

The biological properties of the lake, such as the species, food networks and biological production, depend on many factors, including the structure and development history of the lake and its catchment area, as well as the distribution of different species. Biological activity of the lake affects water chemistry and physics, and visa versa. The northern climate prevents many species from staying, and the biological ice age is still so short that it limits the number of species. (Rönkä & Walls 2004, 31.)

Nutrient rich lakes are full of life, plants and micro organisms. Naturally, there are fewer nutrients in cleaner and clear waters. The micro-organisms in the waters live directly from the nutrients and form the beginning of the food chains of the watercourses. Aquatic plants and microscopically small phytoplankton form the basis of the food chain. Water is an integral part of the plant structure. Plants also get their nutrients through the roots and in the water as they are. Crayfish and other crustaceans, which provide nourishment for fish, in turn eat ciliates. When the animals die, the small bacteria are responsible fordecomposing them with oxygen. This is one of the reasons why the oxygen content of water is very important. In the deep ditches of the bottom of the Lake Päijänne, the food network consists of life forms that eat dead plants and organisms on the bottom of the lake, and the larger organisms that eat them. Päijänne is home to multiple lifeforms, such as thee eel, which can migrate as far as 6000 kilometres to ita spawning area. Bryozoa, or moss animals are very primitive invertebrates that live in colonies. They are thought of as Finnish corals. (Krämer 2009, 82.)

Typical water plants in Päijänne are Yellow waterlily, Crowfoot, Water Smartweed, and Water lobelia. The bottom sediment is the most important nutrient stock for rooted aquatic plants, especially in terms of nitrogen and phosphorus. Plants affect the nutrient cycle of the lake bottom sediment by absorbing nutrients and modifying its chemical conditions. In turn, abundant aquatic vegetation can increase the pH of the water, where the oxidation is not beneficial to the lake and phosphorus can be released into the water. However, aquatic plants can have very different effects on lake conditions, so there are no unambiguous rules. (Rönkä & Walls 2004, 41.)

Many lifeforms live on top of the water surface, like Water striders (the Gerridae). One significant fact is that the lake freezes over in winter, so the life underwater have a long period of darkness beneath the ice. The water molecular structure causes the water density to differ from the normal state behavior. Water expand at below four degrees Celsius, and an ice layer forms on the lake. Another important feature of water is the ability to reserve heat. No other liquid is capable of reserving heat as well as water. (Krämer 2009, 29- 31.)

The fish of the lakes benefit from the water density deviation. Fish are heat-exchange animals, so their body adapts with the temperature of the surrounding water. If the temperature goes too low, the fish's vital functions and metabolism will also be very slow. Fish, such as roach, pike or perch, disappear from the shallow water and go into the ditches, where water is warmer, at about four degrees Celsius. For example, flounder, pouches, simpets, etc. live in the bottom of the lake. The fish are able to live long enough without eating, utilising the accumulated nutrition stored in the liver. (Jensen 2018.)

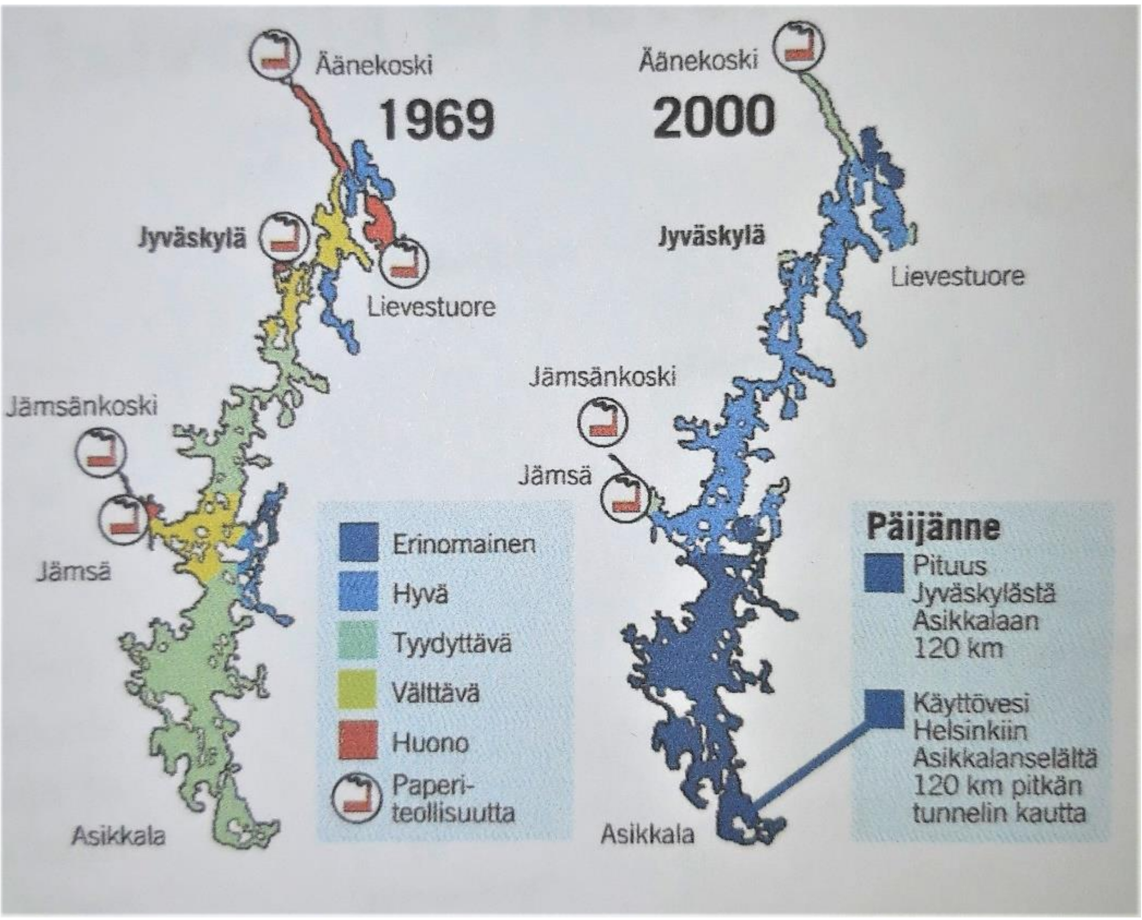


FIGURE 8. In these two different maps of lake Päijänne, shows the difference that has occurred in the lake's condition in 31 years. The colour blue indicates excellent and red a bad condition. (Lönnqvist & Kuhanen 2007, 81.)

PICTURE 4. The Gerridae live on water surface, they are commonly known as water striders or water bugs (Salovaara 2010.)

PICTURE 5. Crowfoot and waterlily pads (Luontoportti 2019.)

4.2.3 Cyanobacteria situation in Lake Päijänne

Cyanobacteria, commonly known as blue-green algae, are bacteria that get their energy through photosynthesis. It is harmful to humans and animals. Water containing cyanobacteria must be considered as a possible health risk. If there is blue-green algae in the water, it should not be used for washing or drinking, even if the water is boiled. Fish and crabs can still be caught and eaten, but fish liver should not be eaten. The fish and hands must be washed thoroughly with clean water after handling the fish. High liver toxin levels have been detected in mussels and conches, so they should be avoided. (Finnish Environment Institute 2018a).

Nowadays Päijänne's cyanobacteria situation is fairly good, but at summer time, certain areas of the lake may still have some areas of blooming algae depending on the weather conditions and other circumstances.

FIGURE 9. The average general Blue- green Algae situation in Lake Päijänne 1998 – 2018, shows that there is not much Cyanobacteria in Päijänne (Järvi & Meriwiki 2018.)

4.3 Measuring the water quality

The Finnish Environment Institute regularly measures lake conditions in Finland. Lahti Region Environmental Services monitor the water quality of Lahti, Hollola and Nastola. Lake Vesijärvi is monitored regularly too, and samples are taken in the Spring and Autumn.

Observation of the water level in Päijänne was started in 1879. The maximum water level difference in one year has been 1.61 meters, in 1974. The largest increase in water level in history (1964-1999) in 7 days was 0.23 meters. The rainfall in the Päijänne area has been measured since 1911 and the area water value since 1946. The average annual rainfall in the Päijänne area is 700 mm (Finland's Environmental Administration 2014. The chemical composition of the lake depends, among other things, on the quality of its bottom sediment and soil in the catchment area. The lake effectively dissolves nutrients and salts from them. Finland's rock and soil are mostly nutrient-rich, which can be seen as a natural barren water. Evaporation, inflow and biological activity also increase concentrations of lake water. Instead, outflow, rain and sedimentation reduce it. (Rönkä & Walls 2004, 31.)

Nitrogen and phosphorus concentrations of water gives information of the nutrient load of the lake. Eutrophication caused by nutrients is one of the most significant factors changing the ecological state of the lakes. Nutrient concentrations can be used to assess eutrophication and its secondary effects on aquatic organisms. Nutritional factors also affect the composition and abundance of aquatic plants and algae, as well as benthic and fish species, in addition to algae production and variety. Groundwater is of superior quality to surface water, but both are susceptible to diverse harmful substances such as agricultural and industrial wastewater. Phosphorus is very important for the assessment of water euthropication. (Krämer 2009, 56.) Agriculture is one of the main sources of nitrogen and phosphorus. Fertilisers used in agriculture, improve pasture growth but contain chemical compounds that add nitrogen, phosphorus and potassium content of the soil. They can be leached from the soil or carried away in runoff, ending up in waterways and groundwater. (Science Learning Hub 2013.)

Nitrogen gets into the lakes with rainwater, waste water, and runoff water especially from agriculture and fields. Measuring the water temperature is one of the basic definitions of water monitoring, which is always done when taking water samples. The colour of the water, opacity, visual depth, and α-chlorophyll content are primarily recorded observations. (Krämer 2009, 56.)

4.3.1 Water attributes

Liquidity is one of the most important characteristics of water for us and for our environment, because of the tight molecular structure of fluid, which combines the mobility of molecules (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 37).

The main characteristic of water is the ability to dissolve other substances. Particularly, water dissolves compounds consisting of ions having an electrical charge, such as salts, acids and bases. Instead, water is a poor solvent for most organic carbon compounds such as fat and oil. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 89.)

Waters has many harmful attributes. As a vapour it causes burns, it is lethal when inhaled, and impure water causes diseases, when consumed in excessive amounts, water dilutes blood and causes poisoning. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 35.)

Water density is about one kilogram per litre. At a temperature of +4 degrees Celsius, the water density is exactly one kilogram per liter. This is rare for other liquids, that the temperature drops, when the maximum density is reached. For all substances, the density depends on the temperature. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 47.)

The conductivity of pure water is good and it is capable of dissolving charged particles, ions. If water is soluble in acids capable of delivering protons to the solution, the acidity of the water increases. Acidity affects other properties of water. Acid water dissolves many compounds better than pure water. In natural waters, acidity is often harmful. For example, when energy is produced with sulfur-containing fuels without purifying the flue gases, sulfur compounds enter the air, which the react with water in the atmosphere to form sulphuric acid. This was previously the case with "acid rain" in the vicinity of energy production plants, causing tree deaths or acidification of lakes. Almost all of the combustion-based energy production produces sulfur compounds, but now the combustion plants are equipped with flue gas cleaning. Acidification of natural waters can, for example, promote the dissolution of harmful metals. Excess acidity can also cause direct damage to lime-rich organisms such as crayfish and mussels, promoting the dissolution of the shell. In Finland, perch and pike adapt well to acidic water. Especially the ponds of the marsh are often acidic due to the natural humic acids, but the pike and perch are also very good at them. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 101.)

4.3.2 Water impurities

Many substances that are considered impurities are that only at high concentrations. Agents treated in agriculture become large quantities harmful to water. Most of the pollution phenomena are the result of population growth. The human body has adapted to life in an environment where small amounts of compounds are dissolved in water. Well water contains all the metals in the soil. Naturally dissolved substances cause problems if concentrations increase. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 105.)

The toxicity depends on the concentration. Some of the toxins are very persistent, such as PCBs, dioxins, cadmium, mercury and lead. Chlorinated hydrocarbons such as DDT, which were used in the past in pest control, continue to be affected. These types of toxins accumulate at the top of the food chain and are ultimately a health risk to humans as well, for example, when a person eats fish to which toxins have accumulated. (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 107.)

4.3.3 Heavy metals

Heavy metals are commonly found in Finnish waters and can be found in large fatty fish such as salmon. Additives used in food and drugs that have been illegally destroyed can eventually also enter the waterways.

Cadmium (Cd) can be released into the environment with contaminated fertilizers and sewage sludge, as well as locally in industrial emissions, although efforts have been made to strictly reduce use. Cadmium accumulates in plants more than any other heavy metal. It is stored in the liver and especially in the kidneys, causing damage. Cadmium is known to be the most cumulative environmental poison because its half-life in the human body is 20-40 years. (Koulu, Mervaala & Tuomisto 2012, 1161-1162.)

Mercury (Hg) was used as a medicament before it was realised that it is detrimental to health. All mercury waste is hazardous waste. Inorganic mercury is toxic to the environment. It was used, for example, in the wood processing industry, from which it spread to the environment in Finland. It still spreads in the air from industry, and the burning of fossil fuels. Mercury is also naturally present in the soil, and fish absorb it in the form of methylmercury. (Koulu, Mervaala & Tuomisto 2012, 1157.)

Arsenic (As) is a natural substance of the environment, but its amounts are significantly increased by coal combustion and industry. It is a poison and drug that has been known for thousands of years. Arsenic in drinking water is a global problem, causing skin, lung and bladder cancer. There are areas in Finland where there may be abundant amounts of Arsenic in groundwater, causing problems with the quality of the water in wells. In Finland no clinical arsenic poisoning caused by drinking water has been detected. Soil contamination has been caused by impregnation of timber in sawmills. (Koulu, Mervaala & Tuomisto 2012, 1162-1163.)

4.3.4. Plastic

The majority of the plastic produced is not biodegradable, but the only way to permanently dispose of the plastic is by burning or pyrolysis. Burning plastic produces energy, but also greenhouse gases and pollutants. So it is difficult to get rid of plastic and therefore it is very much accumulated in the environment, especially in waterways. Due to their longevity, micro- plastics entering watercourses can be an environmental risk. (Geyer, Jambeck & Lavender Law 2017.)

Many consumer products such as plastic bags, plastic containers, synthetic fiber clothing, kitchen utensils, cosmetics, toothpastes, contain micro plastics. Microplastics are plastic particles of less than 5 mm by size. Micro plastics are transported to waterways, for example urban wastewater and storm water. According to studies carried out at the waste water treatment plant in Viikinmäki, Helsinki, 99 per cent of microplastics are purified from wastewater. However, these microplastics remain in the sewage sludge and make it more difficult to use. One of the most significant sources of microplastics for storm water is traffic. (Finnish Environment Institute 2017b.)

In Finland, micro-plastics in waters have not yet been studied extensively. According to the preliminary findings of the Department of Environmental Science, snow samples collected from the center of Helsinki contained significant amounts of asphalt and ring-separated microplastics. With the melting of snow and run-off water, the plastics also reach lakes, still fish and aquatic organisms. In the same waters, several Finnish cities get their drinking water. Another important question is what happens to the sewage sludge. Wastewater sludge contains valuable nutrients in addition to plastic and chemical waste, and the use of sludge is under pressure, for example, in urban landscaping. (Finnish Environment Institute 2017b.)

Also macroplastics, such as plastic bottles, can become microplastics overtime, for example if a plastic object is exposed to UV- radiation for a long time (Woods Hole Oceanographic Institution 2018).

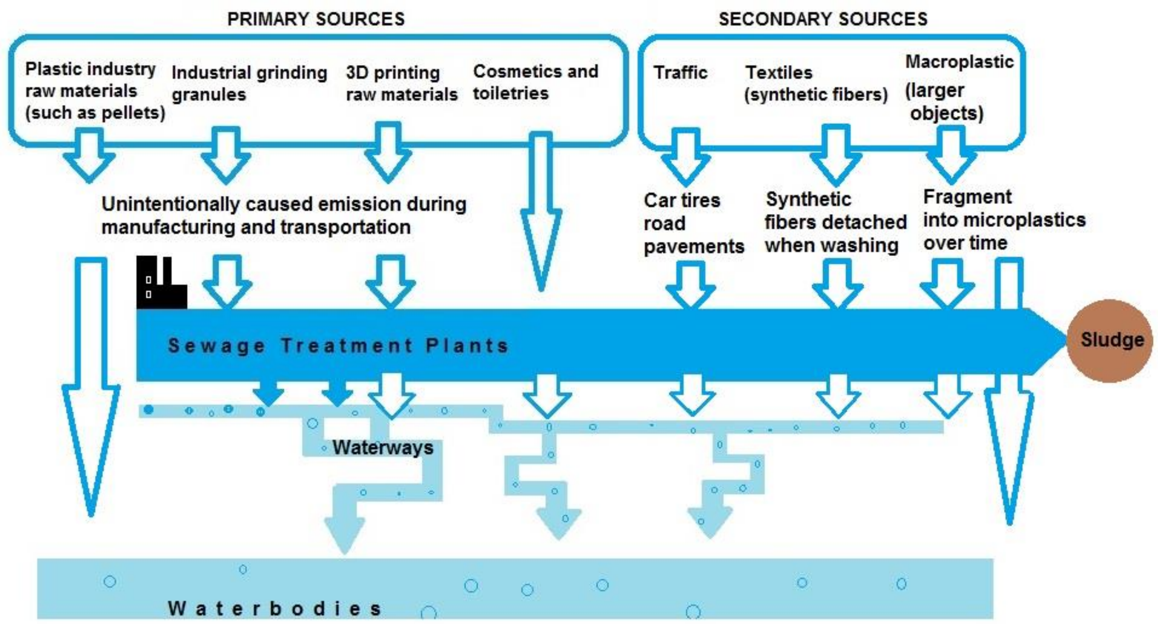


FIGURE 10. Sources of microplastics in Finland (Finnish Environment Institute 2017, modified by author 2019).

4.4 Measuring surface water quality

In addition to elemental and heavy metal concentrations, and acidity of natural waters, also colour, opacity, visual depth, and A- Chlorophyll content are commonly measured from natural waters, and there is field tools and monitoring devices for it.

4.4.1 Colour of water

Pure water is clear and nearly colourless. The colour of the water may be due to the substances dissolved therein or the solids contained therein. The colour of dissolved substances in natural waters is usually yellowish brown due to humic substances. The more water there is in the catchment area is, the browner the water is. Humic compounds are acidic, slowly degradable organic compounds. Surface treatment, deforestation and deforestation increase humic leakage. Finnish waterways are often naturally humic- coloured, yellowish and slightly acidic. Also, a high iron content can sometimes cause a brown colour, especially in samples taken close to the bottom of the lake. In the general water quality class, slightly humic- containing water is less than 50 mgPt / liter. The average measured colour of Central Päijänne in 1990- 2004 was below 40 mgPt / liter. (Mitikka 2013, 1.)

Pt meaning platinum grade. When measuring colour, the water to be examined is compared to the platinum scale by means of a colour wheel.

TABLE 1. Colour of the water versus mgPt / liter (Oravainen 1999, 14).

Colourless lake	5 – 15 mgmgPt / liter
Mild humic substances	20 – 40 mgPt / liter
Dystrophic lake	50-100 mgPt / liter
Brown lake (swamp water)	100 – 200 mgPt / liter

4.4.2 Water opacity

Water opacity is cause by mud, iron, colloidal compounds or abundant algae. The most commonly used measurement of water opacity is the light scattering or nephelometry. The turbidity unit is FTU, which comes from Formazin Turbidity Units. The average opacity of Central Päijänne in 1990 – 2004 was below 1 FTU (Mitikka 2013, 2).

TABLE 2. Opacity classification (Oravainen 1999, 8).

Clear water	< 1 FTU
Mildly opaque water (Typical to slightly eutrophic lake.)	1 – 5 FTU
Opaque water (Eutrophic lake but also for clear water lake *bottoms*.)	5 – 10 FTU

4.4.3 Visual depth

The variation of visual depth depends, on the amount of humic substances in the water, muddy particles and algae in the water. The depth of view reflects the thickness of the illuminated water layers, which is important for the variety of aquatic plants and the amount of algae. The depth of view varies in different seasons. At its lowest, the depth of vision is at the time of algae production and runoff. Depth of visibility may change as a result of eutrophication, soil tillage, or leaching of organic and inorganic matter. The average visual depth of Central Päijänne 1999 – 2004 was 3,5 meters. (Mitikka 2013, 3.)

TABLE 3. Visibility depth of the lakes (Mitikka 2013, 3).

Poor quality lake	Visibility < 1 meter
Good quality lake	Visibility 1 - 2,5 meters
Excellent quality lake	Visibility 2,5 – 10 meters
Excellent quality lake with low humic, often quite rugged lakes	>10 meters

4.4.4 A-Chlorophyll content in the water

The amount of chlorophyll-a measures the abundance of leafy planktonic algae in the water. The result is directly proportional to the amount of algae and hence to the lake's eutrophication level. Because algae biomass varies a lot due to weather factors, assays should be performed several times during the summer. The average amount of A-chlorophyll in the Central Päijänne in 1999- 2004 was about 4 mg / m3.

TABLE 4. The amount of A-Chlorophyll in lake water (Oravainen 1999, 23).

Rugged, clear lake	>4 mg / m3
Slightly euthrophic lake	4 – 10 mg / m3
Eutrophic lake	10 – 20 mg / m3
Very eutrophic lake	20 – 50 mg / m3
Overly eutrophic lake (quick measures must be done)	>50 mg / m3

In addition to the above-mentioned properties, water samples can be taken from the lake and the lake's oxygen content, conductivity, alkalinity and concentrations of various elements can be studied. The following section describes more precisely what elements in water are harmful, and which ones also harmful the lake Päijänne's ecosystem.

4.5 Examples of sustainable development projects in Salpausselkä geopark area

The good status of a lake is assessed by analysing biological variables such as fish and aquatic vegetation, but it is also important for the users of the waters to have their own experience of good quality water and the aquatic environment. Often the positive perception of the state of the water and the water environment arises from the following elements; the water is clear, there is no algae damage, the fish stock is versatile; plenty of predatory fish suitable for fishing, and enough water vegetation but not too much, the shores are clean and suitable for the recreational use. (Salo & Palomäki 2006, 9-10.)

4.5.1 Vesijärvi reconstruction plan

The water of Lake Vesijärvi run north along the river of Vääksy to Päijänne.

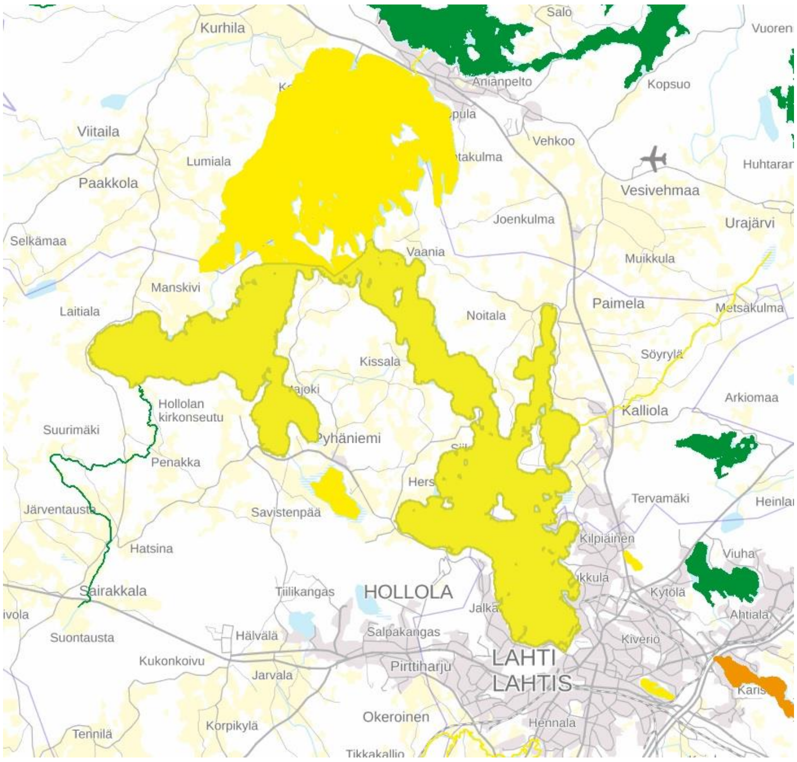


FIGURE 11 Lake Vesijärvi extends to city of Lahti, Hollola and Asikkala (Salmi & Lindholm 2017).

Bright waters and valuable fish stocks were things that Vesijärvi was known for before industrialization in the city of Lahti. The small catchment area makes the lake vulnerable, especially if it happens to be located in industry and densely populated. Lake Vesijärvi was highly eutrophic in the 1960s and 1970s due to heavy industrial and residential wastewater loads. In the 1920s blue- green algae started to bloom, and in the early 1970s the external loading of the lake was the highest. Since then, the load has decreased and the state of Lake Vesijärvi has improved. In Lake Vesijärvi there have been also man-made changes: the lake surface level has been lowered, the Vääksy Canal has been dug, there are several groundwater abstraction plants and water has even been led to another watercourse, the River Porvoonjoki. (Salmi & Lindholm 2017.)

The first Vesijärvi renovation project started in 1987, but it did not develope very far because the funding was hard to find, until the year 1990 when lake renovation got more attention. Human activity has increased eutrophication. Apartments, industrial and commercial activities, forests and farmland and the air quality affects the lakes. (Lahden seudun ympäristöpalvelut 2015, 18.)

The freezing point of a lake is significant for the development of, for example, winter oxygen loss. Lake Vesijärvi is covered with ice on average 150 days a year, but the time has shortened for about a month in 30 years. After the 1990’s Vesijärvi has undergone multiple restoration programmes, with the goal to promote the maintenance of Lake Vesijärvi. (Salmi 2019, 2.)

4.5.2 Vesijärvi today

The ecological status of Lake Vesijärvi is classified as satisfactory by Finnish Environmental Administration in 2016 (Salmi&Lindholm 2017).

Vesijärvi is subject to both external and internal nutrient loads. External load refers to the load coming from outside the lake, from forests, fields, city streets and from the air. In turn, the internal load means that part of the nutrient load that comes from returning the nutrients bound to the bottom of the lake to water, for example, to use algae (Salmi 2019, 4). About 55 percent of City of Lahti is urban areas. In these built-up areas, the water hydrology is significantly affected by an impermeable surface; paved streets, car parks, squares and roofs of buildings. In the centereof Lahti, an estimated 65 per cent of waterless surfaces are present and there are very few unstructured areas in the center. (The City of Lahti 2012, 14.) However, the City of Lahti's Stromwater Plan aims to improve the situation.

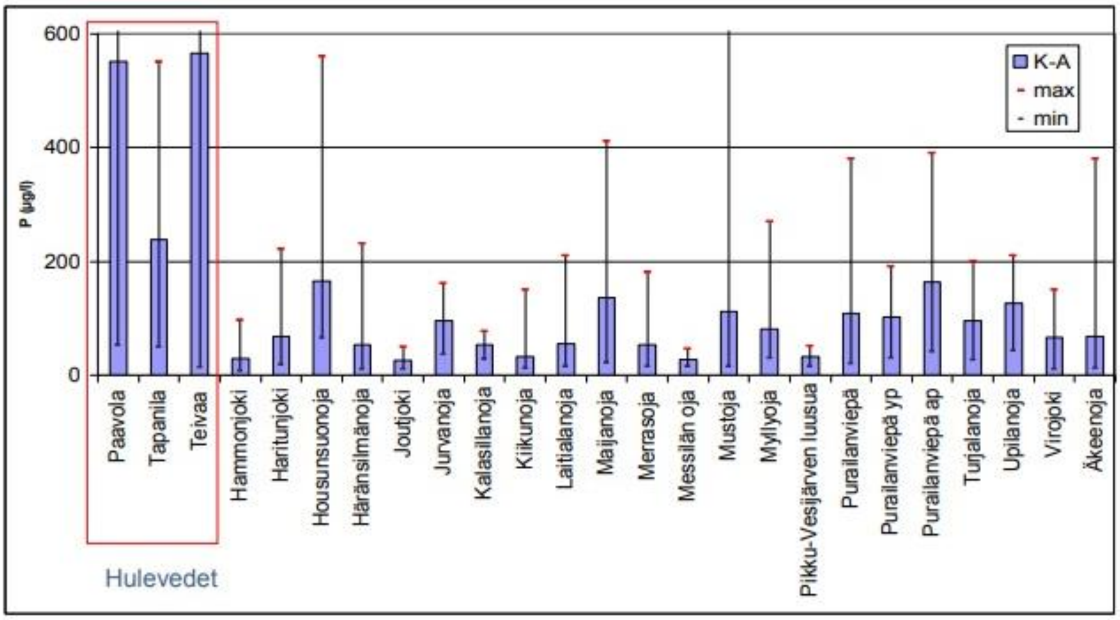


FIGURE 12. The Phosphorus content of Stormwater that enter Lake Vesijärvi (Vauramo 2017, 8).

The deepest depths of Lake Vesijärvi often become oxygen-free in the final winter. The concentration of phosphorus in Lake Vesijärvi is high. The main source of phosphorus is streams and rivers, and other sources are deposition and urban stormwaters of Lahti city. Overall 11 640 kg P/a is coming in Lake Vesijärvi. The continuous recovery of Vesijärvi is currently being promoted by a registered association as well as a foundation. Of particular importance has been the extensive voluntary activities of citizens and local communities for the protection of Vesijärvi. (Salmi & Lindholm 2017.)

4.5.3 Lahti region stormwater management plan

The amount of rainwater is predicted to increase as climate change progresses, with increasing rainfall and heavy rains. In addition, densifying urban structure sets challenges for stormwater management. In addition, rainwater loads waterways by causing quality and erosion hazards. There are several recreational lakes that are important for the inhabitants of the city and that are heavily loaded by storm water. The traditional drainage, in which the storm water is introduced into the pipes, has caused many problems that could escalate in the future. Plenty of storm water gather on the Lahti groundwater areas, because of the tight street structure (The City of Lahti 2012, 6.)

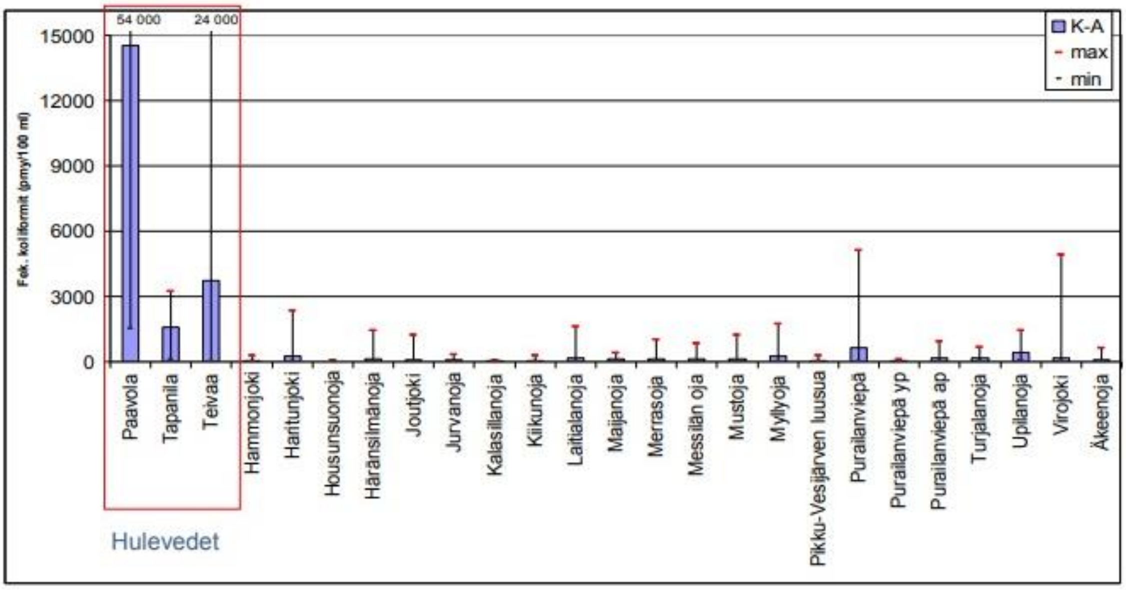


FIGURE 13. Coliform bacteria of stormwater that enter Lake Vesijärvi (Vauramo 2017, 9).

The Lahti City Stormwater Management Programme was launched at a Stormwater Seminar in 2009. The seminar gathered specialists to talk about the stormwater and to gather a group of experts for future planning. (The City of Lahti 2012, 6.)

The starting point of the stormwater management plan was prevention of stormwater. The goals set for the plan were; improve the management of stormwater, fight floods, ensure foundation drainage, safeguard groundwater quality and formation, reduce water load, increase the diversity and appreciation of urban nature, improve public authority cooperation and develop information flow and operational model. According to the plan, the stormwaters should be handled to minimize their impact on natural waters. Special attention should be paid to the groundwater status in Lahti, as the city is located on extensive groundwater reserves. (The City of Lahti 2012, 20-22.)

A stormwater management plan proceeds in stages. Firstly, to survey the area including the type of soil, the direction of the stormwater flow and the catchment areas. The need for and the consequences of the change will then be assessed. If there is a need for stormwater management, a proposal will be made on the basis of which the objectives of the project can be advanced, such as aesthetics, economy, and environmental protection. After that, plans are made by region and more detailed plans. Finally, the construction of the stormwater management system. Monitoring and maintaining the area is also an integral part of the whole project. (The City of Lahti 2012, 40.)

The City of Lahti, among three other cities in Finland, is also involved in a Stormwater Quality Management project, which is developing new ways for purifying and improving the quality of urban run-off water. The aim is to remove microplastics and nutrients from stormwater, which reduces the amount of emissions flowing into water bodies and rest of the environment. (Smart&Clean foundation 2019.)

5 GROUNDWATER

Salpausselkäs are valuable groundwater areas. The largest groundwater resources in Päijät-Häme region are located in the first and second Salpausselkä areas and in the South- Eastern direction of the ridges. The most significant groundwater resource areas for water supply of Salpausselkä geopark are located in municipalities of Asikkala, and Hollola, and the city of Lahti. (Finnish Environment Institute 2014a.)

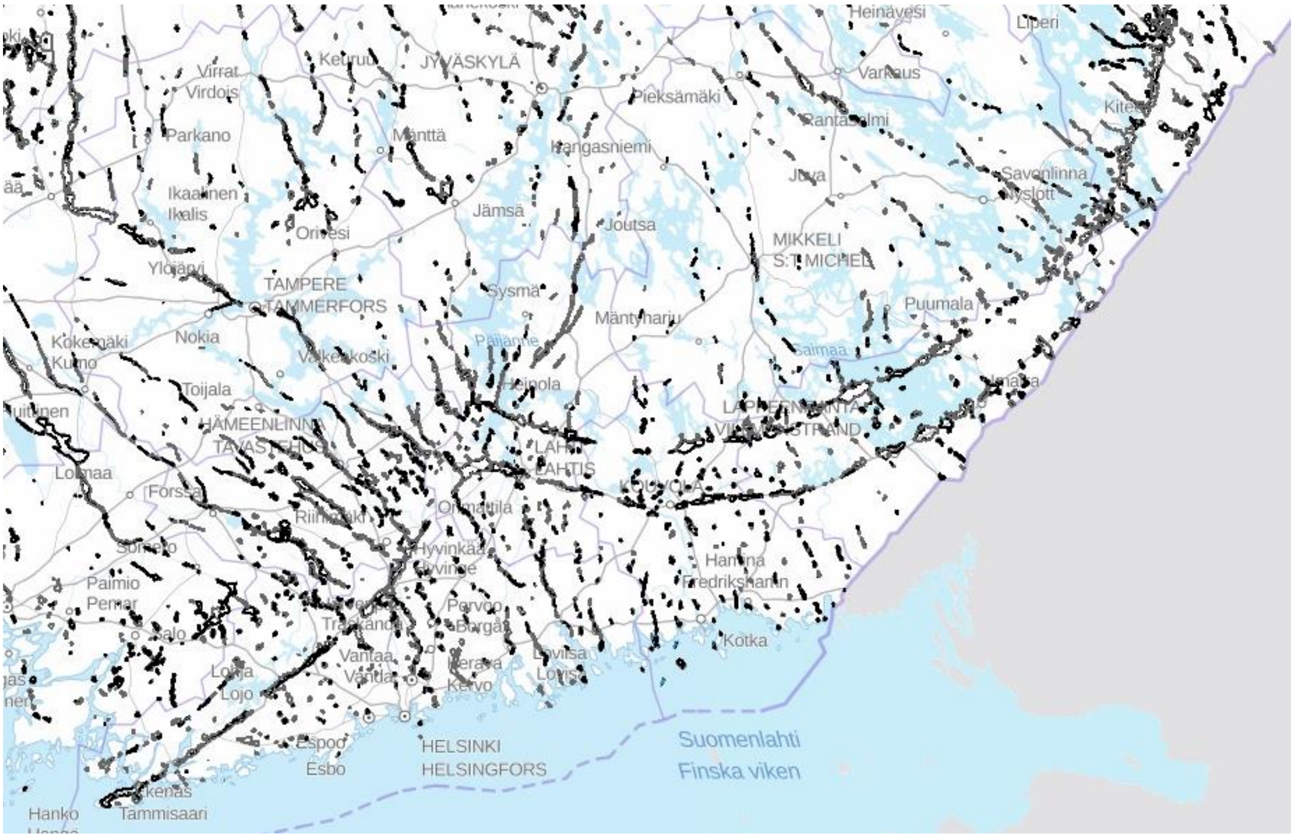


FIGURE 14. Groundwater areas of Southern Finland (National land survey of Finland 2019).

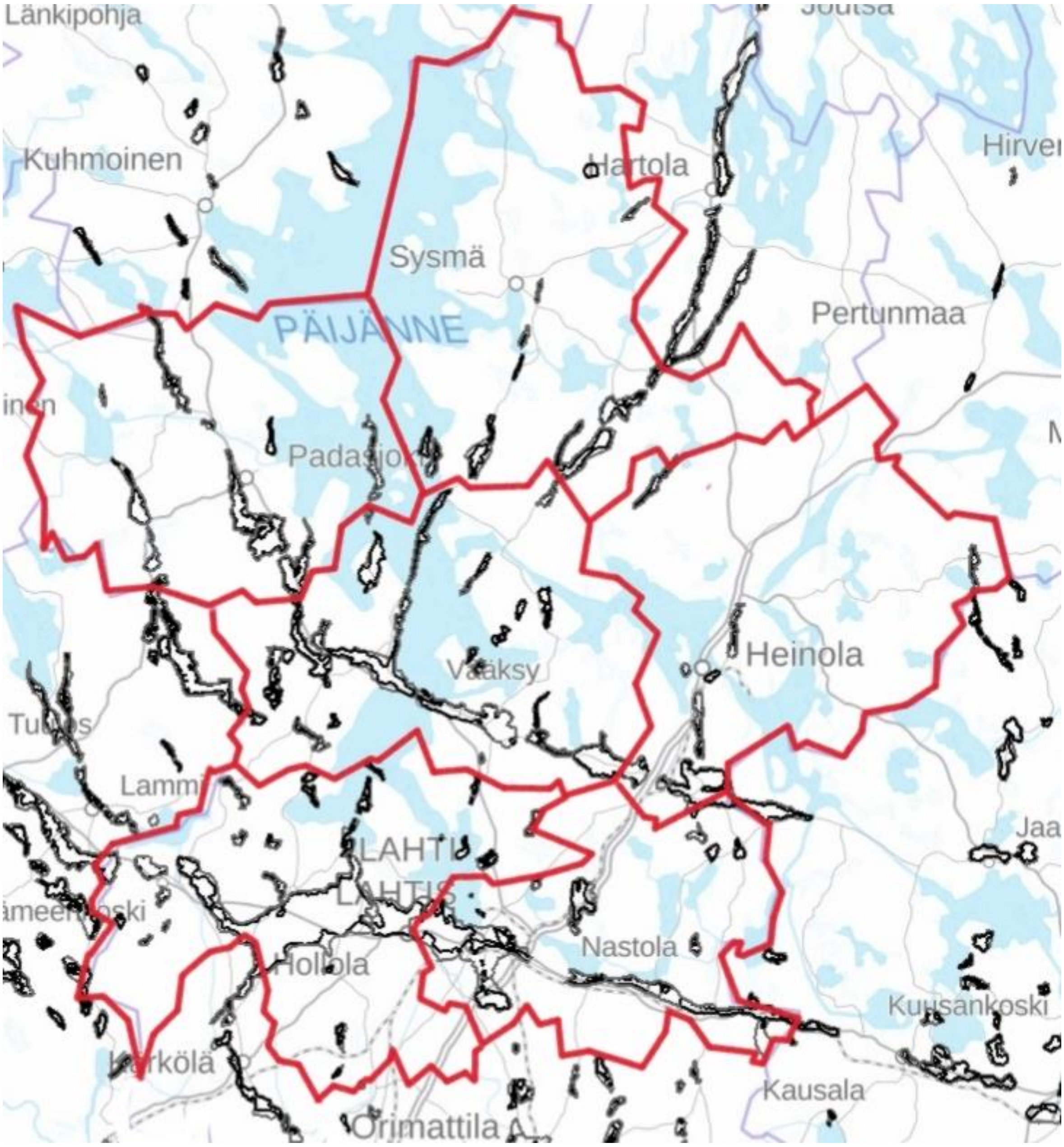


FIGURE 15. Groundwater areas situated in Salpausselkä geopark

5.1 Hydrological circulation

Rainfall and melt waters enter the hydrologic system, and then infiltrates into the subsurface to form groundwater or runs to surface waters. The amount of water penetrating the soil depends on many variables; the intensity of rainfall or irrigation, how permeable and moist soil is. The features, shapes, inclination and topography of the landscape also affect the amount of run-off. Tight and impervious surfaces, such as buildings, roads, parking areas, bedrock, compacted soils, slow down water penetration and thus contribute to drainage. When the water runs in the lakes, the heaviest water falls deeper into the lake, closer to the bottom of the lake, while the surface water tends to follow the air temperature. In winter the water temperature rises to the bottom and in summer the water temperature rises to the surface of the lake. Water can leave the system through stream flow or run-off, evaporate from the lakes back into the air or evaporate from the soil to surfaces or transpire from plants and leaves. (Cornell University 2019.)

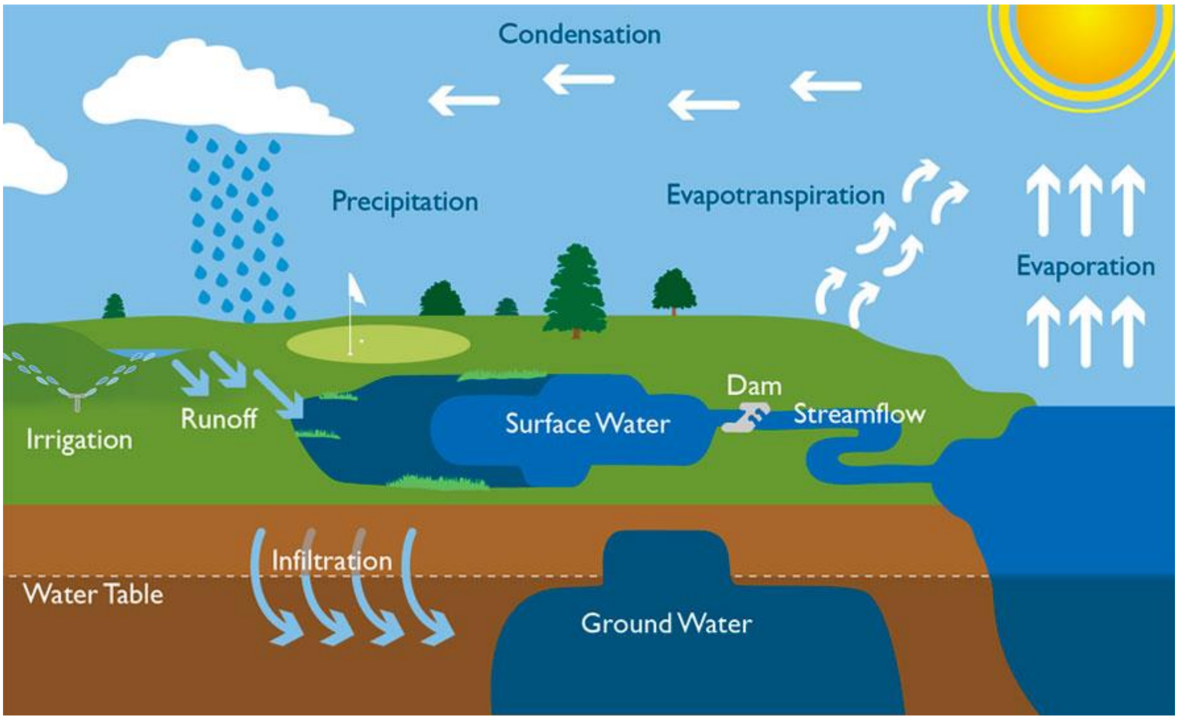


FIGURE 16. Water circulation (Cornell University 2019).

5.1.1 Groundwater meets surface water

Groundwater moves in the soil under the influence of gravity. Usually groundwater flows to meet surface water, and not the other way around, but some exceptions may happen. Groundwater meets surface water mainly in dry seasons. During dry seasons, groundwater reservoirs gives most of its water flow to surface water. Groundwater level out fluctuations in surface water flow in lakes and marshes. Surface waters constantly evaporates. In terms of groundwater bodies, a significant role for rainwater is that part of it is complementary to groundwater reserves keeps groundwater in circulation. Some of the rainwater evaporates into the air and some of it flows into the waterways, depending on the water absorption capacity and the absorption capacity of the ground. Groundwater flow rates vary greatly in different formation conditions. In poorly conducting layers, however, with water inlet flow, there are usually a few centimetres of flow rates per day. Under opposite conditions, rising speeds of up to kilometres per day are observed. (Asheesh, Kaipainen & Leiviskä 2015, 11.)

Groundwater naturally flows along the surface of the ground. To calculate the groundwater flow, you can use the so- called Darcy's Law.

$$Q = K \times A \times \frac{(h_1 - h_2)}{L} = K \times A \times J$$

Q= Flow (m^3/s)
K = Hydraulic conductivity (m/s)
A = Acreage
h = piezometric height
L = distance
J = hydraulic gradience

FIGURE 17. Darcy's Law can be used to calculate the groundwater flow speed (Asheesh, Kaipainen & Leiviskä 2015, 18).

Seasons affect the water cycle, and how the water levels meet. In the Spring, the water temperature slowly rises. After the Winter, the surface water temperature has been close to zero degrees Celsius. As the water temperature rises, the total water mass of the lake is finally +4 degrees Celsius. In this case, a full-blown overturn occurs under the influence of wind. In full overturn, the water mass is completely mixed. Oxygen rich water is transported to the bottom and the nutrient rich water of the bottom is transported to the surface. The phytoplankton increases and the zooplankton also increases with a slight delay. (Finnish Biology Book 2019).

In the Summer, the water temperature rises, and the coolest water is on the bottom. Since the sun heats water surface unevenly, layers of different temperatures are formed in the water. The surface temperature is closer to +20 degrees Celsius, and a bit deeper is a zone to which the solar thermal energy is hardly affected. In this zone, the water temperature quickly becomes colder. The change may be more than ten degrees Centigrade. Methalimnion divides the water column into two parts that do not mix with each other. Thus, no nutrients are transferred from the bottom to the surface water and oxygen is not transferred from the surface to the bottom. Lake production is at its highest. Often, production is limited by the amount of light or nutrients. (Finnish Biology Book 2019).

In the Autumn, the water temperature starts to fall again. Eventually it has cooled down to +4 degrees Celsius, in which case a full overturn takes place. In this case, groundwater gets an important oxygen supplement. Some years, due to weak winds and rapid cooling, the full overturn in the Autumn may not occur. This is often harmful to the lake. (Finnish Biology Book 2019).

5.2 Water security

Nature has a unique central role in regulating the various characteristics of the water cycle. Maintaining healthy ecosystems directly leads to improved safety. According to the United Nations world water development report 2018, the three important global water management goals are improving water availability, improving water quality and reducing water risks. (UNESCO 2018.)

Water risks are caused by a number of causes and consequences. Some of them are, insufficient water resources to meet the basic needs of people, the consequences of insufficient water resources, such as higher energy prices, political and economic instability, migration, and poor water management. (Orr, Cartwright & Tickner 2009.)

Water scarcity normally arises due to a complex interaction of multiple factors, such as social, economic and environmental factors. Achieving these goals requires the creation of a climate for change, including appropriate legal frameworks, appropriate funding mecha-nisms and social acceptance. Without water there would be no life, and without pure drinking water there is no human life, therefore the water security is so essential. Lack of access to adequate drinking water is one of the largest reasons to global health problems. 98 percent of the Earth frozen freshwater is groundwater. Globally, the use of groundwater has increased significantly over the past 50 years. Not only is groundwater essential for human health, it is the basis of food security and the preservation of ecosystems. To achieve water security, mitigate floods and droughts, ensure access to services and manage water resources, vulnerable water systems must be protected. UNESCO's International Hydrological Programme, is a scientific knowledge base to help countries manage water resources in a sustainable way, raise environmental awareness and to develope water management capabilities. The eighth phase of the international hydrological programme is currently underway and will last until 2021. (UNESCO 2019.)

5.2.1 Guidelines for groundwater protection in Finland

The water protection measures, such as identifying the states of the water bodies and monitoring the water quality, began to develope in the early 1960s, when the Water Act and the Water Decree came into force in April 1962. Also, studying the state of polluted water bodies and the extent effects of pollutants, began in different parts of Finland. (Penttinen & Niinimäki 2010, 146).

The main objective of groundwater protection is to preserve unspoilt land and prevent human activities from undermining groundwater quality. The quality of groundwater in Finland is mainly good and groundwater can usually be used without water treatment. However, groundwater bodies in Finland are susceptible to contamination because the soil is generally porous and highly water-conducting. Groundwater is rainwater that has been absorbed through various soil layers or flowed into bedrock slits until it has encountered an impermeable barrier such as a dense clay layer or solid bedrock. From this, the water has continued its journey horizontally until it has filled the free space above the dense ground layer. Groundwater around the surface of the aquifer can be connected to a pond, for example. If more groundwater is used than it is formed, the groundwater level decreases and the pond can dry. The amount of groundwater can also be reduced by drought in addition to its abundant use and soil modification. In Finland, the groundwater level is at its highest during snow melting and Autumn rains, and at its lowest in winter, when the water is frost and snow, and in summer when the water evaporation is high. At its source, groundwater can use rivers and lakes, and it can even fall into the sea. All in all, groundwater is the ideal water reservoir, as the exit from underground storage is naturally very slow (Krämer 2009, 50-51).

The Finnish Environment Institute has set guidelines for the protection of groundwater. The guidelines are intended as a tool for companies, authorities, consultants and applicants who help protect groundwater. The instructions consist of hydrological data and management, modeling and monitoring of groundwater flow and material transfer data. The checklist allows the operator to know what groundwater data is needed and which research methods can reliably identify the data. At the same time, groundwater surveys can be compiled and presented in a comprehensive and comprehensive manner, documenting the methods used, marking responsible families, future needs and schedules (Finland’s environmental administration 2019).

5.2.2 The groundwater classification

The mapping and classification of groundwater areas play a key role in both water supply and groundwater protection. The aim of the classification and refinement of groundwater areas has been to increase knowledge of the location of groundwater areas, groundwater flow conditions, groundwater quality and utility for water supply. In addition to the existing groundwater areas in the municipalities, efforts have also been made to identify other water bodies suitable for water supply. At the same time, information has been gathered on the current use of water in the regions, land use and threats to groundwater. In the mapping and classification of groundwater areas, the areas are classified according to their water supply utility and need for protection. Groundwater mapping and classification are also important for groundwater protection, to find out where country's most valuable and at the same time the most sensitive groundwater resources are and how to target the country's conservation activities. (Britschgi et al. 2009, 10- 13.)

The groundwater in Finland is classified according to the utility of the water supply and the need for protection in different categories (I-III). Classification changed in 2016.

Category I

An important groundwater for water supply, which is used or intended to be used by the community for water supply or as drinking water for more than an average of 10 m3 / day or for more than 50 people (Finnish Environment Institute 2018b).

Category II

Category II area is suitable for watersupply but is not currently used for it. However, this class of groundwater areas is equated with areas important for water supply, the need for protection is not so acute as in Classification I areas. There may be future use in the Category II water supply area, and it is therefore good to recognise the importance of it, for example in land use planning (Finnish Environment Institute 2018b).

Category III

Category III includes all areas with recoverable groundwater found to be capable of being cleaned. If the class III groundwater area is found to be suitable for water procurement, the area may be moved to category I or II. Class III complies with the Water Act and other groundwater protection regulations. Areas found to be unsuitable for water supply are mainly protected for private water supply (Finnish Environment Institute 2018b).

5.2.3 European Union Directives for groundwater protection

Improving water quality and security is a critical element of the European 2030 Sustainable Development Goals. Challenges such as, climate change, population growth, urbanisation, stormwater treatment and more stringent water quality standards, place demands on existing systems. Water treatment infrastructure requires significant finances in order to prevent waterrelated disease outbreaks. As groundwater is a valuable natural resource, etrimental concentrations of harmful pollutants in groundwater must be avoided, prevented or reduced. (European Commission 2019a).

The objective of the EU Water Frame-work Directive (2000/60 EC) is to promote sustainable use of water resources, to prevent groundwater pollution and to reduce existing pollution. By promoting the sustainable use of water resources, preventing groundwater pollution and reducing existing pollution, the aim is to achieve good quantitative and chemical status of groundwater. The Floods Directive relates to Flood Risk Management, and in particular to Flood Risk Management Plans and River Basin Management Plans, to the long-term development and sustainability of the flood risk management cycle. (European Commission 2019b).

5.3 The short history of groundwater pollution in Finland

People in Finland have intervened in the state of the lakes in several ways, during the past 300 years.

Finnish lakes are naturally shallow, and in the 17th Century draining of the lakes started. The reason was mud and clay on the bottom of the lakes, that were good for heinänviljely. More than 3000 lakes were drained in partly or fully. During the 1950s, when the industry started to increase, use of fertilisation became more common and the agricultural production methods intensified. The major causes for rapid deterioration in the status of the lakes in the second half of the 1900s were concentration of population, deficiencies in wastewater treatment and the sharp increase in the use of fertilisers (Finnish Environment Institute 2013).

The 1867 agricultural crisis caused the need to add arable fields. The surface of the lakes began to be lowered in order to get more farmland. After the Second World War, lake recessions became more widespread when new agricultural land was needed to settle immigrants from lost areas. It was not known at that time that the reduction in water depth and volume could expose the calculated lakes to increased aquatic vegetation, oxygen problems and internal load. (Centre for Economic Development, Transport and the Environment 2017.)

The first restoration measures were performed in the 1950s by raising the surface of the underwater, dredging, oxidizing, removing the vegetation and nursing. In the early 1960s, water legislation was amended to promote water protection, and water quality monitoring was initiated in all major water systems. The most commonly used methods were aeration, removal of aquatic plants and raising the water level in the 1960s and 1970s. (Lakso & Ulvi 2005, 9-11.)

During the 1970s and 1980s the knowledge of enhanced water protection increased, so the point source pollution caused by residential wastewater and industry decreased strongly. In the 1980s, more extensive restoration projects started, for example the Lake Vesijärvi Project in Lahti in 1987. In the end of the 1980s, around 500 lakes needed immediate remediation, but funding was difficult to find because the Government directed the renovation funds to only a few new destinations every year. The Finnish Government had participated in 250 projects and used about 150 million marks in the years by the year 1987. In the 1990s lake restoration and protection got more attention, which led to that sanitation was improved in sparsely populated areas and water protection methods in agriculture were developed. Restoration work was done in about 500 lakes. (Finnish Environment Institute 2013).

Fortunately, catastrophes are rare in Finland, but this is illustrated by an accident at Nokia in 2007, when 450 cubic meters of wastewater was discharged into the water supply network via a wastewater treatment plant’s open valve. 10,000 people lived in the contaminated area, and more than a fifth of them suffered from stomach disease caused by campylobacter and norovirus. Drinking water was a part of the operating ban for almost three months. Municipalities have an important role to play in water supply, as water supply and distribution, sanitation and waste water treatment, development and organisation are the responsibility of the municipality. Water supply agencies are responsible for the practical organisation of water supply in their area of operation. Property owners are responsible for the water supply of their property. The quality of household water is monitored by municipal health authorities. Regional Environmental Centers are responsible for monitoring water management, planning control and directing financial support in their regions (Krämer 2009, 58).

When there were fewer people, it might have seemed natural to throw waste into the water. Especially if the waste dissolved in water, the problem was thought to be lost. However, dissolving does not destroy the substances, and can cause damage to the environment and humans even when dissolved in water (Pursinainen, Lajunen, Hohtola & Peltomäki 2014, 105.)

5.3.1 Groundwater pollution factors and causes

Road salting may increase the groundwater chloride concentration locally. Increaing the chloride content is not a health risk but may increase water corrosion. This, in turn, may increase the concentration of metals in tap water when metals are dissolved in water from tap water materials. Mining changes the chemical quality of groundwater in the actual mining area. Impacts outside the mining area may not extend far. However, there is reason to monitor the quality of the wells in the nearby area. A bedrock suitable for mining is inherently abnormal. That is why ore is mined. Thus, the chemical quality of groundwater may be different from normal mining. Chemical accidents, such as the overflow of a transport trolley and the leakage of substances from the transport containers to the ground, may present a risk of substances entering groundwater. The situation is serious if the accident occurs in the groundwater catchment area. Mostly, the spilled material and the soil it has spoiled can be removed quickly, and no bigger damage can occur. In the 1970s, lakes and rivers were used as sewers with wastewater. (Lakso& Ulvi 2005, 9-11.)

Other things that can harm groundwater are petrol stations and other places that store fuel oil, where possible accidents and leaks may happen. Risky areas such as contaminadet lands, airports, old rail yards and depots, chemical laundries, and landfills have the possibility of the wastewater to absorb into soil (Finnish Environment Institute 2014b).

5.3.2 Pesticides

Pesticides are used to kill humanly harmful microbes, plants and animals. Over 20 000 pesticides have been registered in the world. There are small amounts of pesticides in food, water, homes, gardens and more or less in the nature. Most common pesticides are insecticides, used for insects and herbicides, used for plants. In addition to these, there are fungicides for controlling molds and fungi, and rodenticides for gnawer control. (Koulu, Mervaala & Tuomisto 2012, 1167.)

5.3.3 Drug residues in drinking water

Medicines are an example of water chemicalization because they are used abundantly and most of them are water-soluble, so they also easily pass through the body and eventually to the environment. Drug residues in water have also become a challenge in Finland. Hundreds of kilograms of drug residues reach the municipal waste water every year in Finland. Particularly high concentrations of paracetamol are found in wastewater from treatment facilities. Paracetamol is used in anti-inflammatory drugs. The amount have been even 3000 kilograms of Paracetamol in the water per year. The purpose of the new research project is to find out whether it is more advantageous to clean the drug residues at their source than the sludge and drinking water from the municipal treatment plant. Although wastewater treatment works in Finland, municipal wastewater treatment plants have been built to remove solid, organic matter, phosphorus and nitrogen from waste water. According to a study by the University of Helsinki, they are currently unable to handle synthetic organic compounds such as drugs (Helsinki Region Environmental Services Authority 2017).

Much of the drugs that end up in the refinery will flow into the water and bind to the slurry. Drinking water may be produced from the water, and the slurry may, in turn, end up as a soil conditioner. Finnish legislation does not have any removal requirements for the residues of wastewater. However, the EU obliges its member states to monitor diclofenac, an antibiotic, as well as certain other antibiotics and female hormones from the aquatic environment. In 2015–2016, significant concentrations of surface water, such as female hormones and diclofenac, were observed. (Törmänen, 2017.)

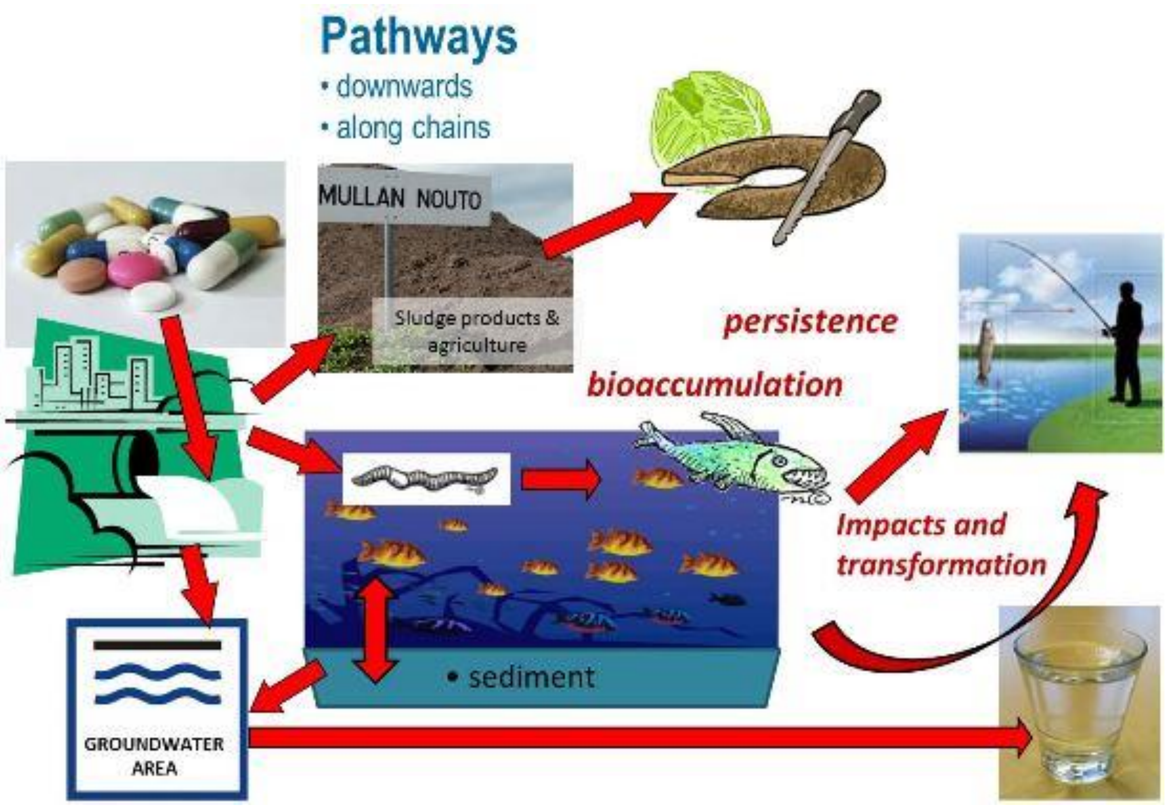


FIGURE 18. How drugs end up in the drinking water and in the human body (Finnish Environment Institute 2019).

The use of medicines has increased since the 1960s in Finland. The most common causes of growth are demographic change, ageing population, longer life expectancy, increased health services and the intensification of the international pharmaceutical industry, which provide new drugs for different symptoms. (Koulu, Mervaala & Tuomisto 2012, 1099.)

5.4 Sustainable use of groundwater

5.4.1 Water consumption habits

Ground water is cleaned to make it drinkable to the residents. The same water is used for washing, laundry and dishwashing, cooking, watering the yards, washing cars and much much more daily rutines. Water is circulating around the dwellings and businesses back into the sewer system, and it will again become waste water.

Metropolitan area residents and companies produce waste water about one hundred million cubic meters a year. Wastewater passes through the sewer system to sewage treatment plants. Waste water treatment requires mechanical, chemical and biological methods. They allow waste water to remove debris and most of the organic matter, nitrogen and phosphorus. There are two wastewater treatment plants in the Helsinki Metropolitan Area, in Viikinmäki, Helsinki and in Espoo, Finland. The treatment plants treat wastewater with over one million inhabitants and industrial waste water (Helsinki Region Environmental Services Authority 2017).

Wastewater treatment is an important part of coastal waters and the Baltic Sea. The wastewater is cleaned from phosphorus and nitrogen contaminants, which, when discharged directly into the sea, would cause severe eutrophication (Helsinki Region Environmental Services Authority 2018).

There are significant groundwater resources in Päijät- Häme, but many companies, transport and centers are mainly located on groundwater areas. In the Salpausselkä geopark area, the centre of Asikkala and Kärköla is located a lot of working places, and at the same time there is an important groundwater area. Päijät-Häme's companies net sales have been Finland's tenth largest in 2014, and about 14 000 work places in the whole area (FCG 2019, 9-12).

TABLE 5. The employment situation and structure in Päijät- Häme (FCG 2019, 10-11).

Municipality	**Amount of work places**	**Amount of workers**	**Industry**	**Primary production**	**Logistics and storage**
Asikkala	788	1 338	22 %	10 %	4 %
Heinola	1 228	4 392	27 %	2 %	4 %
Hollola	1 609	3 801	20 %	7 %	7 %
Lahti	6 911	31 674	17 %	1 %	5 %
Padasjoki	314	440	12%	13 %	4 %
Sysmä	458	602	5 %	11 %	5 %

There are a number of factors that influence the conditions for locating a company in a groundwater area. The nature of the operation and the likelihood of pollution and the risk of accident must be taken into account and it must be ensured that any accident at the plant does not cause groundwater contamination. Depending on the type of the business, the quantity and quality of chemicals to be handled and stored must be taken into account, the structural and operational solutions implemented at the plant, the soil quality of the area and the hydrological conditions. Preventive action is of paramount importance, such as the need for operational transport and related damage and accident prevention. The operator must ensure that the planned operation is in accordance with the intended use of the area and that the operation can also be carried out in accordance with the formula. (Ministry of the Environment 2013.)

5.4.2 Environmental planning in groundwater protection

In land use planning, it is important to recognise what is meant by groundwater area, where are the boundaries, and to recognize the difference between groundwater and groundwater formation areas. The boundaries of the groundwater area play a role in water abstraction, as well as the location of risky activities.

All sectors and activities have no direct impact on groundwater, but indirect impacts can, for example, be found in logistics and transport. Groundwater is particularly vulnerable to industrial sectors, the transport, storage and use of hazardous substances, anti-skid roads and airports, agriculture and forestry, contaminated land, soil extraction and waste water. Preventive actions are important because cleaning up contaminated groundwater is extremely difficult and costly. The primary objective for protection against groundwater damage is to eliminate or remove risks from the area. If risks cannot be eliminated, they need to be minimized, for example by protecting and improving their preparedness to prevent damage. Risk reduction can be influenced by supervision and information. Environmental planning is also important. Protection plans and their updating are especially needed for risk areas and poor groundwater areas. The risk management measures outlined in the conservation plans must be implemented in order to reduce risks and ensure that good quality natural water can be safeguarded in the future. (Ministry of the Environment 2013.)

5.4.3 Structural study on groundwater

The average groundwater level in Finland is about 2 to 4 meters, but the variation is high. In the ridge areas, the ground layer covering the groundwater can be up to tens of meters (Oijala 2016, 16). Ridges are the most important structural formations made by ice age. The groundwater level is often easily accessible at the edges of the ridges. There are three types of ridges; longitudinal ridges, transverse ridges and moraine- shaped formations.

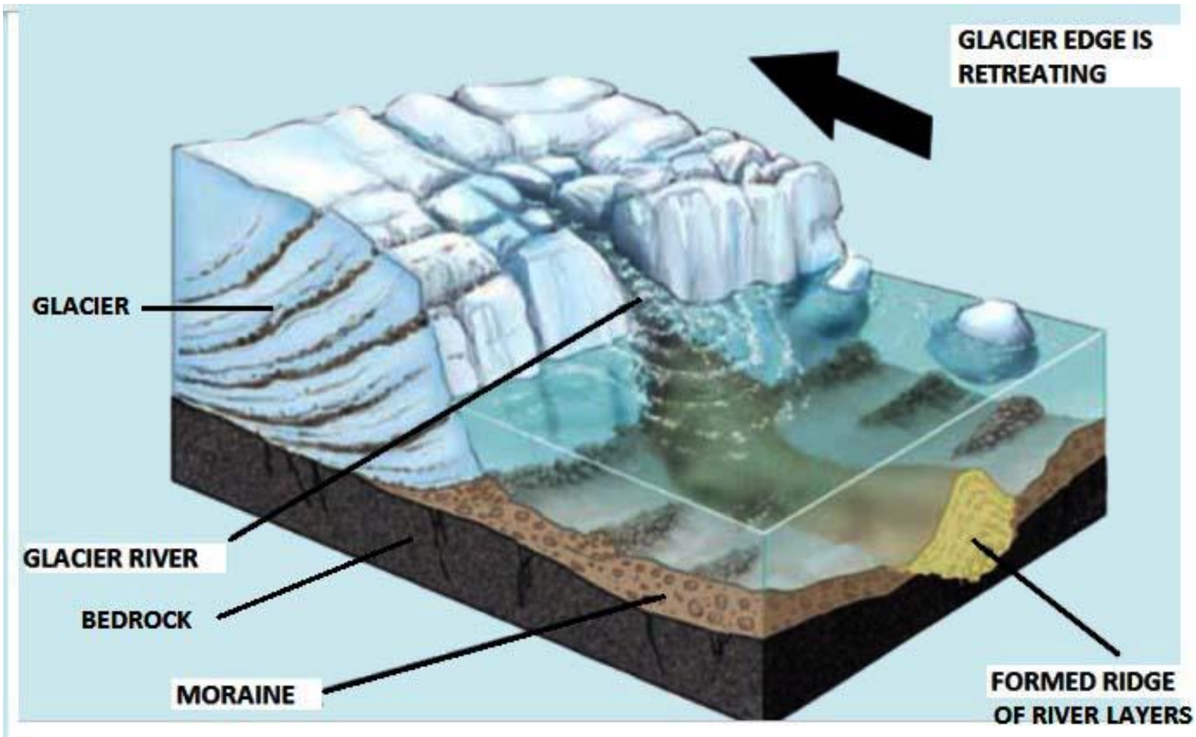


FIGURE 19. Ridge formed by the ice age to the river base (Kutvonen 2015).

TABLE 6. The amount of the rainwater absorbed into groundwater, with different soil types (Asheesh, Kaipainen & Leiviskä 2015, 10.)

Sandy land	60 – 70 %
Harsh Moraine formations	50 %
Peat lands	30 – 40 % (but peat absorbs 80-90%)
Moraine land	10 – 20 %
Cohesion lands (clay, silt, sludge)	<10 - (even negative) %

5.4.4 Aquifers

95% of Finland's groundwater resources are located in aquifers. Aquifers are generally located in Salpausselkä ridges and terminal moraines. There is three types of aquifers in Finland:

Free aquifer

The surface of the free aquifer is not limited to the water-permeable layer, and the surface pressure corresponds to atmospheric pressure. (Asheesh, Kaipainen & Leiviskä 2015, 14.)

Pressurised aquifer

The pressurized aquifer is limited to water-impermeable layers above and below it. It is “pressured between” those layers, which makes its surface pressure to be higher than atmospheric pressure. (Asheesh, Kaipainen & Leiviskä 2015, 14.)

Bedrock aquifer

The bedrock aquifers are associated with the bedrock break zones. Their yield is a few hundred cubic meters a year (Asheesh, Kaipainen & Leiviskä 2015, 14).

Groundwater deposits are separated at groundwater boundaries. Groundwater surface levels rise in different directions across the groundwater limit. The slope depends on the conductivity of the water and the flow of the ground layers. The weaker the ground layer is, the steeper the slope. There may be several aquifers in the same groundwater reservoir that are interconnected. (Asheesh, Kaipainen & Leiviskä 2015, 15.)

5.4.5 Groundwater treatment plants

Päijänne's groundwater is said to be drinkable as such without further purification. The natural water coming from Päijänne is treated in the Pitkäkoski and Vanhakaupunki water treatment plants in Helsinki. The cleaning process is similar in both plants, and both are pumping water to consumers. The water runs along the Päijänne tunnel, through the fresh water treatment plants, to the consumers for about in ten days. (Helsinki Region Environmental Services Authority 2015.)

When fresh water arrives to treatment plants it is still full of organic matter. Most organic matter is removed in the first stage of water treatment. The first part of the cleaning process is to remove sediments from the water. Ferrous sulphate is added to the water to lower the pH of the water. The resulting precipitate is stirred, and ferrous sulphate causes the size of the sediment particles to increase as they adhere to each other. The precipitate is separated from the water in clarification basins and sand filters. Before disinfection, the pH of the water is increased with lime water. Ozone is the most important disinfection step. Ozone distroys microbes and improves the smell and taste of water. Subsequently, carbon dioxide is added into the water, to increase the alkalinity of the water and thus reduces corrosion of the pipes. During this step, the ozone in the water is completely gone. After the purification process, the remaining organic material is further removed with two-phased carbon filtration. The water is then disinfected with UV light. Finally, chloramine, is added to the water to limit microbial growth in the distribution network. After the process in the treatment plant, the water pH is still quite low, so it is raised again, with adding lime to the water. Part of the treated water is stored in the water towers. (Helsinki Region Environmental Services Authority 2015.)

Treated water is coldest and thus better maintained in the distribution network in the winter. Most people do not smell or taste small amounts of monochloramine in the drinking water, but some people detect even smallest changes. (Helsinki Region Environmental Services Authority 2019.)

5.4.6 Water hardness

In the Helsinki water treatment plants, water hardness usually varies between 2,7 and 4,5° dH. The more there is calcium and magnesium in the water, the harder the water. (Helsinki Region Environmental Services Authority 2019.)

The hardness of waters interest industry too, because too hard water can damage equipment, pipes and machines. Hard water causes problems, for accumulation of lime deposits in pipelines and hot water devices and requires more abundant use of detergents. On the other hand, too soft water causes corrosion in the pipelines. Water hardness and pH have a relationship with the corrosive properties of water. If the water is soft and its pH is too low, the water will corrode the piping and dissolve the metals in the piping, such as iron. Corrosion, in turn, causes the pipes to thinner and eventually break down. Rusted piping can cause changes of taste and colour to the drinking water. (University of Helsinki 2019.)

5.4.7 Measuring the quality of tapwater

About 50,000 water analyzes annually are taken of the drinking water of Helsinki metropolitan area, at Helsinki Region Environmental Services Authority 's Pitkäkoski laboratory. Environmental health authorities also take own samples of water for analysis. Water samples are taken from dozens of destinations; starting from Asikkalanselkä, along the water supply network. The natural water is studied for the pH, that should be about 8.5, whereby the water is slightly alkaline and does not rust the distribution net pipes. Other important indicator is the bacteria, which are pathogens. In the water of Päijänne these bacteria have not been found at all, or only in the summer time to some extent. The ozonation of the water treatment plant eliminates these pathogens, which is considered to be the most important disinfection step. Ozone is a pungent, colourless gas that is added to water in small gas bubbles. (Helsinki Region Environmental Services Authority 2010.)

5.4.8 Päijänne tunnel

Regular water supply started in Helsinki in 1876, when the Helsinki Water- works was established. Previously, residents were given drinking water from wells around the city. Päijänne tunnel was completed in 1982. All the drinking water in the Helsinki area and part of Central Uusimaa’s comes from Lake Päijänne. It provides access to natural water for over one million inhabitants. The world's longest rock tunnel starts from Asikkalanselkä and runs at a depth of 30 to 100 meters from the ground. The length of the tunnel is 120 kilometres. Tunnel is so high, that a truck fits to drive along it. It takes 10 days for the water to get from the lake Päijänne to the consumers, throught the treatment plant. (Helsinki Region Environmental Services Authority 2018.)

PICTURE 6. A picture from Päijänne tunnel and water pipes (Sundqvist 2016).

FIGURE 20. The 120 kilometres long tunnel from Asikkalanselkä to Helsinki (Seppälä 2008).

6 FUTURE CHALLENGES OF NATURAL WATER PROTECTION

Today, the importance of Salpausselkä is more widely understood, especially because of its groundwater resources. Groundwater protection is one of the key principles of the region. Salting of roads has decreased and the locations of fuel sales have been removed from the main groundwater areas. There are requirements for many chemicals, such as a geothermal refrigerator.

6.1 Climate change

Climate change affects the nature, and through the nature, and is one of the most important challenges of the future. It affects to economy and human health differently across the globe. Although Helsinki's tap water was rated as the best in the world, in an international comparison ten years ago, accelerating climate change is creating pressure to maintain water quality.

Changes in the environmental conditions in Finland, has already happened, due to climate change. Before the year 2000, there has been no situation in which the lake would not freeze before the end of the year. The shortest ice cover over a hundred years was in the winter of 2014. The same year was exceptionally dry, especially the Spring and Autumn. The river flows were the smallest in the Autumn, which is really rare. According to forecasts, the change in Finland is higher than the average in the world, annual precipitation will increase 13 to 26 percent and temperatures will rise 2 to 6 degrees Centrigrade by the end of the century. The change is predicted to be higher in the winter than in the summer, which will increase the stormwater runoff in the Autumn and Winter. Changes can increase the leaching of disease-causing microbes into Finnish waters. With the growing season in agriculture, more efficient agriculture increases emissions. However, the hygienic state of the water can be maintained by improving the treatment of wastewater in wastewatertreatment plants. Climate change threatens water protection as it increases water load. Of course, climate change can have some positive effects, for example on the oxygen economy of lakes, when the ice- covered time is shorter. (Keskitalo 2017, 75.)

6.2 Euthropication

The period from 1981 to 2010 was statistically warm, due to climate change. Climate change affects the power relations of fish species. In addition to the warmth of the water, oxygen, acidity and nutrient content are important attributes to fish, all of which affect their actions. A large lake like Lake Päijänne does not overgrow easily, but eutrophication is still a risk in the lower shores. Agriculture, forestry, peat production and many other human activities increase the amount of nutrients in the natural waters. Because of these activities, algae growth ruptures, water becomes cloudy, and oxygen conditions deteriorate. In high-nutrient and warm water, plankton grows wildly, and when it breaks down, it consumes the oxygen. Algae blooms can also temporarily raise the pH of the water to fish threatening levels. Poor oxygen conditions are detrimental to fish that no longer find proper breeding sites. (Remes 2011.)

6.3 Water resources

The scarcity of water resources, the depletion of groundwater and the deterioration of natural waters are global problems. Finland is in a good position, there is no shortage of fresh water, but that does not mean that there is no need to worry about the protection of natural waters and the quality of drinking water. Even in the past, even in the early 2000s, the condition of southern Päijänne was poor (Keskitalo 2017, 9). Further, eutrophication and oxygen depletion are a latent threat that needs to be kept under control by continuous monitoring of lakes, especially as the future use of water resources increases.

The largest consumers of groundwater are agriculture, industry and the household. Water consumption, especially plant irrigation, has caused the groundwater level to fall in most parts of the world (Keskitalo 2017, 108.)

It is important to understand the true meaning and value of water, even if we have enough water. The average Finn consumes about 140 liters of water a day. At this point, a geopark and ecotourism may have a great opportunity to influence and educate.

7 CONCLUSIONS AND DISCUSSION

Originally, I was interested in this research, specifically my background as an environmental consultant. One part of my work has been to take soil and water samples, and to some extent to analyze the samples I took, with field studies. Fortunately, water research is highly advanced, and monitoring the drinking water status with laboratory tests is easy and efficient. In this thesis I have been studying the importance of water management, water resources and the devastating results of human activity and climate change to our groundwaters. Salpausselkä belongs to Finland's most abundant water resource area, and the water supply in the region almost completely depends on groundwater resources. Although natural water protection has improved and the risks from human activities are reduced, and better acknowledged, some of the groundwater areas have unfortunately been damaged before, due to chemicals in soil that have mixed with groundwater. Restoration process is often expensive and takes a lot of time and effort.

Groundwater is the largest freshwater reservoir and resource of mankind. Global population growth increase the demand for fresh natural water. Water consumption caused by population growth and industrialization, the deterioration of the state of environment and the complex effects of climate change, urgently demand new ways to manage precious freshwater resources. It is crucial to understand the sensitivity of groundwater pollution and the measures taken to mitigate potential contamination. Tourism puts its own burden on the environment, but if the ecotourism grows, the state of the lake and the surrounding nature will not be burdened as much. As geo- and ecotourism are emerging as a new trend, Salpausselkä geopark would have the opportunity to educate people about valuable natural resourves, with the help of ecotourism. Salpausselkä geopark could demonstrate ways and means of developing and improving water protection. More practical ways to protect natural waters should be brought to the attention of people. Information on the significance of natural waters and where to report on activities and other hazards that endanger the quality of groundwater should be brought to public. The status of surface waters can also be easily and quickly visually examinated by anyone.

It is important to identify the possible risk caused by human activities and businesses and take them into account early on. Preventive actions are most important. When planning new areas, should groundwater zone and their edge zones be carefully monitored and researched, before any construction is made.

Groundwater protection is the protection of the surrounding environment, and this is one of the topics, that I think is essential when educating ecotourists at the geopark area. Groundwater contamination has long- lasting consequences. Cleaning up contaminated groundwater is extremely difficult, expensive and requires a lot of time and resources. Finnish groundwater bodies are susceptible to pollution. If groundwater is contaminated, the possibility that surface waters will suffer too, is real, because at some point groundwaters are connected to surface waters. Groundwater pollution is also strictly prohibited by legislation. In order to meet the needs of future generations, geosciences need to work with many other fields of study, to responsibly develope the resources human kind needs. Most importantly, we need to work together to enable future generations to take the resource challenge into account in all areas.

As important as the water as a resource are, the other side of the things, is the environmental hazards such as floods and stormwater management. In addition, tightening the urban structure poses challenges for stormwater management. Lahti stormwater management plan- type of programmes should be put into practice by gathering working groups and experts. Renovation of Lake Vesijärvi shows that, volunteers and people interested in the subject, are very willing to take the lead, in the absence of funding.

One of the advantages of geoparks, is that it brings together scientists, experts and actors that can influence the state of the lakes. Together, they form a community and their role in understanding global change and evaluating local and regional landscapes is important. This community is needed to identify problems, share valuable information and the negative consequences of climate change and usage of non- renewable natural resources.

There is a strong regional identity in the Salpausselkä area, which has a natural, historical, cultural and educational value. The clear waters and rich biodiversity of Lake Päijänne and Lake Vesijärvi represent examples of valuable geological heritage, which emphasises the importance of understanding and thereby protecting the natural environment for future generations.

8 REFERENCES

Literature references

Caldecott, J. 2009. Vesi: Maailmanlaajuisen kriisin syyt, seuraukset ja kustannukset. Helsinki: HS Kirjat.

Hakala, H. 2017. Päijät- Häme. Mieli-maku-maisema. Lahti: Päijät- Hämeen liitto.

Keskitalo, J. 2017. Rajaton vesi, rajalliset vesivarat. Tallinna: Gaudeamus Oy.

Koulu M., Mervaala, E. & Tuomisto, J. 2012. Farmakologia ja toksikologia. Kuopio: Kustannusosakeyhtiö Medicina Oy.

Krämer, T. 2009. Välttämätön vesi. Hyvinvointi- luonto- tulevaisuus. Jyväskylä: Minerva kustannus Oy.

Muranen, L. 2007. Päijännettä pitkin - ensimmäiset höyrylaivat ja uiton alkuvaiheet Päijänteellä. Tampere: Pilot-kustannus.

Mälkki, E. 1999. Pohjavesi ja pohjaveden ympäristö. Helsinki: Kustannusosakeyhtiö Tammi.

Oijala, M. 2016. Kaikkien aikojen Salpausselkä. Lahti: Päijät-Hämeen Tutkimusseura.

Penttinen, K. & Niinimäki, J. 2010. Vesiensuojelun perusteet ja vesistöjen kunnostus. Helsinki: Opetushallitus.

Pursiainen, J., Lajunen L., Hohtola, E. & Peltomäki, J. 2014. Kaiken takana onkin vesi. Tietokirja vedestä. Jyväskylä: Docendo.

Rönkä, M. & Walls, M. 2004. Veden varassa. Suomen vesiluonnon monimuotoisuus. Helsinki: Edita.

Online references

Alo, B.T. 2018. Classification of Bodies of Water. Different types of water bodies. [Accessed 9.5.2019] Available at: https://sciencing.com/classification-bodies-water-6391647.html

Asheesh, M., Kaipainen, T., Leiviskä, P. 2015. Pohjavesi. Suomen maaperä. Oulun ammattikorkeakoulu. [Accessed 8.5.2019] Available at: https://slideplayer.com/slide/11638246/

Britschgi, R., Rintala, J., Puharinen, S-T. 2018. Pohjavesialueet – opas määrittämiseen, luokitukseen ja suojelusuunnitelmien laadintaan. Ympäristöhallinnon ohjeita 3/2018. Ympäristöministeriö. Helsinki. [Accessed 8.5.2019]. Available at: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161164/OH_3_2018_Pohjavesialueet_opas_nettiin.pdf?sequence=1&isAllowed=y

Centre for Economic Development, Transport and the Environment. 2017. Euroopan Maaseuturahasto. [Accessed 15.4.2019] Available at: http://www.ely-keskus.fi/web/ely/euroopan-maaseuturahasto

Centre for Economic Development, Transport and the Environment. 2017. Pohjois-Savon vesistöt ennen ja nyt. [Accessed at 16.6.2019] Available at: https://www.ely-keskus.fi/web/pohjois-savon-vesistot-ennen-ja-nyt/jarven-laskut-ja-vesistojen-saannostely

Cornell University. 2019. Hydrologic cycle. [Accessed 8.4.2019] Available at: http://nysgolfbmp.cals.cornell.edu/hydrologic-cycle/

European Commission. 2019a. The Sustainable Development Goals. [Accessed 16.6.2019] Available at: https://ec.europa.eu/europeaid/policies/sustainable-development-goals_en

European Commission. 2019. The EU Flood directive. [Accessed 16.6.2019] Available: http://ec.europa.eu/environment/water/flood_risk/implem.htm

European Environment Agency. 2015a. Diffuse Pollution, Degraded WatersEmerging Policy Solutions. [Accessed 8.5.2019] Available at: https://www.oecd.org/environment/resources/Diffuse-Pollution-Degraded-Waters-Policy-Highlights.pdf

European Environment Agency. 2015b. Eutrophication. [Accessed 8.4.2019] Available at: https://www.eea.europa.eu/archived/archived-content-water-topic/wise-help-centre/glossary-definitions/eutrophication

European Environment Agency 2015c. Urban waste water treatment. [Accessed 30.3.2019] Available at: https://www.eea.europa.eu/data-and-maps/indicators/urban-waste-water-treatment/urban-waste-water-treatment-assessment-4

European Geoparks. 2019. What is a Geopark. [Referred to 20.3.2019]. Available at: http://www.europeangeoparks.org/?page_id=165

European parliament. 2018. Mikromuovit: lähteet, haitat ja EU:n ratkaisut. [Accessed 21.3.2019] Available at: http://www.europarl.europa.eu/news/fi/headlines/society/20181116STO19217/mikromuovit-lahteet-haitat-ja-eu-n-ratkaisut

FCG. 2019. Päijät- Hämeen työpaikat. Selvitys Päijät-Hämeen elinkeinoelämän alueiden merkittävyydestä. [Accessed 30.4.2019] Available at: http://www.paijat-hame.fi/wp-content/uploads/2019/02/Selvitys-elinkeinoel%C3%A4m%C3%A4n-alueiden-merkitt%C3%A4vyydest%C3%A4.pdf

Finland's environmental administration. 2014. Päijänteen hydrologia ja sen mittaaminen. [Accessed 1.5.2019] Available: at https://www.ymparisto.fi/fi-FI/Vesi/Vesien_kaytto/Saannostely/Saannostellyt_jarvet_ja_joet/Paijanteen_hydrologia_ja_sen_mittaaminen(18622)

Finland's environmental administration. 2015. Protection of waters. [Accessed 2.5.2019] Available at: https://www.ymparisto.fi/en-US/Waters/Protection_of_waters

Finland's environmental administration. 2018. Pohjavesialueet. [Accessed 14.6.2019] Available at: https://www.ymparisto.fi/fi-FI/Vesi/Vesiensuojelu/Pohjaveden_suojelu/Pohjavesialueet/Pohjavesialueet(26765)

Finland's environmental administration. 2019. Pohjavesien suojelu. [Accessed 1.5.2019] Available at: https://www.ymparisto.fi/pohjavedensuojelu

Finnish Biology Book. 2019. Miten vesiluonto toimii? Vuodenaikojen vaihtelu. [Referred to 8.4.2019]. Available at: https://peda.net/Catalunya/vedet/joki/vv

Finnish Environment Institute. 2014a. Pohjavesialueet- Häme. [Accessed 17.6.2019] Available at: https://www.ymparisto.fi/fi-FI/Vesi/Vesiensuojelu/Pohjaveden_suojelu/Pohjavesialueet/Pohjavesialueet__Hame(28432)

Finnish Environment Insitute. 2014b. Pohjaveden suojelu. Pohjavettä uhkaavat monet ihmisen toimet. [Accessed 8.4.2019] Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=2ahUKEwjW0-2d6cDhAhUpxosKHatzDYkQFjADegQIAxAC&url=https%3A%2F%2Fwww.ymparisto.fi%2Fdownload%2Fnoname%2F%257B51B08DD3-6DEC-40FB-B0EB-C782A5EF4DB8%257D%2F99347&usg=AOvVaw1aKB8BCgI9TaPmj2c76eFl

Finnish Environment Institute. 2016. Pintavesien luokittelun periaatteet. [Accessed 15.6.2019] Available at: https://www.ymparisto.fi/fi-FI/Vesi/Pintavesien_tila/Pintavesien_luokittelu

Finnish Environment Institute. 2017a. Pintavesien tila. [Referred to 16.6.2019] Available at: https://www.ymparisto.fi/fi-FI/Vesi/Pintavesien_tila

Finnish Environment Institute. 2017b. Mikromuovit riski myös Suomen vesistöille. [Accessed 28.5.2019] Available at: https://www.syke.fi/fi-FI/Ajankohtaista/Mikromuovit_riski_myos_Suomen_vesistoill(42492)

Finnish Environment Institute 2018b. [Accessed 28.5.2019] Available at: https://www.ymparisto.fi/fi-FI/Vesi/Vesiensuojelu/Pohjaveden_suojelu/Pohjavesialueet/Pohjavesialueet(26765)

Finnish Environment Institute. 2018a. Blue- green algae in the water are a risk for people and animals. [Accessed 8.5.2019] Available at: https://www.syke.fi/en-US/Current/Bluegreen_algae_in_water_are_a_risk_for_(47443)

Geyer, R., Jambeck, J.R. & Lavender Law, K. 2017. Production, use, and fate of all plastics ever made. Science Advance. [Accessed 2.6.2019] Available at: https://advances.sciencemag.org/content/3/7/e1700782.full

Global Geoparks Network. 2019. Global Geoparks Network. [Referred to 21.3.2019]. Available at: http://www.globalgeopark.org/aboutGGN/51.htm

Groundwater foundation. 2019. What is groundwater? [Accessed 20.3.2019] Available: https://www.groundwater.org/get-informed/basics/groundwater.html

Helsinki Region Environmental Services Authority. 2010. HSY: Puhdasta vettä hanasta. Video. [Accessed 8.5.2019] Available at: https://www.youtube.com/watch?v=ZvjXd9ZW_Ik

Helsinki Region Environmental Services Authority. 2015. Pitkäkoski ja Vanhakaupunki. [Accessed 8.5.2019] Available at: https://www.hsy.fi/fi/asiantuntijalle/vesihuolto/vedenpuhdistuslaitokset/Sivut/Pitkakoski-ja-Vanhakaupunki.aspx

Helsinki Region Environmental Services Authority. 2017. Minne jätevedet menevät? [Accessed 8.5.2019] Available at: https://www.hsy.fi/fi/asukkaalle/kodinvesiasiat/jatevedet/Sivut/default.aspx

Helsinki Region Environmental Services Authority. 2018. Miten jätevesi puhdistetaan. [Accessed 8.5.2019] Available at: https://www.hsy.fi/fi/asiantuntijalle/vesihuolto/jatevedenpuhdistus/Sivut/default.aspx

Heslinki Region Environmental Services Authority. 2019. Vedenlaatu. [Accessed 16.6.2019] Available at: https://www.hsy.fi/fi/asukkaalle/kodinvesiasiat/juomavesi/Sivut/Veden-laatu.aspx

Ilmasto-opas. 2019. Järvillä on iso merkitys ilmastonmuutoksessa. [Accessed 10.6.2019] Available at: https://ilmasto-opas.fi/fi/ajankohtaista/uutinen/-/artikkeli/7570358f-59d0-425b-8ea3-0d3ef29bd692/jarvilla-on-iso-merkitys-ilmastonmuutoksessa.html

Jensen, T. 2018. Kalojen talvi elämää jääkannen alla. YLE. [Accessed 10.5.2019] Available at: https://yle.fi/aihe/artikkeli/2018/02/09/kalojen-talvi-elamaa-jaakannen-alla

Juhahalmu. 2019. Ekomatkailu. [Accessed 8.4.2019] Available at: http://juhahalmu.fi/ekomatkailu/mita-on-ekoturismi/

Järvi & Meriwiki. 2017. Päijänne. [Accessed 8.4.2019] Available at: http://www.jarviwiki.fi/wiki/P%C3%A4ij%C3%A4nne_(yhd.)

Järvi & Meriwiki. 2018. Päijänne / Valtakunnallisen leväseurannan havaintopaikka. [Accessed 15.4.2019] Available at: https://www.jarviwiki.fi/wiki/P%C3%A4ij%C3%A4nne_(yhd.)/Valtakunnallisen_lev%C3%A4seurannan_havaintopaikka_(Tiirinselk%C3%A4)

Koivula, J. 2016. Laboratorion puhdas vesi. Suomen Laboratorioalan Liitto ry:n ammatti- ja yhdistyslehti. 3/2016. 53. Vuosikerta. [Accessed 14.6.2019] Availabe at: https://www.laboratorioalanliitto.fi/wp-content/uploads/2018/02/Analyysi_3_2016_net2.pdf

Kouki, P. 2014. Padasjoki. Leirintäalue 576010005: Raportti kivikautisen asuinpaikan kaivauksesta 8.–19.7.2013. [Accessed 8.5.2019] Available at: https://www.kyppi.fi/palveluikkuna/raportti/read/asp/hae_liite.aspx?id=117369&ttyyppi=pdf&kansio_id=576

Kuusisto, E. 2014. Suomen lähteet. Vesitalous. [Accessed 8.5.2019] Available at: http://www.vesitalous.fi/wp-content/uploads/2014/09/Vesitalous_1404_netti.pdf

Kyrönviita, M., Tuomaala, T. 2018. Päijänteen kansallispuiston kävijätutkimus 2017. Metsähallitus. Metsähallituksen luonnonsuojelujulkaisuja. sarja B 239. [Accessed 14.4.2019.] Available at: https://julkaisut.metsa.fi/assets/pdf/lp/Bsarja/b239.pdf

Lahden seudun luonto. 2019a. Salpausselkä. [Referred to 15.6.2019] Available at: https://www.lahdenseudunluonto.fi/salpausselka/

Lahden seudun luonto. 2019b. Linnaistensuo. [Referred to 15.6.2019] Available at: https://www.lahdenseudunluonto.fi/linnaistensuo/

Lahden seudun luonto. 2019c. Asikkala. [Referred to 31.3.2019.] Available at: https://www.lahdenseudunluonto.fi/asikkala/#geologia

Lahden seudun ympäristöpalvelut. 2015. Lahden seudun ympäristökatsaus 2014. [Accessed 2.4.2019] Available at: http://lahti.fi/www/images.nsf/files/D13BC29DD9AFECFDC2257E5B00286389/$file/YmparistoKatsaus2014_24s.pdf

Lahti University of Applied Sciences. 2018. Geomatkailun kehittämisestä kiinnostuneet yritykset verkostoituvat Salpausselkä Geopark -hankkeessa. Uutiset.

[Accessed 2.6.2019] Available at: https://www.lamk.fi/fi/uutiset/geomatkailun-kehittamisesta-kiinnostuneet-yritykset-verkostoituvat-salpausselka-geopark

Lake Vesijärvi Foundation. 2019. Hoitotoimet. [Referred to 16.6.2019] Available at: https://www.vesijarvi.fi/en/frontpage/

Lakso, E. & Ulvi, T. 2005. Järvien kunnostus. Ympäristöopas. Helsinki: Edita. [Accessed 16.6.2019] Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjAnpKz--7iAhXlh4sKHRCkB2EQFjAAegQIBRAC&url=https%3A%2F%2Fhelda.helsinki.fi%2Fbitstream%2Fhandle%2F10138%2F41746%2FYmp%25C3%25A4rist%25C3%25B6opas_114.pdf%3Fsequence%3D1%26isAllowed%3Dy&usg=AOvVaw3FxrFrgzM-g92bGMb2jaqI

Lane, R. 2019. Lake. [Accessed 1.5.2019] Available at: https://www.britannica.com/science/lake

Lauhanvuori-Hämeenkangas Geopark. 2019. [Accessed 10.6.2019] Availabe at: https://www.lauhanvuoriregion.fi/geopark/mik%C3%A4-geopark/

Metsähallitus. 2018. Suomen luonnonsuojelualueiden hoitaja. [Accessed 8.6.2019] Available at: http://www.metsa.fi/luonnonsuojelu-ja-hoito

Metsähallitus. 2019. Päijänteen luonto. [Accessed 10.4.2019] Available at: https://www.luontoon.fi/paijanne/luonto#vedenalainen

Ministry of the Environment. 2013. Riskialttiiden pohjavesialueiden määrä kasvanut selvästi. Ympäristöministeriö, maa- ja metsätalousministeriö sekä sosiaali- ja terveysministeriö tiedottavat. [Accessed 16.5.2019] Available at: https://www.ym.fi/fi-FI/Ymparisto/Riskialttiiden_pohjavesialueiden_maara_k(16833)

Mitikka, S. 2013. Järvien vedenlaadun aikasarjoja. Järvien vedenlaadun vertailu. [Accessed 30.3.2019] Available at: http://ymparistonc.edelkey.net/fi-FI/Kartat_ja_tilastot/Vesien_tila/Pintavesien_tilan_seuranta/Jarvien_vedenlaadun_aikasarjoja

Nasa Science 2019. Water Cycle. [Accessed 10.6.2019] Available at: https://science.nasa.gov/earth-science/oceanography/ocean-earth-system/ocean-water-cycle

Nenonen, J. 2015. Geoparkit meillä ja muualla tuovat geologiaa tutuksi kaikille. [Accessed 8.5.2019] Available at: http://www.geologinenseura.fi/geologi-lehti/5-2015/Geologi_5_2015_02geopark.pdf

Nikkari, P. 2018. Supat ja niiden synty. [Accessed 15.5.2019] Available at: https://www.jukola.com/2018/supat-ja-niiden-synty/

Oravainen, R. 1999. Vesistötulosten tulkinta – opasvihkonen. Kokemäenjoen vesistön vesiensuojeluyhdistys ry. [Accessed 15.5.2019] Available at: https://kvvy.fi/wp-content/uploads/2015/10/opasvihkonen.pdf

Orr S., Cartwright A. & Tickner D. 2009. Understanding water risks. A primer on the consequences of water scarcity for government and business. WWF Water security series 4. [Accessed 16.6.2019] Available at: http://awsassets.panda.org/downloads/understanding_water_risk_iv.pdf

Palmu, J-P. 2018. Lähigeologiaa kaikille! Kohde 1: Pirunpesä. [Accessed 15.5.2019] Available at: http://www.geologia.fi/wp-content/uploads/2018/05/Hollola_geo-opas.pdf

Pohjois- Karjalan ympäristökeskus. 2019. Talousmetisen luonnonhoito: Lähteiden kunnostus. [Referred to 31.3.2019]. Available at: https://www.metsakeskus.fi/sites/default/files/lahteidenkunnostus_esite.pdf

Remes, K-M. & Nurmilaukas, O. 2018. UNESCOn asiantuntijat vierailivat Saimaa Geopark- alueella. Geologi- lehti 4/2018. [Accessed 14.6.2019] Available at: http://www.geologinenseura.fi/geologi-lehti/4-2018/Geologi_4_2018_02geopark.pdf

Remes, M. 2011. Valta vaihtuu vesissä. Tiede-lehti. [Accessed 15.5.2019] Available at: https://www.tiede.fi/artikkeli/jutut/artikkelit/valta_vaihtuu_vesissa

Rokua Geopark. [Referred to 15.3.2019]. Available at: https://www.rokuageopark.fi/fi/koe

Saimaa Geopark. Mikä on Geopark? [Referred to 20.3.2019]. Available at: https://saimaageopark.fi/mika-on-geopark/

Salmi, P. Vesijärven tila. [Accessed 15.4.2019] Available at: https://www.vesijarvi.fi/wp-content/uploads/2019/05/vesijarven_tila.pdf

Salmi, P. & Lindholm, M. 2017. Vesijärvi. Järviwiki. [Accessed 2.6.2019] Available at: http://www.jarviwiki.fi/wiki/Vesij%C3%A4rvi_(14.241.1.001)

Salo, H. & Palomäki, A. 2006. Espoon pitkäjärven ja lippajärven kunnostussuunnitelma. Jyväskylän yliopisto. Espoon Ympäristöntutkimuskeskus, tutkimusraportti 106/2006. [Accessed 15.5.2019] Available at: https://docplayer.fi/7106631-Hannu-salo-arja-palomaki-jyvaskylan-yliopisto-ymparistontutkimuskeskus-tutkimusraportti-106-2006.html

Salpausselkä Geopark. 2018. Salpausselkä Geopark-hanke. [Accessed 15.4.2019] Available at: https://www.salpausselkageoparkproject.fi/salpausselka-geopark/

Science Learning Hub. 2009. Article. Storage in the water cycle. [Accessed 8.6.2019] Available at: https://www.sciencelearn.org.nz/resources/722-storage-in-the-water-cycle

Smart&Clean foundation. 2019. Juhani Järveläinen: "There is worldwide demand for Finnish stormwater solutions". [Accessed 2.6.2019] Available at: http://smartclean.fi/en/2018/12/31/juhani-jarvelainen-there-is-worldwide-demand-for-finnish-stormwater-solutions/

Sysmän kunta. 2019. Kammiovuoren retkeilyalue. [Referred to 20.2.2019]. Available at: https://www.sysma.fi/kammiovuoren-retkeilyalue

The municipality of Asikkala. 2019. Ekosysteemit. [Referred to 15.6.2019] Available at: https://www.asikkala.fi/ymparisto-ja-luonto/ekosysteemit-2/

The municipality of Padasjoki. 2019. Kunnanhallituksen kokouksen pöytäkirja. [Accessed 15.5.2019] Available at: https://www.padasjoki.fi/loader.aspx?id=ce980a02-d62d-4c12-bd45-540f42629e0b

The city of Heinola. 2019. Luonnonsuojelu. [Accessed 16.6.2019] Available at: https://www.heinola.fi/luonnonsuojelu

The city of Lahti. 2012. Hulevesiohjelma. [Accessed 2.6.2019] Available at: https://www.lahti.fi/PalvelutSite/YmparistoSite/Documents/Hulevesiohjelma_2012.pdf

The lake Vesijärvi Foundation. 2019. Vesijärvisäätiön yleisesite. [Referred to 15.6.2019] Available at: https://www.vesijarvi.fi/wp-content/uploads/2019/05/vesijarvisaatio_yleisesite_web.pdf

Tieteen termipankki. 2014. Headword: Ilmastonmuutos. [Accessed 2.6.2019] Available at: http://tieteentermipankki.fi/wiki/Toiminnot:Oma_kieli/Termipankki:Etusivu

Tieteen termipankki. 2018. Headword: Transgressio. [Accessed 15.5.2019] Available at: https://tieteentermipankki.fi/wiki/Geologia:transgressio.

Tieteen termipankki. 2019. Headword: Limnology. [Accessed 15.5.2019] Available at: http://tieteentermipankki.fi/wiki/Nimitys:limnologia.

Törmänen, E. 2017. Jätevesissä on satoja kiloja särkylääkkeitä ja muita lääkeäaineita – lääkejäämien poisaminen vaikeaa. Tekniikka ja talous. [Accessed 15.5.2019] Available at: https://www.tekniikkatalous.fi/tiede/laaketiede/jatevesissa-on-satoja-kiloja-sarkylaakkeita-ja-muita-laakeaineita-laakejaamien-poistaminen-vaikeaa-6639338

UNESCO. 2017. International Hydrological Programme. [Accessed 15.5.2019] Available at: http://www.unesco.org/new/en/natural-sciences/environment/water/ihp/about-ihp/

UNESCO. 2018. The United Nations world water development report 2018: nature-based solutions for water. [Accessed 15.4.2019] Available at: https://unesdoc.unesco.org/ark:/48223/pf0000261424

UNESCO. 2019. UNESCO in brief - Mission and Mandate. [Accessed 20.3.2019] Available at: https://en.unesco.org/about-us/introducing-unesco

University of Helsinki. 2019. Veden kovuus. Kemian opetuksen keskus. Oppilaan ohje. [Referred to 16.6.2019] Available at: http://www.kemianluokka.fi/files/uudet/Puskurikapasiteetti%20oppilas_Aga.pdf

Uusitalo, A., Kellomäki, E., Vääriskoski-Kaukanen S. 2008. Keski-suomen ympäristökeskuksenraportteja 4/ 2008. selvitys Päijänteen biosfäärialueenperustamisedellytyksistä. [Accessed 31.3.2019] Available at: http://www.doria.fi/bitstream/handle/10024/134167/KSUra4_2008_N.pdf?sequence=2&isAllowed=y

Vauramo, S. 2017. Stormwater management in Lahti. Integrated Storm Water Management and Coastal Area Management – from holistic approach to practical solutions. [Accessed 15.5.2019] Available at: http://www.iwama.eu/sites/iwama/files/12._vauramo_-_stormwater_management_in_lahti.pdf

Vesikartta. 2019. Vesien ekologinen tila. [Accessed 15.5.2019] Available at: http://paikkatieto.ymparisto.fi/vesikarttaviewers/Html5Viewer_2_5_2/Index.html?configBase=http://paikkatieto.ymparisto.fi/Geocortex/Essentials/REST/sites/VesikarttaKansa/viewers/VesikarttaHTML525/virtualdirectory/Resources/Config/Default

Woods Hole Oceanographic Institution. 2018. From Macroplastic to Microplastic. Video. Youtube. [Accessed 5.5.2019] Available at: https://www.youtube.com/watch?v=_tKnodpq

Xiaojun, Y., Shiuin, L. Lei, H., Meiping, S., Linlin, Z. 2018. Definition and classification system of glacial lake for inventory and hazards study[J]. Journal of Geographical Sciences, 28 (2): 193- 205. [Accessed 5.5.2019] Available at: http://www.geogsci.com/article/2018/1009-637X/40133

Picture references

PICTURE 1. Kuusisto, E. 2014. Suomen lähteet. [Accessed 2.4.2019] Available at: http://www.vesitalous.fi/wp-content/uploads/2014/09/Vesitalous_1404_netti.pdf

PICTURE 2. Metsähallitus. 2019. Päijänteen luonto. [Accessed 2.4.2019] Available at: https://www.luontoon.fi/paijanne/luonto#vedenalainen

PICTURE 3. Keski-Suomen museon kuva-arkisto. Näyttely S/S Suomi- laivalla. [Referred to 31.3.2019]. Available at: https://www.paijanne-risteilythilden.fi/nayttely/

PICTURE 4. Salovaara, R. 2010. Vesimittari kulkee vetten päällä. [Accessed 2.4.2019] Available at: https://yle.fi/aihe/artikkeli/2010/11/22/vesimittari-kulkee-vetten-paalla.

PICTURE 5. Luontoportti. 2019. Common water Crowfoot. [Accessed 2.4.2019] Available at: http://www.luontoportti.com/suomi/en/kukkakasvit/common-water-crowfoot

PICTURE 6. Sundqvist, V. 2016. Helsingissä juodaan ehkä mailman parasta vettä – “possuttamisesta” laatuongelmia. Yle Uutiset. Available: https://yle.fi/uutiset/3-8731424

Figure references

FIGURE 1. By the author

FIGURE 2. Metsähallitus. 2017. Päijänteen kansallispuiston ja Natura 2000- alueen hoito- ja käyttösuunnitelma. Metsähallituksen luonnonsuojelujulkaisuja. [Accessed 14.6.2019] Available at: https://julkaisut.metsa.fi/assets/pdf/lp/Csarja/c148.pdf

FIGURE 3. Saarnisto, M., Rainio H. & Kutvonen, H. 1994. Salpausselkä ja Jääkaudet. Geologian tutkimuskeskus. Opas 36. Lahden kaupunginmuseon julkaisu. [Accessed 10.6.2019.] Available at: http://tupa.gtk.fi/julkaisu/opas/op_036.pdf

FIGURE 4. Palmu, J-P. 2018. Lähigeologiaa kaikille! Kohde 1: Pirunpesä. [Accessed 2.6.2019] Available at: http://www.geologia.fi/wp-content/uploads/2018/05/Hollola_geo-opas.pdf

FIGURE 5. Juotavan Hyvä Etelä- Päijänne ry. 2017. Eteläisen Päijänteen helmiä. Päiväretkikohteita ja jääkauden jälkiä. [Accessed 5.4.2019] Available at: http://visitpaijanne.fi/wp-content/uploads/2017/11/Etelaisen_Paijanteen_Helmia.pdf

FIGURE 6 & 7. By the author

FIGURE 8. Lönnqvist, B. & Kuhanen, I. 2007. Päijänne- elämän vesi. Jyväskylä: Atena.

FIGURE 9. Järvi & Meriwiki. 2018. Päijänne / Valtakunnallisen leväseurannan havaintopaikka. [Accessed 15.4.2019] Available at: https://www.jarviwiki.fi/wiki/P%C3%A4ij%C3%A4nne_(yhd.)/Valtakunnallisen_lev%C3%A4seurannan_havaintopaikka_(Tiirinselk%C3%A4)

FIGURE 10. Finnish Environment Institute. 2017. Mikromuovit riski myös Suomen vesistöille. [Accessed and modified 2.6.2019] Available at: https://www.syke.fi/fi-FI/Ajankohtaista/Mikromuovit_riski_myos_Suomen_vesistoill(42492)

FIGURE 11. Salmi, P. & Lindholm, M. 2017. Vesijärvi. Järviwiki. [Accessed 2.6.2019] Available at: http://www.jarviwiki.fi/wiki/Vesij%C3%A4rvi_(14.241.1.001)

FIGURE 12 & 13. Vauramo, S. 2017. Stormwater management in Lahti. Integrated Storm Water Management and Coastal Area Management – from holistic approach to practical solutions. [Accessed 15.5.2019] Available at: http://www.iwama.eu/sites/iwama/files/12._vauramo_-_stormwater_management_in_lahti.pdf

FIGURE 13. Asheesh, M., Kaipainen, T., Leiviskä, P. 2015. Pohjavesi. Suomen maaperä. Oulun ammattikorkeakoulu. [Accessed 2.4.2019] Available at: https://slideplayer.com/slide/11638246/

FIGURE 14. National Land Survey of Finland. 2019. Paikkatietoikkuna. Karttapalvelu. Available at: https://kartta.paikkatietoikkuna.fi/?lang=fi&ver=1.17&zoomLevel=5&coord=562567.11466914_6773273.9201585&mapLayers=base_35+100+default,167+100+,166+100+&&showMarker=true

FIGURE 15. By the author.

FIGURE 16. Cornell University. 2019. Hydrologic cycle. [Accessed 8.4.2019] Available at: http://nysgolfbmp.cals.cornell.edu/hydrologic-cycle/

FIGURE 17. Asheesh, M., Kaipainen, T., Leiviskä, P. 2015. Pohjavesi. Suomen maaperä. Oulun ammattikorkeakoulu. [Accessed 2.4.2019] Available at: https://slideplayer.com/slide/11638246/

FIGURE 18. Finnish Environment Institute. 2019. Lääkejäämiä sisältävän jäteveden puhdistuksen tehostaminen päästölähteillä ja lääkejätteen tehokkaampi käsittely (EPIC). Epic- hanke. Available: https://www.syke.fi/hankkeet/epic

FIGURE 19. Kutvonen, H. 2005. Harjun synty jäätiköltä virtaavan joen uomaan ja suistoon. Available: http://weppi.gtk.fi/aineistot/mp-opas/harjusynty.htm

FIGURE 20. Seppälä J. 2008. Päijänne- tunnelin peruskorjaus alkaa huhtikuussa. Available: https://www.tekniikkatalous.fi/tekniikka/kemia/2008-03-28/P%C3%A4ij%C3%A4nne-tunnelin-peruskorjaus-alkaa-huhtikuussa-3253883.html

Table references

TABLE 1-2 & 4. Oravainen, R. 1999. Vesistötulosten tulkinta – opasvihkonen. Kokemäenjoen vesistön vesiensuojeluyhdistys ry. [Accessed and modified 2.4.2019] Available: https://kvvy.fi/wp-content/uploads/2015/10/opasvihkonen.pdf

TABLE 3. Mitikka, S. 2013. Järvien vedenlaadun aikasarjoja. Järvien vedenlaadun vertailu. [Accessed and modified 2.4.2019] Available: http://ymparistonc.edelkey.net/fi-FI/Kartat_ja_tilastot/Vesien_tila/Pintavesien_tilan_seuranta/Jarvien_vedenlaadun_aikasarjoja

TABLE 5. FCG. 2019. Päijät- Hämeen työpaikat. Selvitys Päijät-Hämeen elinkeinoelämän alueiden merkittävyydestä. [Accessed and modified 2.5.2019] Available: http://www.paijat-hame.fi/wp-content/uploads/2019/02/Selvitys-elinkeinoel%C3%A4m%C3%A4n-alueiden-merkitt%C3%A4vyydest%C3%A4.pdf

TABLE 6. Asheesh, M., Kaipainen, T., Leiviskä, P. 2015. Pohjavesi. Suomen maaperä. Oulun ammattikorkeakoulu. [Accessed 15.5.2019 and modified] Available at: https://slideplayer.com/slide/11638246/