SUSTAINABLE WASTEWATER NETWORK MANAGEMENT IN LEMPÄÄLÄ MUNICIPALITY

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Forward

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ABSTRACT

TAMPERE UNIVERSITY OF APPLIED SCIENCE

Bachelor of Science thesis in environmental engineering

Peter Paul Obijaju	Sustainable wastewater network management in Lempäälä Municipality
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Deterioration of a wastewater network can be attributed to a number of factors, from aging and damaged infrastructure (pipes, manholes and pump stations), to seismic activity and human activities. This deterioration can cause huge problems in a wastewater network, including leakage of water into the network, which can cause overflow and an increase in the cost of transporting and treating the wastewater.

The aim of this study was to determine the level of deterioration in the sewer network of Lempäälä municipality by investigating the different areas connected to the wastewater network. The work was conducted by investigating the network for Inflow and Infiltration (I&I) flow rate in different areas of the Municipality connected to the wastewater network. An additional aim was to assess the increase in cost of transporting wastewater from pump stations to the treatment plant.

Monthly flow of I&I was calculated for each of the pump stations around Lempäälä. The average wastewater flow rate information for Wet (Peak) periods and Dry (Off-peak) periods was taken from the water supply department data base. The Peak wastewater flow rate period was taken in the month of April and the Off-peak period wastewater flow rate was taken in June, both in 2010.

Information for this study was gathered from field investigation of the manholes, pump stations and pipes with the aid of a closed circuit television (CCTV). About 700 manholes were investigated and only faulty ones were documented. Additionally, 52 pump stations were investigated.

This research revealed the difference in cost of transporting wastewater from the pump stations via the networks to the treatment plant for the Peak and Off-peak periods. The field results would be used to renovate the wastewater network in 2011-2012.

Key words: wastewater network, leaks, infiltration and inflow, flow rate, sewer, investigation, peak or wet period, off-peak or dry period.

LIST OF ABBREVIATION AND SYMBOLS

CCTV - Close circuit television

I&I -Inflow and Infiltration

I&E - Inflow and Exfiltration

PVC - Polyvinyl Chloride

PE Polyethylene

PP -Polypropylene

CSO – Combine sewerage overflow

Ø Diameter

% Percentage

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1. INTRODUCTION

Wastewater network system plays a major role in ensuring a healthy and protected environment; it also contributes to sound public health and enhances the standard of living in general. When Wastewater from homes and commercial areas is not disposed of properly it can lead to significant health and environmental problems.

Wastewater can be disposed off in different ways depending on the population density of the area. In densely populated areas it would be unacceptable to use septic tanks because of health and environmental risks in storing and transporting of sewer. In industries the nature of wastewater produced by industries makes it too risky to simply release the wastewater from industries into the environment, the wastewater has to be treated before been released to the environment. Wastewater network is the safest means of transporting wastewater to the treatment plants in densely populated areas. (Auckland council, 2011)

Wastewater is transported to the treatment plant where it is treated before released back to the environment; it also enables the monitoring of pollutants by the Authorities. Maintaining the network is important in ensuring a cost efficient way of transporting wastewater.

Inflow and infiltration (I&I) water enters the network system from cracks and openings found in the system, which leads to additional cost of transporting wastewater from pump stations to the treatment plant and more cost is incurred when treating this additional wastewater in the treatment plant.

Rehabilitation and renovation of network reduces the menace of (I&I) water flowing into the system, it also reduces maintenance and operational cost.

2. BACKGROUND

The volume of water leaking into the wastewater network in Finland from 1977- 1999 was put at an average of 24percent of the total volume of wastewater generated
Because of this Finland has launched a Sewer 2020 Process, which aims at reducing the storm water runoff into wastewater networks and exfiltration from sewer networks by 2020.
The Sewer 2020 Process currently involves 428 sewage plants. Pirkanmaa region is involved in this process and Lempäälä municipality which is a municipality in Pirkanmaa is part of this process. Lempäälä municipality has embarked on this project to evaluate the state of the wastewater network and to carry out repairs if needed in line with the Sewer 2020 process. (Suomen ympäristökeskus 2011)

2.1Lempäälä municipality

Lempäälä municipality is located 20km south of Tampere. It was founded in 1866. The population is about 20399 in 2010, of which urban dwellers accounts for 86.9% of the population. Lempäälä municipality total area is 307.6 km2 with the population concentration on the North South area. At the end of 2003 the population was put at 17,397 so there has been an increase in the population in 2010 by about 14% in 6 years. Lempaala wastewater treatment plant was built in 1973 and was rehabilitated in 1998 and 2000. Lempäälä is involved in the Pirkanmaa central treatment plant project and the Sewer 2020 Process. (Heusala, 2008, Lempäälä kunta 2011)

PICTURE 2.1 Lempäälä Municipality (Google image 2011)

3. PURPOSE AND SCOPE OF THE PROJECT

The purpose of this project was to investigate the Lempäälä municipality wastewater network, for (I&I) leakages. Determine the cost incurred for transporting the extra (I&I) water to the treatment plant.

Pipes, manholes and pump stations were investigated with the aid of a CCTV, to identify the most problematic areas, the origin of leaks, and the type of leaks. The project aims at reducing inflow and infiltration (I&I) leaks into the treatment plant by identifying pipes and manholes that would require renovation and rehabilitation, and reducing operations cost by reducing the life cycle maintenance of the network in the long run.

3.1 Previous study of Lempäälä wastewater network. (Heusala, 2005)

The wastewater network in Lempäälä was last investigated for leaks and overflow in 2005 (Heusala).before that it was studied five times, Twice in 2000's Uusimäki (2000), Virta (2000) three times in the 90s Kivekäs (1998), Nurmikko (1996), PM-suunnittelu (1990). Manholes were also investigated several times in the 90s.

Conditions of Manholes were studied in summer of 2000 by Virta(2000) in the following areas Hemminkilä,Sulkola,Ryynikkä and MoisioII. And the pump stations too. Damaged manholes were renovated after the investigations in the summer with the exception of Hemminkila which had none.

In 2000 by Uusimäki (2000) in his master's thesis investigated the volume of leakages in the pump stations at the southern part of Lempaala. The leakage in the pump stations were calculated based on the running time of the pumps. The study found that the leakage in Hemminkilä pump station was reducing and there was an increase in leaks at Majauslahti pumping station.

Nurmikko(1996) in his master's thesis investigated the whole pump stations for leaks. The leaks were calculated based on the running time of the pump stations.

Heusala in his master's thesis did a comprehensive study of wastewater network, Manholes, pump stations and sewer lines were investigated for leaks and the (I&I) was calculated. (Heusala2005)

4. MATERIALS AND CONPONENTS OF A SEWER

‘This research focuses only on the wastewater network of Lempäälä municipality excluding storm water and water networks. Information for this research was gathered from past investigations of the wastewater network, physical investigation of pump stations, manholes and pipes. The investigation was carried out to find leaks on walls, seams, and joints of manholes, and pump stations too. Leaks caused by overflow levels were investigated too. The amount of storm water (I&I) leaks transported from the pump stations into the treatment plant was calculated based on the average peak flow for both dry and wet periods network flow rate, the estimated maximum monthly average volume of flow from dwellers connected to pump stations was calculated and the result was used in calculating the cost of transporting water leaks to the treatment plant

4.1.1 Material and Methods

Most sewer pipes are circular with **Øs** of 10.2 to 365.8 cm. There are quite a number of physical characteristics essential for the durability and long life of the pipes.

- Abrasion resistance to withstand wastewater carrying gritty materials impervious walls to prevent leakage
- Adequate strength to resist failure or deformation under backfill and traffic loads
- Joints should be easy to install, durable, and watertight to prevent leakages or root entrance
- Withstand electrochemical and chemical reactions from the surrounding soil and wastewater conveyed in the pipe. (Hammer, 2004)

Bacterial activities in anaerobic wastewater produces hydrogen sulphide gas, this occurs mostly in warm climate when sewers pipes are laid on flat grades. The hydrogen sulphide gas absorbed in the water condenses on the crown and is converted to sulphuric acid by aerobic bacterial action. This leads to collapse of the crown if the pipe is not chemically resistant.

Pipe material resistance to corrosion are the most effective prevention against abrasion .Plastic pipes, reinforced concrete with an interior protective coating of coal tar, vinyl, or epoxy. Should be considered when large size connection is needed Generation of hydrogen sulphide in sewer can be reduced by placing the pipes on as steep gradient as possible. (Davis 2011, Hammer, 2004)

4.1.2 Concrete pipes

Precast Concrete pipes are widely used in wastewater networks; they are obtainable in many sizes depending on the location they are to be used, application, and condition for installation. Available from 30.5 to 274.cm, the main material is mostly gravels or crushed rock. The required aggregates would have the appropriate mix of granularity and purity. The blinding agent is usually a Portland cement or the rapid hardening Portland cement. If the concrete is likely to be exposed to sulphate, sulphate resistant cement is used. Example of such exposures includes industrial waste and soil containing sulphate. Additive used in concrete pipes includes plasticizer, retarders, accelerators fibres and dyes. Additives can affect the concrete in various ways from strength, to hardening time and some other properties too. (Heusala2005).

Concrete pipes are available in **Ø**s 225 - 2000 mm, in lengths to 1500 - 2250 mm. they were widely used in Lempäälä in the 70's in the network. (Heusala2005)

Concrete Pipe advantages include compactness and mechanical stability, affordability, and good strength. But they are still highly prone to corrosion (International Water Association 2008)

4.1.3 Plastic pipes

Plastic pipes system is widely used for transporting wastewater from houses to the treatment plant, they display different range of properties. Its flexibility allows it to be adjusted to inevitable ground movement, its smooth inner walls allows for easy flow in gravity sewer reducing blockages. For gravity sewer network system, PVC, PE and PP are the types of material used for the plastic pipes. Plastic pipes are most widely used pipes for wastewater in Lempäälä nowadays because of the quality mentioned above.

PVC or polyvinyl chloride derived from common salt and fossil fuels was first made in the 1930's. It was used to replace corroded metal pipes in the 1950's. Based on the standard PVC material, three other variants are in use. A high performance variant called CPVC is used specifically for indoor applications in hot water supply. OPVC molecular-oriented bi-axial high performance version combines very high strength with extra impact resistance. A ductile variant is the MPVC; PVC modified with acrylics or chlorinated PE. This very ductile material with high fracture resistance is used in high demand applications where resistance against cracking and stress corrosion is important.

Polyethylene or PE is a tough thermoplastic material derived from fossil fuels. PE piping is used for a broad range of pressure applications including the transportation sewers and drainage lines.

PP is a thermoplastic polymer made from Polypropylene. This plastic pipe system is used widely for the transportation of wastewater from buildings to the wastewater treatment plant. This can be used in gravity sewer, pressure or vacuum sewer it is also used in domestic wastewater treatment tanks. Pipeline rehabilitation is also a common application for PP Due to the high impact resistance combined with good stiffness and excellent chemical resistance which make this material very suitable for sewer applications. A good performance at operating temperature range from up to 60°C (continuous) makes this material suitable for in-house discharge systems Soil &Waste.

Plastic pipes are Light to work with, resistant to chemical attacks (normally). Additionally plastic pipes are resistant to wear and tear, and have Hydraulic low-friction surface. But the can crack under heavy mass, deform more easily, and exposed to certain chemical attacks (TEPPFA, 2011)

4. 1.4 Manholes

Manholes are built for observing and maintenance of sewerage system, the inspection chamber is made out of plastic or concrete, the cover is made from cast iron, plastic or stainless steel. Most manholes in Lempäälä are circular with an inside diameter of 121cm, which is considered sufficient for conducting inspection and cleaning. But some of the new ones are smaller. The walls are constructed by one of the followings materials: Precast concrete rings, plastic, bricks or poured concrete.

Wastewater flow in the manholes is usually conveyed in a U-shaped channel formed in the base of the concrete. Where more than one sewer enters the manhole, the flowing through channels is curved to merge the flow stream. When there is a change of direction in the sewer without changing of size, a drop of 1, 5 to 3, 0 cm is provided in the channel to account for head loss. When a small sewer joins a larger one, to maintain uniform flow transition the bottom of the larger pipe is lowered sufficiently. In Lempäälä the older manholes are mostly concrete with metal lids. But more recent ones are mostly plastic manholes, and most of the renovated concrete manholes have been converted to plastic manholes

The Manholes in Lempäälä are placed at all changes in sewer grade, pipe size or alignment, at intersections or at the end of each line; and at a distance not greater than 50m to 120m. (Hammer, 2004,.Lempäälä 2011)

PICTURE 4.2 Concrete Manhole with a cast Iron (Peter Obijaju, 2011)

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PICTURE4.3 Plastic Manhole (Peter Obijaju, 2011***)***

4.2 Pump stations

Depending on the topography and the legislation of the area a gravity sewer or pressures sewerage system may be needed. In Lempäälä and most of the pump stations located at the lowest point, because most of the sewer pipes are laid in steep gradient. Where sewer flows in pipes by the force of gravity and no pressure is applied (gravity sewer). Transporting wastewater requires pump stations; where the refined sewer is pumped to other pump stations or to the treatment plant. The early pumps stations in Lempäälä municipality where made of concrete walls, but the newer ones are made from fibre-glass. They large pump stations allows for vast inflow of wastewater and it can hold huge volume, they small pump station which deals with small amount of inflow is used in very sparsely populated residential areas of Lempäälä. There are small lifting stations for transporting effluent away from buildings. Most modern pump stations have monitoring solution to monitor overflows and huge leaks. Pump stations in Lempäälä are located at the lowest points because of the gravity flow of sewer. The pump stations are mounted on the lowest points to allow for easy inclined flow of sewer to the pumps stations. The effectiveness of pump stations to constantly pump wastewater to the treatment plant is based on the number of pump starts and the capacity of the small pump. The wet wall should be large enough to maintain proper pump control in large pump stations ; in small wet walls, keeping the mixed wastewater moving at a sufficient velocity is necessary to reducing accumulation of settled and floating solid. Yet, if wastewater detention time is too short it increases the mechanical wear of the pumps. Also temperature increase of the drive motors is likely to occur with the on and off cycling. For the best performance a combination of inflow and pumping, of about 6 starts per hour or about 10min for the cycle of operation for each pump is adequate, and the maximum detention time for wastewater in the wet wall should be 30min. (Hammer, 2004.Grundfos 2011. Lempäälä 2011)

PICTURE 4.4 Glass fiber pump station in Lempäälä (Obijaju, 2011)

5. WASTEWATER NETWORK SYSTEM FAILURES

Failures that occur in wastewater networks are caused by different factors, from low quality material, aging infrastructure, to poor management, and seismic activities too. All this factors contributes to the problems of leaks in wastewater network which leads to an increase in maintenance and increased life cycle cost.

5.1 Plastic pipes failures

The life service of a modern plastic pipe for sewer is between 100-50years. But there are possibilities of failure if the following occurs

1. Very shallow pipelines under traffic area (< 1m) when pipes are lead in shallow holes near traffic the constant earth movement could lead to deformation and cracks.
2. Weak soil, no reinforcement. Reinforcement may be required to help in equal settlement of the pipes where the soil is weak.
3. Border between soft soil and rock if the pipes are covered without adequate backfill material like gravel the possibility of rocks cracking the pipes is high.
4. Initial poor quality installation, when initial installation is bad there is a risk of infiltration from the joints of the pipe. (International Water Association, 2008.Davis,2011)

5.2 Concrete pipes failures

The wide variety of application makes it easy to use concrete pipes and the modern concrete pipes have good corrosion resistance, its life service is about 100years.but there are major problems with the pipes.

Hydrogen Sulphide which occurs in wastewater would destroy even modern concrete pipes.

Because of the stiffness small movements in the earth can cause cracks in pipes and displacement in joints leading to leakages.

They are very heavy which makes them not easy to handle.

Corrosion under septic conditions. (International Water Association, 2008.Hammer, 2004)

5.3 Manholes failures

There are quite a number of failures that can occur in manholes which allows for (I&I) into the manholes as shown in table 1.3

Table5.1 Manhole failures (ASCE, 1997)

Component	Defects
cover	-open vent or pick holes -bearing surface worn or deteriorated -no gasket or bolts for gasket or bolted covers -poor fitting lose -cracked or broken
frame	-bearing surface worn or deteriorating -frame offset from chimney -leaking frame -no seal -cracked or missing seal -frame offset from chimney
chimney	-cracked/ broken -deteriorating
cone	-cracked/loose or missing mortar -leaking cone/wall joints -leaking lifting hole -deteriorate
wall	-deteriorated or corroded -cracked /loose or missing mortar -leaking wall joint -leaking lifting hole -root intrusion
pipe seal	-cracked /loose mortar or none -deteriorating

PICTURE5.1 Leaks from the walls and seams of the Manhole (Obijaju, 2011)

PICTURE 5.2 Leaks from the lower part of Concrete manhole (Obijaju,2011)

PICTURE 5.3 Broken cast iron frame source of Inflow (Obijaju,2011)

5.4 Pump stations failures

Failures of pump stations can lead to high cost of transporting wastewater to treatment plants, overflow and reduced performance capacity of the pump station, which may lead to a reduced life span of the station. Such failure can occur as a result of different faults including.

Constant overflow leading to prolonged on and off start cycle of the pumps, causing increase mechanical wearing of pumps.

Leakages from walls and pipes of the pump station leading to increase inflow and pumping, prolonging the running time of pumps and wearing the motor drivers by increasing start time of the pumps.

Leakages from manhole and network pipes leading to overflow in the pump station (Hammer,2004)

PICTURE5.4 Leaks from the pipe inside pump station (Obijaju, 2011)

PICTURE 5.5 Little leaks from the pipes in a pump stations (Obijaju, 2011)

5. 5 Flow rate and sources of wastewater

Wastewater may be classified into the following components.

Domestic wastewater flows. Wastewater discharged from residences, commercial (banks, restaurants, retail stores), and institutional facilities (schools and hospitals).

Industrial wastewater, wastewater discharged from industries (e.g., manufacturing and chemical processes)

Infiltration and inflow, groundwater that infiltrates the sewerage and storm water that enters through roofs drains; foundation drains, and submerged manholes. (Hammer, 2004. Davis 2011)

Table5.1 Water and wastewater flow rate in Ahosti (Lempäälä 2010)

Types	**Water supplied/ Expected amount of wastewater in 2010 (m^3)**
Domestic Water and Wastewater flow rate	
Single housing	3724
Apartment building	33600
Commercial water and wastewater rate	
Sport facility	4691
State building	284
Municipality building	1156
Industrial water and wastewater rate	2287
Total	45742

5.6 Leaks in Wastewater networks

Inflow/infiltration (I/I) this processes interact with and directly affects the sewer network and the treatment plant performances as well as ground water quality.

(I/I)In combined sewer system, inflow dwarfs infiltration flows during large storms. However in a separate sewage system, Infiltration is the dominant contributor to the peak flow. And the sources includes. Leaking manholes, leaking pipes and unsealed manholes

Infiltration in sewer systems occurs in two main ways. The first is leakage from trench backfill, loose or broken joints and deteriorating pipe network. The second source mechanism is by hydraulic leakage from elevated groundwater level into the sewer pipe mostly after wet weather condition. (Ellis, J.B 2001)

PICTURE 5.1 worn cast iron lid source inflow ***(***Obijaju 2011)

PICTURE 5.2 Frame offset source of inflow ***(***Obijaju 2011)

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PICTURE 5.3 Infiltrations into a pump station (Peter Obijaju2011)

PICTURE5.4 Leaks from the wall of a Pump station (Obijaju2011)

6. LEAK DETECTION

6.1 Current practice in sewage Assessment

Assessing sewer condition requires physical inspection to determine (I&I) condition, structural condition, and hydraulics. There are quite a number of techniques that can be used to observe the overall performance of the system.

In Dye and Smoking testing technique the records of the sewers should be accurately known, all connection in the network must be known before using this technique. For new sewer the standard testing technique is the Air pressure testing technique. In older sewage system new robotic technique allows for insertion of stoppers in sewer making it feasible and cost effective to use air pressure testing, the limitation of this testing is that only the main manhole is investigated, but none of the lateral once.

All the testing methods cannot detect leaks 100% in wastewater network, except for Water testing technique which gives very accurate results in infiltration and exfiltration testing but is very labor intensive and disruptive. Presently manual inspection is the most cost effective way of tracing infiltration More detail investigation of specific pipe-line for I&I structural condition can be done through internal inspection and three meth-ods could be used, Physical inspection, CCTV inspection and the use of Photographic inspection. (International, Water Association, 2008.)

6.2 Consequence of leakage

I&I leaks are of great concern because of the operational and capital cost associated with I&I, and the impact is felt in the following ways:

Increase cost of pumping wastewater the volume of flow into the pump station increases because of the leaks, therefore, increasing the running time of the pumps.

Reduced hydraulic capacity leading to potential sewer surcharging and thus increasing the risks of surface overflow

Increased frequencies of combined sewer overflow (CSO). Overflow is a possibility even during dry weather conditions if there are locally very high groundwater levels

Sewer collapse if damages are not checked it could lead to an overwhelming cost of running the plant network

May easily lead to interference with treatment plant performance

Increased surface sediment and soil contamination (Maynes, j, 1976)

6.3 Environmental effects of leaks

Leakage in wastewater network can have significant health and ecological implications, if an overdesign of the wastewater systems does not occur, sewer overflow is a possibility.Sewer overflow can lead to contamination of the ground water, food and soil. This may easily lead to illness. It could easily endanger aquatic lives by polluting waters. When overflow occurs the odors from the sewer are unpleasant and disturbing.(Geyer, J.C.)

7. RESULT AND DISCUSSION

Table 7.1 Outcome of network investigation

Months	**Area**	**Pump station and manholes investigated**	**Comments**
April	Lastenkoti	Pump station Pump station Manhole Manholes all the manholes in the area were checked.	Leaks were found on the wall of the pump station. No leaks found Leaks found on top seam of manhole number 12107. Disproportionate high flow from house connection manhole number 12111
April	Myllyranta	Pump station Manholes that were investigated covers this areas 18201-18225 and 18102-18107	Leaking from wall seam. 18201 Leaks from the seam. 18 102 Leak from the seam. 18 205 lid is leaking a little.
April	Ryynikkä	Pump station Pump station manhole Manholes in the area were comprehensively investigated from manholes numbers 22201-22208,and 22119-22126 Ryynikäntie Kotipellonkatu 22 106	No leaks found. No leaks found.
April	Halkola	Halkola Pumping Station pump station manhole Manholes in Halkola area were systematically investigated through the streets of Alatie, Hopealinjatie, Halkolantie and Pastellintie	No leaks or overflow. No leaks found.

April	Hemminkilä	Pump station Pump station manhole Manholes that were inspected are in Väinämöisentie between 04301-04306 and Hauralantie between 04322-04329	 The walls were leaking heavily
April	Sulkola	Pump station Manholes investigated were between 24102 and 24113.	The whole area surrounding the pumping station was flooded. The Pumping station had plenty of water leaking in. The problem was reduced when a channel was made for the water, but the wall and joints of the pump were still leaking.
April	Kulju	pump station pump station manholes Manholes The Manholes around the areas supplying pump station were investigated this included Myllykolunpolun, Myllykoluntien and Myllykolunrannan	No leaks found One was leaking at the bottom and one was good 11105 Had a small leak from the seam. 11 106 Had Leaks from the floor. 11 107 Had leakage from the floor. 11 111 Leaking seam All manholes were in good condition and no leaks were detected. The flow from these areas was relatively minor compared to the other side of the river . The other side of the river were inspected the line between the manholes, 11302-11313. And nothing reveal was abnormal. The manholes from 314 to 323 were checked and from 11601-11607 no leaks where found
April	Ahosti	Ahosti Pump station pump station manholes Manholes connected to the Pump	No leaks detected. No leaks detected. No leakages found

		station network from number 01102 to 01130 were inspected. The manholes in Aittomäentie from number 01326 to 01332	Flow from the industrial connection were high compared to the residential connections
April	Kesoil	Kesoil Pump station Manholes in the area were not inspected	No leaks
April	Karhunpelto	Karhunpellon Pump station pump station manhole	No leaks No damages
April	Vanattara	Vanattara Pump station Pump station manhole Manholes in the area inspected includes the ones in Vanattaran Pysäkkitien to the rail station (401-407), to Vanattarantie road (312-319), and the west side of Tampereentie network line was inspected from Mosiontie to the pump station. And finally the pump station net work was also inspected (30101-30107) to Vanattarantie. The line 30301 to 30303 was not found.	No damages No damages Manhole number 30103 top most ring is loose may allow for inflow
April	Veräjäntausta	Veräjäntaustan pump station Pump station manhole The pipe was not in the labeled in the map. Significant part of the flow was from the Puskiastentie direction. A pipe from a real estate number 106393/06. a considerable amount of rock was noticed at the bottom of manhole Manholes were inspected from 101-109, 110-117 and 201-211.	No leaks found A small trickle of water was leaking flowing in from the overflow pipe
April	Välimäki	Välimäki Pumping Station Pumping Station manhole key did not fit the lock does not opened. Manholes in the region were inspected from 29126-29128 and Masnholes in Mäyräahteentien were randomly inspected.	No leaks detected. No leakages were found except Manhole number 29 132 had a small leak at the bottom.

April	Höytämö	Höytämön pump station and pump station manholes. manholes	No leaks detected in both. lots of dirt at the bottom of manhole 15201
May	Mustanniementie	Mustanniemen pump station and pump station manholes. Manholes in the area around Simunantien were inspected from (38216-38222)	No leaks detected in both. No leaks where found except for number 38 216 which was leaking from the bottom seams
April	Sipilä 1	Sipilä 1 n pump station and pump station manhole. Manholes in the area were not investigated	No leaks detected
April	Sipilä 2	Sipilä, 2 pumping station. Pumping Station manhole Manholes in the area were not investigated	No leaks detected. Top ring moved out of alignment.
April	Marjamäki	Marjamäen pump station and pump station manholes. Manholes in the area were not investigated	No leaks detected
May	Moisio 1	Moisio 1pump station and pump station manholes. Manholes	No leaks detected Manholes found with leaks 14103 Lowest seam leaks. 14 104 the cover provides access to inflow. 14 105 bottom joint leaks in two places. 14 108 wet ground, the lowest seam leaks. 14 119 wet ground, the lowest seam leak s. 14 203 impounded wastewater much.
April	Moisio 2	Moisio 2 pump station Pump station manhole Manholes (15201- 15220) were	Little leaks in the pipes inside the pump station No leaks The source of the upper pipe in the manhole could not be determined

		investigated and many were found leaking	Leaking manholes. 15 217 Leak s from the top of the inlet pipe. 15 218 Leak at the seams in two places. 15 220 leaks from several places. 15 267 A small leak at the seams.
April	Koivunokka	Pump station Pump station manhole Manholes numbers 18101 to 18109 were inspected.	One pipe at the base of the shutoff valve was leaking No leaks detected
May	Hollo	Pump station and pump station manholes. Manholes Pappilantien manholes inspected	No leaks detected 13 111 Leaks from the bottom seams. 13 112 house connection had very high flow rate
May	Tuuliala 1	Pump station. Pump station manholes. Manholes in the area were not investigated	No leaks detected Small leaks detected from the walls
May	Tuuliala 2	Pump station. Manholes in the area were not investigated	A leak from the internal pipe
May	Moisionlammintie	Moisio Lammintausta Road Pumping Station. Pump station manhole No manholes were investigated	No leaks detected. No leaks detected but there was an overflow with lots of water leaking in from the overflow pipe but it was stopped with a hose
May	Lohikalliontie	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Hulikka 2	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Hulikka 1	Pump station and pump station manholes No manholes were investigated.	No leaks detected

May	Kannistonpolku	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Asemakylä	Pump station and pump station manholes No manholes were investigated.	No leaks detected
June	Ostolantie	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Vastamäentie	Pump station. Pump station manholes. Manholes in the area were not investigated	No leaks detected Little amount of dirt at the bottom
June	Savontie	Pump station. Pump station manholes. Manholes in the area were not investigated	No leaks detected No leaks detected
May	Kotik. 1	Pump station. Pump station manholes. Manholes in the area were not investigated	No leaks detected
May	Kotik. 2	Pump station. Pump station manholes. Manholes in the area were not investigated	No leaks detected, but lots of dirt at the bottom No leaks detected
May	Vaihmala	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Laasonportti 1	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Laasonportti 2	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Pärjälä	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Pauninlahti	Pump station and pump station manholes No manholes were investigated.	No leaks detected
May	Pipu	Pump station and pump station manholes No manholes were investigated.	No leaks detected
April	Putkisto	Pump station pump station manholes No manholes were investigated.	No leaks detected No leaks detected. Overflow pipe cracked at the base.

April	Maakala	Pump station and pump station manholes No manholes were investigated.	No leaks detected
April	Maakalankuja	Pump station and pump station manholes No manholes were investigated.	No leaks detected
April	Vainionkuja	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Majauslahti	Pump station Pump station manholes No manholes were investigated.	No leaks detected, but lots of dirt on the surface. No leaks detected
April	Uoti	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Myllyvainio	Pump station and pump station manholes No manholes were investigated, a manhole in front of the pump station was not found even with a metal detector	No leaks detected
April	Jaakkola	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Hulaus	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Mattila 1	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Mattila 2	Pump station and pump station manholes No manholes were investigated	No leaks detected
April	Saksansaari	Pump station and pump station manholes No manholes were investigated	No leaks detected
June	Lumiala	Pump station	No leaks detected
June	Näsärö	Pump station	No leaks detected
June	Pirkkalantie	Pump station and pump station manholes	No leaks detected

7.1 Outcome of inflow and infiltration investigation

The data used for this calculation was obtained from the Lempäälä Municipality Water Utility Department data base, on water supply and wastewater estimate for different house types for each area connected to the networks. Also data for the calculation was obtained from the Wastewater treatment plant, on the volume of wastewater in m^3 that was pumped from each of the pump station to the treatment plant.

The purpose of the calculation was to determine the percentage increase in infiltration flow rate in the Wet-period, to determine the increase in cost of transporting the wastewater to the treatment plants.

The calculation for the infiltration was done based on the information obtained from, the Estimated wastewater flow rate which was obtained from the Utility department, and the amount of wastewater pumped from the various pump stations to the treatment plant which was obtained from the Treatment plant data base.

In the calculation pipe network distance was not used, size of the pipes, and the inflow were not considered in the infiltration calculation. The monthly estimate of wastewater flow rate, for the dry and wet periods in 2010 was obtained by calculating the average flow estimation of wastewater for a particular area for the whole year. The estimate of the wastewater flow rate is the same for the dry and wet periods, April was assumed to be the wet period and June the dry period all in 2010. To obtain infiltration rate, the monthly estimate of wastewater from each area was taken away from the volume of wastewater pumped from the pumping station connected to that area. Based on the amount pumped by a particular pump station the difference in the wet and dry periods were determined. The network connection was strictly followed while making this calculation so flows from connecting pump stations where calculated.

Infiltration was obtained by taking away estimated wastewater flow from Pumped wastewater for each area.

Infiltration in dry period was taking away the infiltration in the wet period to determine the cost of transporting the extra wastewater during the wet period.

Table 7.2 Flow rate and infiltration M^3/d, 2010 April

Areas	**Average monthly flow [m^3]**	**Infiltration volume [m^3]**
AHOSTI	9606.67	36797.04
ASEMAKYLA	541	1170.27
HALKOLA	896	681
HEMMINKILA	5671	26483.88
HOLLO	1291.08	4336.31
KARHUNPELTO	4314.42	13540.67
KESOIL SAAKJ	160.83	1230.35
KOIVUNOKKA	30244.25	49804.27
KOTITE KOULU	980.67	1064.24
KOTITE LISUU	749.5	1769.54
KULJU	21482.25	22585.72
LASTEN	429.3	1554.78
MAJA1	20673	15827.25
MOISIO 1	2820	5921
MOISIO 2	26035	22274.57
MYLLYKOSKI	80.5	247.18
MYLLYRANTA	2594.7	3220.39
RAJASILTA	166.75	1031.75
RYYNIKKA	9682.47	121440.73
SIPI 1	1420.45	919.58
SULKOLA	1995.42	9487.64
TATEKA	35	194.56
TUULI 1	1934.13	280.77
TUULI 2	165.83	575.2
UOTI	1110.25	-84
VALIMAKI	1792.75	14063
VANATTARA	23844.45	16968.55
IHAMAA	318.25	1482.59
VERAJANTAUSTA	1270.67	5730.77
HAKKARI	-15.67	30.8
SIPI 2	1186	2445.36
MOISIOLAMMEN	68.25	111.75
MUSTANIEMENT	2796.8	1826.2
HÖYTÄMÖ	663.92	-131.26
VAIHMALA	31	412.63
MARJAMAKI	2643.8	5556.2
PUTKITSO	901.7	17.37
PAUNINLAHTI	808.75	-18.79
PÄRJÄLÄ	800	3.67
HULAUS	207	359.61
LOHIKALIO	91.4	-52.6
RAUTIONIE	201.5	-61.84
MYLLYVAIN	31.8	90.2
MATTILA	79.5	264.2
HULIKKA	232.9	744.1
LAASONPORT	678.9	75.8

Table 7.3 Flow rate and infiltration in M^3/d, 2010 June

Areas	**Average monthly flow [M^3]**	**Infiltration volume[M^3]**
AHOSTI	9606.67	16157.57
ASEMAKYLA	541	676.61
HALKOLA	896	206.4
HEMMINKILA	5671	11656.4
HOLLO	1291.08	467.73
KARHUNPELTO	4314.42	5945.72
KESOIL SAAKJ	160.83	1020.83
KOIVUNOKKA	30244.25	13116.55
KOTITE KOULU	980.67	-120.03
KOTITE LISUU	749.5	146.38
KULJU	21482.25	1685.84
LASTEN	429.3	589.16
MAJA1	20673	-3268.2
MOISIO 1	2820	2104.86
MOISIO 2	26035	5479.33
MYLLYKOSKI	80.5	36.69
MYLLYRANTA	2594.7	831.83
RAJASILTA	166.75	435.27
RYYNIKKA	9682.47	54370.23
SIPI 1	1420.45	1374.31
SULKOLA	1995.42	2735.99
TATEKA	35	500.53
TUULI 1	1934.13	-1030.21
TUULI 2	165.83	119.82
UOTI	1110.25	-192.09
VALIMAKI	1792.75	6519.47
VANATTARA	23844.45	-1102.36
IHAMAA	318.25	1040.39
VERAJANTAUSTA	1270.67	2718.41
HAKKARI	-15.67	22.33
SIPI 2	1186	1038
MOISIOLAMMEN	68.25	10
MUSTANIEMENT	2796.8	-436.25
HÖYTÄMÖ	663.92	-414.4
VAIHMALA	31	2.45
MARJAMAKI	2643.8	3045.38
PUTKITSO	901.7	2.26
PAUNINLAHTI	808.75	-317.67
PÄRJÄLÄ	800	80.11
HULAUS	207	153
LOHIKALIO	91.4	-66.62
RAUTIONIE	201.5	-78.79
MYLLYVAIN	31.8	43.63
MATTILA	79.5	152.5
HULIKKA	232.9	418.59
LAASONPORT	678.9	-244.16

Both tables shows the final Outcome of both the wet period and dry period infiltration calculation for the whole area connected to the Lempäälä wastewater network.

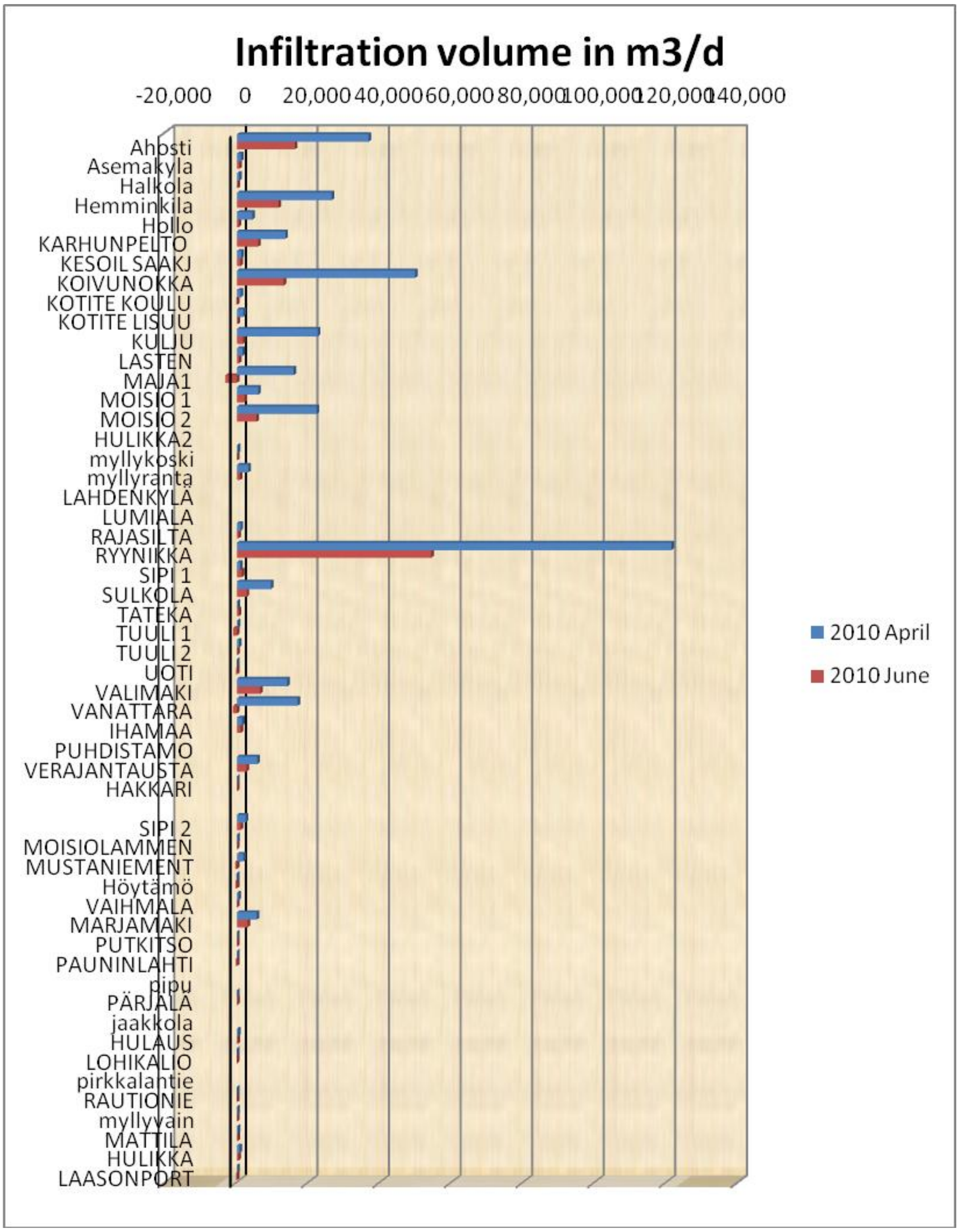

Figure 7.4 Graphic presentation of the infiltration flow for wet and dry periods.

Some of the areas which showed high infiltration wastewater in 2010 were investigated in 2011 and leaks were found. Such areas includes Moisio2, Vanattara, kulju, koivu, Hollo,and Hemminkila. In Ryynkka there was a very high flow but no leaks was found in the investigation in 20011.

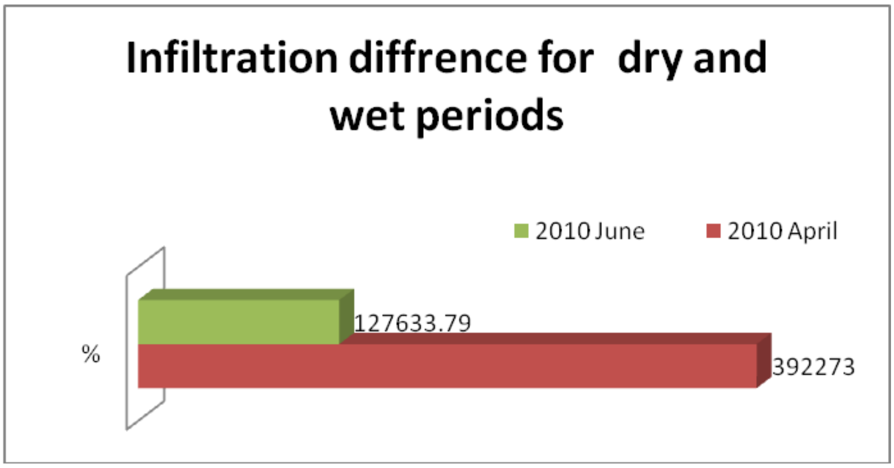

Figure 7.2 Percentage differences for the Peak and off peak flow rate

8. SUMMARY

A number of factors affected the accuracy of this result. Data for a number of areas were missing. This area includes Pipu, Rajapolku, Lumiala and Lahdenkylä. Also missing where data for jaakola and pirkkalantie. The monthly flow rate used for the calculation was actually the average monthly flow rate and not the actual monthly flow. Inflow from various sources (Rug washing spots, unsealed manholes and cracked manhole lids) were not considered at all.

From the results it would be seen that the average monthly infiltration rate in the Peak period increased to about 67% from the Off- Peak period, which was quite a high percentage and would increase pumping cost and transportation cost greatly.

The cost could be reduced drastically when missing data are included and when inflow is included too. But infiltration was quite high in a few area those areas should be investigated, such area includes Moisio2, Vanattara, Kulju, Koivu, Hollo,and Hemminkila.

The daily cost of treating wastewater in Lempäälä in 2010 went up by 2.3% in the wet period of one month. When the monthly flow is added up it is a huge cost to the municipality. More investigation should be carried out and aging infrastructure should be changed completely, if the life cycle cost of the network is to be reduced in the long run.

In order to reduce the problem of (I&I) the aging network infrastructure needs to be replaced and Investigative maintenance needs to be done more frequently to reduce the huge infrastructural damage and minimize spending in the long run.

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