“Understanding the Performance of a New Water Treatment Plant to Improve Water Quality Outcomes in Rural Minnesota”

Report by:

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The City of MORRIS MINNESOTA

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University of Minnesota EXTENSION

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1. Summary

The city of Morris draws its water from a Quaternary-age aquifer, which causes the city to have extremely hard drinking water. Specifically, it is hard because of dissolved calcium and magnesium. In the past, this hardness resulted in technical and aesthetic water quality problems, which is why an estimated 90% of all households and businesses in Morris used in-home ion-exchange water softeners that used salt. The community use of these water softeners created a lot of wastewater that was high in chloride concentration, and which accumulated in wastewater ponds and local ecosystems. Because chloride is toxic to aquatic life, the Minnesota Pollution Control Agency (MPCA) set a limit of 400 mg/L of chloride in any municipal wastewater discharges to the river. Before the new plant was built, Morris was exceeding that level by almost double, so something needed to change. The city built a new Water Treatment Plant, which has a built-in water softening technique that doesn't use salt -- but soda ash and lime, instead. The water is now softened from 45 to 5 grains of hardness per gallon before it pumped out to households in Morris. This report shares the story of how the city of Morris transitioned from a decentralized approach in water softening to a centralized approach.

The Water Treatment Plant serves a population of about 6,000 people and treats around 1,000 gallons per minute or 480,000 gallons of clean drinking water per day. The most important treatment steps are Aeration, Softening, Filtration and Chlorination. It costs around $500,000 a year to support the plant's operation -- the biggest costs are chemicals and trained staff.

Data from Morris wastewater shows that the implementation of the new Water Treatment Plant decreased the Chloride pollution by over 60%, which indicates that people stopped or decreased their use of water softeners. This highlights that the $19M project was a success and that the City of Morris is a role model in Integrated Water Resource Management.

2. Morris

FIGURE 1 MORRIS MINNESOTA (CBS)

Morris is a rural town in Stevens County, about 50 miles southeast of the North Dakota-South Dakota border in western Minnesota. It has a population of 5,100 and a size of 4.90 sq mi. About 0.22 sq mi are water bodies, including Lake Crystal, and the Pomme de Terre River, which is east of the town. Morris was platted in 1869 on the green prairie, and its economy has been dominated by agribusiness ever since. One of the largest employers is the University of Minnesota Morris, which has an enrollment of 1,100 students. UMN Morris has been ranked as one of the "Top 10 Liberal Arts Colleges" in the U.S.[1] The city of Morris is pursuing big goals in sustainability and carbon neutrality in collaboration with community partners, like UMN Morris. The community has an award-winning partnership called the "Morris Model" (morrismodel.org), which was mentioned in the New York Times in July 2022.[2] The city of Morris is also part of a transatlantic project led by the University of Minnesota called "Climate Smart Municipalities." The CSM program facilitates exchange knowledge between Minnesotan and German cities and is focused on climate protection and adaptation across multiple sectors.[3]

3. Context

Even though Minnesota is called the ''The land of 10,000 lakes,'' rural communities such as Morris have always had to address challenges related to drinking water supply, quality and distribution. One of the biggest problems is caused by the extreme hardness of the groundwater. Most rural communities in western Minnesota get their drinking water from groundwater sources. Morris, for example, has some of the hardest water in the whole country. The large amount of minerals, such as magnesium and calcium, can give the water an undesirable taste and causes problems in everyday household use, as well as technical problems. Because most of the citizens prefer soft water, nearly everyone had used in-home ion-exchange water softeners that required massive amounts of salt for operation. Eventually, this salty water, which was flushed down toilets, dishwashers, showers, etc., entered the sewage system and went all the way to the Morris Wastewater Treatment Plant (WWTP). Because there is no financially viable way to remove salt in sewage water, big amounts of chloride (a key compound of salt) ultimately ended up flowing into the Pomme de Terre River, which runs through the city. High concentrations of chloride are toxic to aquatic ecosystems, which is why the Minnesota Pollution Control Agency (MPCA) set a limit of 400 mg/L of chloride in the discharge of all municipal WWTPs. Because the city of Morris exceeded the limit by almost double the amount, something had to be done about their drinking water. Instead of fighting the regulations imposed by the MPCA, the city decided to tackle the problem. The city determined the best solution was to build a new Water Treatment Plant (WTP) that had a built-in water softening technique that didn't use salt -- but soda and lime ash, instead. At the newly built plant, the water hardness is reduced from 45 to 5 grains, so citizens have fewer reasons to use at-home water softeners and less chloride gets into the river. The $19 million dollar plant was finished in 2019 and almost entirely funded by a state grant. [4] [5]

The project and especially the cooperation between the City of Morris, MPCA and the Minnesota legislature is a prime example of Integrated Water Resource Management to improve drinking water quality in a rural Minnesotan city and protect aquatic ecosystems at the same time.

This report explores the new Morris Water Treatment Plant in simple language, explaining its basic functions, and highlighting how it has affected the community and ecosystem positively. It also explains why the plant is considered a role model, and how other rural communities with the same problems in rural Minnesota could benefit from these solutions as well. Furthermore, the report is part of an effort to raise awareness of options for a more sustainable municipal water supply and reduced chloride pollution. The report also explores how solar power could be integrated at the WTP, as a potential option to improve the carbon footprint of the plant, save on energy costs, and improve its resilience.

3.1 Morris as an example of Integrated Water Resource Management

Integrated Water Resource Management (IWRM) was first publicly discussed at the World Summit on Sustainable Development in 1992 in Rio de Janeiro and is a worldwide recognized concept for sustainable, social and financial use of natural water resources.

It basically advances the idea that water-related problems and challenges need to be addressed in a **multi-sectoral way** to meet the needs of different stakeholders. It is an exercise in systems-thinking. Regarding the water cycle, natural water resources are interconnected and highly sensitive to anthropogenic (human-based) influences such as pollution and climate change. [6]

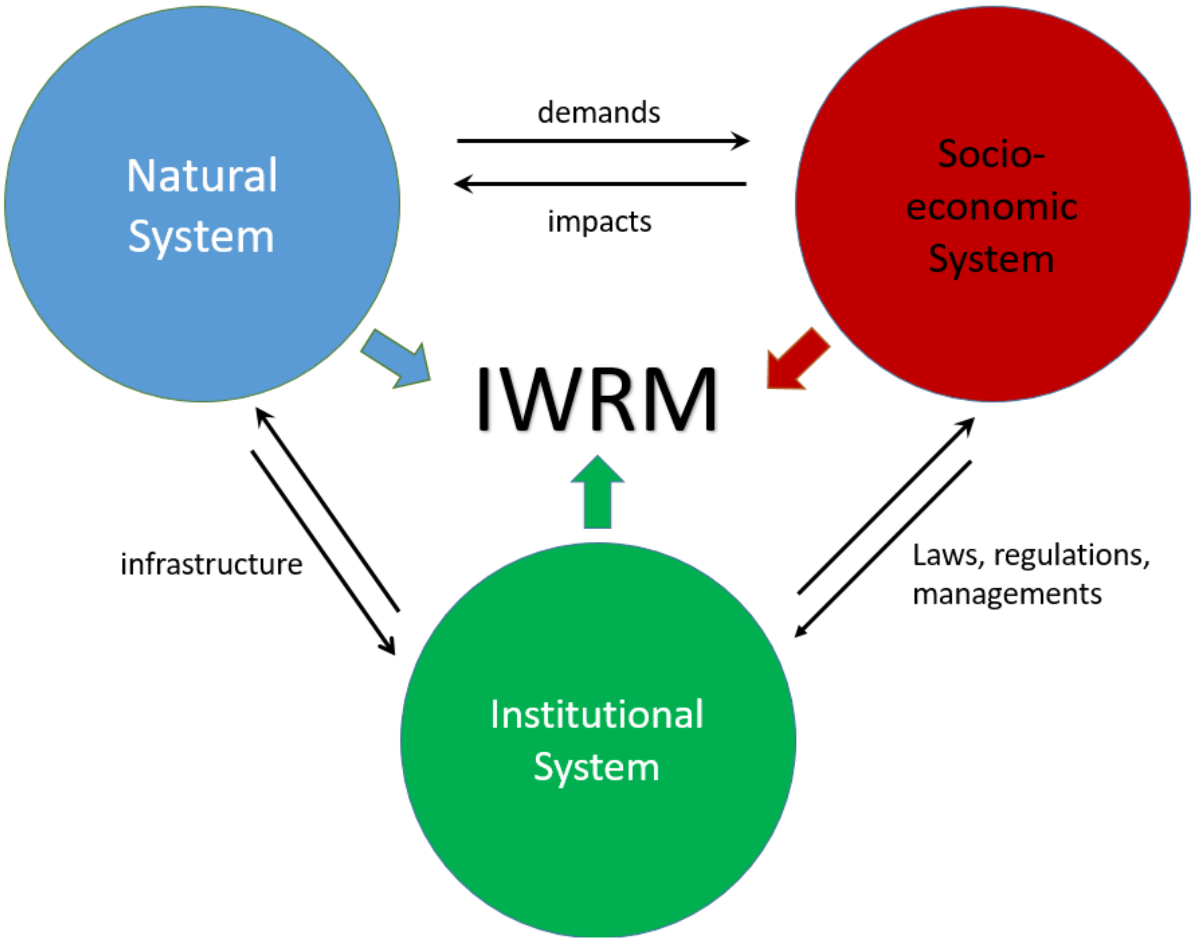


FIGURE 2 INTEGRATED WATER RESOURCE MANAGEMENT

In the context of the city of Morris, the natural system consists of large water bodies like the Pomme de Terre River and the natural groundwater in the aquifer under the city. These natural resources are impacted by the demands of the socio-economic system in two ways. Households and companies draw water out of the aquifer, while discharging treated wastewater into the river at the same time. The institutional system is formed by the city of Morris and the state of Minnesota. While the city of Morris manages the care of the infrastructure, like the water or sewage pipes and treatment processes, the state of Minnesota manages water quality using laws, regulations and limits. Each system is directly or indirectly influencing each other and needs to be acknowledged to address problems regarding the water quality and quantity outcomes.

3.2 DPSIR-Framework for Morris

The DPSIR (**D**rivers, **P**ressure, **S**tate, **I**mpact, **R**esponse) framework is a widely used framework in environmental studies to identify interactions between society and the environment. It is an illustrative tool to simplify the complex interconnections between human use of natural resources and the impact on ecosystems.[7] The following figure demonstrates the DPSIR-Framework for the **Morris Water Hardness and Chloride Discharge Problem**, and helps us get a bigger picture on the general problem.

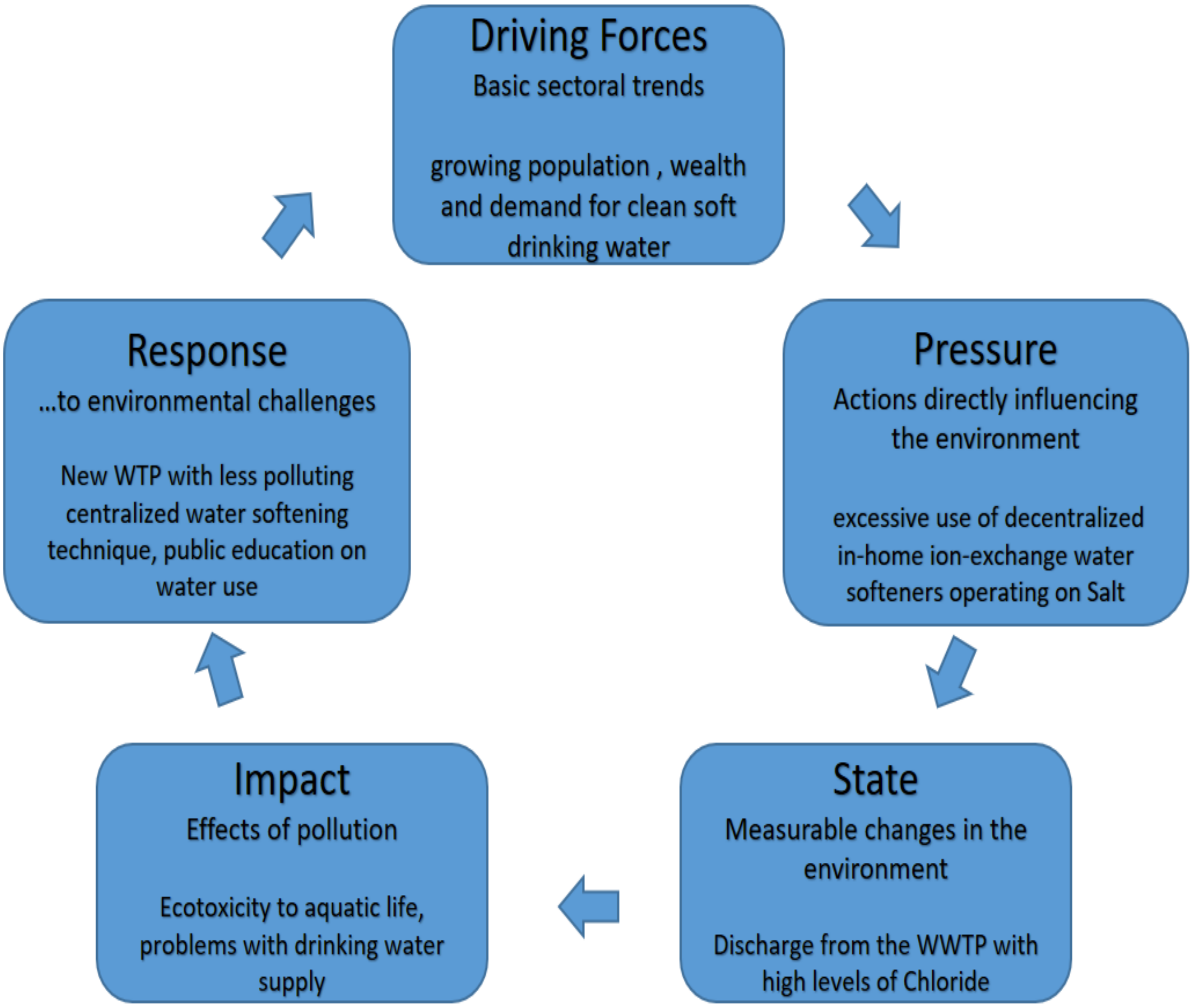


FIGURE 3 DPSIR FRAMEWORK FOR THE CITY OF MORRIS

4. Water Chemistry Basics

4.1 What is hard water and where does it come from?

Water hardness is defined as the measurement of dissolved metal cations, of which calcium (Ca2+) and magnesium (Mg2+) are the most abundant. It is mostly determined by the underlying geological structure and stone formations, through which water from precipitation travels to the aquifer. Hard groundwater is common to most places in the U.S., while very hard water can be found in the Midwest, Texas and Florida. [8]

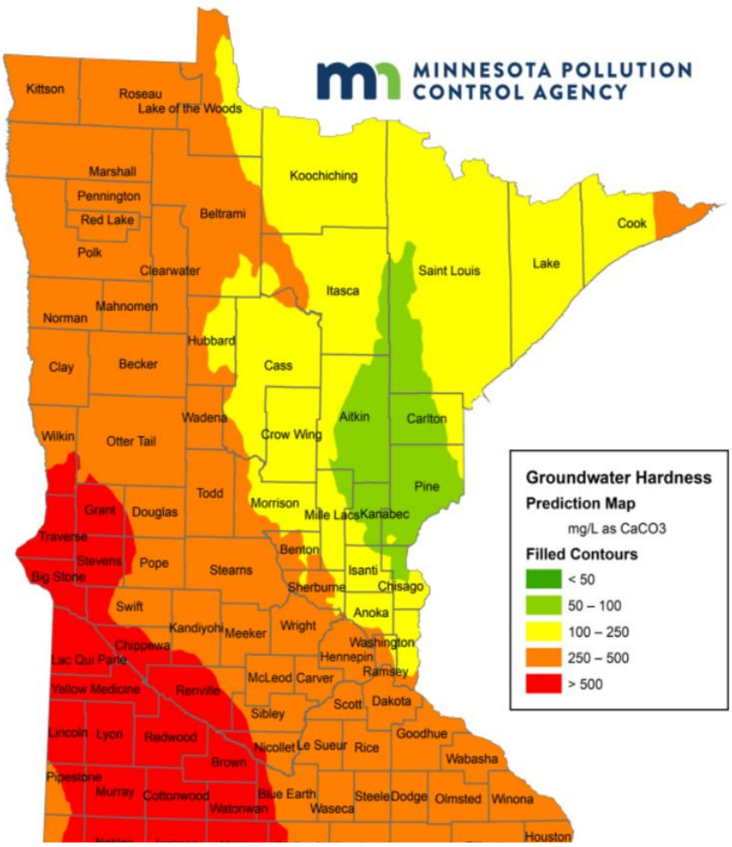


FIGURE 4 WATER HARDNESS MINNESOTA (MPCA)

Total water hardness consists of two categories, carbonate and non-carbonate hardness. Carbonate hardness is determined by the amount of carbonate and bicarbonate salts of calcium and magnesium and is sometimes called ‘’temporary hardness,’’ because it can be removed by heating the water above 61C/141F. On the other hand, non-carbonate hardness cannot be removed by boiling and is therefore called ‘’non-temporary hardness.’’ It mainly consists of dissolved sulfates, nitrates and chlorides such as CaSO4 and MgCl2. The distinction between those two categories becomes crucial in the complex water softening process of the plant. [9] Magnesium hardness is caused by complexes with Mg2+, and Calcium hardness is caused by complexes with Ca2+. Total water hardness is usually reported in mg/L (=PPM) or Grains per gallon of Calcium Carbonate (CaCO3) equivalents and is differentiated in classes ranging from soft to very hard. Classification usually differs from organization but can be defined as followed:

TABLE 1 WATER HARDNESS CLASSIFICATION IN CACO3 EQUIVALENTS [10]

	Milligrams per liter (mg/L) or parts per million (ppm)	Grains per US gallon (gpg)
Soft	0-60	0 - 3.5
Moderate	60-120	3.5 - 7.0
Hard	120-180	7.0 - 10.5
Very Hard	> 180	> 10.5
Morris Groundwater	770	45

The city of Morris draws its drinking water from a Quaternary-age water aquifer that is located between layers of limestone, which is naturally rich in calcium and magnesium. Water from precipitation (like rain and melted snow) seeps through the rock formations and dissolves the minerals to accumulate in the aquifer. [11] This causes Morris's water to have one of the highest hardness levels in the US states -- ranging up to 45 gpg or 770 mg/L, which would be classified as very hard or even extremely hard. As Figure 4 shows, extremely hard water above 500 mg/L is common to south-western Minnesota and poses challenges to the water distribution of the city of Morris and neighboring counties as well.

4.2 Is hard water dangerous and why is it a problem?

Various studies and the World Health Organization confirm that hard water has no known adverse health effects. Hard water and very hard water could be even seen as a supplementary contribution to a healthy diet, because calcium and magnesium are essential minerals to the human body. Assumed negative effects, such as the increased likelihood of cancer or cardiovascular disease could not be confirmed significantly. Therefore, despite the degree of hardness, Morris's drinking water is drinkable and safe. However, a lot of people prefer the taste of soft water over hard water.[12] The problems mainly occur in everyday use, because hard water requires more soap or detergent, while feeling unpleasant on the skin and creating dingy laundry at the same time. When hard water evaporates or gets heated it leaves white lime scale (calcium carbonate) or ''water spots" on silverware, glassware or plumbing fixtures. When the pH level is too low, limescale can also build up in equipment and pipes, causing a decrease in water pipe carrying capacity, which has caused other technical problems in the city of Morris in the past. [13]

FIGURE 5 LIMESCALE BUILT-UP IN PIPES (ENVIROFLUID)

FIGURE 6 WATER SPOTS (KINETICO)

4.3 What were citizens required to do before the new plant was built?

In order to reduce water hardness and to avoid any negative effects listed above, 90% of the 1,972 households in Morris used in-home ion-exchange water softeners. They are usually located in the basement, where municipal water supply lines enter their house. [14]

Ions are small atoms or molecules with either positive or negative electric charge. The process of "ion exchange" describes the process of replacing hardness-causing ions (like Mg^{2+} or Ca^{2+}) with non-hardness causing ions, such as Sodium (Na^+). Sodium is provided by manually loading the water softener with table salt ($NaCl$), which dissolves into a brine containing Sodium (Na^+) and Chloride (Cl^-).

The basic process which most water softeners operate on can be divided into two steps: the softening process and the recharge process (Figure 7). During the softening process the hard water enters the Water Softener Tank, which is filled with microporous material, usually sulfonated polystyrene beads. These beads are loaded with loosely held Sodium Atoms. As the hard water passes through the tank -- the beads exchange the Sodium Ions with Magnesium and Calcium Ions. The softened water containing Sodium is ready for in-home use and is distributed throughout the household.

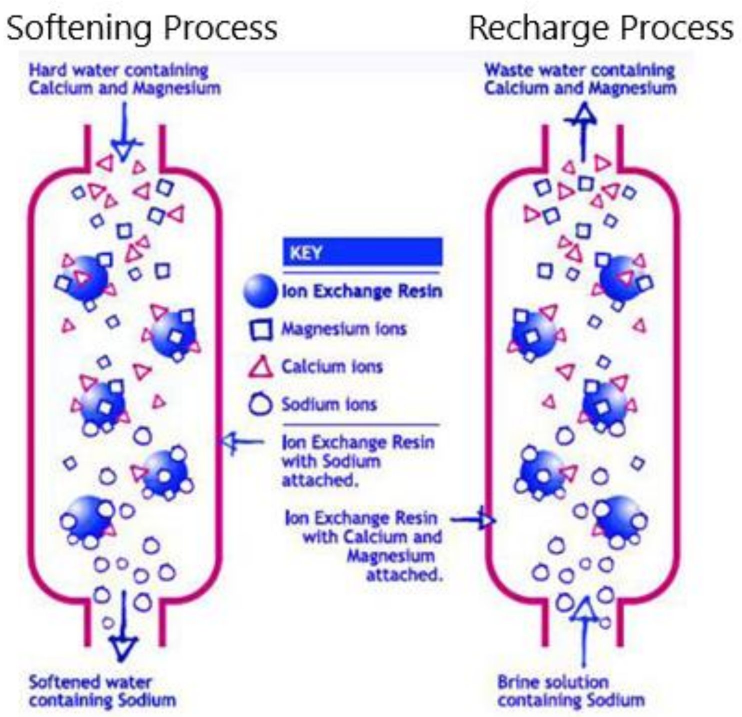


FIGURE 7 ION-EXCHANGE IN A WATER SOFTENER (NDSU)

After a while the beads in the tank get supersaturated (filled up) with Magnesium and Calcium, and the water ion-exchange stops. The water will no longer become softened, so the recharge process needs to take place. During the recharge cycle, the tank gets backwashed with brine (salty water). The Calcium and Magnesium ions on the beads are replaced again with Sodium Ions. During the recharge cycle, the wastewater leaving the water softener and flowing into the municipal sewage system is high in Calcium and Magnesium, and the trouble-causing Chloride ions as well. The Water Softener is now recharged and ready for further use. This process can be repeated over and over if enough table salt is provided by the operator. [15] One recharge cycle happens around every two days and discharges around 27 Gallons of water with high Chloride concentration into the sewer. [16]

There are different types and sizes of in-home ion-exchange water softeners, but they could be generally divided into two categories, high- and low-efficiency systems. Water softeners that are recently installed are usually high-efficiency systems that use 1 pound of Salt to soften 5,000 grains of hardness. They only operate on-demand and therefore use 80% less salt than low-efficiency water softeners that would use 5 pounds of salt for the same result.[17] The water softener should always be designed for the actual amount of water that is used in the household, and adjusted to the hardness of the municipal water in the settings.

FIGURE 8 CITY MANAGER BLAINE HILL ADJUSTING HIS HIGH EFFICIENCY WATER SOFTENER (MPRNEWS)

4.4 How does chloride enter the ecosystem?

There are multiple ways that Chloride enters aquatic ecosystems. The MPCA estimates that about 42% of statewide Chloride pollution comes from de-icing roads, 23% from agriculture, 22% from municipal WWTPs and the rest from other minor natural or anthropogenic sources such as residential septic systems. [18] Because Morris is considered a rural city with a lower density of roads and has extremely hard water, the WWTP likely contributes more Chloride pollution compared to statewide values. While there is no data for road de-icing, studies suggest that 81% of chloride pollution flowing into the WWTP came from residential ion-exchange and 19% from industrial or commercial ion-exchange water softening in the year 2014, before the new WTP was built. [19]

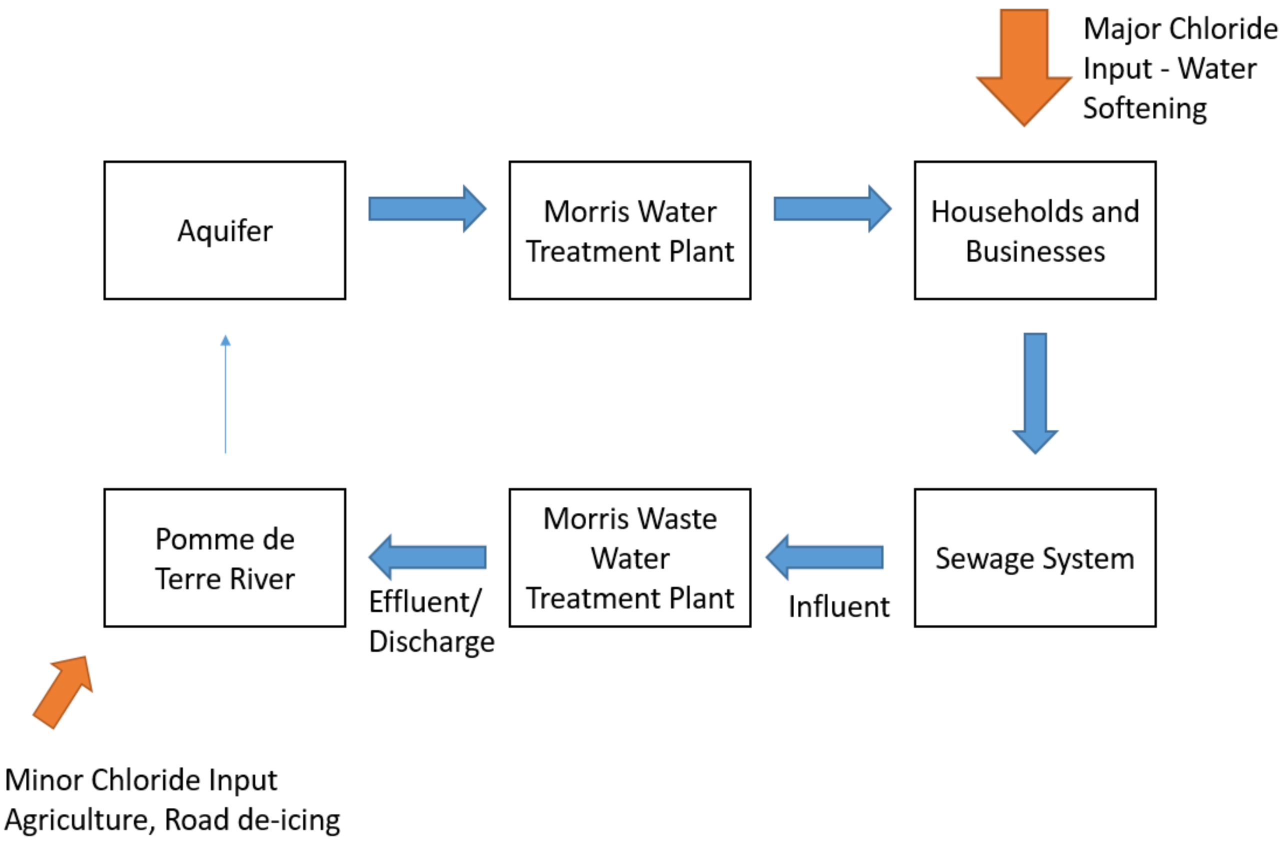


FIGURE 9 URBAN WATER CYCLE FOR THE CITY OF MORRIS

Figure 9 simplifies the previous urban water-cycle for the city of Morris. Raw water was drawn from the aquifer and was treated in the Morris WTP. From there water was distributed to households and businesses, where the major input of Chloride was taking place. The discharge from in-home water softeners entered the sewage system underground as influent (the water flowing into a process) to the **Morris Waste Water Treatment Plant (WWTP).**

FIGURE 10 MORRIS WWTP (GOOGLE EARTH)

The Morris Wastewater Treatment Plant (WWTP) consists of 5 pools with a total area of 0.23 square miles and treats 0.7 MGD (Million Gallons per day) of sewage that comes from the 6,000 inhabitants and several businesses within the city of Morris. The treatment process is quite simple, but effective, and mainly consists of sedimentation and natural biodegradation by adding bacteria. Some of the pools get dyed with dark, water-safe colorant to block off certain sun rays to prevent excessive algae growth. While overall discharge parameters (like CSB, bacteria levels…) can be met, there is not a financially viable or technically reasonable way to extract Chloride from the treated wastewater.

The plant is designed to retain incoming sewage for 180 days and to discharge twice a year from pool 4 or 5. One discharge event consists of releasing water for 8 days at 6 inches/day, so that the water level of the last pool is reduced by 4 feet in total. After testing the Chloride concentration in an external lab in the Twin Cities (Appendix 7.1), the treated water is slowly diluted with the Pomme de Terre River water to prevent heavy oxygen depletion that could possibly lead to fish dying or algae blooming. [20]

Agricultural work and road de-icing are minor inputs of Chloride Pollution that directly or indirectly enter the Pomme de Terre River through infiltration or storm water drainage.

4.4 How is chloride affecting the ecosystem negatively?

While small amounts of Chloride are essential for the survival of plants and animals as a micronutrient, too much Chloride discharge from WWTP affects entire ecosystems negatively and can be toxic to aquatic organisms. Because there is no significant natural degradation process, long-term inputs lead to accumulation and high concentrations of Chloride in aquatic water bodies, such as rivers, streams and lakes. Higher salinization has a variety of negative effects on chemical and biological water quality, such as acidification of streams, higher levels of toxic metals, interfering or inhibiting microbiological processes that are crucial for removing nitrate and maintaining a healthy milieu for aquatic and terrestrial life. [21] Its ecotoxicity on water life, including plants and fish, is mainly determined by interfering with the osmotic pressure in their cells, which basically means that their management of bodily fluids is impaired. For example, long term exposure above 800 mg/L leads to toxic effects on catfish, trout, snails or carp. [22] Combined with the consistently elevated levels of Chloride, further fluctuations caused by intense drought and heavy rainfalls and/or sudden discharge from the WWTP can aggravate the already high ecotoxicity. Any impairment of even one or more taxa can lead to unpredictable negative effects on other ecosystems nearby, caused by changing nutrient spiraling and disruptions of sensible and complex food webs. [23]

Furthermore, Chloride pollution of surface water enters groundwater systems via infiltration, which ultimately creates a new problem affecting the drinking water supply. While high concentrations of Chloride promote negative health effects and taste degradation, already 30% of wells in the Twin Cities exceed the EPA drinking water guideline. [24] Additionally, dissolved Chloride ions increase the corrosivity of the water, resulting in higher concentrations of toxic metals that are used in plumbing material, such as lead (Pb), copper (Cu) and iron (Fe). [25]

5. The new Morris Water Treatment Plant

In order to solve the water problems discussed above, the city came up with the best possible solution, building a new Water Treatment Plant with a centralized Water Softening Process. The plant was designed by Bolton & Menk Engineering Company and was finished and ready for operation in June 2019. It is considered a high-technology solution to help the city provide the best financial and eco-friendly way to ensure the supply of clean drinking water to the city and protect water quality outcomes at the same time.[26] The total cost for planning and building was about $19 million, three quarters of which was financed by a state grant.

FIGURE 11 MORRIS WATER TREATMENT PLANT

The following picture shows the control panel, as it is used in the plant itself. The control panel can be used to examine every treatment step individually and to control and monitor the chemical and mechanical processes. The whole operation can be started and supervised remotely via laptop or phone, if no engineer is at the plant.[27] The most important components of the plant are numbered and explained in more detail in the following Walkthrough (5.1)

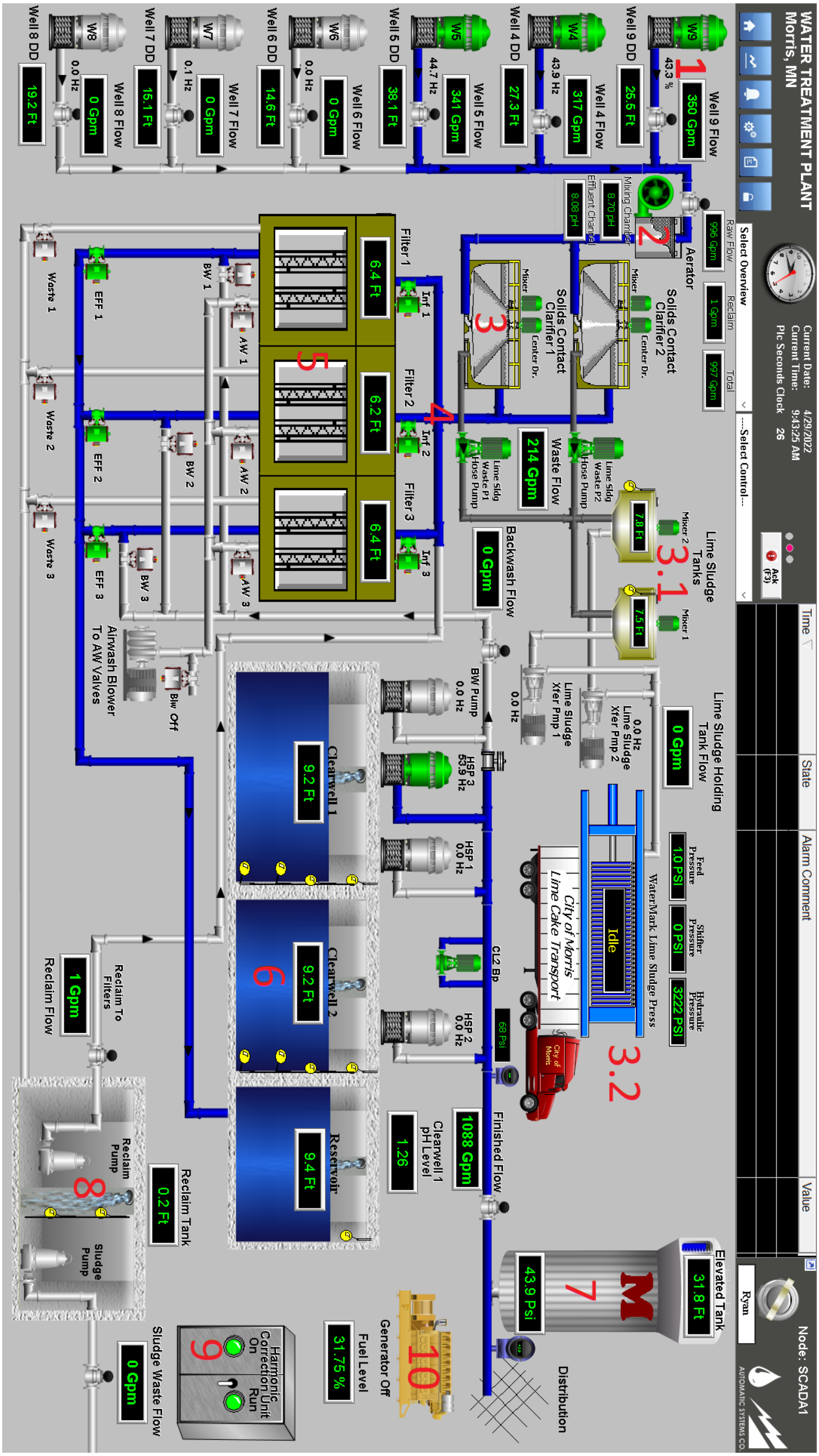


FIGURE 12 MORRIS WATER TREATMENT PLANT SCHEMATIC

5.1 Treatment Steps – Walkthrough

The following Walkthrough explains every major treatment step, as it can be seen in the control panel above. In order to visualize it even further, the following Figure 13 simplifies the way the Water flows through the plant by using a flowchart. After that every treatment step is explained in more detail. Non-quoted information in this chapter originates from a personal visit at the Plant on 04/28/22.

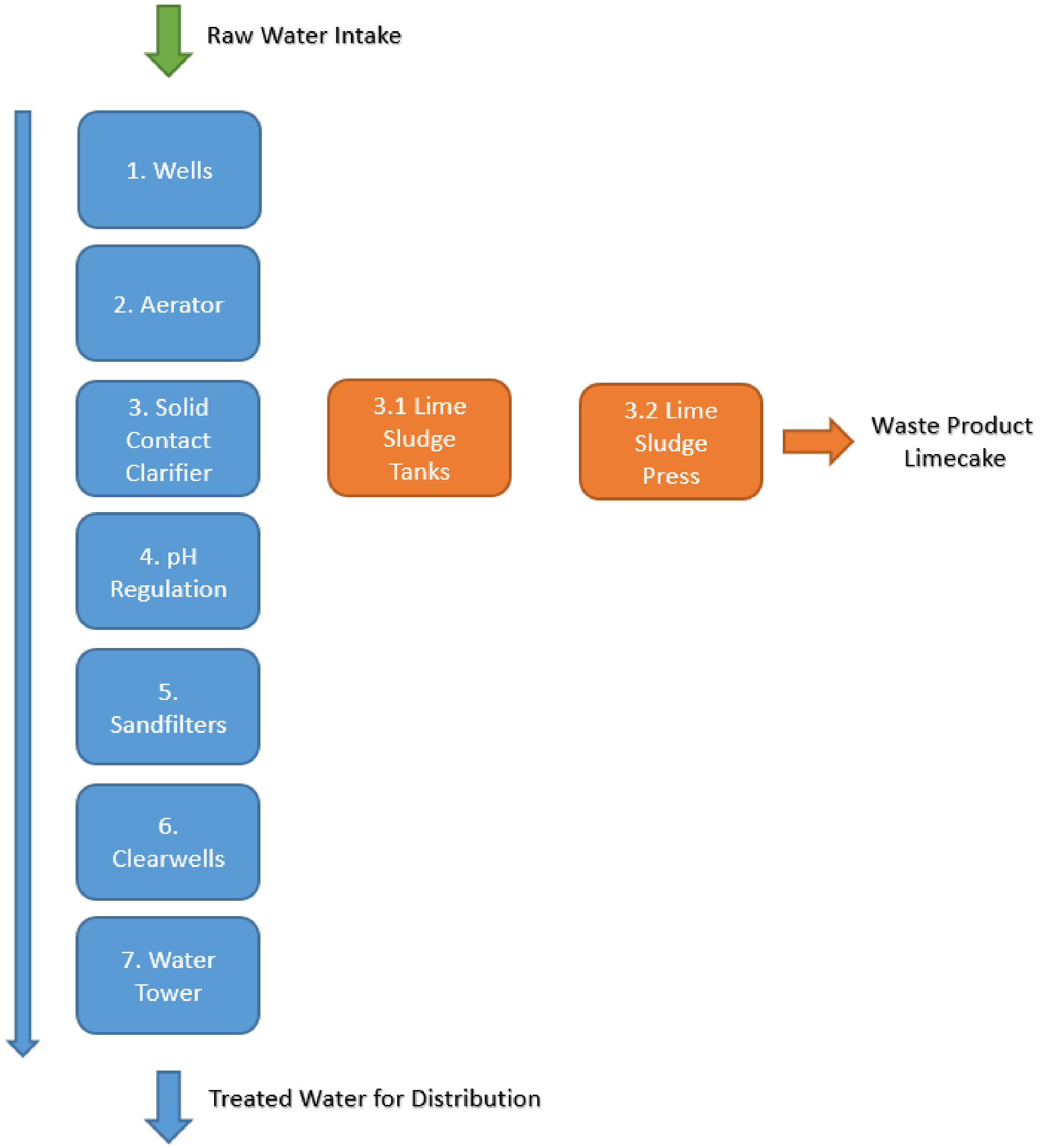
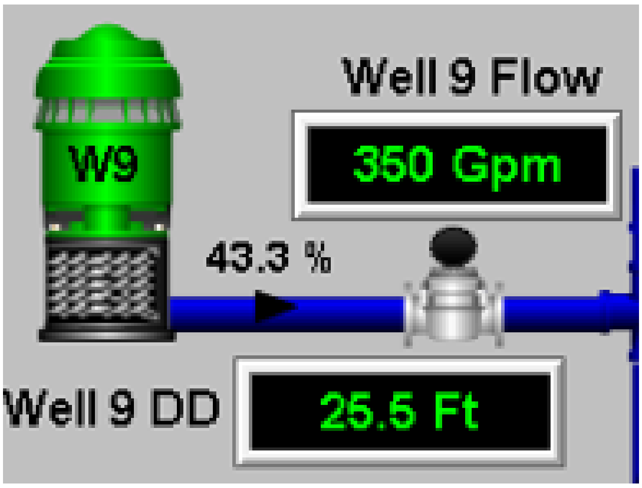


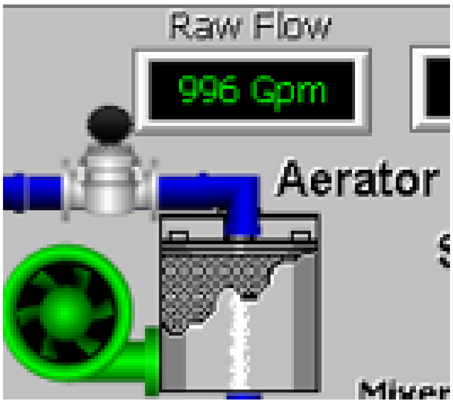
FIGURE 13 FLOWCHART - MORRIS WTP

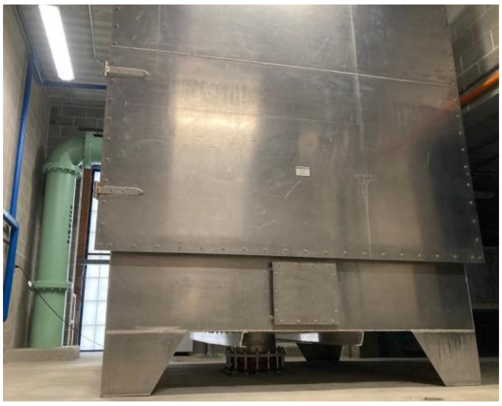
1. Wells



The first step in the water treatment process is extracting raw water out of the Aquifer right underneath the facility. The Morris WTP makes use of 6 individual operating wells W4 to W9, which are roughly 60 to 80 feet deep to pump water to the surface by the use of pumps. There are three wells operating simultaneously that can reach the plant's maximum treatment capacity of 1,800 Gallons per minute (gpm). In order to secure the best treatment outcomes, the 3 pumps combined usually operate at only 1,000 gpm. Every month the Engineers rotate the pumps. Raw water with a pH level of 7.4 flows from the pumps through 6-inch plastic pipes to the next treatment step, the Aerator.

2. Aerator





The aerator uses an electrified fan to mix raw water with unfiltered outside air to saturate the water with Oxygen. The Oxygen helps with two groundwater-related problems. First it gets rid of the "rotten-egg smell" that is natural to groundwater that has a low oxygen content, by oxidizing the Hydrogen Sulfide (H2S). At the same time it oxidizes the dissolved iron and manganese, for further extraction.

$Fe (HCO_3)_2 + ½ 0_2 + H_2O \longrightarrow 2 FeO(OH) \bullet H_2O + 4 CO_2$

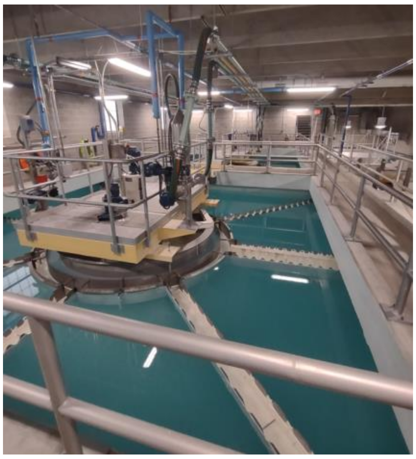
Dissolved Ferrous Bicarbonate oxidizes to insoluble Ferric Hydroxide

$Mn (HCO_3)_2 + ½ 0_2 \longrightarrow MnO_2 \bullet H_2O + 4 CO_2$

Dissolved Manganese Bicarbonate oxidizes to insoluble Manganese Oxide[28 29]

The resulting iron and manganese complexes are not soluble in water and create a precipitate, forming dense flakes, which are filtered out in the solid contact clarifier or sand filters in the next steps. Making an element that is dissolved in water come out of solution and become a solid is called precipitation. At the same time, chlorine is added for the first time, which helps to oxidize the iron even more.

3.1 Solid Contact Clarifier (SCC)



From there the water flow is split into separate pipes going to the two SCC units, which are both controlled independently of each other. The SCC is where the water softening process is taking place and is one of the main reasons why the plant was built in the first place. The SCC combines the process of mixing, flocculation, and sedimentation in a single tank that has the shape of a cone. Flocculation is a process where chemicals are added that work to bind smaller particles together into bigger flakes. Once the particles become bigger flakes, they start to get heavy and fall downward into the tank, which is called sedimentation. **Significantly different from the in-home ion-exchange water softeners, the SCC is not operating with the use of salt -- but soda ash and lime instead, so it is not adding chloride to the wastewater**. [30]

The raw water gets pumped into the bottom of the SCC. The tank uses a turbine, that creates axial and radial flow, to rapidly mix the water with the two added softening chemicals, which are Lime ($Ca(OH)_2$ - Calcium Hydroxide) and Soda ash (Na_2CO_3 - Sodium Carbonate). Lime is used to reduce the carbonate hardness, while soda ash is added to take care of the non-carbonate hardness. The whole chemical process is rather complicated but can be simplified:

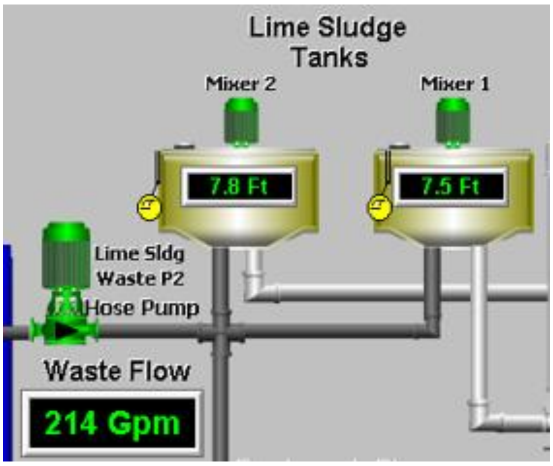
1) Hardness caused by Calcium reacts to form Calcium Carbonate ($CaCO_3$)
2) Hardness caused by Magnesium reacts to form Magnesium Hydroxide $Mg(OH)_2$

The resulting chemicals precipitate, which means they form a thick dense lime sludge that falls to the ground of the SCC.

The amount of chemicals that are added is regulated automatically depending on the hardness of the raw intake water, but can be changed manually as well. During this step, the pH rises to 11.5, which is crucial for the non-carbonate hardness removal.[31]

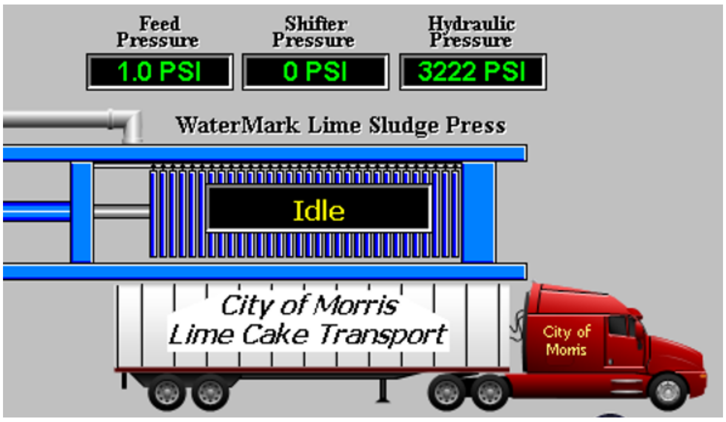
The softened water flows to the top of the SCC and is collected via overflow for the next steps of treatment. **This treatment step can reduce the hardness of 45 gpg in the raw water to about 5 gpg in the treated water.** The waste product of the chemical reaction accumulates at the bottom of the SCC in a thick lime sludge. It mainly consists of the extracted minerals, such as Calcium, Magnesium and a lesser amount of Iron and Manganese.

3.2. Lime Sludge Tanks



After the SCC, the material flow splits into two separate treatment lines. The softened water flows to the sand filters, while the waste of the chemical process flows to the Lime Sludge Tanks for storage. The thick sludge gets pumped out of the bottom of the SCC to the two Lime Sludge Tanks for further treatment. The sludge is diluted with raw water to make handling through pumps and pipes easier to manage. They are both equipped with a big motorized mixer, to prevent the sludge from settling and clogging up the equipment.

3.3. Lime Sludge Press



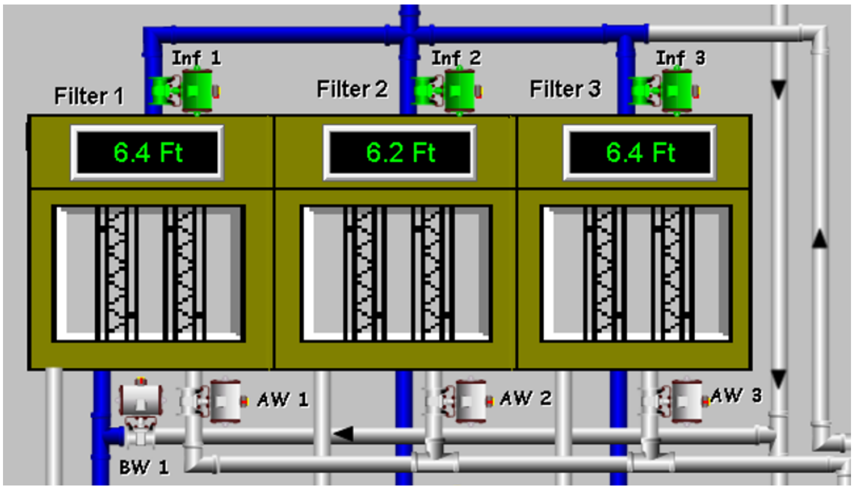
Next, the sludge gets drained of excess water at the Lime Sludge Filter Press.

The semi-automatic hydraulic press separates the sludge into two parts, the solid filter cake, also called lime cake, and the liquid filtrate. The filtrate gets pumped to the reclaim water tank, to be reintroduced to the water treatment process at the start of the plant, while the filter cake gets dumped into a trailer 8 to 12 times per week. The plant produces 48 tons of lime cake weekly, which is 2 trailers a week. It gets used on farmer fields as fertilizer.

4. PH Regulation

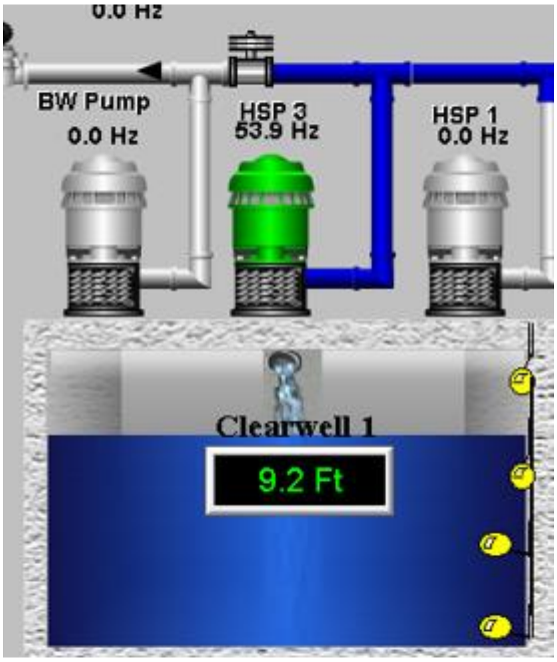
After the SCC the softened water flows to the pH regulation unit, to reduce the pH level from 11.5 to around 9.6 with the use of CO_2 injection to rebalance the equilibrium of calcite and carbonic acid. If the pH is to low, the water causes more corrosion in metallic pipes. A raised pH level would result in lime scale buildup in the pipes. Generally, if something has a pH of 7 is it considered neutral, if it is below 7 it is considered acidic, and if it is over 7 is it considered basic, also called alkaline.

5. Sand Filter



The next step in the Morris Water Treatment Plant is Filtration using 3 conventional-gravity slow-speed Sand Filters. Filtration is a key element of removing non-dissolved solids and involves the processes of physical and chemical adsorption and sedimentation.[32] The actual filter has a surface space of 20 ft by 12 ft, and consists of three critical layers, the filter media, gravel, and underdrain block (see Appendix 7.2). The Water is pumped onto the filter media, where it is dammed up to 6 feet. From there it slowly percolates through the filter media that consists of 2.5 feet of fine sand. Under that there is a 1-foot layer of gravel that prevents the filter media from escaping into the underlying drainage system. The drainage block collects the filtered water underneath and brings it to the pump unit, where it will get pumped to the Clearwells afterwards. While passing through the filters the pH-Level drops another 0.5 to meet the perfect pH Range for Water distribution of around 8 to 9 pH. The Filters are mostly running at the same time, but can be turned off individually for maintenance or troubleshooting. The amount of non-dissolved solids accumulates on the filter media over time so that the filter needs to be backwashed by an Airwash Blower (AW) every 100 hours of runtime. The blower uses air and already treated water from the Clearwell to clean the sand and reactivate the filter for further use. This happens about once per week in winter and two times per week in summer due to the higher demand. The sludge created by the Airwash Blower gets pumped to the reclaim tank at the end of the plant for further water reuse.

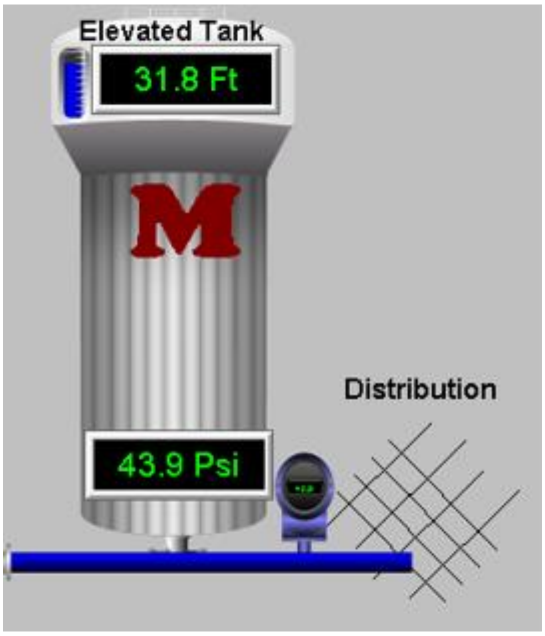
6. Clearwells



Before the already treated water goes to the Clearwells, it gets chlorinated for the second time to meet the target concentration of Chloride of 1 mg/L. Chloride is mostly used to disinfect the treated water, to prevent bacteria built-up and the cause of waterborn illnesses in the distribution net. At the same time Fluoride is added at 1 mg/L as well. Fluoride is a widely used in American Water Treatment and is a typical additive that is used for making human teeth stronger and more resilient to cavities.

From there the water flows to 1 of the 3 underground Clearwells for additional storage of fully treated drinking water. The 3 Clearwells together have a capacity of around 500,000 gallons or roughly 1,900 cubic meters, which means that the plant with a demand of 1,000 gpm would need to run 9 hours to fill up the whole storage capacity.

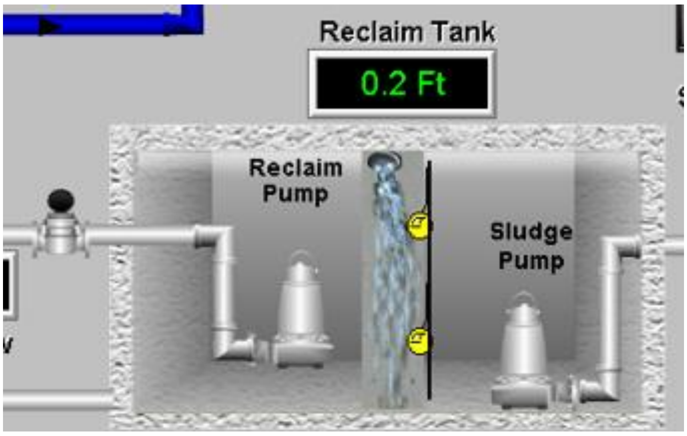
7. Water Tower and distribution



An additional 750,000 Gallons of storage is provided by the famous 100 ft high Morris Water Tower. Contrary to what many assume, only the elevated tank, which has a length of 40 ft, holds all the Drinking Water. The entire structure is not filled with water. The elevated tank is so high off the ground that the water in the line from the tank to the ground is under a lot of pressure. The little pipe under the elevated tank is under enough pressure that it can distribute the water throughout Morris and all the way to Alberta without any additional pumping energy needed. Once the Water Tower runs out of water it tells the WTP automatically to pump freshly purified water from the Clearwells all the way up to the tank at the top of the Tower. That usually happens before the start of the peak demand in the morning or at late noon.

Additional Components:

8. Reclaim Tank

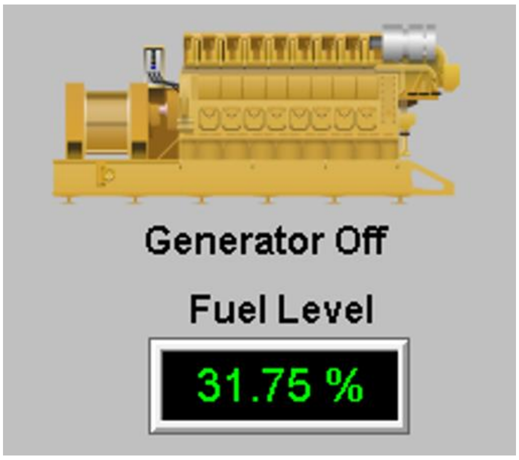


The Reclaim Tank at the end of the MWTP is used to recycle any accumulating waste water that is a by-product of the water purification process. The Tank is mainly fed by the filtrate of the Lime Sludge Press and the wastewater that gets produced while backwashing the sandfilters. It makes use of an easy sedimentation process, where most of the non-dissolved solids such as residue of the softening process settles to the ground. The surface water of the reclaim tank gets reintroduced to the water treatment process at the Sandfilters, while the accumulating sludge gets pumped into the municipal sewage system. This method makes the whole process more sustainable and efficient because very little water is wasted.

9. Harmonic correction unit:

The Harmonic Correction is an important component in the Electrical Room. It filters out damaging harmonic currents from the power grid, allowing pumps to run at their designed frequencies.

10. Generator:



The Morris WTP is equipped with a Caterpillar Model C52 Diesel Generator that has a maximal capacity of 1000 kW. It becomes super important in case of power outages, which are not very common for this region. Even if there is no power in the whole City, the Plant would be able to provide clean Drinking Water nevertheless. In May 2022, the city of Morris experienced a severe wind event, called a derecho, which knocked out power across the entire city, and affected the normal operation of both the Morris WTP and WWTP.

5.2 Is the Morris Drinking Water safe to drink?

Every municipal drinking Water Supply, including the Water out of the Morris Water Treatment Plant is subject to the regulations of the federal Safe Drinking Water Act (SDWA) administered by the Environmental Protection Agency (EPA) and is therefore heavily monitored by the Minnesota Department of Health (MDH). Even though Morris drinking water comes from groundwater and is less likely to be influenced by pollutants compared to surface water, a lot of testing needs to take place.[33] Just like nearly 99% of all Community Public Water Systems in Minnesota, Morris Drinking Water has no problems regarding the limits and regulations.

In order to monitor the effectiveness of the treatment process, the engineers at the plant test daily for pH levels and total hardness. Monthly measurements are taken for iron, manganese, fluoride, and chlorine. Bacteria tests are usually taken 3 to 4 times a year and take place at various points throughout the distribution system. They measure the amount of *total coliform bacteria*, which is an indicator for bacterial contamination, which could cause waterborne illnesses, and is most likely caused by the wrong dose of disinfectants or water stagnation in the pipes. [34] Additionally, there are multiple other parameters that are monitored in external laboratories on a yearly basis or less, such as Nitrate/Nitrite, Inorganic Chemicals, Radioactive Elements, Disinfection Byproducts, Copper and Lead. [35] Lead cannot be found in the Water that leaves the Plant. However, there is a chance that old houses in Morris (built before 1950) still use lead water pipes that could cause high lead levels that would greatly exceed the federal standards. Those pipes may create big health risks and should be changed immediately[36]. But to answer the question conclusively: Morris Water is safe to use and safe to drink. Nevertheless, should any problems occur, which is very unlikely, the residents would be informed immediately through public announcements via radio or newspaper.

FIGURE 14 BACTERIA TESTING (BRELJE&RACE)

5.3 Material Flow and Operation Costs

The Morris Water Treatment Plant treats and provides roughly 480,000 gallons of clean drinking Water a day, which adds up to about 170 million gallons annually. The operating costs to the city are estimated at around $500,000 annually or $40,000 a month, which does not include additional costs such as taxes, property costs, loans, and permit costs (Figure 15).

FIGURE 15 OUTPUTS AND INPUTS SCHEME

Inputs:

The biggest input to the Plant is obviously the raw water that the Plant draws from the Aquifer. In order to do so the city pays a small fee to the State of Minnesota according to a federal permit. [37] The chemicals needed for treatment make up over half of the annual operating budget -- about $300,000 a year. This includes a variety of chemicals, such as Soda Ash and Lime for the Softening Process, liquid CO_2 for the pH control, and additives like Chloride and Fluoride. Another factor is the Energy Input, which gets bigger attention in Chapter 6. The multiple pumps and moving parts throughout the plant use about 2,100 kWh daily or 747,000 kWh yearly, which rounds up to $65,000 in Electric Utility Costs per year (Appendix 7.3).

Outputs:

Flowing out of the Plant is the treated Drinking Water that the city sells to citizens or companies for around $4.60 per 100 cu. ft. or $0.006 per Gallon (+ additional fees). [38] The second major output of the plant is Lime Cake. Lime Cake is the powdery white substance that is the waste product of the Soda Ash/Lime Softening. The total amount of Lime Cake that gets produced is about 48 tons or two trailers a week, which adds up to 2,500 tons a year. Because there is no financially valuable way to use Lime Cake, it gets dumped on farmer fields for pH control. Lime Cake removal and disposal costs the City about $10,000 a year. One additional waste product of the treatment process is the sludge that accumulates in the Reclaim Tank. Other than the Lime Cake, the diluted sludge can be simply disposed of in the municipal sewage system and provides no or insignificant additional costs.

Together with other expenses, such as cost for Human Resources/Staffing, Operating Supplies, the total budget for the Water Treatment Plant sums up to about $500,000 a year.

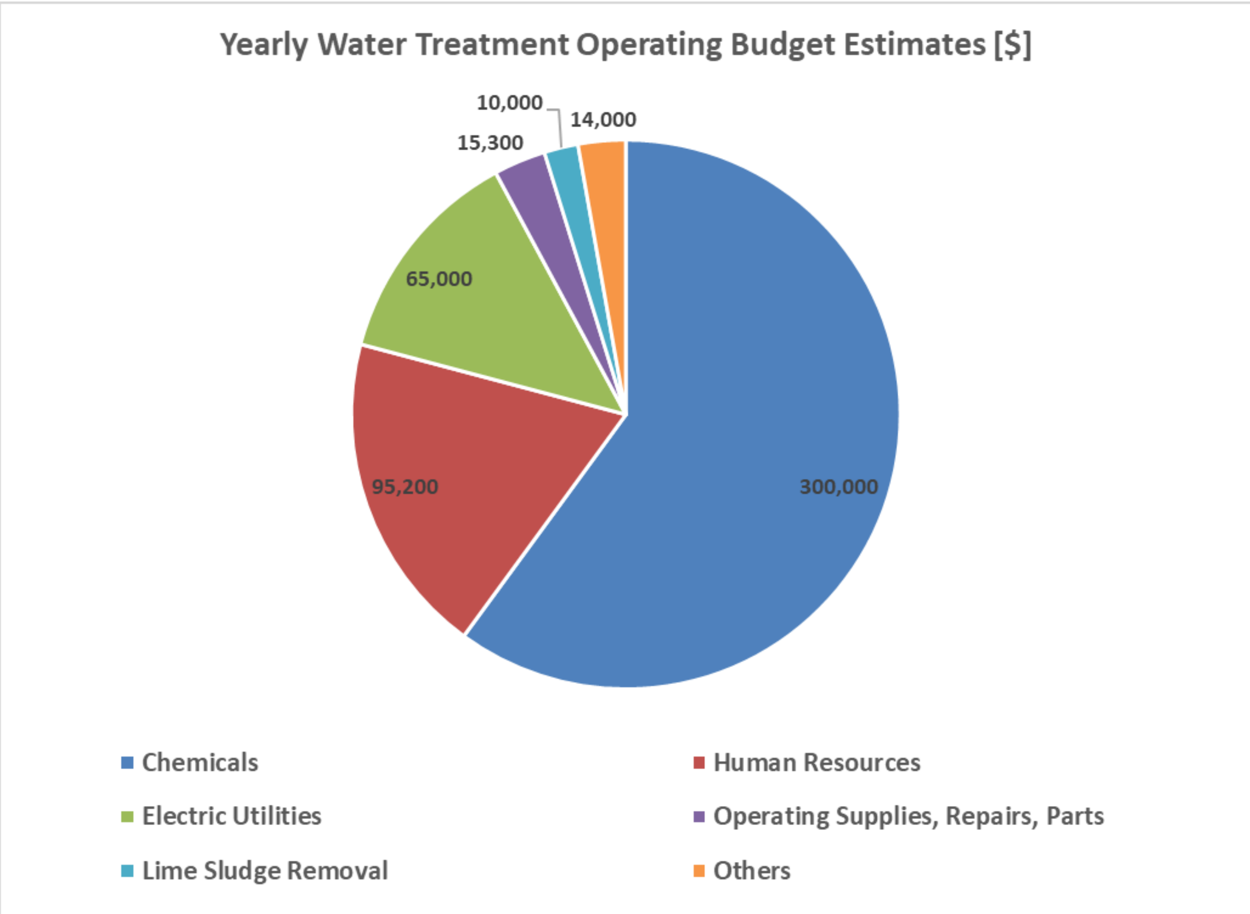


FIGURE 16 YEARLY WATER TREATMENT OPERATING BUDGET

5.4 In what way did the new Water Treatment improve Water Outcomes?

Before the Plant was built and finished in the year 2019, the Old Morris Water Treatment Plant was operating on the same piece of land as today. That basically means that the water that is being used hasn't changed since then, only the treatment got improved. The Old Plant was rather small and not as modern. Its key components were a small aerator and a sand filter, which operated in a similar way as in the new plant but was less effective. The main differences can be distinguished when it comes to the Water Softening Process.

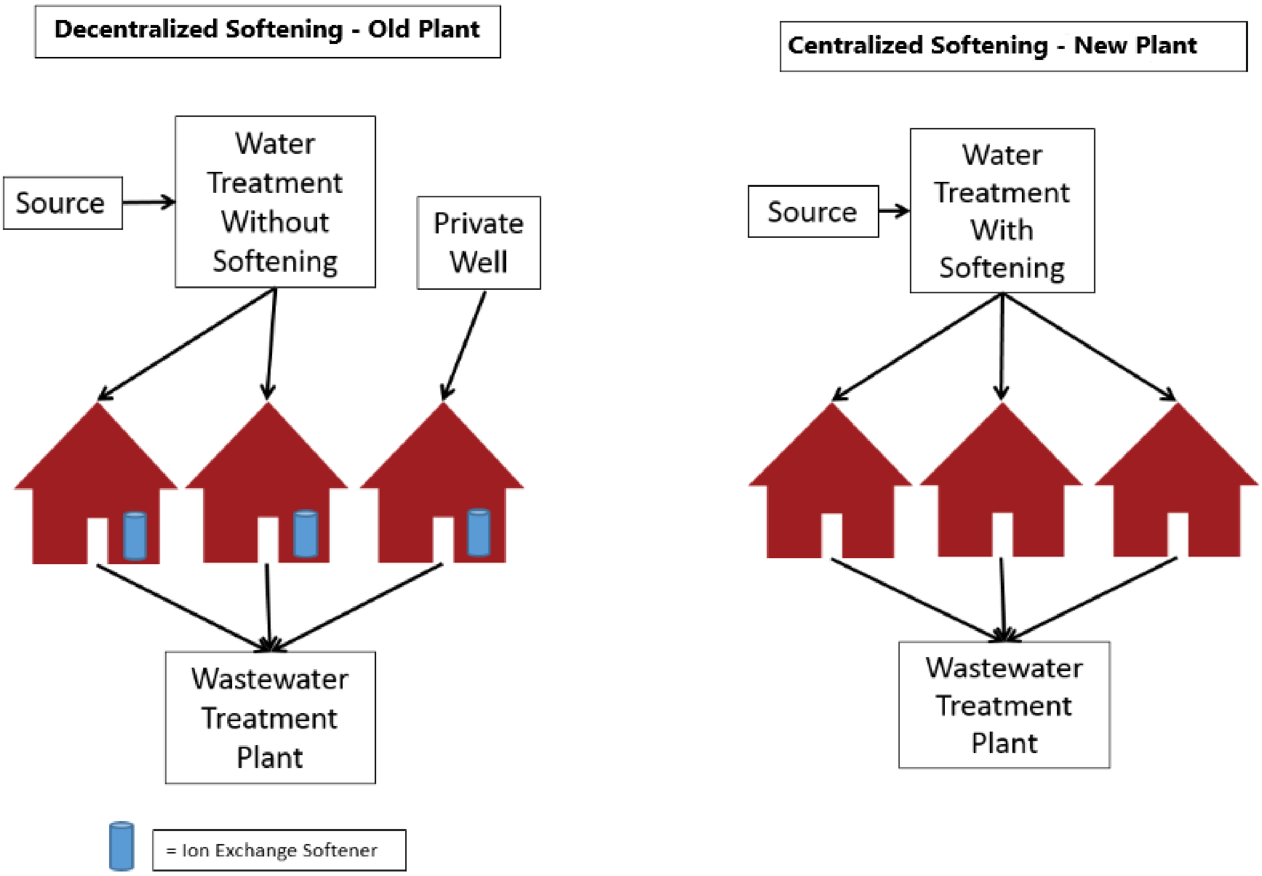


FIGURE 17 DE-CENTRALIZED WATER SOFTENING (BAISHALI, CHANGED)

As Figure 17 shows, the City made a transition in how treated water is distributed throughout the City. The Old Plant didn't have any Softening Techniques implemented in its Treatment Process so extremely hard water flowed directly to customers. In order to minimize unwanted effects of hard water (clogging pipes, etc.) the residents needed to take actions in their own households -- and installed their own Ion Exchange Softener, which resulted in a decentralized Softening. With the implementation of the New Plant and the Lime/Soda Ash process the City made its transition to a centralized Softening that reduces the hardness **before** the Water arrives at the customers, which has the following positive aspects:

1) Centralized Softening makes in-home softeners obsolete, which results in lower chloride discharge to the WWTP and ecosystems
2) It saves the customer money, because it eliminates the costs for salt, energy, and purchase/rental costs of Water Softeners
3) Less water is drawn from the Aquifer, because Centralized Softening produces far less waste water.
4) Centralized Softening is easier to optimize and control on a bigger scale [39]

Although the positive effects clearly outweigh the old system, there are still some drawbacks to this change. While the softened Water that flows out of the new Plant has a hardness of less than 5 gpg, some households want even lower levels of hardness close to 0 gpg for their own comfort, so it is likely some form of decentralized Water Softener use will be continued in the future by some customers. Moreover, the multi-million-dollar investment led to slightly increased water bills and higher prices per gallon, which may create financial challenges for some of the residents in Morris. The assumption that the savings of a Centralized Softening approach are bigger than the rising water bills could be analyzed further.

5.5 How did the new WTP change the intensity of Chloride Pollution? Success Analyses

In order to answer the question whether the project of lowering chloride pollution was a success, we can examine data collected by the Morris WWTP. To ensure the performance of the plant and to meet regulations and important limits, the City keeps track of different chemical and biological parameters of the treated discharge. For Chloride a distinction is made between two important measurements, influent and effluent levels. Influent levels describe the chloride concentration [mg/L] of the raw sewage that enters the WWTP, while the Effluent Levels measure the chloride concentration of the treated wastewater that exits into the Pomme de Terre River. The Effluent levels are important and relate to the statewide chloride limits of 407 mg/L that is set by the MPCA. While this is an important value, the Influent levels are a better indicator whether the new Water Softening Technique lowers overall pollution right now and in the future. Using an in-home ion-exchange water Softener to reduce overall hardness was a common practice for several decades before the plant was built. Therefore, over many years, significant amounts of Chloride accumulated in the ponds of the WWTP. Even if no additional Chloride entered the pond, the effluent would still show evidence of the pollutant for the next several years and possibly decades. The exact concentration of Chloride in the ponds and how other biological processes in the treatment process influence the concentration is not discussed further but could be subject to future studies. The goal is to hit a Chloride level in the Influent way under 400 mg/L to meet the discharge regulations in the future.

Figure 18 shows the quarterly Chloride Levels of the WWTP (y-axis) ranging from quarterly measurements in 2017 until June 2022 (x-axis). The green line marks the date, when the new WTP with the centralized water softener went online on June 6, 2019. It also represents the time when public announcements were made in the radio and in the newspaper, that in-home water softeners were no longer needed because of the decreased hardness in municipal drinking water. Everything before 2019 is considered the “Old WTP” regime and after 2019 as “New WTP” regime. The Orange line represents the Chloride target discharge level of 407 [mg/L]. When the Old WTP was online, the Influent levels in the years from 2017 to 2019 had an elevated average of 749 mg/L (Figure 19), which is almost double the amount of the limit. There is also a high variety in measurements ranging from 246mg/L to 1840 mg/L. Why some of these measurements are relatively low remains unanswered. It could be due to other circumstances, like heavy rain falls entering the sewer system. The more important thing is that almost all Chloride levels after the new WTP went online, are well below the level of 400 mg/L with an average of 306 mg/L in the month from Summer 2019 to present. As expected, the Effluent levels in Figure 20 are well above the Influent levels but with a trend towards lower Chloride Pollution during the past 2 years. The discharge limit of 400 mg/L from the municipal WWTP can be met.

These values taken together are good indicators of success for the project. The fact that Chloride pollution flowing into the WWTP was cut by over half of the previous amount demonstrates that residents stopped or drastically decreased the use of in-home ion-exchange water softeners, likely due to improved water quality by the implementation of the new Plant. This analysis also assumes that other pathways for Chloride pollution stayed the same during this time period, like Road-Deicing or Agriculture. Taken together, this means the City will be able to meet the MPCA pollution limits – and shouldn’t expect to face any financial or legal challenges in the future.

(One aside: the elevated Chloride value on 9/15/2020 of 1080 mg/L needs to be highlighted, given that it is an outlier. This value is significantly different from the other values around the same time and is almost three times as high. The Engineers at the WWTP noticed this outlier measurement but are unsure about the cause. Additional measurements also showed high values on TSS (Total Suspended Solids), which could mean that some sediments in the pipes could have been stirred up and affected the measurement. Ultimately, the true reason for the outlier measurement is unanswered. If this outlier measurement were excluded from the calculation, the average value for the new Influent Chloride concentration would be EVEN lower at 235 mg/L. This is likely the new average concentration that can be expected from the new WTP. However, it is generally not considered good engineering practice to just discard an outlier if the cause is unknown.)

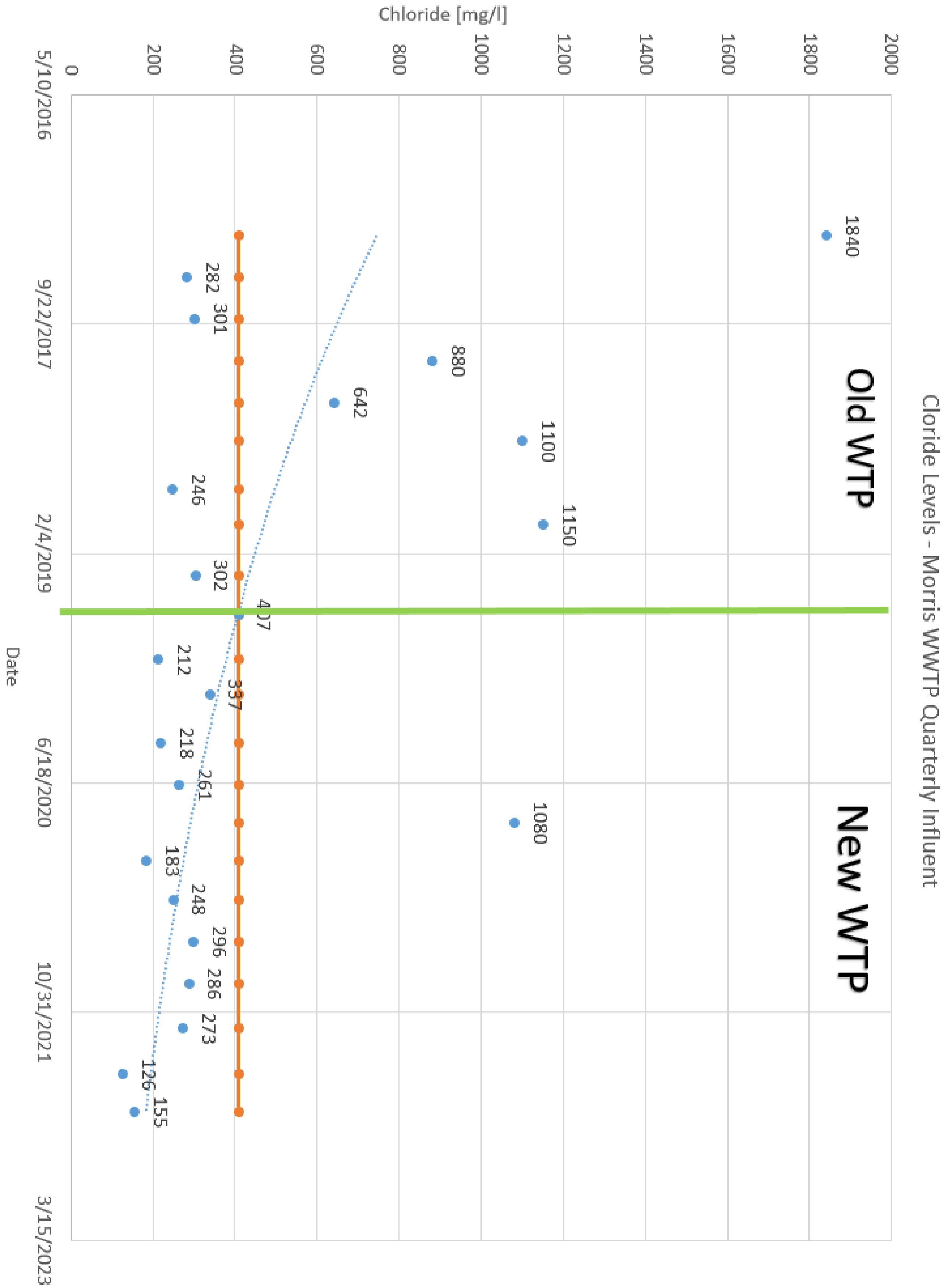


FIGURE 18 INFLUENT CHLORIDE LEVELS - MORRIS WWTP

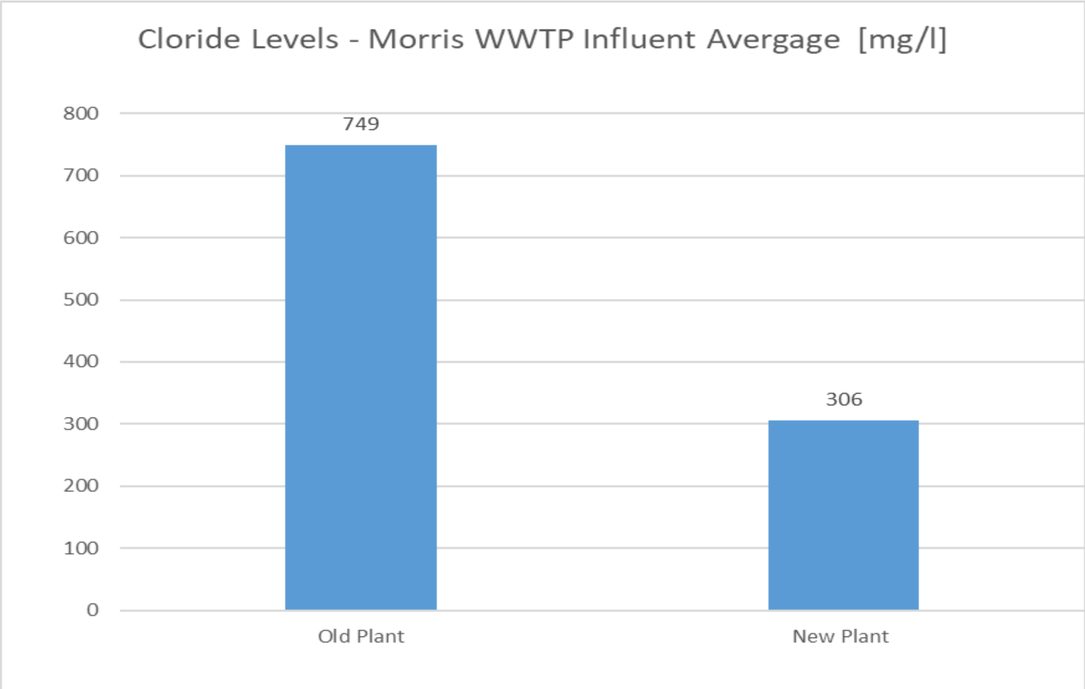


FIGURE 19 INFLUENT CHLORIDE LEVELS AVERAGE

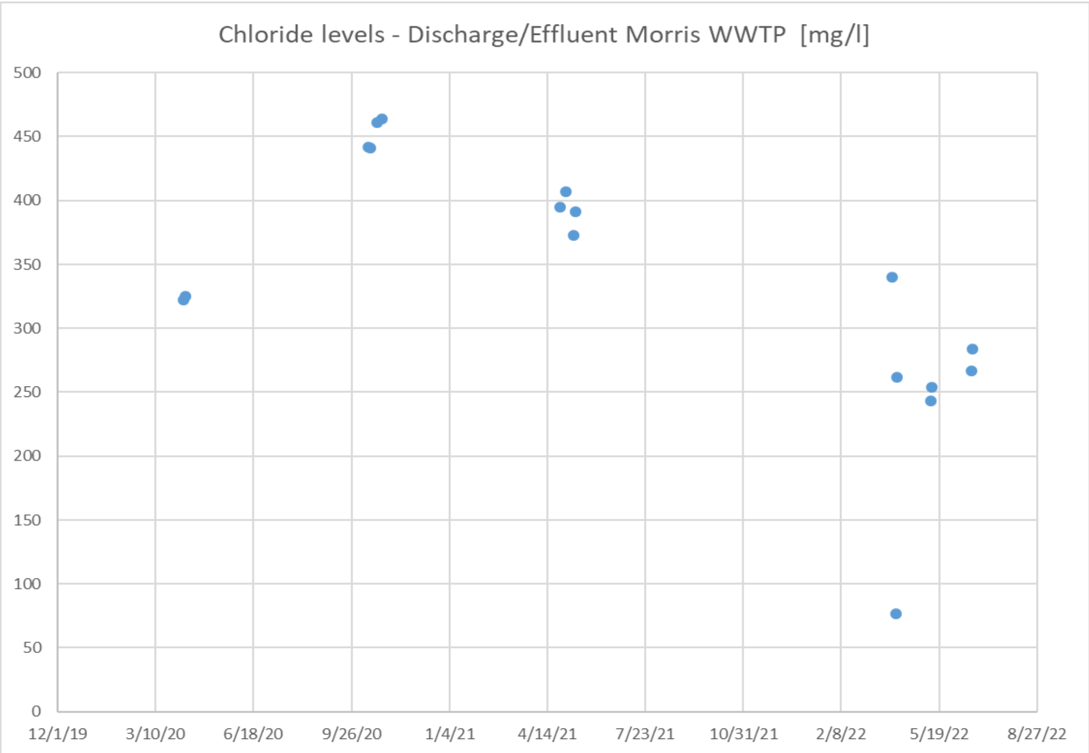


FIGURE 20 EFFLUENT CHLORIDE LEVELS

6. Energy Analysis

This report also examines the possibilities to make the plant more resilient and sustainable with the use of solar energy and the optimization of energy use. To begin the analysis, the general energy characteristics of the plant need to be analyzed first. For clarity, two energy concepts are important to understand, kilowatt [kW] and kilowatt-hour [kWh]. Kilowatt is the unit of power, and describes the rate at which energy is generated or used. It is also sometimes labeled as demand. Kilowatt-hour is the unit of energy usage and results from multiplying power by time. For example, a plant that always uses 100 kW of power and runs for one hour, would use 100 kWh of energy every hour. [40] The following observations are based on the data extracted from an online software platform called PowerProfiler, which is an optional software program provided by Otter Tail Power Company and allows the City to track their energy usage of public buildings.

6.1 What does the energy usage of the Plant look like?

To get a feeling of how much energy a modern Water Treatment Plant uses to produce clean drinking water for around 6000 people, we can first examine the energy consumption. Figure 21 shows the average daily energy consumption by month in kWh. The energy consumption is consistent throughout the year with slightly higher numbers in the summer months, due to higher water demand and in the winter months, when UMN Morris campus enrollment is the highest. It averages out to about 2,160 kWh of energy use each day. As a result, the Morris Water Treatment Plant uses about as much energy as 70 typical American homes would use in a day. [41]

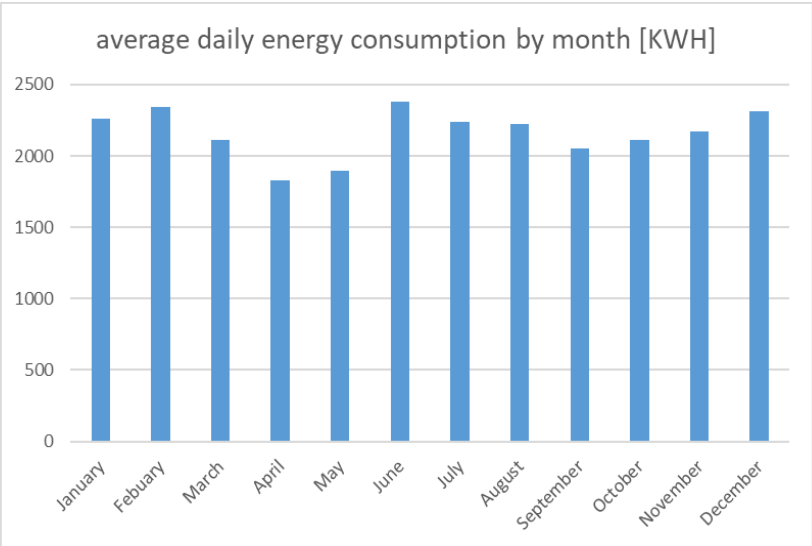


FIGURE 21 MORRIS WTP AVERAGE DAILY ENERGY CONSUMPTION

6.2 What does the energy demand of the plant look like?

The energy demand of the plant is highly dependent on the runtime of the plant and is different from day to day and can even change every couple of hours. However, the power consumption (or demand curve) on most of the days shows a specific pattern that is visible in Figure 22. We can observe the power demand of the WTP (in kW) at every hour of the day. The first thing we see is that the power demand is never lower than 50 kW. This round-the-clock demand could be called the baseload and describes the power demand of the plant in idle mode. This basically means that the plant is not treating any water during these times, but the basic operations of a building still consume some energy. When we consider the 24/7 operation of the Lime Sludge Tanks the plant demands a baseload of 50 kW. Additionally, there are usually two spikes or plateaus in the power demand, one usually around the early morning hours and one later in the afternoon. These plateaus are around 4 hours long, and resemble the Water Treatment operation time of about 8 hours daily. Occasionally when there isn't enough water left in the Reservoirs there is only one big plateau per day, which is itself 6 to 8 hours long. The use of multiple pumps and moving parts that are needed for operation, causes the power demand to go up to around 150 kW. As Figure 23 shows, the plateaus have sometimes even higher spikes that can go up to 220 kW. That is most likely caused by higher demand due to pumping up treated water to the Morris Water Tower while treating water at the same time. The ramping up of the plateaus follows a pattern as well. As Figure 22 shows, the first incline is caused by the pumps that draw the raw water out of the ground. After some time the initial treatment such as Softening, and Filtration kicks in, so the demand inclines even more. This information of average demand and demand spikes are useful and necessary for the further discussion of solar power possibilities, or even energy storage in the future.

FIGURE 22 ENERGY DEMAND OF A TYPICAL DAY

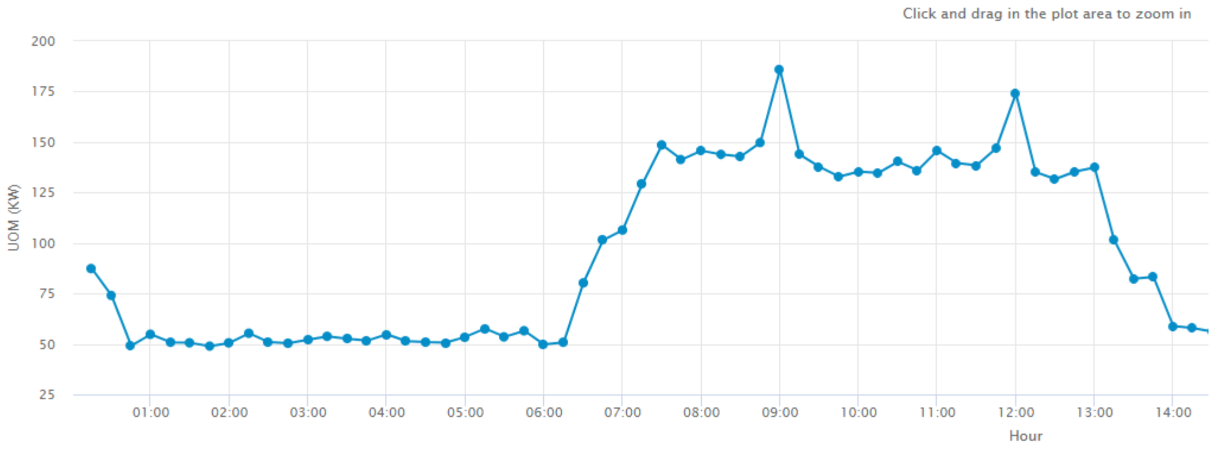


FIGURE 23 ENERGY DEMAND WITH SPIKES

6.3 How could Solar Power lower the electricity costs of the Plant?

The use of Solar Power via Photovoltaic Panels is a great way to produce your own electricity. It helps to reduce energy bills and is climate friendly at the same time. There are many options when it comes to the preferred size or performance of a solar panel array. The best possible solution for solar implementation would take a lot more data analysis and optimization than this report can provide, but it attempts to take a first look at what options would be possible and financially valuable.

40 kW

Choosing a PV array of up to 40 kW would have following advantages:

1) The Net Metering Law of Minnesota allows easy and quick implementation of Solar arrays up to 40 KW. This law makes it easier for homeowners or public entities to take actions that involve fewer regulations, paperwork and complications with utility companies. [42]
2) Ottertail Power Company (OTP), the energy utility of the City, promotes the use of solar power with a Program called ''Publicly Owned Property Solar (POP)'', which means that the City would be funded $1,500 per kilowatt of installed PV panels, which provides up to 50% of the project costs. The funding is limited for projects with a capacity of up to 40 kW. [43]
3) As previously stated, the Plant has a baseload of 50 kW around the clock. That would mean all the energy that gets produced by the potential 40 kW solar array would be directly used in the plant. That would save the trouble of implementing energy storage or exporting excess energy back to OTP for far less money.

To consider out how much energy a 40 kW array would produce, a closer look can be taken at the production of a PV array at the UMN West Central Research and Outreach Center (WCROC). We can access real-time data showing the maximum production in kW in 15- minute increments throughout the year 2020. A 40 kW PV array in Morris, Minnesota would produce roughly 51,900 kWh a year, which adds up to 6.75% of the total energy usage of the entire plant. Considering a price of conventional Energy from the utility OTP of $0.08/kWh, the PV would save $4,150 annually.

In order to categorize the financial benefits of a 40 kW array in more detail, the Net Present Value (NPV) can be calculated. The NPV is a tool that helps to find out whether an investment is profitable by comparing the initial costs with future cash flow. A negative NPV means that an investment would lose money, a positive NPV means the investment would generate income. The NPV can be calculated for each year after the investment was made. [44]

The calculation for a 40 kW uses the following estimated values:

TABLE 2 NPV CALCULATION PARAMETER [45]

Parameter	Value	Explanation
PV capacity	40 kW	
Yearly Solar Energy Production	51900 kWh	
Annual Solar Output Degradation	0.60%	PV panels lose about 0,6% of their energy output every year
Cost per kWh	0,08$	Energy Price that the Plant would have to pay for the conventional energy from OTPC
Installation Cost POP Funding Total Initial Cost	120.000 $ -60.000 $ 60.000 $	Estimated at 3$/W 1500$/W
Future Value Discount Rate	1.5 %	Interest rate on borrowings
Electricity Price Inflation Rate	2,50 %	Average rate for growing Electricity Prices annually
Repair Costs	14.400 $	PV-Inverters most likely need to be replace after 15 years. Replacement costs are usually around 12% of Installation Cost
NPV after estimated PV lifespan of 25 years	**42.750$**	

Figure 24 shows the calculated NPV of a potential 40 kW Array in each year after the initial installation. When taking all the parameters listed above into consideration, the ''Break-Even Point" is in year 15. That means that after 15 Years the investment has paid for itself and starts to generate profit. Assuming a lifespan of 25 Years, the 40 kW array would generate a profit of around $42,750.

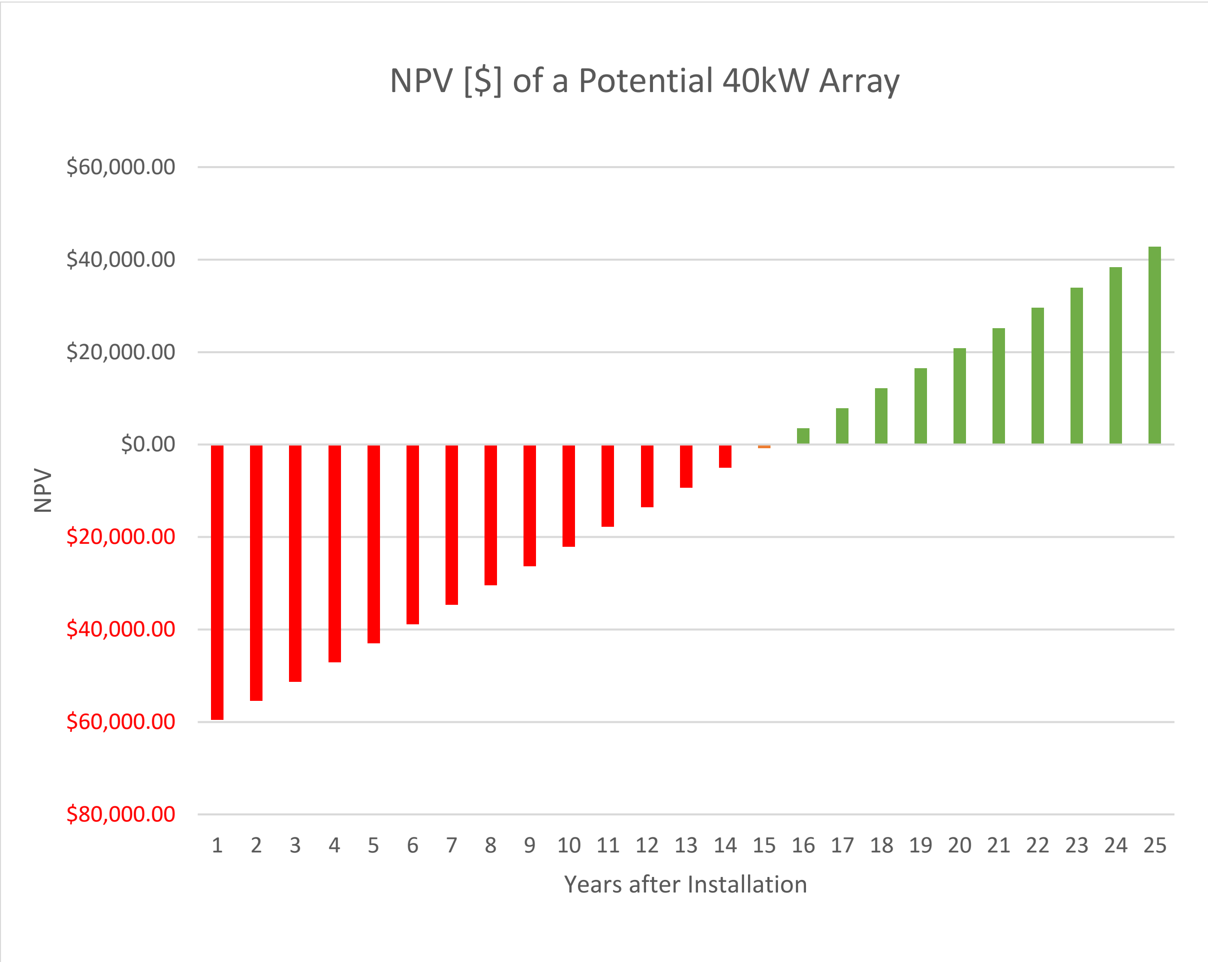


FIGURE 24 NPV OF A POTENTIAL 40KW ARRAY

In addition to the accumulating financial benefits, the environment would be protected at the same time. The solar production is carbon neutral and would decrease the necessity to buy energy from OTP. The energy production in Minnesota is mainly dominated by coal, nuclear and a lesser amount of wind and solar, and adds up to roughly 816 lbs of CO_2 (carbon dioxide) produced per MWh. Taking this into account the Plant has the opportunity to improve its Carbon Footprint. [46]

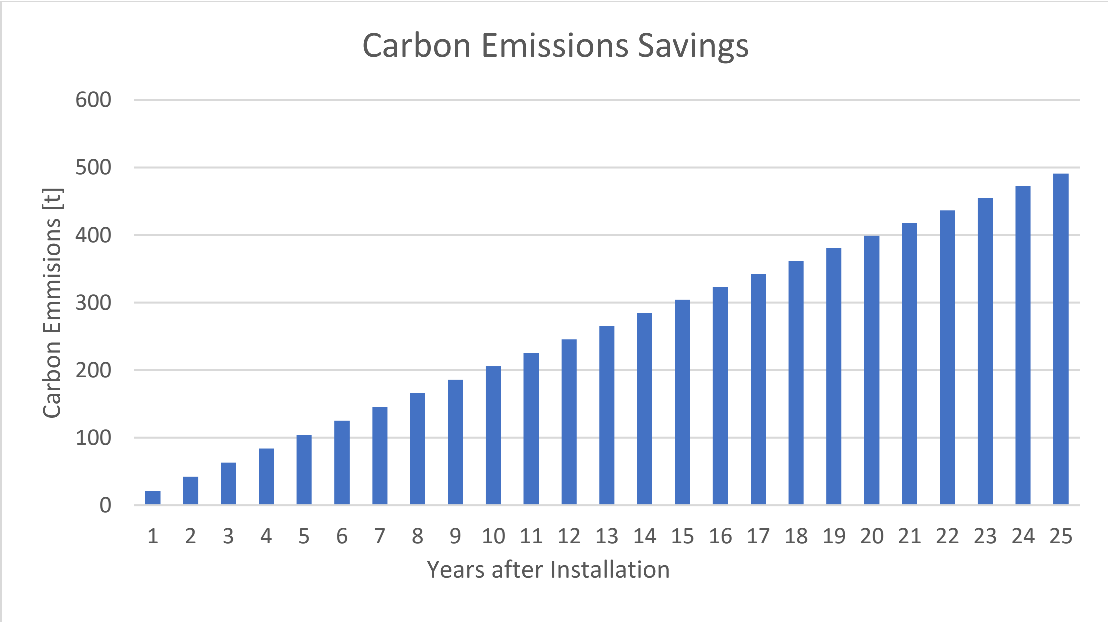


FIGURE 25 CARBON EMISSIONS SAVINGS

Figure 25 shows the possible Carbon Emissions Savings that a 40 kW would generate. The First Year the array would save up to 21 U.S tons of CO2. Taking the annual solar output of about 0.6% degradation into account, the array could save up to 490 tons of CO2 during its entire estimated lifetime of 25 years. While this doesn't consider the CO2 emissions of the manufacturing process of the PV panels -- it is a great way to improve the overall carbon footprint of the Morris WTP. A further lifecycle analysis could be performed. To put this into perspective: Assuming an average car emits about 410 grams of CO2 per mile, the 40 kW array would save as much CO2 in its lifetime as a car would emit while driving the distance from the earth to moon 4 and a half times over.[47]

It also saves as much CO2 yearly, as it would take to fly a German graduate student on a commercial airplane from Amsterdam to Minneapolis 54 times over, so that he can write a report about the Morris Water Treatment Plant. [48]

7 Appendix

7.1 Wastewater Testing (City of Morris)

MINNESOTA VALLEY TESTING LABORATORIES, INC.

MVTL

1126 N. Front St. ~ New Ulm, MN 56073 ~ 800-782-3557 ~ Fax 507-359-2890
2616 E. Broadway Ave. ~ Bismarck, ND 58501 ~ 800-279-6885 ~ Fax 701-258-9724
1201 Lincoln Highway ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885
www.mvtl.com

MEMBER ACIL

Page: 1 of 1

Report Date: 30 Jun 2022
Lab Number: 22-A31129
Work Order #:12-11571
Account #: 013218
Sample Matrix: WASTEWATER
Date Sampled: 21 Jun 2022 14:00
Date Received: 22 Jun 2022 10:07

Temp at Receipt: 9.8C

RYAN MOGARD
CITY OF MORRIS
PO BOX 438
MORRIS MN 56267-0438

Sample Description: POND 4 DISCHARGE

	As Received Result		Method RL	Method Reference	Date Analyzed	Analyst
Phosphorus Water Digest					25 Jun 22	AKF
Water Digestions					23 Jun 22	JMS
BOD, Carbonaceous	4.58	mg/L	2.00	SM5210B-2011	22 Jun 22 15:02	JR
Solids, Total Suspended	21	mg/L	2	USGS I-3765-85	22 Jun 22 12:00	JD
Specific Conductance	2023	umhos/cm	0.1	SM 2510 B-97	28 Jun 22 17:36	MDH
Bicarbonate	267	mg/L CaCO3	0	SM 2320 B-97	28 Jun 22 17:36	MDH
Fecal coliform	* < 10	MPN/100 mL	10.0	SM9223B-04 (QT-18)	22 Jun 22 13:45	BH
Bicarbonate	326	mg/L HCO3	NA	SM 2320B 18th Ed	28 Jun 22 17:36	MDH
Hardness, Total	370	mg/L CaCO3	NA	SM 2340 B-97	24 Jun 22 17:57	TMM
pH - Client	8.92	units	NA	Client	21 Jun 22	Client
Dissolved Oxygen - Client	10.2	mg/L	NA	Client	21 Jun 22	Client
Sulfate	241	mg/L	5.0	ASTM D516-11	23 Jun 22 9:01	SS
Chloride	267	mg/L	3.0	SM 4500 Cl E	23 Jun 22 9:19	SS
Nitrate+Nitrite	1.55	mg/L as N	0.05	353.2	22 Jun 22 14:56	KRM
Nitrogen, Ammonia	1.67	mg/L	0.16	SM 4500 NH3 C-97	28 Jun 22 8:15	AR
Phosphorus, Total	2.64	mg/L	0.10	EPA 365.1	27 Jun 22 14:35	KRM
Nitrogen, Total Kjeldahl	5.0	mg/L	0.2	SM 4500 NH3 C-97	28 Jun 22 11:28	TAM
Solids, Total Dissolved	1270	mg/L	10	SM 2540 C-97	23 Jun 22 16:00	MDH
Calcium	73.30	mg/L	0.500	200.7	24 Jun 22 17:57	TMM
Magnesium	45.40	mg/L	0.500	200.7	24 Jun 22 17:57	TMM
Sodium	343.0	mg/L	0.500	200.7	24 Jun 22 17:57	TMM
Potassium	18.00	mg/L	0.500	200.7	24 Jun 22 17:57	TMM

Temperature outside the requirement specified in Minnesota Statute 4740.2087 Subpart 2.A. Client contacted and has authorized MVTL to proceed with analysis.

* Holding Time Exceeded

Fecal coliform was analyzed beyond the EPA allowed holding time of 8 hours, but within the MPCA allowed holding time of 24 hours.

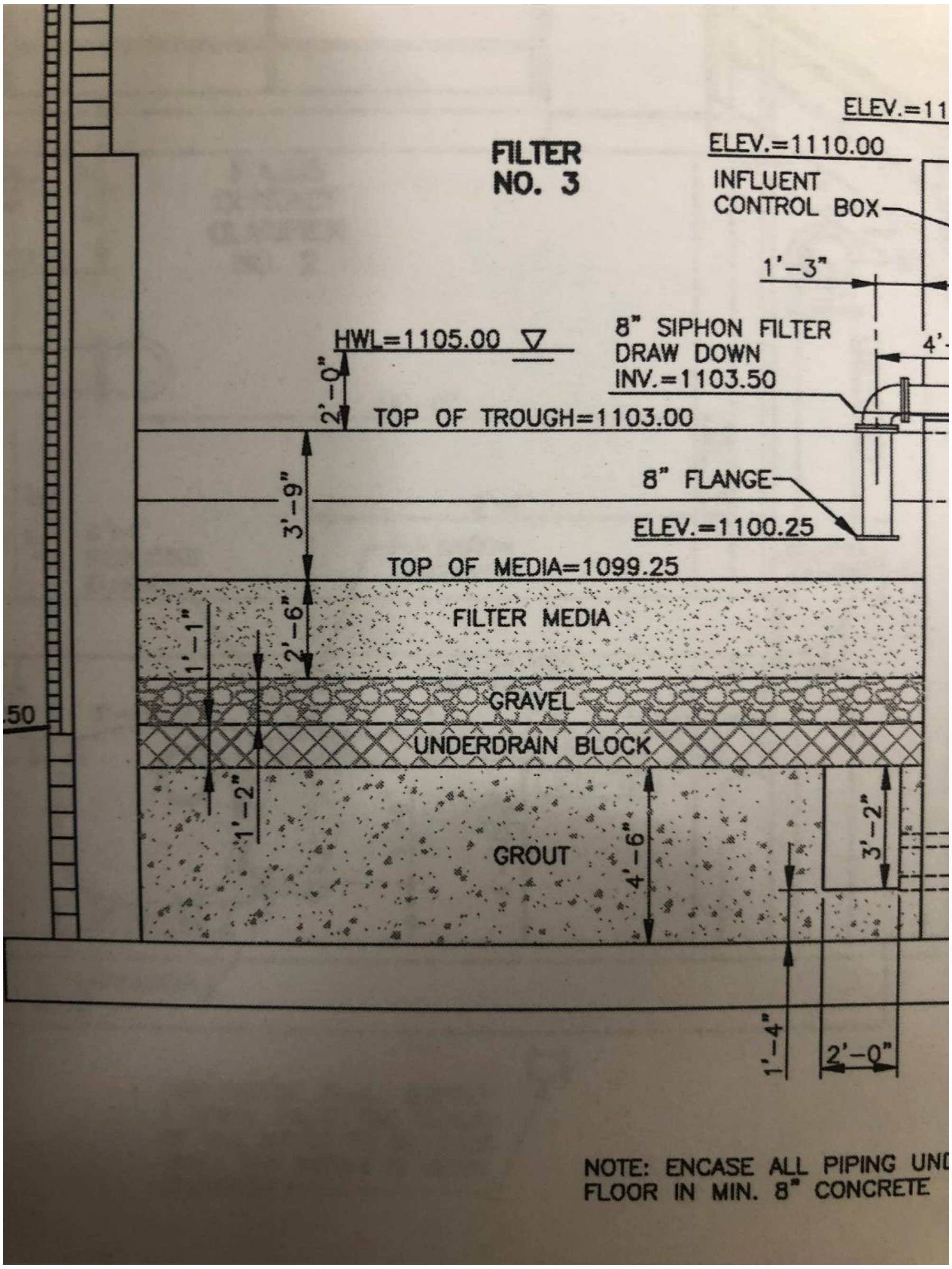
Approved by:

David Smahel, Chemistry Lab Manager New Ulm, MN

Sarah Garza, Microbiology Lab Manager New Ulm, MN

RL = Reporting Limit

7.2 Technical drawing of the Sandfilters (City of Morris)



7.3 Morris WTP Energy Bill (City of Morris)

OTTER TAIL POWER COMPANY

☐ Check for mailing address change (see reverse side)

04000811 2 000479768 17

CITY OF MORRIS
P O BOX 438
MORRIS, MN 56267-0438

OTTER TAIL POWER COMPANY
PO BOX 2002
FERGUS FALLS MN 56538-2002

Due Date: **Jun 30, 2021**
Amount Due: **$4,797.68**

Your payment is recorded upon receipt.
Please return this stub with your payment.

Please allow sufficient mailing time.

4000811-2 $4,797.68

Status of Your Account

OTTER TAIL POWER COMPANY

Account Number: **4000811**

CITY OF MORRIS

E 2ND ST
MORRIS, MN 56267

Billing Date: Jun 04, 2021

If payment is not credited to your account by Jul 06, 2021, and your account balance is more than $10.00, a late payment charge of 1.5% (18% per year) or a minimum of $1.00 will be charged, whichever is greater.

Previous Payment: 05/17/21	4,077.90
Current Billing:	4,797.68
Amount Due:	**$4,797.68**

We're here to answer any questions, concerns, or complaints you might have about your bill.
Call us at 800-257-4044 or 218-739-8877.

Write our office at:
PO BOX 2002
FERGUS FALLS MN 56538-2002

www.otpco.com

Account Detail (4000811)
01.Mun Pumping Serv-Sec Win

P	05/28/21 Reading	14649
	04/28/21 Reading	14002
	Meter Multiplier 100.0 X 647	
	Kilowatt Hours Used	64700
	kvar	1.0
	Metered Demand	200.2
	kW reactive dem.	0.0
	kW total demand	200.2
	Max Demand	229.9
	Customer Charge (12.00 x 12/365) x 30	11.84
	Facilities Charge 229.9 kW at .97	223.00
64700	kWh at .03836	2481.89
	Energy Adjustment	
4313	kWh at .01345	58.01
60387	kWh at .01373	829.11
	Total:(01)	3,603.85

Customer Charge and Fixed Facilities Charge are prorated based on Fixed Monthly Charge x 12/365 x days in billing period. For more information refer to www.otpco.com.

02.Other Charges/Credits

Interim Rate Adjustment	589.53
Resource Adjustment	604.30
Total:(02)	1,193.83
Current Billing:	4,797.68

***P Indicates Prorated Billing**

More account information on back.

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8.1 Information

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8.2 Figures and Tables

Figure 18 “Influent Chloride Levels – Morris WWTP”, Abbing, based on internal data from the City of Morris

Figure 19 “Influent Chloride Levels Average”, Abbing, based on internal data from the City of Morris

Figure 20 “Effluent Chloride Levels”, Abbing, based on internal data from the City of Morris

Figure 22 ,,Morris WTP Average daily Energy Consumption” Abbing, based on data from Powerprofiler, City of Morris

Figure 23 ,,Energy Demand of a Typical Day”, Abbing, based on data from PowerProfiler, City of Morris

Figure 24 ,,Energy Demand with Spikes”, Abbing, based on data from PowerProfiler, City of Morris

Figure 25 ,,NPV of a Potential 40 kW Array”, Abbing

Figure 26 ,,Carbon Emmissions Savings”, Abbing

Table 1 “Water Hardness Classification in CaCO3 Equivalents”, Abbing based on Pallav Segupta, August 2013: ‘’Potential Health Impacts of Hard Water’’ *https://www.researchgate.net/publication/256765379_Potential_Health_Impacts_of_Hard_Water*

Table 2 ,,NPV Calculation Parameters”, Abbing, based on https://energyd.ie/npv/

Figures in Chapter 4.1 origin from Figure 12. Pictures in Chapter 4.1 were taken by Abbing.