Environmental and Economic Life-Cycle Assessment of Alternative Source Water at Bell's Brewery, Inc.

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Inspired Brewing®

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TABLE OF CONTENTS

1 ACKNOWLEDGEMENTS

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2 EXECUTIVE SUMMARY

Bell's Brewery, Inc. is a craft beer brewer based out of Kalamazoo, Michigan. Bell’s gives high priority to sustainability and has undertaken numerous initiatives within the company to reduce energy usage as well as water consumption. Water is one of the most important components of the brewing process. One gallon of beer production requires five gallons of water. The company’s current annual production of 9.6 million gallons of beer requires 150,000 gallons of water per day. Bell’s projects their water consumption will increase to 500,000 gallons per day within the next five years.

Bell’s currently sources water from the Kalamazoo Water Division. Considering the company’s forecasted growth, their current infrastructure only supports their water treatment requirements for the next two years. In addition, the risk of source water contamination has led Bell’s to consider alternative sources to meet the quantity and quality of water required for the brewing process.

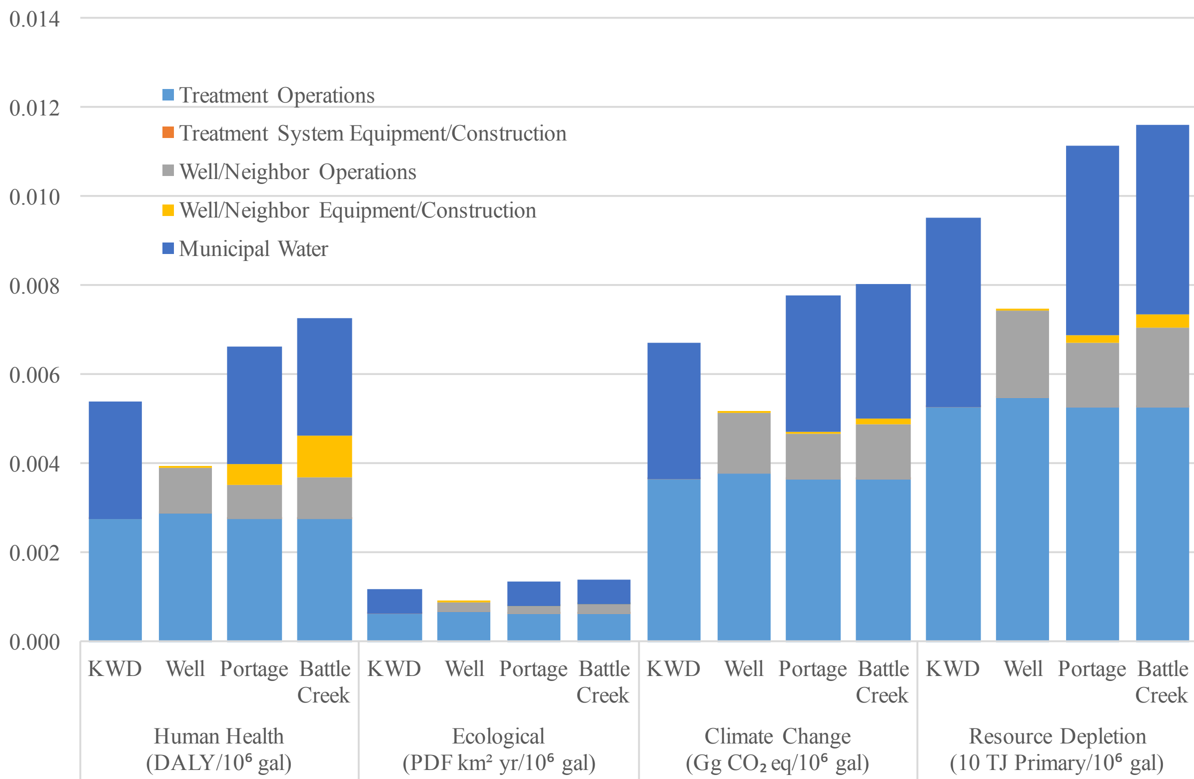
The team identified and analyzed the following four alternative sources:

1. Continue sourcing water from the Kalamazoo Water Division
2. Drill an on-site water well
3. Source water from Portage
4. Source water from Battle Creek

We determined different life stages involved in these four different options and performed life-cycle analysis and financial analysis to analyze the environmental, financial, human health, and social impacts of each option.

Based on our analysis, the well option has the lowest human health impact, ecological impact and global warming potential. The chief reason is that in the well option, water is being pumped the shortest distance which uses the least energy. The adjacent municipality options are the least appealing from an environmental perspective. The combination of the impacts of the municipal water system, the energy to pump water from that adjacent municipality, and the significant infrastructure needed renders these options hard to justify.

The four options were also evaluated by their total cost. Extensive information was gathered through interviews with well digging professionals and county officials in addition to secondary research of publicly available information. This allowed the project team to develop comprehensive financial models and equivalent annual costs for each potential option. Based on the models developed, it was discovered that digging a well would be the most affordable option for its assumed lifespan.



Given the results for each option, the team developed a scorecard, which consisted of five factors. Each factor was weighted based on what the team believed would be the preferences of Bell's Brewery. The weighted results, shown below, allowed the team to compare the total effects of each option. In the end, it was determined that the construction of an on-site well would be the best option due to its relatively small environmental impact and low cost.

	Financial (USD)	**Global Warming** (Gg CO_2 eq/yr)	**Ecological Impacts** (PDF km² yr/yr)	**Human Health Impacts** (DALY/yr)	**Resource Depletion** (TJ Primary/yr)	**Total Score** (Normalized)
Kalamazoo	$136,093	1.22	0.22	0.99	17.4	0.57
On-site Well	$108,201	0.94	0.16	0.71	13.6	0.43
Portage	$638,131	1.42	0.25	1.21	20.3	0.96
Battle Creek	$651,449	1.47	0.26	1.32	21.2	1.00

Because of these results, the team developed a wellhead management plan, which would help Bell's further reduce its impact on the local water table. To isolate the wellfield from the existing surface and underground infrastructure, a recommended 150' was established around all of the buildings on the property. The placement of the wellfield was determined by an optimization program with the recommended location of 42.28347144° N, -85.45125228° W to mitigate nearby stream drawdown, which may otherwise promote litigation.

An additional measure to legally insulate the company is the pursuit of a social license to operate before installing a wellfield on-site. This would require engaging the local community, explaining the company's environmental initiatives, and involving community members in the planning of the wellfield.

3 BACKGROUND

3.1 Bell's Brewery

Bell's Brewery, Inc. is a craft beer brewer based in Kalamazoo, Michigan with its main production facility located in Comstock, Michigan. The company currently produces over 310,000 barrels of beer, roughly equivalent to 9.6 million gallons, annually.[i]

Bell's places a high priority on reducing the environmental and human impacts of their operations. From their website: "We view sustainability as the capacity for our business to thrive in future generations through the practices of environmental stewardship, economic robustness and social integrity."[ii] To this point, the company has undertaken many initiatives to increase energy efficiency such as using outside air to cool the cold storage warehouse during colder months, installing a modular sedum green roof above the warehouse to increases insulation efficiency and recycling waste products from different processes.[iii]

Water is the most important ingredient for the brewing process and hence Bell's is concerned with the environmental, social, ecological and financial impacts of its water sourcing decisions. Bell's has undertaken numerous initiatives to reduce the water requirement at their brewery by using sub-meters to track the water usage, installing clean-in-place systems to clean the treatment equipment, etc.[iv]

Currently, the company consumes around 150,000 gallons of fresh water per day from the municipality of Kalamazoo, which pumps most of its water from the underlying Kalamazoo River Groundwater Reservoir. For every gallon of beer produced, five gallons of water is required. Future expansion plans forecast water usage to increase to 500,000 gallons per day over the next five years. Due to this projection of increase in water requirement at the brewery, Bell's has become interested in looking for alternative sources of water to meet the peak demand in a manner which would be environmentally sustainable, socially inclusive, and cost-effective.

3.2 Infrastructure Concerns

The company currently sources its water from the Kalamazoo Water Division. As Bell's Brewery looks to expand its production over the next five years, the risk of contamination to its only source of water is a top priority. This concern was highlighted by the recent water crisis in Flint, MI.

In December 2011, the City of Flint was placed in receivership after a financial emergency was declared by Governor Rick Snyder.[v] In an effort to reduce costs, the city elected to switch its municipal water supplier from the Detroit Water and Sewerage Department (DWSD) to the Karegnondi Water Authority. This plan required the construction of a new pipeline from Lake Huron to service the residents of Flint. While the pipeline was under construction, the city would rely on water provided from the nearby Flint River.[vi]

In early 2014, only a few months after the switch from DWSD to the Flint River, the city issued two separate warnings to its residents regarding the presence of coliform bacteria contamination.[vii] By early 2015, the EPA had notified the Michigan Department of Environmental Quality (MDEQ) that lead levels in in Flint's drinking water were nearly "seven times greater than the EPA limit."[viii] It was later revealed that the service lines delivering water to residents were constructed of galvanized iron and had developed rust over the years. MDEQ had neglected to treat the water from the Flint River with the proper anti-corrosive agents,[ix] which would have prevented the lead present in the service line's rust from leaching into the water supply. Due to the elevated levels of lead, and the hazard it posed the residents, the city eventually switched its water service back to DWSD by late 2015.[x] By January 2016, the state and federal government had declared a state of emergency in Flint. The CDC estimates that 99,000 residents were affected by the contaminated water supply.[xi]

3.3 Legacy contaminants

Legacy contamination of municipal water sources is another major concern for Bell's Brewery. The City of Kalamazoo sources its water from 98 production wells, contained in 17 wellfields, most of which are within the city limits.[xii] To prevent future contamination, the city currently has in place a wellhead protection overlay ordinance that prevents entities from storing hazardous material within a "ten year time-of-travel capture zone" of the wellfields.[xiii] However, risk is inherent given the four EPA designated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites within the city limits of Kalamazoo, in addition to several brownfields. These sites include industrial waste storage facilities undergoing remediation that have the potential to leach contaminants into the local aquifer. Furthermore, many of the municipal wellfields derive water from the Kalamazoo River Groundwater Reservoir within the glacial drainage channel of the Kalamazoo River itself.[xiv]

The Kalamazoo River has a history of industrial pollution and was designated as a CERCLA site in 1990. Kalamazoo's CERCLA site spans 80 miles beginning on the west side of the Morrow Lake Reservoir to where the river flows into Lake Michigan.[xv] The site was mainly contaminated with industrial waste generated by paper mills including the potentially responsible parties. Allied Paper, Inc. (Millennium Holdings, LLC), the Georgia-Pacific Corporation, and the Simpson Plainwell paper Company.[xvi] The wastewater from facilities owned by the aforementioned companies contained polychlorinated biphenyls (PCBs), which were used from the 1950s through the 1970s as a carrier for ink in carbonless copy paper.[xvii]

This is cause for concern due to the connectivity of the Kalamazoo River surface water and underlying aquifer within the glacial channel. Because remediation activities for the operable CERCLA units are still underway, resuspension of contaminated sediments may result in their transport down gradient. If hazardous chemicals from sediments within the river were to be pulled into the underlying aquifer via induced infiltration, contamination of the municipal water supply could occur. This would result in the contamination of brewery source water, and ultimately the beer itself, forcing the brewery to suspend all brewing activities.

Groundwater contamination may also result from the migration of toxicants from one of the 37 brownfield sites throughout the city. These sites, owned by the Kalamazoo Brownfield Redevelopment Authority, may undergo remediation and cleanup activities that have the potential to disturb sediments, re-suspend toxicants and induce the migration of material into the groundwater. However, remediation activities are often meticulous in the removal of toxic material and the risk of groundwater contamination and migration to Kalamazoo's drinking water sources is low.

3.4 Bell's Current Water Treatment Facility

Water treatment is the processing of water to make it suitable for specific end uses. It is a critical component to any brewing operation as specific levels of contaminants within the water can affect the quality of the final product. Additionally, absence of proper water treatment can cause scale formation or corrosion inside the pipes of the brewing equipment. This, in turn, reduces the life of the equipment and affects its efficiency.

The company's current water treatment program mainly focuses on the removal of iron, chlorine, hardness, and alkaline compounds. Per Bell's specifications, brewing water should have a maximum of 0.2 ppm iron and no chlorine while utility water can have a maximum of 35 ppm alkalinity and 0.05 ppm hardness.

Currently, Bell's water is sourced from the City of Kalamazoo. The city water is filtered to comply with the Safe Drinking Water Act. When the water reaches Bell's Brewery, filtered city water is sent through the company's own pre-filtration system and iron filters. It then passes through carbon filters for brewing operations or a softener for clean-in-place systems. Clean-in-place systems are the facilities within the brewery used for washing the inner parts of pipes, filters, fittings and other equipment without dismantling them. The water directed through the softeners can be further filtered through a dealkalizer before being routed into the boilers. **Figure 3.4.1** shows the flow diagram for the existing water treatment infrastructure at the Comstock brewery. The width of the arrows represent the percentage of water flow through in a particular stream. Additionally, **Appendix A** shows the detailed test points location and connected facility details for every stream.

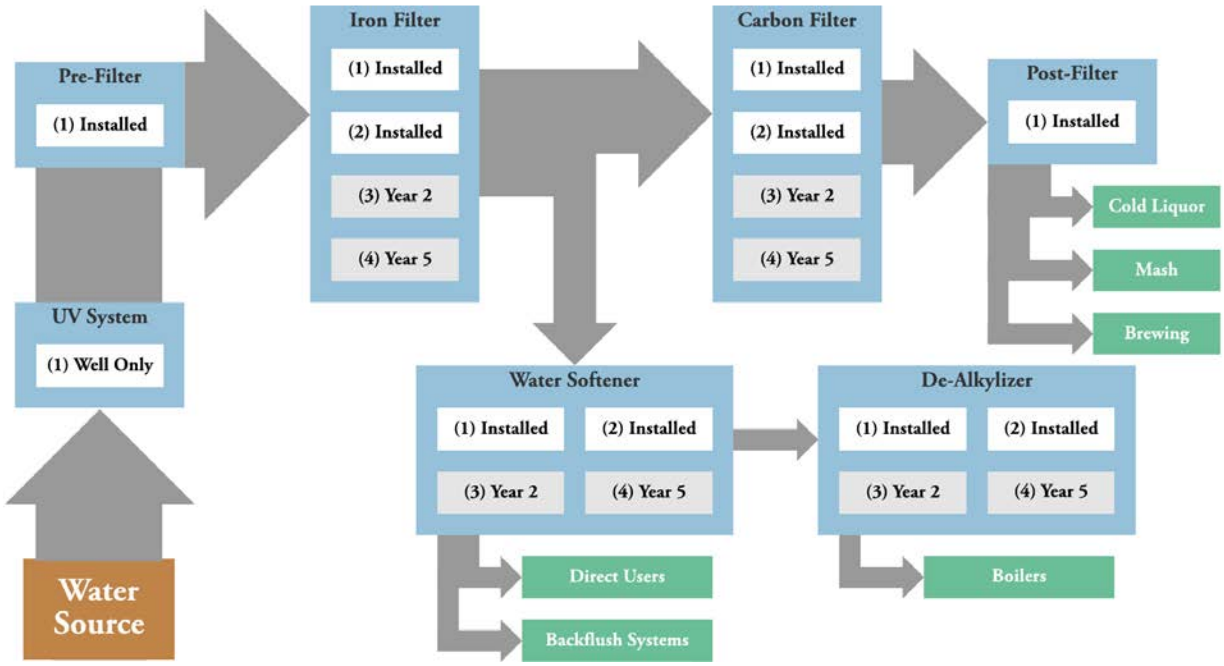


Figure 3.4.1: Current water treatment facility at the Comstock Brewery

3.5 Future Needs

Meeting the water requirements of Bell's increased beer production will require changes to its internal water treatment facilities, a change to its water source, or both. Bell's quality requirements for water used in brewing are more stringent than the legally binding water quality criteria that municipal water suppliers must meet. For this reason, even the safe and clean water currently delivered by the Kalamazoo Water Division requires additional treatment, particularly to remove iron. In the past, Bell's has seen highly variable iron concentrations in its municipal water supply.[xviii] This variability is due to the fact that different municipal pumping stations utilize different filtration facilities. As Bell's demand for water increases, Bell's receives a greater proportion of water from a high pressure pumping station that does not have iron filtration.[xix] Because higher iron concentrations are associated with greater use in its pressure zone, it is likely to be exacerbated by Bell's own increasing consumption. It is even possible that in the future, all of Bell's water would come from this adjacent pressure zones without iron filtration.[xx] For this reason, even if Bell's does not change its water sourcing, it will need to accommodate water with higher iron concentrations.

4 PROJECT SCOPE

In light of Bell's high priority on sustainability and responsible growth, as well as the risks posed by only sourcing water from the Kalamazoo Water Division, the company has partnered with this Master's Project team from the University of Michigan's School of Natural Resources & Environment.

Research Question

In an effort to understand Bell's commitment to industrial ecology and sustainability, the project team visited the company's brewing operation in Comstock, MI. This allowed for a first-hand view of Bell's current water and energy practices. Additionally, it provided the team an opportunity to discuss with the project liaisons the company's goals in diversifying its water sourcing, while still maintaining its commitment to the community and the environment. Based on the Bell's needs, the team constructed the following research question:

If the water volume and/or quality required for Bell's brewing operations could not be met by the current municipal source due to increased consumption, how could the company diversify in a way that would be economically viable with the least impact on the environment and the surrounding community?

Based on this simple question, the team devised four possible scenarios:

4.1 Option 1: Continue Sourcing Water from the Kalamazoo Water Division (KWD)

This option serves as a base case scenario in which Bell's would continuing sourcing water from the Kalamazoo Water Division. As a result of Bell's increased demand, the water would come from high-pressure stations, instead of its low-pressure stations, during the company's peak demand. This would result in higher levels of iron in the water due to the previously mentioned factors surrounding high-pressure stations, and would require Bell's to increase its water filtration infrastructure.

4.2 Option 2: Drill an On-site Water Well

This option would require Bell's to drill two wells to a depth of 150 feet within the property of the Comstock brewing facility. The wells would allow the company to pump water from the underlying aquifer, which would provide a suitable hedge in the event of a contamination of the current source. The team identified two well drilling companies for interviews and developed an LCA analysis for well construction and use.

If the water is pumped from the underlying aquifer through the wells, it would need to be treated in a UV filtration system to kill microorganisms. **Appendix A** displays the quotations for the water treatment plant equipment at Bell's Brewery provided by Water Surplus, Inc.

4.3 Option 3 & 4: Source Water from Adjacent Municipalities (Portage or Battle Creek)

This option would require Bell's to run a water main from either Portage or Battle Creek to the Comstock brewing facility. This water main would allow the company to source its water from and rely on the infrastructure of one of these other municipalities. The team used direct distances to model this option. The actual distances may vary due to the terms of the permitting process and the acquisition of the required easements. The team estimated the main from Portage and Battle Creek to be 12 and 24 kilometers, respectively. To better understand the logistics and permitting process, the team contacted a consultant who specializes in complex easement cases in a jurisdiction where private water mains are more common.

5 METHODOLOGY

To understand the current and alternative water sourcing of Bell's Brewery, it was necessary to employ a number of methods to characterize the local hydrogeological setting, the municipal water infrastructure, technology for on-site extraction, and tools to perform the impact analysis. These methods included interviews with Bell's staff and subject matter experts, literature review, computer simulation and data analysis.

In conducting the literature review, relevant articles were compiled from various local institutions, and state and federal environmental agencies. These agencies include the City of Kalamazoo, the Kalamazoo River Watershed Council, the Michigan Department of Environmental Quality, the U.S. Geological Survey and the U.S. Environmental Protection Agency. Furthermore, academic articles were used to develop the groundwater impact model for on-site well water extraction.

5.1 Site Visit and External Interviews

Bell's Brewery Tour

The project began with a visit to Bell's brewing operations in Comstock, MI. The team gained a first-hand look at how the company produces, bottles, and distributes its wide portfolio of beers. Integral to the entire process was Bell's emphasis on sustainability. Bell's has successfully woven into their operations heat recycling, natural cooling, and most importantly, water efficiency. This oriented the team to Bell's strong emphases on resource efficiency and stewardship. Additionally, it gave the team a look at how the company utilizes water during its daily operations. This was critical for the development of boundaries for the project's life-cycle analysis and capital requirements for all options.

Well Research and Katz Drilling Interview

The team first conducted initial research to gain an understanding of the well digging process, industry terminology, and accepted practices. The team relied heavily on the *Water Well Manual* published by the Michigan Department of Environmental Quality in 2015. This document formed the foundations of how the team conceptualized the categories of aquifers, the geology which determines the type of well to be constructed, the basic components of a well, and the environmental impacts and regulations surrounding a well's operation.

From there, the team reached out to companies around the Comstock area to gain a clear understanding of the financial, social, and environmental impacts of digging a well to grow Bell's operations. A 10 question interview template was developed **[Appendix C]** to structure the conversation. The team learned that two wells would be required, each with a pumping capacity of 350 gallons per minute. This would protect Bell's from the possibility of one well going down for an extended period of time, and provide the capacity to meet Bell's projected peak demand. The answers to the team's questionnaire, displayed in **Appendix C**, in addition to a work proposal [**Appendix D**] helped lay the framework for construction of the project's models.

City of Kalamazoo Interview

To better understand the regulatory requirements of constructing a well for commercial operations, the team began by calling the Kalamazoo County Health and Community Services Department. The singular question was simple, "What types of regulations and costs should Bell's expect if they were to dig an onsite well?"

The team would need to make sure the property was not located on Part 201 and 213 sites, which were categories for landfill and fuel oil contaminations. The Comstock property was well clear of these zones.

Next, Bell's would be required to pay a one-time permitting fee of $366 per well to Kalamazoo and would be subject to various water quality testing and operator continuation training at various intervals. These fees and intervals are laid out in **Appendix E**.

Cribley Drilling Interview

In order to better visualize the well construction process, validate the information gathered from the Katz Drilling interview, and address additional gaps in knowledge, the team reached out to a local Ann Arbor drilling company.

A site visit to Cribley Drilling was conducted in late April of 2016. The visit consisted of a one hour interview, and a 30-minute tour of their facility. The interview was structured via the questionnaire in **Appendix F**.

5.2 Water Treatment Facility Components

Pre-filtration System

The pre-filtration system is used to remove organic matter and dirt from the source water.[xxi] For our analysis, we are considering Snafa Engineering Model RFC-4540V-CS-F6-150. It consists of 45 round 40" filters made up of polypropylene. These filters have high surface area as well as high efficiency for particulate removal.

Iron Filter

Iron filters are used to remove iron, rust, sulfur, manganese, dirt, turbidity, tastes, odors and chlorine.[xxii] During the pre-treatment, an oxidant is used to precipitate and settle out the contaminants in the water. Precipitated contaminants clump together and are further removed through straining. After the precipitation, filtration is carried out. Backwashing is done for cleaning purposes. We are considering 60" Iron Filtration/ Sediment Control Backwash Filters for the analysis as suggested by Water Treatment Technologies & Water Surplus, Inc. based on the water demands provided by Bell's. Each tank contains 60 cubic feet of NextSand media and 820 lbs. of 1/16 x 1/8 washed underbed stone. NextSand media is made up of high purity clinoptilolite and has high dirt holding capacity.[xxiii]

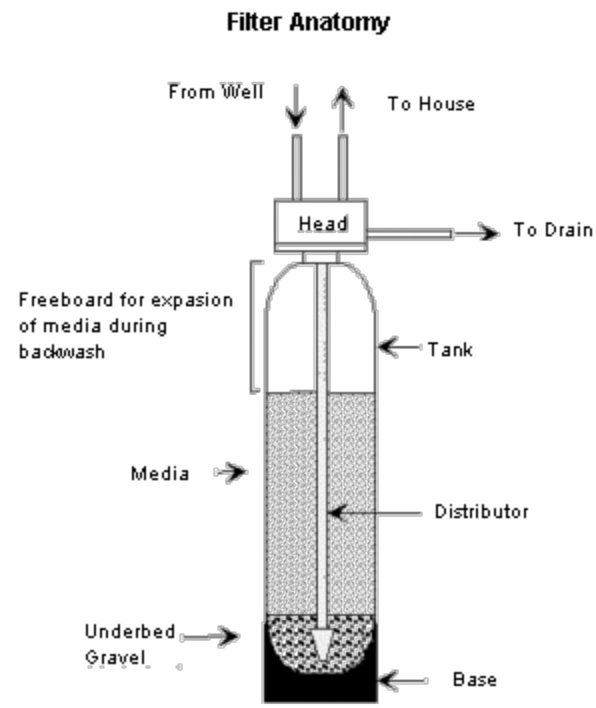


Figure 5.2.1: Schematic diagram for a filter with backwash

<u>Carbon Filter</u>

Carbon filtering is a type of chemisorption that involves the use of activated carbon to remove impurities. It is used to remove chlorine, volatile organic compounds, taste and odor from water. Each particle of carbon provides a large surface area structure which maximizes the exposure to the active sites inside the filter media. For the analysis, we are considering 60" Carbon Backwash Filters with 65 cubic feet each of Coconut shell hardened 12 x 30 mesh Carbon and 820lbs. of 1/16 x 1/8 washed underbed stone. **Figure 5.2.1** shows the typical schematic of a filter with backwash facility.[xxiv]

Water Softening System

Water softening refers to the removal of metals like calcium and manganese from the water. The softening can be done by various methods, however, the most popular are lime softening or ion-exchange resins. For our analysis, we are considering 36” x 72” duplex softeners containing 10% cross-linked macro-porous cation resin.

Dealkalizer

Dealkalizers are used to remove alkalinity from the water using ion exchange resins. Dealkalizers are important because they reduce boiler blowoff, and hence keep the water treatment chemicals in the boiler longer, reduce return line corrosion and reduce chemical contamination.[xxv]

They contain strong base ions which are exchanged with alkaline ions like bicarbonates and carbonates. For our analysis, we are considering a 24” x 72” de-alkalizing system with Thermax A32 Anion resin.

UV Filtration System

UV filtration systems are used to kill bacteria in water. Ultraviolet rays from the UV lamp kills harmful pathogens present in the water. The water from municipalities is treated to remove microbes. Hence, we are using UV filtration only in the well option. For the analysis, we are considering an Aquafine CSL-23R/6-HE ultraviolet sterilizer shown in **Figure 5.2.2**.[xxvi xxvii]

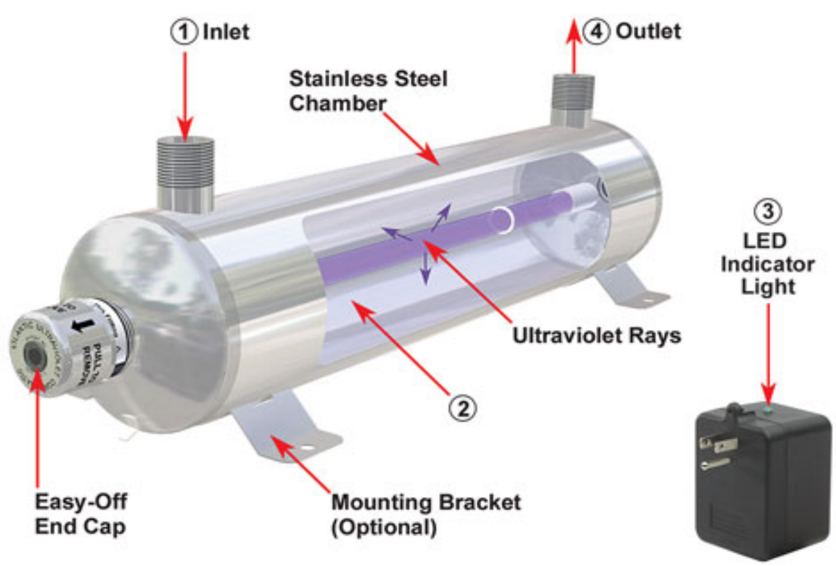


Figure 5.2.2: Schematic diagram of UV filtration system

5.3 Water Demand Projection

Bell's has projected that its water demand will increase from 150,000 gallons per day to 500,000 gallons per day. The third column in **Figure 5.3.1** shows the mean and peak capacity of all the equipment used in the water treatment plant. As the flow of water is distributed into different channels and water quality specifications for various operations are different, the mean and peak flow rates through different filters are different.

For the projected demand, the team assumed an exponential growth rate of 27.3% and that the mean water demand would also increase by 27.3% every year.

To calculate peak water demand for water treatment equipment requirements, the team calculated the difference between mean and peak water demand at the beginning of the project (Year 0) from the available data. Additionally, it was assumed that the peak demand would be higher than mean demand, by the same constant difference that was calculated for Year 0, for Years 1-5. The difference between mean and peak demand is equipment specific.

Equipment Name	Capacity in thousand gallons per day	Capacity	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Iron Filtration / Sediment Control Duplex 60"	Mean Flow	212	150	191	243	309	394	501
	Peak Flow	404	560	601	653	719	804	911
Carbon Backwash Filters Duplex 60"	Mean Flow	125	88	113	143	182	232	296
	Peak Flow	186	330	354	385	424	474	537
Water Softener System –Duplex 36x72 System	Mean Flow	88	62	79	101	128	164	208
	Peak Flow	152	232	249	271	299	334	378
De-Alkalizing System 24x72	Mean Flow	20	14	18	23	29	37	47
	Peak Flow	33	33	37	42	48	56	66
Pre-Filtering System	Mean Flow	500	150	191	243	309	394	501
	Peak Flow	500	150	191	243	309	394	501
UV Filtration System	Mean Flow	520	150	191	243	309	394	501
	Peak Flow	520	150	191	243	309	394	501

Figure 5.3.1: Water Demand Projections

<u>Water Treatment Plant Scale Up</u>

Designing a filtration system involves analysis of various parameters like volumetric velocity of water, contact time, filtration area, pressure difference, bed depth and density. Various water sources will have different water quality. Therefore, the specifications of the water treatment plant will vary, which will directly affect the cost, energy consumption, and carbon footprint of the brewery. Consideration of all these factors is an important part of the decision-making process.

The number of each piece of water treatment equipment required by Bell's will depend on the flow rate of the water and the capacity of the equipment itself. The frequency of filter media changes will depend on the quality of water that is passing through it. While municipal water sourced from

Kalamazoo, Portage, and Battle Creek is pretreated for microorganisms, Bell's still requires the use of pre-filters, iron filters, carbon filters, softeners and dealkalizers to treat water further. Additionally, in the case of the well option, Bell's would need to add a UV filtration system to kill pathogens.

As the flow rate of water will be the same for each of the cases, as shown in **Figure 5.3.1**, it can also be assumed that the capital requirements will also be the same for all the cases, except for the additional UV filtration for the well. Since municipal water is treated to comply with the Safe Drinking Water Act, it can be assumed that the water quality of Kalamazoo, Battle Creek and Portage is similar and, therefore, will have similar filter change frequencies. **Appendix G** shows Safe Drinking Water Act Compliant, Potable water specifications. **Appendix H** shows the sample water test results for city water conducted by KAR Laboratories.

In order to find the number of pieces of equipment required to meet the projected water demand, the team calculated the number of pieces of equipment that can handle the mean flow rates and peak flow rates by dividing projected mean flow rate by mean capacity and projected peak flow rate by peak capacity. One additional piece of equipment is kept at every instance accounting for contingency for mean flow rate calculations for all the equipment except the pre-filtration system and UV filtration system. We then considered the higher of the number of pieces of equipment required to handle the peak flow and mean flow to be the number of pieces of equipment required to meet the treatment requirement.

Equipment	Scenarios	Capacity of the equipment	FLOW RATE IN THOUSAND GALLONS PER DAY						NUMBER OF EQUIPMENT					
			Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Iron Filtration / Sediment Control Duplex 60"	Mean Flow	212	150	191	243	309	394	501	2	2	3	3	3	4
	Peak Flow	404	560	601	653	719	804	911	2	2	2	2	2	3
Carbon Backwash Filters Duplex 60"	Mean Flow	125	88	113	143	182	232	296	2	2	3	3	3	4
	Peak Flow	186	330	354	385	424	474	537	2	2	3	3	3	3
Water Softener System –Duplex 36x72 System	Mean Flow	88	62	79	101	128	164	208	2	2	3	3	3	4
	Peak Flow	152	232	249	271	299	334	378	2	2	2	3	3	3
De-Alkalizing System 24x72	Mean Flow	20	14	18	23	29	37	47	1	2	3	3	3	4
	Peak Flow	33	33	37	42	48	56	66	1	2	2	2	2	3
Pre-Filtering System	Mean Flow	500	150	191	243	309	394	501	1	1	1	1	1	1
	Peak Flow	**500**	150	191	243	309	394	501	1	1	1	1	1	1
UV Filtration System (Only for the well)	Mean Flow	520	150	191	243	309	394	501	1	1	1	1	1	1
	Peak Flow	520	150	191	243	309	394	501	1	1	1	1	1	1

Figure 5.3.2: Theoretical Scale Requirements for Water Treatment

Figure 5.3.2 shows the theoretical number of each kind of treatment equipment required by the method mentioned above. However, there are many practical constraints involved with installing new equipment every year, such as additional engineering, construction cost, temporary loss of production capacity, and plant shutdowns. Therefore, the team assumed that new equipment would be installed only in Years 2 and 5. For the well option, it is assumed that the UV filtration is installed in Year 0 when the well is constructed. **Figure 5.3.3** shows the theoretical and practical number of pieces of equipment to be installed each year. Numbers in red are for theoretical installation that is either preponed or postponed due to the practical constraints mentioned above.

Equipment	Additional number of equipment required (Theoretical)					Additional number of equipment required (Practical)				
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Iron Filtration / Sediment Control Duplex 60"	0	1	0	0	1	0	1	0	0	1
Carbon Backwash Filters Duplex 60"	0	1	0	0	1	0	1	0	0	1
Water Softener System –Duplex 36x72 System	0	1	0	1	1	0	1	0	0	1
De-Alkalizing System 24x72	1	1	0	0	1	0	2	0	0	1
Pre-Filtering System	0	0	0	0	0	0	0	0	0	0
UV Filtration System (only for the well)	0	0	0	0	0	0	0	0	0	0

Figure 5.3.3: Additional Number of Equipment Required Each Year (Theoretical & Practical)

As mentioned, the requirement for filter media change is different for municipal water and the well. For the NextSand media of the iron filter, the media isn't consumed in the filtration process. A simple periodic backwash keeps the media clean and operating efficiently for five years or more.[xxviii] As the water from the well has more contaminants we assumed that the filtration media has to be changed every five years for city water and three years for well water.

In the case of the carbon filter, the media has to be changed after every (500,000 x volume of filter media in cubic feet) gallons.[xxix] Since the project utilizes 65 cubic feet of media, the company would need to change the media after 32.5 million gallons for city water. Since the well water is untreated, it is assumed that filter media will deplete 1.5 times faster. As a result, the carbon filter media will need to be changed every 2,166,667 gallons.

For the softener, the resin lasts 10 years or more for the city water and five years for the well water due to its levels of iron, manganese and organic contamination.[xxx] The resin replacement frequency for the softeners is also assumed for the dealkalizer.

For the pre-filtration system, it is assumed that the media will last for three years for municipal water and two years for the well based on the past media change frequency at the brewery. **Figure 5.3.4** and **Figure 5.3.5** summarize the media change frequencies for municipal water and well water, respectively.

Equipment	Media	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Iron Filter	NextSand Filter Media	Change after every 5 years.					
Carbon filter	Carbon media - Coconut shell	Change after 32500000 gallons.					
	Flow rate through the carbon filter	88	113	143	182	232	296
	Number of filter changes required	0	1	1	2	2	3
Softner	10% cross linked macro porous cation resin	Change after every 10 years.					
Dealkalizer	Thermax A32 Anion resin	Change after every 10 years.					
Prefiltration system	40" melt blown depth filters – 5 micron	Change after every 3 years.					

Figure 5.3.4: Filter Media Change Requirement for Municipality Water

Equipment	Media	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Iron Filter	NextSand Filter Media	Change after every 3 years.					
Carbon filter	Carbon media - Coconut shell	Change after 21666667 gallons.					
	Flow rate through the carbon filter	88	113	143	182	232	296
	Number of filter changes required	1	1	2	3	3	4
Softner	10% cross linked macro porous cation resin	Change after every 5 years.					
Dealkalizer	Thermax A32 Anion resin	Change after every 5 years.					
Prefiltration system	40" melt blown depth filters – 5 micron	Change after every 2 years.					

Figure 5.3.5: Filter Media Change Requirement for Well Option

5.4 Sourcing Water from a Neighboring Municipality

The complexity of this option is not technical, but logistical. There is no standard process, as far as the team could discover, for a private party to seek approval for running a water main across property they do not own. To learn more about what might be required, the team contacted a consultant who works on projects involving complex permits and approvals with knowledge of a jurisdiction where private water mains are relatively common. The issues he raised are likely to be similar to what Bell's would encounter.

In California, the central issue is the kind of easements required. If the main can be run on municipal land, such as along a road, then the company would require public easements. In that case, the entire project could fall under a single permit and the negotiation on terms, depending on jurisdictions, could be with a single party, such as the municipality or local authority. If running the main required digging under privately owned land, that would require case-by-case negotiation with each landowner and every private easement would require its own permit. In cases where no agreement could be reached with a landowner, one option would be to go to court and attain the easement by condemnation. In addition to the easements, a project of this type would probably also require an environmental permit and possibly a planning permit for the entire project.[xxxi]

Another important consideration would be the ability of either Portage or Battle Creek to deliver the required volume of water without their own infrastructure upgrades. Portage and Battle Creek's water authorities are smaller than Kalamazoo's. Bell's projected use in five years is 10% of Portage's current daily average production and 5% of its peak capacity. When the team contacted the Portage Water Service, they were not aware of any previous case where a customer outside their service area connected to their system, but indicated there was nothing to prevent it.[xxxii] However, it is certainly possible that the negotiation of such a connection by a water-user of Bell's size would require special consideration and additional fees.

5.5 Software Tools

SimaPro

SimaPro was used to construct unit processes for the various subsystems described in the inventory. Once those were constructed, each subsystem was analyzed using the IMPACT 2002+ methodology which generated results by impact category and by indicator. This data was then used to build a model in Excel which was used to construct specific scenarios and compute their impacts. IMPACT 2002+ provides both mid-point characterizations (e.g. ozone layer depletion in kg CFC-11 equivalents) and end-point damage assessments (e.g. DALYs or disability-adjusted life-years). In general, the former are more certain and the latter are easier to interpret. The team has calculated both but will focus on the latter for ease of aggregation and clarity.

IMPACT 2002+ also provides normalized unit-less measures for all impact categories that allow for the various categories to be aggregated, generating a single-score. Normally, this is where it would be advised to use caution when relying on the single scores, as they can obscure tradeoffs between impact categories within a set of scenarios. Fortunately, and somewhat peculiar to this scenario set, the scenarios all have the same rank in the major damage assessment impact categories so the single-scores are not obscuring significant and incommensurable tradeoffs.

Stella

To model the energy and water flows in the well and neighboring municipality scenarios the team used isee Systems's Stella Professional. Stella Professional is a visual programming language for modeling dynamic relationships between stocks, flows, and arbitrary converters. This allowed the simulation of different possible system designs and sensitivity analysis around key design parameters. These simulations were used to test different pump, pipe, and tank sizes for adequacy. It also allowed the team to develop recommendations on final system specifications. Energy values produced by these simulations were then used as inputs in the use-phases of LCAs and to compute electricity values in the financial analyses.

R/ArcGIS

Because of the spatial nature of the groundwater impact model, geographic information systems were employed. The software package ArcGIS was used to import, reproject, and rasterize regional layers with vector data including roads, streams, lakes and wells on adjacent properties. ArcGIS was also used in the creation of thematic maps illustrating the property and the groundwater impact. A statistical programming language, R, was used for the raster calculation of the groundwater impact and the simulation of water wells throughout the Comstock brewing facility property.

5.6 Life-Cycle Assessment in SimaPro

Life-cycle assessment (LCA) is the process of calculating environmental impacts associated with a product or service from manufacturing phase to use phase to end-of-life. Life-cycle assessments of the various options and the calculation of their environmental impacts were done using SimaPro. For the well option, the team considered processes, energy, and material involved with digging a well and operating the water treatment plant. For the municipal water options, the team considered processes, energy and material involved in the piping infrastructure and water treatment plant.

Appendix H shows the list of assumptions, simplifications, and specifications of various components for the well digging process, water treatment plant, and piping infrastructure. The basis for all the components is one single unit. All the processes were normalized with respect to this unit for analysis in SimaPro. The impacts are reported in terms of a functional unit of one million gallons of water or approximately two days of projected use.

Various life stages involved in the four scenarios are as follows:

1. Continue sourcing water from the Kalamazoo Water Division:
    a. Water treatment
       (Pre-filter, Iron Filters, Carbon Filters, Softeners, Dealkalizers)
        i. Components of water treatment plant
            1. Materials acquisition
            2. Manufacturing
        ii. Backwashing of filter media
            1. Energy requirement
        iii. Filter media change
            1. Materials acquisition
            2. Manufacturing
        iv. Energy required to run the equipment

2. Drill an on-site well:
    a. Drilling a well
        i. Consumables involved in well drilling process
            1. Materials acquisition
            2. Manufacturing
        ii. Well infrastructure (casing, cement, etc.)
            1. Materials acquisition
            2. Manufacturing
        iii. Energy required to drill a well
    b. Transportation of water from the well to the brewery
        i. Piping infrastructure

            1. Materials acquisition
            2. Manufacturing
        ii. Pumping infrastructure
            1. Materials acquisition
            2. Manufacturing
    c. Water storage tank to meet peak demand of water
            1. Materials acquisition
            2. Manufacturing
    d. Water treatment
    (Prefilter, Iron Filters, Carbon Filters, Softener, Dealkalizer, UV filtration system)
        i. Components of water treatment plant
            1. Materials acquisition
            2. Manufacturing
        ii. Backwashing of filter media
            1. Energy requirement
        iii. Filter media change
            1. Materials acquisition
            2. Manufacturing
        iv. Energy required to run the equipment

3. Source water from the City of Portage:
    a. Transportation of water from Portage to the brewery
        i. Piping infrastructure
            1. Materials acquisition
            2. Manufacturing
        ii. Pumping infrastructure
            1. Materials acquisition
            2. Manufacturing
    b. Water treatment
    (Prefilter, Iron Filters, Carbon Filters, Softener, Dealkalizer)
        i. Components of water treatment plant
            1. Materials acquisition
            2. Manufacturing
        ii. Backwashing of filter media
            1. Energy requirement
        iii. Filter media change
            1. Materials acquisition
            2. Manufacturing
        iv. Energy required to run the equipment

4. Source water from the City of Battle Creek:
    a. Transportation of water from Battle Creek to the brewery
        i. Piping infrastructure
            1. Materials acquisition
            2. Manufacturing
        ii. Pumping infrastructure
            1. Materials acquisition
            2. Manufacturing
    b. Water treatment
    (Prefilter, Iron Filters, Carbon Filters, Softener, Dealkalizer)
        i. Components of water treatment plant
            1. Materials acquisition
            2. Manufacturing
        ii. Backwashing of filter media
            1. Energy requirement
        iii. Filter media change
            1. Materials acquisition
            2. Manufacturing
        iv. Energy required to run the equipment

Figure 5.6.1 shows the quantitative specifications (for the final 5th year) of various components for which we performed material analysis and energy analysis.

Actual Use	Kalamazoo	Well	Portage	Battle Creek	Units
Well	0	2	0	0	Total number of wells in the scenario
PVC pipe from the well to facility	0	272	0	0	m PVC (8")
100 hp Pump	0	0.66	2	4	100 hp
Neighboring Muni	0	0	11.75	24.14	km pipe
Iron Filter	4	4	4	4	Total number of apparatus in the scenario
Carbon Filter	4	4	4	4	Total number of apparatus in the scenario
Softener	4	4	4	4	Total number of apparatus in the scenario
De-Alkalizer	4	4	4	4	Total number of apparatus in the scenario
Pre-Filter	1	1	1	1	Total number of apparatus in the scenario
UV Device	0	1	0	0	Total number of apparatus in the scenario
Electricity to pump water to the facility	0.0	281762.0	209768.0	256018.0	kWh/year
Electricity for water treatment	742406.6	753791.6	742406.6	742406.6	kWh/year
Volume of Municipal Water	690837.8	0.0	690837.8	690837.8	m^3
Water storage tank size	0	7	0	0	m^3

Figure 5.6.1: System Specifications for various scenarios

One of the important factors to be considered while carrying out life-cycle analysis is the useful life of different components. **Figure 5.6.2** shows the lifespan of various components in different scenarios. Depending on the useful life, we calculated amortized usage of the components on a yearly basis in **Figure 5.6.3**.

Component	Useful life (years)
Well	40
PVC pipe from the well to facility	40
Pumps	20
PVC pipe from the well to facility	40
Iron Filter	20
Carbon Filter	20
Softener	20
De-Alkalizer	20
Pre-Filter	20
UV filtration device	20

Figure 5.6.2: Useful life of various components in different scenarios

Amortized Use (per year)	Kalamazoo	Well	Portage	Battle Creek	Units
Drill Well	0	0.05	0	0	Number of wells in the scenario
PVC to facility	0	6.8	0	0	m PVC (8")
Large Pump	0	0.03	0.1	0.2	100 HP
Neighboring Muni	0	0	0.29	0.60	km pipe
Iron Filter	0.2	0.2	0.2	0.2	Number of apparatus in the scenario
Carbon Filter	0.2	0.2	0.2	0.2	Number of apparatus in the scenario
Softener	0.2	0.2	0.2	0.2	Number of apparatus in the scenario
De-Alkalizer	0.2	0.2	0.2	0.2	Number of apparatus in the scenario
Pre-Filter	0.05	0.05	0.05	0.05	Number of apparatus in the scenario
UV Device	0	0.05	0	0	Number of apparatus in the scenario
Electricity Conv	742406.6	1035553.6	952174.6	998424.6	kWh/year
Electricity Wind	0.0	0.0	0.0	0.0	kWh/year
Electricity Solar	0.0	0.0	0.0	0.0	kWh/year
Municipal Water	690837.8	0.0	690837.8	690837.8	m^3
Iron Filter Media	1.0	1.7	1.0	1.0	Annual frequency for filter media change
Carbon Filter Media	5.6	8.4	5.6	5.6	Annual frequency for filter media change
Softener Media	0.5	1.0	0.5	0.5	Annual frequency for filter media change
De-Alkalizer Media	0.4	0.8	0.4	0.4	Annual frequency for filter media change
Pre-Filter Media	0.6	1.0	0.6	0.6	Annual frequency for filter media change

Figure 5.6.3: Yearly amortized usage of various components

5.7 Energy Modeling

Life-cycle analyses of systems often find that the single largest impact of the system is energy usage during the use-phase. The team confirmed that this was indeed true of these various water sourcing systems by running a crude version of the well system (the system we assumed to have the largest non-use-energy component) in SimaPro, the result was as expected, over 95% of the impact was from energy-use during the use-phase. For this reason, the team decided to expend relatively more time carefully modeling the energy used by the various non-KWD water-sourcing options. The outputs of these energy models were then used as inputs in the LCA and financial models to understand the full impacts of energy use.

Before the team could begin modeling the energy-use of each scenario, they needed to specify and size the components required for each scenario. This required integrating water-use data provided by Bell's, information from an interview with the manager of a well drilling company, and manufacturer's specifications. To model the energy required to pump water for the well and neighboring municipality scenarios, and ensure that the systems that were designed could handle Bell's peak water demand, the team used Stella, a system dynamics software package.

Bell's provided the team with one month of water-use data with flow rates at thirty second intervals. That data gave an average daily use of 515 cubic meters (136,147 gallons). That average is somewhat deceptive as the actual distribution of flow rates is nearly exponential with a peak flow rate over five times the average. Planning for growth toward an average daily use of 1,893 cubic meters (500,000 gallons), in the worst case, means multiplying every interval's flow rate by the ratio of future average use to current average use. The team viewed this future water-use profile as unlikely but used it to test the systems we designed to assess their adequacy.

<u>Treatment System Energy</u>

In order to calculate the consumption of electricity of the equipment in the treatment plant, we carried out a literature review and found data for estimates of electricity consumption of water treatment for various unit processes. Given that pumping water is the most energy intensive part of the filters, dealkalizers and softeners and the operating pressure is similar for all the processes (as displayed in **Appendix J**), we assumed that the electricity consumption by the carbon filter, iron filter, pre-filtration system, softener and dealkalizer is the same as the energy required for an ultrafiltration unit process found in the literature.[xxxiii]

	Plant Production (Milllion Gallons per Day)						
UNIT PROCESS	**1**	**5**	**10**	**20**	**50**	**100**	**200**
Ultrafiltration (contaminant removal)	800	4000	8000	16000	40000	80000	200000
UV disinfection	62	310	625	1250	3120	6240	15600
Backwash water pumps	15	60	125	250	660	1290	3220

Figure 5.7.1: Estimates of Electric Energy Intensity of Wastewater Treatment Unit Processes (in kWh/day)

Figure 5.7.1 shows estimates for various unit processes for different treatment plant sizes. We fit a regression model in R (code is displayed in **Appendix J**) and found out the electricity consumptions for our plant size. The iron and carbon filters in the brewery, when originally installed, were backflushed 2 or 3 times a week. However, by the end of the media's life, they were backflushed twice a day. Therefore, we assume that every piece of equipment, on average, is backflushed once a day.

		Kalamazoo	Well	Portage	Battle Creek
Water Use	m^3/day	1,893	1,893	1,893	1,893
Filtration	times/m^3/day	5	5	5	5
Backwash	times/m^3/day	5	5	5	5
UV	times/m^3/day	-	1	-	-
Total Electricity Consumption for Water Treatment	kWh/day	742,407	753,792	742,407	742,407

Figure 5.7.2: Electricity consumption for water treatment plants of various sizes

Based on these assumptions and analysis, we calculated electricity consumption for the water treatment plant as shown in **Figure 5.7.2**.

Well System

The well system is modeled as two wells of equal size. At the bottom of each well is a submergible pump that lifts the water from the bottom of the well and delivers it to a tank within the brewery at relatively low pressure. On the other side of the tank is a pump that then delivers the water at the required pressure to Bell's water treatment equipment. The mechanical power the pumps must produce is computed as follows:

$$P = q\lambda\left\{h + \frac{p}{\lambda} + \left[\frac{q}{\pi(d/2)^2}\right]^2 \frac{1}{2g} + \frac{10.67\,l q^{1.852}}{C^{-1.852} d^{-4.8704}}\right\}$$

Where P is power in kW, q is the flow rate in m^3/s, γ is the specific weight of water in kN/m^3, h is the well depth in meters, p is the pressure in kilopascals, d is the diameter of the pipe in meters, g is the acceleration due to gravity (9.8 m/s^2), l is the length of the pipe in meters, and C is the pipe roughness coefficient (150 for PVC and 110 for steel). To note, the last term in the brackets is the

Hazen-Williams equation which is an empirical equation that relates the flow of water in a pipe to the loss of energy-head due to friction.

Translating this mechanical power into electrical power requires knowing the efficiency of the pump, and ideally, the efficiency of the pump at every rate of flow. Indeed, maximizing this efficiency over the whole range of flow rates is part of the reason that variable-frequency drives (VFDs) such as the ones recommended by the well drilling contractor are beneficial. Unfortunately, modeling VFDs properly and then controlling them optimally so as to actually achieve the full theoretical benefits is very complicated and not always successful, typically achieving only 40% of the theoretical benefit.[xxxiv] The team therefore chose a number at the higher end of pump efficiencies reported in the literature on account of the use of VFD controllers which was 80%.[xxxv]

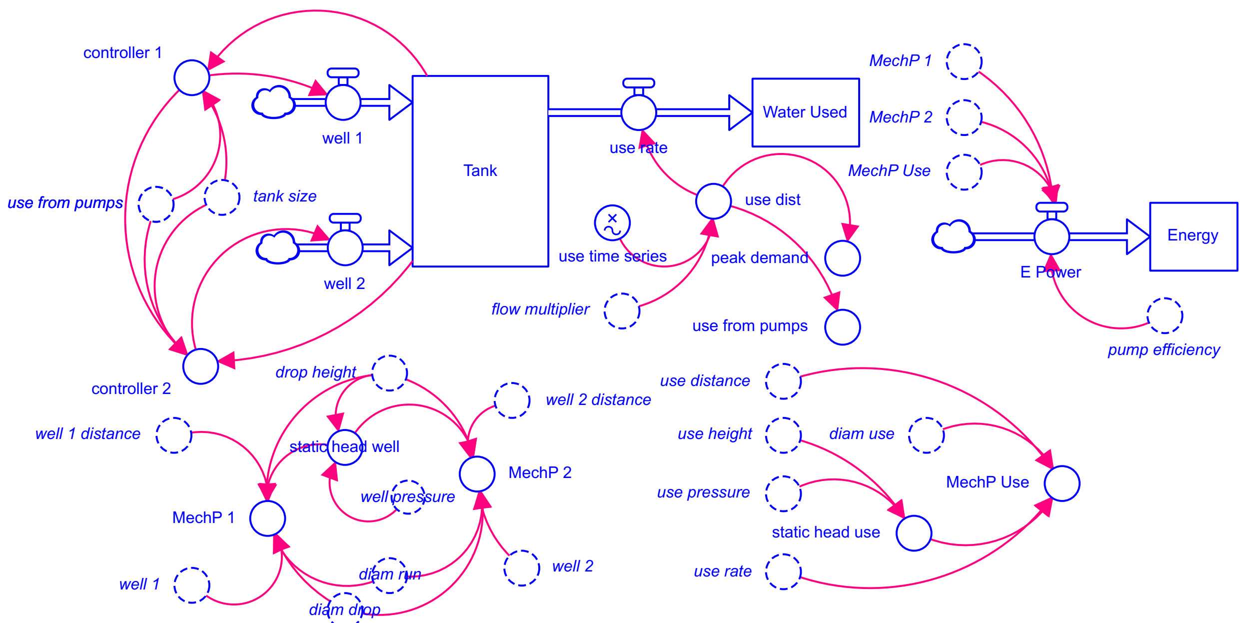


Figure 5.7.3: Stella energy model for well system

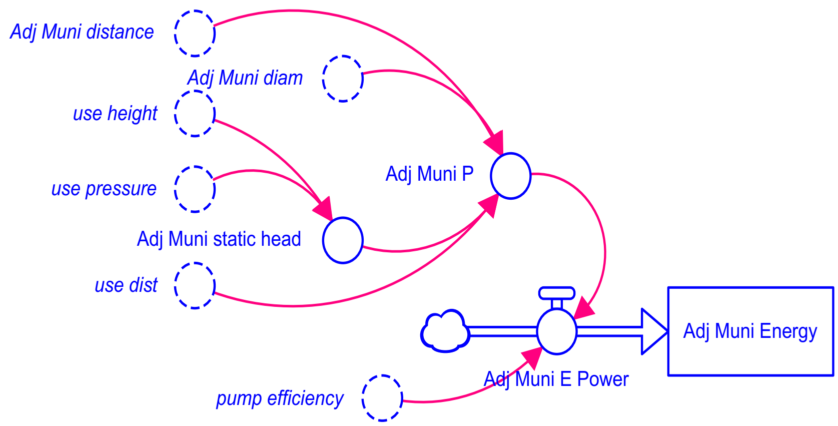


Figure 5.7.4: Stella energy model for adjacent municipality system

Even with VFDs, a pump operating well below its maximum power is less efficient than one operating closer to its maximum power. For this reason, there are tradeoffs involved in sizing tanks and pumps to meet highly variable demand. Further, these tradeoffs are difficult to accurately quantify on account of the nonlinearities in the system and the uncertainty in the shape of the distribution of future flow rates. While one can expect average flow rates to rise by a factor of approximately 3.7, the team was far less confident in using the same factor for the peaks. However, that is in fact how the systems were modeled for two reasons: The first is that it is reasonable to assume that this is an edge scenario and the worst-case one at that. The second is that without detailed information about how water is used, how high-use processes are scheduled and the operational difficulty of changing how water is used, changing the use distribution would require making assumptions for which we have no meaningful basis.

Assuming a 7 m^3 tank, and that optimal operation for a pump is either off or running at greater than 95% of capacity. With 25 horsepower pumps, the primary pump runs optimally 33% of the time, the secondary pump runs optimally 76% of the time, and both pumps are running optimally 9% of the time. Over the course of a month, this system fails to deliver 0.02% of the total water on time. With 50 horsepower pumps, the primary pump runs optimally 9% of the time, the secondary pump runs optimally 93% of the time, and both pumps are running optimally less than 2% of the time. Over the course of a month, this system fails to deliver ~0% of the total water on time.

Because at this point the models are assuming constant pump efficiency, the differences in energy use between those two options are negligible. The energy penalty for the larger system is likely to be considerable since it spends a greater portion of its time operating at much less than peak capacity. While VFDs are able to expand the range of high efficiency operation they still see penalties below 50%.

Sizing a system to meet peaks that last only 15 minutes a month at the expense of the system's overall efficiency is a questionable proposition, especially given the fact those peaks may never actually occur. A system able to meet this projected peak use is twice as large the one specified, twice as expensive and, depending on configuration, of equal or lesser efficiency. The other possible route is to increase the tank size. Unfortunately, that is an even less efficient option. A tank large enough to meet peak demand with the specified pumps would need to be in excess of 200 m^3.

Adjacent Municipality System

The system to deliver water from an adjacent municipality is similar but simpler than the well system. We model it as a 10" PVC pipe running from the adjacent municipality's closest water main to Bell's Brewery. We assumed the pipe would be laid along roads so we used the driving distance from Google Maps and then made reasonable adjustments based on a map of the area. The actual route would be determined by the permitting process and contingent on acquiring easements along the route. This uncertainty in the route reduces the reliability of our energy estimates as friction increases with both length of pipe and number (and sharpness) of bends. We also assume that in this case there is no tank so the water is always pumped at the required instantaneous use rate and delivered at the desired pressure of 414 kilopascals. We calculate the power requirement only once for the length of pipe in the energy model but it is likely that multiple pumps would be placed along the route.

5.8 Financial Modeling

The financial models for each scenario were built in excel using the data gathered during the research phase and various assumptions discussed below.

Filtration Equipment Requirements

The financial analysis began by laying out all the incremental capital requirements for increasing the water consumption from Bell's current water source (**Figure 5.8.1**).

Equipment	Useful Life	Cost	Current Inventory	Required Upgrade				
				Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Iron Filter								
Iron Filtration / Sediment Control Duplex 60 in; Backwash Filters	15	20,118	2	0	1	0	0	1
OPTIONAL Automated Differential Pressure Sensing system adder	5	2,235	2	0	1	0	0	1
Next Sand Filter Media		2,700	2	0	1	0	0	1
Carbon Filter								
Carbon Backwash Filters Duplex 60 in	15	19,148	2	0	1	0	0	1
OPTIONAL Automated Differential Pressure Sensing system adder	5	2,235	2	0	1	0	0	1
Carbon media adder CR1230C-Coconut shell, add		5,760	2	0	1	0	0	1
Water softener								
Water Softener System –Duplex 36x72 System	15	7,221	1	0	1	0	0	1
10% cross linked macro porous Cation resin.		2,068	2	0	1	0	0	1
De-alkalizer								
De-Alkalizing System (1) 24x72	15	5,240	1	0	2	0	0	1
Thermax A32 Anion resin		3,024		0	2	0	0	1
Pre-filtration system								
UV filtration system [WELL OPTION ONLY]	10	7,850	0	1	0	0	0	0

Figure 5.8.1: Treatment Upgrade Scenario Costs and Requirements

After identifying the required equipment, it was then necessary to determine when each piece would be installed and the intervals at which they would need to be replaced (*i.e.* their useful life).

As mentioned before, the installation of new treatment equipment to support the increased water requirements would take place in years two and five. The only exceptions would be the useful life of the equipment listed in **Figure 5.8.1** and **Figure 5.6.2**.

Another key assumption regarding the filtration systems was that each system came with all components installed. For example, in Year 2, each Dealkalizer installation came with the De-Alkalizing System and the Thermax A32 Anion resin as a package. The same can be said for the Iron Filter, Carbon Filter, Water Softener, and Pre-filtration system.

<u>Discount Rate</u>

Bell's does not have an internal Weighted Average Cost of Capital or standardized discount rate for internal financial modeling. Therefore, for discounting purposes, the team was advised by Bell's to use an inflation rate plus an additional three percent. The team opted to calculate the inflation rate from 1976 to 2016, since the longest lifespan between all four models would be 40 years. The inflation rate plus three percent yielded a discount rate of 6.68%.

<u>Equivalent Annual Costs</u>

Since the well has a 40-year project lifespan, the Battle Creek and Portage options were given similar project useful lives. In reality, the team doesn't know how long Bell's would continue to use Battle Creek or Portage, but assumed that with the high capital investment, the asset would last over several decades. However, for the base case, the team assigned the project a 15 year lifespan primarily under the assumption that at some point, within 10 years of the completed upgrade, Bell's would look for further ways to expand the company and its water requirements.

Since all four options have unequal lifespans, an equivalent annual cost, which is the annual cost of ownership over the life of a project, is the accepted method of comparing these projects. The method involves turning the project's net present value into an annuity over the its lifespan.

Well Model Assumptions

Appendix L display the costs used to build the financial model for the well. Additional assumptions are that the well will be utilized for a period of 40 years and its pump will be running on a frequent basis, which will limit its useful life to 10 years.

Municipality-Based Models

As stated previously, there was very little information regarding similar projects of this type or magnitude. Interviews with the Portage and Battle Creek county offices revealed that water transmission lines to Comstock did not exist and officials were unable to provide any estimate on what they would cost to build.

Therefore, the project team utilized a number of resources to help build an analogue which would aid in the development of assumptions for the financial model. In 2003, Michigan's Department of Treasury published its STC Assessor's Manual, a guide for establishing property values for tax purposes. Within the manual, Section UIP 12 Page 2 under the heading "General Information" begins with, "The pipe costs on this and the following page are averages of installed costs per linear foot including contractor's overhead and profit, but excluding any design layout costs or fees."[xxxvi] The manual further describes that costs are listed under two categories, Service Piping and Utility Piping, for which Utility Piping refers to "pipes, fittings, and valves installed outside and up to the building lines."[xxxvii] Within Utility Piping, the subcategory of pressure lines refers to lines that carry water (**Figure 5.8.2**).

PIPING

SECTION UIP 12

UTILITY PIPING

Cost per linear foot for underground utility lines, including fittings, an allowance for trenching and backfill and contractors' overhead and profit. For non-circular pipe, use the average diameter of the smallest and largest dimension.

PRESSURE PIPE	4"		6"		8"		10"	
Asbestos cement	$21.50 –	$ 27.30	$26.80 –	$34.95	$34.60 –	$44.30	$57.55 –	$71.15
Ductile iron	22.15 –	27.15	24.25 –	30.80	37.40 –	48.30	45.35 –	59.70
Concrete	----- –	-----	----- –	-----	----- –	-----	----- –	-----
Plastic	11.80 –	15.40	13.95 –	18.00	20.60 –	26.45	25.30 –	36.10
Steel	26.05 –	28.65	31.85 –	36.35	39.80 –	47.00	59.05 –	71.40
Valves, each	555 –	720	1,225 –	1,475	2,100 –	2,500	3,325 –	3,850

Figure 5.8.2: Michigan Assessor's Manual Vol II: UIP 12 - Utility Piping Costs

Utilizing **Figure 5.8.2**, the team assumed Bell's would require a 10" diameter plastic pipe beginning at the closest main in each municipality and leading to the Comstock brewery. Using a 2% inflation adjustment of the median price of $30.70 per linear foot, it was estimated that transmission mains from Portage and Battle Creek would span a distance of 7.3 and 15 miles, respectively. Based on these assumptions, **Figure 5.8.3** shows the estimated costs of the transmission main construction for Portage and Battle Creek.

Cost per linear foot	$30.70	10" plastic
Cost after inflation	$40.51	2% from 2003-2017

***Note:** Inflation calculated using 2% CAGR from 2003-2017*

City	Closest Main	Distance (miles)	Total Cost
Portage	Kilgore Rd	7.3	$1,590,911
Battle Creek	Columbia Ave & 94	15	$3,208,233

Figure 5.8.3: Portage and Battle Creek Transmission Mains Costs

For the total cost of the project, the team used the 2013 Karegnondi Water Authority (KWA) cost proposal to the State of Michigan Department of Treasury. The proposal was to be the blueprint for Flint's eventual connection to the Lake Huron Pump Station. The team made reasonable assumptions, based off **Figure 5.8.5**,[xxxviii] as to the additional costs required to lay the transmission mains from the municipality to Comstock. Using the KWA and municipality Transmission Mains as a ratio to the total cost, the team was able to create an estimated total cost of construction for each municipality (**Figure 5.8.4**).

KWA Total Cost Comparison				
Description	**KWA Cost**	**Percent of Total**	**Portage Cost**	**Battle Creek Cost**
Transmission Mains	$ 217,645,389	92.84%	$ 1,590,911	$ 3,208,233
Construction Management	14,434,410	6.16%	105,510	212,773
Administration	349,440	0.15%	2,554	5,151
Legal/Easement/Contract Documents	831,000	0.35%	6,074	12,249
Easements	1,166,170	0.50%	8,524	17,190
Total	**$ 234,426,409**	**100.00%**	**$ 1,713,574**	**$ 3,455,597**

Figure 5.8.4: KWA Total Cost Comparison

Description	KWA Estimate	TYJT Estimate
Intake/Crib	$ 27,596,063	$ 27,596,063
Pump Stations	30,772,600	71,042,808
Transmission Mains	207,752,895	217,645,389
Power	4,000,000	4,000,000
Redundant Power for PS		1,273,200
Land for Lake Huron Pumping Station	2,300,000	2,300,000
Design Engineering/PS and Transmission		16,939,581
Construction Management		14,434,410
Administration		349,440
Legal/Easement/Contract Documents		831,000
Easements		1,166,170
Total	**$ 272,421,558**	**$ 357,578,061**

Figure 5.8.5: KWA Cost Estimate

Water commodity rates were based on publicly available information for Portage, Battle Creek, and Kalamazoo. The rates, shown in

Figure 5.8.6, were applied to the water capacity schedule required for Bell's operations.

Municipality	Published Rate	Rate (per 1,000 US gal)
Kalamazoo	$0.42 per cubic meter[xxxix]	$1.59
Portage	$3.19 per 1,000 gallons[xl]	$3.19
Battle Creek	$1.68 per 100 cubic feet[xli]	$2.25

Figure 5.8.6: Municipality Water Commodity Rates

Finally, it was assumed that project planning and construction would begin in Year 0 and continue through the end of Year 2 for Portage and Battle Creek. Bell's would have full access to these respective water sources beginning in Year 3, and would then begin incurring the associated costs.

5.9 Groundwater-Surface Water Impact Modeling

The social impacts of an on-site water well include the widespread effects that aquifer depletion would have on water production from residential wells on adjacent properties, whereas the ecological impacts involve the induced infiltration of surface water in nearby lakes, streams and wetlands. While considering this as an option for sourcing the brewery's water, it was necessary to develop a groundwater impact model that would simulate the water table drawdown. This was then used to attempt to quantify the social and ecological impacts on the surrounding region. In so doing, the location of the well field on the property was optimized to meet these different social and ecological objectives.

Hydrogeology of the Morrow Lake Groundwater Reservoir

To understand the impact that the well pumping regime would have on the local water table, it was necessary to first determine the hydrogeological characteristics of the underlying aquifer. Although these characteristics could be determined using localized well pump tests, budgetary and time constraints limited the discovery of these properties to a scientific literature review. The Comstock brewing facility of Bell's Brewery exists on property about 150 meters from Morrow Lake, a manmade impoundment on the Kalamazoo River. Underlying the property is the Morrow Lake Groundwater Reservoir, an unconfined aquifer composed of sandy-gravelly glacial deposit. The closest test well to the Bell's property includes lithological data indicating an upper aquifer 99 feet thick with a 5 foot thick layer of sand at the surface, 15 feet of sand and gravel, 24 feet of sand, 25 feet of clay and 30 feet of gravel and sand. Underlying this aquifer is the Coldwater Shale, a bedrock formation approximately 500 feet thick. Few wells have penetrated the shale where "yields are small and water is largely mineralized." The transmissivity of the Morrow Lake groundwater reservoir is estimated to be between 40,000 and 80,000 (gal/day)/ft. Given the sustained induced recharge from the overlying river and streams, its estimated limit of development is the extraction 10 million gallons of water per day, roughly 20 times the amount that the brewery is projected to consume by 2020.[xlii]

Groundwater Drawdown Model

The groundwater drawdown model was developed to simulate what is known as the "cone of depression" below a hypothetical water well field on the property of the Comstock brewing facility. The cone of depression is the drawdown of the water table that develops from the pumping of water from an unconfined aquifer. The magnitude of the drawdown is greatest near the well field and decreases as the radius away from it increases. The size and shape of the cone depends on the well pumping rates, how long the wells are operated at a given time and the hydrogeological parameters of the underlying aquifer. Because of the numerical, spatial nature of the model, software-based and script-based geographic information systems were employed.

ArcGIS, a geographic information system software package, and R, a statistical programing language, were used to generate a raster map layer representing the cone of depression lateral area of influence radiating from a simulated water well field. This was done by first importing a layer representative of the Comstock brewing facility property and the surrounding area into ArcGIS.

Impact Space Layer

The "Estimated Groundwater Recharge" layer was downloaded from the Michigan Geographic Data Library and imported into ArcGIS. The layer was then clipped to only include the four recharge areas encompassing the property and surrounding region; an area of 10.4 square kilometers, roughly 11.4% of the area of the entire Comstock township, to be representative of the well field "impact space." The impact space layer was reprojected into a longitude and latitude projection on the World Geodedic System (WGS84) ellipsoid and rasterized with an extent of xmin = -85.47308, xmax = -85.43358, ymin = 42.27395, ymax = 42.3032. The resolution of the layer was set at 0.00005 decimal degrees, setting each pixel size to roughly four square meters.

Decision Space Layer

In creating the "decision space" layer, a copy of the pre-rasterized impact space layer was used and then manipulated to represent the property of Bell's Comstock brewing facility. The clip was overlaid with the Kalamazoo County roads layer imported from the Michigan Geographic Data Library. Next, an aerial image of the site from Google Earth was imported into ArcGIS and georectified using road intersections. This image, from 2015, illustrates the brewery in the process of constructing its new logistics facility. Although the facility is not completed in the image, the outline of the foundation was adequate in determining the layout of the buildings on the property. Heads-up digitization was then used to create a vector layer representing the land, buildings, paved surfaces and the holding pond in the back of the property. Both the aerial and digitized images are presented below (**Figure 5.9.1** & **Figure 5.9.2**).

Figure 5.9.1: Aerial Image of Comstock Facility

The Michigan Department of Environmental Quality requires minimum isolation distances for Type 2a industrial wells. These include distances were determined to avoid the contamination of industrial water supplies. While the minimum distance from a building is three feet under Act 399 of the Michigan Safe Water Drinking Act of 1976, given the size of the brewery's property, we recommend an isolation distance of 150 feet to remove the well field from existing underground infrastructure and possible contaminants. In ArcGIS, a 150-foot buffer was generated around the buildings and the remaining space on the property was rasterized to the same resolution as the impact space layer.

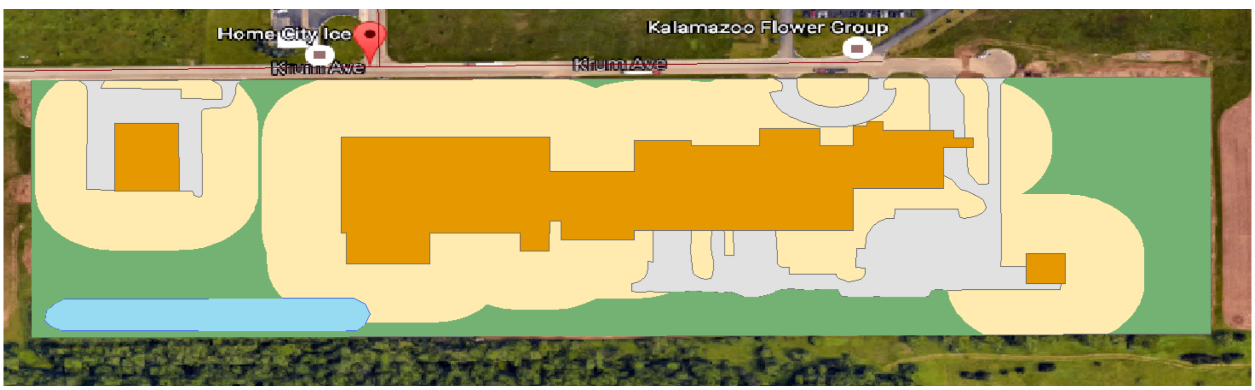


Figure 5.9.2: Digitized Image of Comstock Facility

<u>Surface Water, Stream and Lake Layers</u>

To understand the interactions between the well field pumping regiment, surface water and wells on adjacent properties, layers were added to the model to include these data. The Kalamazoo County "MI Geographic Framework Hydrography (v14a)" layer was downloaded from the Michigan Geographic Data Library and clipped to the same extent of the impact space. This layer illustrated a section of Morrow Lake and the ephemeral streams that feed into it. In fact, one of the streams is piped under the property, a section that is likely not subject to induced infiltration from the well field pumping. A "surface water" layer with combined lake and stream vectors was generated, while a "stream" layer and "lake" layer were generated to isolate the impact on each separately. These three layers were clipped to the same extent as the impact space layer and rasterized with the same resolution.

Water Well Layer

Depending on the actual depth of the wells and a more accurate understanding of the aquifer, the well field may impact the production of water from wells on adjacent properties. To mitigate this impact, the locations of these wells were taken into consideration in the well field placement optimization and a "well" layer was generated. The Kalamazoo County "Drinking Water Wells" layer was downloaded from the Michigan Geographic Data Library, clipped to the same extent and rasterized with the same resolution as the impact space.

Cone of Depression Model

The impact space layer was imported into RStudio for raster processing. For the initial drawdown model, a point on Bell's property 150 feet from the facility's water main connection was selected for the origin of the hypothetical well field at 42.28422144° N, -85.45245228° W. To model the cone of depression, the Neuman solution for late time drawdown in an unconfined aquifer[xliii] was used:

$$h_0 - h = \frac{Q}{4\pi T} W(u_\beta, \Gamma)$$

Where h_0–h is the drawdown in feet, Q is the well pumping rate in ft^3/d, T is transmissivity in ft^2/d and $W(u_\beta, \Gamma)$ is the well function for an unconfined aquifer. Although the well function is approximated by the following infinite series,

$$W(u_\beta) = -0.577216 - \ln(u_\beta) + u_\beta - \frac{u_\beta^2}{2\times2!} + \frac{u_\beta^3}{3\times3!} - \frac{u_\beta^4}{4\times4!} + \cdots$$

It can be estimated in a table[xliv] if the values for u_β and Γ are known. These respective values are found using the following equations:

$$u_\beta = \frac{r^2 S_y}{4Tt} \qquad \Gamma = \frac{r^2 K_v}{b^2 K_h}$$

Where r is the radial distance, in feet, from the well, S_y is the dimensionless value of specific yield, T is the transmissivity in ft^2/d, t is time in days, b is the saturated thickness of the aquifer in feet, K_v is vertical hydraulic conductivity, in ft/T and K_h is horizontal hydraulic conductivity, in ft/T.

In RStudio, a distance layer was generated from the impact space layer, where each pixel represented the distance, in feet, from the origin of the hypothetical well field. Two functions were written to perform the drawdown raster calculation: a lookup function where the inputs u_β and Γ

are used to determine the estimated well function value from the table; and the actual drawdown function. The drawdown function was parameterized using the projected pump rate and the hydrogeological values from the literature, as seen in **Figure 5.9.3**.

Parameter	Value from literature
Q (ft^3/day)	66,840.2778
T (ft^2/day)	8,021[xlv]
t (day)	0.33
S_y (dimensionless)	0.25
b (ft)	44[xlvi]
K_v	1
K_h	1

Figure 5.9.3

The previous parameters include a pumping rate of 150,000 gal/day, which converts to 66,840.2778 ft^3/day, an average transmissivity of 60,000 (gal/day)/ft, which converts to 8,021 ft^2/d, the dimensionless yield rate of 0.25, and the aquifer thickness of 44 ft, indicated by Bell's irrigation well permit. The vertical and horizontal hydraulic conductivity were both set at one, assuming the unconfined aquifer is isotropic, meaning the resistance through the sand and gravel horizontally equals the same resistance vertically.

The raster layer was processed to produce the cone of depression illustrated in the following map:

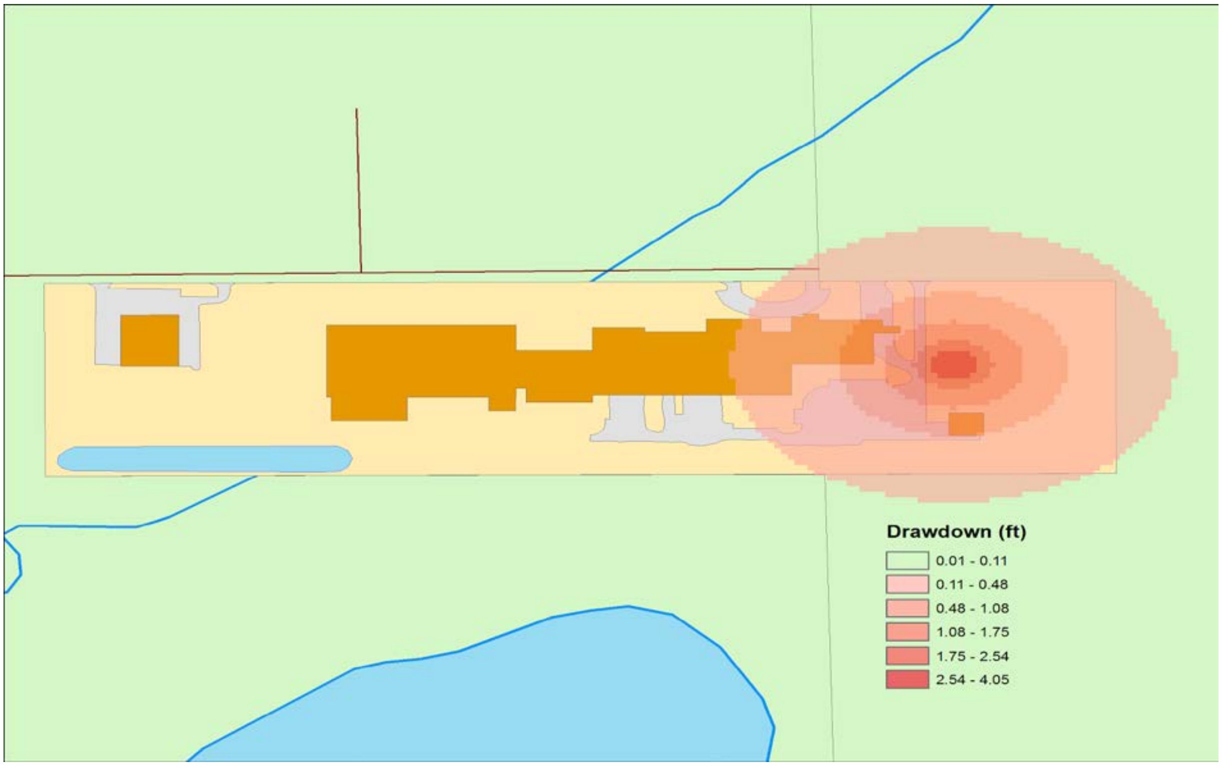


Figure 5.9.4: The above map indicates the cone of depression at the closest feasible point to the water main hookup, given the 150-foot buffer around the building.

6 ANALYSIS

6.1 Environmental Impact

Introduction

Before getting into the results of the LCAs for the various water sourcing options, there are a few things to point out. The first is that the process data used are often global (or European) averages. The team attempted to customize the processes in SimaPro to most closely reflect local conditions (*e.g.* the grid mix for on-site and municipal electricity use is that of Consumers Energy), but for many processes (*e.g.* steel fabrication) global averages are all that are available. In the case of commodities, this is not such a concern since the market for most commodities is global, reliable sourcing information is hard to come by, and in most of the scenarios, materials have little contribution to total impact.

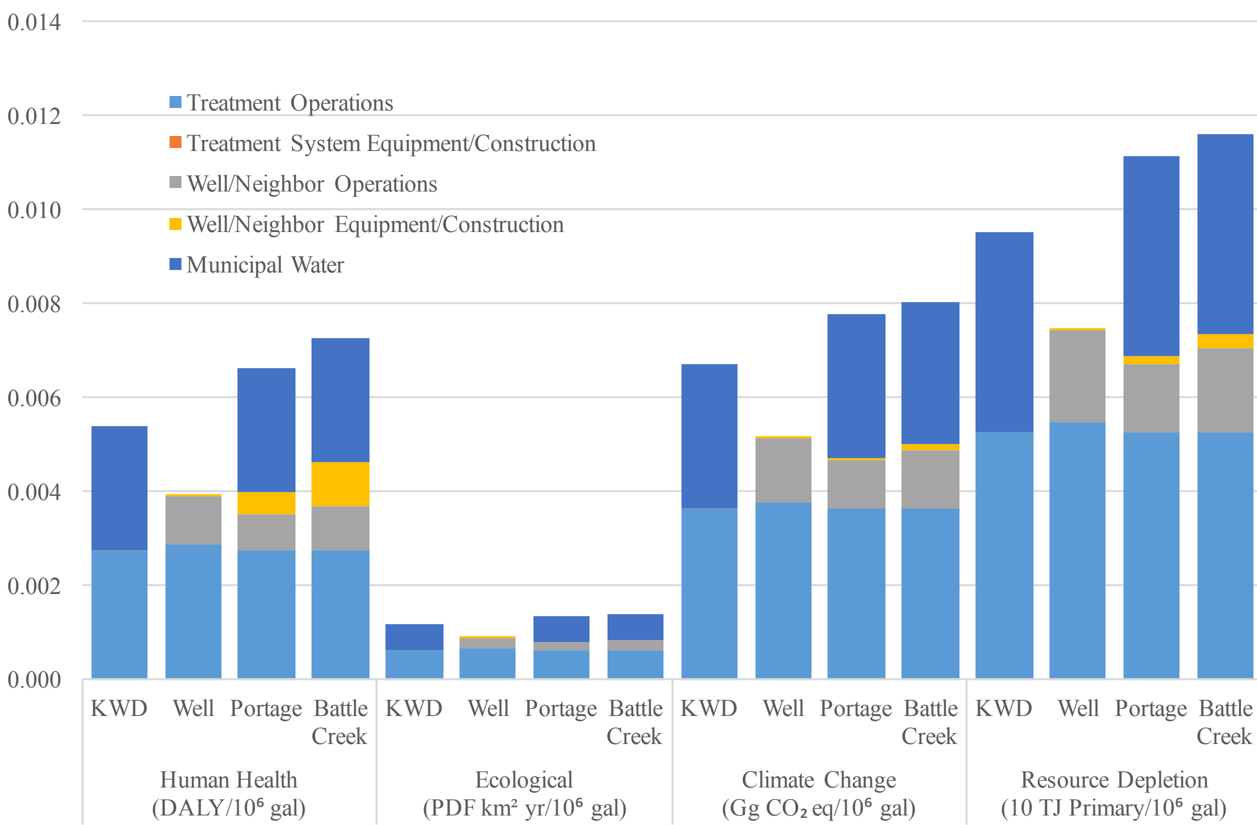


Figure 6.1.1: Life cycle impacts, category endpoints

The global averages issue ties into the second peculiarity of this type of LCA which is that the impacts it describes are global. In certain impact categories, that is a non-issue, climate change is a global phenomenon so where the emissions take place is immaterial, resource depletion is similar, though an argument could be made that location is meaningful in that impact category.

That argument would be stronger if resource depletion included water; in these LCAs, resource depletion does not include water. LCAs typically characterize water depletion in a region using some measure of that region's water stress. Since the region in which Bell's is located is not water stressed, the water depletion impact category was naught. Additionally, because water use is the same in all scenarios and occurs in the same region in all scenarios—and indeed is drawn for a connected system of aquifers in all scenarios—the team determined that water depletion need not be included in resource depletion.

For human health and ecological impact, the location of the emissions *do* matter. But again, the vast majority of these human health and ecological impacts are from on-site or municipal electricity use, and those emissions occur at the power plants from which Consumers buys electricity. For the majority of the impacts in these categories, the general location of the emissions is known, and that location is within the region.

For clarity, we report LCA results for only a single year of operation. Since the goal was to investigate the impacts of different water sourcing options that can deliver 1,893 cubic meters (500,000 gallons) of water per day, the team used that as the annual production level. This gives a total annual use of 690,838 cubic meters (182,500,000 gallons).

The team reported the impacts of four aggregated impact categories: human health impact, ecological impact, climate change and resource depletion. The human health category is reported in DALYs (disability-adjusted life-years) which describe the severity of human health impact in both mortality and morbidity. For clarity, 1 DALY is the loss of one year of life distributed over an entire population, not a single person. Ecological impact is reported in PDF km^2 y not PDFm^2y as is standard. This represents the fraction of species that would potentially disappear on one km^2 during a year. Climate change is reported in Gg of CO_2 equivalents (not kg CO_2 equivalents as is standard). Resource Depletion is measured in units of 10 TJ of primary energy (not MJ as is standard), this amount of energy is intended to quantify the expected increase in energy needed to extract resources as resource quality declines.[xlvii] The team has changed the scales of the all the units except DALYs so that they range over similar orders of magnitude while preserving the absolute meanings that these non-normalized units provide. It also just so happens that these adjustment factors are very similar in relative size to the actual normalization and weighting factors used by IMPACT 2002+. This makes it more reasonable to make comparisons of relative size between impacts of different categories.

Continue Sourcing from the Kalamazoo Water Division

This option has three significant components. The first is the upgrade to the treatment plant and equipment. The second is the energy used to treat the water which includes the filters, chemicals and other media consumed during water treatment. The third is plant, equipment, consumables and energy required for the Kalamazoo Water Division (KWD) to deliver water to the brewery.

The first component, the treatment equipment, has no significant contribution in any impact category. One reason is that because equipment is assumed to last 15 years, only one fifteenth of the impact is experienced in any particular year. The share of each category's impact from this component are similar and vary between 0.2% and 0.4% (Even if that were not the case and the entire hit were taken in a single year, this component would still only represent 5.6% of the ecological impact and less for each of the other impact categories.)

The second component, the operation of the on-site treatment system, is a significant contributor in all impact categories, representing between 51% and 55% of the total impact in each category. Of that impact between 93 and 97% of it is on-site electricity used during water treatment. The third component is similar to the second both in the scale of its contribution (45 to 49%) and the scale of the energy share in that impact. In this case the contribution of electricity is between 73 and 88%.

These last two components highlight the importance of electricity in all the LCAs in this report. To a first approximation, for these options, electricity use determines impact in the major categories (human health, ecology, climate change, and resource depletion).

Build an On-site Well

The well system contains the same upgrade to the treatment plant and equipment, but in this case also includes a UV device. The energy and consumables used to treat the water on-site are also the same, but again now also includes energy for the UV device. The effect of the UV device is not significant on either the impacts resulting from the new treatment equipment or the energy it uses.

This option has the additional component of drilling the well and installing the infrastructure and equipment to pump water. The impacts in all categories are higher for the well construction and well equipment than for the treatment equipment by a factor of two to three, but in absolute terms these impacts are still minimal. Operating the equipment is tens to hundreds of times as impactful as manufacturing the equipment.

The significant difference in this scenario is that instead of receiving water from KWD, it is pumped from a well on Bell's property. Based on the team's energy modeling, pumping water from a well on Bell's property requires just over half the energy it takes KWD to deliver the same quantity of water.

This makes intuitive sense given that, in both cases, the water must be lifted approximately 50 meters, pumped along a pipe, and delivered at approximately 414 kPa. The chief difference is the length of pipe through which the water must be pumped. The other differences are of course that KWD adds chlorine and other treatment chemicals but these are comparatively minor. That difference in energy use explains essentially the entire difference in the impacts in the major categories between KWD and the Well option.

Source Water from Portage or Battle Creek

This scenario is much like a combination of the previous two. Again, there is the treatment upgrade and operating the treatment upgrades. Again, there is the impact of the municipal water system, though in this case it is not Kalamazoo's, but either Portage's or Battle Creek's. The major difference is that instead of drilling a well, tens of kilometers of plastic pipe is installed to bring water from an adjacent municipality to the brewery. These are the only scenarios where equipment and infrastructure make a significant contribution to the scenario's impact. The scale of that impact is sensitive to the expected life of the infrastructure, the more so because the un-amortized impact of it is large. But even if this infrastructure could be expected to last one hundred years it would still represent as much as 20% of the ecological impacts of this scenario and up to 10% of the human health impacts.

Even without these infrastructure impacts, the adjacent municipality will always be higher than either a well or continuing to source water from KWD. The reason is that these scenarios incur the impacts both of a municipal water system *and* the energy needed to pump water tens of kilometers through Bell's own pipes. The exact scale of the latter is uncertain but it is not zero.

6.2 Financial

Figure 6.2.1 displays the results of the financial methodology for each of the four options. The construction of the on-site well is the least expensive option due to its relatively low upfront construction costs, when compared to the costs for the adjacent municipalities, and its potentially longer lifespan than that of the KWD upgrades. Had the lifespan of the KWD upgrades been longer, it would have been the lowest cost option but would not have satisfy Bell's requirement for water source diversification.

Historic 40 year Inflation	3.68%
Premium	3%
Discount	**6.68%**

	Project Lifespan	Net Present Value	Equivalent Annual Cost
Continue Sourcing from KWD	15 years	$ (1,884,532)	$ (136,093)
Construct On-site Well	40 years	$ (1,498,296)	$ (108,201)
Source Water from Portage	40 years	$ (8,836,442)	$ (638,131)
Source Water from Battle Creek	40 years	$ (9,020,871)	$ (651,449)

Figure 6.2.1: Comparative financial results of four options

7 RECOMMENDATIONS

7.1 Multi-criteria Decision Analysis

Based on our life-cycle analysis, financial analysis and energy modelling, we ranked our alternative sources of water and carried out multicriteria decision analysis to choose the best option for Bell's. **Figure 7.1.1** summarizes our results in 5 different categories:

1. Financial Impacts in USD
2. Global Warming in gigagrams of CO_2 equivalents
3. Ecological Impact in Potentially Disappeared Fraction of species km^2 year
4. Human Health in Disability Adjusted Life-Years (DALY)
5. Resources Depletion in 10 TJ Primary Energy

	Financial Impacts	Global Warming	Ecological Impacts	Human Health Impacts	Resource Depletion
	USD	Gg CO2 eq/yr	PDF km2 yr/yr	DALY/yr	10 TJ Primary/yr
Kalamazoo	$136,093	1.22	0.22	0.99	1.74
Well	$108,201	0.94	0.16	0.72	1.37
Battle Creek	$651,449	2.01	0.82	2.49	2.96
Portage	$638,131	1.68	0.53	1.78	2.43

Figure 7.1.1: Comparative analysis results

From our analysis results, we normalized our results with the base reference of the highest value under every category i.e. we divided every entry by maximum value under that impact category. Thus, **Figure 7.1.2** shows the percentage of maximum value under every impact category.

We then weighted different impact categories based on what the team believed would be the preferences of Bell's would be. We gave 40% weight to financial impacts, 25% weight to global warming, 10% weight to ecological impacts, 10% weight to human health impacts and 10% weight to resource depletion and calculated single point score for four different options.

	Financial Impacts	Global Warming	Ecological Impacts	Human Health Impacts	Resource Depletion
Kalamazoo	20.89%	60.70%	26.83%	39.76%	58.78%
Well	16.61%	46.77%	19.51%	28.92%	46.28%
Battle Creek	100.00%	100.00%	100.00%	100.00%	100.00%
Portage	97.96%	83.58%	64.63%	71.49%	82.09%

Figure 7.1.2: Multi Criteria Decision Analysis

Figure 7.1.3 shows the heat map and cumulative scores for different options.

	Financial (USD)	Global Warming (Gg CO_2 eq/yr)	Ecological Impacts (PDF km² yr/yr)	Human Health Impacts (DALY/yr)	Resource Depletion (TJ Primary/yr)	Total Score (Normalized)
Kalamazoo	$136,093	1.22	0.22	0.99	17.4	0.57
On-site Well	$108,201	0.94	0.16	0.71	13.6	0.43
Portage	$638,131	1.42	0.25	1.21	20.3	0.96
Battle Creek	$651,449	1.47	0.26	1.32	21.2	1.00
Weighting Factors	0.40	0.25	0.10	0.15	0.10	1.00

Figure 7.1.3: Cumulative score for alternative resources

As we can see, the best option in all the categories and hence, as per the cumulative score is drilling an onsite well, followed by Continue sourcing water from the Kalamazoo Water Division. Sourcing water from Portage and Battle Creek are relatively more expensive and less environment friendly. Thus, our recommendation is to drill an on-site well.

8 WELLHEAD MANAGEMENT PLAN

Because the on-site water well field is considered the best option because it has the lowest environmental impact and is the least costly alternative, a wellhead management plan was developed to further mitigate any impacts on the local watershed. In addition, the legal implications of an on-site water well field are considered when pursuing this option and some community engagement measures are recommended to avoid litigation.

Well Field Simulation

The Comstock brewing facility of Bell's Brewery includes about 132,000 m^2, or 32.6 acres. Including the buildings, buffer, parking lot and holding pond, the area in which a well field could be installed includes 21,728 m^2, or 5.4 acres. Given this amount of space, it was necessary to simulate the well field and cone of depression to determine the optimal location for the field.

The rasterized impact space, decision space, surface water, stream, lake and well layers were imported into RStudio. An iterative program simulated the cone of depression at each of the 1,358 pixels in the decision space. For each simulated well field, the program quantified and aggregated the drawdown values for pixels in the impact space representing surface water, stream, lake and water well, respectively. The outputs of the program included heat map layers for the optimal well field locations, layers simulating the cone of depression at optima and a table that includes the aggregated drawdown objective values at each of the 1,358 points on the property.

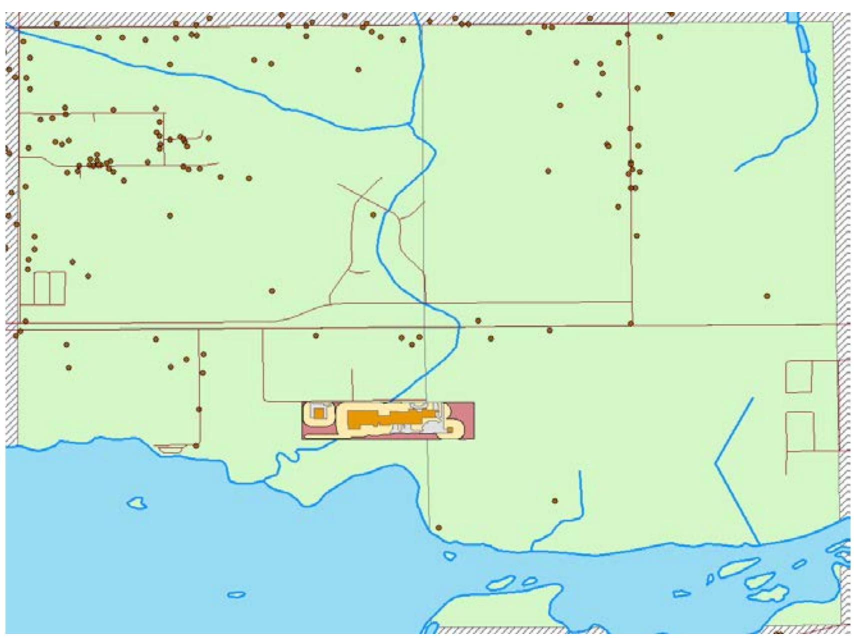


Figure 8.1.1

The map in **Figure 8.1.1** illustrates all GIS layers used in the well field optimization analysis. The blue lines indicate ephemeral streams, the blue field indicates Morrow Lake, brown lines indicate roads, brown dots indicate water wells and the red space indicates the feasible locations for water wells on the property of Bell's Comstock brewing facility.

Surface Water Impact Well Field Placement Optimization

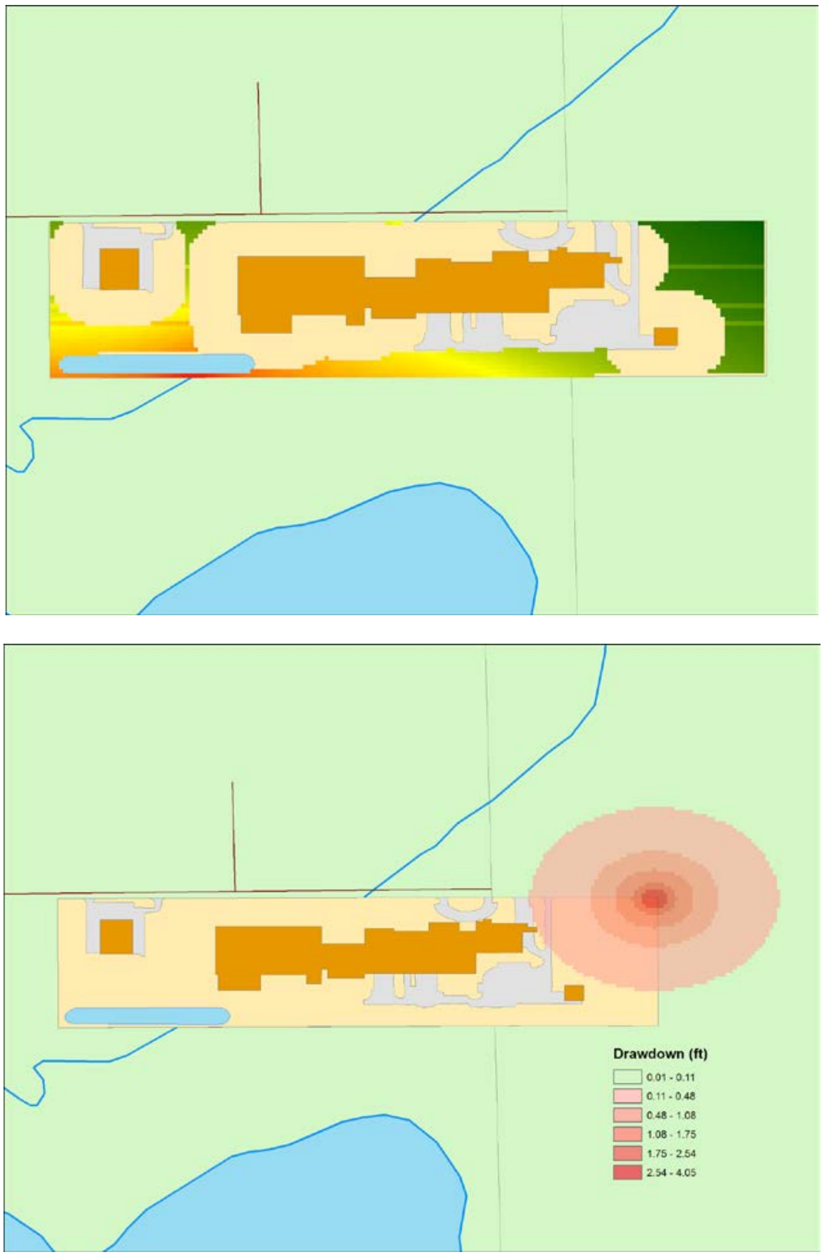


Figure 8.1.2: The heat map (above) indicates areas of relatively high surface water impact (red) and areas of relatively low surface water impact (green). The drawdown map (below) indicates the optimal well location and water table drawdown after one work day of pumping water from the aquifer.

Stream Impact Well Field Placement Optimization

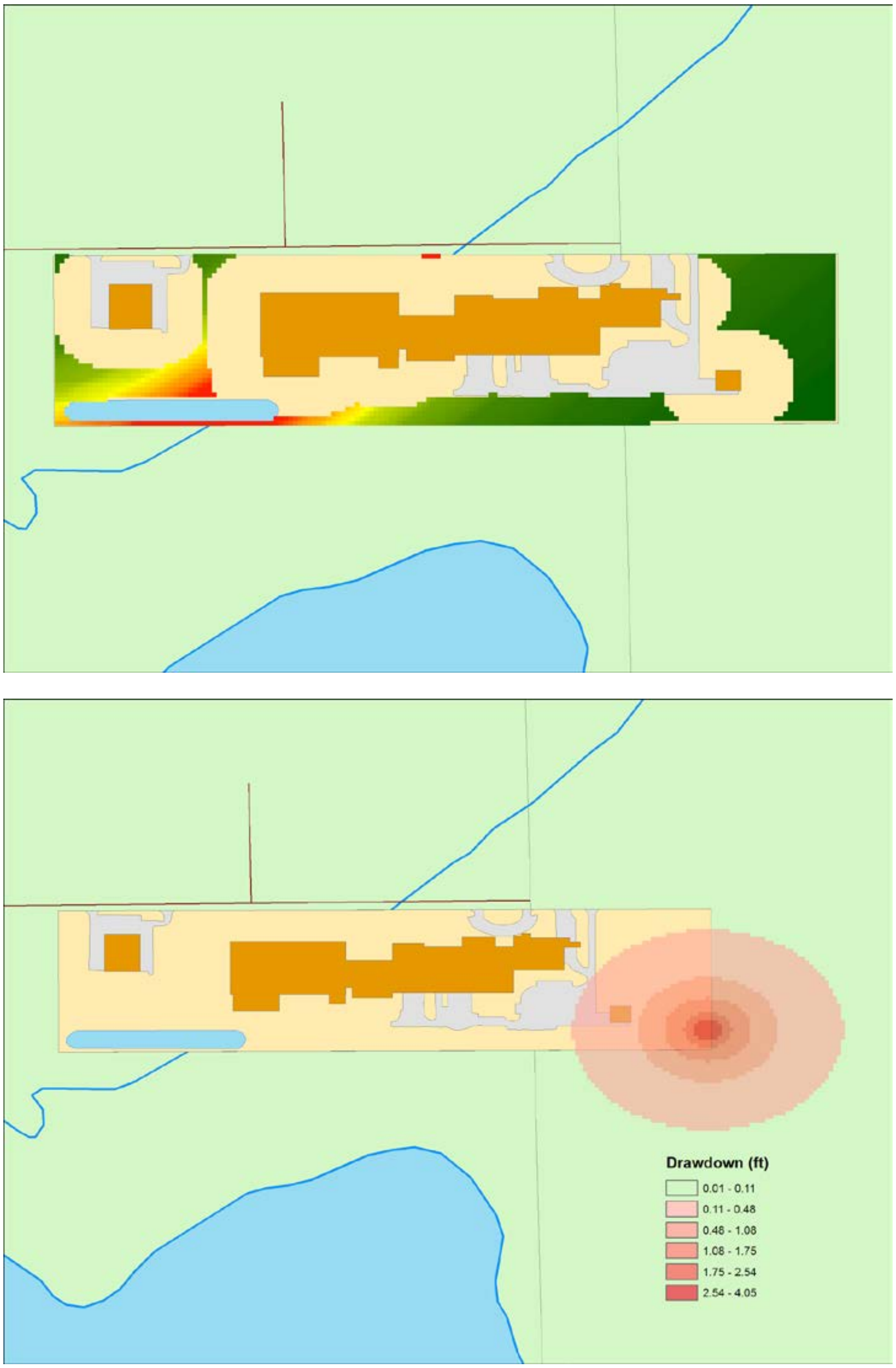


Figure 8.1.3: The heat map (above) indicates areas of relatively high stream water impact (red) and areas of relatively low stream water impact (green). The drawdown map (below) indicates the optimal well location and water table drawdown after one work day of pumping water from the aquifer.

Lake Impact Well Field Placement Optimization

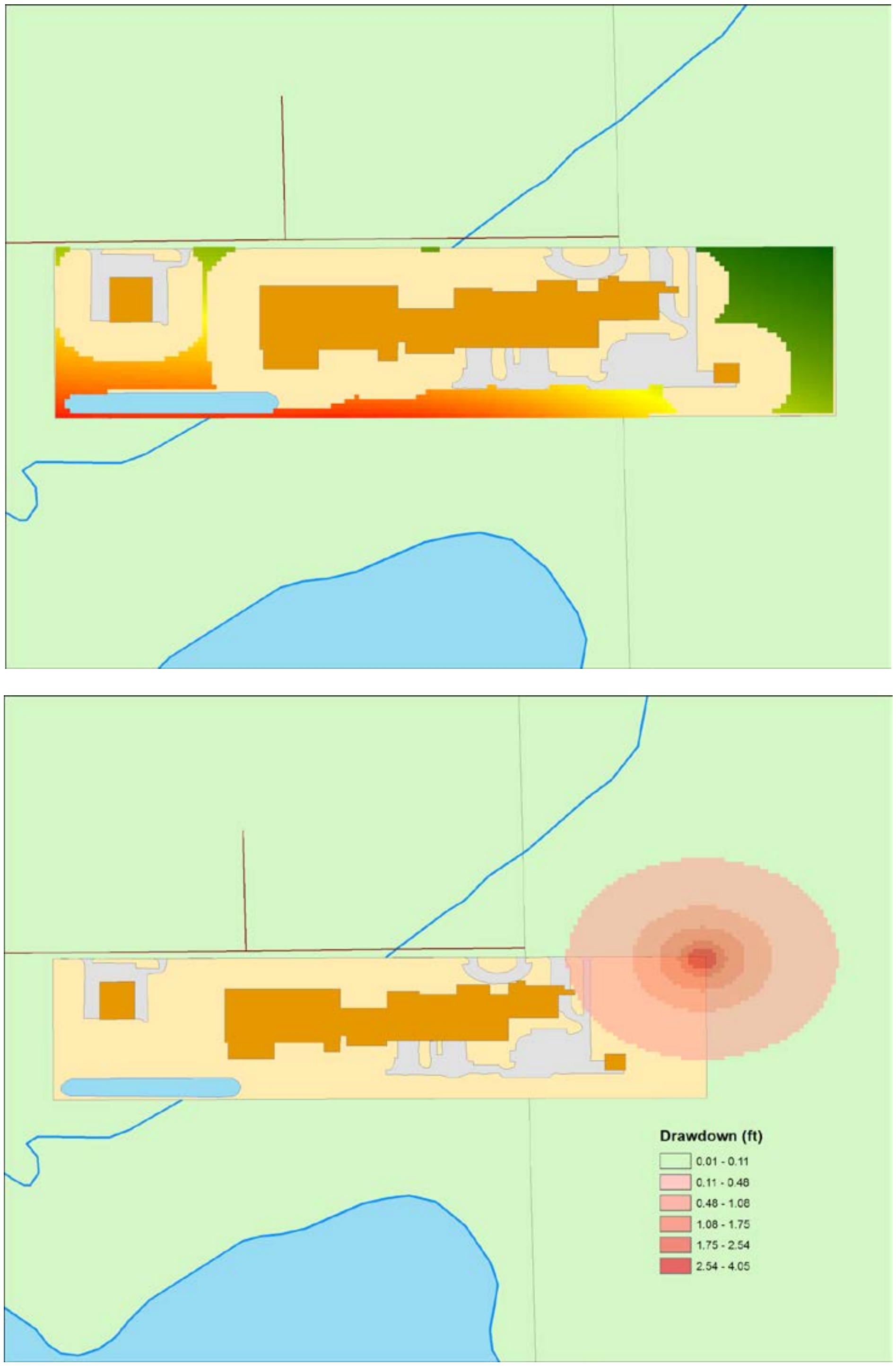


Figure 8.1.4: The heat map (above) indicates areas of relatively high lake water impact (red) and areas of relatively low lake water impact (green). The drawdown map (below) indicates the optimal well location and water table drawdown after one work day of pumping water from the aquifer.

Water Well Impact Well Field Placement Optimization

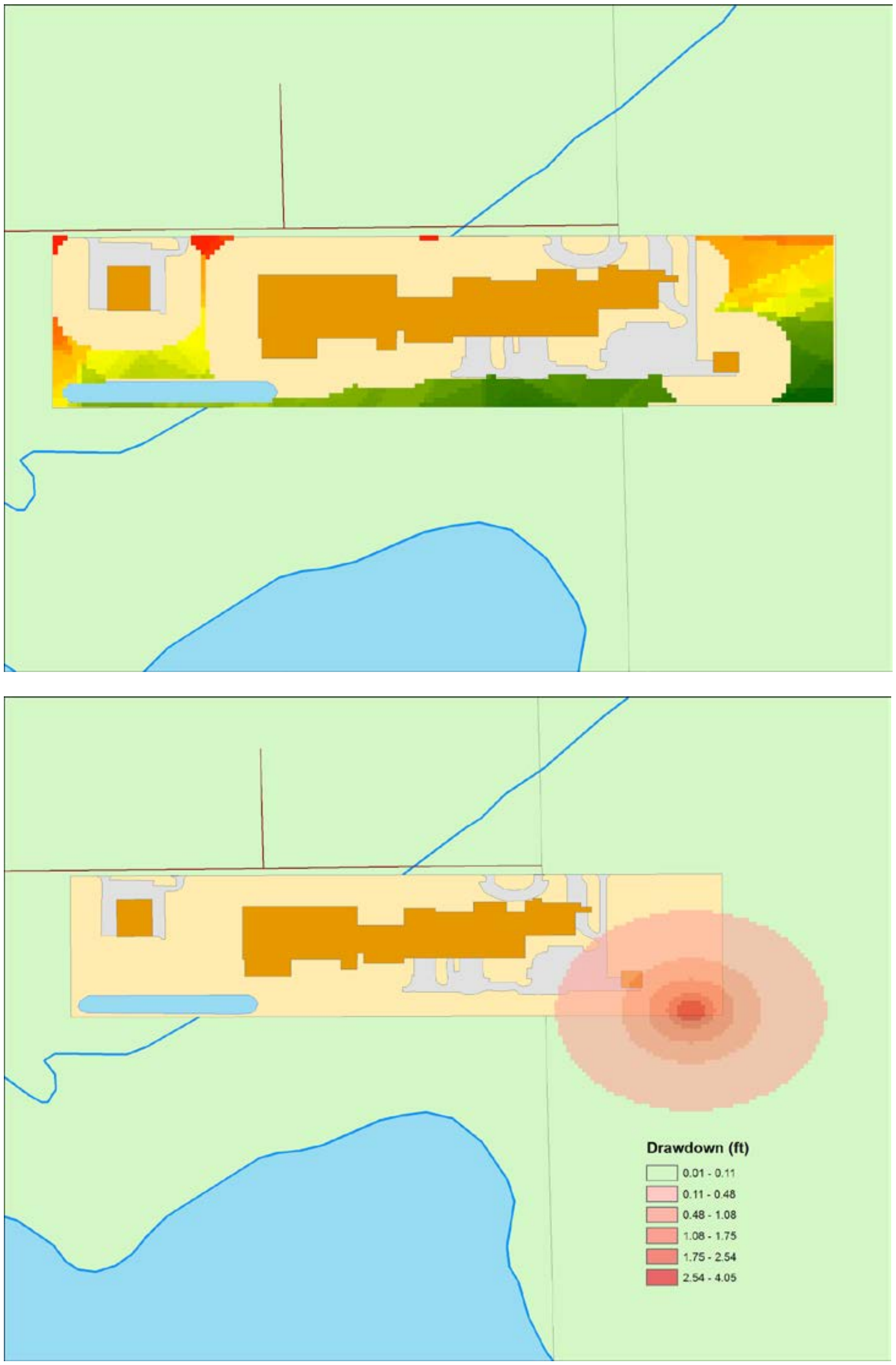


Figure 8.1.5: The heat map (above) indicates areas of relatively high well water impact (red) and areas of relatively low well water impact (green). The drawdown map (below) indicates the optimal well location and water table drawdown after one work day of pumping water from the aquifer.

Results

Impact objective	Latitude (DD)	Longitude (DD)	Distance from building connection (m)
Min distance	42.28422144	-85.45245228	55
Surface water	42.28497144	-85.45125228	162
Streams	42.28347144	-85.45125228	183
Lake	42.28497144	-85.45125228	162
Adjacent wells	42.28327144	-85.45160228	175

Figure 8.1.6: Results of the well field optimization model for different impact objectives

For the optimized well locations meeting different objectives, there is a trend in the output. Each of the scenarios locate the well on the eastern side of the property. In addition, each well is located at the edge of the property, which is not surprising considering the property boundaries are constraining the optimization. The surface water impact well field and lake impact well field are located at the same location which is due to the fact that for the surface water impact objective, different weights were not put on stream and lake pixels and the stream pixels had no marginal effect on the abundance of lake pixels.

Legal Implications of an On-site Water Well Field

Installing a water well field on-site shifts the environmental sourcing of water from the City of Kalamazoo to Bell's Brewery, Inc. In so doing, the brewery may become liable for damages related to the regional aquatic resources that are affected by its water pumping activities. Common law torts as a result of pumping activities may include several causes of action. Damages related to pumping activities may also infringe on statutes of the State of Michigan. The intent of this project is to minimize the environmental impact of the Bell's Brewery, Inc. first and foremost and the following provides the legal framework to foresee and mitigate possible litigation should it arise.

MCWC v. Nestlé

In 2000, Nestlé Waters North America, Inc. was sued by the Michigan Citizens for Water Conservation (MCWC), RJ and Barbara Doyle and Jeffery and Shelley Sapp. Nestlé had just installed four wells to pump water at a rate of 400 gallons/min from a local aquifer in Mecosta County, MI. These plaintiffs were concerned about the projected drop in surface water levels on the Dead Stream, Thompson Lake, Osprey Lake and some local wetlands. The Mecosta County Circuit Court ruled in favor of the plaintiffs because of a provision in the Michigan State Constitution under the Michigan Environmental Protection Act (MEPA) that states, *"The attorney general or any person may maintain an action in the circuit court having jurisdiction where the alleged violation occurred or is likely to occur for declaratory and equitable relief against any person for the protection of the air, water, and other natural resources and the public trust in these resources from pollution, impairment, or destruction."*

The judge ordered an injunction against Nestlé that required it to cease all pumping activities from the aquifer. However, Nestlé appealed the case and it was brought before the Michigan Supreme Court. The question before the court was not whether Nestlé's pumping activities had adverse effects on local natural resources, but if MCWC, the Doyles, and the Sapps had "standing" to bring a claim under MEPA. "Standing" is essentially a plaintiff's right to initially bring a case against a defendant based on his or her interest in the conflict. Because the Doyles and the Sapps lived on property adjacent to Dead Stream and Thompson Lake, respectively, they had standing to bring a claim. However, the Michigan Supreme Court held that the plaintiffs did not have standing to bring a MEPA claim for the drawdown of Osprey Lake and the wetlands because there was no "concrete, particularized injury" to the plaintiffs. Although the ruling was in favor of the plaintiffs with regard to the Dead Stream and Thompson Lake and the injunction on the Nestlé plant remained, the court's decision with regard to standing set a new precedent with the citizen suit provision of MEPA.[xlviii]

Potential causes of action

The pumping activities of Bell's Brewery, Inc. may result in the drawdown of streams and wetlands throughout the locality. Although induced infiltration may occur from beneath Morrow Lake, the lake's size, relatively high turnover rate and replenishment from the Kalamazoo River will likely mask whatever induced drawdown occurs. Because of the recent precedent established in MCWC v. Nestlé, the only plaintiffs able to bring an MEPA claim against the brewery are the owners of property on which the affected bodies of water exist. In addition, it is likely that the only two common law tort claims an individual could bring against the brewery would be private nuisance and negligence. Private nuisance holds if the plaintiff shows that he or she suffered unreasonable interference with the use and enjoyment of his or her property and that it was intentionally caused by the defendant. In this instance, the plaintiff would have to show that the drawdown of a wetland or ephemeral stream affected his or her use of the property and that it was caused by the brewery pumping from the aquifer. Negligence is upheld where the plaintiff alleges that the defendant owes a duty to the plaintiff and that duty was breached. With negligence, the plaintiff would have to prove that Furthermore, with negligence, the plaintiff has to show causation and damages.

Social License to Operate

Because Bell's is dedicated to outreach and MEPA and common law tort claims can only be brought from the local community, it is in the best interest of the company to pursue a social license to operate. This entails reaching out to the local community to demonstrate the brewery's environmental initiatives and to invite stakeholders in the involvement of the well field project planning. To this end, avoiding litigation should be a priority to the company, but community outreach and engagement should be considered nonetheless in demonstrating Bell's socially responsible values.

9 CONCLUSION

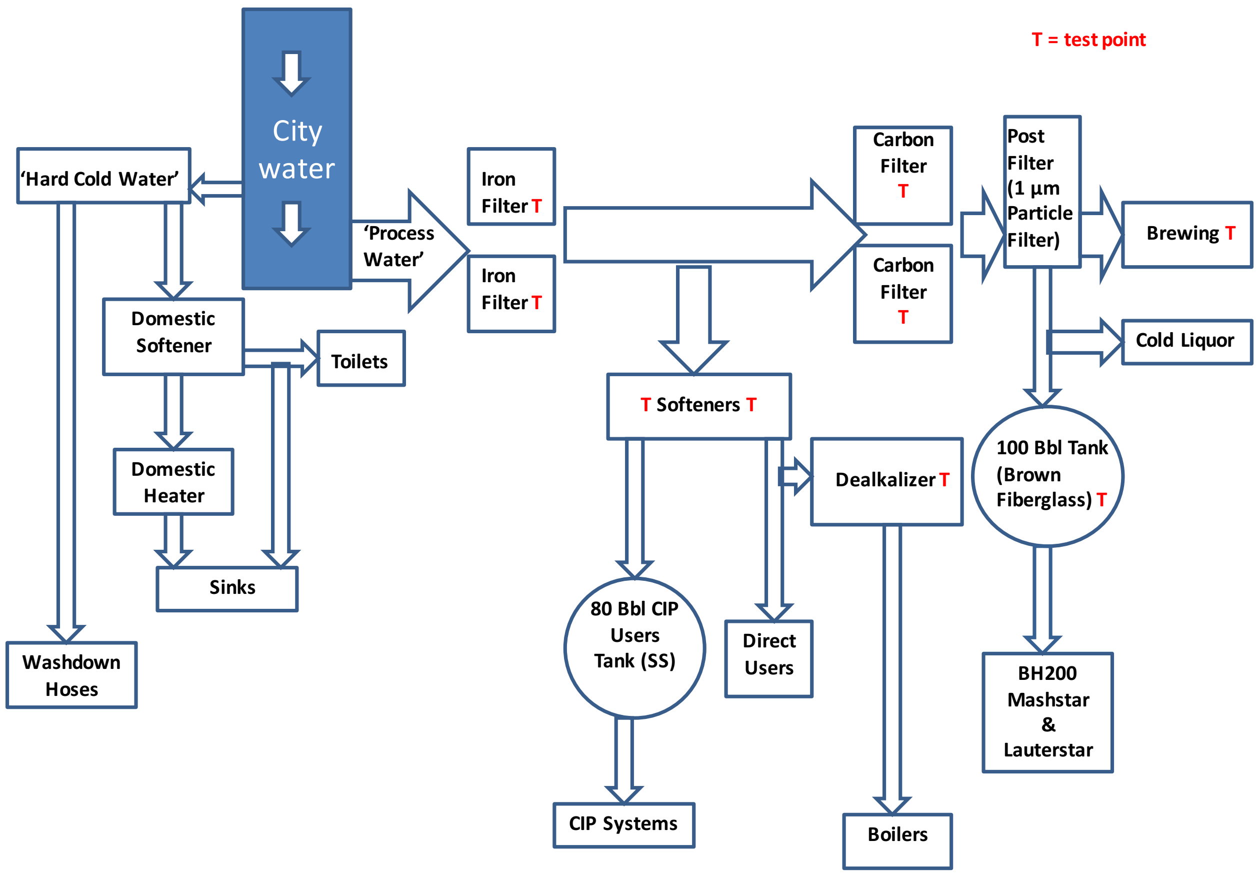
From a purely environmental perspective, the Well is the best single-source option. The chief reason—and the intuitive one as well—is that in the Well Option, water is being pumped the shortest distance. For this reason, its energy use is the lowest. The adjacent municipality options are the least appealing options from an environmental perspective. The combination of the impacts of the municipal water system, the energy to pump water from that adjacent municipality, and the significant infrastructure material needed renders these options hard to justify. With regards to the baseline option, continuing to source water from Kalamazoo, its environmental impacts are higher than the well option but in most categories, not significantly. This option also means no change in impact on a per unit basis than Bell's current water sourcing.

The foregoing all assumes a single source for all water. Such a solution would be simple but fails to provide any benefits in terms of diversification or flexibility. It also requires building infrastructure to meet peak demand which then must spend most of its time sitting idle, or worse, operating far from its optimal level. For these reasons the best option is to use both Kalamazoo water and water obtained from wells on Bell's property. Such an option provides numerous benefits. First is that in the event of a service interruption or local well equipment failure, production need not be interrupted since another source of water is available. Second is that it would allow Bell's to manage the operation of the well pumps to optimize an appropriate combination of pump efficiency and service life. Third is that while Bell's does not control the source of KWD's electricity, they can control their own. This means through rooftop solar or PPAs, Bell's could displace some or all of Consumers' grid electricity in their water treatment operation. This could reduce the total environmental impact of their water use by as much as 70%.

Although a well field is the best option, local social and ecological impacts must be taken into consideration when pursuing this alternative. The Morrow Lake groundwater reservoir has more than enough water to sustain the brewery's projected yield well into the future. This will allow Bell's to pump from the aquifer with little to no impact on the production of water from wells on adjacent properties. Because of the unconfined nature of the aquifer, however, the pumping regime may induce infiltration of surface water on nearby streams and wetlands. Under the Michigan Environmental Protection Act civil suit provision, or environmental torts, property owners on which affected surface water exists may file a claim against brewery as in *MCWC v. Nestle*. However, given the facility's location near the Kalamazoo River, it is likely that induced infiltration will occur from Morrow Lake before it has an impact on upland surface water. Furthermore, using the output of the well placement optimization model, the well field should be placed at 42.28347144° N, -85.45125228° W at the stream impact location. The ephemeral streams are likely to be the most affected by pumping activity and this location is well away from the brewing facilities and the hop garden, where possible sources of contamination and conflicting infrastructure exist.

10 APPENDICES

Appendix A – Current Water Treatment at the Comstock Brewery



Appendix B – Quotations for Water Treatment Plant Equipment

Water Surplus, Inc.
1940 Observatory Ave SE
Grand Rapids, MI 49546
Ph: 616-940-9030
Fax: 616-940-0980

Water Treatment Equipment Specifications
Bells Brewery –Kalamazoo, MI expansion

The following Water Treatment equipment is based upon the water demands supplied to us by Dace Dixon on 2.15.11.

	Nominal flow	Peak flow
Iron Filter	212 GPM	404 GPM
Carbon Filtration	125 GPM	185.7 GPM
Water Softening	88 GPM	152.1 GPM
De-Alkalizer to Boiler	20 GPM	33 GPM

After input from Dace Dixon and Evan we are supplying sediment filtration control by utilizing NextSand media (see accompanying media specifications). This system shall be Duplexed and consist of the following:

Iron Filtration –Sediment Control

- (2) 60" DIA. X 72" side shell tanks with 12" x 17" Manway on top and on the side for media installation and removal. Inlet and outlets shall be 3" flanged connections. The exterior of the tanks shall be epoxy primed and painted. The interior shall be lined with an epoxy composite.
- Each tank shall contain **60 cubic feet** of **NextSand** media and 820lbs. of 1/16 x 1/8 washed underbed stone.
- Control valves shall be Bray 4" Pneumatic controlled valves.
- Liquid filled 0-100 psi pressure gauges on the inlet and outlet of each vessel as well as ¼" sampling ports on the outlet of each vessel.
- Controller shall be an I3 Intelligent Control Station PLC/HMI combo unit dual tank controller with a monochrome 160x128 touch screen graphic panel and real time clock with time initiated regeneration cycle.
- The backwash rate shall be 345 GPM for 10 minutes per vessel with a 3 minute settle rinse.
- **OPTIONAL** - Backwash sequence shall be initiated by the deferential pressure of the inlet and outlet of the vessels of a 15% loss of pressure across the filter bed.

Carbon Filtration

- (2) 60” DIA. X 60” side shell tanks with 12” x 17” Manway on top for media installation and removal. Inlet and outlets shall be 3” flanged connections. The exterior of the tanks shall be epoxy primed and painted. The interior shall be lined with an epoxy composite.
- Each tank shall contain **65 cubic feet** of Acid Washed 12x40 mesh Granular Activated Carbon media and 820lbs. of 1/16 x 1/8 washed underbed stone.
- **Optional Carbon-** As an option the Carbon Backwash Filters can be supplied with 65 cubic feet each of Coconut shell hardened 12x30 mesh Carbon model # CR1230C.
- Control valves shall be Bray 3” Pneumatic controlled valves.
- Liquid filled 0-100 psi pressure gauges on the inlet and outlet of each vessel as well as ¼” sampling ports on the outlet of each vessel.
- Controller shall be Controller shall be an I3 Intelligent Control Station PLC/HMI combo unit dual tank controller with a monochrome 160x128 touch screen graphic panel and real time clock with time initiated regeneration cycle.
- The backwash rate shall be 220 GPM for 10 minutes per vessel with a 5 minute settle rinse.
- **OPTIONAL** - Backwash sequence shall be initiated by the deferential pressure of the inlet and outlet of the vessels of a 15% loss of pressure across the filter bed

Water Softener

- (2) 36” x 72” Fiberglass FRP media tanks each containing **22 cubic feet** of 10% cross linked macro porous Cation resin. Each tank shall be fitted with a 3” PVC Hub and Lateral.
- Each tank shall be fitted on top with a Fleck 3900 – 3” metered Control Valve with an inline 3” Electronic meter.
- The control system shall be a Fleck NXT Electronic Controller. The configuration of he Water Softeners shall be one on line and one in the standby position. Upon the set point gallon age initiating regeneration the standby tank shall go into service while the expended tank regenerates.
- (1) 42” x 50” Salt storage tank with a ¾” safety float. The Salt storage tank shall be equipped with a salt grid set at approximately. 14” from the bottom.
- The Water Softener shall have a backwash rate of 35 GPM and use 242 lbs of salt per regeneration.

De-Alkalizer

- (1) 24 x 72” Fiberglass media tank containing (10) cubic feet of Thermax A32 Anion resin. Internals of the tank shall have hub and lateral distribution.
- (1) Fleck 2850 – 1.5” Meter controlled Water Softener Valve Controlled by a Fleck NXT Controller

- (1) 30” x 50” poly Brine tank with 4” brine well and safety float brine valve and salt grid.
- (1) Stenner 45MHP10 chemical feed pump with a 15 gallon holding tank for Caustic chemical
- (1) 24V/115V relay to energize Chemical pump from Control signal.

Alternate De-Alkalizer (revised 3/31/11)

- (2) 21x62 Fiberglass media tanks each containing (7) cubic feet of Thermax A32 Anion resin. Internals of the tanks shall have hub and lateral distribution
- (1) Fleck 9500-1.5” metered control Valve with XT Electronic Controller. This shall be a Duplexed alternating regeneration.
- (1) 24” x 50” poly Brine tank with 4” brine well and safety float brine valve and salt grid.
- (1) Stenner 45MHP10 chemical feed pump with a 15 gallon holding tank for Caustic chemical
- (1) 24V/115V relay to energize Chemical pump from Control signal.

Pre-Filter Housing (sized for total flow incoming)

- (1) Used Snafa Engineering Model RFC-4540V-CS-F6-150, 45 round – 40” filters. This filter housing has the ability to filter water at up to 800 GPM using 5 micron depth filters.

PLC Controller for Flow meter Monitoring

- Water Surplus, Inc. shall mount a i3 Integrated PLC/HMI as per the submitted specification sheet. The Controller shall be mounted on a common panel used for the Iron Filter PLC Control. If this option is taken then a larger Panel box shall be supplied. Per our discussion on 3/18.2011 at Surplus Management there are a possibility of at least 9 points where water shall be monitored. This control is capable of 3 more additional input points beyond the 9. Bells Brewery shall supply the meters (Signet 2536). Greg Wright shall engineer the logics and programming of the controller and install with terminal strip connections labeled for specific meter points. Greg would require K-Factors of the meters and pipe sizing that the meters would be installed on. Further input will be needed from Bells to determine the exact programming/engineering for monitoring points.

Pricing

Iron Filtration / Sediment Control Duplex 60” Backwash Filters …… $40,236.00
OPTIONAL Automated Differential Pressure Sensing system adder $ 2,235.00

Carbon Backwash Filters Duplex 60” …………………………………..$38,295.00
Carbon media adder CR1230C-Coconut shell, add…………………… $ 780.00

OPTIONAL Automated Differential Pressure Sensing system adder $ 2,235.00

Water Softener System –Duplex 36x72 System ………………………. $14,441.00
De-Alkalizing System (1) 24x72 ……………………………… $ 5,240.00
ALERNATE De-Alkalizer- Twin Alternating 21x62 ……………………… $ 6,397.00

Pre-Filtering System ………………………………………………… $ 6,000.00
40" melt blown depth filters – 5 micron (20/case) @ $ 7.45 each $ 149.00/case
i3 PLC/HMI Controller for monitoring plant flows ……………… $ 8,300.00

All pricing as shown above are FOB Loves Park, IL 61111

Warranty

Water Treatment Technologies, LLC and Water Surplus, Inc. shall warranty all mechanical equipment, Vessels and Controls against any defects, workmanship or materials. Any part proving defective shall be provided at no charge during the one year period. A representative from Water Treatment Technologies and or Water Surplus, Inc. shall be present upon start-up of the equipment to verify proper operation and validate the Equipment Warranty.

On site & Engineering Services

Water Treatment Technologies & Water Surplus, Inc. can provide the following services as desired by Bells Brewery at the estimated cost. This cost may vary depending on how involved Bells Brewery desires us to be.

Overall System Engineering – we can provide layout and plans for on site mechanical contractors to work from in installing the described equipment for a fee basis to be determined on what will be required

On site supervision for installation and start-up/commissioning

Water Treatment Technologies & Water Surplus, Inc. can provide the following services as desired by Bells Brewery at the estimated cost. This cost may vary depending on how involved Bells Brewery desires us to be.

Cost to include:

- Being present when the equipment arrives and assisting in placement of the equipment.
- Review installation with the on-site Mechanical Contractor or Bells Employees installation standards and techniques.
- Supervise proper installations of Media to be installed in the media tanks.
- Set up Controls and programs with on-site Contractor or Bells employees.

● Supervise pressure testing of the equipment and proper start-up procedures
● Train Bells employees in system operations and maintenance procedures.
● Prepare on-site Log Book for regular Maintenance test.
Estimated cost not to exceed……………………………………………………_**$4,000.00**

<u>Payment Terms:</u>
25% down payment due within 30 days of issuance of order, 25% due upon completion of equipment build in the Surplus Management facility, 25% due upon receipt of the Equipment on site and 15% due within 30 days of receipt of the equipment and a hold back of 10% for 60 days for Warranty retention.

Submitted by: Jerry A Dykstra
Date: 3/9/2011 Revised 3/23/11 – Revised 3/31/11

Appendix C – Katz Drilling Questionnaire

1. Based on the requirements listed for Bell's Brewery, what type of well would they need to acquire?
    a. First, a ~150 foot test drilling would be needed. This will provide information on the type of water contained in the aquifer, the depth of the aquifer, water contamination, and sand analysis required for construction.
    b. Based on the area, I'd estimate you would need a 150 foot deep, 8 inch screened in well. You'll want a 25 HP submersible pump in order to reach 350 gallons per minute, which would satisfy your capacity of 500,000 gallons a day.
2. What methodology and materials would be required for the installation of the well? For electrical components, what are the typical make and model?
    a. We would be using a rotary drill to burough the hole and drilling mud to soften the soil. Most of the materials required will be on the proposal. The pipes and casing will be PVC.
3. What equipment would be required to dig the well?
    a. We'll use a standard drilling rig. The make and model will be an International 7300. We'll also require a water truck for the drilling mud, a mobile crane and a back hoe.
4. What additional equipment would need to be installed to support the additional water?
    a. Depending on the operations, you may need to consider installing a well house to store the control equipment for operations. Additionally, if you require storage tanks, they can be placed inside a well house. With regards to the controls, the usage and flow profile of your operations will determine what type of starter you'll need. I recommend installing a variable frequency drive (VFD). It'll be more expensive, but it will allow you to move from a low flow to high flow demand more seamlessly. Otherwise, if you anticipate a constant demand state, you can save money with a magnetic starter.
5. What is the typical useful life of the well? Do the electrical and mechanical components have different useful lifespans?
    a. The well should last a very long time. If I had to place a number on it, I'd say at least 40 years.
    b. The pumps can last anywhere between 6-10 years, depending on if you use them constantly. They can last as long as 18 years if you don't use them very often.
    c. The motor can last around 10 years as well.
    d. Your VFD will last around 10 to 15 years, unless it is hit by lightning. The odds of that are pretty low.
6. What type of maintenance would be required?
    a. Maintenance on the well itself will be minimal. You may want to have it checked out annually, but other than replacing the parts I mentioned, there's really no other maintenance.

7. What regulations must Bell's adhere to before construction and during the well's useful life?
    a. For this type of well, you'd need to check with the city. It'll be a Type II well most likely and that's all I can tell you.
8. What are the initial and lifetime costs associated with construction and maintenance?
    a. That will be attached with the work proposal I send you.

Appendix D – Katz Drilling Proposal

KATZ WELL DRIILLING, INC.
1479 East Michigan Avenue
Battle Creek, Michigan 49014
Phone: (269)964-9170 • Fax: (269) 964-6635

PROPOSAL AND ACCEPTANCE

PROPOSAL SUBMITTED TO
Chris Monti cmonti@umich.edu **916-402-6041** **04/01/16**
STREET *JOB NAME*
Bell's Brewery
CITY, STATE & ZIP CODE *JOB LOCATION*
8938 Krum Ave Galesburg MI

We hereby submit specifications and estimates for: **2 – Type 2 wells and pumps**

150' Test Drilling	$15.50/ft	$2325.00
150' 8" PVC Cased Well	50.00/ft	7500.00
130' grout	8.00/ft	1040.00
Additional for cement grouting		500.00
20' – 8" Screen and Developing	125.00/ft	2500.00
20' Gravel Pack	10.00/ft	200.00
	Sub Total	**$14,065.00/well**
25 Hp pump		$3960.00
25 Hp motor		4108.00
105' 4" Drop pipe and wire 8-3	27.50	2887.50
Splice Kit		25.00
Check Valve		514.00
Pitless Adapter 8"		5767.00
Test Pumping		1000.00
Installation		1200.00
	Sub Total Pump	**$19,461.50/Pump**

VFD if needed	$9000.00
Transducer if Needed	242.00
Sub Total VFD	**$9,242.00**

Estimated Total well , Pump, $33,526.00
2nd Well and Pump 33,526.00

Estimated Total wells and pumps only $67,052.00
Add/ded 15.50/ft test drilling add/ded $50.00/ft 8" well add/ded 27.50/ft 4" drop pipe and wire

Contact you r local health dept for required well permit

We Propose hereby to furnish material and labor – complete in accordance with above specifications. For the sum of:

Payments to be made as follows: **1/2 Down, Balance Due upon Completion.** **$ 67,052.00**

All material is guaranteed to be as specified. All work to be completed in a workman-like manner according to standard practices. Any alteration or deviation from above specifications involving extra costs will be executed only upon written orders, and will become an extra charge over and above the estimate. All agreements contingent upon strikes, accidents or delays beyond our control. Owner to carry fire, tornado and other necessary insurance. Our workers are fully covered by Workman's compensation Insurance.

Authorized Signature Kathy Katz Secretary

Note: *This proposal may be withdrawn by us if not accepted within 60 days*

Appendix E – Pricing for Type II Well Program

KALAMAZOO COUNTY
HEALTH AND COMMUNITY SERVICES DEPARTMENT

Promoting Health For All

Gillian A. Stoltman, PhD, MPH
Director/Health Officer

Environmental Health

Pricing for Type II Program

1. Annual fee to MDEQ $538.76 ($25.00 late fee/per month)
2. ~$15.00/bacteria testing – monthly if employ over 1,000, quarterly if less than 1,000.
3. ~$15.00/nitrate testing – annual testing
4. Certified Operator – test is only offered in the spring & fall ($75.00). Need to keep up with 9 CECs every three years. Need to re-register every three years ($45.00). A facility can hire a certified operator (not sure what certified operators charge).
5. The following are pricing from the State Lab. Other laboratories may vary.
    - Cyanide (every 9 years) - $25.00
    - VOCs (every 6 years) - $100.00
    - SOCs (every 6 years) - $365.00
    - Metals (every 6 years) - $102.00
    - Lead & Copper (every 6 months) - $26.00. Lead & Copper will not be one location. It may be up to 20 different locations. Locations have to be where people would consume water (drinking fountain, kitchen sink). These samples need to be done on a first draw basis. The water system needs to sit for 6-8 hours before the sample can be taken. No flushing of toilets or running of water.

If a routine bacteria sample comes up positive, four repeat samples need to be collected within 24 hours. If any of those samples are positive, the facility will need to have a level 1 assessment completed and it's recommended to be on bottled water. I have provided the flow chart of what is required after a routine positive bacteria sample.

Also, if the water from the well exceeds the maximum contamination level of a standard, a treatment system will need to be installed. That will include monitoring operating reports, certified operator and annual site visits.

Hope this information helps.

Hope Stanley

Hope Stanley
Noncommunity Program Coordinator
(269) 373-5355
hestanl@kalcounty.com

3299 Gull Road • P.O. Box 42 • Nazareth, MI 49074-0042
Ph (269) 373-5200 • Fax (269) 373-5363 • www.kalcounty.com

Appendix F – Questionnaire for Cribley Drilling

1. What types of material will be used for the grout?
    a. Cement - mainly due to the fact that this will be a Type II well.
2. What material will be used for the drilling mud?
    a. Approximately 100 lbs of Bentonite per well.
3. What material will the well screen be made of?
    a. Stainless steel.
4. What brand and model would you recommend for the pump and motor?
    a. Pump: Grundfos 300S250 7AA
    b. Motor: 6" Franklin
5. What type of tank would be required for water storage?
    a. If using a VFD, a commercial tank rated for 150 psi made of steel or fiberglass. You'll need three tanks that are approximately seven feet tall with a three to four foot diameter. The expected cost will be at least $500 per tank.
6. How would the well be integrated into Bell's existing operations?
    a. Fuse piping would be required. This would bring water from the well to either a tank or connect to the company's existing infrastructure. This may require construction under the flooring, which will be much more expensive.
    b. Trenching and installing a conduit pipe would be about $25 a foot and be constructed of 4" HDPE. This option would also negate the need for a well house.

Appendix G – Safe Drinking Water Specifications

Safe Drinking Water Act Compliant, Potable			
Alkalnity (as CaCO3)	less than	100	ppm
Bromate	less than	0.01	ppm
Calcium		50 - 150	ppm
Chlorine	less than	4	ppm
Chloride	less than	250	ppm
Copper	less than	1	ppm
Haloacetic Acids	less than	0.06	ppm
Iron	less than	1	ppm
Magnesium		0 - 40	ppm
Manganese	less than	0	ppm
N Nitrate	less than	44	ppm
N Nitrite	less than	3	ppm
Silicate	less than	25	ppm
Sodium		0 - 50	ppm
Sulfate	less than	250	ppm
TDS	less than	500	ppm
Trihalomethanes (THM)	less than	0.1	ppm
Turbidity	less than	0.5	ntu

Appendix H Analysis of Drinking Water Sample from Bell's Brewery

KAR *Laboratories, Inc.*

4425 Manchester Road
Kalamazoo, MI 49001
Phone 269 381-9666
Fax 269 381-9698
www.karlabs.com

RDS Engineering
70 W. Michigan Ave., Suite 420
Battle Creek, MI 49017

Attn : ***Ms. Dace Dixon***

KAR Project No. :	***103830***
Date Reported :	***09/29/10***
Date Activated :	***09/15/10***
Date Due :	***09/29/10***
Date Validated :	***09/29/10***

Project Description : ***Analysis of one drinking water sample from Bells Brewery.***

Dear Client,

Your laboratory data is presented to you in this report. Unless otherwise stated under the "Comments" heading, all tests were performed within the maximum allowable holding times, have met or exceeded QC requirements and the result represents the sample as it was received. If a sample was identified as drinking water under the Safe Drinking Water Act, the "Comments" column may also contain federal drinking water information including MCL which is the Maximum Contaminant Level set by USEPA. Values enclosed in brackets ([]) are Secondary MCL's and are non-enforceable guidelines for aesthetic quality.

If you wish to contact us about this work please mention KAR Project No. 103830. To arrange additional sampling or testing please contact our Client Services Department. If you have any questions regarding quality assurance please contact us.

Thank you for the opportunity to serve you. Please do not hesitate to call if we can provide additional assistance.

Respectfully submitted,

David R. Alkema
Laboratory Manager

KAR Laboratories, Inc. maintains Full Certification status for Bacteriology, Inorganics, Regulated Organics and Synthetic Organics through USEPA, Michigan Department of Public Health and Indiana State Department of Health. This report may only be reproduced in full and not without the written consent of **RDS Engineering**.

Page 1

LABORATORY DETAIL REPORT

Client: ***RDS Engineering***

KAR Project No. : ***103830***

Date Reported: ***09/29/10***

Attest:
David R. Alkema, Lab Manager

Project Description: ***Analysis of one drinking water sample from Bells Brewery.***

Sample ID : ***"City Water"***

Sampled By :
Sample Date : ***09/15/10***
Sample Time : ***1510***

Date Received : ***09/15/10***
Sample Type : ***SDWA***
KAR Sample No. : ***103830-01***

Test	Result	Units of Measure	Method	Analyzed	Analyst	Comments
Prep, metals	Completed		EPA 30xx,200.x	09/16/10	PML	
Aluminum, total	<0.1	mg/L	EPA 200.8	09/23/10	PML	MCL*=[0.050 mg/L]
Barium, total	0.081	mg/L	EPA 200.8	09/23/10	PML	MCL*=2 mg/L
Calcium, total	95.5	mg/L	EPA 200.7	09/17/10	DBL	
Copper, total	<0.02	mg/L	EPA 200.8	09/23/10	PML	MCL*=1.3 mg/L
Iron, total	0.05	mg/L	EPA 200.7	09/17/10	DBL	MCL*=[0.3 mg/L]
Magnesium, total	30.9	mg/L	EPA 200.7	09/17/10	DBL	
Manganese, total	0.007	mg/L	EPA 200.8	09/23/10	PML	MCL*=[0.05 mg/L]
Potassium, total	2.1	mg/L	EPA 200.7	09/17/10	DBL	
Sodium, total	44.4	mg/L	EPA 200.7	09/17/10	DBL	MCL*=[20 mg/L]
Strontium, total	0.12	mg/L	EPA 200.7	09/17/10	DBL	
Bicarbonate (as HCO3)	351	mg/L	SM 2320 B	09/21/10	PML	
Carbonate (as CaCO3)	1.70	mg/L	SM 2320 B	09/21/10	PML	
Chloride	86.3	mg/L	EPA 300.0A	09/28/10	DMC	MCL*=[250 mg/L]
Chlorine residual, total	1.22	mg/L	SM 4500-Cl I	09/15/10	DMC	
Dissolved solids, total	510	mg/L	SM 2540 C	09/19/10	JHB	MCL*=[500 mg/L]
Fluoride	0.62	mg/L	EPA 300.0A	09/28/10	DMC	MCL*=4 mg/L
Hydroxide alkalinity	<5	mg/L (as OH)	SM 2320 B	09/21/10	PML	
Nitrogen, nitrate	1.0	mg/L	EPA 353.2	09/16/10	ALK	MCL*=10 mg/L
Phosphate, ortho (as P)	0.43	mg/L	SM 4500-P E	09/15/10	JHB	
Silica	13.9	mg/L	SM 4500-Si E	09/29/10	DMC	Result represents molybdate-reactive silica only.
Sulfate	37	mg/L	EPA 300.0A	09/27/10	ALK	MCL*=[250 mg/L]
Suspended solids, total	<4	mg/L	SM 2540 D	09/19/10	JHB	
TOC	1.0	mg/L	SM 5310 C	09/16/10	LAE	

Appendix I – Life Cycle Assessment Assumptions

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Well	Drilling Mud	Bentonite {GLO}| market for | Alloc Def, U			45.3	kg	
	Casing cement	Cement, Portland {US}| market for | Alloc Def, U	Assuming 2 inches thickness (OD=10" and ID=8") and density of cement = 1.35 g/cm3		379.3	kg	XLIX
	Drop pipe 4"	PVC pipe E	Assuming 150 ft casing SDR26 by JM Eagle.	weight= per foot weight * height = 0.72*150	108.8	kg	L
	Check valve	Cast iron {GLO}| market for | Alloc Def, U		28.66213152	28.6	kg	LI
	Well casing 8"	PVC pipe E	Assuming casing SDR26 by JM Eagle. Assuming 150 ft casing.	weight= per foot weight * height =2.67*150	401.4	kg	LII
	Well gravel	Gravel, round {GLO}| market for | Alloc Def, U	Assuming that the gravel weighs about 150 pounds per cubic foot. Considering a cylindrical surface with diameter = 10" , thickness= 1" and height = 20', we can calculate the volume of the gravel required.	weight=pi*(outer radius^2 - inner radius^2)*h*density =(pi()*((10/2)^2-(8/2)^2)/144)*20*150	589	kg	LIII
	Drop wire	Copper Wire, 8 awg, 4 conductor	Assuming 150 ft wire		45.7	m	LIV
	Well screen	Stainless Steel Well Screen	Considering 6" diameter	28.7	28.7	kg	LV
	Drilling water	Tap water {CA-QC}| tap water production, underground water without treatment | Alloc Def, U		227.4	227.4	kg	

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
	Water for casing cement	Tap water {CA-QC}| tap water production, underground water without treatment | Alloc Def, U			602.4	kg	
	Pump	Pump 25hp, 6"			1	p	LVI
	Motor	Motor 25hp, 6"			1	p	LVII
	Centralizer	Stainless Steel Well Centralizer			10	kg	
		Processes					
	Energy from burning diesel	Energy, from diesel burned in machinery/RER Mass	Assuming density of diesel to be 0.832kg/L	188.968	8466	MJ	
Prefiltration Apparatus	Apparatus	Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of steel (density = 0.284 lb/in3). Assuming that the height is 45 inches, outer radius is 7 inches and thickness in 0.2 inches. Correction factor to account for joints and fittings is assumed to be 1.2.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.2*3.14*(7*7-6.8*6.8)*45*0.284*0.453	60	kg	LVIII

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
	Metal Working	Metal working, average for chromium steel product manufacturing {GLO}| market for | Alloc Def, U	Calculating energy for metal working for calculated weigh of steel.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.2*3.14*(7*7-6.8*6.8)*45*0.284*0.453	60	kg	LIX
Iron Filter Apparatus	Apparatus	Steel, low-alloyed, hot rolled {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of steel (density = 0.284 lb/in3). The height is 72 inches, outer radius is 30 inches and thickness in 0.5 inches. Correction factor to account for joints and fittings is assumed to be 1.212.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(30*30-29.5*29.5)*72*0.284*0.453	1048.7	kg	LVIII
	Metal Working	Metal working, average for steel product manufacturing {GLO}| market for | Alloc Def, U	Calculating energy for metal working for calculated weigh of steel.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(30*30-29.5*29.5)*72*0.284*0.453	1048.7	kg	

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Carbon Filter Equipment	Apparatus	Steel, low-alloyed, hot rolled {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of steel (density = 0.284 lb/in3). The height is 60 inches, outer radius is 30 inches and thickness in 0.5 inches. Correction factor to account for joints and fittings is assumed to be 1.212.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(30*30-29.5*29.5)*60*0.284*0.453	873.9	kg	LVIII
	Metal Working	Metal working, average for steel product manufacturing {GLO}| market for | Alloc Def, U	Calculating energy for metal working for calculated weigh of steel.	weight=pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(30*30-29.5*29.5)*60*0.284*0.453	873.9	kg	LVIII

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Softner Apparatus	Aparatus plus salt storage tank for backwash	Glass fibre reinforced plastic, polyester resin, hand lay-up {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of E-glass fibre(density = 0.095 lb/in3). The height is 72 inches, outer radius is 18 inches and thickness in 0.5 inches. Correction factor to account for joints and fittings is assumed to be 1.212. Assuming that the cylindrical storage tank is made up of PVC (density=1.4g/cm3) and has dimension 42"X50" with thickness of 0.2".	weight of softner equipment =pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(18*18-17.5*17.5)*72*0.095*0.453 =209.3 kg weight of salt storage tank =1.01*1.1*0.0245*3.14*(21*21-20.8*20.8)*50 =35.72kg	245	kg	LX

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
	Glass Working	Thermoforming, with calendering {GLO}| market for | Alloc Def, U	Calculating energy for thermoforming for calculated weigh of fibre.	weight of softner equipment =pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(18*18-17.5*17.5)*72*0.095*0.453 =209.3 kg weight of salt storage tank =1.01*1.1*0.0245*3.14*(21*21-20.8*20.8)*50 =35.72kg	245	kg	LX

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Dealkalizer Equipment	Apparatus, brine tank, caustic chem tank	Glass fibre reinforced plastic, polyester resin, hand lay-up {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of E-glass fibre(density = 0.095 lb/in3). The height is 72 inches, outer radius is 12 inches and thickness in 0.5 inches. Correction factor to account for joints and fittings is assumed to be 1.212. Assuming that the cylindrical storage tank is made up of fibre glass and has dimension 24"X50" with thickness of 0.2". Assuming 15 gallon holding tank for Caustic chemical is 3.71 kg.	weight of softner equipment =pi*(outer radius^2 - inner radius^2)*h*density =1.01*1.2*3.14*(12*12-11.5*11.5)*72*0.095*0.453 =138.5 kg weight of poly brine storage tank =3.14*(12*12-11.5*11.5)*50*0.095*0.453 =79.3kg	221.7	kg	LXI

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
		Thermoforming, with calendering {GLO}| market for | Alloc Def, U	Calculating energy for thermoforming for calculated weigh of fibre.		221.7	kg	LX
UV filtration apparatus	Apparatus	Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U	Assuming that the equipment is made up of stainless steel and weighs 299 kg.		299	kg	
	Metal Working	Metal working, average for chromium steel product manufacturing {GLO}| market for | Alloc Def, U	Calculating energy for metal working for calculated weigh of steel.		299	kg	
Prefilter media		Polypropylene, granulate {GLO}| market for | Alloc Def, U	Assuming 20 tubes made up of polypropelyne, each weighing 33.25 pounds. Correction factor is assumed to be 1.01.	304.3	304.2	kg	LXII

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
		Thermoforming, with calendering {RoW}| production | Alloc Def, U			304.2	kg	LXIII
Iron Filter media		Zeolite, powder {GLO}| market for | Alloc Def, U	Assuming 60 cubic feet of the filter media with 85% porosity.	3104.9	3104.9	kg	
		Gravel, crushed {GLO}| market for | Alloc Def, U			371.9	kg	
Carbon Filter Media		Coconut husk, from dehusking, at plant/ID Mass		83.5	85.4	kg	LXIV
		Electricity, low voltage {ID}| market for | Alloc Def, U			2.2	MJ	LXIV
		Gravel, crushed {GLO}| market for | Alloc Def, U		371.9	371.9	kg	

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Softener Media		Polystyrene, general purpose {GLO}| market for | Alloc Def, U	Assuming 22 cubic ft of polystyrene as the media as matrix of the 10% cross cation resin is made up of polystyrene.	791.2	791.2	kg	LXV
		Thermoforming, with calendering {RoW}| production | Alloc Def, U			791.2	kg	
		Polystyrene, general purpose {GLO}| market for | Alloc Def, U	Assuming 7 cupic feet of filter media made up of polystyrene (75% by wt) and ammonium chloride(25% by wt). Backwash density is assumed to be 45lb/ft3.	104.6	125.6	kg	LXVI

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Dealkalizer media		Ammonium chloride {GLO}| market for | Alloc Def, U	Assuming 7 cupic feet of filter media made up of polystyrene (75% by wt) and ammonium chloride(25% by wt). Backwash density is assumed to be 45lb/ft3.	61.9	61.9	kg	LXVI
		Thermoforming, with calendering {RoW}| production | Alloc Def, U			125.6	kg	
		Electricity, high voltage {RFC}| electricity production, hard coal | Alloc Def, U			0.3	kWh	LXVII
		Electricity, high voltage {RFC}| electricity production, nuclear, pressure water reactor | Alloc Def, U			0.1	kWh	LXVII

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
Consumers electricity		Electricity, high voltage {RFC}| electricity production, natural gas, at conventional power plant | Alloc Def, U High CH4			0.4	kWh	LXVII
		Electricity, high voltage {RFC}| electricity production, oil | Alloc Def, U			0.1	kWh	LXVII
		Electricity, high voltage {RFC}| electricity production, wind, 1-3MW turbine, onshore | Alloc Def, U			0.1	kWh	LXVII
		Electricity, low voltage {RFC}| electricity production, photovoltaic, 570kWp open ground installation, multi-Si | Alloc Def, U			0	kWh	LXVII

<table>
<tr><th>Item name</th><th>Component</th><th>Material of construction/ Specifications in SimaPro</th><th>Assumptions</th><th>Sample Calculations</th><th>Specification</th><th>Unit of measurement</th><th>Reference</th></tr>
<tr><td></td><td></td><td>Electricity, high voltage {RFC}| electricity production, hydro, reservoir, alpine region | Alloc Def, U</td><td></td><td></td><td>0.1</td><td>kWh</td><td>LXVII</td></tr>
<tr><td></td><td></td><td>Transmission network, electricity, high voltage {CA-QC}| transmission network construction, electricity, high voltage | Alloc Def, U</td><td></td><td></td><td>0</td><td>mm</td><td>LXVII</td></tr>
<tr><td></td><td></td><td>Transmission network, long-distance {GLO}| market for | Alloc Def, U</td><td></td><td></td><td>0</td><td>mm</td><td>LXVII</td></tr>
<tr><td></td><td></td><td>Transmission network, electricity, medium voltage {CA-QC}| transmission network construction, electricity, medium voltage | Alloc Def, U</td><td></td><td></td><td>0</td><td>mm</td><td>LXVII</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U</td><td></td><td></td><td>156</td><td>kg</td><td>LXVIII</td></tr>
</table>

Item name	Component	Material of construction/ Specifications in SimaPro	Assumptions	Sample Calculations	Specification	Unit of measurement	Reference
100 hp pump		Chromium steel product manufacturing, average metal working/RER U			156	kg	LXVIII
100 hp motor		Steel, chromium steel 18/8 {GLO}| market for | Alloc Def, U			426	kg	LXVIII
		Chromium steel product manufacturing, average metal working/RER U			426	kg	LXVIII
		Copper {GLO}| market for | Alloc Def, U			142	kg	LXVIII
		Wire drawing, copper/RER U			142	kg	LXVIII

Appendix J – Equipment Specifications for Existing Water Treatment Facility

IRON FILTRATION				
Flow	404 gpm	max		
	230 gpm	nominal		
spec	Total Fe	less than	0.2	ppm
	Total Mn	less than	0.2	ppm
Pressure		greater than	100	psig
SOFT WATER				
Flow	228 gpm	max		
	120 gpm	nominal		
Spec	Total hardness	less than	0.5	ppm
Pressure		greater than	100	psig
CARBON FILTER				
Flow	185 gpm	max		
	125 gpm	nominal		
Spec	Chlorine		0	ppm
	THM removal		0.1	ppm
Pressure		greater than	100	psig

Appendix K – Regression for Electricity Consumption Assumptions

Code in R for regression estimates for electricity consumption for various unit processes

```
Flowrate =c(0,3785,18927,37854,75708,189271,378541,946353)

UV=c(0,62,310,635,1250,3120,6240,15600)

Backwash=c(0,15,60,125,250,660,1290,3220)

Ultrafiltration=c(0,800,4000,8000,16000,40000,80000,200000)

A=summary(lm(UV~Flowrate))

B=summary(lm(Backwash~Flowrate))

C=summary(lm(Ultrafiltration~Flowrate))
```

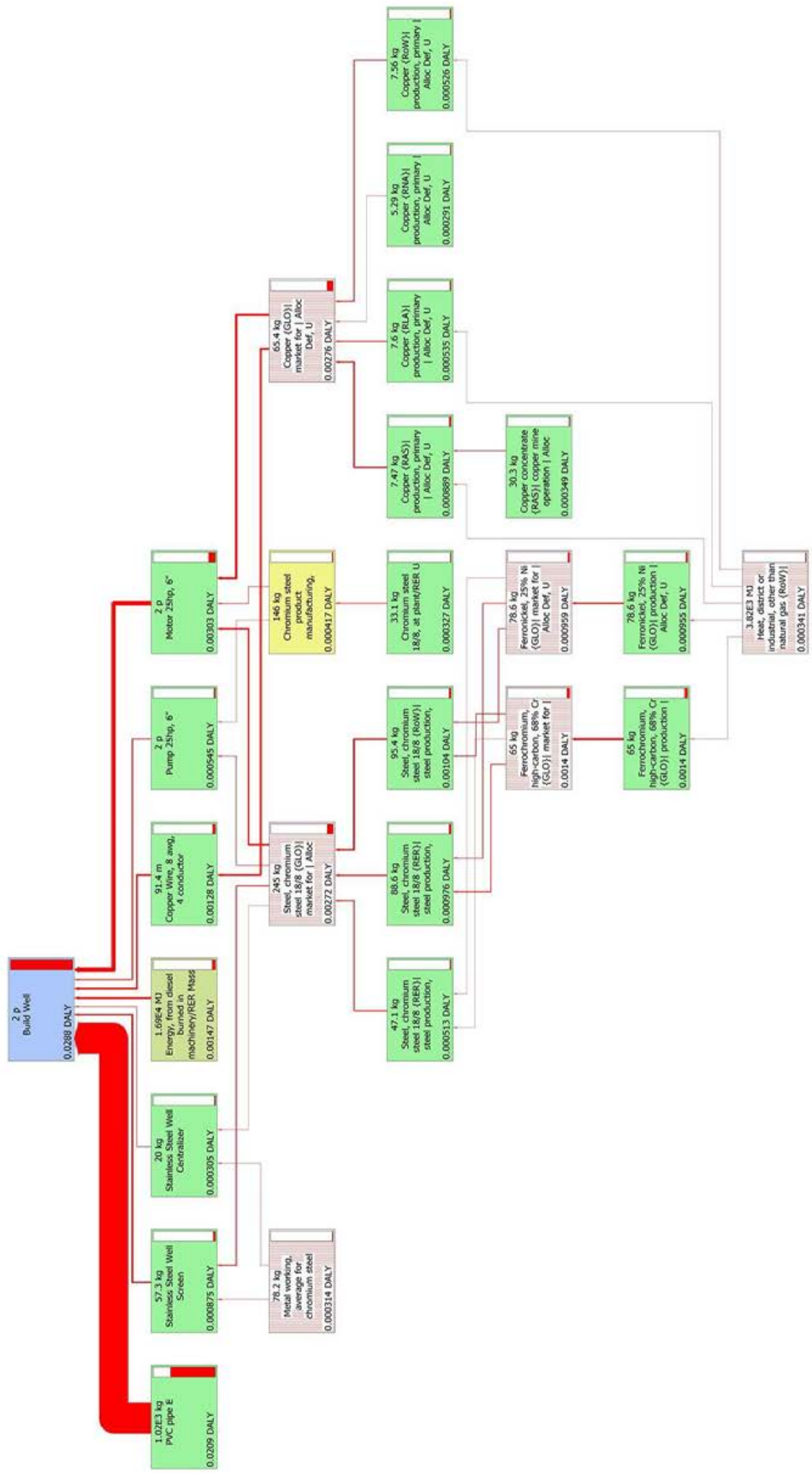
```
> A

Call:
lm(formula = UV ~ Flowrate)

Residuals:
    Min      1Q  Median      3Q     Max 
-3.7447 -1.8842 -1.1543  0.3439  9.2987 

Coefficients:
             Estimate Std. Error  t value Pr(>|t|)    
(Intercept) 1.788e+00  1.840e+00    0.972    0.369    
Flowrate    1.648e-02  5.004e-06 3294.048   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.309 on 6 degrees of freedom
Multiple R-squared:      1,     Adjusted R-squared:      1 
F-statistic: 1.085e+07 on 1 and 6 DF,  p-value: < 2.2e-16

> B

Call:
lm(formula = Backwash ~ Flowrate)

Residuals:
   Min     1Q Median     3Q    Max 
-7.770 -4.000 -1.296  1.268 15.507 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) -4.363e-02  3.251e+00  -0.013     0.99    
Flowrate     3.405e-03  8.839e-06 385.255 2.06e-14 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 7.613 on 6 degrees of freedom
Multiple R-squared:      1,     Adjusted R-squared:      1 
F-statistic: 1.484e+05 on 1 and 6 DF,  p-value: 2.064e-14

> C

Call:
lm(formula = Ultrafiltration ~ Flowrate)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.101740 -0.012932  0.004533  0.030270  0.064318 

Coefficients:
             Estimate Std. Error   t value Pr(>|t|)    
(Intercept) 2.287e-02  2.273e-02 1.006e+00    0.353    
Flowrate    2.113e-01  6.180e-08 3.420e+06   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.05322 on 6 degrees of freedom
Multiple R-squared:      1,     Adjusted R-squared:      1 
F-statistic: 1.169e+13 on 1 and 6 DF,  p-value: < 2.2e-16
```

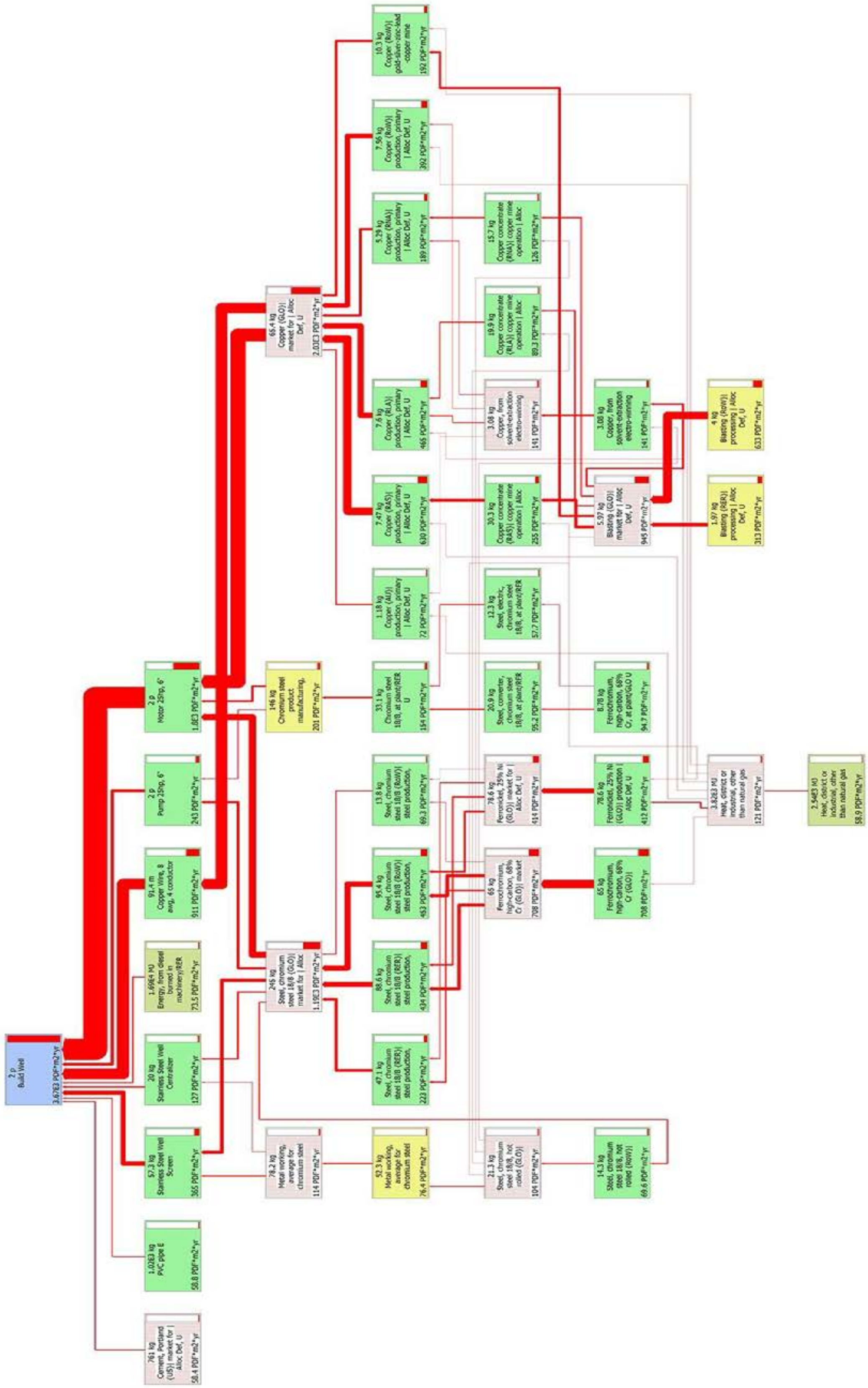
Appendix L – Well Model Cost Assumptions

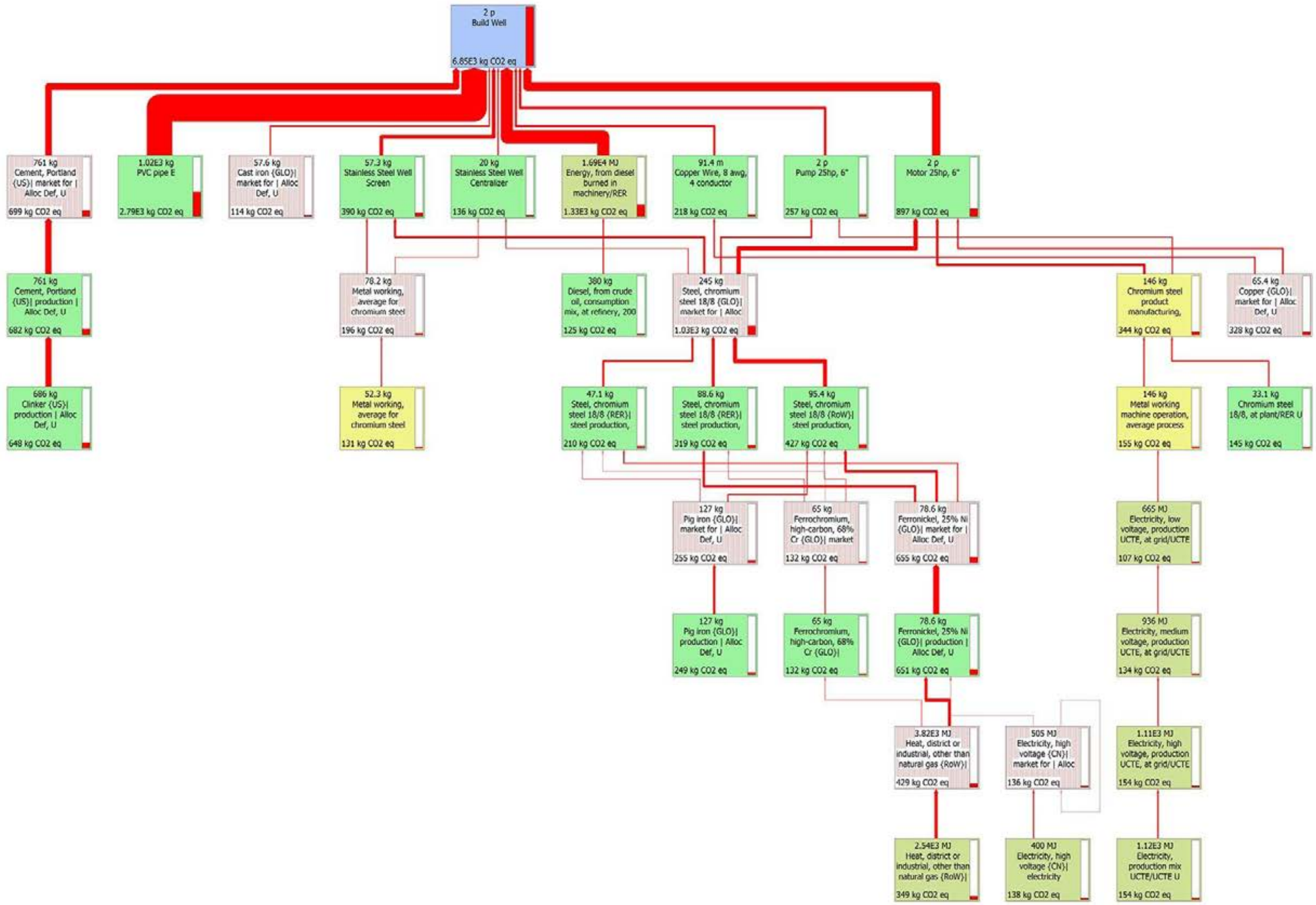
Item	Cost/Unit	Unit	Total	Replacement Year	Source	Note
150' Test Drilling	15.50	foot	2,325	40	*Katz Drilling Quote*	
150' 8" PVC Cased Well	50.00	foot	7,500	40	*Katz Drilling Quote*	
130' Grout	8.00	foot	1,040	40	*Katz Drilling Quote*	
Cement Grouting			500	40	*Katz Drilling Quote*	
20' - 8" Screen and Developing	125.00	foot	2,500	40	*Katz Drilling Quote*	
20' Gravel Pack	10.00	foot	200	40	*Katz Drilling Quote*	
First Well Total			14,065			
Additional Well Total			14,065			
Total			**28,130**			
Pump Installation						
25 Hp pump			3,960	6 to 10 (always on)	*Katz Drilling Quote*	Life can go up to 10-18 years (infrequent use)
25 HP Motor			4,108	10	*Katz Drilling Quote*	
105' 4" Drop pipe and wire 8-3	27.50	foot	2,888	50	*Katz Drilling Quote*	
Splice Kit			25		*Katz Drilling Quote*	
Check Valve			514		*Katz Drilling Quote*	
Pitless Adapter 8"			5,767		*Katz Drilling Quote*	
Test Pumping			1,000		*Katz Drilling Quote*	
Installation			1,200		*Katz Drilling Quote*	
First Pump Total			19,462			
Additional Pump Total			19,462			
Total			**38,923**			
Variable Frequency Drive						
Variable Frequency Drive			9,000	10	*Interiew with Katz*	assumption based on VFD life expectancy
Transducer			242	10	*Interiew with Katz*	assumption based on VFD life expectancy
VFD Total			9,242			
Additionall VFD Total			9,242			
Total			18,484			
Other Costs						
Storage Tank	500	per tank	500		*Cribley Drilling Interview*	
Piping	25	per foot	2500		*Cribley Drilling Interview*	
Operating Expenses						
Well Inspection	400	per well	800	annual	*Interiew with Katz*	Check Amps and Pump Motors
Regulatory Costs						
Application Fee	366	both wells	366	one time	*Kalamazoo Permit Application/Hope Stanley*	
MDEQ fee	539	both wells	539	annual	*Pricing for Type II Program/Hope Stanley*	
Bacteria Lab Test	180	both wells	180	annual	*Pricing for Type II Program/Hope Stanley*	
Nitrate Lab Test	15	both wells	15	annual	*Pricing for Type II Program/Hope Stanley*	
Lead and Copper Lab Test	52	both wells	52	annual	*Pricing for Type II Program/Hope Stanley*	
Certified Operator Test	75	both wells	75	every 3 years	*Pricing for Type II Program/Hope Stanley*	
Certified Operator Registration	45	both wells	45	every 3 years	*Pricing for Type II Program/Hope Stanley*	
SOC Lab Test	365	both wells	365	every 6 years	*Pricing for Type II Program/Hope Stanley*	
VOC Lab Test	100	both wells	100	every 6 years	*Pricing for Type II Program/Hope Stanley*	
Metal Lab Test	102	both wells	102	every 6 years	*Pricing for Type II Program/Hope Stanley*	
Cynide Lab Test	25	both wells	25	every 9 years	*Pricing for Type II Program/Hope Stanley*	

Electical Expenses	
Year	Expenses
0	
1	4,414
2	11,968
3	22,547
4	39,410
5	67,036

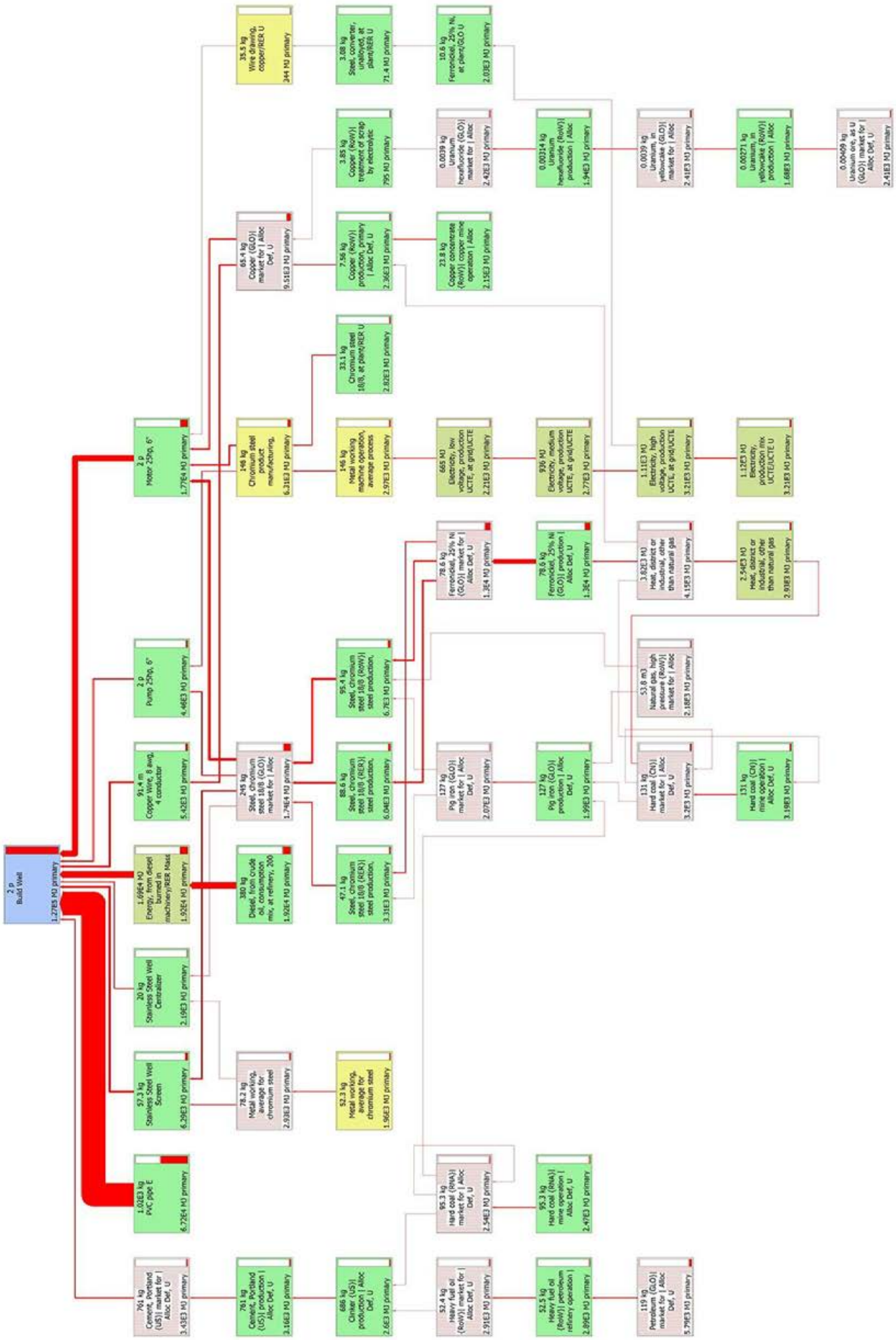
Appendix M – SimaPro Model Outputs

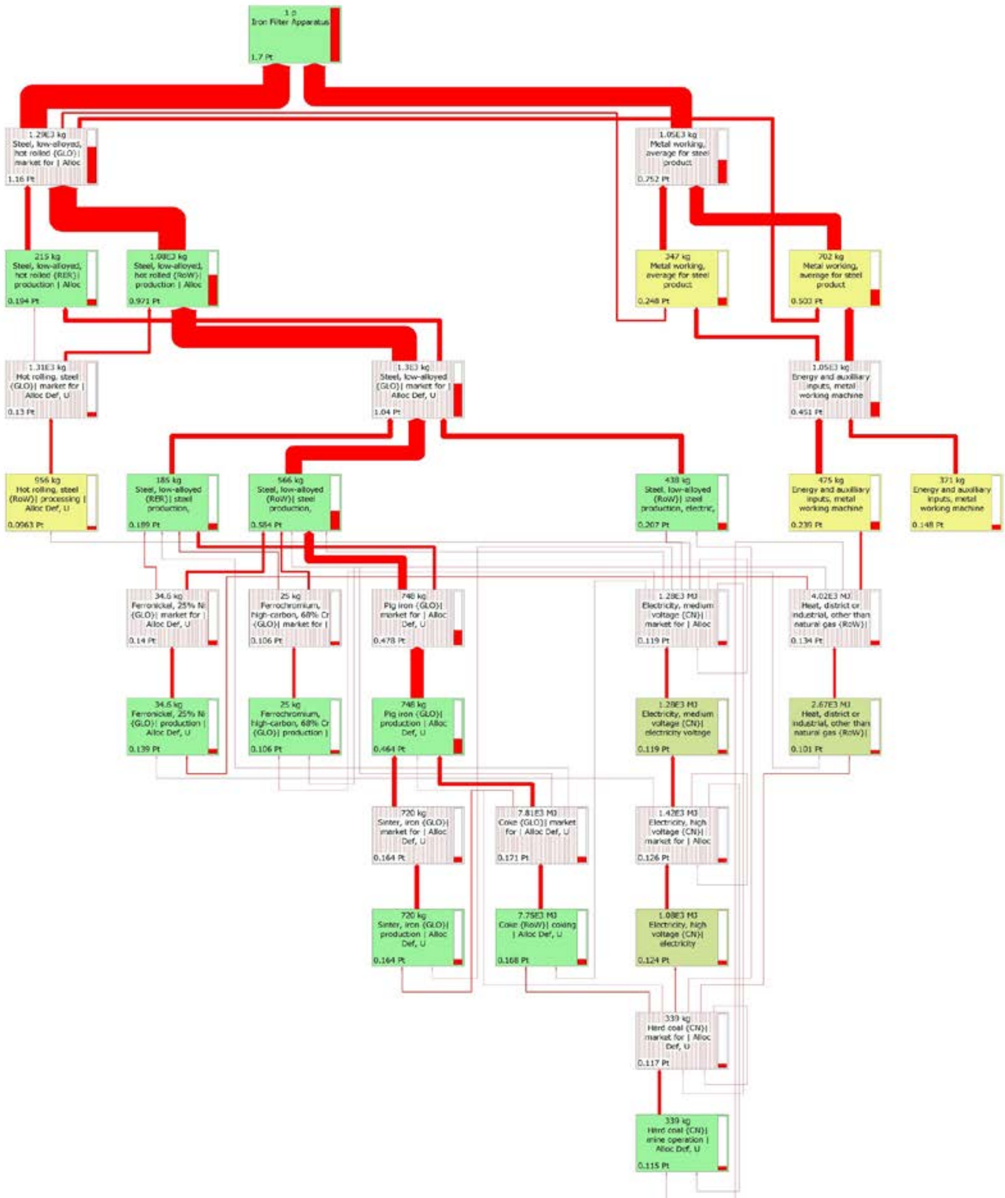






2 p
Build Well
6.85E3 kg CO2 eq
761 kg
Cement, Portland {US}| market for | Alloc Def, U
699 kg CO2 eq
1.02E3 kg
PVC pipe E
2.79E3 kg CO2 eq
57.6 kg
Cast iron {GLO}| market for | Alloc Def, U
114 kg CO2 eq
57.3 kg
Stainless Steel Well Screen
390 kg CO2 eq
20 kg
Stainless Steel Well Centralizer
136 kg CO2 eq
1.69E4 MJ
Energy, from diesel burned in machinery/RER
1.33E3 kg CO2 eq
91.4 m
Copper Wire, 8 awg, 4 conductor
218 kg CO2 eq
2 p
Pump 25hp, 6"
257 kg CO2 eq
2 p
Motor 25hp, 6"
897 kg CO2 eq
761 kg
Cement, Portland {US}| production | Alloc Def, U
682 kg CO2 eq
78.2 kg
Metal working, average for chromium steel
196 kg CO2 eq
380 kg
Diesel, from crude oil, consumption mix, at refinery, 200
125 kg CO2 eq
245 kg
Steel, chromium steel 18/8 {GLO}| market for | Alloc
1.03E3 kg CO2 eq
146 kg
Chromium steel product manufacturing,
344 kg CO2 eq
65.4 kg
Copper {GLO}| market for | Alloc Def, U
328 kg CO2 eq
686 kg
Clinker {US}| production | Alloc Def, U
648 kg CO2 eq
52.3 kg
Metal working, average for chromium steel
131 kg CO2 eq
47.1 kg
Steel, chromium steel 18/8 {RER}| steel production,
210 kg CO2 eq
88.6 kg
Steel, chromium steel 18/8 {RER}| steel production,
319 kg CO2 eq
95.4 kg
Steel, chromium steel 18/8 {RoW}| steel production,
427 kg CO2 eq
146 kg
Metal working machine operation, average process
155 kg CO2 eq
33.1 kg
Chromium steel 18/8, at plant/RER U
145 kg CO2 eq
127 kg
Pig iron {GLO}| market for | Alloc Def, U
255 kg CO2 eq
65 kg
Ferrochromium, high-carbon, 68% Cr {GLO}| market
132 kg CO2 eq
78.6 kg
Ferronickel, 25% Ni {GLO}| market for | Alloc Def, U
655 kg CO2 eq
665 MJ
Electricity, low voltage, production UCTE, at grid/UCTE
107 kg CO2 eq
127 kg
Pig iron {GLO}| production | Alloc Def, U
249 kg CO2 eq
65 kg
Ferrochromium, high-carbon, 68% Cr {GLO}|
132 kg CO2 eq
78.6 kg
Ferronickel, 25% Ni {GLO}| production | Alloc Def, U
651 kg CO2 eq
936 MJ
Electricity, medium voltage, production UCTE, at grid/UCTE
134 kg CO2 eq
3.82E3 MJ
Heat, district or industrial, other than natural gas {RoW}|
429 kg CO2 eq
505 MJ
Electricity, high voltage {CN}| market for | Alloc
136 kg CO2 eq
1.11E3 MJ
Electricity, high voltage, production UCTE, at grid/UCTE
154 kg CO2 eq
2.54E3 MJ
Heat, district or industrial, other than natural gas {RoW}|
349 kg CO2 eq
400 MJ
Electricity, high voltage {CN}| electricity
138 kg CO2 eq
1.12E3 MJ
Electricity, production mix UCTE/UCTE U
154 kg CO2 eq




1 p Iron Filter Apparatus 1.7 Pt
1.29E3 kg Steel, low-alloyed, hot rolled {GLO}| market for | Alloc 1.16 Pt
1.05E3 kg Metal working, average for steel product 0.752 Pt
215 kg Steel, low-alloyed, hot rolled {RER}| production | Alloc 0.194 Pt
1.08E3 kg Steel, low-alloyed, hot rolled {RoW}| production | Alloc 0.971 Pt
347 kg Metal working, average for steel product 0.248 Pt
702 kg Metal working, average for steel product 0.503 Pt
1.31E3 kg Hot rolling, steel {GLO}| market for | Alloc Def, U 0.13 Pt
1.3E3 kg Steel, low-alloyed {GLO}| market for | Alloc Def, U 1.04 Pt
1.05E3 kg Energy and auxiliary inputs, metal working machine 0.451 Pt
956 kg Hot rolling, steel {RoW}| processing | Alloc Def, U 0.0963 Pt
185 kg Steel, low-alloyed {RER}| steel production, 0.189 Pt
566 kg Steel, low-alloyed {RoW}| steel production, 0.584 Pt
438 kg Steel, low-alloyed {RoW}| steel production, electric, 0.207 Pt
475 kg Energy and auxiliary inputs, metal working machine 0.239 Pt
371 kg Energy and auxiliary inputs, metal working machine 0.148 Pt
34.6 kg Ferronickel, 25% Ni {GLO}| market for | Alloc Def, U 0.14 Pt
25 kg Ferrochromium, high-carbon, 68% Cr {GLO}| market for | 0.106 Pt
748 kg Pig iron {GLO}| market for | Alloc Def, U 0.478 Pt
1.28E3 MJ Electricity, medium voltage {CN}| market for | Alloc 0.119 Pt
4.02E3 MJ Heat, district or industrial, other than natural gas {RoW}| 0.134 Pt
34.6 kg Ferronickel, 25% Ni {GLO}| production | Alloc Def, U 0.139 Pt
25 kg Ferrochromium, high-carbon, 68% Cr {GLO}| production | 0.106 Pt
748 kg Pig iron {GLO}| production | Alloc Def, U 0.464 Pt
1.28E3 MJ Electricity, medium voltage {CN}| electricity voltage 0.119 Pt
2.67E3 MJ Heat, district or industrial, other than natural gas {RoW}| 0.101 Pt
720 kg Sinter, iron {GLO}| market for | Alloc Def, U 0.164 Pt
7.81E3 MJ Coke {GLO}| market for | Alloc Def, U 0.171 Pt
1.42E3 MJ Electricity, high voltage {CN}| market for | Alloc 0.126 Pt
720 kg Sinter, iron {GLO}| production | Alloc Def, U 0.164 Pt
7.75E3 MJ Coke {RoW}| coking | Alloc Def, U 0.168 Pt
1.08E3 MJ Electricity, high voltage {CN}| electricity 0.124 Pt
339 kg Hard coal {CN}| market for | Alloc Def, U 0.117 Pt
339 kg Hard coal {CN}| mine operation | Alloc Def, U 0.115 Pt

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