MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

TO: File

FROM: Izabel Hartman

DATE: January 19, 2016

SUBJECT: Drinking Water Revolving Fund Project No. 7411-01
City of Grand Rapids (North Walker Tank)
Green Project Reserve (GPR) Funding Cost Calculation

The purpose of this memo is to document the cost calculations for the green project reserve funding for the city of Grand Rapids, DWRF Project No. 7411-01. The total loan amount is $2,830,000. The entire project qualifies as green (North Walker Tank and Water Main).

Per the Project Priority List, if the GPR amount is less than $5M and exceeds $2M, then principal forgiveness is $500,000.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

TO: Izabel Hartman, Project Manager
Office of Drinking Water and Municipal Assistance
Revolving Loan Section

FROM: Luke Dehtiar, P.E., District Engineer
Office of Drinking Water and Municipal Assistance
Field Operations Section – Grand Rapids District Office

DATE: June 4, 2015

SUBJECT: City of Grand Rapids – Project Number 7411-01
Qualification for Green Project Reserve Funding

The purpose of this memo is to document the basis for determining whether the City of Grand Rapids DWRF Project No. 7411-01 (North Walker Tank & Water Main and Lake Michigan Filtration Plant (LMFP) High Service Pumps Work) qualifies for green project reserve funding. These two projects are intended to save significant electrical energy usage at two facilities within the City's distribution system.

A new tank in the North Walker pressure district will provide needed storage to this area of their system. The City currently uses pressure reducing valves (PRVs) to bleed excess water back into the lower pressure district while pumping continuously in order to maintain pressure in the area. As one might expect, this leads to a very high electrical cost relative to the water demands in the North Walker district. The tank will allow the pump(s) to cycle on and off as the tank empties and fills, rather than remaining on indefinitely. FTC&H's analysis shows that this change in operation alone will save roughly 80% of the station's electrical consumption. As this project provides a reduction in energy consumption that is greater than 20%, it should qualify as a categorically-accepted energy efficient project. Both the tank itself and the associated water main work to connect the tank to the system should be considered for the GPR funding, as one is useless without the other.

The proposed variable frequency drive (VFD) for High Service Pumps 5 and 6 at the LMFP will allow the city to reduce their energy costs by better matching the demand conditions in the system and operating the pumps at a more efficient point on their curve. Frictional losses in the transmission lines can be great, given the distance between the treatment plant and the primary distribution system. Reducing the velocity at which water flows through the transmission mains will decrease the amount of energy the pump must use to deliver the water to the system. Additionally, the replacement of the motors on pumps 3 and 4 with new, more efficient models will add to these savings. FTC&H's analysis shows that the City will save 2,333,300 kWh/yr by utilizing the VFD and the new motors. This equates to a 15% savings over their current setup. Given that the project should reduce energy consumption by greater than 10%, this portion of the project should be eligible for GPR funding as well. The business case submitted by FTC&H identifies that the entire project is necessary to realize the energy savings, and should be considered for GPR funding.

VFD project dropped for DWRF 7411-01, so only North Walker Tank/WM GPR applicable for 7411-01

June 2, 2015
Project No. G150011

Ms. Izabel Hartman
Project Manager
MDEQ - Office of Drinking Water and Municipal Assistance – Revolving Loan Section
Constitution Hall - 4th Floor South
525 West Allegan
Lansing, MI 48933

Re: City of Grand Rapids Drinking Water Revolving Fund (DWRF) Fiscal Year (FY) 2016
Green Project Reserve Letter – Reply to MDEQ Questions

Dear Ms. Hartman:

This letter is in response to your request for additional information regarding the Green Project Reserve business case for the Lake Michigan Filtration Plant (LMFP) High Service Pumps (HSP) 5 and 6. The original analysis was conservative and focused on the energy savings from operating HSP 5 and 6 using the proposed variable frequency drive (VFD). As noted in the May 1, 2015 letter, the analysis underestimated the energy that the existing pumps would use, did not account for the energy lost by operating HSP 3 and 4 with the crossover valve partially closed, and did not evaluate the energy savings due to the increased efficiency of the pumps and motors. This letter is a follow up to clarify the energy savings at the LMFP.

The initial analysis estimated that in 2014, the existing pumps would have used 13,500,000 kilowatt hours per year (KWh/year); using the VFDs would have saved 1,429,000 KWh/year ($137,000). Based on the analysis comparing the existing with the proposed, this would be a savings of 10.6%. However, in the original submittal, the energy savings was compared to the actual energy use in 2014 of 15,923,000 KWh/year for an energy savings of 9%. As noted, some of the additional energy used in 2014 is due to the crossover valve being closed when operating HSP 3 and 4. This is an operational change that will be addressed in design, but not presented herein.

The other energy savings mentioned above is the efficiency of the pumps and motors. As shown in the equation below, the energy used by the pump is a factor of flow (Q in gallons per minute) times the head (H pressure in feet of water) divided by the Pump Efficiency and Motor Efficiency. The other terms in the equation include specific gravity (sp. gr. = 1 for water) and conversion factors. In looking at the equation, it can be seen that as the efficiencies of the pump and motor increase, the KW used by the pump and motor decrease.

$$KW = \frac{Q(gpm)\ X\ H(in\ feet)\ X\ sp.gr.X\ 0.7457}{3960\ X\ Pump\ Eff\ X\ Motor\ Eff}$$

Based on the data from 2014, 15,923,000 KWh/year of energy was used by HSP 3, 4, 5, and 6. The flow and head from each pump, as well as the KW used are known. From this data, the overall efficiency (Pump Eff. X Motor Eff.) of each pump-motor assembly was calculated. The efficiency ranged from 69.8% to 73% and averaged 71.6%. When the pumps were new, using the efficiencies shown on the pump curves, and assuming 95% efficient motors, the average efficiency of the pump-motor assemblies was 80.6%. The loss in efficiency is attributed to both the pumps and motors for the following reasons:

1. Pumps
   a. Pump 6 was purchased in 1949. Pumps 3, 4, and 5 were purchased in 1940. A 66- to 75-year-old pump will lose efficiency due to wear.
   b. Actual operating data showing the flow and head have been graphed against the original pump curves and show that the curves have slipped, meaning that at a particular flow the pump produces a lower head. One explanation for this, after consulting with the pump manufacturer, may be the need for the wear rings to be replaced. As the name implies, the wear rings wear away over time and are meant to be replaced. Service records indicate that wear rings for HS 5 and HSP 6 have not been replaced since 1972. HSP 3 has no record of wear rings ever being replaced. HSP 4 was repaired in 2015 and new wear rings were installed. The existing wear rings were described as "worn and washed out." The impeller was also inspected and was described as good and only required some weld repairs.
2. Motors
   a. HSP 3 and 4 had new induction motors installed in 1990 that were rated as 95.4% efficient. These motors are 25 years old and likely have lost some efficiency. The new motors will be synchronous and 96% to 97.5% efficient.
   b. HSP 5 and 6 have the original synchronous motors from 1940. The motors have been rewound and cleaned, but are still 66 to 75 years old. The new motors will either be induction motors (93.5% to 95% efficient) or synchronous motors (96% to 97.5% efficient). Synchronous motors are significantly more expensive, so induction motors are being considered since operation with a VFD corrects the power factor to 1.

If the repair of the pumps returns their condition to that reflected by the original pump curve and assuming that the new motors operate at the minimum efficiencies (96% and 93.5%), the overall average efficiency for the pump and motor assemblies would be 80.8%. As stated above, the current overall efficiency of the pumps and motors is averaged at 71.6%.

A 1% increase in overall efficiency would save 210,650 KWh/year, which is a 1.38% savings beyond the 9% presented in the May 1 letter. A 9% increase in overall efficiency would save 1,707,650 KWh/year, which is an 11.17% savings beyond the 9% presented in the May 1 letter. Given that this project is a rebuild of existing equipment, including replacing older less efficient motors with new more efficient motors, it is assumed that half of the potential efficiency could be reclaimed, or a 4.5% increase in efficiency to 76.1%. The increased efficiency would produce an energy savings of 904,300 KWh/year, a 5.91% energy savings, and a cost savings of $86,800.

Combining the energy savings of the VFD with the energy savings from repairing the pumps and adding more efficient motors, the project estimates a total energy savings of 2,333,300 KWh/year, which is a 15% reduction in energy use and a monetary savings of $223,800.

Over twenty years, assuming a constant energy cost, this savings would be $4,476,000; 86% of the project cost. Assuming a constant energy cost, this project would have a payback of 23 years.

We respectfully submit the entire project as a Green Project. The VFDs increase the efficiency of the pumps by lowering the operating head. The VFD cannot be installed in the space available without changing the motors to 4160V power from 2300V power. Plus, changing the motors allows the added benefit of installing more efficient motors. With the motor change, the thrust of the pump and coupling the motor to the pump requires the shaft and the bearings to be replaced. When the shaft and bearings are removed, the impeller will be inspected and repaired as needed to increase efficiency, and the wear rings will be replaced as needed in HSP 3, 5, and 6.

If you have any questions or require additional information, please contact me at 616-464-3848 or ccirving@ftch.com.

Sincerely,

Cynthia C. Irving, P.E.

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Attachment
By e-mail and Fed Ex
cc: Mr. Luke Dehtiar, P.E. - MDEQ
Mr. Wayne Jernberg, P.E. – City of Grand Rapids
Mr. John Allen - City of Grand Rapids
Mr. Jeff McCaul, P.E. – City of Grand Rapids
Mr. Arden Postma, P.E. – City of Grand Rapids
Mr. Alex Fleet – City of Grand Rapids
Mr. David P. Bratt, P.E. – FTCH

May 1, 2015
Project Nos. G150011 and G150149

Ms. Izabel Hartman
Project Manager
MDEQ - Office of Drinking Water and Municipal Assistance – Revolving Loan Section
Constitution Hall - 4th Floor South
525 West Allegan
Lansing, MI 48933

Re: City of Grand Rapids Drinking Water Revolving Fund (DWRF) Fiscal Year (FY) 2016
Green Project Reserve Letter

Dear Ms. Hartman:

This letter is in response to your request for Green Project Reserve business cases for DWRF projects scheduled for Fiscal Year 2016. The City of Grand Rapids has two projects that have been identified as green projects: the North Walker Elevated Storage Tank and Water Main (Formerly the West High-High Tank and West High-High Water Main) and the LMFP High Service Pumps 5 and 6 VFD.

The business cases are attached. The North Walker Elevated Storage Tank will operate with the existing fixed speed pumps at the Bristol Pump Station to eliminate water circulated through pressure reducing valves. This project will not only provide redundant supply and reliability for the North Walker Pressure District, it is estimated to reduce the energy use at the Bristol Pump Station by 80% and save 133,740 KWh ($14,295) to 224,327 KWh ($23,808) per year.

The business case for the LMFP High Service Pumps 5 and 6 VFD is attached. The addition of the VFD is estimated to reduce the energy use of the High Service Pumps by 9%, for a yearly savings 1,429,000 KWh ($137,000). In addition, the new motors and VFD for Pumps 5 and 6, plus new synchronous motors for Pumps 3 and 4, are expected to exceed the current total efficiencies and produce a power factor closer to 1.

If you have any questions or require additional information, please contact me at 616-464-3848 or ccirving@ftch.com.

Sincerely,

Cynthia C. Irving, P.E.

nes
Attachment
By e-mail and Fed Ex
cc: Mr. Luke Dehtiar, P.E. - MDEQ
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Mr. Scott Conners, PE – City of Grand Rapids
Mr. Arden Postma, P.E. – City of Grand Rapids
Mr. Alex Fleet – City of Grand Rapids
Mr. David P. Bratt, P.E. – FTCH

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North Walker (Formerly West High-High) Elevated Tank and Water Main
Green Project Reserve Business Case

Our first projects being submitted for Green Project Reserve Funding are the West High-High Elevated Storage Tank and Water Main. Since completion of the 2014 DWRF, the West High-High Pressure District has been renamed the North Walker Pressure District. Hence the West High-High Elevated Tank and Water Main are now referred to as the North Walker Tank and Water Main.

The funding mechanism for the North Walker Water Main has been modified. Figure 1 shows the project extent with the DWRF funded portion of the projects in red. The portion of water main from Walker to Bristol Avenue is highlighted in light blue and will be funded with non-DWRF funds. The original cost estimates from the 2014 DWRF were $2,325,000 for the West High-High Elevated Tank and $2,590,000 for the West High-High Water Main. Table 1 presents the updated cost estimates. The Estimated Construction Cost for the Tank remained the same. The Estimated Construction Cost for the DWRF funded portion of the water main is $480,000. The total project cost is estimated at $3,085,000.

Table 1 – Updated North Walker Tank and Water Main Project Preliminary Cost Estimate

Item	Estimated Cost
Elevated Tank and Foundation	$1,414,000
Painting	$165,000
Pavement	$70,000
Site Work and Stormwater	$120,000
Water Main Onsite	$91,000
16-Inch Water Main	$260,000
Easements	$30,000
Surface Restoration	$190,000
Subtotal – Estimated Construction Cost	$2,340,000
Contingency	$365,000
Design and Construction Engineering/Inspection	$380,000
Total – Estimated Project Budget	**$3,085,000**

The West High-High Pressure District is a pumped system supplied by the Bristol Pump Station. Once the North Walker Elevated Tank is completed, this pressure district will be expanded to the west to serve other existing customers, and will be renamed the North Walker Pressure District. This project will save energy because the existing constant speed pumps exceed the demand and excess water is pumped and then returned to the supply side of the pump station through pressure reducing valves (PRVs).

The Bristol Pump Station currently takes water from the West High Pressure District (suction side) and pumps it into the West High-High Pressure District (discharge side). The Bristol Pump Station has three pumps: one small 25 horsepower (HP) pump to supply demands in the West High-High Pressure District and two large 150 HP pumps (one to supply fire flow while the other is a backup pump).

Table 2 – Bristol Avenue Pumps

Pump*	Design Flow (gpm)	Design Flow (mgd)	Design Head (ft)	Horsepower (HP)
Pump 1** – Large	3000	4.3	142	150
Pump 2** – Large	2,800	4.3	142	150
Pump 3 – Small	1,000	1.4	69	25

* Pumps are constant speed
**The DWRF listed data for the old 40 HP large pumps. The current pumps are 150 HP.
mgd - million gallons per day

The demands for the current West High-High pressure district as presented in the DWRF are listed in Table 3. Also listed are the demands of the North Walker Pressure District. All of the Bristol Pumps exceed the demand in the West High-High Pressure District. The small Bristol Pump can supply all current demands, including peak hour demand, as demonstrated in operating records. The large pumps are only needed for fire flow.

Table 3 - Demands in the West High-High Pressure District

	Demand (gpm)	Demand (mgd)
2010 ADD	264	0.38
2010 MDD	569	0.82
2030 ADD	424	0.61
2030 MDD	903	1.30

In order to supply the district using the constant speed pumps, two pressure reducing valves (PRVs) are used to control the pressure by circulating excess pumped water back to the suction side of the Bristol Pumps (i.e., the West High Pressure District). One PRV is in the Bristol Pump Station, is set at 85 pounds per square inch (psi), and circulates water from the discharge side of the pumps back to the suction side. The other PRV is on the opposite side of the pressure district near Alpine and I-96, is set at 100 psi, and also circulates water back to the West High Pressure District.

To summarize, the West High-High Pressure District is supplied by three constant speed pumps. In a typical year, Pump P3 would run 24 hours per day 7 days per week and the water that exceeds the demand would be circulated back to the suction side of the pump. The yearly average demand for the West High High Pressure District is 0.38 million gallons per day (mgd) and Pump P3 produces an average of 1.27 mgd of water. This means that 0.89 mgd is pumped but not needed.

Electric bills for the Bristol Pump station from December 2012 through March 2015 were reviewed. The electric use is constant year round, indicative of Pump P3 always operating and producing a fairly constant flow. In contrast, other pump stations in the Grand Rapids water system will see reduced energy use in the winter (low demand) and increased energy use in the summer (high demand). The electric use also captured a seven week period in the summer of 2014 when the small Bristol Pump had a broken shaft and the large pumps were operated while it was repaired. The station experienced over a fourfold increase in electric use. A graph of the electric use shown as KWh/day is presented in Figure 2.

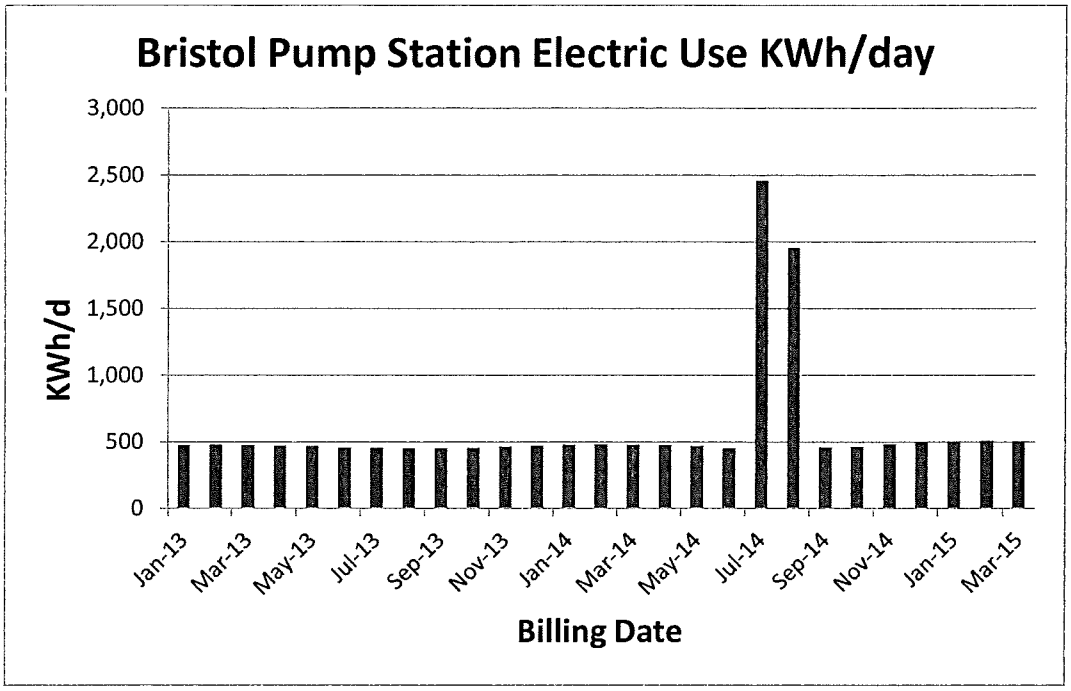

Figure 2 - Electrical Use in kilowatt hours per day for January 2013 through March 2015

The energy use at Bristol Pump Station, the demands from billing records, the pump curves for the 25 HP and 150 HP pumps, and the pressure readings from the pump station were used to confirm the hydraulic model. For instance, the energy bills show an average electrical use of 468 KWh/day when P3 is running, and the hydraulic model predicts an energy use of 467 KWh/day. Appendix 1 summarizes the Bristol Pump Station Operation and Energy Use currently, and the prediction once the North Walker Tank is online.

The key information presented in Appendix 1 is:

1. Results Column 1 – The existing operation with P3 running continuously is presented.
    a. The demand for the West High-High Pressure District is 0.38 mgd.
    b. The pump produces an average of 1.27 mgd, so 0.89 mgd (70% of the water) is circulated back through the PRV.
    c. The average energy cost at the Bristol Pump Station is 10.6¢ per KWh, the daily energy use is 467 KWh/day, the daily cost is $50, the yearly energy use is 170,527 KWh/year, and the yearly cost is $18,076.

2. Results Column 2 – The proposed operation of P3 with the new North Walker Tank is presented.
   a. The demand for the new North Walker Pressure District is higher at 0.44 mgd since some existing users to the west will be moved into the North Walker Pressure District.
   b. The pump produces an average of 1.47 mgd. The water in excess of the demand fills the elevated tank, and the pump is turned on and off in response to the tank level. There is no water circulated through the PRV, because the pressure in the station stays below 85 psi.
   c. The average energy cost at the Bristol Pump Station is 10.6¢ per KWh, the daily energy use is 100 KWh/day, the daily cost is $11, the yearly energy use is 36,614 KWh/year, and the yearly cost is $3,881.
3. Results Column 3 – The existing operation with P1 or 2 running is presented.
   a. The demand for the West High-High Pressure District is 0.38 mgd.
   b. Either pump will produce an average of 4.47 mgd, so 4.09 mgd (91.5% of the water) is circulated back through the PRV.
   c. The average energy cost at the Bristol Pump Station is 10.6¢ per KWh, the daily energy use is 2,673 KWh/day, the daily cost is $283, the yearly energy use would be 975,734 KWh/year, and the yearly cost would be $103,428 if the larger pumps were operated year round instead of P3.
   d. P1 and P2 are not used for daily operation. However, in 2014 when the pumps were operated for 48 days, 128,315 KWh were used at a cost of $13,601.
4. Results Column 4 – The proposed operation of P1 or P2 with the new North Walker Tank is presented.
   a. The demand for the new North Walker Pressure District is 0.44 mgd.
   b. The pump produces an average of 4.51 mgd. The water in excess of the demand fills the elevated tank, and 1.81 mgd of water is circulated through the PRV to maintain the pressure below 85 psi. The pump is turned on and off in response to the tank level.
   c. The average energy cost at the Bristol Pump Station is 10.6¢ per KWh, the daily energy use is 436 KWh/day, the daily cost is $46, the yearly energy use is 159,320 KWh/year, and the yearly cost is $16,888.
   d. Had the tank been available in 2014 during the 48 days that P1 and P2 were operated, 20,951 KWh would have been used at a cost of $2,221 as compared to the actual cost of $13,601.

Table 4 summarizes the energy and cost savings with the proposed operation of the Bristol Pumps with the North Walker Tank. The tank reduces the energy use at the Bristol Pump Station by 80%. Over a twenty year period assuming no escalation in energy costs, there would be a minimum savings of $283,900 with P3 operating at all times. Based on current operation, assuming that P3 will require a seven week shut down every 3 years, the savings could be $341,570 (14 years saving $14,195 and 6 years saving $23,808).

Table 4 - **Energy Use of Bristol Avenue Pumps**

	Energy Savings (KWh/yr)	**Cost Savings ($/yr)**	**Percent Energy Reduction**
Pump P3 Supplying Demand 365 days/year	133,740	$14,195	78.5%
2014 Operation, 48 days with P1 & P2	224,327	$23,808	81%

As presented in Table 1, the total estimated project cost is $3,085,000. The twenty year savings are between 9% and 11% of the capital cost. More importantly, the station will reduce energy consumption by 80%.

Appendix 1 -- Basis of Design

Green Project Reserve: Energy and Cost Calculations for Existing and Proposed Operation

	Existing P3 Based on Model	Existing P3 Operation with North Walker Tank	Existing P1 or P2 Based on Model	Existing P1 & P2 Operation with North Walker Tank
Average Day Demand	0.38	0.44	0.38	0.44
Flow (mgd)	1.27	1.47	4.47	4.51
Flow (gpm)	882	1021	3,104	3,132
Suction Pressure (psi)	52	53	50	46.90
Discharge Pressure (psi)	86.68	73.08	108.29	104.09
Total Dynamic Head (ft)	79	47	134	132
Pump Eff (%) Assumed from Curve	79.0%	77.0%	80.0%	80.0%
Motor Efficiency (%) Assumed	85.5%	85.5%	88.0%	88.0%
Pump Brake HP (BHP)	22	16	131	131
Motor HP (HP)	26	19	149	148
Power (KW)	19	14	111	111
Water Through Bleedback Valve	0.89	0	4.09	1.81
Run time per day (hours)	24	7.24	24	3.94
Volume of water pumped per day (gallons)	1,269,992	443,520	4,469,971	740,843
Average Power Used (KW-h/d)	**467**	**100**	**2673**	**436**
Power Used (KW-h/year)	170,527	36,614	975,734	159,320
Energy Costs ($ per KW-h/d)	0.106	0.106	0.106	0.106
Daily Operating Costs ($)	$50	$11	$283	$46
Yearly Operating costs ($)	$18,076	$3,881	$103,428	$16,888

LMFP High Service Pumps 5 and 6 VFD
Green Project Reserve Business Case

The second project being submitted for Green Project Reserve Funding is the Lake Michigan Filtration Plant (LMFP) High Service Pumps 5 and 6 Variable Frequency Drive (VFD) project. This involves adding a VFD to be shared by High Lift Pumps 5 and 6 (HLP-5 and HLP-6) and changing the motors on HLP-3, HLP-4, HLP-5, and HLP-6 from 2300V to 4600V power. The addition of the VFD reduces the operating pressure (head) on HLP-5 and HLP-6, thereby reducing energy use. The motor change from 2300V to 4600V accomplishes two objectives. First, a 4600V VFD is smaller and fits within the existing building space. Second, the motors on HLP-3 and HLP-4 are induction motors and energy bills show that when these pumps are operated, the power factor is 0.8. Replacing the motors with synchronous motors will produce a power factor closer to 1.0. The Project Cost as presented in the DWRF is presented in Table 1.

Table 1 – Updated North Walker Tank and Water Main Project Preliminary Cost Estimate

Item	Estimated Cost
Demolition	$50,000
New Motors	$2,600,000
VFD, Electrical, and Instrumentation	$1,200,000
Subtotal – Estimated Construction Cost	$3,850,000
Administration, Engineering, Contingency	$1,350,000
Total – Estimated Project Budget	**$5,200,000**

The energy savings for this project comes from reducing the operating pressure of the pumps, hence, the energy needed to transport treated water from the LMFP to the City. The water for the City of Grand Rapids Metropolitan Area is taken from Lake Michigan and treated at the LMFP. Once the water is treated, it is pumped roughly 30 miles to the City of Grand Rapids through two transmission mains:

1. The 46-inch-diameter North Transmission Main which is supplied by the North High Lift Pumps (HLP 3, 4, 5, 6, and 7).
2. The 60-inch-diameter South Transmission Main, which is supplied by both the South High Lift Pumps (HLP 8, 9, 10, 11, and 12) and the North High Lift Pumps.

The North High Lift Pumps can help supply the 60-inch-diameter South Transmission Main because of two crossover valves that tie the North and South Transmission Mains together before they exit the LMFP. Typically, the North Transmission Main is operating at a higher pressure so the water flows from North to South. The first crossover valve is a manual 10-inch-diameter flow control valve that is always 10% open. The 10-inch manual valve ensures that there is always water flowing through both transmission mains, keeping them pressurized. The second crossover valve is a 16-inch-diameter automated flow control valve that can be set by the operators between 0% and 100% open. Opening the 16-inch-diameter crossover valve allows water to be diverted from the North Transmission Main to the South Transmission Main. The pumps and valves are summarized in Table 2.

Table 2 – LMFP Pumps and Valves
2016 GPR Submittal
High Lift Pumps 5 and 6 VFD

North High Lift Pumps			Crossover Valves		South High Lift Pumps (Low Speed)*		
Pump #	Design Flow (mgd)	Design Head (feet)	10" Manual	16" Automated	Pump #	Design Flow (mgd)	Design Head (feet)
3	21.0	255	Setting 10%	Setting 0% to 100%	8	12.5	185
4	25.0	280			9	25	225
5	31.0	325	Typical Flow Range 0.5 to 1.5 mgd	Typical Flow Range 1.0 to 7.0 mgd	10	25	225
6	36.0	338			11	12.5	185
7**	50.0	300			12	25	225

mgd – million gallons per day
Note: The table lists the rated capacities taken from the 2011 Sanitary Survey.
** Pump 7 is not currently operated and is not addressed in this project.
* The South High Lift Pumps have two speed motors, but have been operated on low speed for the past 10 years.

As shown in Table 2, all of the North High Lift Pumps operate at higher heads than the South High Lift Pumps. HLP 3 and HLP 4 are the smaller of the North Pumps and they operate at a lower discharge head. Pumps 5 and 6 are the larger North Pumps and their heads are 100 to 113 feet (43 to 49 psi) greater than the South High Lift Pumps. This relationship can be more clearly shown by looking at a graph of the pump curves as shown in Figure 1.

When reviewing Figure 1, the key opportunity for energy savings is adding a VFD to HLP-5 and HLP-6. The 60-inch South Transmission Main, being larger than the North Transmission Main and newer with less friction, allows more flow at lower head (pressure). HLP-3 and HLP-4 can operate with the crossover valve 100% open and flow splitting between the North and South Transmission Mains. In contrast, HLP-5 and HLP-6 will run off the right side of their curves if the crossover valve is 100% open, causing the motors to overheat and shut down. Therefore, the crossover valve must be closed (typically 0% to 30% open) to keep HLP-5 and HLP-6 operating properly. By adding a VFD, the pumps can simply be slowed down and operated at a lower head, thereby allowing the crossover to be open and avoiding pumping against a closed or mostly closed valve.

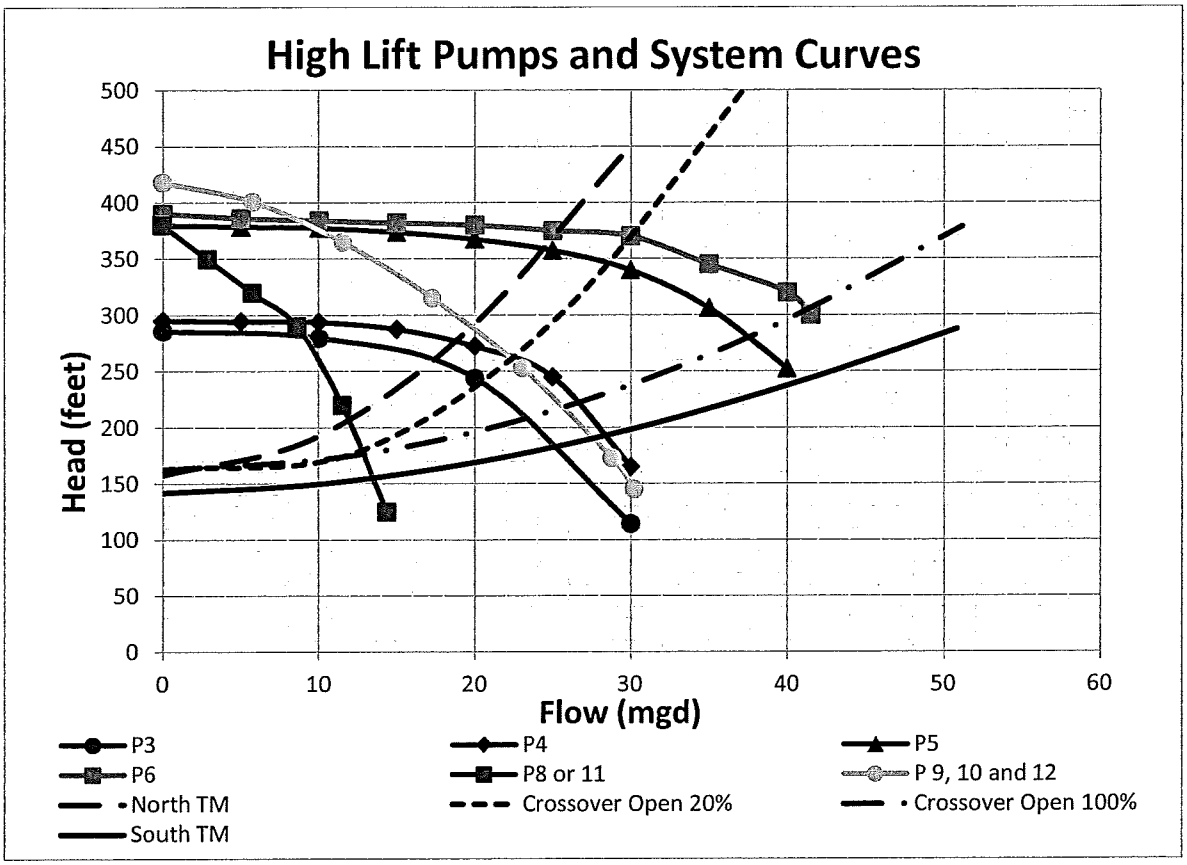

Figure 1 – North and South High Lift Pumps and Typical System Curves

Notes: North TM is the highest head for the North Pumps with the 16-inch crossover closed. South TM is the lowest head on the pumps with the 16-inch crossover opened. Crossover Open 20% is for the North Pumps when the 16-inch crossover is open 20%. Crossover Open 100% is for the North Pumps while one South pump is also operating.

Operating records for 2014 were reviewed including:

1. Daily volume of water pumped by the High Service Pumps, reported as million gallons per day (mgd).
2. Electric bills for January 10, 2014 through January 7, 2015.
3. Daily operator logs showing:
   a. Pumps operating.
   b. Position of the crossover valve.
   c. Gallons of water pumped for each pump (mgd).
   d. Kilowatts used by each pump.

From this data, it was shown that certain flow ranges are delivered by combinations of specific pumps as listed in Table 3. Column 1 shows the flow range and Column 2 shows the pump combinations. Next, the daily volume of water pumped was analyzed to determine the number of days falling within each flow range as shown in Column 3. The operating records also record for each pump combination the flow rate produced for each pump

and the kilowatts allowing the kilowatts used per million gallons pumped to be calculated (KW/MG) as shown in Column 4.

Table 3 – Pump Combinations to Meet Demands
2016 GPR
VFD for HLP 5 and 6

Flow Range (mgd)	Pump Combination	Days in 2014 in Range	KW/MG
20 – 27	Pump 3 or 4	56	42
27 – 31	Pump 6	64	64 to 44
31 – 35	Pump 3 or 4 and 8 (small South)	137	40
36 – 40	Pump 6 and 8 (small South)	21	48 to 40
41 – 50	Pump 3 or 4 and 10 (large South)	56	38
51 – 59	Pump 6 and 10 (large South)	28	48 to 40
60 – 68	Pump 6 and 8 (small) and 10 (large)	3	47 to 40

In reviewing the operating records, it was noted that Pump 6 drew greater than 20 KW/MG more than the other pumps due to the higher operating head. When run alone, Pump 6 drew 64 KW/MG as compared to Pumps 3 and 4 which drew 42 KW/MG. By adding a VFD and opening the crossover valve, it is estimated that Pump 6 could produce the same flow while drawing an estimated 44 KW/MG. When north and south pumps are operated together, P3 or P4 with either P8 or P10 draw a total of 38 to 40 KW/MG as compared to combinations with P6 that draw 47 to 48 KW/MG. Adding the VFD is estimated to drop the P6 combinations to 40 KW/MG. Taking the 2014 daily flows and KW/MG for each flow range, a total energy use for 2014 of 13,500,000 KWh/year was calculated. The electric bills documented a total of 15,923,000 KWh/year. This means that the analysis presented in Table 3 is conservative and actually the energy used in 2014 was 15% higher. Part of the higher energy use is due to the crossover valve being closed when operating P3 and P4.

Next, the same daily flows were used to calculate the energy that would have been used if P6 operated on a VFD and used 44 KW/MG when operating alone, and 40 KW/MG when operating in combination. With the addition of the VFD, the analysis predicts that 1,429,000 KWh/year could be saved; a reduction of 9% of the total energy used in 2014. From the 2014 Electric Bills, the average energy cost was $0.096/KWh. Therefore, a 1,429,000 KWh/year reduction would save $137,000 per year in energy costs. Over twenty years assuming a constant energy cost, this would be $2,740,000; 53% of the estimated project cost. In addition to the energy saved by reducing the head when HLP-5 and HLP-6 are operating, further savings are anticipated by reviewing and modifying the use of the 16-inch crossover valve to minimize head. Also, the combined pump and motor efficiency for the North Pumps (3-6) was estimated at 70% based on the flow, head, and kilowatts used. The efficiency with the new motors, even with some loss of energy through the VFD, is expected to exceed the current efficiency.