Water System Reliability Study

City of Allegan

WSSN #MI0000120

November 2011

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EXECUTIVE SUMMARY

This report represents the five year update of the City of Allegan Water System Reliability Study. Based on the three primary components of the water distribution system (the source water system and water treatment plant, the water distribution system (pipe), and the storage requirements), the following conclusions could be made:

- The water supply has met most regulations for microbiological, radioactive, inorganic and volatile organic contaminants.
- The existing supply capacity is adequate for Year 2021 water demands and further into the future.
- The transmission and distribution system is strong for this community. The City provides adequate water supply for normal (non-emergency) system conditions.
- The City provides fire protection to residential customers of 1,000 gpm for 2 hours and to industrial customers of 3,500 gpm for 3 hours. Specific distribution and transmission system improvements have been recommended for improved fire protection in some areas of the City to meet goals.

DATA SOURCE: CENTER LINE DATA, AERIAL IMAGERY ARE FROM ALLEGAN COUNTY LAND INFORMATION.

CITY OF ALLEGAN

ALLEGAN COUNTY, MICHIGAN

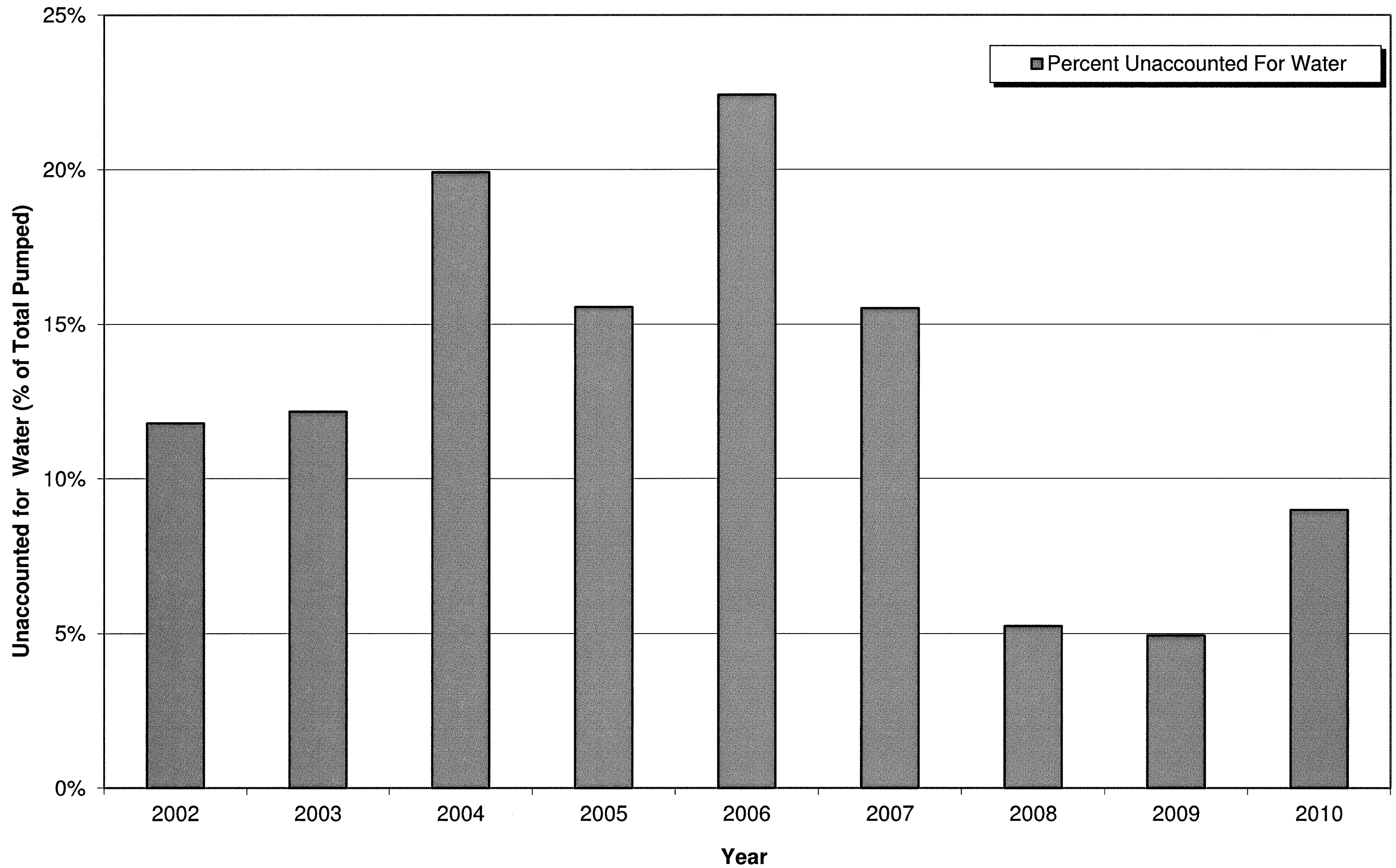
WATER ATLAS

Figure 5
General Plan Map

Prein&Newhof
November 2011

City of Allegan Water System Reliability Study

Historical Water Loss
Figure 6



I. INTRODUCTION

The City of Allegan is located in Allegan County in western Michigan. Presently, the City of Allegan has a water supply system that serves the entire City. The service area is shown on Figure 1.

The City relies on groundwater as the source of its drinking water. The City has one well field with three wells located at the water treatment plant near the center of the City on the banks of the Kalamazoo River. One well was abandoned and a new well was drilled with the construction of the new Water Treatment Plant in 2010. The three production wells are equipped with new pumps, motors, and variable frequency drives to provide a total capacity of 4.3 mgd and a firm capacity of 2.9 mgd.

The purpose of this report is to provide a reliability study of the water system for the City of Allegan. This reliability study is intended to fulfill the requirements of Part 12, Rule R325.11201 through R325.11207 promulgated under Michigan's Safe Drinking Water Act, 1976, P.A. 399, as amended. The Act calls for a 10 year projection of water demands and an evaluation of each of the system components on a five year interval.

This report contains population projections made by the West Michigan Regional Planning Commission using data from the United States Department of Commerce, Bureau of Census (through the 2000 census). Population data for Year 2010 and a revised population count for Year 2000 were provided by the Michigan Department of Technology, Management and Budget – 2010 U.S. Census. The report identifies current and projected water demands and includes a computer assisted network analysis of the water distribution system.

The City of Allegan has completed major improvements to the water system in recent years to improve system reliability. The most considerable improvements to the system include a new water treatment plant, direct high service pumping from the plant to the high pressure district, transmission main improvements in both the low and high pressure districts, and significant distribution improvements for improved fire protection.

Based on the analysis, recommendations for improvements to the water supply system are made and cost estimates are presented for the improvements.

II. WATER DEMANDS

The City of Allegan supplies water to all residents within the City limits and to some residents of the surrounding Allegan Township. The City's land use is diverse with a significant residential area, a downtown commercial area, and a large industrial area to the northeast including one significant water supply customer in Perrigo Company. Figure 2 is the city Zoning Map showing the land use distribution.

Historical water demand data based on metered data and Monthly Operating Reports was provided by the City of Allegan. The data included the monthly water demands for years 1991 through 2010 as shown in Table 1. From this data, the following parameters were estimated: average day demand, which is the average water use for the year; maximum day demand, which is the highest daily use for the year; and peak hour demand, which is the estimated maximum hour of water use during the year. Figure 3 graphically illustrates the historical water use along with projections based on this information.

Demands were estimated and probability ranges determined for each demand condition. The average day demand for Year 2011 is estimated to be 0.98 mgd based on the historical trend. The highest average annual water use over the past 10 years was 1.06 mgd in 2007. As a result, the upper end of the probability range is approximately 1.06 mgd. The highest demand value in the probability range for a given year was selected for the model simulation.

The maximum day demand, which is the highest daily water use for the year, has averaged just over 1.7 times the average day water use over the past 10 years. A maximum day multiplier of 2 times the average day demand was assumed for the system modeling, which corresponds to a maximum day demand of approximately 1.97 mgd.

Actual peak hour water use is not metered by the City, and can vary significantly primarily due to weather fluctuations. Based on typical water use for similar communities, a peak hour factor of 4.0 was assumed for model simulations.

Water system demands were projected through Year 2021 based on the percentage population growth expected in the City. In addition, water demands were adjusted to reflect a shift in water usage from the low pressure district to the high pressure district. In 2007, the water usage in the high pressure district represented under 40-percent of total water demand. Water consumption in the high pressure district increased to just over 50-percent of total water demand in 2010. Projections assumed an even distribution (50-50 split) of water demand between the low and high pressure districts. Population projections are provided in Table 2, and water use projections are shown in Table 3.

III. WATER SUPPLY SOURCE

The City of Allegan has been providing water to its customers from a ground water supply since 1935. Initially, groundwater was pumped directly to the distribution system with no treatment. In the early 1970’s, the city constructed a treatment plant to soften the water and remove iron, improving the aesthetic quality of the water. Additional wells were drilled at that time to increase the supply capacity of the water treatment plant. In 2010, the City of Allegan demolished the 1970’s plant and constructed a reverse osmosis water softening treatment plant. The oldest water supply well (drilled in 1935 for the original treatment plant) was abandoned, and a new well was drilled on the plant site.

The city currently has a total of four (4) water supply wells. Three wells (described as Wells #1, # 2, and #5) are located at the water treatment plant in the center of the city. A fourth well (Griswold) is located on the other side of the Kalamazoo River about 2,000 feet away. This well is used strictly for emergencies. It pumps directly into the distribution system with no treatment. Well #3 was abandoned in 2010 with the construction of the reverse osmosis water treatment plant. The location of the wells and the treatment plant are shown in Figure 1.

The two existing wells (#1 and #2) at the water treatment plant were equipped in 2010 with new submersible pumps, motors, and variable frequency drives (VFDs) to match the new Well #5. The VFDs allow the flow into the plant to be varied with differing production demands. Each well has a pitless adapter and the well casings were extended above the 500-year flood elevation. The three wells at the treatment plant site are each rated at 1,000 gallons per minute (gpm). This provides a total capacity of 3,000 gpm (4.3 mgd) and a firm capacity of 2,000 gpm (2.9 mgd). The firm capacity is based on the capacity with one well out of service. This firm capacity is greater than the projected 2021 maximum day demand of 1,419 gpm (2.04 mgd).

The wells draw water from a prolific, leaky-confined, sand and gravel aquifer. Basic data about each well and pump is provided in Table 4.

IV. WATER TREATMENT FACILITIES

Between 1935, when the City of Allegan started a public supply and the early 1970's, groundwater was pumped into the system without treatment. In 1972, the city completed construction of a treatment plant at its current location adjacent to the Kalamazoo River and began softening the water, providing more aesthetically pleasing water to its citizens. Most recently in 2011, the city completed construction of a new water treatment plant on the same site along the Kalamazoo River. The water currently is softened via the process of reverse osmosis.

Raw groundwater is pumped to the treatment plant from the three on-site water supply wells. A schematic of the treatment process is provided in Figure 4 and the major processes are discussed below.

The treatment plant is staffed by two state licensed operators and a superintendent who is also licensed. The treatment plant typically operates twenty-four (24) hours per day and the number of treatment units operated varies depending on the system demands.

A. Raw Water Quality

The primary reason for treatment of water by the city is to remove hardness. The hardness in water is caused by the presence of polyvalent metal cations. The primary cations in most naturally occurring waters are calcium and magnesium. Hardness generally increases the use of soap and detergent for cleaning purposes. Iron and manganese, when present, contribute to hardness and can also cause staining of fixtures and laundry.

Other water quality parameters, such as metals, synthetic organic compounds, pesticides and herbicides, are routinely tested in the raw water to ensure that there are no other contaminants present in the raw water that could pose a health hazard. No contaminants have been found in the groundwater supply at or above maximum contaminant levels (MCLs) set under the Safe Drinking Water Act, Act 399, P.A. 1976, as amended. A summary of these results is reported in the Water Treatment Report, which is published each year by the City and provided to its customers. The 2008 Water Treatment Report is included in Appendix D.

B. Design Treatment and Demand Rates

Average day and maximum day system demands based on the historical water usage for the last ten years were utilized for design. The following data conservatively was used for the design treatment rates:

Annual Average Day Demand:	1.0 million gallons per day
Maximum Day Demand:	2.3 million gallons per day

In general, the production capacity of the new plant was sized to meet the maximum day demand with the largest treatment unit out of service. Peak hour demands and fire flow demands are met by system storage and high service pumping. A summary of the treatment plant element capacities is provided in Table 5.

C. Iron Removal Treatment

The raw water contains approximately 1.3 mg/l of iron. All the iron is removed in the reverse osmosis (RO) treatment process. A bypass flow is routed around the RO treatment to blend the non-softened water with the softened water to achieve the desired hardness level in the finished water (see Blended Flow in Section IV.E. below).

The bypass flow is treated with an iron removal filter so that the finished water iron level is comparable to the pre-2010 treatment system. A pressure filter is utilized for the iron removal process. Oxidation of the iron in the raw water is initiated by the addition of liquid sodium hypochlorite (chlorine) upstream of the iron filter. Bench scale testing was performed to determine the required doses of chlorine to achieve oxidation of the iron (see Chemical Feed in Section IV.I. below).

The following sizing criteria apply:

Average Iron Filtration Rate:	0.92 gpm/sf
Maximum Iron Filtration Rate:	3.0 gpm/sf

Maximum Bypass Flow:	1.1 mgd
Filtration Area required @Max. Flow:	250 sf

Filter Type:	Enclosed steel pressure filter with multimedia
Median Type:	24" of 1.2 mm anthracite
Filter Size:	10' diameter x 25' long
Number of Filter Cells:	2

The filter is divided into two cells and can be backwashed one cell at a time with a simultaneous air/water backwash system. A blower is provided for the air component of the backwash and is enclosed in a sound attenuating enclosure. The water for the backwash is provided via a line from the high service pump header equipped with a meter and throttling valve to achieve the desired backwash rate. The waste backwash water is drained to the existing filter backwash waste pond.

Backwash System:	Automatic with air/water backwash
Water Backwash Rate:	12 gpm/sf max, 1,500 gpm peak instantaneous
Air Backwash Rate:	3 cfm/sf
Average Backwash Volume:	12,000 gallons

Space was provided for and two supplementary iron filters were installed in the water treatment plant for pre-filtration before the RO treatment. The water treatment plant alternates operation of the three iron filters to maximize filter life.

D. Reverse Osmosis Softening Treatment

Softening of the raw water is completed by a reverse osmosis (RO) treatment system. The water produced from the RO process is referred to as "Permeate" and the waste stream, which contains the dissolved solutes that could not permeate through the membrane, is referred to as "Concentrate". The ratio of permeate to concentrate is referred to as "System Recovery". The higher the system recovery, the less waste stream is produced. To produce a higher recovery, however, the concentration of the concentrate increases and the difficulty in maintaining the membrane system from scaling is increased. Thus, a system recovery is targeted which minimizes the waste stream while not overly burdening the operation of the system and prematurely fouling the membranes.

The membrane skids are configured in stages. The first stage takes all of the flow, and the second stage takes the concentrate flow from the first stage, further concentrating it. The R/O system is designed as a 2/1 array with the first stage being twice the size of the second stage.

A number of spiral wound membrane elements are contained in a series of pressurized tubes referred to as "skids". The following data applies:

Number of Skids:	3
Number of Stages per skid:	2
Target Recovery:	75%
Number of membrane elements per skid:	144
Permeate Capacity per Skid:	0.75 mgd
Firm capacity of RO system:	1.5 mgd
Target Hardness of Permeate:	1 mg/l

1. Membrane Feed Pumps

Each membrane skid is equipped with a feed pump to boost the pressure of the water and force water through the semi-permeable membrane surface. Each pump is equipped with a variable frequency drive to vary the inlet pressure to the membrane skid, as the pressure requirements increase over time as the membranes foul. The following data applies:

Number of Membrane Feed Pumps:	3
Type of Pump:	Vertical turbine can pump
Pump Capacity:	695 gpm @ 165 psi

Motor Horsepower:	100 hp

2. Interstage Boost Pumps

Each membrane skid is equipped with an inter-stage boost pump. The inter-stage boost pump boosts the pressure of the water feeding the second stage membranes to increase the permeate production from this stage. Boosting the feed pressure to the second stage is required in order to produce an equivalent amount of permeate per square foot of membrane surface area in the second stage. Each pump is equipped with a variable frequency drive to vary the feed pressure to the second stage membranes as the pressure requirements increase over time. The following data applies:

Number of Inter-stage Boost Pumps:	3
Type of Pump:	Vertical Multistage Centrifugal
Pump Capacity:	342 gpm @ 75 psi
Motor Horsepower:	20 hp

3. Membrane Cartridge Filters

Each membrane skid is equipped with a cartridge pre-filter. The purpose of the cartridge filter is to provide a final defense of the membranes from any particulates which may be in the raw water, especially any oxidized iron, which could easily foul the membranes. The following data applies:

Number of Cartridge filters:	3
Filtration Size:	5 micron
Filter Capacity:	695 gpm
Maximum Headloss:	15 psi

4. Membrane Clean-in-Place System

The membranes will foul and/or scale over time, and a chemical cleaning system is provided to restore them. The cleaning frequency is different for every membrane system but can be as frequent as once every 3 months to once every few years. The skids have to be taken off-line to be cleaned, and they are set up so that each of their stages can be cleaned separately. A CIP pump is provided to pump the cleaning solution through the membranes, while a water heater heats the CIP solution for more efficient cleaning. The cleaning chemicals are fed into the CIP tank by hand and "batched" for a cleaning. The CIP cleaning solution is sent to the sanitary sewer after the cleaning is complete. The following data applies.

CIP tank volume:	1500 gallons
CIP pump capacity:	300 gpm @ 70 psi
CIP Water Heater Capacity:	24 kW
CIP Cleaning Chemicals:	Avista RoClean P303 & Avista RoClean P111

E. Blended Flow

The hardness of the finished water from the previous water treatment plant is approximately 130 mg/l. For the new system, the hardness level can be adjusted by varying the blend ratio of permeate to iron filtered water. To achieve the target hardness, permeate is blended with iron treated bypass flow in a computer controlled ratio. This is done by taking the reading from the permeate flow meter and adjusting the throttling valve on the iron removal effluent to achieve the desired flow rate measured by the iron removal effluent meter. The following data applies:

Raw Water Hardness:	300 mg/l
Permeate Hardness:	1 mg/l
Target Finished Water Hardness:	100 mg/l
Flow Stream	Maximum Day Flow, mgd
Raw Water Pumping	2.80
RO Feed	2.04
Permeate	1.54

Concentrate	0.50
Iron Filter Bypass	0.76
Finished Water	2.30

For any other production rates, the ratios of the various flows are similar.

A bypass line also is provided around the entire treatment system to provide raw groundwater to the distribution system in the event of equipment failure or malfunction.

F. High Service Pumping

Plant high service pumps convey flow from the on-site storage tanks to the distribution system. High service pumps are provided to pump flow to each of the two pressure districts in the system. Two existing pumps in the high pressure district (Hooker Road Booster Station) act as backup to the pumps provided.

The following data applies:

Pressure District:	Low
Number of Pumps:	2
Capacity of Pumps:	1,050 gpm @ 210’ TDH
Type of Pump:	Horizontal Split Case

Pressure District:	High
Number of Pumps:	2
Capacity of Pumps:	770 gpm @ 270’ TDH
Type of Pump:	Horizontal Split Case

Pressure District:	Dual Zone: Low or High
Number of Pumps:	1
Capacity of Pumps:	1,050 gpm @ 210’ TDH or 770 gpm @ 270’ TDH
Type of Pump:	Horizontal Split Case

G. On-Site Finished Water Storage

On site storage is provided to meet overall system storage requirements and provide a buffer between the water production and water pumping. A 250,000 gallon steel tank and a 500,000 gallon concrete tank are on the water treatment plant site. The tanks are piped/valved so that either tank can be used separately to provide maximum flexibility.

H. Air Stripping

An air stripper is provided downstream of the RO permeate before the 500,000 gallon ground storage tank. The air stripper provides pH adjustment for the permeate flow before it is blended with the bypass flow and water in the site storage tank. The air stripper is sized for a permeate flow of 1.54 mgd and will use a fan to provide aeration to the permeate flow for pH adjustment.

I. Chemical Feed

1. Sodium Hypochlorite

An on-site chlorine generation system is provided for generation of liquid chlorine to be used for iron oxidation in front of the iron filters and to provide a distribution system residual. The system will generate a dilute (0.5%) chlorine solution from salt. The backup to the system in case of equipment failure is the ability to feed commercially produced sodium hypochlorite solution.

Field testing was completed prior to the water treatment plant construction to verify the oxidation rate of the iron and the chlorine dosage required. The following data applies:

Iron Oxidation Dosage:	1.0 mg/l as Chlorine
Average Flow Dosed:	0.38 mgd
Average Daily Usage:	3.2 ppd Chlorine, 90 gal. NaOCl (0.4% soln)

Feed Pump Avg/Max Flow:	3.8 gph avg/19.8 gph max

System Residual Dosage:	1.0 mg/l as Chlorine avg, 2.0 mg/l max
Average Daily Usage:	8.3 ppd Chlorine, 148 gal. NaOCl (0.4% soln)
Feed Pump Avg/Max Flow:	6.2 gph avg/30 gph max

Feed pumps are provided for both the iron oxidation feed and the distribution residual feed, and the pumps are interconnected to provide redundancy. The following data applies:

Number of NaOCl Feed Pumps:	4
Type of Feed Pump:	motor driven, positive displacement
Pump Capacity Range:	3 gph min., 30 gph max.

The system is capable of feeding sodium hypochlorite upstream of the iron filter, upstream of the on-site finished water storage, or at the High Service Pump Discharge (both service districts).

The iron filter feed is paced from the iron filter effluent meter. The finished water feed is paced from the combination of the permeate and iron filter meters, and the high service pump discharge feed is paced from the finished water flow meter.

2. Antiscalant (Scale Inhibitor)

Antiscalant is used to limit the potential of sparingly soluble salts from forming scale in the membrane system. The antiscalant feed is measured by a flow meter to ensure proper dosage and to act as an alarm shutoff for the R/O trains should the flow set-point not be met. The following data applies:

Manufacturer:	Avista Technologies
Product:	Vitec 3000
Dosage:	3 mg/l
Feed rate to RO trains (neat):	6.3 ml/min - 18.9 ml/min (0.1 gph - 0.3 gph)

Antiscalant Storage Volume:	150 gallons (20-30 days)

Number of Feed Pumps:	2
Type of Feed Pump:	motor driven, positive displacement
Pump Capacity Range:	0.01 gph min - 0.3 gph max

The system is capable of feeding antiscalant to the influent of the RO strainers. The pumps are paced by the antiscalant flow meter to maintain a set point based on the number of R/O trains in operation.

3. Fluoride

Fluoride currently is fed into the finished water as a dental supplemental to aid in the prevention of tooth decay. It is fed in the form of hydrofluosilicic acid (H_2SiF_6). The hydrofluosilicic acid is delivered and stored in 15-gallon containers and then fed directly from the tanks by liquid metering pumps. The chemical feed rate is automatically metered from the control system based on the permeate and iron bypass flow meters before it enters the storage tanks. The usage is measured with an electronic scale. The following data applies:

Fluoride Dosage (as F):	1.0 mg/l
Fluoride Concentration of H2SiF6:	79% F (by weight)
Hydrofluosilicic Acid Concentrations:	26% H2SiF6
Hydrofluosilicic Acid Dosage:	4.0 mg/l
Average Daily Hydrofluosilicic Usage:	3 gpd (1.0 mgd @ 4.0 mg/l)
Average Feed Rate (24 hour operation):	0.14 gph
Max. Feed Rate (2,100 gpm):	0.4 gph
Storage Volume Required:	120 gallons (30 days storage)
Storage Provided:	150 gallons (10 - 15 gallon drums)

Number of Feed Pumps:	2
Type of Feed Pump:	motor driven, positive displacement

Pump Capacity Range:	0.1 gph min., 0.5 gph max.

4. Caustic Soda

Caustic Soda (Sodium hydroxide, NaOH) is used to raise the pH of the finished water for stability before pumping. It is assumed that the blended permeate after air stripping and iron filtered water will have a pH of approximately 7.0. The finished water pH will normally be adjusted to approximately 7.5. Provisions are made to pump additional caustic soda if the air stripper is not being used or if additional pH adjustment is needed.

Storage of caustic soda is provided in the form of a bulk storage tank and can also be ordered at 25% strength in the winter months if freezing is an issue. Transfer pumps are provided from two (2) 2,000 gallon day tanks. Usage is measured with an electronic scale. The following data applies:

Caustic Soda Concentration	50% NaOH (Alternately 25%)
Assumed Feed rate of NaOH:	10-20 mg/l
Average Pump Flowrate:	0.8 gph at 50% 1.6 gph at 25%
Maximum Pump Capacity	6.1 gph (no air stripping)
Number of Pumps:	3
Average Usage:	18 gallons per day
Peak Day Usage:	147 gpd (25% no air stripping)
Storage provided:	4,000 gallon storage tank (2 @ 2000 gal)
	80 gallon day tank

The Caustic feed is set up to feed into the iron filter effluent header or the suction of the high service pumps and is paced from the combined flow reading from all of the permeate flow meters and/or high service meters.

5. Phosphate

A phosphate feed system is provided as a corrosion control measure in the finished water before it enters the distribution system. Storage space for eight 15 gallon drums or a bulk storage tank with a capacity of between 800-1000 gallons and feed lines for the chemical pumps is provided in the chemical feed room.

6. Sodium Bisulfite

Space was provided to add a future sodium bisulfite feed system for the elimination of free chlorine in the RO feed, should iron filters ever be used as pretreatment for the RO. Space is provided in the fluoride feed room for storage of chemical and pipes are run from this room to the membrane skids. The future pumps are paced from the influent flow meters.

7. Sulfuric Acid

Based on pilot testing, no acid feed was required to the membrane skids. However, in the future it may be desired to feed acid due to changing water chemistry and/or chemical costs. Room has been provided in the Fluoride feed room for acid chemical storage and pipes are run from this room to the membrane skids. The future pumps would be paced from the permeate flow meter from each skid.

V. WATER SYSTEM INFRASTRUCTURE

A. Storage Facilities

The City maintains three elevated storage tanks and two ground storage tanks. The Western Avenue elevated storage tank is located on Western Avenue between Davis Street and Pine Street. The tank was constructed in 1949 and has a storage capacity of 250,000 gallons. A 500,000 gallon elevated storage tank constructed in 1972 is located on Hooker Road east of Eastern Avenue. Both the Western Avenue and Hooker Road storage tanks are located in the City's low pressure district. The low pressure district consists of all water main west of the Kalamazoo River along with a band of main on the east side of the river as illustrated in Figure 1.

The Northside elevated storage tank is a 300,000 gallon storage tank located on the north end of the City east of the intersection of River Street and Riverview Park. It was constructed in 1989 to serve the City's high pressure district. The high pressure district is described roughly as the northern and eastern portions of the City including Eastern Avenue, Grand Street from Hill Street to the east, Main Street from North Street to the north, and River Street from North Street northwards. The high pressure district boundaries also are illustrated in Figure 1.

The City maintains two ground storage reservoirs at the water treatment plant site. A 250,000 gallon steel reservoir was constructed in 1972 with the original lime softening treatment plant. A 500,000 gallon concrete reservoir was constructed in 2010 with the new reverse osmosis softening plant. On-site water storage is provided to meet overall system storage requirements and provide a buffer between the water production and water pumping. The site piping is configured such that the tanks can be used separately or together to provide maximum flexibility in pumping to either the low or the high pressure district, or both pressure districts combined.

Table 6 provides a summary of the elevated storage facilities. The Northside elevated storage tank has an overflow elevation of 856 feet, approximately 44 feet above the Western Avenue and Hooker Road tanks. The Northside tank provides storage for the homes at higher elevations, and in an emergency it can provide flow to the low pressure district by opening valves between the pressure districts.

B. Booster Station

In the past, the City has operated a booster station located adjacent to the Hooker Road elevated storage tank to serve the high pressure district. In 2010, however, the City added pumps at the new water treatment plant. These pumps convey flows from the plant directly to the high pressure district. As a result, the booster station is used as a standby facility to supplement high pressure district flows from the plant in case of emergency. The booster station is equipped with two pumps, each with a capacity of 1,100 gpm. The nominal capacity of the existing booster station is 2,200 gpm and the firm capacity is 1,100 gpm based on the design capacity of each pump.

C. Water Distribution Mains

The City of Allegan has a complex network of water mains providing transmission and distribution to City and Township customers. The service area covers approximately 5.5 square miles and is supplied through a water distribution network consisting of over 40 miles of water mains ranging from 2 to 16 inches in diameter. An approximate breakdown of the water mains by size is presented in Table 7.

The oldest water mains in the system, located in the downtown area, were installed about a century ago using lead joints. These mains are shallow and water is susceptible to freezing under low flows. The City has been diligent in replacing areas of the oldest water main as evidenced by the significant system improvements completed in recent years (see below). Water mains in the southwestern portion of the system were installed 50 to 60 years ago along with the Western Avenue Tank.

The high pressure district was created in 1988 with the construction of the Hooker Road Booster Station. Since then, the industrial area in the high pressure district has grown, with water main extensions to the northern and eastern City limits. With the completion of the new water treatment plant in 2011, the high pressure district is supplied by designated high service pumps in the water plant. The Hooker Road Booster Station serves as back-up to the water treatment plant pumps. Ground elevations vary in the low pressure district from 620 to 720 feet, and from 670 to 735 feet in the high pressure district.

The City has made the following water distribution system improvements since the 2003 Water System Reliability Study:

Low Pressure District Improvements

1. Kalamazoo River Crossing at Water Treatment Plant

   A14-inch O.D. HDPE (same I.D. as 12-inch D.I.P.) water main was installed under the Kalamazoo River from the new water treatment plant discharge to the low pressure district 12-inch water main in Water Street between Trowbridge Street and Hubbard Street. This new transmission main provides additional redundancy and reliability in the transmission system.

2. Cook Street and Race Street Distribution Loop

   An 8-inch main was constructed along Cook Street from River Street to Race Street and along Race Street from Cook Street to Main Street. This main replaces the existing 4-inch main, closes a distribution loop and improves fire protection in the northeast area of the low pressure district.

3. Pine Street, Hastings Street, and Monroe Street Distribution Main

   An 8-inch water main was constructed in Pine Street from Delano Street to Western Avenue, in Hastings Street from Pine Street to Cedar Street, and in Monroe Street from Pine Street to Cedar Street. These mains replace segments of old, 4-inch main and provide looping for redundancy and improved fire protection in the area.

4. Grove Street Transmission Loop

A 12-inch water main was constructed in Grove Street from Western Avenue to Ely Street to replace existing 4-inch main. This new main is part of a large new transmission loop in the southwestern portion of the low pressure district.

5. Ely Street Transmission Main

A 12-inch water main was constructed in Ely Street from Grove Street to Knapp Street and from Sunset Street to the east City limit to replace segments of 4-inch main. This new main is part of a large new transmission loop in the southwestern portion of the low pressure district.

6. Vernon Street Transmission Main

A 12-inch water main was constructed in Vernon Street from Sherman Street to Knapp Street to replace existing 4-inch main. This new main is part of a large new transmission loop in the southwestern portion of the low pressure district.

7. Sherman Street and Sunset Street Transmission Main

A 12-inch water main was installed in Sherman Street from Western Avenue to Vernon Street, and an 8-inch main was constructed in Sherman from Vernon to Sunset Street to replace existing 4-inch water main. The new mains are part of the large new transmission loop in the southwestern are of the City.

8. Thomas Street Transmission Main

A 12-inch water main was constructed in Thomas Street from Ely Street to Linn Street, and an 8-inch main was installed in Thomas from Linn to Jackson Street, both of which replace existing 4-inch main. These new mains are part of the new transmission system in the southwestern low pressure district.

9. Jackson Street Transmission Main

To connect to an 8-inch dead end main, an 8-inch water main was constructed in Jackson Street from Linn Street to the east. This improvement, along with the Linn Street project below, completes the water main loop in the southern low pressure district west of the Kalamazoo River.

10. Linn Street Transmission Main

An 8-inch water main was installed in Linn Street from Jackson Street to Thomas Street; 12-inch main was installed in Linn from Thomas to the existing 12-inch main north of Thomas, including a new 6-inch water service to the hospital. The 8-inch main is new line, and the 12-inch main replaces existing 6-inch main to complete the south low pressure district transmission loop.

In addition, 8-inch main was installed in Linn from Maple Street to Cedar Street (just south of Jenner Drive) to replace existing 4-inch main.

11. Maple Street Transmission Main

An 8-inch water main was installed in Maple Street from Linn Street to the dead end west of Jenner Drive to replace existing 4-inch main.

12. S. Cedar, Spruce, Cherry, and Walnut Streets Distribution Main

8-inch water main was installed along Cedar Street from Spruce to just north of Linn; on Spruce Street from Linn to Cedar and from Walnut to the west; along Cherry Street from Cedar to Walnut; and along Walnut Street from Cherry to Spruce. This project significantly improved the level of service and fire protection in the area by replacing all the 4-inch and smaller main.

High Pressure District Improvements

1. Grand Street Transmission Main

A 12-inch transmission main was constructed along Grand Street from Park Avenue to Eastern Avenue to connect the existing 12-inch high pressure water main in Park Avenue to the existing 12-inch water main in Eastern Avenue. This new transmission main replaces existing 4-inch water main and connects the high pressure district to the new high pressure pumps at the water treatment plant.

In addition, a new 8-inch water main was installed in Weeks Street from Grand Street to the north dead end to replace existing 4-inch water main.

2. Charles Street and Glenn Street Distribution Main

An 8-inch main was constructed in Charles Street and Glenn Street south of Briggs Street to replace the existing 4-inch main. This provides improved service to the area.

A plan view of the City's high and low pressure districts and the current water distribution network is presented in Figure 1.

VI. WATER SYSTEM ANALYSIS

A. Water Storage Analysis

1. Existing System

Ten State Standards states in Section 7.01: "Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands and where fire protection is provided, fire flow demands".

In addition to fire demand, storage tanks must be capable of storing the maximum hour water demand in excess of the maximum day water demand for the period of time in which the maximum hour water demand occurs. This considers that the water supply system delivers the maximum day water demand.

An analysis for each pressure district was performed with consideration for the pumping capacity. Storage for the low pressure district is more than adequate, providing equalization and more than 3,500 gpm of fire flow for 3 hours, with consideration that storage from the high pressure district is available for emergencies in the low pressure district.

Since the new Water Treatment Plant pumps directly to the high pressure district, the Hooker Road booster pumps can be used to supplement peak flows to the high pressure district. Incorporating the water treatment plant high service pumps and the booster station pumps into the firm pumping capacity determination, the 300,000 gallons of storage provides equalization storage and more than 3,500 gpm for 3 hours. While no requirements exist for fire protection, the Insurance Services Office typically rates industrial customers with a fire flow of 3,500 for full insurance credit, depending on the industry and building.

An analysis of the total water system (low pressure and high pressure districts combined) indicates the existing elevated tanks provide equalization storage and more than 3,500 gpm for 3 hours. Therefore, the existing storage can be considered adequate. Table 8 provides the results of the storage analysis.

2. Future Conditions

The system-wide storage was analyzed for future conditions to determine whether additional storage will be needed. Table 8 projects the recommended storage through Year 2021.

The analysis was completed on each pressure district based on demands and pumping capacity. The pumping and storage facilities in the low pressure district meet suggested volumes through the year 2021 and beyond. The available fire storage to the low pressure district exceeds 3,500 gallons per minute for 3 hours. The City also has the ability to open the isolation valves to bleed water from the high pressure district during an emergency.

The pumping and existing storage facilities for the high pressure district meet suggested volumes through the year 2021 and beyond. The available fire storage to the low pressure district exceeds 3,500 gallons per minute for 3 hours. These results are shown in Table 8.

A final note regarding reliability of storage involves the aging of the Western Tank. This tank was built over 60 years ago and could be replaced within the next 20 years, if deteriorating. If it is replaced, the City should consider constructing the new tank in the southwestern corner of the City. This will improve system hydraulics, particularly in the southwest portion of the system.

B. Distribution System Analysis

The City of Allegan Water Supply System network was analyzed using the water distribution software WaterCAD V8i. This software combines the ability to perform complex hydraulic computations and the ability to present results in a graphical format through its interface with AutoCAD. Model input data consisted of lengths, sizes, and roughness factors (Hazen-Williams coefficients) for pipes, and ground elevations and demands for nodes, storage tank elevations and volumes, and pump curves and capacities.

1. Model Development

A Cybernet model, originally developed for the 1999 Water Distribution System Computer Hydraulic Analysis report and updated for the 2003 Water System Reliability Study, was used as the basis for the current WaterCAD model. The WaterCAD model was then updated to reflect the recent water system improvements discussed previously. Water demands were updated using the historical water demand data provided by the City, including the monthly water pumpage for years 1991 through 2010. All water mains larger than 2-inch diameter were included in the model.

To calibrate the model, hydrant testing results were used. A hydrant flow test measures the transmission capabilities of a system by measuring and comparing the static pressure at a given location under typical conditions and the residual pressure at that same location for a given hydrant flow. The test data provides information for model calibration; that is, model parameters can be adjusted so that predicted results compare favorably to measured results. In addition, the test data can provide information to determine locations at which a valve might be partially closed, or locations at which an unknown connection could exist.

City of Allegan personnel performed hydrant tests on September 30, 2011. The results of these tests are shown in Table 9. The tests were performed at a variety of locations dispersed throughout the system and provide data to adjust roughness coefficients and demands when necessary to simulate results.

Using the hydrant test data, the model was calibrated as follows:

- Simulate system conditions using initial assumptions for parameters
- Adjust water main roughness coefficients and system demand distribution

- Perform a sensitivity analysis on adjusted results
- Fine tune results based on previous steps

Table 10 compares the calibrated model results at the nearest model node to the fourteen test hydrant sites. One high pressure district high service pump was operating for tests 2, 3, 4, 11, 12, and 13. One low pressure district high service pump was operating for tests 5, 6, 7, and 10. No pumps were operating during the remainder of the hydrant tests.

The model reasonably simulates the hydrant test results. Static pressures are within 1 psi at all but one hydrant test locations and within 2 psi for all tests. Residual pressures are within 3 psi at all but three locations and within 5 psi at all locations.

Given the limitations in the hydrant test data, fluctuations in system demands, and other factors, the calibration results can be considered reliable.

Based on the calibration results, the Hazen-Williams coefficient is approximately 65 for the oldest mains of 4-inch diameter or less and 75 for 6-inch mains. This represents the effects of scaling and/or tuberculation. The Hazen-Williams coefficient was assumed to be 95 to 115 for 8-inch to 12-inch mains and 110 to 120 for larger mains. The water mains constructed since the 2003 Water System Reliability Study (see Section V.C. above) were assumed to have a Hazen-Williams coefficient of 125-130.

2. Existing System

Using the calibrated model, simulations were performed for various demand conditions. Resulting pressures were reviewed to determine the adequacy of the system under high demand. Pressures during peak hour demands and without fires should not fall below 35 psi, nor should pressures in the system exceed approximately 100 psi.

The available fire flow is generally the standard by which a system is measured since that is typically the highest demand experienced. Typically, the available fire flow represents the flow available at a given location without creating a low pressure problem anywhere in the system. The minimum system pressure which should be maintained at all times is 20 psi. While recommended fire flows vary based on many factors, the generally suggested fire flows are 1,000 gpm for residential customers, 2,500 gpm for commercial customers and 3,500 gpm for industrial customers.

Table 11 provides results of simulations for existing conditions. Table 11 shows the results for average day, maximum day and peak hour demand pressures and the available fire flow. The locations shown represent a cross-section of areas across the City and noted areas of concern.

Results indicate that pressures appear to be adequate throughout the system. The model results bear out that the system transmission capacity is adequate throughout the city. In many areas, the available fire flows are less than suggested due to undersized distribution main. The older 2, 3, 4 and 6-inch mains restrict the available fire flows to some locations in the system.

Pressures are greater than the desired 35 psi for peak hour demands in all locations. As stated above, many areas served by old 6-inch diameter and smaller mains can not achieve fire flow of 1,000 gpm. Results shown in Table 11 also show that fire flows are less than suggested at several of the schools and residential customers in areas scattered throughout the low pressure district. Figure 5 identifies the areas of less than suggested fire flow capability.

Appendix C includes output of the model results.

3. Future Conditions

Using the model, simulations were performed for future demand conditions to determine where improvements to the existing infrastructure may be needed. All water main Hazen Williams coefficients were reduced by 5 to simulate aging. Resulting pressures and available fire flows were reviewed to determine the adequacy of the existing system under future demands.

Table 12 provides a summary of model results with Year 2021 demands and the existing infrastructure. Results indicate that pressures would be adequate and fire flows will be further reduced from existing fire flow capabilities. As a result, potential improvements were analyzed to improve the fire protection in the deficient locations. Figure 5 shows the areas with available fire flows less than suggested.

4. Distribution System Improvement Alternatives

Based on the results of the existing system analysis with future demand projections, improvement alternatives were considered. Many alternatives were considered and then selected and prioritized based on the most cost-effective alternatives to enhance fire protection, and overall service.

Each of the following projects provides improved available fire flow to the system.

a. Fire Protection on Monroe

The available fire flow in Monroe Street at Walnut Street is approximately 900 gpm. To increase available fire flows in the area and to improve transmission from the Water Treatment Plant to the western low pressure district, the City plans to replace approximately 1,700 feet of aging 4-inch main with 8-inch main.

The improvement will extend from Cedar Street on the west to Water Street on the east and is scheduled to be completed in Year 2012 (Project #1).

b. Fire Protection on Bond and Herkimer

The available fire flow on Bond and Herkimer Street near the South Ward Elementary School is approximately 590 gpm. This is below the suggested 1,000 to 1,500 gpm and should receive higher priority in the City's long-term planning as the City replaces the old, deteriorating 4-inch mains. To improve the fire protection to the customers on these streets and to the South Ward School building, it is recommended to replace about 1,700 feet of 4-inch main with 8-inch main on Herkimer & Bond Streets (Project #2).

c. Fire Protection in Academy Street and James Street Area

The available fire flow in the residential areas of Academy Street from Knapp to James and James Street from Academy to Thompson are less than 500 gpm. The available fire flows would be increased to over 2,000 gpm by replacing approximately 2,750 feet of 4-inch main with 8-inch main in Knapp, Academy, James, and Thompson Streets. This improvement (Project #3) is in a large residential area served by aging 4-inch water main. This project should receive higher priority in the City's long-term plan to replace old, deteriorating, small diameter mains.

d. Fire Protection in Wayne and Kalamazoo Area

The available fire flow at 5th and Wayne is currently less than 400 gpm. To increase the available fire flow in the area to more than 1,000 gpm, replace 580 feet of 4-inch main with 8-inch main along 4th Street, from Marshall to Wayne, and replace about 550 feet of 4-inch main with 8-inch main in Wayne from 4^{th} to 5^{th} (Project #4).

e. Fire Protection in Lincoln, Russell, and Robinson Area

The fire flow available to the residential area around Lincoln, Russell, Robinson, and Adams Street is approximately 700 gpm. To increase the fire protection in the area to more than 1,000 gpm, approximately 2,600 feet of 4-inch main should be replaced with 8-inch main in Lincoln Street, Russell Street, and Robinson Street (Project #5). Similar to previous projects, this project is in a residential area served by aging, small-diameter main.

f. Fire Protection in Grand and River Area

The fire flow available to the residences along Grand Street between South Main Street and the Kalamazoo River is about 570 gpm due to the dead end and the existing 4-inch main in Grand Street. To meet the suggested fire flow for residential areas, approximately 630 feet of 4-inch main should be replaced with 8-inch main in Grand Street between the river and S. Main Street (Project #6). This project would increase the available fire flows to about 2,000 gpm.

g. Fire Protection on Streeter

The fire flow available to the apartments on Streeter Street is about 650 gpm due to the dead end 6-inch main, which is less than the recommended 1,500 gpm fire flow for apartment buildings. Constructing an 8-inch loop to the north and east to Eastern Avenue (approximately 800 feet) would increase the available fire flow to about 2,200 gpm (Project #7).

h. Fire Protection on Cora Street

The available fire flow on Cora is currently restricted by the hydrants. If these are replaced, the available fire flow would be approximately 1,000 gpm.

To increase the available fire flow to more than 2,000 gpm, the City could consider replacing 350 feet of 4-inch main on Jenny Street, from Ida to Cora Street. At this time, however, this is not a high priority, and Project #8 only includes installing new hydrants on Cora. If the City plans to reconstruct the road on Jenny, however, the 4-inch main should be replaced concurrently.

i. Fire Protection in north Arnold Street and Lake Drive

The available fire flow in the residential area of Arnold Street and Lake Drive is less than 400 gpm. Replacement of approximately 1,600 feet of 4-inch water main with 8-inch main would increase available fire flows to approximately 1,600 gpm. The 4-inch main should be replaced in Arnold Street from Tamarack to Lake, and in Lake Drive from Arnold to Goodwin Street. This is a residential area with relatively low water demand; therefore, upsizing the water main would increase the susceptibility to water stagnation. This project should be considered in the City's long-term plan to replace aging, small-diameter mains (Project #9).

j. Fire Protection on Highland

The available fire flow in Highland Street is less than 300 gpm. Thus, to improve the fire protection to more than 1,000 gpm, replace 700 feet of 4-inch main on Wolcott to Highland & Riverside Drive with an 8-inch main to improve fire protection. Most of the residences in the Highland area can be served by fire hydrants with greater available flows. In addition, upsizing the water main would increase the potential for water stagnation and decreased water quality. Therefore, this should be considered a low priority project (Project #10).

k. Fire Protection on Brookside Drive and Knapp Street

The available fire flow at the Brookside Drive cul-de-sac is less than 300 gpm. Approximately 350 feet of 8-inch main should be constructed between the Brookside Drive cul-de-sac and the Knapp Street dead end to increase the available fire flow to approximately 1,100 gpm. This would meet the 1,000 gpm fire flow suggested for residential areas (Project #11).

l. Fire Protection for Pine Trails School

Pine Trails School is a relatively new building that is equipped with sprinklers. As a result, the suggested fire flow is less than at other schools. However, the closest fire hydrant is more than 300 feet from the school. Thus, a new hydrant is recommended near the school on the existing 6-inch main going south from Maple Street (Project #12). Approximately 700 gpm would be available just outside the school.

To further increase the available fire flow at the school, the 6-inch main from Maple Street to the school and the 6-inch main in Maple Street could be replaced with 8-inch main. This would increase the available fire flow to more than 2,000 gpm at the school. This is not a high priority at present since the school has sprinkler protection (it is not included in recommended projects), but could be re-evaluated in the future.

m. Fire Protection at Dawson School

The available fire flow at Dawson School is nearly 1,200 gpm. The City should consider providing additional fire protection in the future.

Several alternatives were considered for increasing the fire protection. Constructing a main from the County Fair Grounds to Lake Drive, then south to the school will increase the available fire flow to just over 2,000 gpm at the school (which would also improve the fire protection at the Fair Grounds). Replacing the 4-inch main in Lincoln and Elm to the school and a 6-inch section in Delano will increase the available fire flow to more than 2,000 gpm. Replacing just the 4-inch main in Lincoln will increase the available fire flow to approximately 1,500 gpm, and replacing just the 6-inch main in Elm and Tamarack will increase the available fire flow to 1,800 gpm.

Since 1,200 gpm is currently available at the school, a project has not been specified. However, the City should study this further if additional fire protection is desired.

Model simulations were performed including each of these potential improvements, as well as other alternatives. Simulation results with all the potential improvements and Year 2021 demands are summarized in Table 13.

Results show that the available fire flows throughout the system meet the general suggestions for fire protection.

VII. RELIABILITY ISSUES

A. Redundancy

The water treatment facility for the existing system is located toward the center of the City, in the low pressure district. As a result, transmission from the water treatment facility to the rest of the low pressure district and elevated storage tanks is important. Transmission from the water treatment plant to the high pressure district significantly was improved with construction of the new water treatment plant and the new transmission main in Grand Street.

1. River Crossings

Prior to October 2011, there were only two river crossings near the plant, one of which is 8-inches in diameter. In October 2011, the City completed construction of and placed into service a new 14-inch O.D. HDPE (equivalent to 12-inch DIP) river crossing southwest from the new plant. This new river crossing is critical for redundancy of the transmission system around the water treatment plant.

2. Water Transmission

Adequate transmission main exists between the water treatment plant and the Western Tank, and recent 12-inch main construction to the Hooker Road Tank has improved transmission to the southeastern portions of the City. In addition, significant improvements have been completed in the southwest area of the City since 2003.

To further improve overall system redundancy of transmission, the City could consider completing the transmission main on 2nd Street under the river and in the downtown area (replacing the old shallow mains) in the long term.

B. Backup Power

The new water treatment plant is equipped with a permanent standby generator for use during a power outage.

A portable emergency generator is available for the Hooker Road Booster Station in the event of a power outage. This generator is also used for emergency power to the sanitary sewer system.

Emergency operation of the inactive City Well, located on Walnut Street, between Hubbard and Marshall, is provided through a gas powered engine. This well can be used in case of a power failure.

The City also purchased a second portable generator in 2011 for use in the water and/or wastewater system during a power outage.

C. Interconnections between Low and High Pressure Districts

The City of Allegan has a low pressure district serving the majority of the City, and a high pressure district which primarily serves the industrial area in the eastern portion of the City. The water treatment plant pumps directly to the high pressure district, and a back-up booster pump station is located at Hooker Road with a bypass to the suction but no pressure regulating valve.

No pressure regulating valves exist between the pressure districts but they are separated by closed valves. In the event of a fire in the low pressure system, field technicians open the closed valves as necessary, allowing water from the high pressure district to flow to the low pressure district.

D. Service to High Pressure District

The City of Allegan has a low pressure district serving the majority of the City, and a high pressure district which primarily serves the industrial area in the eastern portion of the City. Water service directly to the high pressure district was completed with the construction of the new water treatment plant. New high service pumps in the water treatment plant enable the Hooker Road Booster Station to be used as a back-up for high pressure district supply.

1. Pressure Control Valves

The City may wish to consider providing pressure control valve(s) between the high and low pressure district. This would remove the need to open a valve in an emergency to feed the low pressure district. A pressure control valve would be set automatically to open if the pressure in the low pressure district drops below a set level, and would thereby provide short-term fire protection in the low pressure district.

In addition, the valves between the high and low pressure district are not exercised. As a result, they may not be operable when opening. The City should set up a valve exercising program to ensure the valves are operable when needed or replacing them with pressure control valves.

E. Deteriorating Mains

Much of the old, deteriorating water main in the City of Allegan water distribution system has been replaced in the last decade. However, there are still some areas with old, small-diameter main that should be included in the City's long-term plan to replace. The 4-inch and smaller mains restrict flow and many of the 6-inch mains are also deteriorating. These older mains should be replaced in conjunction with street work, whenever possible.

VIII. RECOMMENDATIONS FOR IMPROVEMENTS

The following categories of improvements to the City's water system were used to prioritize the recommended system improvements.

A. Improvements to Address Problems with Existing Infrastructure

- Comply with Federal and State Regulations
- Improve general level of service

- Improve redundancy of transmission

B. Improvements Required to Expand Service for Projected Growth

- Improvements to existing infrastructure to serve new areas
- Improvements which would enhance the level of service

Recommendations have been separated into projects and general improvements based on the above criteria and demand projections. The following are recommended for long-term capital improvement planning:

C. Recommended Projects

Project 1: Replace about 1,700 feet of 4-inch main from Monroe and Cedar to Monroe and Water with 8-inch main.

Project 2: Replace approximately 1,700 feet of 4-inch main with an 8-inch main on Bond Street from Marshall to Herkimer, and on Herkimer southeast to the existing 12-inch main in 6th Street.

Project 3: Replace approximately 2,750 feet of 4-inch main with 8-inch main in Knapp, Academy, James, and Thompson Streets.

Project 4: Replace about 600 feet of 4-inch main along 4th Street from Marshall Street to Wayne Street and approximately 450 feet of 4-inch main along Wayne from 4th to 5th with 8-inch main.

Project 5: Replace approximately 2,600 feet of 4-inch main with 8-inch main in Lincoln, Russell, and Robinson Streets.

Project 6: Replace approximately 630 feet of 4-inch main with 8-inch main in Grand Street from South Main Street to the Kalamazoo River.

Project 7: Construct approximately 800 feet of 8-inch main to loop the Streeter Street water main back to Eastern Avenue.

Project 8: Replace the existing hydrants on Cora Street with new hydrants.

Project 9: Replace approximately 1,600 feet of 4-inch main with 8-inch main from Arnold and Tamarack to Lake and Goodwin.

Project 10: Replace about 700 feet of 4-inch main from Wolcott and River Street to Riverside and Highland with 8-inch main.

Project 11: Construct approximately 350 feet of 8-inch water main between the dead ends in the Brookside Drive and Knapp Street cul-de-sacs.

Project 12: Provide a hydrant near the end of the 6-inch main serving the Pine Trails School.

D. General Recommendations

1. Replace Older, Deteriorating Mains

At present, the hydraulic restriction of older 2, 3, 4 and 6-inch mains is the primary deficiency associated with the water system. The City should continue in their effort to replace all old distribution mains, as well as any other deteriorating mains. In the downtown area, there are still areas with shallow, lead-joint mains that also should be replaced.

This can be done in conjunction with other street and utility projects. Significant tuberculation may have occurred in some of these distribution mains; therefore, these should be replaced when other construction is completed in these areas.

2. Dead End Mains

Whenever possible, dead end mains should be looped. Water tends to become stagnant in dead end mains, often affecting the quality of water provided to nearby customers. Thus, whenever feasible, dead end mains should be removed by closing loops, thereby improving the circulation of water and fire protection.

While looping the dead end mains in certain areas is preferred, it is not always feasible and, while the available fire flow is nearly 1,000 gpm, the fire department can supplement fire fighting capability with flow from nearby hydrants. In addition, upsizing the existing small diameter main to 8-inch main is not necessarily recommended due to the resulting degradation of water quality. These areas are described as follows:

- Marshall St at southeast City limit (WaterCAD Junctions J-9, J-10, J-11)
- Marshall St at Bridge Rd. (J-18)
- Kalamazoo at Division (J-30, J-31)
- Oak Ct. northeast of Marshall (J-36)
- Hooker Rd from Bond to 6th (J-40, J-516)
- Crescent at Academy St (J-100)
- Arbor southeast of Academy St (J-120)
- Circle Drive east of Knapp St (J-135)
- 6" service line off Ely at SW city limit (J-141)
- Service line off Jenner north of Thomas (J-148)
- Allegan Co. Fair Dr. west of Davis (J-201)
- Lake Dr. northeast of Arnold (J-221)
- Allett St. south of North St. (J-225)
- Catherine south of Grand St. (J-247)
- Green St. east of Main St. (J-259)
- Hickory west of River St. (J-270)
- Pleasant south of Briggs St. (J-285)
- Service line off Lowe St. west of Airway (J-291)
- Airport south of Grand (J-304)
- Padgham east of Eastern Ave. (J-307)
- Service line off Eastern south of Padgham (J-309)
- Service line off Eastern north of Streeter (J-311)
- Grant south of Western (J-318)
- Elm north of Delano (J-517)
- Della east of River (J-612)
- Service line off Hooker Rd east of Eastern (J-627)
- Thompson west of Julia (J-639)

3. Reliability Study

Update the Water System Reliability Study within 5 years. Given the uncertainty of growth, demand projections should be reviewed periodically. Based on current demand projections through Year 2021, the City's maximum day demands will not reach 80 percent of the well capacity, and the well supply will be adequate for the longer term. However, adjustments to the projections may dictate the need and priority of future improvements.

4. Valve Exercising Program

The City is in the process of mapping a valve exercising program in zones throughout the city. The City should continue to develop a routine valve exercising program. This will enhance the reliability of the system and improve public protection. A schedule/checklist should be maintained to track the progress of this maintenance work.

4. Water Storage Tank Maintenance

The City should develop a maintenance schedule for all water storage tanks. The elevated tanks were last inspected as detailed in Table 6. The City should plan for tank inspections in the near future and subsequent maintenance as a result of the inspections.

5. Water Accountability Plan

The City has tracked water accountability for the past decade and the data is provided graphically in Figure 6. Historical data indicates an average water loss exceeding 14-percent since Year 2000. However, the water loss has averaged only about 6-percent since 2008. This reflects the significant improvements made to the system in recent years. The City should further develop the water accountability program. This will enable the City to continue to monitor whether a source of lost revenue exists and ultimately to identify the source, if necessary. This includes estimating all water system usage including water used during emergencies, system flushing and for street sweeping, among others.

6. Meter Testing Program

The City is in the process of changing all water meters to a radio read system and is in the third year of a five-year program. Over $50,000 has been budgeted for meter replacement in the following year. The City should continue with the existing meter change-out program. This will help maintain accurate customer billing and could provide a significant increase in system revenue. The recommended change-out period for commercial meters is every 3 years, and for residential meters is every 10 years. We understand that the City monitors the accuracy of the larger, commercial meters. Therefore, the current program is considered adequate.

7. Flushing Program

The City currently flushes the entire system and inspects the hydrants in April and October. The City should continue the bi-annual flushing program and make modifications based on the effectiveness. The City may also wish to consider preparing a plan for flushing, chlorination and de-chlorination of the entire system in the event of an emergency.

8. Fire Protection at Schools

The recommendations in this report for improved fire protection at schools were prepared with the intent of providing at least 1,200 gpm of available fire flow. However, because each school differs, including the school's construction, number of classrooms, and generally policy of the City, we would suggest each school be evaluated to determine whether additional improvements are warranted to further improve the fire protection.

IX. COST ESTIMATES

An Opinion of Project Costs has been prepared for each element of the project. Costs for projects of similar size and scope that have been constructed in southwest Michigan were reviewed for relevant information.

The cost estimates have been prepared including an allowance of approximately 25% above the estimated construction cost. This allowance is intended to include the cost of construction contingencies (issues which are presently unknown), legal fees, engineering design and construction services (including preliminary and final design, soil borings, topographic survey, bidding assistance, construction staking, compaction testing, construction inspection and project administration during the entire project) and administrative expenses related to the project.

It has been assumed that land is available for construction of the described improvements. No provision has been made in the cost estimate for extraordinary cost of land or right-of-way purchase or easements.

Cost estimates are included in Table 14.