

**CITY OF ST. JOSEPH WATER FILTRATION PLANT**  
**OPERATIONAL REPORT**  
**JUNE 2016**



**Mission Statement**

WSJOB- The City and Authority working together to provide safe drinking water of the highest quality to all of our customers at the lowest possible price.

## WATER PLANT REPORT-JUNE 2016

Water demand in June was up by 61,538,106 gallons or 43.8% from last year. This year 202,035,888 gallons were delivered which compares to 140,497,782 gallons delivered June of 2015. The June 2016 pumpage ranked 15<sup>th</sup> in the thirty year tabulation dating back to 1987.

### **GENERAL ACTIVITIES**

#### *Spring Intake Inspections/Repair*

In June and early July several blockages of the south intake were experienced. These were probably residual effects of the emergency riser separation from the intake pipe in 2014 and 2015. Divers from Underwater Construction inspected the repair plate on the riser joint and found it to be fully intact. In addition, they made visual inspections of the lake bottom from shore to the intake cribs and found no irregularities that would be indicative of a break in the intake pipe itself. After more than forty full wheelbarrels of material consisting of sand, zebra mussels, rocks and gravel at least partial hydraulic capacity was restored to the south intake. Thus far plant demands have limited testing to 9.0 MGD. The south intake which was built in 1955 now serves as an emergency and maintenance back up to the north intake built in 2011.

The inspections of the North Intake proceeded upon restoration of operation on the South Intake. Underwater Construction found 100% zebra mussel growth on the cribs at varying thicknesses of from two to five inches. Sand was found in the bottom of the cribs and in the inlet pipes. The sand inside the inlets was 30" and level. There was some tapering of the sand which rose to three feet in the structures. The emergency intake located 1,500' from the cribs and 3000' from shore was opened and a penetration dive was made to approximately 820' toward the cribs wherein the sand level reached two feet. The intake pipe is 48" in diameter. Staff is awaiting a full report and video from Underwater Construction.

#### *Filtration Capacity Study/Phase 1 SCIP*

MDEQ approval of the Filtration Capacity Study was received July 7<sup>th</sup> begin in July and be complete by December 5, 2016. CH2M Hill will conduct the hydraulic capacity assessment of the filter piping on July 20<sup>th</sup> and review the filter test plan. Dr. Alex Yavitch of Optimization Solutions will model high turbidity applied water based on filter performance data obtained by plant staff and CH2M Hill. This will enable the capacity assessment to be done without adversely affecting finished water quality. In addition, we have learned from Dr. Yavitch that high turbidity water produced under natural operating conditions cannot be artificially induced in the clarifiers

The filtration rate capacity study was identified in the Strategic Capital Improvement Plan (SCIP). This study will address hydraulic limitations in the filter piping and assess the feasibility of rerating filters 5-12 to handle the increased flow upon retirement of filters 1-4. A hydraulic study will also be done on the filter piping to determine whether it can handle the flow. A new DWRP project plan will have to be done for the SCIP. The last project plan was completed in 2007 and included the intake, E&P improvements and clarifier upgrades.

The DWRP project plan will include the City of St. Joseph distribution system and be submitted in late 2016 upon completion of the filter study. The bid review committee recommended CH2M Hill. The WSJOB and St. Joseph City Commission approved the recommendation. Filter trial runs will begin in June. The study will be complete by December 2016.

#### Fluoride Overfeed Protection

Fluoride is added in the treatment process at the water plant for dental health. The MDEQ does not require the addition of fluoride but does regulate treatment due to the fact that fluoride is regulated under the Safe Drinking Water Act. MDEQ has published guidance for community water supplies to assure that fluoride is not overfed. In May, an additional safeguard was installed at the St. Joseph Water Plant. An interlock was added that functions to prevent fluoride feed in the event of a low service pump failure. The plant has been equipped since 1998 with anti-siphon valves, limited size day tank and a low service pump de-energize interlock. An online fluoride analyzer is on order which will provide real time finished water fluoride data as well. This instrument will also enable plant staff to conduct tracer studies on plant process flows. Staff did reassess the day tank capacity in June and determined the tank to be too large to assure that the MCL for fluoride would not be exceeded in the event of an overfeed. A new smaller tank was ordered and will be installed in July. The current tank capacity of eighty gallons will be replaced by a smaller forty gallon tank.

#### Raw Water Monitoring: Cryptosporidium and Giardia

Plant staff completed a monitoring plan for LT2 collection and analysis of Cryptosporidium and Giardia. The Long Term 2 Enhanced Surface Water Treatment Rule addresses the health effects associated with Cryptosporidium in surface water such as Lake Michigan as a drinking water supply. Over the course of the next two years beginning this October we will be sampling raw lake water prior to treatment and sending the samples to a qualified laboratory to analyze for the presence of Cryptosporidium, Giardia and E. coli. The results of this testing will determine whether further improvements are needed at the SJWTP to effectively remove these pathogens. Testing was last done in 2009-2010. The results of the testing at that time indicated that no changes were needed. However, the recently completed SCIP did factor in treatment upgrades in the event that LT2 testing indicated the need.

#### Consumer Confidence Report

The 2015 Water Quality Report was completed in June and mailed to our customers. A new article was included on the subject of Lead in Drinking Water. Water quality in 2015 continued to be outstanding. There were no violations. Some thought was put into changing the graphics this year.

#### Emergency Response Plan

The ERP was updated and submitted to MDEQ.

### OSHA PSM Inspection

Michigan OSHA conducted the first of two programmed inspections of the Water Plant's Process Safety Management Program. USEPA audited the plant's Risk Management Program in 2012. Both programs pertain to on site chlorine storage and management.

### AWWA ACE 2016

Staff attended the American Water Works Association Conference and Exposition at McCormick Place in Chicago during the week of June 20<sup>th</sup>. This event is the annual national meeting of the AWWA. The exposition is a trade show wherein vendors display new products and technology. The conference included several break-out sessions which were attended by staff. Much was learned from the following sessions over the course of three days:

*Innovative Solution Stops Intake Anchor Ice Formation in Winter*, Laura Biggs, City of Evanston

*Solutions to Severe Winter Weather Impacts on Chicago's Water Distribution System*, Barrett Murphy, City of Chicago.

*Utility Collaboration Promotes Resiliency: Haz-Mat Spill Concerns Unite Mississippi River Water Suppliers*, Gregory Swanson, Davenport, IA.

*Great Lakes-St. Lawrence Basin Compact: Successes and Impacts on Public Water Supplies*, David Naftzger, Council of Great Lakes Governors

*Understanding Drivers of Rapid Water Level Changes on the Great Lakes*, Drew Gronewold, NOAA Great Lakes Research Laboratory.

*Mission Impossible: Performing \$10M of Construction in 16 Weeks at the Orinda WTP*, Casey Leblanc, East Bay Municipal Utility District

*Key Factors in Maintaining Water Quality and Quantity During a \$200M Plant Rehabilitation*, S. Ramsey, CH2M Hill

*Rehabilitation of Existing Clarifiers While Maintaining Plant Operations: Lessons Learned*, Peter Buss, Gibson-Thomas Engineering Co., Inc.

*Flint, Michigan, Water Quality Challenges: A Chronology and Contributing Factors*, Darren Lytle, USEPA Office of Research and Development.

*Flint, Michigan, Moving Forward: Data Collection Strategy*, Michael Schock, USEPA Office Research and Development

*High-Velocity Home Flushing to Reduce Lead Levels*, Richard Brown, Environmental Engineering and Technology, Inc., David Cornwell.

*Lead Service Line Replacement-Construction and Replacement*, Maureen Schmelling, DC Water

*Corrosion Control Treatment Techniques and Unintended Consequences*, Rebecca Slabaugh, Arcadis

*Tools to Monitor Effectiveness of Corrosion Control and Metals Release*, Abigail Cantor, Process Research Solutions.

Alex Yavich of Optimization Solutions who developed St. Joseph WTP's Alum Model presented, *Adapting Conventional Water Treatment For Increasing Concentrations of NOM in Surface Water Supplies*. 'NOM' stands for 'Natural Organic Matter'.

#### Lead & Copper Rule

Water Plant staff conducted a pipe material survey of the homes in our sample pool to verify that the plumbing in the homes is in compliance with the Lead & Copper Rule. Site visits were conducted and information was gathered regarding pipe material, water filters and softeners. (Samples taken downstream of filters and softeners are not permitted). Compliance sampling is done every three years and is due again in 2017.

The City of St. Joseph last sampled for Lead and Copper during the summer of 2014. We were notified by the MDEQ of our compliance with the Safe Drinking Water Act. Our results of 2.0 parts per billion (ppb) for Lead is considerably lower than the action level of 15 ppb for compliance with the SDWA.

In May, a materials evaluation of the remaining 159 meter pits in the system was done. Thirty four lead goosenecks were found. During the course of the summer these customers will be notified and asked to collect samples which will be sent to a certified laboratory to determine lead and copper concentrations. Customers will be notified of the results. In addition, MDEQ has requested that even non-compliance test results be sent to their Lansing office.

#### Travel & Training

Greg and Mark attended ACE in Chicago. See above.

#### Fairplain Interconnect Project

The Fairplain interconnect project will begin during the week of July 12<sup>th</sup>. The contractor has one month to complete construction. The contractor is Jon Boettcher Sewer & Excavating of Mishawaka, IN.

# Monthly Maintenance Notes

JUNE 2016

Normal PM Maint. done Monthly	Check all High Service and Low Service Pumps, BPS pumps, Service BPS Chlorinators, Change out air filters on VFD Drives and Air Handlers. Mow and grounds work at Plant, Booster Stations and Water Towers
06/01/16	Installed new GFI outlet for refrigerator in chlorine feed room
06/03/16	Pulled signal cable for New CL17 Chlorine Analyzer for clarifier # 1
06/06/16	Hach - Service call for Filter # 10 Turbidimeter, burned wire and light bulb harness
06/07/16	Repaired Check Valve for Reclaim Pump # 2
6/7 to 6/8/16	Northern A-1 - Cleaned out reservoir overflow pit and lower 16" pipe outfall to the lake.
06/09/16	Installed New Guard on Lower Reservoir Overflow Pipe to the lake
06/10/16	Repaired center blow off valve for Clarifier # 2
06/15/16	Power washed front steps and building of 1931 section of plant
06/23/16	Switched plant over to South Lower Service @ 12:00 pm to prep for underwater inspection of North Intake on Friday.
06/24/16	Had to switch plant back over to North Low Service @ 1:00 am due to South Low Service wet well level dropping due to heavy sand and debris build up.
06/23/16	Plumbed water line and installed New CL17 chlorine analyzer for Clarifier #1
06/27/16	Cleaned South Low Service wet well and screen of sand and debris from short run on 6/23/16
06/28/16	Back flushed South Intake using North Low Service for 1 hour @ 8.5 to 9 mgd to clear pipe and intake structure of debris.
06/28/16	MI OSHA Inspection / Audit of PSM plan, met with Mark Scott (Inspector) for Opening meeting and tour of Chlorine Feed and Storage rooms, Reviewed the first 5 questions of the 15 total questions for the Audit. Greg has scheduled the follow up visit for July 19th. to complete Audit.
6/28 to 6/29/16	Drained Clarifier # 3 and replaced broken cable for moveable wing with Chain. Clarifier back in service 6/29/16
06/29/16	Boelcke Heating - Annual service and inspection of roof top heating and A/C units

**ST. JOSEPH WATER FILTRATION PLANT**  
**1701 LIONS PARK DRIVE**  
**SAINT JOSEPH, MI. 49085**

By: Greg Alimenti  
 St. Joseph Water Plant  
 700 Broad St.  
 Saint Joseph, MI. 49085-1276  
 (269) 983-1240

**JUNE 2016**

DISTRIBUTION:	
Total Gallons	202,035,888
Average Day	6,734,530
Maximum Day	8,276,178
Minimum Day	4,995,643

TREATMENT:	
Total Low Service	206,350,610
Wash Water Gals.	2,359,802
Wash Water %	1.12%
Plant Use Gals.	1,692,043
Plant Use %	0.84%

FILTRATION:		
Ave. Filter Run	121.5	hours
Ave. Filter Rate	2.34	g/sqft/min
Filter Eff. Index	233.6	
Ave. Loss of Head	4.5	feet
Plant Sewer Usage		

LABORATORY REPORT		
Average of	Raw	Tap
Chlorides mg/L	15.9	17.4
Fluoride mg/L	0.11	0.75
Alkalinity mg/L	112	99
Hardness mg/L	138	138
pH	8.1	7.3
Calcium mg/L	39	39
Magnesium mg/L	10	10
Turbidity NTU	7.04	0.03
Temperature °F	57	
Total Coliform		0.0
Chlorine Residual		
		mg/L Free
Mixing Basin		0.84
Applied		1.64
Tap		1.49
Distribution		1.08

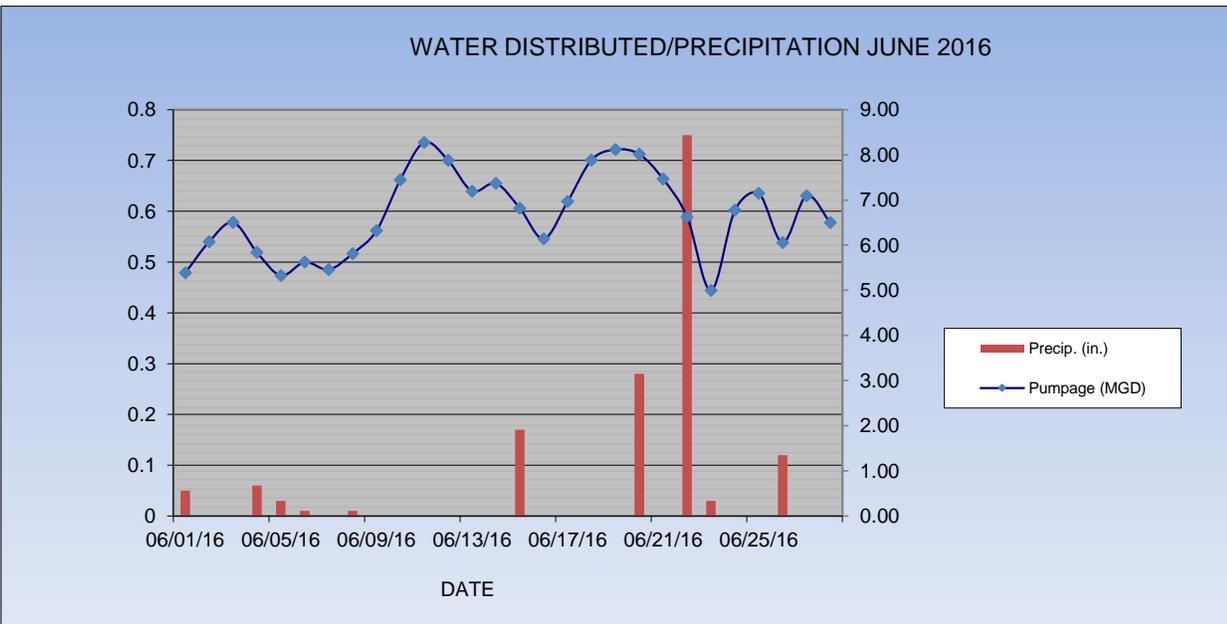
TREATMENT CHEMICAL SUMMARY:					
	Applied mg/L	Total Lbs.	Cost	Inventory lbs.	Days Supply
		CHEMICAL			
Alum (Al <sup>+3</sup> )	1.85	3,159	\$10,403.03	97,680	928
Chlorine (Cl <sub>2</sub> )	3.17	5,420	\$1,456.35	10,216	57
Fluoride (F <sub>2</sub> )	0.76	1,301	\$2,280.03	14,137	326

			REMARKS:			
Total Cost all Chemicals		\$14,139.42				
Chemical Cost per Mil. Gallon Treated		\$68.52				
Chemical Cost per Mil. Gallon Delivered		\$69.98				
PLANT UTILITIES SUMMARY						
Electric:						
Total KWH		325,800	***includes measure of melted snow			
Total Power Cost		\$ 22,806.00	visit the City of Saint Joseph's Home page at <a href="http://www.sjcity.com">www.sjcity.com</a>			
Power Cost per Million Gallon Treated		\$ 110.52	e-mail comments to either: <a href="mailto:operator@sjcity.com">operator@sjcity.com</a> or <a href="mailto:galiment@sjcity.com">galiment@sjcity.com</a>			
Power Cost per Million Gallon Delivered		\$ 3,747.11	WEATHER CONDITIONS AT THE PLANT		Air Temp. °F	
Gallons Pumped per KWH			SJWW Weather Computer		Avg.	69.6
			Rain Guage, Inches	1.51	Max.	92.4
			days it rained***	10	Min.	50.3
Natural Gas:			Wind Speed, Avg	6.1	Lake Temp. °F	
Metered Cubic Feet		56	Wind Speed, Max	51	Avg.	57.2
Natural Gas Cost		\$72.43	Prevailing Wind Dir.	North	Max	71.4
Emergency Power Diesel Fuel Inv., Gals.	North	600	Lake Level (USACE)	580.15	Min	48.6
	South	2400				

**ST JOSEPH WATER PLANT PUMPAGE-WATER DELIVERED/RAINFALL  
JUNE 2016**

DATE	PUMPAGE (gallons)	PUMPAGE (MGD)	RAINFALL (in)	Day to Day Comparison 2016/2015	
				2016	2015
06/01/16	5,385,530	5.39	0.05	5,385,530	4,166,272
06/02/16	6,074,794	6.07	0	6,074,794	4,381,964
06/03/16	6,503,964	6.50	0	6,503,964	4,421,510
06/04/16	5,840,144	5.84	0.06	5,840,144	5,577,110
06/05/16	5,325,601	5.33	0.03	5,325,601	5,172,208
06/06/16	5,625,402	5.63	0.01	5,625,402	5,451,028
06/07/16	5,457,522	5.46	0	5,457,522	4,546,442
06/08/16	5,812,558	5.81	0.01	5,812,558	4,440,073
06/09/16	6,318,961	6.32	0	6,318,961	4,410,329
06/10/16	7,448,989	7.45	0	7,448,989	5,343,974
06/11/16	8,276,178	8.28	0	8,276,178	5,101,471
06/12/16	7,878,264	7.88	0	7,878,264	4,129,597
06/13/16	7,196,950	7.20	0	7,196,950	4,396,243
06/14/16	7,370,629	7.37	0	7,370,629	4,323,388
06/15/16	6,818,571	6.82	0.17	6,818,571	4,521,326
06/16/16	6,141,708	6.14	0	6,141,708	3,772,989
06/17/16	6,965,139	6.97	0	6,965,139	4,571,612
06/18/16	7,885,631	7.89	0	7,885,631	4,137,533
06/19/16	8,117,380	8.12	0	8,117,380	4,138,551
06/20/16	8,014,354	8.01	0.28	8,014,354	4,453,579
06/21/16	7,462,533	7.46	0	7,462,533	5,081,709
06/22/16	6,624,414	6.62	0.75	6,624,414	4,223,147
06/23/16	4,995,643	5.00	0.03	4,995,643	4,997,065
06/24/16	6,773,504	6.77	0	6,773,504	5,327,053
06/25/16	7,148,184	7.15	0	7,148,184	4,538,043
06/26/16	6,057,941	6.06	0.12	6,057,941	5,001,718
06/27/16	7,092,052	7.09	0	7,092,052	4,445,415
06/28/16	6,497,577	6.50	0	6,497,577	5,209,932
06/29/16	7,606,378	7.61	0	7,606,378	4,704,472
06/30/16	7,319,395	7.32	0	7,319,395	5,462,027
<b>TOTAL</b>	<b>202,035,888</b>	<b>202.04</b>	<b>1.51</b>	<b>202,035,888</b>	<b>140,497,782</b>

<b>Average Day</b>	<b>6,734,530</b>
<b>Maximum Day</b>	<b>8,276,178</b>
<b>Minimum Day</b>	<b>4,995,643</b>

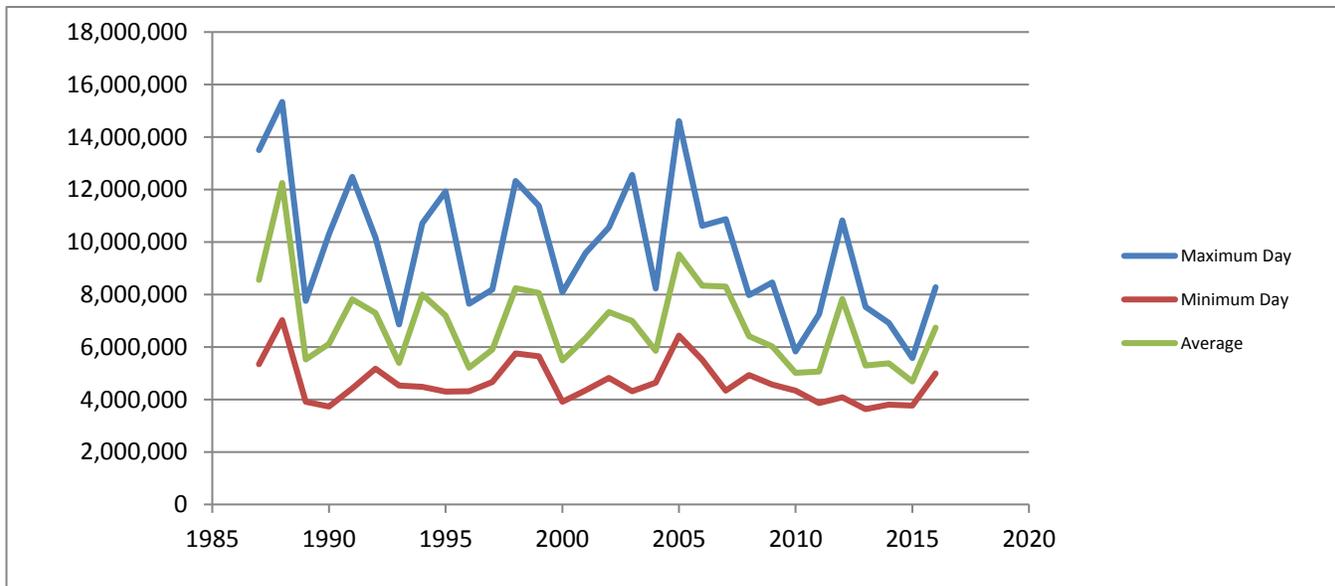


# ST JOSEPH WATER PLANT PUMPAGE-WATER DELIVERED

JUNE 2016

Year	Average	Maximum Day	Minimum Day	Monthly Total
1987	8,558,823	13,500,700	5,341,700	256,765,700
1988	12,250,440	15,336,400	7,024,700	367,513,200
1989	5,518,973	7,756,300	3,907,000	165,569,200
1990	6,114,560	10,296,200	3,732,200	183,436,800
1991	7,822,020	12,489,000	4,416,100	234,660,600
1992	7,294,707	10,167,700	5,176,200	218,841,200
1993	5,393,460	6,855,200	4,530,100	161,803,800
1994	7,998,343	10,718,900	4,478,600	239,950,300
1995	7,198,127	11,928,500	4,300,200	215,943,800
1996	5,213,475	7,647,600	4,314,450	156,404,250
1997	5,904,247	8,197,900	4,666,500	177,127,400
1998	8,245,142	12,326,050	5,760,800	247,354,250
1999	8,054,910	11,383,350	5,645,950	241,647,300
2000	5,492,322	8,084,500	3,917,500	164,769,650
2001	6,333,114	9,586,150	4,343,000	189,993,420
2002	7,326,472	10,561,700	4,826,500	219,794,150
2003	6,994,901	12,554,770	4,311,750	209,847,020
2004	5,847,159	8,226,140	4,644,750	175,141,780
2005	9,527,567	14,599,440	6,436,750	285,827,000
2006	8,336,510	10,615,250	5,508,500	250,095,310
2007	8,299,610	10,869,000	4,339,000	248,988,310
2008	6,408,335	7,971,500	4,935,500	192,250,040
2009	6,022,007	8,461,750	4,564,750	180,660,240
2010	5,013,884	5,824,610	4,342,220	150,416,523
2011	5,064,754	7,249,460	3,858,296	151,942,626
2012	7,827,161	10,828,342	4,079,686	234,814,831
2013	5,291,064	7,524,443	3,631,587	158,731,916
2014	5,384,486	6,917,391	3,804,617	161,534,590
2015	4,683,259	5,577,110	3,772,989	140,497,782
2016	6,734,530	8,276,178	4,995,643	202,035,888

Rank	Year	Monthly Total
1	1988	367,513,200
2	2005	285,827,000
3	1987	256,765,700
4	2006	250,095,310
5	2007	248,988,310
6	1998	247,354,250
7	1999	241,647,300
8	1994	239,950,300
9	2012	234,814,831
10	1991	234,660,600
11	2002	219,794,150
12	1992	218,841,200
13	1995	215,943,800
14	2003	209,847,020
<b>15</b>	<b>2016</b>	<b>202,035,888</b>
16	2008	192,250,040
17	2001	189,993,420
18	1990	183,436,800
19	2009	180,660,240
20	1997	177,127,400
21	2004	175,141,780
22	1989	165,569,200
23	2000	164,769,650
24	1993	161,803,800
25	2014	161,534,590
26	2013	158,731,916
27	1996	156,404,250
28	2011	151,942,626
29	2010	150,416,523
30	2015	140,497,782



**DISTRIBUTION REPORT**

*For the Month of June 2016*

Activity		Number/Description	
Water Main Breaks		0	
MISS DIGS		398	
Delinquent Shut Off		23	SJCT (East and West)
Delinquent Shut Off (Broken Payment Plans)			
Hydrants (Repaired/Replaced)		1	1236 West John Beers Rd. (hit by vehicle)
Valve Turning		437	LCT (Stevensville), Royalton (part of). Wachs Water by contract
Valves		0	
Taps (1")		6	5772 Dunham Path (LCT) New construction
			4513 Trails End Path (RCT) New construction (2")
			5009 Pheasant Way (LCT) New construction
			2516 Locust (LCT) Bad well
			5791 Hayden Court (LCT) New construction
			787 Miners Road (RCT) Bad well
			1020 State St. (SJ) Inc of tap size 3/4" to 1" (see below)
Cross Connection Control (Hydro Designs)			
Repair of Curb box/Shut-Off Valves		4	
Service Repair		1	
Service Replacements		3	1020 State St. (SJ) Lead Service Repl. Util side
			Lead on homeowner side replaced by plumber.
Water Quality Complaint(s)		0	
Hydrant Flushing to maintain water quality		0	
Hydrant Flushing (Stage 2 Rule)		0	
Service line complaints (customer side)		2	Low pressure (domestic side due to plugged aerators, part closed valve)
Staff Education/Training		2	Posture of Positivity Training, Municipal Safety Days
Overtime-Total		87	(Including Sanitary and Storm)
Turn Off		6	(Note: For delinquent Shut off see above)
Turn On		9	
Finals		185	
<b>Meter Repair/Replacement</b>			
		Audit Meter	
		Verify Read	1
	Meter Repair	Move Mxu Box	
	Per detail	New Installation	21
	Meter leaking	9 New Installation-Benton Harbor	
	Stopped Meter	15 Replaced/various reasons (e.g.downsize, defective)	5
	Faulty Register	1 Rockwell Replacement	
	Frozen Meter	1 Mxu Replaced	3
	Move Meter Inside	Sprinkler meter removed/line capped	1
	Hard to read	6 Removals/demo	1
	Replace/Adding Sprinkler Meter	Curb box location	1
	Damage to Meter	1 Broken Remote	
	New Plumbing	3 Noisy Meter	2
	New siding	1 Upgrade 5/8" to 3/4" (upgrade to 1")	2
	Meter sent out for testing	Meter Change/Benton Harbor	

CLEVELAND BOOSTER STATION

HILLTOP BOOSTER STATION

DATE	FLOW MGD	FEED GAL	CHL LBS/DAY	CHLORINE APPLIED mg/l	Cl <sub>2</sub> PRE mg/l	Cl <sub>2</sub> POST mg/l	Cl <sub>2</sub> MON mg/l	FLOW MGD	FEED GAL	CHL LBS/DAY	CHLORINE APPLIED mg/l	Cl <sub>2</sub> PRE mg/l	Cl <sub>2</sub> POST mg/l	Cl <sub>2</sub> MON mg/l	BOOSTER MGD
1-Jun	2.533	116	16.45	0.78	2.20	2.13	2.27	1.905	76	10.78	0.68	2.20	1.97	2.06	4.438
2-Jun	2.421	66	9.36	0.46	2.17	1.69	1.93	1.464	39	5.53	0.45	1.45	1.87	2.01	3.885
3-Jun	3.342	83	11.77	0.42	1.44	1.67	1.87	1.705	40	5.67	0.40	1.41	1.83	1.97	5.047
4-Jun	2.612	84	11.91	0.55				1.169	19	2.69	0.28				3.781
5-Jun	2.612	84	11.91	0.55				1.169	19	2.69	0.28				3.781
6-Jun	2.612	84	11.91	0.55	2.05	1.60	1.69	1.169	19	2.69	0.28	1.38	1.54	1.59	3.781
7-Jun	2.400	85	12.05	0.60	2.17	1.72	1.88	1.222	52	7.37	0.72	2.20	2.16	2.28	3.622
8-Jun	2.969	95	13.47	0.54	1.77	1.85	1.98	0.932	43	6.10	0.78	2.20	2.14	2.35	3.901
9-Jun	2.711	90	12.76	0.56	1.85	1.59	1.83	1.869	51	7.23	0.46	1.41	1.88	1.93	4.580
10-Jun	1.828	66	9.36	0.61	1.58	1.76	1.86	2.222	92	13.04	0.70	1.48	1.84	1.89	4.050
11-Jun	3.344	109	15.45	0.55				2.799	89	12.62	0.54				6.142
12-Jun	3.344	109	15.45	0.55				2.799	89	12.62	0.54				6.142
13-Jun	3.344	109	15.45	0.55	1.52	1.52	1.59	2.799	89	12.62	0.54	1.51	1.66	1.72	6.142
14-Jun	2.975	111	15.74	0.63	1.50	1.79	1.93	2.399	66	9.36	0.47	1.50	1.78	1.86	5.375
15-Jun	2.482	97	13.75	0.66	1.95	1.81	1.95	2.081	53	7.51	0.43	1.73	1.87	1.97	4.564
16-Jun	2.546	96	13.61	0.64	2.18	1.88	2.01	1.712	36	5.10	0.36	1.48	1.69	1.75	4.258
17-Jun	3.709	132	18.71	0.60	2.19	2.00	2.15	2.153	36	5.10	0.28	1.51	1.73	1.78	5.862
18-Jun	2.662	90	12.76	0.57				2.414	41	5.81	0.29				5.076
19-Jun	2.662	90	12.76	0.57				2.414	41	5.81	0.29				5.076
20-Jun	2.662	90	12.76	0.57	1.50	1.72	1.77	2.414	41	5.81	0.29	1.54	1.70	1.74	5.076
21-Jun	3.930	164	23.25	0.71	1.53	1.99	2.07	1.740	95	13.47	0.93	2.19	1.81	1.95	5.670
22-Jun	3.491	141	19.99	0.69	2.18	1.68	1.87	1.744	94	13.33	0.92	2.20	2.10	2.32	5.235
23-Jun	2.198	103	14.60	0.80	1.96	1.60	1.73	1.896	84	11.91	0.75	2.20	1.92	2.07	4.094
24-Jun	2.863	124	17.58	0.74	2.20	1.89	2.05	0.559	25	3.54	0.76	1.17	1.67	1.71	3.423
25-Jun	2.908	144	20.42	0.84				1.723	86	12.19	0.85				4.631
26-Jun	2.908	144	20.42	0.84				1.723	86	12.19	0.85				4.631
27-Jun	2.908	144	20.42	0.84	2.20	1.74	1.88	1.723	86	12.19	0.85	1.33	1.75	1.79	4.631
28-Jun	2.929	128	18.15	0.74	2.20	1.71	1.85	1.963	56	7.94	0.49	1.46	1.64	1.71	4.891
29-Jun	3.339	152	21.55	0.77	1.41	1.84	1.98	1.109	41	5.81	0.63	1.41	1.95	2.05	4.448
30-Jun	4.064	180	25.52	0.75	1.67	2.07	2.25	1.104	42	5.95	0.65	2.03	1.98	2.17	5.168
TOTAL	87.308	3,310	469.3					54.094	1,726	244.71					141.402
AVE DAY	2.910		15.6	0.64	1.9	1.8	1.9	1.8031		8.2	0.56	1.68	1.84	1.94	4.713
MAX	4.064		25.5	0.84	2.2	2.1	2.3	2.7985		13.5	0.93	2.2	2.16	2.35	6.142
MIN	1.828		9.4	0.42	1.4	1.5	1.6	0.5595		2.7	0.28	1.17	1.54	1.59	3.423
MONTHLY TOTALS:	Cleveland	Total MG Treated	87.308		SJCT EAST				Hilltop	Total MG Treated	54.094	Cleveland Pump Station:			87.308
		Untreated	0.000		Average Day			0.284		Untreated	0.000	Hilltop Pump Station:			54.094
Total Authority Flow:	146.351				Month Total			8.508				TOTAL AUTHORITY (Trted.)			141.402

**MONTHLY CLIMATOLOGICAL SUMMARY**

**June**

**2016**

**NAME: sjwwweather**

**St. Joseph Water Plant - 1701 Lions Park Drive - St. Joseph, MI**

DAY	MEAN TEMP	NORM MEAN TEMP	HIGH TEMP	TIME	NORM HIGH TEMP	REC HIGH TEMP	YEAR	LOW TEMP	TIME	NORM LOW TEMP	REC LOW TEMP	YEAR	HEAT DEG DAYS	COOL DEG DAYS	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
1	70.4	71	77.1	7:00p	82	95	1963	64.7	12:00p	59	39	1982	0	5.4	0.05	3.2	37	9:30a	SE
2	68.5	71	80.4	5:30p	82	96	1974	62.7	7:00a	60	40	1988	0.2	3.7	0	4	17	2:00a	SW
3	67.8	71	74.5	7:30p	82	95	1974	58.4	6:30a	60	39	1988	1.1	3.9	0	3.6	10	5:30p	N
4	68.2	71	76.7	11:30a	82	96	1990	63.5	9:00p	60	43	1996	0.1	3.3	0.06	3.5	17	2:00p	SSW
5	65.6	71	70.2	10:00p	82	95	1990	61.3	11:30p	60	43	1996	0.8	1.4	0.03	10	51	10:30p	SW
6	66.5	72	76.5	6:00p	82	97	1991	61.5	12:00m	60	43	1972	0.9	2.4	0.01	10.1	30	9:00p	N
7	57.7	72	61.8	12:30a	82	95	1980	54.5	12:00m	60	43	1983	7.3	0	0	13.8	27	10:00a	N
8	56.7	72	61.8	8:00p	82	95	1980	50.9	6:30a	60	39	1984	8.3	0	0.01	5.4	18	6:30p	N
9	63.2	72	73.6	3:30p	82	95	1988	50.3	4:30a	60	49	1963	4.4	2.6	0	2.7	16	4:00p	SE
10	74.7	72	88.5	6:00p	82	95	1976	66.3	5:00a	60	45	1962	0	9.7	0	6.1	19	9:00p	SSW
11	76.5	72	90.1	6:00p	82	93	1984	68	3:30a	60	41	1996	0	11.5	0	5.9	21	1:30a	SSW
12	64.5	72	76.8	12:30a	82	95	1987	57.6	12:00m	60	48	1975	1.9	1.4	0	9.2	25	12:30p	N
13	67.3	72	81.1	6:00p	82	99	1995	53.8	5:30a	60	48	1990	3.2	5.5	0	3.1	18	9:00a	NNE
14	74.9	72	86	6:30p	82	100	1995	65.9	8:30a	61	46	1950	0	9.9	0	3.8	18	11:30a	SE
15	76.3	72	86.9	8:30p	82	99	1995	66.8	6:00a	61	47	1960	0	11.3	0.17	3.6	24	12:00m	SE
16	63.1	72	82.7	12:30a	82	99	1988	59	5:30p	61	46	1987	3.1	1.2	0	13.4	31	2:00p	N
17	66.8	72	82.8	12:30p	82	95	1986	59.5	5:30a	61	45	1985	1.6	3.4	0	5.8	22	6:30p	NNE
18	70.9	72	81.3	7:00p	82	93	1986	60.2	6:30a	61	48	1979	0.6	6.5	0	2.3	15	7:00p	NNE
19	78.5	72	92.4	7:30p	82	95	1991	66.5	7:00a	61	47	1979	0	13.5	0	4	16	10:00a	ESE
20	76.7	72	80.1	2:30a	82	96	1980	70.4	12:00m	61	46	1951	0	11.7	0.28	9.9	36	2:00p	SSW
21	71.7	72	81.7	7:30p	82	95	1983	66.8	2:00a	61	44	1970	0	6.7	0	5.4	16	12:30p	WNW
22	71.3	72	79.1	5:00p	82	96	1983	66.1	4:30a	61	47	1970	0	6.3	0.75	5	29	1:00p	SSW
23	70.4	72	76.8	2:00p	82	96	1983	67.6	7:00a	60	44	1985	0	5.4	0.03	4.8	18	11:30a	N
24	72.9	72	84.7	3:00p	82	94	1965	64.2	7:00a	60	42	1957	0	7.9	0	3.3	14	11:30a	ENE
25	78.3	72	90.5	5:30p	82	92	1964	65.6	4:30a	60	50	1990	0	13.3	0	3.9	17	12:30p	SSE
26	76.9	72	83.6	2:00p	82	92	1966	70.7	10:30a	60	49	1961	0	11.9	0.12	5.2	26	10:00a	SSE
27	74.7	72	83.2	4:00p	82	91	1949	70.5	12:00m	60	45	1991	0	9.7	0	9.2	22	6:00p	SW
28	63.5	72	70.5	12:30a	82	99	1983	60.8	1:30p	60	51	1992	2	0.5	0	17.4	30	8:30a	N
29	64.8	72	75.8	6:30p	82	100	1983	57.5	5:00a	60	46	1968	2	1.9	0	3.3	13	12:30a	NE
30	69.6	72	81.8	4:30p	82	104	1999	58.9	7:00a	60	47	1984	1.4	6	0	2.9	11	12:00m	SE
31																			
AVE	69.63	71.8333											1.3	5.9	0.1	6.1	22.1		N
MAX	78.5	72	92.4			104		70.7		61	51		8.3	13.5	0.75	17.4	51.0		
MIN	56.7	71	61.8					50.3		59	39		0	0	0	2.3	10		
TOTAL															1.51				

Max Rain: 0.75 ON 06/22/16  
 Days of Rain: 8 (>.01 in)4 (>.1 in) 0 (>1 in)

# Ecosystem Transformations of the Laurentian Great Lake Michigan by Nonindigenous Biological Invaders

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## Keywords

benthification, ecosystem engineering, oligotrophication, invasive, food web

## Abstract

Lake Michigan, a 58,000-km<sup>2</sup> freshwater inland sea, is large enough to have persistent basin-scale circulation yet small enough to enable development of approximately balanced budgets for water, energy, and elements including carbon and silicon. Introduction of nonindigenous species—whether through invasion, intentional stocking, or accidental transplantation—has transformed the lake's ecosystem function and habitat structure. Of the 79 nonindigenous species known to have established reproductive populations in the lake, only a few have brought considerable ecological pressure to bear. Four of these were chosen for this review to exemplify top-down (sea lamprey, *Petromyzon marinus*), middle-out (alewife, *Alosa pseudoharengus*), and bottom-up (the dreissenid zebra and quagga mussels, *Dreissena polymorpha* and *Dreissena rostriformis bugensis*, respectively) transformations of Lake Michigan ecology, habitability, and ultimately physical environment. Lampreys attacked and extirpated indigenous lake trout, the top predator. Alewives outcompeted native planktivorous fish and curtailed invertebrate populations. Dreissenid mussels—especially quagga mussels, which have had a much greater impact than the preceding zebra mussels—moved ecosystem metabolism basin-wide from water column to bottom dominance and engineered structures throughout the lake. Each of these nonindigenous species exerted devastating effects on commercial and sport fisheries through ecosystem structure modification.